EDITED BY DAVID LITTLEFIELD

METRIC HANDBOOK

PLANNING AND DESIGN DATA

THIRD EDITION

Architectural Press

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Third Edition

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David Littlefield

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Preface

It is remarkable that, since the *Metric Handbook* first appeared in 1979, it has been revised just twice – in 1998 and, with this 3rd edition, in 2008. This is a testament to both its enduring popularity and the fact that compiling and updating a volume of this size is a vast undertaking. Building regulations and standards of good practice are almost constantly being updated, tightened and rewritten. Agendas also change and awareness of issues such as environmental performance and access for people with disabilities have not only changed the way architects detail buildings – they have changed the way architects think.

The *Metric Handbook* attempts to provide some steady ground on which to lay some fundamental principles. It is a sourcebook which aims to provide architects, and students of architecture, with the essential data and principles required to undertake their work professionally. It seeks to explain and present the principles and protocols of architectural design based on proven best practice and legal requirement. The *Metric Handbook* is a sourcebook to be relied on as good first place to look for data – a volume to be reached for, annotated, written on and book-marked by design teams getting a project off the ground. It is a book of many hundreds of pages but, in spite of the thousands of pieces of data it contains, it represents only a small percentage of the technical/procedural/statutory obligations that architects are expected to meet. This is a book that tells not the whole story (no book ever could) but one which acts as a companion to the wealth of documentation heavy enough to make any library shelf sag.

For the practice moving into new territory, for the student, or for the architect merely needing confirmation of a hunch, this book can be regarded as a trusty friend. There are countless specialist booklets and websites which purport to provide up-to-the-minute data on regulations, laws, products and techniques, and a book of this immensity cannot possibly attempt to compete with other resources. But it does, in a sense, bring all these resources together into a consistent and accessible format. And at every step of the way the many people who have contributed to this new edition have asked themselves the question: ''is this useful for the practising architect?''

Of course, the *Metric Handbook* does not seek to guide architects in terms of aesthetics and poetics; rather it seeks to provide them with the essentials from which to undertake a design. It is a foundation only. Users of this book, who can expect it to get them off the starting blocks, would be unwise to rely on it to detail an entire building. Even if building codes don't change (and they have been changing regularly) protocols and standards of good practice are constantly evolving, and users of this book should regard it as one important resource among many.

This 3rd edition represents a major revision of the book. There are brand new chapters, covering masterplanning, whole life costing and inclusive design, while the book also recognises that computers and CAD are now part of normal life. Many chapters have been completely rewritten (such as the chapters on healthcare, laboratories and libraries); others have been significantly updated (schools, student housing and factories); others have been mildly adjusted while some have been left alone. The completed book therefore represents a balance between the time required to update the detail and the need to actually publish. It is like painting the proverbial bridge. We ask readers to forgive any omission or inaccuracy.

David Littlefield
August 2007

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Acknowledgements

This update represents a considerable amount of work from a large number of architects, engineers and academics, and heartfelt thanks are due to all of them.

There are chapters within this book that are the result of a considerable team effort, while other chapters have been assembled by sole practitioners or consultants (such as Andy Thompson) who spent many days on this book when they could have been earning fees elsewhere. We are particularly grateful to them.

We also thank those organisations which have provided images to illustrate this book, including the Department of Health, the Central Office of Information, Stephen George and Partners and Hampshire County Council.

All the writers of the new and revised sections within this book are credited at the top of their chapters, but it is worth mentioning some individuals by name who deserve particular thanks – Catherine Nikolaou of Sheppard Robson; David Clarke of Clearwell Healthcare Planning; Fred Lawson; Arthur Lyons; and Norman Seward of the University of Wales.

There will inevitably be people who have helped in the creation of this book who receive no mention. We understand that no book of this size and complexity could be produced without an army of graphic designers, administrators and specialist consultants who have been prepared to fact check, answer questions, push things along and source material from deep within the archives. We thank all of them.

1 Notation, drawing office practice and dimensional coordination

CI/SfB (1976 revised) (A3t) and (F43)
UDC: 744 and 69.032

KEY POINT:
- *For clear understanding the conventions must be followed*

Contents

Updated 2007, with contribution on CAD standards by Nigel Davies, director of Evolve Consultancy

1 NOTATION

1.01 Decimal marker

The decimal marker (full stop) on the baseline is the standard decimal point in the UK; but the marker at the halfway position is also acceptable. It should be noted that Continental practice is to use the comma on the baseline.

When the value to be expressed is less than unity it should be preceded by zero (e.g. 0.6 not .6). Whole numbers may be expressed without a decimal marker. The appropriate number of decimal places should be chosen depending on the circumstances in which the resulting value is to be used.

Thousand marker

To avoid confusion with the Continental decimal marker, no thousand marker should be used. Where legibility needs to be improved a space can be left in large groups of digits at every thousand point. Where there are only four digits, a space between the first digit and the others is not desirable (e.g. 15000, 1500). (However, the comma is used in currency, e.g. £115,000.)

1.02 Symbols

1 The main symbols should be used as shown in Table I. The same symbol, i.e. m, mm, kg, should be used for singular and plural values (1 kg, 10 kg), and no full stops or other punctuation marks should be used after the symbol unless it occurs at the end of a sentence. Use a 'solidus' or sloping line as a separator between numerator and denominator, i.e. 3 kg/m^3 or 3 kg/cu m (three kilograms per cubic metre).
2 A single space should separate figures from symbols: 10 m, not 10m.
3 The unit should be written in full if there is any doubt about the symbol. For example, the recognised unit symbol 1 for the unit litre can be confused with the number 1 and it is less confusing to write litre in full. Also, the unit symbol t for tonne may in some circumstances be confused with the imperial ton, and the unit tonne should then be written in full.

Table I Summary of symbols and notation

Quantity	Description	Correct unit symbol	Acceptable alternatives	Incorrect use	Notes
Numerical values		0.1 0.01 0.001		.1 .01 .001	When the value is *less* than unity, the decimal point should be *preceded* by zero
Length	metre millimetre	m mm		m. M meter m.m. mm. MM M.M. milli-metre	
Area	square metre	m^2	sqm	m.sq sm sq.m sqm.	
Volume	cubic metre cubic millimetre	m^3 mm^3	cu m cumm	cu.m m.cu. cu.mm. mm.cub. mm.cu.	
	litre (liquid volume)	l, ltr		l. lit.	Preferably write *litre* in full to avoid 'l' being taken for figure 'one'
Mass (weight)	tonne	t		ton	Preferably write *tonne* in full to avoid being mistaken for imperial ton
	kilogram	kg		Kg kG kg. kilogramme	
	gram	g		g. G.	
Force	newton	N		N. n	Note that when used in written text, the unit of newton is spelled out in full and begins with a lower-case letter 'n'. When used as unit symbol, in calculation or in a formula it is then expressed as capital letter 'N'

4 When symbols are raised to various powers, it is only the symbol which is involved and not the number attached to it. Thus $3\,m^3$ equals $3(m)^3$ and not $3\,m \times 3\,m \times 3\,m$ (i.e. the answer is 3 cubic metres and not 27 cubic metres).
5 Difficulty may be experienced when reproducing the squaring and cubing indices m^2 or mm^2, and m^3 or mm^3. In such cases, units may be written with the indices on the line instead of as superscripts (m2, m3). Alternatively, particularly when the general public is involved, the abbreviations 'sq' and 'cu' may be used (sqm, cu m).
6 Units should not be hyphenated (milli-metres).

1.03 Notation

1 As a rule the sizes of components should be expressed in consistent and not mixed units, e.g. 1500 mm × 600 mm × 25 mm thick and not 1.5 m × 600 mm × 25 mm thick. However, for long thin components such as timbers, it is preferable to mix the units, e.g. 100 mm × 75 mm × 10 m long.
2 It is important to distinguish clearly between the metric tonne and the imperial ton. The tonne is equivalent to 2204.6 lb while the ton is equal to 2240 lb – a difference of 1.6 per cent.
3 The interval of temperature should be referred to as degree Celsius (°C) and not as centigrade. The word centigrade is used by the Continental metric countries as a measure of plane angle and equals 1/10000th part of a right angle.

Examples

Correct use	Incorrect use
33 m	3 cm 3 mm
10.100 m	10 m 100 mm*
50.750 kg	50 kg 750 g

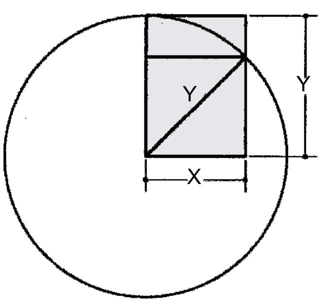
* *Note*. Some metric values are expressed differently in certain countries. The value of 10.100 m, for example, could mean ten thousand one hundred metres and not ten metres one hundred millimetres, as in the UK.

2 PAPER SIZES

The International A-series of paper sizes is used for all drawings and written material.

2.01 Sizes in the A-series

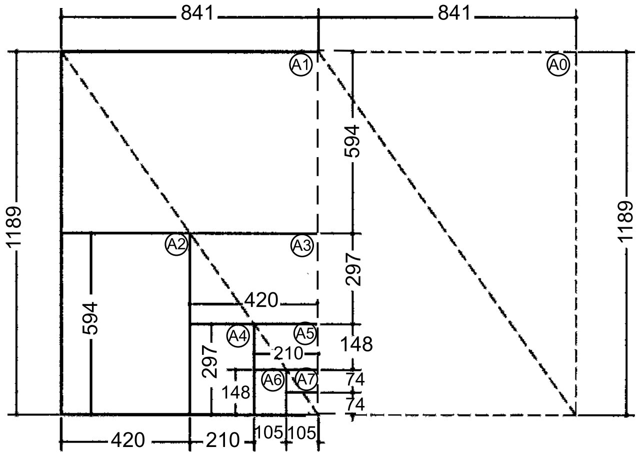
The A range is derived from a rectangle AO, **1.1**, of area $1\,m^2$ with sides x and y such that $x{:}y = 1{:}\sqrt{2}$ (i.e. x = 841 mm; y = 1189 mm). The other sizes in the series are derived downwards by progressively halving the size above across its larger dimension. The proportions of the sizes remain constant, **1.2**.



1.1 *Derivation of the rectangle AO, which has a surface area of 1m²*

2.02 Trimmed sizes and tolerances

The A formats are trimmed sizes and therefore exact; stubs of tear-off books, index tabs, etc. are always additional to the A



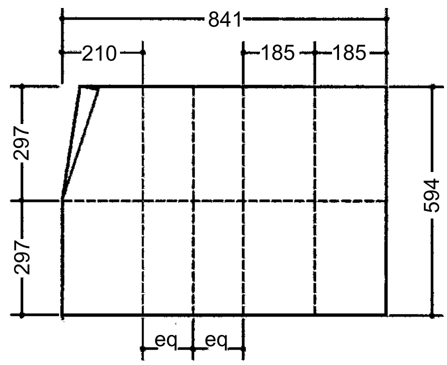
1.2 *A-sizes retain the same proportion (1:√2), each size being half the size above folding A1 size*

dimensions. Printers purchase their paper in sizes allowing for the following tolerances of the trimmed sizes:

- For dimensions up to and including 150 mm, +1.5 mm
- For dimensions greater than 150 mm up to and including 600 mm, +2 mm
- For dimensions greater than 600 mm, +3 mm. Recommended methods of folding the larger A-sized prints are given in **1.3**.

A size	mm
A0	841 × 1189
A1	594 × 841
A2	420 × 594
A3	297 × 420
A4	210 × 297
A5	148 × 210
A6	105 × 148
A7	74 × 105
A8	52 × 74
A9	37 × 52
A10	26 × 37

measurements represent trimmed sizes



folding A1 size

1.3 *A-series of paper sizes*

2.03 Pre-metric paper sizes

Old drawings will frequently be found in the sizes common prior to the changeover to metric. These sizes are given in Table II.

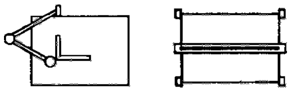
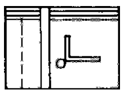
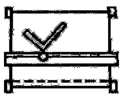
Table II Pre-metric paper and drawing board sizes

Name	Paper size	Board size
Half imperial	559 × 381	594 × 405
Imperial	762 × 559	813 × 584
Double elephant	1016 × 679	1092 × 737
Antiquarian	1346 × 787	1372 × 813

2.04 Drawing boards

Drawing boards are currently manufactured to fit A-size paper, while vertical and horizontal filing cabinets and chests have internal dimensions approximately corresponding to the board sizes listed in Table III. Boards, cabinets and chests designed for the pre-metric paper sizes are still in use.

Table III Nominal sizes of drawing boards for use with parallel motion or drafting machines attached

Type of board	Size	Width (mm)	Length (mm)
Parallel motion unit only or parallelogram type drafting machine	A2	470	650
	A1	730	920
	AO	920	1270
	3AO	1250	1750
			
Track or trolley type drafting machine requiring additional 'parking' area to one side	A1 extended	650	1100
	AO extended	620	1500
			
Parallel motion unit with drafting head requiring additional 'parking' area at bottom of board	A1 deep	730	920
	AO deep	1000	1270
			

3 ORDNANCE SURVEY MAPS

3.01

Ordnance Survey maps are now based completely on metric measurements and are immediately available to the following scales:

1:50 000, 1:25 000, 1:10 000, 1:25 000 and 1:1250.

However, new computer methods of storage and retrieval mean that maps can be supplied to any desired scale.

Architects and surveyors inevitably need to refer back to old maps and plans from time to time. These may have been drawn to almost any scale, but the common scales to which OS maps were drawn were as follows:

1 inch to the mile (1:63 360)
6 inches to the mile (1:10 560)
88 feet to the inch (1:1056)

Where these are stored on microfiche, etc., they can be reproduced to a scale more suited to modern use.

3.02 Bench marks and levels

Points used for measuring and marking levels are known as *bench marks.* On a particular site a temporary *bench mark* (TBM) may be established, to which all other levels on that site are referred. The level value allocated to the TBM may be to Ordnance Datum; more commonly it is given an arbitrary value. This value should be large enough not to require any negative levels (including levels of drains, etc.), as these can lead to errors. All levels in and around buildings are recommended to be given to three decimal places, although BS 1192 permits two decimal places for landscape work.

The heights of Ordnance Survey bench marks are given in Bench Mark Lists obtainable from Ordnance Survey Headquarters, Romsey Road, Maybush, Southampton SO9 4DH. Modern OS maps to the larger scales include Ordnance Bench Marks related to Newlyn Datum. Older maps may have levels to Liverpool Datum; levels on maps other than of Great Britain will be related to other datums. Where known, the datum and date of levelling should be stated.

OS maps include contours. On the 1:10 000 series the contour interval is 10 metres in the more mountainous areas and 5 metres in the remainder of the country.

4 DRAWINGS

4.01 Centimetres or millimetres

Continental building practice uses metres or centimetres depending on the particular application. In the UK, since the change to metric dictated the practice, the millimetre is used instead of the centimetre, although this does lead to a mistaken perception of the degree of accuracy.

On a drawing, either metres or millimetres should be used: these units should not be mixed. If this rule is followed, ambiguity is avoided – it is not possible to confuse which units are intended. Dimensions in metres should include either the decimal marker or the letter m: 2.0 or 2 m.

Avoid using capital M for metres. M is used to indicate the number of *modules*: e.g. where a module of 100 mm is adopted 5M means 500 mm.

4.02 Specifying both imperial and metric sizes

If work is being done on an old building that was built to imperial dimensions, and it is desired to show these on new drawings, show them in feet, inches and fractions of an inch to an accuracy of 1/16th inch, followed by the metric equivalent in brackets to the nearest millimetre. The reverse should never be required.

Imperial dimensions may be indicated by the abbreviations *ft* and *in*: 4ft–6in, or using single and double inverted commas: 4'–6''. The hyphen is used as the separator.

4.03 Levels on plan

It is important to differentiate on site layout drawings between existing levels and intended levels, thus:

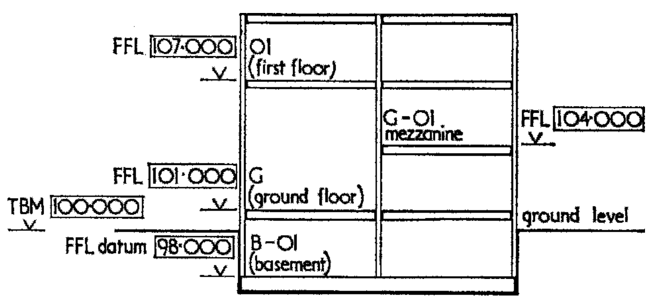
Existing level: × 58.210

Intended level: [60.255]

The exact position to which the level applies should be indicated by 'x'. Finished floor levels should be indicated by the letters FFL followed by the figures of the level, thus: FFL *12.335.*

4.04 Levels on section and elevation

The same method should be used as for levels on plan except that the level should be projected beyond the drawing with an arrowhead indicating the appropriate line, as in **1.4**.



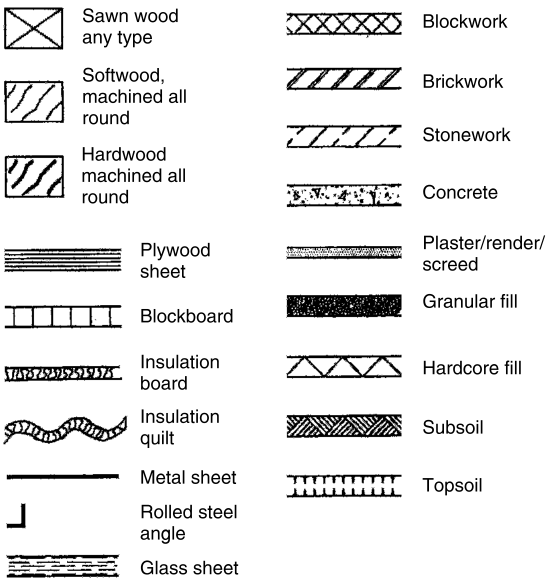
1.4 *Method of indicating levels on sections and elevations*

4.05 Conventional symbols

BS 1153 specifies certain standard symbols for use on drawings. A selection of these are given in **1.5**.

4.06 Scales

The internationally agreed and recommended range of scales for use in the construction industry is given in Table IV. The scale or scales used should be stated on each drawing; drawings that are to read by the non-specialist (e.g. sketch drawings) or that are to be microfilmed or published should have a drawn scale in addition. Where two or more scales are used on the same sheet, these should be clearly indicated. **1.6** shows some dimensions to various scales.



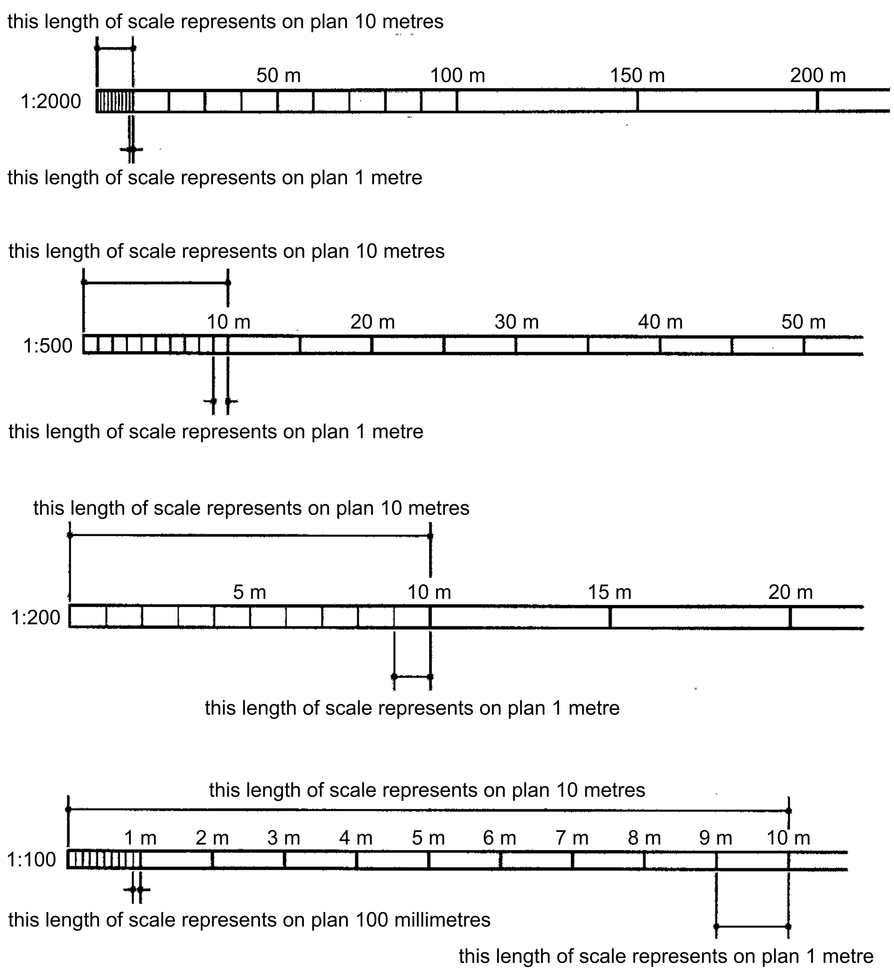
1.5 *Conventional shadings for various materials in section*

4.07 Types of drawings

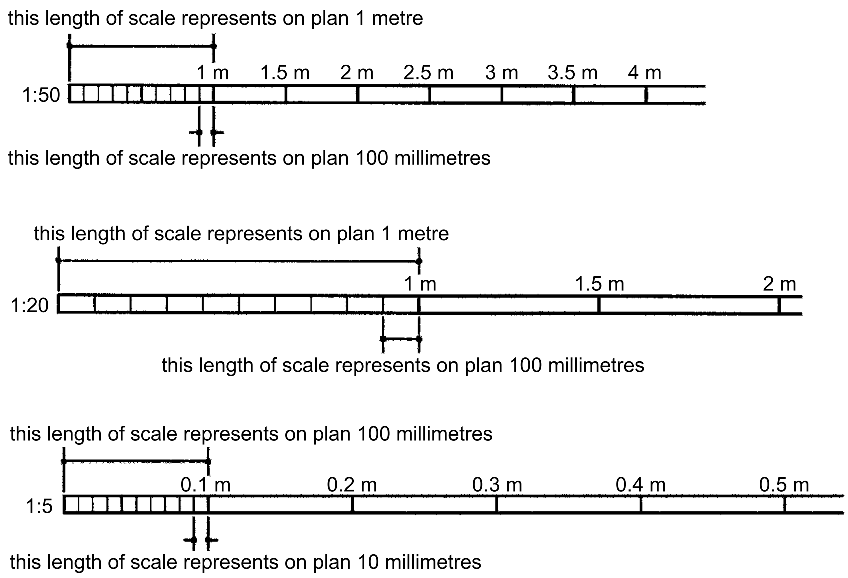
Types of drawings done to the most suitable scales are shown in **1.7** to **1.13**. Note that in **1.10** and **1.11** alternative dimensional units are shown for comparison. The method of expressing dimensions as shown in the shaded drawings is not recommended.

Table IV Preferred scales

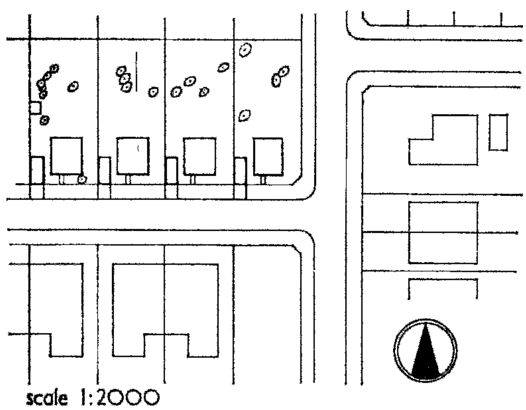
Use	Scale
Maps	1:1000000
	1:500000
	1:200000
	1:100000
Town surveys	1:50000
	1:20000
	1:10000
	1:5000
	1:2500
	1:2000
Block plan	1:2500
	1:2000
	1:1250
	1:1000
Location drawings	
Site plan	1:500
	1:200
General location	1:200
	1:100
	1:50
Ranges	1:100
	1:50
	1:20
Component drawings	
Assembly	1:20
	1:10
	1:5
Details	1:10
	1:5
	1:1



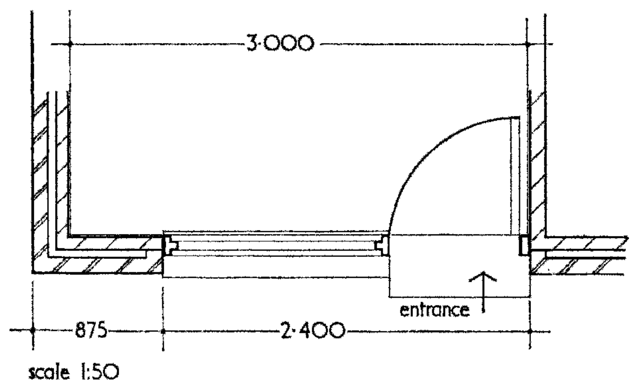
1.6 *Representations of lengths to scale. This drawing may be used to check the correct interpretation of a scale (continued over)*



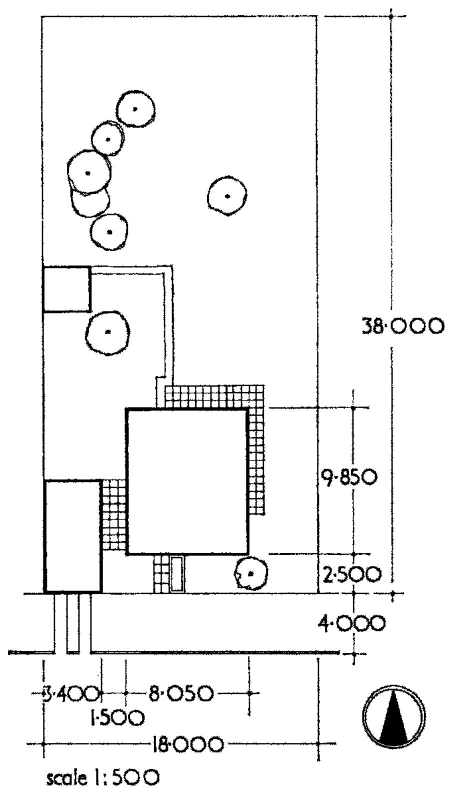
1.6 *Continued*



1.7 *Layout plan (note that the Ordnance Survey continue to use the 1:2500 scale)*



1.9 *Location drawing*



1.8 *Site plan*

5 STANDARDS FOR DRAWING, CAD AND LAYERING

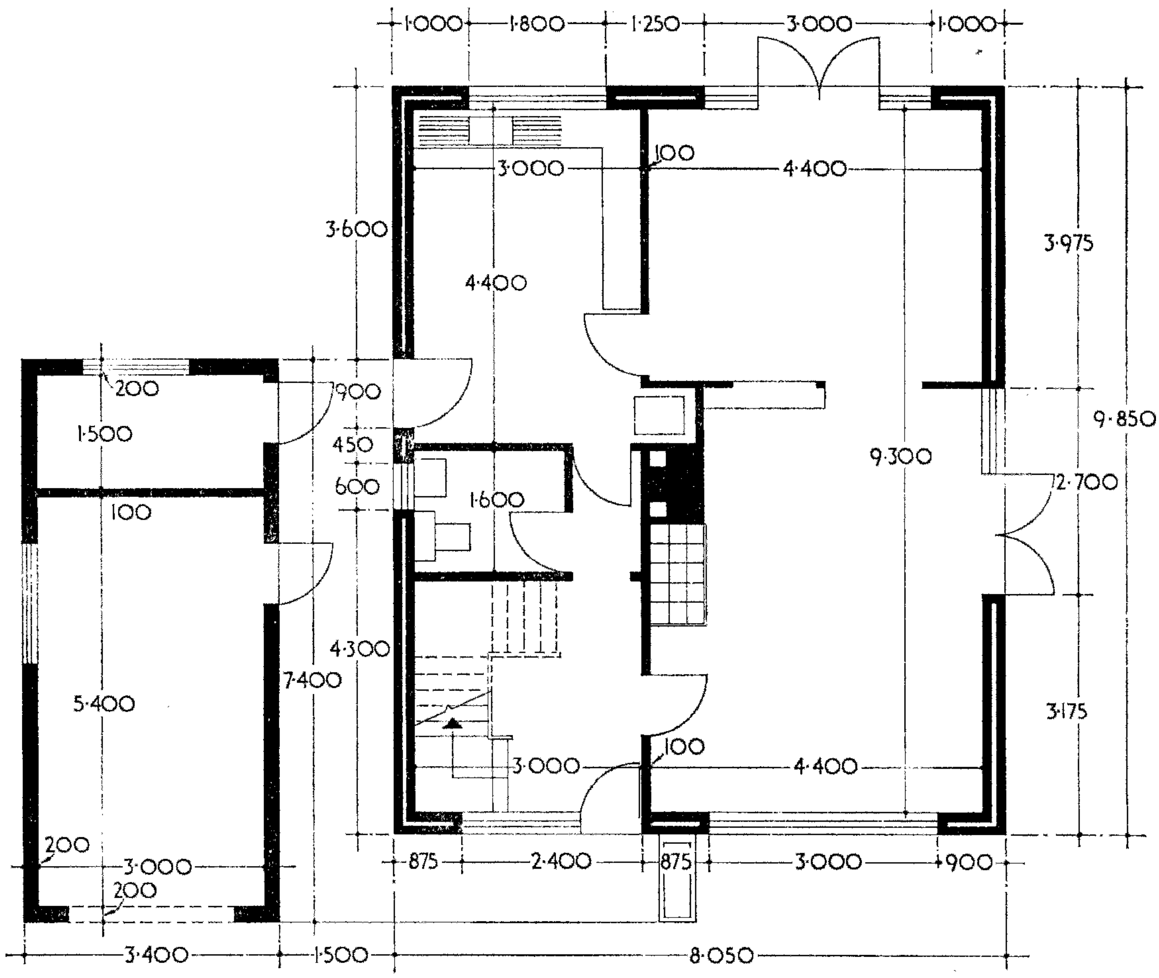
5.01 Drawing standards

Drawing standards concern a wide variety of items associated with the content of the drawing: layering, the drawing border itself, drawing numbering systems, layout considerations, titling, the text and dimension styles, standard notes and symbols. These standards generally fall to the CAD manager, who may also have some responsibility for formulating and regulating checking/approval and issue procedures that ensure the correct QA controls are being applied (the sign-off is usually down to a senior architect or engineer).

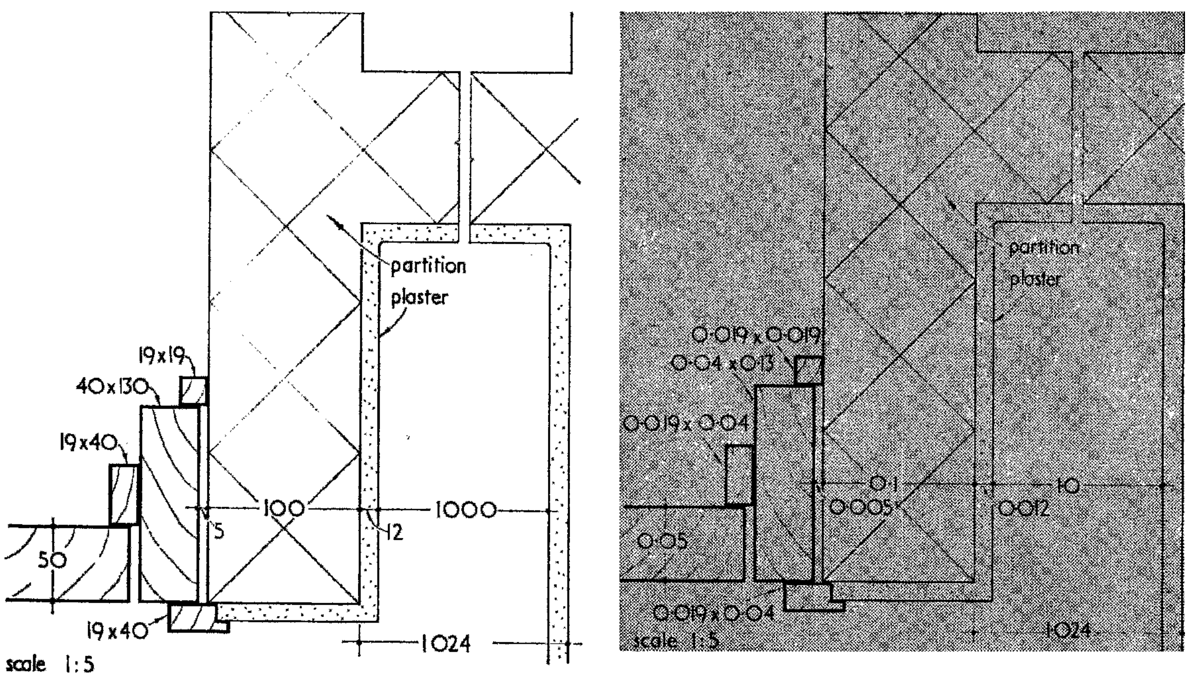
One can argue that individualism is crucial to a drawing, but not when one contrasting style highlights the inadequacies of another. One needs to define base expectations of drawing quality. To do that, it is worth revisiting some 'golden draughting rules' that seem to have been forgotten with the advent of CAD, but are just as applicable in the twenty-first century.

5.02 Draughting standard rules

1 Never draw a line unless you understand what it represents.
2 A drawing should be laid out to allow clear interpretation of the data.
3 Sections and elevations should be drawn as projections of the plan whenever possible; the plan grids should line up with the elevational grids for easy reference.
4 Sections and details should line up so the floors can be easily identified and related.



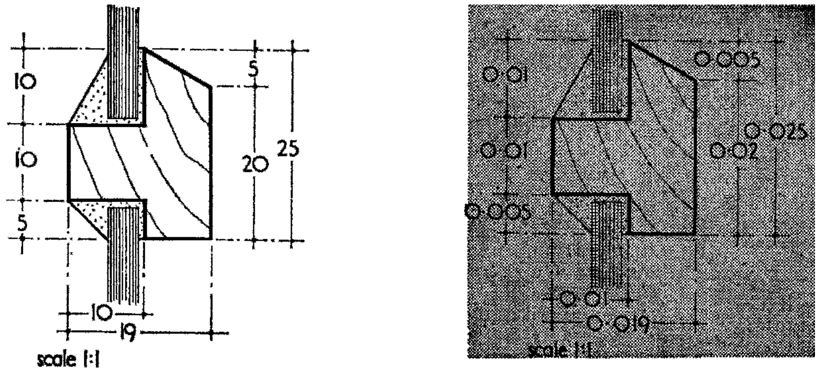
1.10 *Location drawing (sketch plan)*



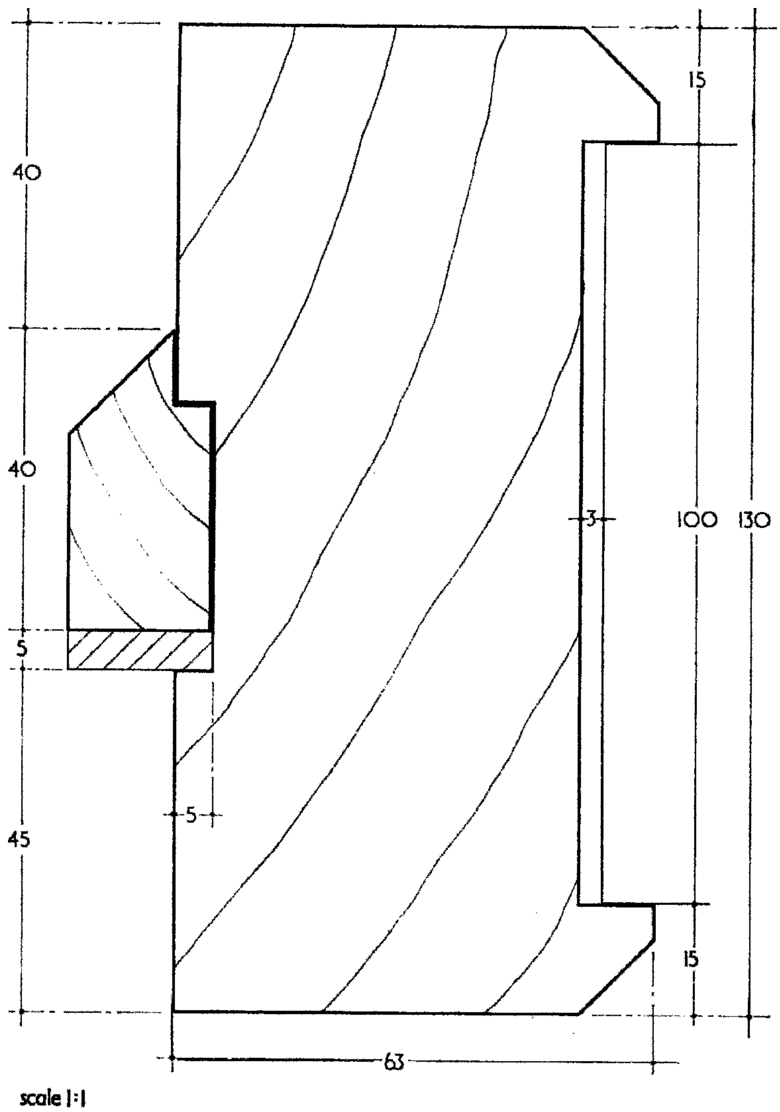
1.11 *Assembly detail drawing (shaded version not recommended)*

5 Annotation can destroy a legible drawing if not used carefully. Notes should never be used unless they clarify the drawing content. You should never repeat notes on two drawings as this may lead to ambiguity. If a note is repeated on two drawings, remove one or question the need for that drawing.

6 Annotation should be close to the information it relates to, but clear of linework.



1.12 *Full size detail (shaded version not recommended)*



1.13 *Full size detail*

7 The use of abbreviations should be avoided, unless space dictates otherwise.
8 Ensure any drawings is independently checked and approved before issue. One rarely sees ones own mistakes.
9 Symbols should be consistent on all drawings.
10 Certain standard notes should always be considered, including: do not scale from this drawing; all dimensions are in millimetres unless noted otherwise; all levels are in metres above ordnance datum unless noted otherwise; this drawing is to be read in conjunction with other relevant architects' and engineers' drawings and specifications; all setting out is to be confirmed on site prior to construction. Within CAD, these notes can be included as a layer within the drawing border file; if these are on by default, a conscious decision needs to be made before they are omitted.

5.03 Standard symbols

Annotation and symbols are a critical part of the language of a drawing. Symbols – in the form of blocks or cells – are used to either define specific types of annotation – such as North arrows, level markers, spot heights, door and room numbers – or to represent diagrammatically building components such as valves, manholes or insulation. Part of the role of managing an efficient CAD system is to make the use of office-specific symbols and hatching (all part of a high quality, consistent drawing set) quicker than having to redraw the required information. For insulation, this is straightforward; nobody wants to redraw the continuous repeating curve that is commonly used. Ensuring a consistency for level markers, break lines and standard brick hatching is more difficult. The CAD manager can provide all the necessary symbols and hatch patterns so that they appear by default for all users. Each CAD system has ways of enabling this.

No matter how technologically advanced the software configuration, it is useless unless the output (the drawing) is of consistent high quality. A CAD standard is useless if nobody follows it.

5.04 Layer standards

Layer standards should cover more than just layer names; they should include:

- CAD Standards (folder structures, file names, blocks and cells, text and dimension styles, etc.);
- Drawing Standards (drawing borders, layouts, annotation, drawing numbering, revision control, etc.); and
- Related procedures and processes (issue management, archiving, incoming CAD file use, etc.).

The development of layer standards should not be static, but should evolve to account for changing software, working practices and needs of the users.

5.05 Chosing a layer standard

There is a wide variety of standards to choose from, and standards change according to need and location. Indeed, the standard one chooses should be reviewed regularly. The principal layer standards comprise the following:

UK

There is an official British Standard, BS1192 pt 5, that defines the format of layer names for the distribution of digital data. It is part of the complete BS1192, most of which is now out-of-date. Part 5 itself is listed as ‘withdrawn’. The codes break down into numerous fields and, consequently, are cumbersome to implement.

There are also the BAA CAD Standards, developed for all British Airports Authority projects and based on the CI/SfB classification system. This is even more comprehensive than BS1192, covering standard naming to the *n*th degree including blocks/cells and even software that can/ca not be used.

AEC (UK) CAD Standards are not actually a standard but, in fact, a ready-to-use implementation of BS1192 pt 5 using Uniclass. The committee responsible for this was made up of actual end-users (architects and engineers) who took BS1192 pt 5 and ISO 123567, bent certain rules (like fixed field lengths) and provided a standard which is free.

US

The main recognised layer structure employed in the USA is the US National CADD Standards (NCS). This is not an official standard in the same manner as an ISO or BS standard but is ‘officially sanctioned’ by the National Institute of Building Science (similar to the UK’s Building Research Establishment) and is ISO compatible. It was put together by a committee comprising members of the American Institute of Architects, the US Corp of Engineers and the US Coast Guard. The NCS also covers other items alongside the layer standards, including drawing sets, drawing sheets, annotation standards, etc.

The layer codes, effectively a republishing of the AIA CAD Layer Conventions, work in a similar way to most of the other world layer standards in that they is broken down into fields to describe the information.

Europe

The European standard, ISO 13567 is very similar to BS1192 in that it provides a framework and guidelines rather than a single unified standard. Its fields are very similar and are just as convoluted and complex.

The trick is to identify the one which best suits your company’s area of work (UK, Europe, USA, etc.) and implement it to suit your internal needs for element segregation. If you are mostly working in the USA, use the US National CADD Standards, but if you are a firm split between say, London and New York, consider the AEC (UK) CAD Standard, designed specifically to utilise the ‘User Defined’ field as other languages or CAD codes.

5.06 Standards for objects and 3D

There is no current standard for definition of objects, and none of the existing standards take 3D into account – simply because this was not a prevalent use of CAD systems when those standards were devised.

The International Alliance for Interoperability (IAI) was formed to tackle this issue and has provided the IFC (Industry Foundation Class) for software-independent exchange of non-graphical data. That is, the geometry of a CAD element will normally survive when translated from one format to another (e.g. DGN to DWG), but the additional intelligence that makes it an object – the material, its weight, cost, accessories, etc. – is lost. The IFC format provides a standard structure for defining and storing this data so that it can be passed from one system to another. Even with many CAD systems now supporting IFC 2.× the industry has still not taken to this approach.

Instead, the industry appears to be developing its own specialist formats for exchange of data. The appearance of, for example, the CIMsteel CIS/2 format for the exchange of steel members has transformed the steel design and fabrication chain. CIS/2 is a simple text file format that stores only what it needs to regarding a steel member, such as its start and end co-ordinates, section size and so on.

5.07 Devising a robust standard layering convention

The following 10 point plan should help a CAD manager devise a robust and standardised layering convention:

1. Refuse to pay for standards. Standards will only become standard when they are freely available and easy to implement.
2. Always opt for a recognised standard wherever possible.
3. Avoid internal standards. Even if your standard has survived for many years, consider updating it to a national system. You can still keep the layers and just apply the national codes.
4. Use only the layers you need, not all those that are available. Do not, for example, print out a list of all the available layers or classifications and tick the ones you could use. Instead, work out what distinctions you need to make and then find the layer code to suit.
5. Involve your users in all the segregation decisions.
6. Avoid superseded classification systems.
7. Avoid the optional fields, they only confuse matters and make information difficult to classify.
8. Use the CAD system to best effect. If you can add descriptions to layers do so. No one likes codes – but it does make them universally interchangeable.
9. Make sure your layer standards are software neutral (as far as is possible) and work regardless of dimension. You should not have two standards, one for 2D one for 3D (and even a third for visualisation).
10. Distribute your layer standards to all other collaborators and try to get them to do the same. Then you are in no doubt as to what and where things are. Point out non-compliance.

6 MEASURING INSTRUMENTS

The following notes are based on BS 4484.

6.01 Folding rules and rods, laths, and pocket tape rules

Lengths of instruments are as follows:

(a) Folding rules: 1 m
(b) Laths: 1 m, 1.5 m or 2 m
(c) Folding and multi-purpose rods: 2 m
(d) Pocket tape rules: 1 m, 2 m, 3 m, or 5 m.

The forms of graduation are shown in **1.14**. The instruments are graduated in millimetres along one edge with 5 m and 10 m graduation marks. Along the other edge the millimetre graduations are omitted.

6.02 Steel and synthetic tapes

Lengths are 10 m, 20 m, or 30 m long. Etched steel bands are available in 30 m and 50 m lengths.

Tapes are graduated at intervals of 100 mm, 10 mm (with the 50 mm centre graduation mark 'arrowed') and 5 mm. The first and last metre of the tape are further subdivided into minor graduation marks at 1 mm intervals (see **1.15**). Note that synthetic material tapes, however, are not subdivided into millimetres over the first and last metre.

6.03 Chains

Studded steel band chains are in lengths of 20 metres, divided by brass studs at every 200 mm position and figured at every 5 metres. The first and last metre are further divided into 10 mm intervals by smaller brass studs with a small washer or other identification at half-metre intervals. The markings appear on both sides of the band.

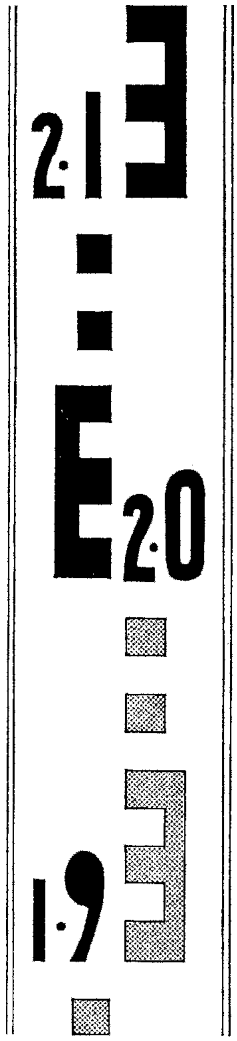
Land chains are also in lengths of 20 metres, made up of links, which from centre to centre of each middle connecting link measure 200 mm. Tally markers are attached to the middle connecting ring at every whole-metre position. Red markers are used for 5 m positions, with raised numerals; yellow markers of a different shape and with no markings are used for the rest, **1.16**.

6.04 Levelling staffs

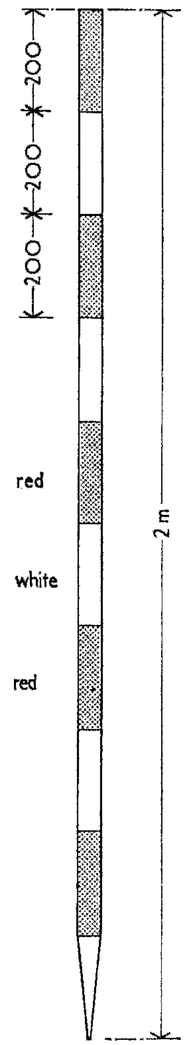
Lengths are 3 m, 4 m or 5 m long with a reading face not less than 38 mm wide. Graduation marks are 10 mm deep, spaced at 10 mm intervals. At every 100 mm the graduation marks offset to the left and right of centre, **1.17**. The outside edges of the lower three graduation marks join together to form an 'E' shape. Different colours distinguish graduation marks in alternate metres. Staffs are figured at every 100 mm interval with metre numbers (small numerals) followed by the decimal point and first decimal part of the metre (large numerals).

6.05 Ranging rods

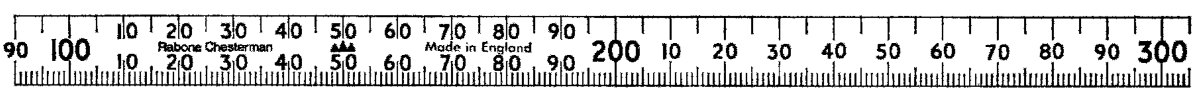
Lengths are 2 m, 2.5 m or 3 m painted in either 200 mm or 500 mm bands alternating red and white. A rod of 2 m length painted in 200 mm bands is shown in **1.18**.



1.17 *Levelling staff marked in 10 mm increments*

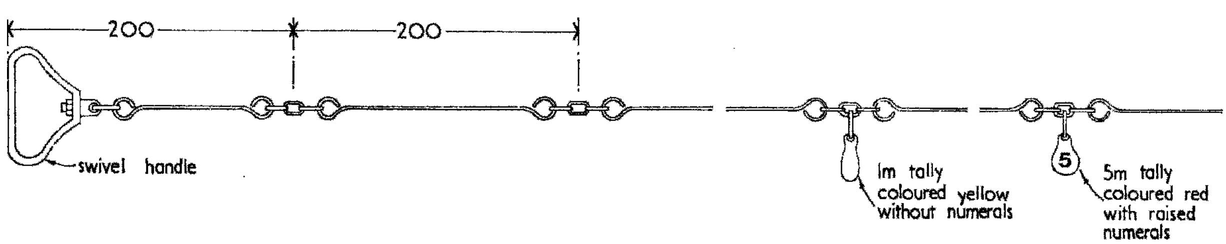


1.18 *Ranging rod*



1.14 *Graduation markings for folding rules and rods, laths and pocket tape rules*

1.15 *Graduation markings for steel tapes*



1.16 *Land chain markings*

7 DIMENSIONAL COORDINATION

7.01

Current building practice involves the assembly of many factory-made components: in some cases (called *industrialised building*) the whole project consists of such components slotted together like a child's construction kit. Dimensional coordination (DC) is essential to ensure the success of the system, and consists of a range of dimensions relating to the sizing of building components and assemblies, and to the buildings incorporating them. DC enables the coordination of the many parts that go to make up the total construction which are supplied from widely separated sources. At an international level, 100 mm is accepted as the basic module (often referred to by the letter 'M').

Dimensional coordination relies on establishment of rectangular three-dimensional grids of basic modules into which components can be introduced in an interrelated pattern of sizes, **1.19**. The modular grid network delineates the space into which each component fits. The most important factor of dimensional coordination is that the component must always be undersized in relation to the space grid into which it has to fit (but not to too great an extent).

In the engineering world the piston and cylinder principle establishes the size relationship between dimensional space grid and component, **1.20**. The size of the cylinder must allow for the right degree of accuracy and tolerance to enable the piston to move up and down.

The degree of inaccuracy to be allowed for in the building process is related to the economics of jointing. Adequate space must be allowed for size of component plus joint. Transgressing the rules of locating components within the allotted space contained by grid lines will cause considerable difficulty in site assembly.

The basic arrangement of components within the grid layout shows them fitting into the spaces allocated to them: dimensionally they are coordinated, thus allowing the designer maximum use of standard components, **1.21**.

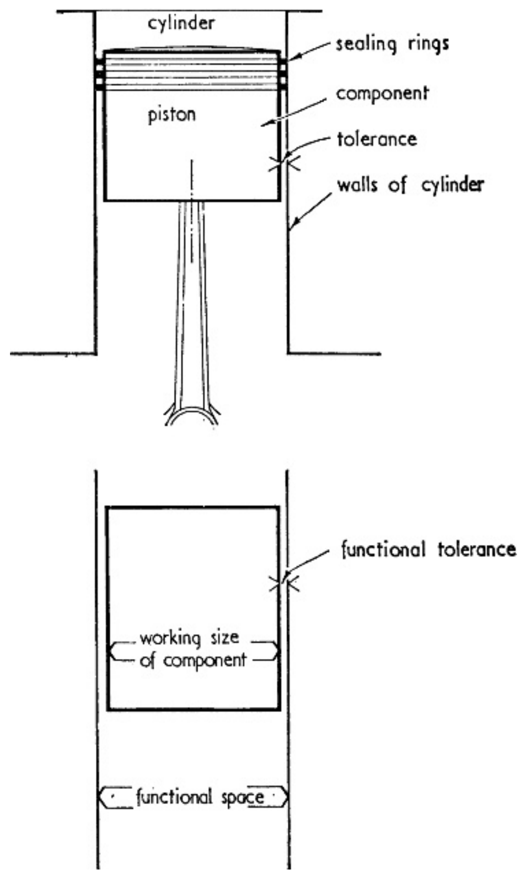
7.02

The basic aims of DC (as was defined in BS 4011:1966) were:

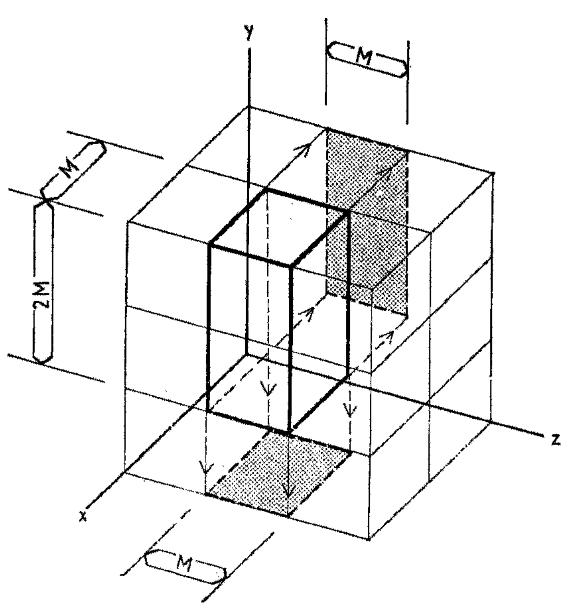
- To obtain maximum economy in the production of components
- To reduce the manufacture of non-standard units
- To avoid wasteful cutting on-site.

Advantages to designers may include:

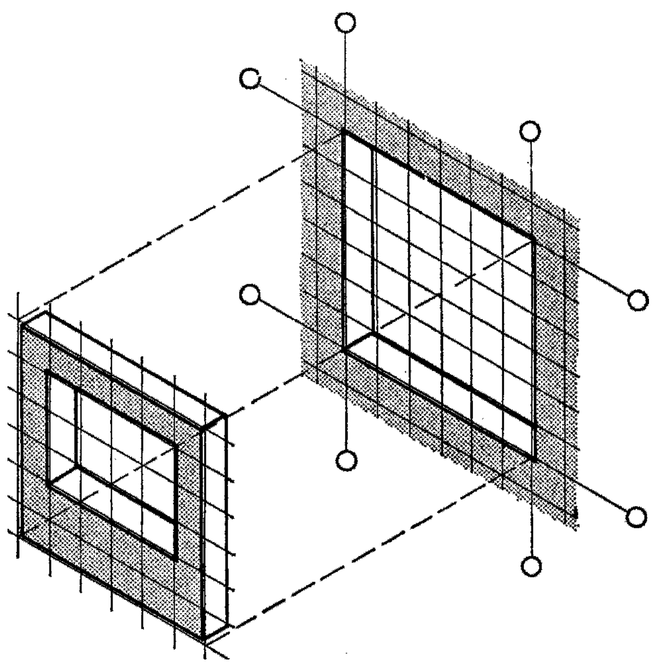
- Reduction in design labour
- Reduced production of working drawings by the use of standard details
- Choice of interrelated standard components at the various price levels.



1.20 *The piston and cylinder principle*



1.19 *Three-dimensional grid of basic modules*



1.21 *Fitting a component into a dimensionally coordinated grid*

Potential advantages to manufacturers include:

- More effective use of labour in producing standard lines
- Reduction in the stocking, invoicing and other operations connected with numerous differently sized products. There should also be advantages to contractors, not only through better design of components for fit but also through increasing familiarity with standard components.

BS 4011 has now been superseded by BS 6750:1986.

7.03 Basic elements of DC

Preference for size

The preferred increments are:

- First preference (multimodule) multiples of 300 mm
- Second preference (basic module) multiples of 100 mm
- Third preference (submodule) multiples of 50 mm up to 300 mm
- Fourth preference (submodule) multiples of 25 mm up to 300 mm.

Reference system

Grid and line

The DC reference system identifies controlling dimensions by the use of a grid on plans and a series of horizontal lines on elevations and sections.

The terminology is precise:

- Controlling dimensions lie between key reference planes (e.g. floor-to-floor height). They provide a framework within which to design and to which components and assemblies may be related.
- Key reference planes define the boundaries of controlling zones or structural axes.
- Controlling lines on a drawing represent a key reference plane.
- Axial controlling lines are shown on drawings by a chain dotted line with a circle at the end, in which the grid reference is given.
- Face controlling lines are shown by a continuous line with a circle at the end in which the grid reference is given.
- Zones between vertical or horizontal reference planes provide spaces for one or more components which do not necessarily fill the space. Provided that use of associated components is not inhibited, a building component (or group of components) may extend beyond the zone boundary, as may trims and finishes.

7.04 Drawings

A typical project will require three series of drawings:

1 *General location drawings* showing controlling lines with identifiers
2 *Assembly drawings* showing the relationships between the components and the controlling lines
3 *Component drawings* where required.

Specialists such as structural and service engineers provide assembly and component drawings in their own disciplines to fit in with this system.

The representation of the dimensional coordination framework should be consistent on all drawings. On general location drawings a grid representing 300 mm (or a multiple of 300 mm) may be used. Assembly details may use grids of 300 or 100 mm.

Reference lines

Reference lines or grids should be thin, to distinguish them from other, particularly constructional, lines.

Gridded paper and scales

Table V gives the recommended range of scales for each type of drawing related to appropriate paper grid sizes. Scale and the increment represented by the grid should be indicated on all gridded sheets.

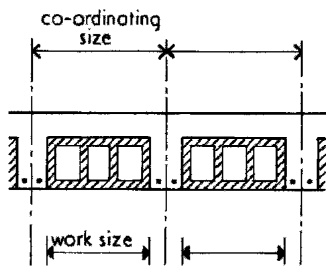
Table V Choice of scales and grids

Type of drawing	Scale	Paper grid size (mm)	Increment represented (mm)
Block plan	1:2000 1:1000	Not applicable	
Site plan	1:500 1:200	Not applicable	
Sketch	1:200 1:100	6 3*	1200 300
General location	1:100	6 3*	600 300
	1:50	6 2*	300 100
Component ranges	1:100	6 3*	600 300
	1:50	6 2*	300 100
	1:20	15 5	300 100
Component details	1:10	10 5	100 50
	1:5	20 10 5	100 50 25
	1:1	100 50 25	100 50 25
Assembly	1:20	15 5	300 100
	1:10	10 5	100 50
	1:5	20 10 5	100 50 25

* These sizes are below the linits for hand-drawn grids.

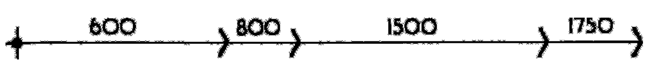
Dimension lines

Different types of dimensions should be distinguished by the type of arrowhead, **1.22**.



1.22 *Coordinating and work sizes*

Running dimensions should be set off from a datum, **1.23**.



1.23 *Running dimensions. The symbol at the datum should be as shown. An arrowhead is sometimes used, but is not the preferred alternative*

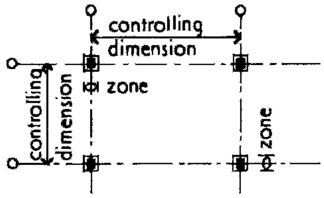
Assembly details

Assembly details should show components in their context, i.e. in relation to the adjoining element, with details of the joint.

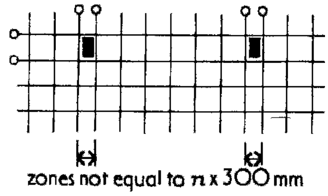
7.05 Locating components by grid

Types of grid

The structural grid of axial controlling lines, **1.24**, is established physically by the contractor on-site; it serves as the main reference in construction. It is subject to setting-out deviations which affect the spaces required for assemblies of components; but this should

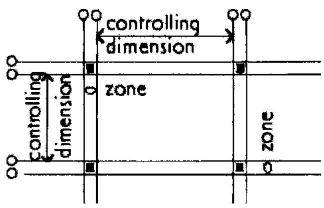


1.24 *Axial control*



1.29 *Interrupted grid and neutral zones (tartan)*

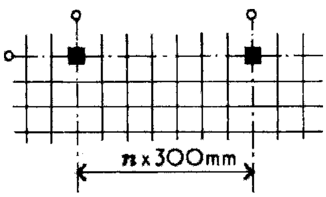
have been allowed for in the design stage. A planning grid of face controlling lines, **1.25**, locates non-structural elements.



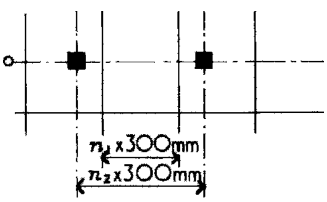
1.25 *Facial control*

Relation between structural and planning grids

Structural and planning grids may coincide but do not necessarily do so. The controlling dimensions for spacing structural elements on plan on axial lines are in multiples of 300 mm (Table VI). If a 300 mm square grid is used then axial controlling lines will coincide with the grid, **1.26**, but if the grid is a multiple of 300 mm then the controlling lines will be offset from the axial grid by 300 mm or by a multiple of 300 mm, **1.27**.



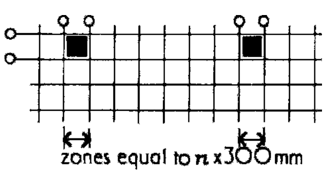
1.26 *Uninterrupted grid*



1.27 *Controlling lines offset from grid*

Relating zones to a 300 mm grid

If widths of structural zones are multiples of 300 mm, the grid is continuous, **1.28**. If the zone is not a multiple of 300 mm, however, the grid is interrupted by the dimension of that zone, **1.29**. This is referred to as a neutral zone.



1.28 *Continuous grid*

- A neutral zone is a zone that does not conform to the recommended dimensions given in Table VI.

Table VI Sizing of zones and heights

Range (mm)	Multiples of size (mm)
Horizontal controlling dimensions	
Widths of zones for columns and loadbearing walls	
100 to 600	300 (first preference) 100 (second preference)
Spacing of zones for columns and loadbearing walls	
From 900[1]	300
Vertical controlling dimensions	
Floor to ceiling heights	
2300[2] to 3000	100
3000 to 6600	300
over 6600	600
Heights of zones for floors and roofs	
100 to 600[3]	100
over 600	300
Floor to floor (and roof) heights	
2700[4] to 8400	300
over 8400	600
Changes in level	
300 to 2400	300
above 2400	600

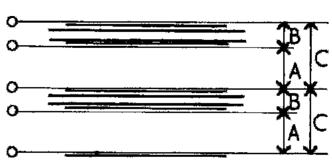
[1] Housing may use 800
[2] Farm buildings may use 1500 and 1800
Domestic garages may use 2100
Housing may use 2350
[3] Housing may use 250
[4] Housing may use 2600

Key reference planes

Key reference planes, **1.30**, should generally occur at:

- Finished floor level
- Finished suspended ceiling level
- Finished wall surface.

Sizes of zones indicated by key reference planes should be selected from Table VI. Where controlling or reference lines bound floor or roof soffits, deflection should be allowed for in the zone.



1.30 *Vertical control: A being floor-to-ceiling height controlling dimension; B floor and roof zone; C floor-to-floor and floor-to-roof controlling dimension*

Table VII Planning use classes under the Town and Country Planning (use Classes) Order 1987 as amended 1991 and twice in 1992

Class	Used for the main or primary purpose
Al Shops open to the public	(a) Selling goods retail other than hot food (b) Post office (c) Ticket or travel agency (d) Take-away selling sandwiches or other cold food (e) Hairdresser (f) Funeral director (g) Displaying goods for sale (h) Hiring out domestic or personal goods or articles (i) Washing or cleaning clothes or fabrics (j) Receiving goods to be washed, cleaned or repaired
A2 Financial and professional services where provided mainly to visiting members of the public	(a) Financial services (b) Professional services (other than health or medical services) (c) Any other services (including use as a betting office) appropriate to provide in a shopping area
A3 Food and drink	The sale of food or drink for consumption on the premises or of hot food for consumption off the premises
B1 Business, providing the use can exist in a residential area without detriment because of noise, vibration, smell, fumes, smoke, soot, ash, dust or grit	(a) An office other than a use within class A2 (b) Research and development or products or processes (c) Any industrial process
B2 General industrial	Carrying on an industrial process other than one in class B1 or B4 to B7
B3	Deleted class
B4 Special Industrial Group B, except where the process is carried out in association with and adjacent to a quarry or mine	(a) Smelting, calcining, sintering or reducing ores, minerals, concentrates or mattes (b) Converting, refining, reheating, annealing, hardening, melting, carburising, forging or casting metals or alloys other than pressure die-casting (c) Recovering metal from scrap or drosses or ashes (e) Pickling or treating metal in acid (f) Chromium plating
B5 Special Industrial Group C, except where the process is carried out in association with and adjacent to a quarry or mine	(a) Burning bricks or pipes (b) Burning lime or dolomite (c) Producing zinc oxide, cement or alumina (d) Foaming, crushing, screening or heating minerals or slag (e) Processing pulverised fuel ash by heat (f) Producing carbonate of lime or hydrated lime (g) Producing inorganic pigments by calcining, roasting or grinding
B6 Special Industrial Group D	(a) Distilling, refining or blending oils (other than petroleum or petroleum products) (b) Producing or using cellulose or using other pressure sprayed metal finishes (other than in vehicle repair workshops in connection with minor repairs, or the application of plastic powder by the use of fluidised bed and electrostatic spray techniques) (c) Boiling linseed oil or running gum (d) Processes involving the use of hot pitch or bitumen (except the use of bitumen in the manufacture of roofing felt at temperatures not exceeding 220°C and also the manufacture of coated roadstone) (e) Stoving enamelled ware (f) Producing aliphatic esters of the lower fatty acids, butyric acid, caramel, hexamine, iodoform, napthols, resin products (excluding plastic moulding or extrusion operations and producing plastic sheets, rods, tubes, filaments, fibres or optical components produced by casting, calendering, moulding, shaping or extrusion), salicylic acid or sulphonated organic compounds (g) Producing rubber from scrap (h) Chemical processes in which chlorphenols or chlorcresols are used as intermediates (i) Manufacturing acetylene from calcium carbide (j) Manufacturing, recovering or using pyridine or picolines, any methyl or ethyl amine or acrylates
B7 Special Industrial Group E	Boiling blood, chitterlings, nettlings or soap Boiling, burning, grinding or steaming bones Boiling or cleaning tripe Breeding maggots from putrescible animal matter Cleaning, adapting or treating animal hair Curing fish Dealing in rags and bones (including receiving, storing, sorting or manipulating rags in, or likely to become in, an offensive condition, or any bones, rabbit skins, fat or putrescible animal products of a similar nature) Dressing or scraping fish skins Drying skins Making manure from bones, fish, offal, blood, spent hops, beans or other putrescible animal or vegetable matter Making or scraping guts Manufacturing animal charcoal, blood albumen, candles, catgut, glue, fish oil, size or feeding stuff for animals or poultry from meat, fish, blood, bone, feathers, fat or animal offal either in an offensive condition or subjected to any process causing noxious or injurious effluvia Melting, refining or extracting fat or tallow Preparing skins for working

Table VII (Continued)

Class	Used for the main or primary purpose
B8 Storage or distribution	Storage or as a distribution centre
C1 Hotels and hostels	Hotel, boarding or guest house or a hostel where, in each case, no significant element of care is provided
C2 Residential institutions	Residential accommodation and care for people (other than a use within class C3) Hospital or nursing home Residential school, college, training centre
C3 Dwelling houses whether or not sole or man residences	(a) For a single person or by people living together as a family, or (b) By not more than 6 residents living together as a single household (including a household where care is provided for residents)
D1 Non-residential institutions	(a) For any medical or health services except when attached to the residence of the consultant or practitioner (b) Creche, day nursery, day centre (c) For education (d) For the display of works of art (otherwise than for sale or hire) (e) Museum (f) Public library, public reading room (g) Public hall, exhibition hall (h) Public worship, religious instruction
D2 Assembly and leisure	(a) Cinema (b) Concert hall (c) Bingo hall or casino (d) Dance hall (e) Swimming bath, skating rink, gymnasium, area for other indoor or outdoor sports or recreations, not involving motorised vehicles or firearms
UNCLASSED	(a) Theatre (b) Amusement arcade or centre, funfair (c) Laundrette (d) Petrol station (e) Motor vehicle showroom (f) Taxi or motor hire office (g) Scrapyard, yard for the storage or distribution of minerals or car-breaking (h) For any work registerable under the Alkali, etc. Works Regulation Act 1906

7.06 Size of components

Coordinating and work sizes
Controlling dimensions are coordinating sizes:

- Coordinating sizes, **1.22**, make allowance for fitting and jointing. They represent the overlaid grid which does not usually coincide with actual junction lines on the face of the building. They are indicated by open arrowheads.
- Work sizes are the specified manufactured sizes (within permissible deviations). They are indicated by closed arrowheads.

Tolerance and fit
Joint sizes are critical. There are graphical aids (see References) to help reconcile all the factors affecting tolerance, such as

- Expansion and contraction
- Variability in manufactured size
- Satisfactory joint clearance range
- Variations in setting out dimensions, adjacent components, etc.
- Number of components in an assembly
- Variations in interpretation of work size from a given coordinating size.

Degree of accuracy
Designers should identify where fit is critical and where not, or they must assess:

- Where standard sizes are appropriate and readily available
- If some components can be made to order without a significant cost penalty
- Whether cutting is acceptable (and the effect on performance)
- The likely order of assembly.

7.07 Boundary conditions

Some assembly and support conditions may necessitate variations in elements to allow for:

- An extended floor slab beyond the clear span to gain a bearing on a wall
- Reduction in size to permit the application of a finish
- An increased height of positioning to allow for building directly off the floor slab or extending through a suspended ceiling to reach the soffit of the floor slab.

These allowances (termed ‘boundary conditions’) should be in multiples of 25 mm. They may be uneconomic to produce, limiting the applications of the product to which they apply.

7.08 Dimensionally co-ordinated products

Section 5 of DD 51 lists British Standards where products are dimensionally coordinated. Many appear in Chapter 46 of this handbook.

8 PLANNING

8.01

In most countries of the world some permit or permission is required for building to take place. In Britain, this involves seeking planning permission from the local authority in whose area the development is proposed. There are a number of circumstances under which permission is not required, and the local authority will, if asked, provide a certificate to that effect in each particular case. Generally, permission will be required for:

- A building, engineering or mining operation on land,
- The material change of *use* of a building or land.

Building operations which affect only the interior of a building or which do not materially affect the external appearance of a building do not generally require planning permission. The exception to this is where works on *Listed Buildings* are involved. In this instance *Listed Building Consent* is required for both internal and external works, and always where demolition is involved, whether in part or whole.

8.02 Change of use

The more common uses of buildings are classified by statute into classes which are detailed in Table VII. Planning permission is required for any change of use from one class to another; for example, from a funeral directors (A1f) to a solicitor's office (A2b). However, some changes from one class to another can be made without permission, e.g. from A3 to A1 or A2 but not the other way round. Changes permitted in this way are ones which would generally constitute an environmental improvement.

8.03 Conservation areas

Certain areas, such as the centres of historic towns or areas of particular environmental quality, are designated *Conservation Areas*. The controls in these areas are generally similar to those elsewhere, except with regard to demolition and permitted development rights. Furthermore, where permission is required, there is a duty that development must not harm the character or appearance of the Conservation Area (i.e. undermine the reasons why the Conservation Areas was designated). Demolition of buildings or parts of buildings in a Conservation Area requires *Conservation Area Consent*.

8.04 Permitted development

Some categories of development enjoy permitted development rights. This means that some development can take place *without* permission from the local authority. The removal of some or all of these rights can be undertaken by the local authority through the issuing of an *Article 4 direction*. Article 4 directions are generally made where some environmental harm would be caused if these rights were exercised (e.g. in Conservation Areas). Consult the appropriate planning authority in each case to discover the local controls. Most permitted development rights apply only to single-family dwelling houses, and relate to such matters as garden walls, porches, changes to windows, etc.

9 REFERENCES

BS 1192: Part 1: 1984 Construction drawing practice, recommendations for general principles

BS 1192: Part 2: 1987 Construction drawing practice, recommendations for architectural and engineering drawings

BS 1192: Part 3: 1987(1993) Construction drawing practice, recommendations for symbols and other graphic conventions

BS 1192: Part 4: 1984 Construction drawing practice, recommendations for landscape drawings

BS 1192: Part 5: 1998. Construction drawing practice. Guide for structuring and exchange of CAD data

BS 4484: Part 1: 1969 Measuring instruments for constructional works. Metric graduation and figuring of instruments for linear measurement

BS 5606: 1990 Guide to accuracy in building

BS 6750: 1986 Modular co-ordination in building International Organisation For Standardisation

ISO 1791: 1973 Modular co-ordination – vocabulary

ISO 1006: 1973 Modular co-ordination – basic module

ISO 2848: 1974 Modular co-ordination – principles and rules

ISO 1040: 1973 Modular co-ordination – multimodules for horizontal co-ordinating dimensions

ISO 1790: 1970 Modular co-ordination – reference lines of horizontal controlling coordinating dimensions

ISO 1789: 1973 Modular co-ordination – storey heights and room heights for residential buildings

ISO 2776: 1974 Modular co-ordination – co-ordinating sizes for door-sets – external and internal General

ISO 13567-1: 1998 Technical product documentation – Organization and naming of layers for CAD – Part 1: Overview and principles

ISO 13567-2: 1998 Technical product documentation – Organization and naming of layers for CAD – Part 2: Concepts, format and codes used in construction documentation

ISO/TR 13567-3: 1999 Technical product documentation – Organization and naming of layers for CAD – Part 3: Application of ISO 13567-1 and ISO 13567-2

Graphical aids for tolerances and fits: handbook for manufacturers, designers and builders, Building Research Establishment Report, London, HMSO, 1974

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2 Basic design data: People and space

KEY POINTS:
- *Certain dimensions are crucial to individual use and health*
- *Satisfying the average situation is unlikely to help the majority*
- *Each case must be carefully considered with all classes of users, particularly people with different disabilities, in mind*

Contents

1 INTRODUCTION

In this chapter will be found basic data which are needed for the design of most types of buildings. However, some basic matters are dealt with in later chapters, principally the following:

- Sanitary provision and activity spaces in Chapter 5
- Requirements for vehicles in Chapter 31
- External and landscape design in Chapter 7
- Eating and drinking in other than domestic situations in Chapter 17.

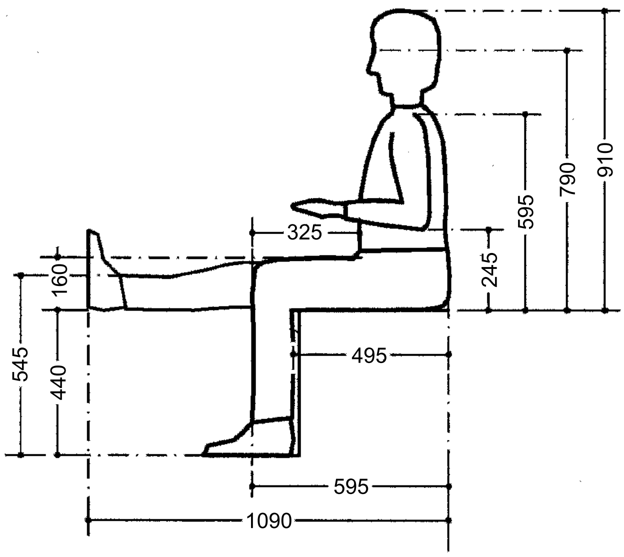
2 ANTHROPOMETRICS

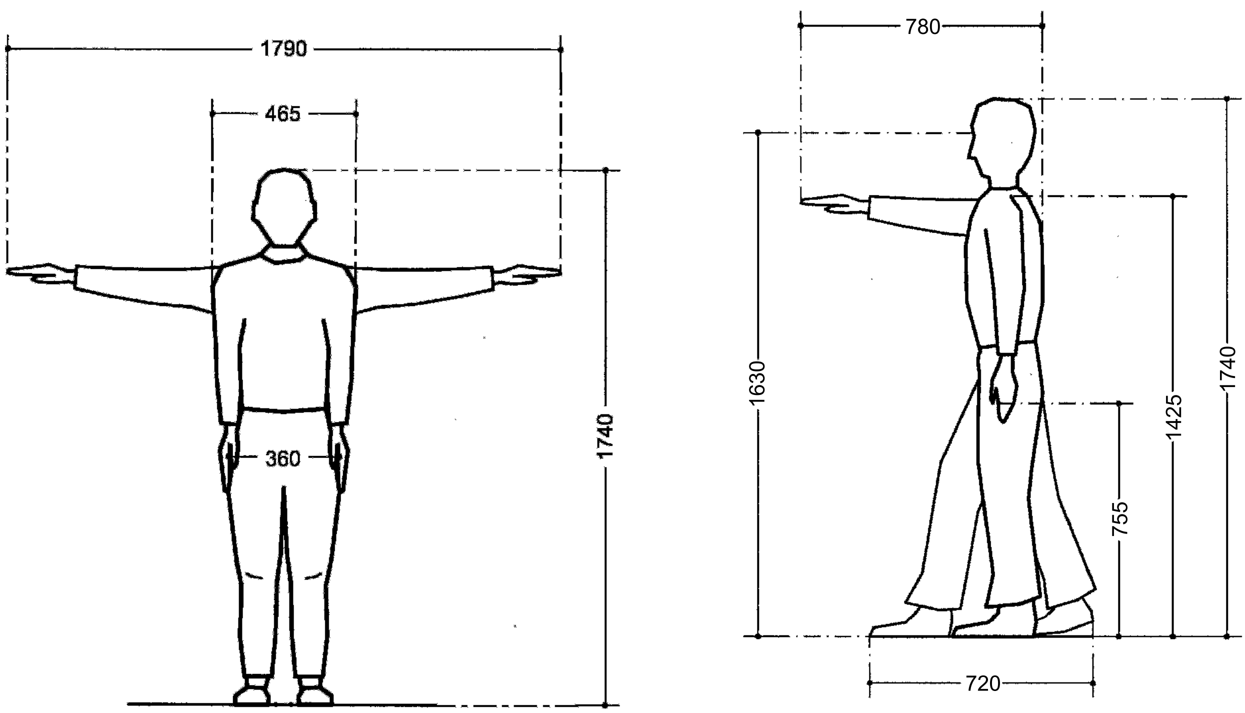
2.01

Anthropometrics is the science concerned with the measurement of humankind. Inevitably it is bound up with statistics, as people vary considerably in most dimensions. Anthropometrics is of crucial importance to architects as the ultimate basis of the design of most buildings must be the size of the people using them. Average dimensions for British adults are given in **2.1** and **2.2**, but in most cases the use of an average dimension will not produce satisfaction for the majority of users.

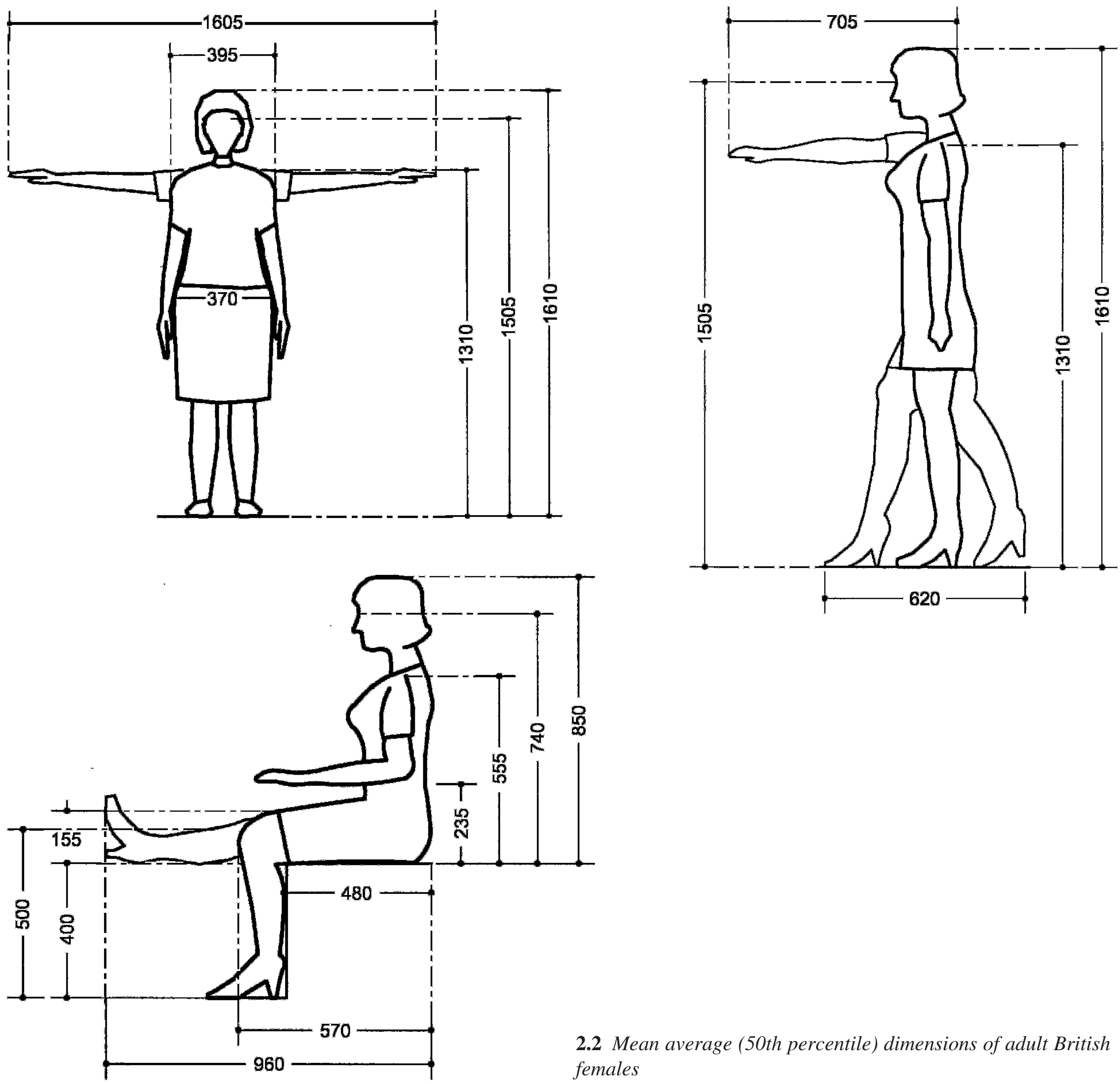
2.02 Normal distribution

When surveys are taken of adult males, for example, they show a 'normal distribution' curve: the traditional statistical bell shape,





2.1 *Mean average (50th percentile) dimensions of adult British males*



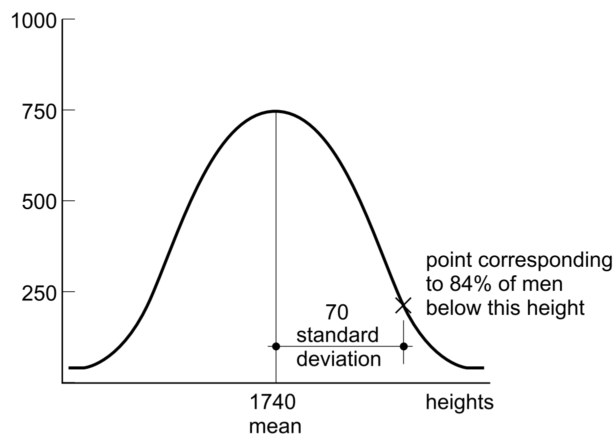
2.2 *Mean average (50th percentile) dimensions of adult British females*

2.3. This shape is totally definable by the two parameters, mean and standard deviation (SD). The mean (in this case) is the average already discussed. For the purposes of the architect, the standard deviation can be taken as the difference from the mean within which 84 per cent of the population are included. The percentage included is called the 'percentile', and it has become accepted (with certain exceptions) that designers generally seek to accommodate those within the band between the 5th and 95th percentile – that is, they do not attempt to satisfy the last 10 per cent of the people. In each case it is the job of the architect to decide whether in fact this will be acceptable.

Table II gives the principal dimensions as shown in **2.4** for men and women, for the 5th, 50th and 95th percentiles.

When a survey of a non-cohesive group (such as of mixed-age adolescents, or men and women together) is taken, a normal distribution curve is not obtained. We cannot predict the percentile dimensions for these populations, and this is why the tables here and elsewhere segregate populations into groups. Within these groups the dimensions are calculable given the mean and the SD, using the formula:

$$X_{(p)} = \text{mean} + \text{SD} \times z$$



2.3 *Normal distribution 'bell' curve. The y-axis plots the numbers of men (in this example) in a group who are the height given on the x-axis (within certain limits). In a normal distribution the average, the mean and the median are all equal*

where: $X_{(p)}$ is the value of the dimension for the *p*th percentile
z is a factor from Table I

In the tables the standard deviation is not directly given, but may itself be calculated from the values of the 50th (or mean) and 95th percentiles: e.g.

$$X_{(95)} - \text{mean} = \text{SD} \times 1.64 \text{ (the value of } z \text{ for } p = 95)$$

Example: A doorway is to be designed to accommodate 99.9 per cent of British men. We see from Table II that the mean stature is 1740 mm and the SD is $(1855 - 1740) \div 1.64 = 70$. The height that will fulfil the 99.9 per cent criterion is thus $1740 + (70 \times 3.09) = 1956$ mm, a considerable increase on the value of 1855 mm which accommodates the 95th percentile. In both cases the addition of a further 25 mm would be necessary to allow for footwear (see Table III).

Table I Selected *p* and *z* values for the normal distribution curve

p	*z*
0.001	−4.26
0.01	−3.72
0.1	−3.09
0.5	−2.58
1	−2.33
2	−2.05
2.5	−1.96
3	−1.88
4	−1.75
5	−1.64
10	−1.28
20	−0.84
25	−0.67
30	−0.52
40	−0.25
50	0
60	0.25
70	0.52
75	0.67
80	0.84
90	1.28
95	1.64
96	1.75
97	1.88
97.5	1.96
98	2.05
99	2.33
99.5	2.58
99.9	3.09
99.99	3.72
99.999	4.26

2.03 Clothing

The tables are all consistent in giving the dimensions of the unclothed body. Increases due to clothing vary considerably but Table III gives the normally acceptable values.

2.04 Other nationalities

Dimensional surveys taken elsewhere show considerable variations. Table IV gives the range of stature found in various countries. For most purposes other dimensions can be approximately derived by proportionality with Table II, but more accurate figures can be obtained from the References at the end of this chapter.

2.05 Children and adolescents

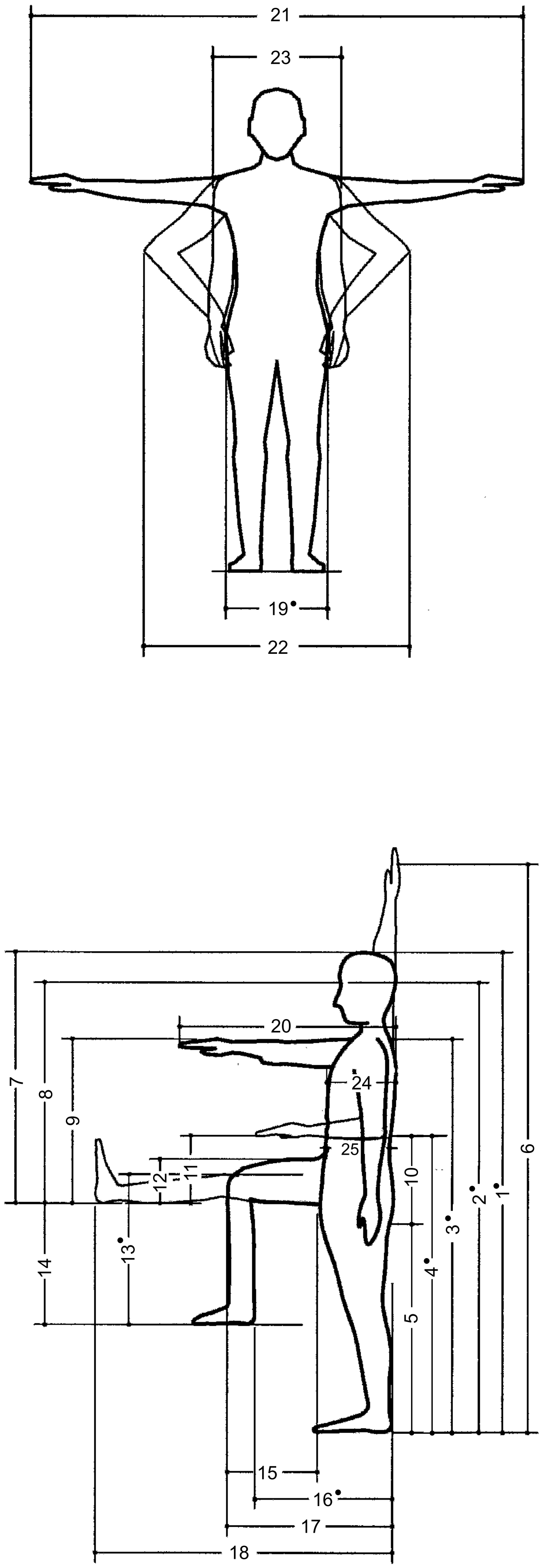
Statures (or equivalents) for various ages in Britain are given in Table V. Here proportionality may not give sufficient accuracy, and reference should be made to one of the references for other dimensions.

2.06 Elderly people

People tend to shrink slightly with age. More significantly, the body tends to be less flexible in regard to adapting to dimensionally unfavourable situations. It is therefore more important that design allows for elderly people where that is appropriate, accepting that younger people may be slightly disadvantaged. Table VI gives dimensions for people between the ages of 65 and 80.

Table II Dimensions of British adults

	Men Percentiles			Women Percentiles			
	50th	50th	95th	50th	50th	95th	
Standing							
1 Stature	1625	1740	1855	1505	1610	1710	95th: minimum floor to roof clearance; allow for shoes and headgear in appropriate situations
2 Eye height	1515	1630	1745	1405	1505	1610	50th: height of visual devices, notices, etc.
3 Shoulder height	1315	1425	1535	1215	1310	1405	5th: height for maximum forward reach controls worktop height (see para. 302)
4 Elbow height	1005	1090	1180	930	1005	1085	controls worktop height (see para. 302)
5 Hand (knuckle) height	690	755	825	660	720	780	95th: maximum height of grasp points for lifting
6 Reach upwards	1925	2060	2190	1790	1905	2020	5th: maximum height of controls; subtract 40 mm to allow for full grasp
Sitting							
7 Height above seat level	850	910	965	795	850	910	95th: minimum seat to proof clearance; may need to allow for headgear
8 Eye height above seat level	735	790	845	685	740	795	50th: height of visual devices above seat level
9 Shoulder height above seat level	540	595	645	505	555	610	50th: height above seat level for maximum forward reach
10 Length from elbow to fingertip	440	475	510	400	430	460	50th: easy reach forward at table height
11 Elbow above seal level	195	245	295	185	235	280	50th: height above seat of armrests or desk tops
12 Thigh clearance	135	160	185	125	155	180	95th: space under tables
13 Top of knees, height above floor	490	545	595	455	500	540	95th: clearance under tables above floor or footrest
14 Popliteal height	395	440	490	355	400	445	50th: height of seat above floor or footrest
15 Front of abdomen to front of knees	253	325	395	245	315	385	95th: minimum forward clearance at thigh level from front of body or from obstruction, e.g. desktop
16 Buttock – popliteal length	440	495	550	435	480	530	5th: length of seat surface from backrest to front edge
17 Rear of buttocks to front of knees	540	595	645	520	570	620	95th: minimum forward clearance from seat back at height for highest seating posture
18 Extended leg length	985	1070	1160	875	965	1055	5th (less than): maximum distance of foot controls, footrest, etc. from seat back
19 Seat width	310	360	405	310	370	435	95th: width of seats, minimum distance between armrests
Sitting and standing							
20 Forward grip reach	720	780	835	650	705	755	5th: maximum comfortable forward reach at shoulder level
21 Fingertip span	1655	1790	1925	1490	1605	1725	5th: limits of lateral fingertip reach, subtract 130 mm to allow for full grasp
22 Width over elbows skimbo	865	945	1020	780	850	920	95th: lateral clearance in workspace
23 Shoulder width	420	465	510	355	395	435	95th: minimum lateral clearance in workspace above waist
24 Chest or bust depth	215	250	285	210	250	295	
25 Abdominal depth	220	270	320	205	255	305	



2.4 *Key dimensions listed in Table II. These figures are based on surveys of unclothed volunteers, and in using them allowances should be made for the wearing of clothes and shoes (see Table III). Dimension references marked • are most commonly used*

Table III Allowance for clothing

	Men	Women
Shoe height	25 mm	45 mm
Hat height	75 mm	100 mm

Table IV Statures of the adults of various nationalities

	Men Percentiles			Women Percentiles		
	5th	50th	95th	5th	50th	95th
British	1625	1740	1855	1505	1610	1710
US	1640	1755	1870	1520	1625	1730
French	1600	1715	1830	1500	1600	1700
German	1645	1745	1845	1520	1635	1750
Swedish	1630	1740	1850	1540	1640	1740
Swiss	1535	1690	1845	1415	1590	1765
Polish	1595	1695	1795	1480	1575	1670
Japanese	1560	1655	1750	1450	1530	1610
Hong Kong Chinese	1585	1680	1775	1455	1555	1655
Indian	1535	1640	1745	1415	1515	1615

Table V Statures (or equivalents) for Britons in various age groups

	Percentiles		
	5th	50th	95th
New-born infants	465	500	535
Infants less than 6 months old	510	600	690
Infants 6 months to 1 year old	655	715	775
Infants 1 year to 18 months	690	745	800
Infants 18 months to 2 years	780	840	900

	Boys/men Percentiles			Girls/women Percentiles		
	5th	50th	95th	5th	50th	95th
Children, 2 years old	850	930	1010	825	890	955
Children, 3 years old	910	990	1070	895	970	1045
Children, 4 years old	975	1050	1125	965	1050	1135
Children, 5 years old	1025	1110	1195	1015	1100	1185
Children, 6 years old	1070	1170	1270	1070	1160	1250
Children, 7 years old	1140	1230	1320	1125	1220	1315
Children, 8 years old	1180	1280	1380	1185	1280	1375
Children, 9 years old	1225	1330	1435	1220	1330	1440
Children, 10 years old	1290	1390	1490	1270	1390	1510
Children, 11 years old	1325	1430	1535	1310	1440	1570
Children, 12 years old	1360	1490	1620	1370	1500	1630
Children, 13 years old	1400	1550	1700	1430	1550	1670
Children, 14 years old	1480	1630	1780	1480	1590	1700
15 years old	1555	1690	1825	1510	1610	1710
16 years old	1620	1730	1840	1520	1620	1720
17 years old	1640	1750	1860	1520	1620	1720
18 years old	1660	1760	1860	1530	1620	1710
Aged 19–25	1640	1760	1880	1520	1620	1720
Aged 19–45	1635	1745	1860	1515	1615	1715
Aged 19–65	1625	1740	1855	1505	1610	1710
Aged 45–65	1610	1720	1830	1495	1595	1695
Aged 65–85	1575	1685	1790	1475	1570	1670
Elderly people	1515	1640	1765	1400	1515	

3 ERGONOMICS

3.01

This is the discipline that deals with the dimensions of people at work, including activities not directly connected with earning a living. Such matters as the space required by people using motor-cars, flying aeroplanes and operating machinery come under this heading. Many of the dimensions required for this will be found in Table II.

Table VI Dimensions for British people aged 65 to 80

	Men Percentiles			Women Percentiles		
	5th	50th	95th	5th	50th	95th
Standing						
1 Stature	1575	1685	1790	1475	1570	1670
2 Eye height	1470	1575	1685	1375	1475	1570
3 Shoulder height	1280	1380	1480	1190	1280	1375
4 Elbow height	975	895	975	740	810	875
5 Hand (knuckle) height	670	730	795	645	705	760
6 Reach upwards	1840	1965	2090	1725	1835	1950
Sitting						
7 Height above seat level	815	875	930	750	815	885
8 Eye height above seat level	705	760	815	645	710	770
9 Shoulder height above seat level	520	570	625	475	535	590
10 Length from elbow to fingertip	425	460	490	390	420	450
11 Elbow above seat level	175	220	270	165	210	260
12 Thigh clearance	125	150	175	115	145	170
13 Top of knees, height above floor	480	525	575	455	500	540
14 Popliteal height	385	425	470	355	395	440
15 Front of abdomen to front of knees	210	280	350	325	295	365
16 Buttock – popliteal length	430	485	535	430	480	525
17 Rear of buttocks to front of knees	530	580	625	520	565	615
19 Seat width	305	350	395	310	370	430
Sitting and standing						
20 Forward grip reach	700	755	805	640	685	735
21 Fingertip span	1605	1735	1860	1460	1570	1685
23 Shoulder width	400	445	485	345	385	380

3.02 Worktop heights

The most common ailment after the common cold is probably the 'bad back'. Many believe that this can be caused by working on a surface that is too low, causing stooping. Both when standing and sitting to work, it is important that the worktop should be as follows:

- For manipulative tasks involving moderate degrees of both force and precision: between 50 and 100 mm below elbow height of the person concerned
- For delicate tasks: between 50 and 100 mm above elbow height
- For heavy tasks, particularly those involving downward pressure on the workpiece: between 100 and 300 mm below elbow height.

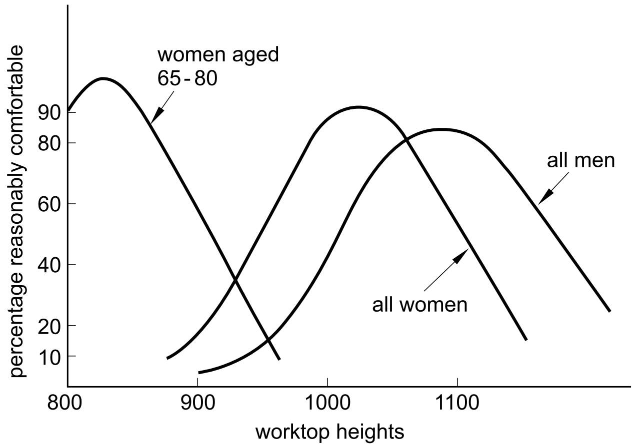
3.02 Standing worktops

Worktops at which people stand are found in factories and in the home kitchen. Since women are generally shorter in stature than men, the heights of these respective surfaces have tended to reinforce the traditional roles of the sexes: factory worktops at 1050 mm being seen as too high for many women and kitchen worktops at 900 mm (or lower) being too low for men. It is possible in factories to provide small moveable platforms to assist women workers, but this type of solution is not available where the worktop is too low for the user.

In **2.5** the percentage comfortable at each worktop height is plotted assuming that the users are wearing shoes and comfort is achieved with tops between 50 mm above elbow height and 100 mm lower. It can be seen that the standard kitchen worktop height of 900 mm actually seems to suit no-one. 850 mm would be a good height where only elderly women are likely to use it. The surprising thing is that 900 mm is uncomfortable for 84 per cent of all women! 1000 mm is ideal for most women, but only for 40 per cent of men. The traditional men's height of 1050 mm appears to satisfy both 76 per cent of men and 84 per cent of women.

3.03 Sink heights

One of the most common domestic chores is washing up. It is customary for sinks to be set into worktops, or fitted with their rims level with them. Since the effective working surface in this case is the base of the sink, usually about 100 mm lower than the rim, this further worsens the situation. It is recommended that sink surrounds should be fitted at least 75 mm above normal worktop height.



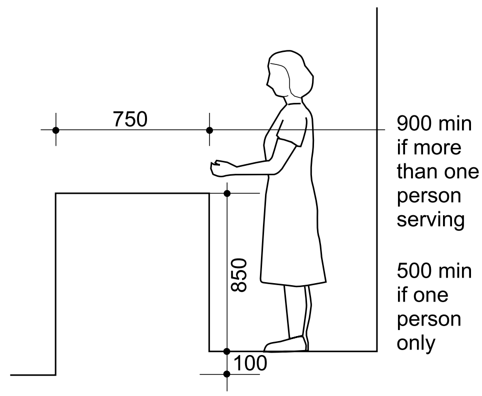
2.5 *Graphs of percentages comfortable at each worktop height. These assume that the worktop is between 50 mm above and 100 mm below elbow height, and that shoes are worn*

3.04 Serveries

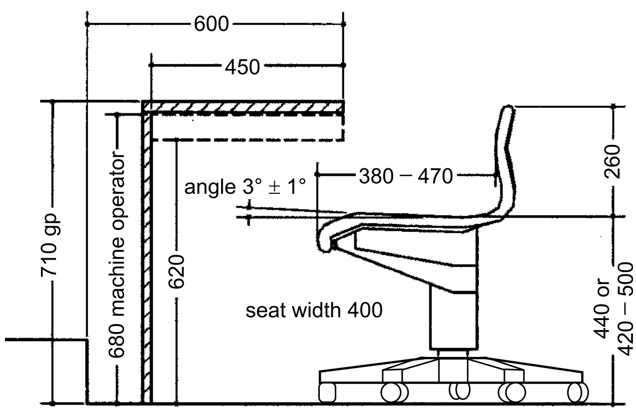
A particular type of standing worktop is a counter, **2.6**. This can be in a shop, restaurant or public house, or be a reception counter in an office or a hotel. There is often no good reason why the same height is needed on each side, and it is common for the non-public side to be higher than the other. Details of such can be found in the appropriate specialist chapters.

3.04 Sitting worktops

Traditionally, writing desks are standard in height at 710 mm, **2.7**. Desks for typewriters and word processors (where the working



2.6 *Serving counter*

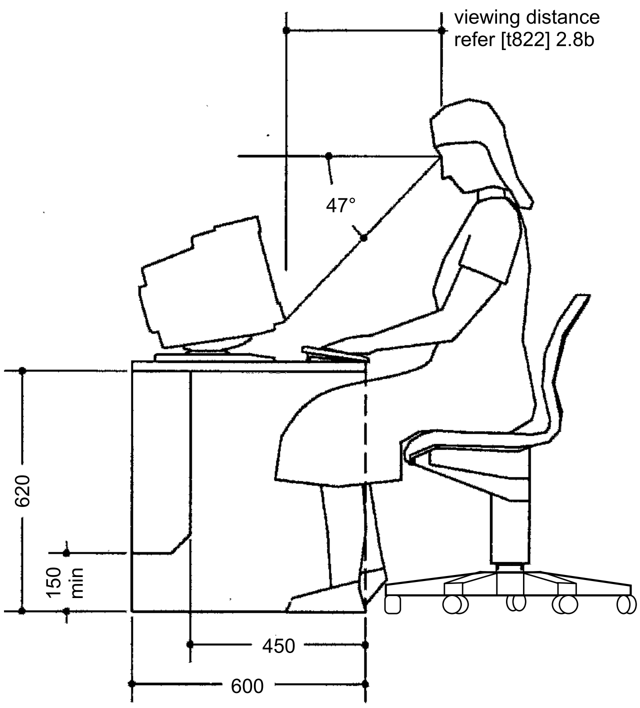


2.7 *Sitting worktop*

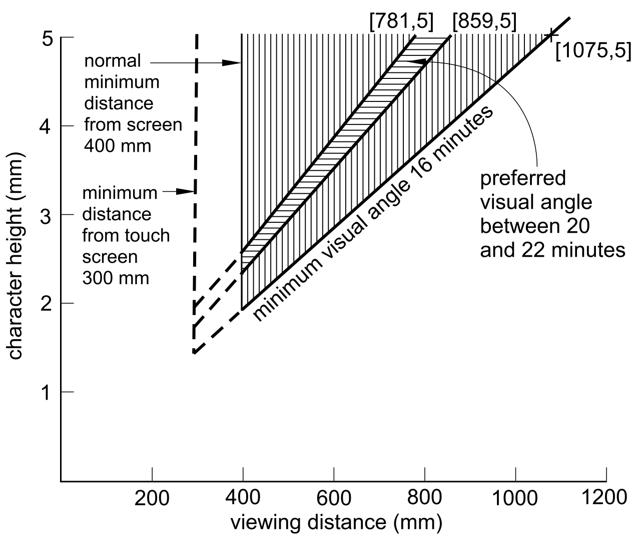
surface is the top of the keyboard) are available 30 mm lower. Chairs for sitting workers are now by legislation required to provide for vertical adjustment so that each individual can find the right relationship with the worktop. However, it is important that the feet remain in contact with the ground, and where this is not possible, footrests should be provided.

3.05 Computer work stations

Many office workers now work with visual display units (VDUs), and these introduce further requirements for comfortable and healthy working. People often find working at a screen tiring to the eyes. **2.8** gives the recommended dimensions for minimising fatigue; some people may need special spectacles. Most VDUs are placed at or above eye level so that normal bifocals do not help. Opticians are now used to supplying ‘intermediate’ spectacles with the normal bifocal facility for viewing the keyboard and material on the desk, with the upper part allowing focus on the near distance. This permits the VDU to be placed between 900 to 1000 mm distant from the user.



2.8 a *Computer workstation*



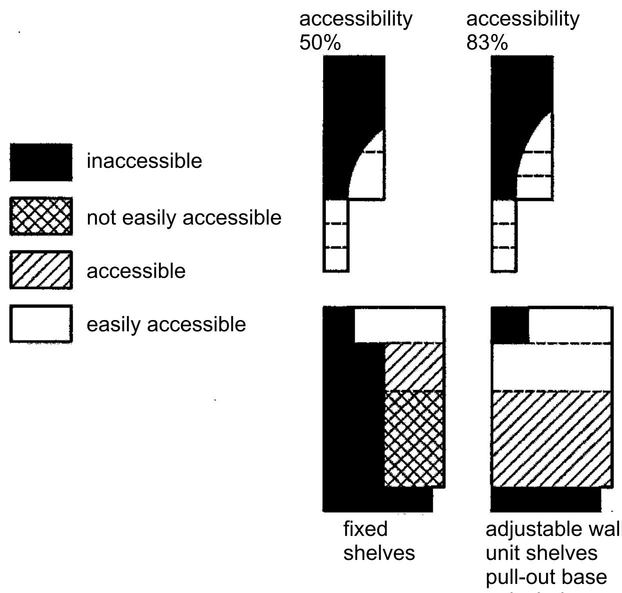
2.8 b *Viewing distance*

3.06 Storage

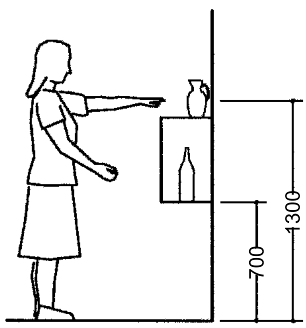
Two of the commonest operations at work and in the home is the stowage and retrieval of items into and from storage. **2.9** shows the recommended heights for various storage areas for general use; **2.10** gives particular requirements where elderly people are concerned.

3.07 Maintenance

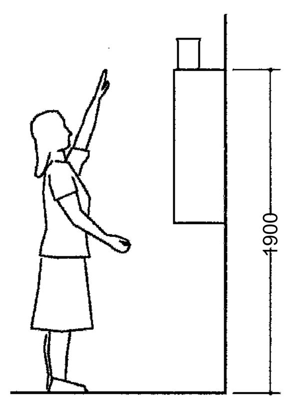
Buildings and the services and plant therein need constant maintenance. Something frequently forgotten is the need for easy access to certain areas. It is reasonable to assume that people employed on maintenance work will be sufficiently agile and not greatly above average size. The dimensions shown in **2.11** to **2.18** are therefore less than would be required for use by the general public.



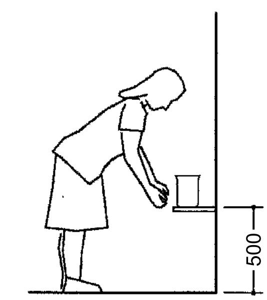
a *Zones of accessibility*



b *Frequently needed articles*

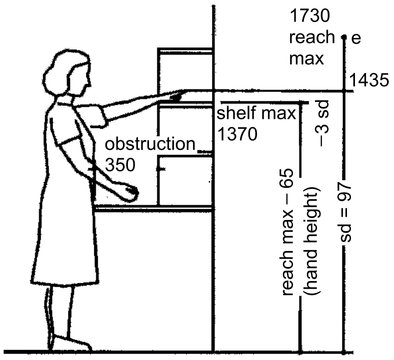


c *Less frequently needed articles higher*

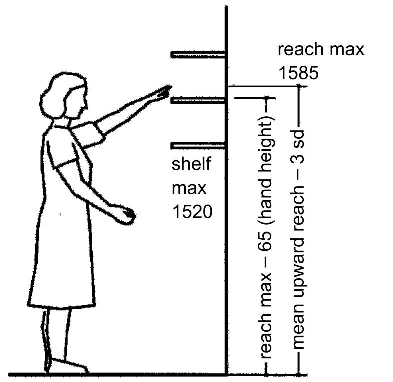


d *Less frequently needed articles lower*

2.9 *Accessibility of storage*

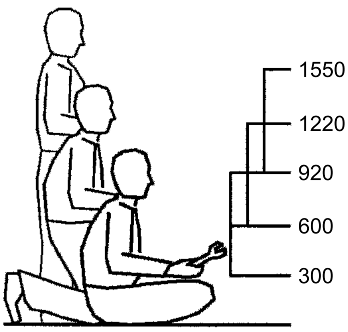


a *Maximum reach over worktop*

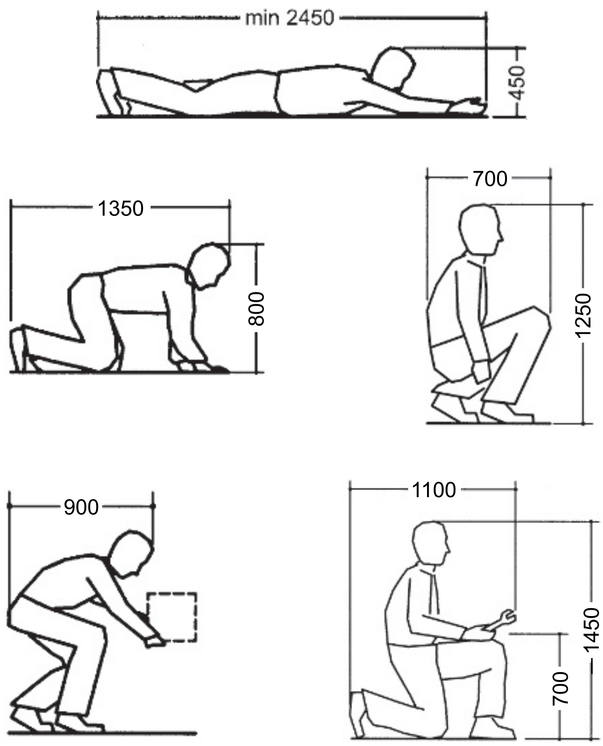


b *Maximum reach to unobstructed wall-mounted cupboard*

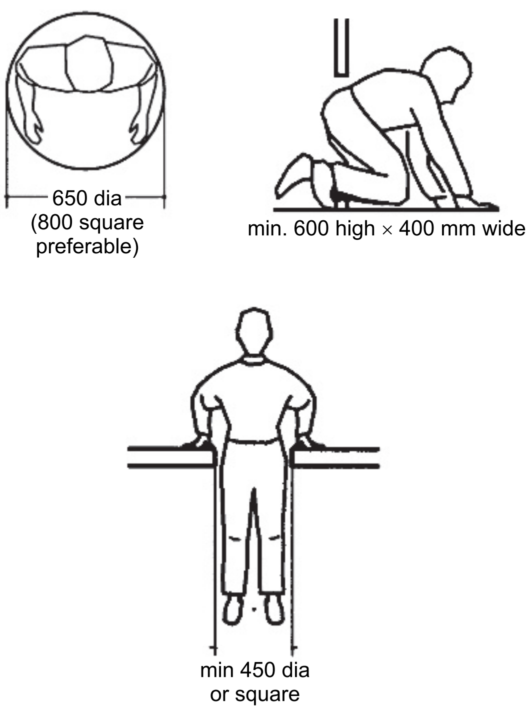
2.10 *Accessibility of storage used by elderly people*



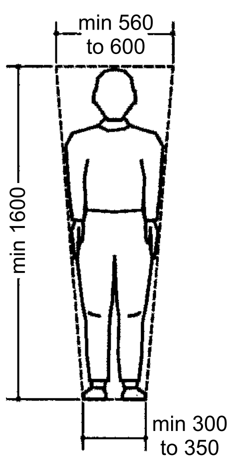
2.11 *Body clearance: maintenance reach levels*



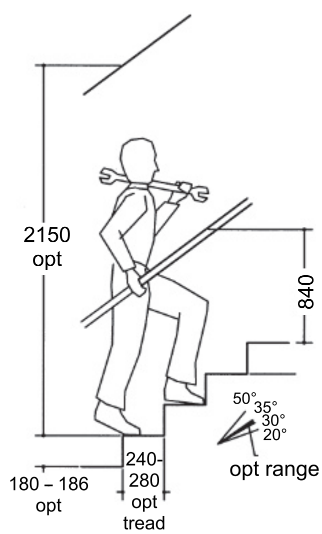
2.13 *Body clearances*



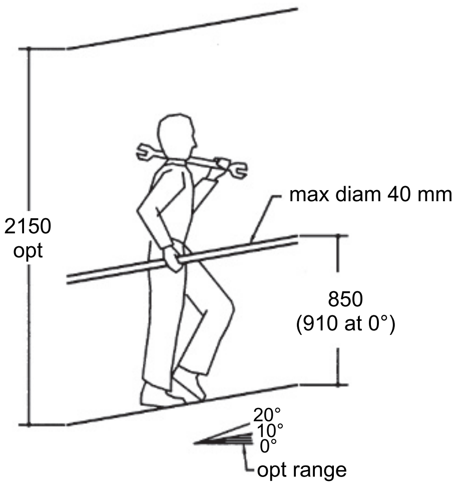
2.12 *Service accesses*



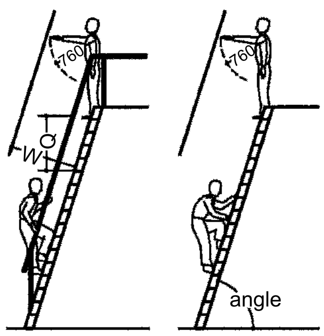
2.14 *Service access: catwalk*



2.15 *Service access: stairs*



2.16 *Service access: ramps*



recommended for angles 50° to 75°
handrails are required on both sides if risers are not left open or if there are no side walls
widths: 500 mm to 600 mm with handrails
600 mm min between side walls

angle	W(mm)	Q(mm)
50°– 55°	1620°– 1570°	880
57°– 60°	1500°– 1450°	900
63°– 66°	1370°– 1320°	910
69°– 72°	1270°– 1200°	920
74°– 77°	1150°– 1050°	950

recommended riser 180 mm to 250 mm
tread 75 mm to 150 mm
45 mm diam max for handrail

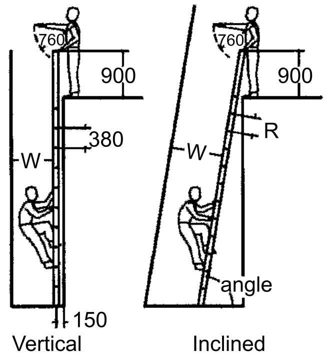
2.17 *Service access: step ladders*

4 DISABLED PEOPLE

4.01

At any one time about 8 per cent of people in Britain are in one way or another disabled. The principal disabilities of concern to the architect are those that mean the person has to use a wheelchair for most or all of the time. That person is handicapped by this in two significant ways: first, the eyes and arms are permanently at sitting rather than standing level, and second, the wheelchair itself takes up to five times the space needed by an ambulant person. While people in wheelchairs constitute only about one quarter of one per cent of the population, society has rightly decided that the design of most buildings should take their needs into account.

There are other forms of disability that are of importance to the building designer. People on crutches can be disadvantaged by ramps provided for wheelchairs, and all ramps should normally be paralleled by steps. Provision for blind people needs to be made



generally suitable for vertical movements from 75° to 90° ladder frame should extend 900 mm above platform
widths: 380 mm min, 450 mm desirable
600 mm min between side walls
150 mm toe space

angle	R(mm)	W(mm)
75.0°	330	1150
78.0°	335	1050
80.5°	340	1000
83.0°	350	950
85.0°	360	900
87.5°	370	850
90.0°	380 max 300 min	800

provide back guard over 6000 mm high

2.18 *Service access: rung ladders*

in the design of signs, raised letters being preferable to Braille, particularly in lifts. Lifts should ideally provide audible as well as visual indication of floor level.

Chapter 44 of this Handbook described inclusion design in greater detail.

4.02 People in wheelchairs

Wheelchairs are of three main types:

- Manually self-propelled
- Propelled by motor
- Propelled by attendant.

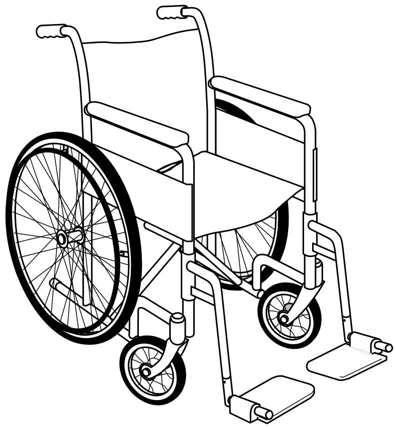
It is the manually self-propelled chair that is used by most active disabled people, and needs to be routinely catered for in buildings. **2.19** gives the dimensions relevant to this type of chair, and **2.20** and **2.21** has dimensions of men and women in such a chair.

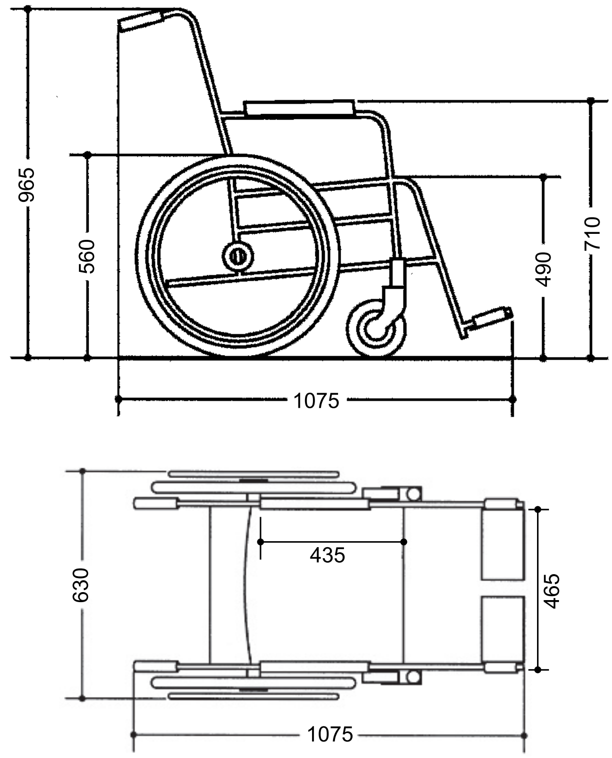
4.03 Ramps

The most common provision made for wheelchairs is a ramp. However, most such ramps are difficult to use, both in mounting and in descending. Except for very short ramps (less than 0.5 m) they should be no steeper than 8 per cent (preferably 6 per cent) and unbroken lengths of ramp no longer than 10 m. For a rise of only 650 mm, therefore, a good ramp would take up a considerable area, **2.22**. The use of a chair lift or of ordinary lifts is therefore often preferable to a ramp, although these suffer from the need for adequate maintenance, and problems arise when they break down. Details of lifts designed for use by elderly and disabled people are given in Chapter 5.

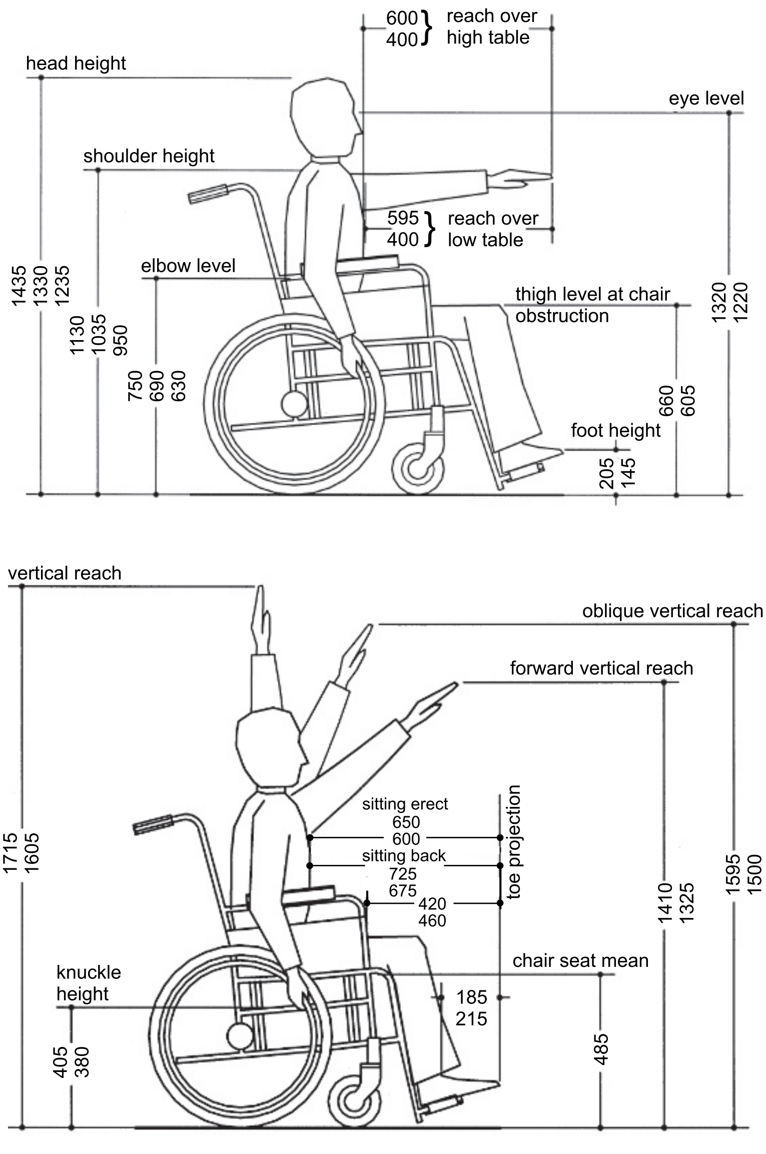
4.04 Width of corridors

The other necessity for wheelchair users is adequate width and design of corridors and doorways. The width of a corridor should not be less than 900 mm for a self-propelled wheelchair, or 1.8 m if two wheelchairs are likely to want to pass each other, **2.23** to **2.26**.

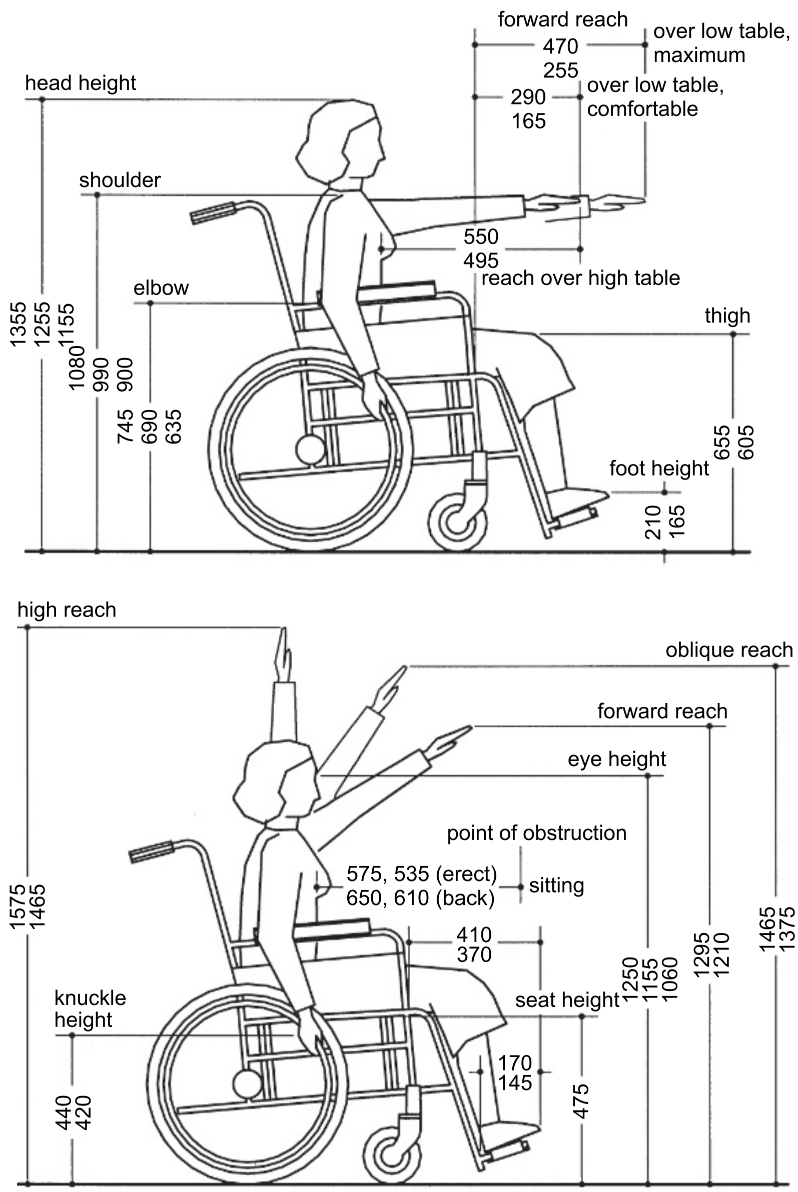




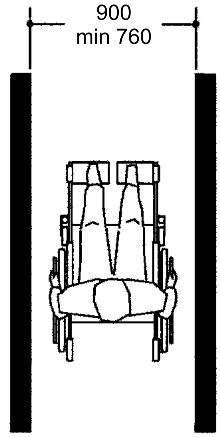
2.19 *DSS model 8G wheelchair, a common type*



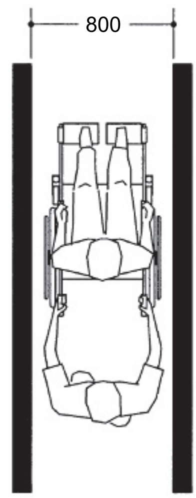
2.20 *Dimensions of different percentiles of adult male wheelchair users. These dimensions and those in* **2.21** *relate to people who use standard wheelchairs and have no major impairment of upper limbs. Figures are given for 95th, 50th and 5th percentiles or two of these*



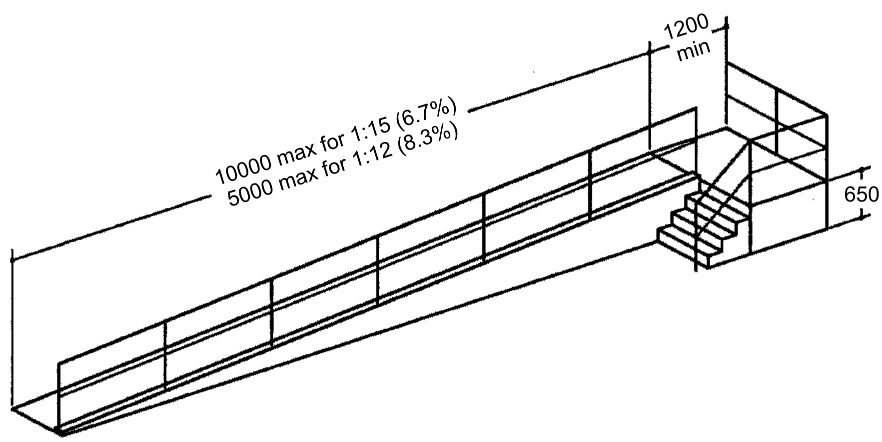
2.21 *Dimensions of adult female wheelchair users. Figures are given for 95th, 50th and 5th percentiles or two of these*



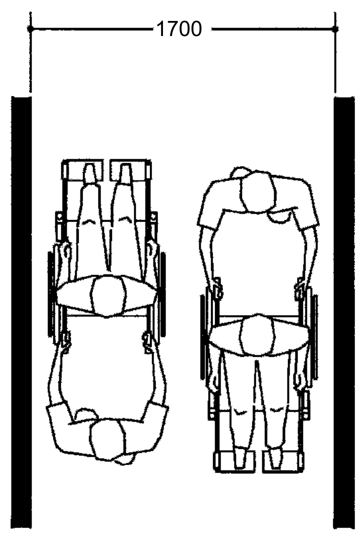
2.23 *Forward movement for self-propelled wheelchair*



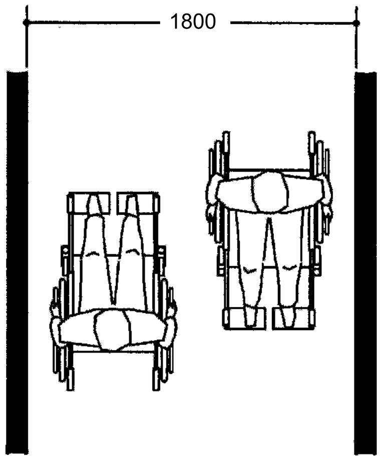
2.24 *Forward movement for wheelchair with attendant*



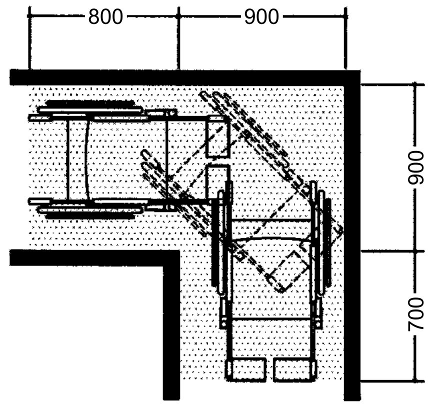
2.22 *Wheelchair ramp of rise 650 mm*



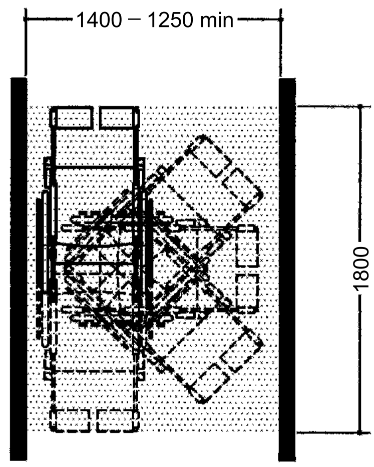
2.25 *Passing place for two wheelchairs with attendants*



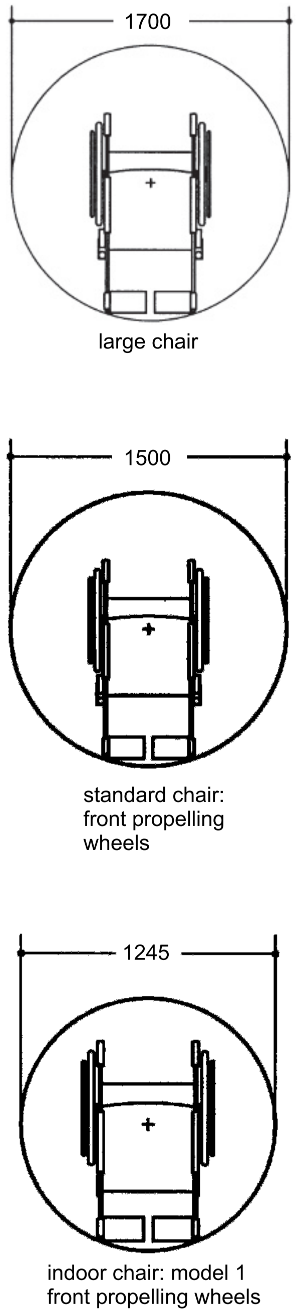
2.26 *Passing place for two self-propelled wheelchairs*



2.28 *Wheelchair forward turn through 90°*



2.29 *Wheelchair turn through 180°*



2.27 *Wheelchair turning circles*

4.05 Turning space

Most wheelchairs require a space 1.4 m square to turn around. This determines the minimum size of lift cars and circulation spaces in rooms.

Turning circles for manœuvering in various ways are shown in **2.27** to **2.29**.

4.06 Doorways

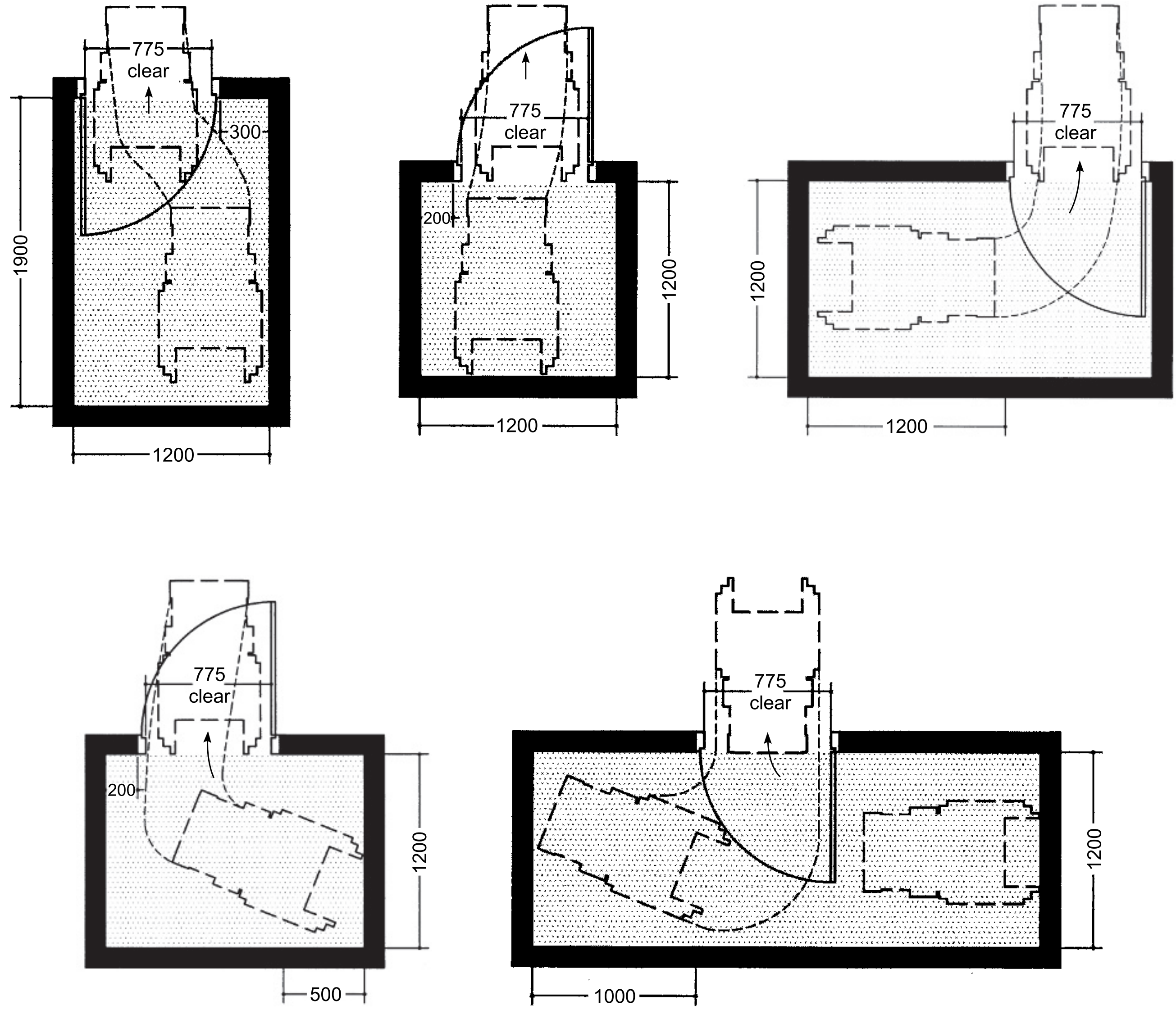
Since the minimum clear opening required is 750 mm, the standard 800 mm (coordinating size) doorset is not wide enough (clear opening 670 mm); a minimum 900 mm set should be used in most buildings. External doors should preferably be 1000 mm, although the 900 mm size has a clear opening just wide enough for most chairs. **2.30** illustrates wheelchairs using doorways.

Where a door opens off a corridor, it may be difficult for a wheelchair to turn sufficiently to go through a minimum width doorway unless the corridor is wide enough. **2.31** indicates preferred widths of opening for various corridor widths.

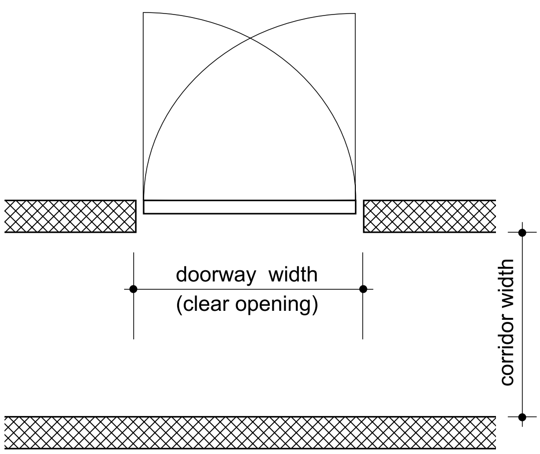
Where double or single swing doors are used these can be difficult for wheelchair users to open. In certain circumstances, sliding doors can be easiest and are often fitted in housing converted or specially built for wheelchair users.

In blocks of flats, offices, etc. the entrance doors are frequently heavy with strong springs to combat the effects of wind. These are not only difficult for wheelchair users, but often also for elderly, ambulant disabled and even people with prams. Consideration should be given to fitting such doors with mechanical opening and closing systems.

Other doors often give problems to people in wheelchairs and elderly people with limited strength. The doors to lavatories designed for disabled people can be particularly difficult. As a



2.30 *Wheelchairs negotiating various doorways*



corridor width	clear doorway required
760	935
800	920
900	885
1000	855
1200	785

2.31 *Width of doorways opening off narrow corridors*

rule, the force required to open such a door should not exceed 35 N (based on a French standard).

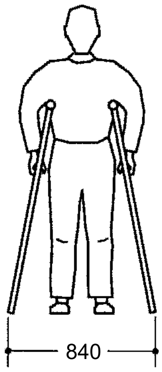
4.07 People on crutches

2.32 gives generally accepted dimensions for a person using crutches. However, such people vary greatly. Most people use them for a short time following an accident, and will be inexpert in their use. Users fall into two broad groups: those who have some use of both legs and feet, and those who have use of only one leg. The former can usually negotiate most obstacles such as steps and staircases. However, those who can use only one leg require a handhold wherever there are steps, even a single step at a building threshold. There is little need for this to be provided for them on both sides as two good arms are needed to use crutches. However, elderly people may also need handholds, and many of these are only able to use one of their hands.

Crutch users often find ramps more of a problem than steps. Ideally, all wheelchair ramps should be adjacent to supplementary steps as in **2.22**.

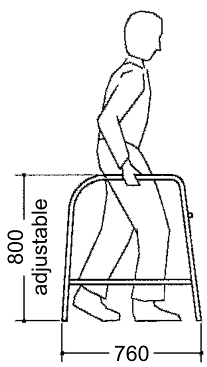
4.08 People with other mobility impairments

Dimensions of people using walking sticks and walking frames are given in **2.33** and **2.34**.



2.32 *Crutch user*

2.33 *Stick user*



2.34 *Person using walking frame*

4.09 Large people

Pregnant women are not usually greatly disadvantaged except that stairs can be very tiring. There are a very small number of people who are so large that it is difficult to pass through a narrow doorway. A single door other than a cupboard should not be narrower than a 800 mm doorset with a clear opening width of 670 mm. In certain buildings such as football stadia, deliberately narrow doorways are used to ensure control over entry. In these cases, and also where turnstiles are used, additional provision for large people should be made.

Problems may also arise where there is fixed seating as, for example, in a theatre. A very small number of oversize seats or benches could be provided, or a loose seat of appropriate size could be used in a position normally occupied by a wheelchair.

5 CIRCULATION SPACES

5.01

Many aspects of internal circulation derive from regulations concerned with fire safety. These are covered in Chapter 42. Increasingly, others relate to the needs of disabled people.

For lifts and escalators see Chapter 5.

As a guide to assessing space allowances, the areas listed in Table VII may be used: these include requirements for both the activity and the associated circulation. Waiting areas are given in Table VIII and the flow capacities of corridors and staircases in Table IX.

5.02 Corridors

The properties of various corridor widths are shown in **2.35**. Some examples of space allowances from Germany are given in **2.36** to **2.39**. In **2.40** to **2.48** a variety of other corridor users are shown, and **2.49** details a number of obstructions commonly found in corridors, and for which additional width may need to be allowed for.

5.02 Internal stairs

Definitions of terms used in relation to staircases are shown in **2.50**. The preferred form and dimensions of steps for ambulant disabled and elderly people are shown in **2.51**. The formula for most staircases of twice the rise plus the going lies between 600 and 630 mm will give a suitable relationship. The rise should not exceed 190 mm, and the going should not be less than 250 mm.

Table VII Minimum areas per person in various types of buildings

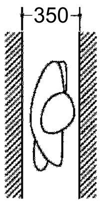
Occupancy	Area per person (m^2)
Assembly halls (closely seated)	0.46 m^2 (based on movable seats, usually armless, 450 mm centre to centre; with fixed sealing at 500 mm centre to centre will increase to about 0.6 m^2)
Dance halls	0.55 m^2 to 0.9 m^2
Restaurants (dining areas)	0.9 m^2 to 1.1 m^2
Retail shops and showrooms	4.6 m^2 to 7.0 m^2 (including upper floors of department stores except special sales areas)
Department stores, bazaars or	0.9 m^2 (including counters, etc.)
bargain sales areas	0.46 m^2 (gangway areas only)
Offices	9.3 m^2 (excluding stairs and lavatories)
Factories	7 m^3

Table VIII Area per person to be allowed in various circulation areas

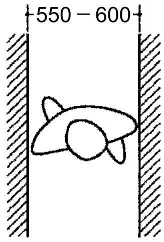
Occupancy	Area per person (m^2)
Overall allowance for public areas in public-handling buildings	2.3 to 2.8
Waiting areas, allowing 50 per cent seating, 50 per cent standing without baggage, allowing cross-flows (e.g. airport lounge)	1.1 to 1.4
Waiting areas, 25 per cent seating, 75 per cent standing, without serious cross-flows (e.g. waiting rooms, single access)	0.65 to 0.9
Waiting areas, 100 per cent standing, no cross-flows (e.g. lift lobby)	0.5 to 0.65
Circulating people in corridors, reduced to halt by obstruction	0.2
Standing people under very crowded conditions – acceptable temporary densities	Lift car capacities: 0.2 m^2 (four-person car); 0.3 m^2 (33-person car)

Table IX Flow capacities of corridors and staircases

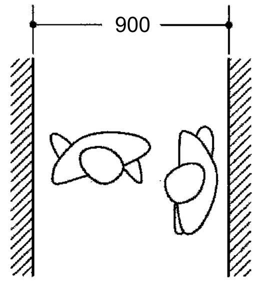
General design purposes	0.8 m^2 per person
People moving at good walking pace (1.3 m/s)	3.7 m^2 per person
People moving at a shuffle (0.4 to 0.9 m/s)	0.27–0.37 m^3 per person
People at a standstill due to obstruction	0.2 m^2 per person



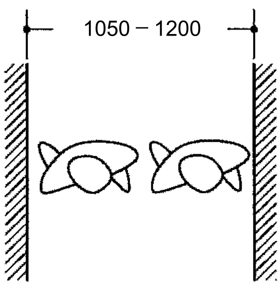
a *Edging width: suitable for short distances or occasional use*



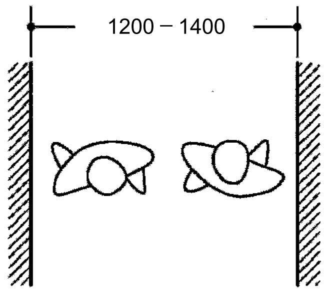
b *One person width (750 clearance would give comfort for various postures)*



c *Normally used by one person, but occasional passing required*

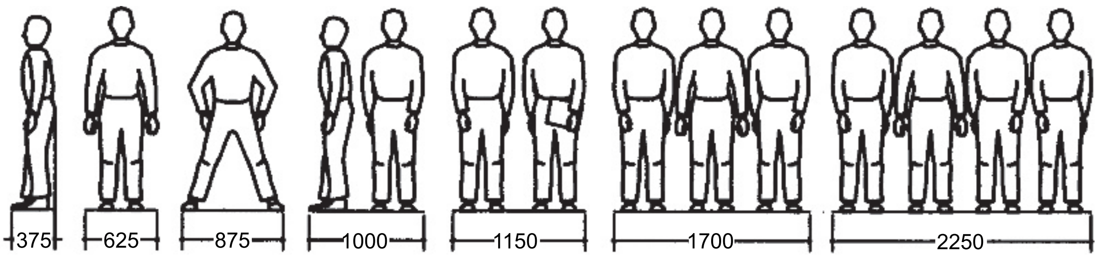


d *Two-person use in same direction*

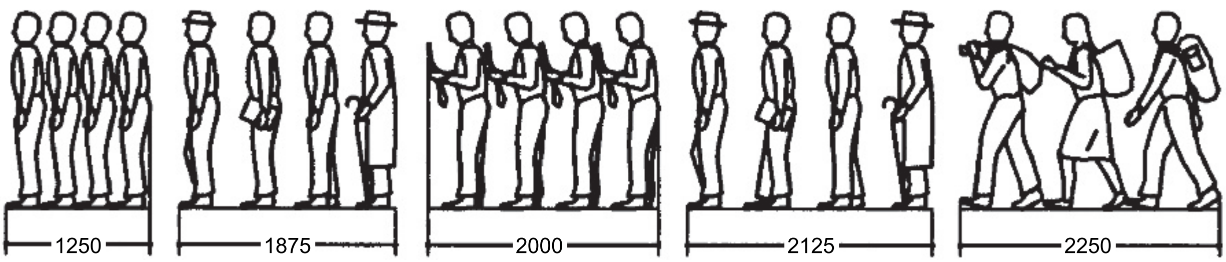


e *Two people passing*

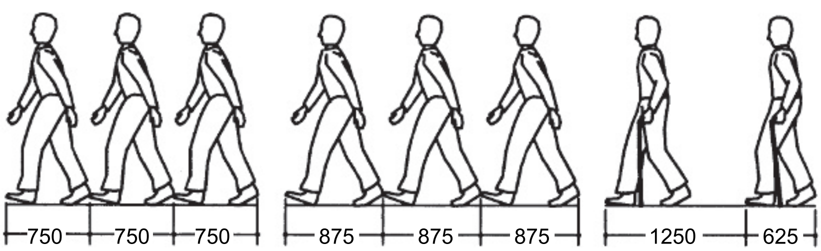
2.35 *Corridor widths*



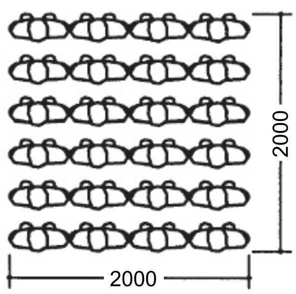
2.36 *Space requirements between walls allowing 10 per cent for easy movement*



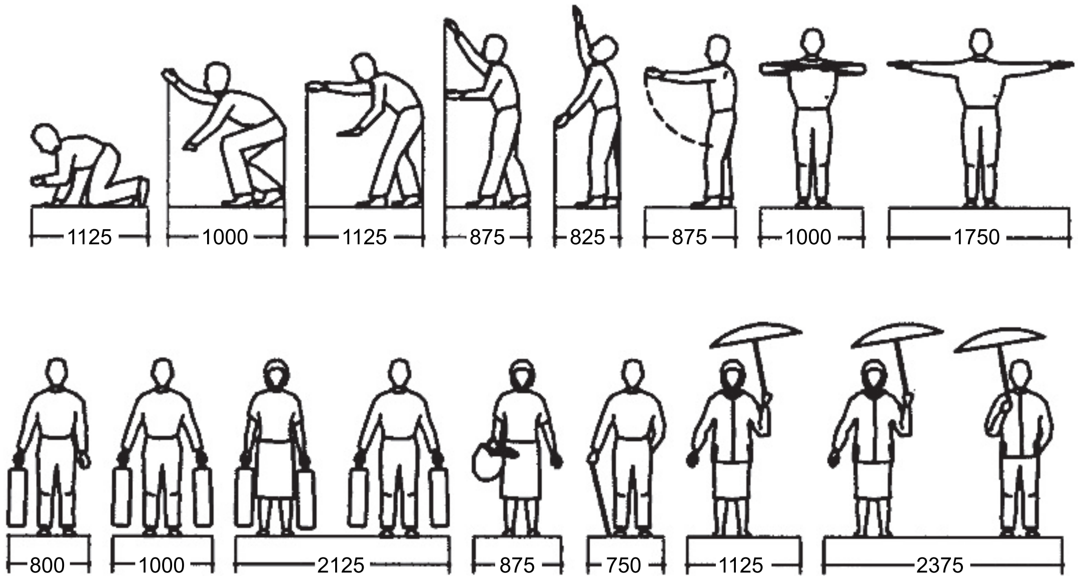
2.37 *Space requirements for closely spaced groups*



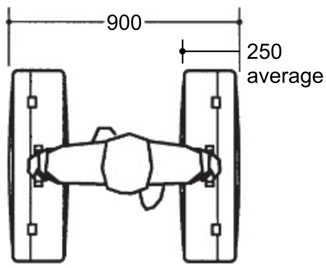
2.38 *Pace measurements*



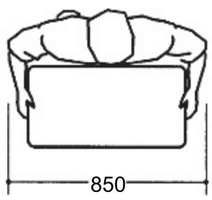
2.39 *Greatest density possible 6 people per m*^{2}



2.40 *Space for various body positions*

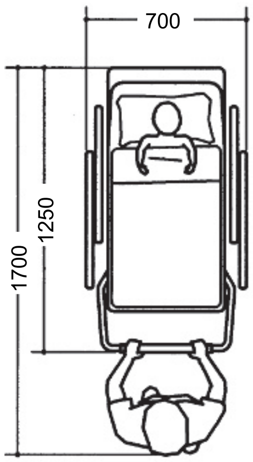


2.41 *Person with baggage*

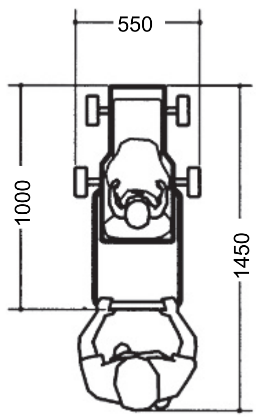


2.42 *Person with tray*

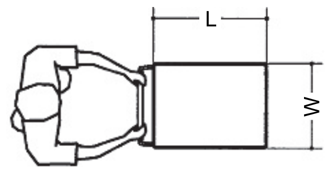
2.43 *Person with small child*



2.44 *Person with pram*

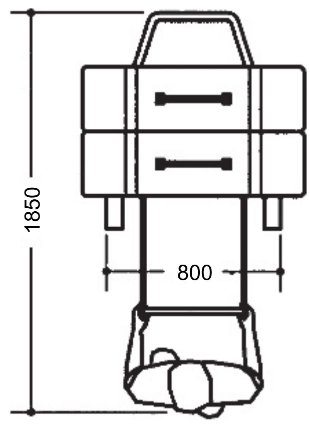


2.45 *Person with pushchair*

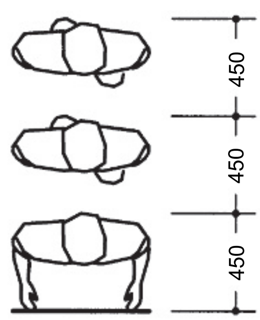


Type	L	W
Food (small)	600	450
Railway	1850	1100
Baggage (airport, hotel, etc.)	2500	800

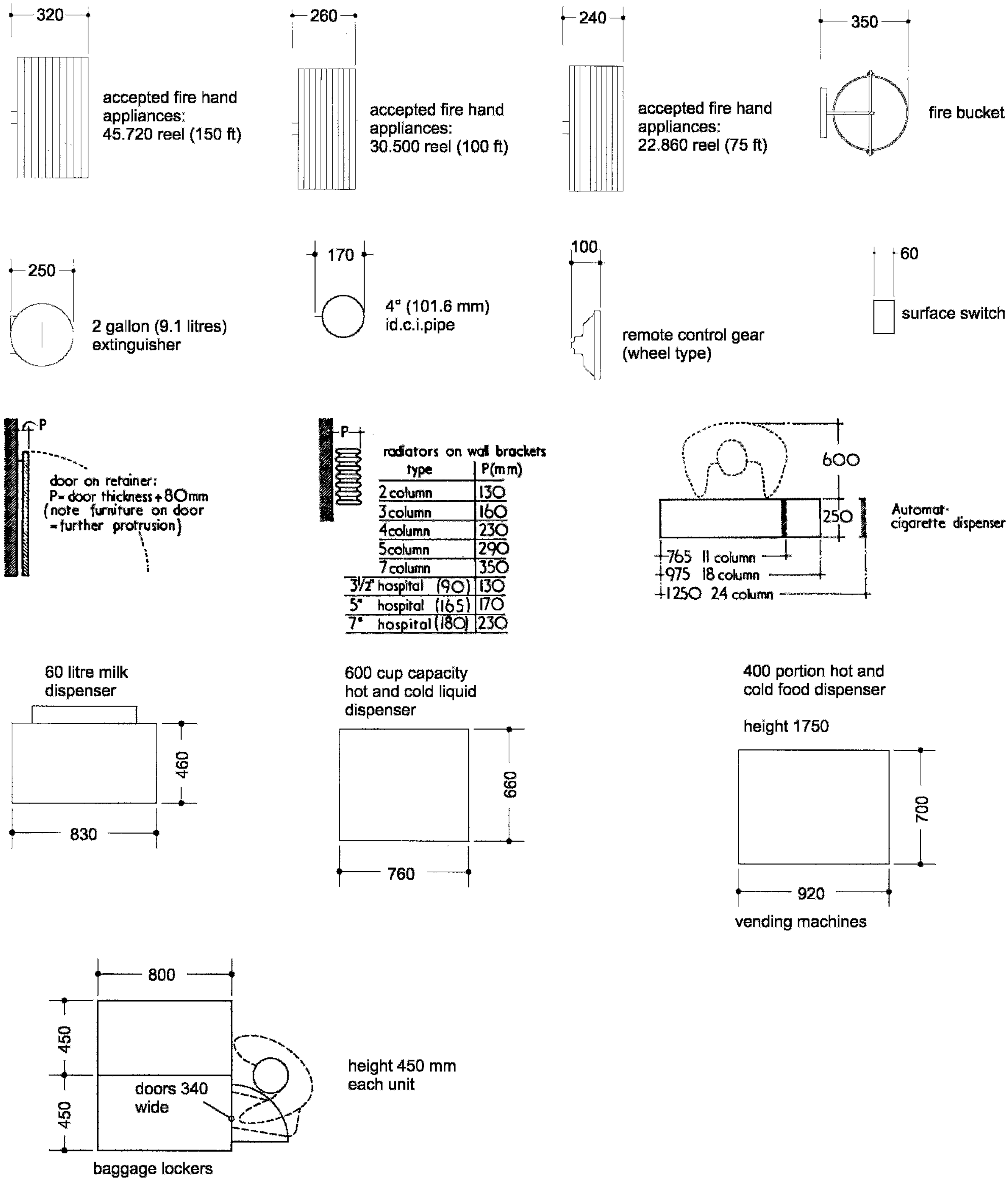
2.46 *Person with trolley*



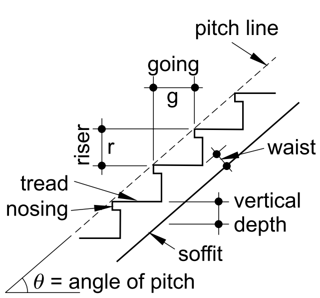
2.47 *Person with luggage trolley*



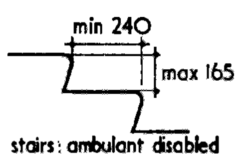
2.48 *Single queue no baggage*



2.49 *Obstructions in corridors*



2.50 *Definitions of staircase terms*



2.51 *Preferred form and dimensions of steps for elderly and ambulant disabled people*

Table X Regulations for internal steps and staircases

Building Regulation		Maximum pitch	Minimum rise (mm)	Maximum rise (mm)	Minimum going (mm)	Minimum going (mm)	Maximum clear width (mm)	Maximum rise per flight
K1.3	Private stair	42°	155 165	220 200	220 223	260 300		
K1.3 B3.15	Institutional or assembly building with floor area less than 100 m^2	35.7°	135	180	250	340	800 for 50 people 900 for 100 people	16 risers
K1.3 B3.15	Institutional and assembly stair	32.7°	135	180	280	340	1100 for 220 people plus 5 mm per person more than 220	
M2.21	Buildings in which provision for disabled people is mandatory	34.2°		170	250		1000	1800 mm
B2.30	Common stair	37.2°	150	190	250	320	1000*	
B2.30	Common stair also a firefighting stair	37.2°	150	190	250	320	1100*	
K1.3	Other	37.2°	150	190	250	320		

* Width in these cases may be encroached by stringers up to 30 mm and handrails up to 100 mm.

Table XI Design of staircases

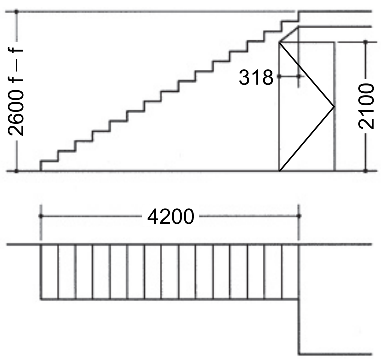
This table is constructed on the following bases: Rise r is between 75 mm minimum and 220 mm maximum. Going g is greater than 220 mm minimum. In each box the figures represent: Twice the rise plus the going (2r + g) between 600 and 660 mm.
The angle of pitch ($\tan^{-1}$ r/g) less than 40° and more than 30°. Shaded boxes indicate pitch angles greater than 35° which are less suitable for elderly and disabled people
The design of staircases is under almost constant discussion. Refer to parts K and M for detailed guidance. Many designers believe that not exceeding 12 consecutive risers represents good practice for non-residential work

Floor-to-floor	No of risers	rise r	Going g								
			220	230	240	250	260	270	280	290	300
2500	13	192.3		615 40.0°	625 38.7°	635 37.6°	645 36.5°	655 35.5°			
	14	178.6				607 35.5°	617 34.5°	627 33.5°	637 32.5°	647 31.6°	657 30.8°
	15	166.7						603 31.7°	613 30.8°	623 29.9°	
2600	13	200.0			640 39.8°	650 38.7°	660 37.6°				
	14	185.7		601 38.9°	611 37.7°	621 36.6°	631 35.5°	641 34.5°	651 33.6°	661 32.6°	
	15	173.3				597 34.7°	607 33.7°	617 32.7°	627 31.8°	637 30.9°	647 30.0°
	16	162.5							605 30.1°		
2700	14	192.9		616 40.0°	626 38.8°	636 37.7°	646 36.5°	656 35.5°			
	15	180.0			600 36.9°	610 35.8°	620 34.7°	630 33.7°	640 32.7°	650 31.8°	660 31.0°
	16	168.8					598 33.0°	608 32.0°	618 31.1°	628 30.2°	
	17	158.8							598 29.6°		
2800	14	200.0			640 39.8°	650 38.7°	660 37.6°				
	15	186.7		603 39.1°	613 37.9°	623 36.8°	633 35.7°	643 34.7°	653 33.7°		
	16	175.0				600 35.0°	610 33.9°	620 32.9°	630 32.0°	640 31.1°	650 30.3°
	17	164.7					599 32.4°	609 31.4°	619 30.5°		
2900	15	193.3		617 40.0°	627 38.8°	637 37.7°	647 36.6°	657 35.6°			
	16	181.2			602 37.1°	612 35.9°	622 34.9°	632 33.9°	642 32.9°	652 32.0°	
	17	170.6					601 33.3°	611 32.3°	621 31.4°	631 30.5°	
	18	161.1							602 29.2°		
3000	15	200.0			640 39.8°	650 38.7°	660 37.6°				
	16	187.5		605 39.2°	615 38.0°	625 36.9°	635 35.8°	645 34.8°	655 33.8°		
	17	176.5				603 35.2°	613 34.2°	623 33.2°	633 32.2°	643 31.3°	653 30.5°
	18	166.7						603 31.7°	613 30.8°	623 29.9°	

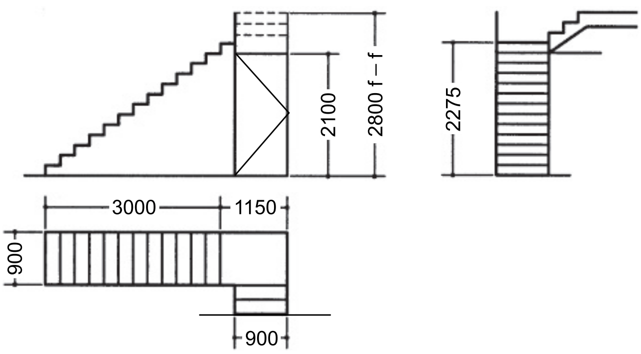
Building Regulations allow that twice the rise plus the going may be between 550 and 700 mm, and permits rises of up to 220 mm and goings of minimum 220 mm in private stairs. One Continental source recommends that twice the rise plus the going should be between 630 and 660 mm.

Table X summarises the various statutory requirements for internal staircases. Table XI covers the design of common types of staircases. External stairs and steps should not be designed to internal standards, as they will often appear to be precipitous. See Chapter 6 for these.

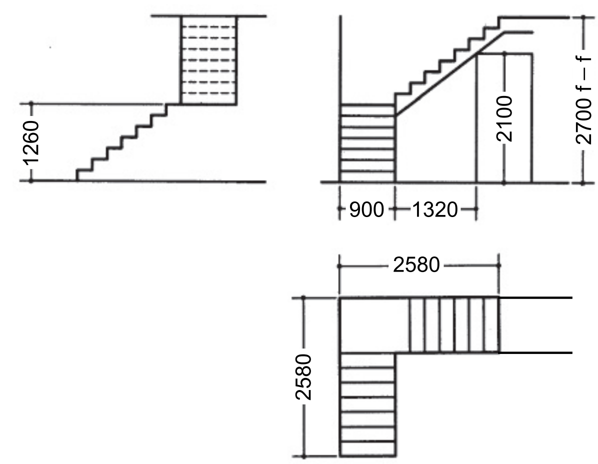
2.52 to **2.57** show examples of different types of staircases, and **2.58** illustrates the moving of a wardrobe up a typical stair.



2.52 *Straight flight staircase*



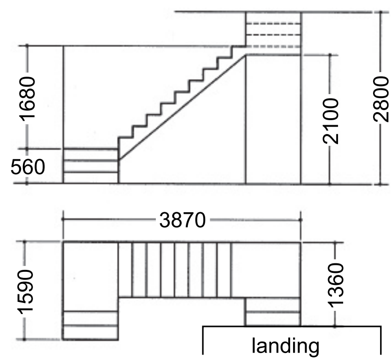
2.53 *Staircase with a short L at the top*



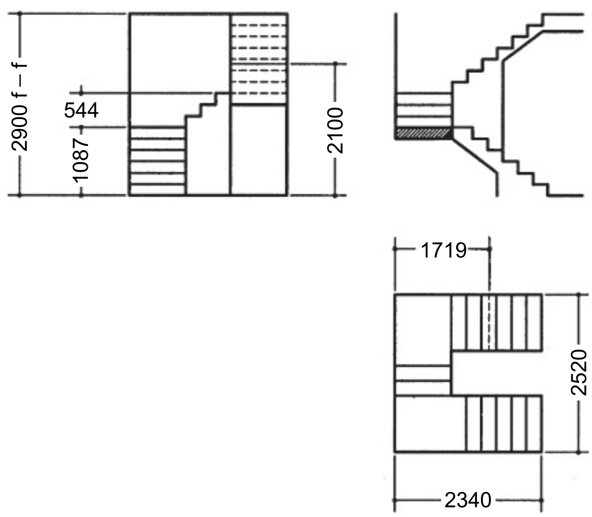
2.54 *Staircase with 90° turn at half-height*

5.03 Handrails and balustrades

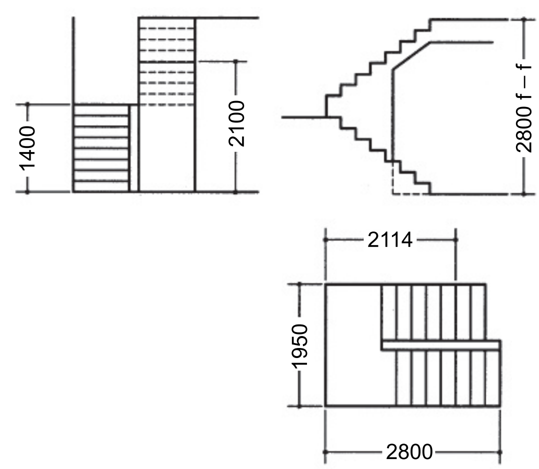
All staircases and steps should have handrails. If the staircase is less than 1 m wide they are not mandatory on both sides, but should if possible be so provided to allow for arthritic hands. The top of the handrail should be between 900 and 1000 mm above the pitch line, and of a design to facilitate proper gripping. It is important, particularly for users of crutches, that they should extend at least one tread depth beyond the last riser at both top and bottom of each flight. In a multi-flight staircase, the handrails should be as



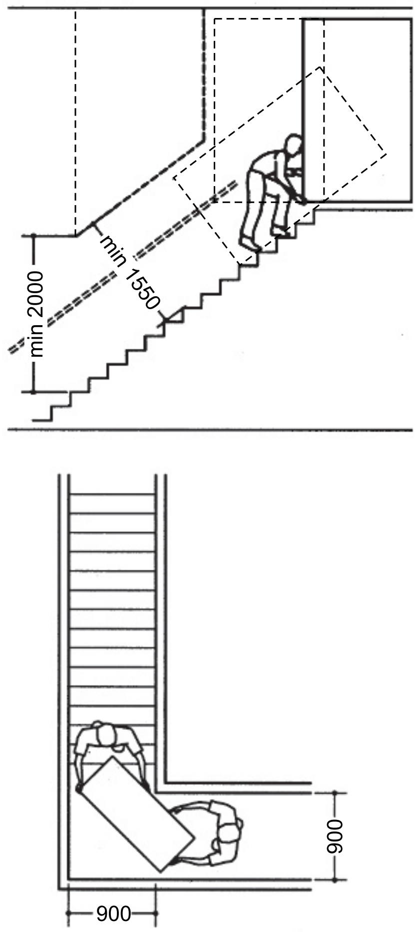
2.55 *Staircase with short Ls at top and bottom*



2.56 *Staircase around a square well*



2.57 *Dog-leg staircase*



2.58 *Moving a double wardrobe up a staircase, showing minimum headroom, clearance, handrail height. Going 215 mm, rise 190 mm*

continuous as possible to assist blind people; they will deduce that a break in the rail indicates a doorway or other way off the stairs.

Where there are likely to be small children, an additional handrail at about 425 mm high may be provided. Care should be taken to avoid designs that facilitate climbing over balustrades. Open wells should be protected by walls or balustrades at least 900 mm high.

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3 Practice management

David Littlefield

Architectural writer
Director of architectural IT firm Evolve Consultancy

KEY POINT:

- *Staff are the most valuable asset of any architectural organisation*

Contents

1 INTRODUCTION

Managing and maintaining an architecture practice is a demanding enterprise, requiring sound administration and management skills as well as design acumen. Practices need to take notice of employment law as well as building codes, and financial imperatives are just as significant as aesthetic ones. Finally, computing has revolutionised the practice of architecture over the last decade.

2 RECRUITING AND MANAGING STAFF

2.01

It has long been a cliche that staff represent the most valuable asset of any business. That is true if you have the right staff. Do not employ an architect if you need only a technician. Employing architects merely through force of habit can lead to frustrated employees and needlessly inflated wage bills. It is not unheard of for a successful architectural practice to employ twice as many technicians as architects.

2.02 Consultants, contractors and agency staff

Taking on staff is a major undertaking, and many architects prefer to stay small simply to absolve themselves from the responsibility of it. One option is to engage people as consultants, which both simplifies and reduces the tax overhead; also, this style of employment allows a business to test someone out before offering them a full-time position. Contractors are particularly useful to help practices cope with sudden workload bulges, and recruitment agencies are only too happy to supply them; however, charges for agency staff can be considerable – 10–15% of the first year's salary.

2.03 Legal responsibilities

Employing staff also brings legal responsibilities; bodies such as the Chartered Institute of Personnel and Development and the website www.compactlaw.co.uk are helpful in this regard. Briefly, employers need to abide by legislation governing equal opportunities, working hours and employment protection. Working Time Regulations place a ceiling of 48 h on the working week, unless an employee declares in writing that they wish to work beyond this limit. Furthermore, the Employment Rights Act (1996) opens employers up to heavy financial penalties if they are found, by Employment Tribunals, to be in breach of the law. Unfair dismissal, for example, can cost an employer £55,000.

The simplest way to deal with the law is to be fair and transparent in all employment-related matters. Recruitment decisions should be seen that they have been taken against clear and objective criteria; and the same applies to cases of dismissal or redundancy ('last in, first out' was once seen as a legitimate policy, although the outlawing of age discrimination has brought this into question, as 'last in' might also be the most youthful). Put everything in writing. Provide employees with an unambiguous contract of employment which includes the following: rates of pay, working hours, holiday entitlement, disciplinary procedures and a job description. Importantly, seriously entertain the idea of introducing flexible working practices if an employee makes a request.

2.04 Employee satisfaction

Beyond the legal contract, there is also the 'psychological contract' – an unspoken agreement about the expectations of employer and employee. This can include rather subtle expectations – hopes of stimulation, satisfaction, a creative environment, early responsibility, career advancement and so on. A mismatch between expectations and reality can cause resentment, low morale and high staff turnover.

2.05 Practice management

Large practices employ their own full-time personnel specialists, but this will be beyond the means of small and medium-sized firms. Any practice beyond the size of three or four people will benefit from employing a part-time practice manager, even for just one day a week.

3 ADMINISTRATION

3.01

Administration – covering everything from invoicing, timesheets, payroll, archiving and contact management – is crucial the efficiency (even profitability) of any architectural practice. The signature of a good administration system is being able to conduct an 'audit trail', which means being able to find out who did what and when they did it.

3.02 Information management

A database of key project information is essential. Once in place, the database can help a practice quickly assess itself against a range of key performance indicators: cost-efficient projects, profitable sectors, productive teams, reliable suppliers and so on. Also, databases allow a practice to rapidly put together a bid for work; by retrieving data from past projects, a convincing, detailed and customised document can be delivered within a day or two.

Importantly, different administration systems should be integrated as far as possible. Larger practices have invested huge sums in systems which bring together drawings, document templates, supplier information, project management stages and even payroll information. The result is that practices develop an efficient and predictable way of working, that they can easily prove their value to a client, that invoices are chased when appropriate and that official documentation is written to pre-determined standards.

4 INCOME

4.01 Fee structure

Every practice needs a fee structure. Fees are generated in one of two ways, either as a percentage of contract value (a figure which diminishes as the value grows) or as an hourly rate. Generally, practices will charge different amounts according to the level (and perceived value) of staff, and there will be a sliding scale covering partners/directors, senior associates, associates, job architects and students. Fees may also vary to match the job.

4.02 Negotiating fees

When negotiating fees, never feel sorry for the client, even if you like them. If a client likes the quality of your design, or even just your general approach, the chances are they will pay for it. Fees are only a very small part of the overall cost, which is worth pointing out if fees become the subject of negotiation. Generally, domestic clients negotiate less than commercial clients. Unless it is your first job and you need something for your portfolio, there is little point in reducing your fees to a level at which the job becomes unprofitable.

5 HEIRARCHY

5.01

Unless a senior-level architect wants to become a full-time manager and keep only a passing interest in design work, they need to hand the responsibility for day-to-day administrative matters over to specialist staff. In medium to large practice, specialists are employed to handle technical issues such as office management, human resources, marketing and IT, leaving directors to look for new business, handle clients and oversee design output at a strategic level, via regular design reviews and corporate crits. Directors of large practices may spend no more than 25% of their time on design-related matters.

5.02 Pyramid structure

For most practices a traditional pyramidal hierarchy provides a structure which, as well as fostering both stability and certainty, can survive periods of growth and contraction relatively intact. The whole point of a hierarchy is simple; it is there to facilitate the efficient running of the business, not to indulge the ambitions of individuals. The further up the hierarchy one moves, the more strategic the role. Terminology may vary but, broadly, this means installing a board of directors, including a chairman and chief executive. There may even be a non-executive director or two, someone from outside the industry who is recruited to provide advice rather than assume management responsibilities.

Ideally, each director will assume responsibility for a specific issue (HR, IT, etc.) to which full-time specialist managers will report. Well-qualified, non-architectural support staff, like HR (which covers functions like payroll, recruitment, employment policy, training and equal opportunities) might well be taken on at fairly senior level, especially if these employees are to be given some sort of strategic voice.

5.03 Flat management structure

The alternative to a centralised pyramidal hierarchy is the flat management structure, perhaps even comprising equal partners who manage their own affairs, recruit their own staff, bring in their own work and pool their earnings. This brand of practice will have no single voice or leader. The danger with flat management structures, however, is that decision-making can be slow and frustrating, and there is less clarity about where the buck stops. Also, practices which operate in this way need to recruit/coach a special breed of person, someone who is competitive enough to make it to the top table, but restrained enough to resist the temptation to dominate.

4 Capital and whole life costs of buildings

Simon Rawlinson and Maxwell Wilkes

Davis Langdon LLP

KEY POINTS:

- *Clear communication with clients from the beginning of the project is vital*
- *Changes made later in the project are more difficult and more costly to implement than those made at an earlier stage*
- *Maintenance and operational costs of a building dwarf the construction costs*
- *Whole life costing is a valuable tool to enhance decision making, but can be heavily influenced by decisions on time-span and discounted cash flow*

Contents

1 INTRODUCTION

1.01 Cost and value

This chapter examines the relationship between cost and value in construction projects, and discusses why architects should pay particular attention to their client's budgetary constraints. It also describes the degree of risk which clients accept when undertaking construction projects, and the steps which designers can take to mitigate these risks. In describing the estimating and cost-planning process, it explains the discipline of the cost-planning process, and the importance of the achievement of an appropriate level of fixity of design and specification at the conclusion of each RIBA project stage. It also outlines the information that is available to cost consultants in preparing estimates at different projects stages, and the degree of certainty that can be attached to these estimates.

1.02 Relationship between cost elements

Capital costs are of course only one aspect of construction economics, and recent research has been carried out by Constructing Excellence in the Built Environment (CeBe) into the operational costs of buildings. Their findings, published in the report Be Valuable, identifies a 1:3:35 relationship in the order of magnitude of capital, operational and occupational costs for a typical mechanically ventilated office building.

1.03 Occupation costs

The existence of this relationship suggests that expenditure on design and construction can have significant leverage relative to the costs of occupation. For example, appropriate investment in design and construction could potentially have a significant and valuable impact on the productivity of building occupiers. With many buildings procured by the public sector on the basis of design, build and operate arrangements such LIFT, used for primary healthcare, whole life costing is being taken far more seriously today than hitherto. Furthermore, with the growing significance of the sustainability agenda, concerned with managing energy consumption, carbon emissions and other environmental impacts, opportunities to invest to save energy and to mitigate environmental impacts are taken increasingly seriously.

2 WHY ARE CONSTRUCTION COSTS SO IMPORTANT?

2.01

Very few clients have the luxury of an unlimited budget, and even with generous funding, all clients will want to make sure that the proposed design solution represents the best way of meeting their purpose and that their investment makes the best use of finite resources.

Financial discipline on a project does not mean that budgets have to be unrealistically tight. However, it does mean that the client's investment should be managed responsibly by the project team to focus on elements, which relate specifically to the client's value criteria. Typical value criteria influencing projects are discussed below.

2.02 The value agenda

For many buildings, particularly those constructed for commercial markets, the client's principal measure of worth is the building's exchange value, typically measured by rental or sales revenue. Exchange value is used by clients in investment appraisals to determine whether projects are financially viable. In effect, exchange value determines the 'bottom line' of most schemes. Exchange value is generally defined by third parties and, particularly in commercial property markets, it is often difficult to secure a premium valuation for innovation. As a result, clients may have surprisingly little room for manoeuvre in setting their construction budgets. Exchange value issues can affect public sector projects too. Many public sector clients, including the NHS, operate internal marketplaces where facilities are 'bought' – using the volume of demand to establish the size and quality of the building that can be afforded.

2.03 Non-financial values

Value is of course not just about financial considerations and there are many other ways in which buildings contribute benefits to their owners, occupiers and neighbours. Some of the sources of these are listed below:

- *Operational value*. The benefits generated through the occupation and use of the building, which might include greater staff productivity, or improved educational outcomes associated with a new school.
- *Social value*. The broader benefits to society of a development, which might include local residents feeling more secure in their neighbourhood following the completion of an urban realm improvement project.
- *Brand value*. Messages communicated by a building which are derived from its design, and which reflect positively on the occupier. The Wessex Water HQ is a good example of this benefit.
- *Civic value*. The contribution that a development can make to a neighbourhood in terms of physical improvement to the quality of the building fabric, public realm and so on, this benefit is secured by all users of the neighbourhood.
- *Esteem value*. The reflected prestige that neighbouring buildings can secure from proximity to a high-quality development, be it

Tate Modern or a major redevelopment scheme such as Paradise Street in Liverpool, this is secured by owners and occupiers of the neighbouring buildings and may in turn be reflected in an increase in the exchange value of the neighbouring buildings.

Whilst not all of these sources of value have an immediate financial dimension, all require a focused and disciplined approach by the design team to concentrate effort and investment on aspects of the design which maximise the client's, end users' and wider community benefits, without compromising the fundamental financial viability of the project.

3 CONSTRUCTION RISKS AND THEIR MITIGATION

3.01

Samuel Johnson famously wrote that 'to build is to be robbed'. Facing the same challenges, but with the benefit of hindsight, Pope Pius II praised his architect for 'lying about the costs. . .' following budget overruns on the building of Pienza Cathedral, which threatened at the time to bankrupt the Vatican. Both of these experiences suggest that clients have been and continue to be exposed to a significant degree of cost risk when undertaking construction projects. Invariably, they also pick up much of the financial consequences of decisions, omissions and mistakes made by others working on their behalf. Decisions made at the outset of a project: investing in land, selecting one project opportunity in favour of others; confirming a brief; or establishing project governance could all potentially have a substantial impact on project outcomes, and as a result carry significant risk. Unfortunately, many of these early decisions have to be made without the benefit of a considered design response and may, as a result, be sub-optimal. Whilst it is important that advice given to clients early in a project should give the team some 'wiggle room' to develop a preferred solution, it is also important to work within project disciplines once these are established. Effective teamwork during the design development process between the designer and cost consultant can help to mitigate many of these potential risks.

3.02 Design stages

As a client's brief and concept designs are developed, a greater degree of fixity in terms of the design solution and predicted costs can be provided by the project team. This process is discussed in more detail in the section focused on cost planning. However, as the design develops and cost certainty increases, so does the cost of changing the design, and the client and project team's resistance to change. This relationship is illustrated in **4.1** and emphasises why it is so important to stick to the discipline of progressive sign-off at the end of each design stage.

3.03 Risk and risk transfer

As a project progresses to the appointment of contractors, the client's overall financial commitment becomes better defined. More risk can also be transferred to third parties if the client so wishes. Whilst under most procurement routes the client is required to accept risks associated with design performance, they will generally seek to transfer commercial and construction risks to the contractor through some form of a fixed price, lump sum contract. Quite clearly, if the design information upon which the client obtains a contractual commitment is not complete, is ambiguous or is not fully coordinated then, not only will the client retain outstanding design risk, but will also find that the basis of his commercial risk transfer to the contractor is weakened. Evidence from *Construction Key Performance Indicators*, published by the DTI, indicates the scale of this potential problem, showing that fewer than 80% of projects are completed with ±10% of their original tender sum. Moreover, only around 50% of projects are completed within ±5% of the tender sum. Whilst some of this cost variation may reflect client changes, or problems on site, it is likely that some of these increases will have resulted from the consequences of continuing design development.

In order to mitigate the client's risk, it is incumbent upon the team to ensure that the design is completed to the appropriate level of detail and fixity required by the procurement route. To do otherwise risks rendering some of the effort expended in design development and cost-planning abortive.

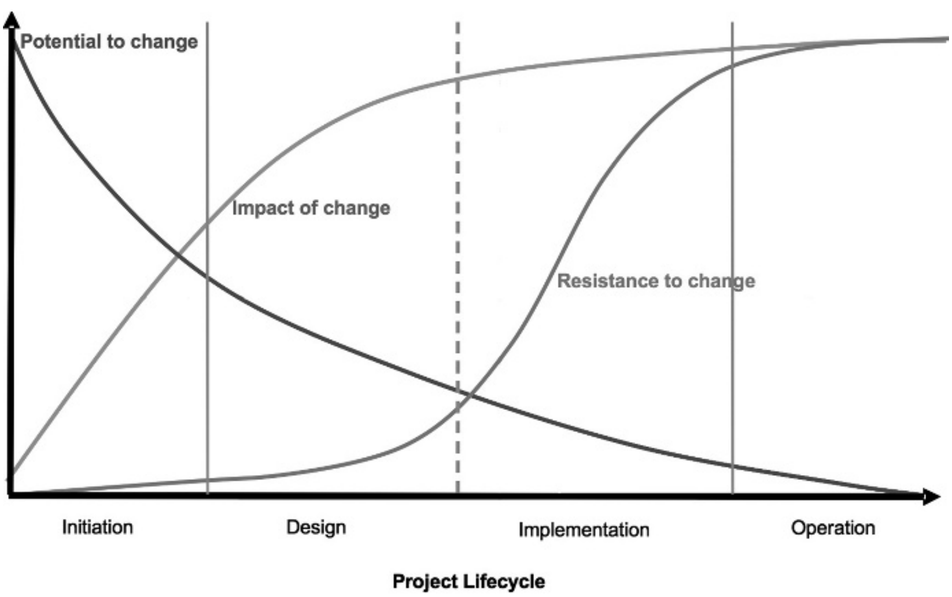
4 COST ESTIMATING

4.01

This section describes the stages of cost estimating, the purpose and relative accuracy of estimates produced at different design stages, and the information required from the architect to produce the estimate. This section also considers what heads of costs might be included in an estimate, including non-construction expenditure.

4.02 Understanding requirements

It is often said that the first cost received by the client is the cost that is always remembered. So, it is important that the design team and cost consultant clearly understand each other's requirements and that estimates submitted to the client include all relevant heads of cost.



4.1 *The relationship between programme and the ability to introduce change*

4.03 Feasibility estimate

The first cost advice that an architect will typically present to a client on a project is a feasibility estimate. These are sometimes termed order of cost estimates. Feasibility estimates are typically calculated on the basis of the gross internal floor area of the building, or a functional unit such as beds, number of pupils and so on. The cost information used in these estimates is taken from completed projects or, in the case of the public sector, nationally set cost levels. Some building clients in the public sector, such as the NHS, have complex business case processes where initial costs are derived from an estimate of the health functions that are required rather than from an initial design concept.

4.04 Key variables

At this early stage, in order for the estimate to be representative of the proposed design solution, the key variables that a designer needs to have developed to an appropriate degree of certainty are:

- The floor areas upon which the estimate is based
- Proposed elevations
- The implied level of specification
- The scope of sources of additional costs, which are not related to the floor areas of the building, including external works, fittings and furniture and loose equipment.

The accuracy associated with feasibility estimates of this nature is probably no better than ±20–25%. However, most clients require a single point estimate, even at the earliest stage of a project, and the architect and cost consultant must agree an appropriate allowance for design development and other unknowns, balancing requirements for early cost certainty alongside the need for competitive, value for money solutions appropriate to the client's needs.

4.05 Costs for building types

Table I sets out feasibility cost information for a range of building types, illustrating the range of costs that can relate to a particular building function. The variation in costs illustrated in the table is driven by a wide range of factors including site conditions, level of specification, extent of building services installations and so on, together with aspects of building efficiency such as wall:floor ratio or net:gross floor area efficiency.

Table I Feasibility estimating rates

	Construction cost (£/m^2 gifa)
Office Buildings	
Offices for letting	
Low rise, air-conditioned, high-quality speculative	1200–1510
Medium rise, air-conditioned, high-quality speculative, 8–20 storeys	1460–2000
Medium rise, air-conditioned, city fringe, deep plan speculative office towers	1770–2080
Offices for owner occupation	
Low rise, air conditioned	1300–1510
Medium rise, air conditioned	1770–2080
High rise, air conditioned	2000–2500
Offices, prestige	
High rise, air-conditioned, iconic speculative towers	2000–2500
Housing	
Private developments	
Single detached houses	890–1380
Houses two or three storey	780–1930
High-quality apartments in residential tower – Inner London	2290–2500
High-quality multi-storey apartments – Inner London	1770–2030
Mid-market apartments in residential tower – Outer London	1770–2140
Affordable apartments in mixed tenure development – Inner London	
Three- to four-storey villa – Inner London	1230–1460
Multistorey	1410–1560

The building costs set out in Table I should be applied to the gross internal floor area of a building. The rates are current at first quarter 2007 based on an Outer London location, include preliminaries and contractor's overheads and profit but do not include external works and services, loose furniture and equipment or specialist installations. Professional fees and VAT are also excluded.
Source: Spons Architects' and Builders' Price Book 2007, Taylor and Francis

4.06 Building elements

Cost plans are typically organised into 'building elements'. Consistently defined elements, such as substructure, frame or external walls, are widely used by cost consultants when preparing cost plans. They enable the costs of buildings or individual elements to be compared with equivalents from other schemes. As the design becomes increasingly detailed, budgets are set for each element providing further discipline for design development. According to the client preference, and depending upon the procurement route adopted, some estimates may also be organised in accordance with trade-based packages. The definition of the content of packages varies from project to project. For projects procured either on the basis of construction management or two-stage tenders, estimates prepared in a packages format provide a direct link between the documentation necessary to procure the package and the management of its costs.

4.07 Costing planning

As a project passes through RIBA stages of scheme design and detailed design, the cost estimate will become progressively more detailed and will reflect a greater degree of certainty. Cost consultants describe this process that they adopt as 'cost planning'. In its simplest form, cost planning involves the setting of expenditure targets for each element of construction such as the frame, external walls, internal doors, floor finishes and so on. The cost targets might be derived from an analysis of completed projects or from a cost model specifically developed for the project. In order for the cost plan to be prepared, the design needs to be sufficiently developed to enable measurements of elemental quantities (external wall, etc.) to be obtained. As the design progresses to stage D, the cost plan is developed into a detailed estimate, which establishes a clear relationship between quantity, specification and cost.

4.08

Cost consultants recognise that the design process is not linear, and in many instances the cost plan will include allowances based upon informed assumptions as to what the designer's eventual solution will be. Working together effectively, an architect and the cost consultant can ensure that the cost plan provides appropriate allowances for the realisation of the design, whilst at the same time delivering a cost effective and functional solution. Where the designer does not engage actively in the cost-planning process, there is a risk that a cost consultant will make inappropriate allowances for incomplete work, potentially creating unnecessary constraints for future design development.

Table II sets out examples of cost-planning rates used in a typical stage D estimate. The rates are presented as a range to account for variations in specification, quantity and working method. A higher rate might apply for discontinuous work for example. In the cost plan itself, a single rate will be used.

4.09 Pareto rule

Cost-planning items at this stage are headline descriptions of the work and their selection and pricing should follow the principles of the *pareto rule*, where 80% of the value of the work is captured by 20% of the measurable items. Cost-planning rates such as these include all costs associated with materials, labour, interfaces and detailing, together with specialist contractors and main contractor's overheads and profit. Many of these rates are obtained by 'market testing' with costs obtained from contractors. Architects sometimes undertake elements of market testing themselves, for example, if

Table II Cost-planning rates. External walls – brick and block cavity walling

Item	Unit	Range (£)
Cavity wall; block outer skin; 50 mm insulation; lightweight block inner skin		
Outer block rendered	m^2	60.00–85.00
Extra for		
Architectural masonry outer block	m^2	1.20–2.40
75 mm thick cavity insulation	m^2	1.40–4.10
Cavity wall; facing brick outer skin; 50 mm thick insulation; plasterboard on stud inner skin; emulsion		
Machine-made facings; PC £300.00/1000	m^2	91.00–110.00
Hand-made facings; PC £450.00/1000	m^2	105.00–130.00
Cavity wall; facing brick outer skin; 50 mm thick insulation; with plaster on lightweight block inner skin; emulsion		
Machine-made facings; PC £300.00/1000	m^2	85.00–110.00
Hand-made facings; PC £450.00/1000	m^2	99.00–130.00
Add or deduct for		
Each variation of £100.00/1000 in PC value	m^2	1.00–1.20
Extra for		
Heavyweight block inner skin	m^2	1.20–2.40
Insulating block inner skin	m^2	2.40–6.40
75 mm thick cavity insulation	m^2	5.00–5.70
100 mm thick cavity insulation	m^2	6.40–7.10

The estimating rates set out above should be applied to the quantity of the work itself, calculated using approximate quantities. The rates are current at first quarter 2007 based on an Outer London location and include all labour, materials, plant and incidental items. The rates also include for the contractor's overhead and profit. Preliminaries, professional fees and VAT are excluded.
Source: Spon's Architects' and Builders' Price Book 2007, Taylor and Francis

there is a disagreement over cost allowances made by the cost consultant. If an architect does undertake such market testing exercises, then in presenting the results to the design team and client he/she has to be absolutely certain that all costs necessary to complete the work have been included, and proper allowance has been made for the cost implications of the procurement route adopted. In general, it is better to leave these exercises to the cost consultant.

4.10 Certainty and detail

At stage D, the cost plan is intended to provide a level of accuracy of ±10%. For this level of accuracy to be achieved, the design needs to have reached a corresponding degree of certainty and detail so that quantities can be relied upon, sources of complexity recognised, and the cost implications of the proposed specification can be properly assessed.

4.11 Sources of cost information

In preparing cost plans, cost consultants obtain information from a wide range of sources which will include:

- prices of similar work undertaken on previously completed projects;
- quotations obtained from suppliers and specialist contractors; and
- cost information published by third parties, including price books, journal articles and so on.

In order to normalise this diverse range of information for location, price inflation, etc. cost consultants apply a range of adjustment factors derived from the statistical analysis of large project datasets, undertaken by bodies such as the Building Cost Information Service (BCIS).

4.12 Inclusions and exclusions

When presenting estimates, to the client, the cost consultant and design team make some important decisions with regard to costs that are included and excluded from an estimate. Heads of cost, which are typically excluded from a cost plan, but might need to be reinstated or included elsewhere in the client's budget include:

- inflation;
- site acquisition costs;
- professional and statutory fees;
- furniture, fittings and equipment;
- costs related to planning agreements (sections 106 and 278);
- the client's own project management, finance and insurance costs;
- overall project contingencies;
- value added tax;
- Local Authority and Statutory Authority charges for road closures etc.;
- archaeological surveys and/or excavation; and
- costs of services diversions and off-site services reinforcement.

Clearly the list of exclusions for a project could be very extensive. The intention of presenting them in the estimate is to make it clear that the client will potentially be exposed to these additional costs and that allowances have to be made somewhere within the overall project budget.

4.13 Cost plan document

The cost plan is generally submitted as part of the RIBA stage design report. It is a detailed document, which requires a considerable amount of time and effort to prepare. It also provides a valuable resource for the project team to monitor the development of the design. In order for it to be an effective control document, the cost plan must provide an accurate reflection of the quantum and specification of the design at the conclusion of the design stage. This means that whilst designers can continue to develop detailed design solutions ahead of the completion of a stage, they should freeze the key parameters of their design sufficiently early for the cost plan to be produced with some certainty. Whilst new technology such as CAD-based measurement have sped up the production process, proper allowance still has to be made in the programme for the compilation of the cost plan based on relatively firm information.

5 OPTION STUDIES

5.01

Throughout the design process, architects and engineers need to examine alternative design solutions, be it structural options, different air conditioning systems or alternative floor finishes. The cost consultant can contribute to the selection of preferred solution through the preparation of an option study, taking into account the full cost implications of each choice, which might include effects on the costs of other building elements, overall project duration and so on. Increasingly, option studies are prepared on the basis of whole life costs, taking into account the operational dimensions of specification as well as short-term considerations based on capital cost, programme and procurement.

6 COST CHECKING

6.01

Once the stage D estimate is agreed, and the client approves substantial investment in the preparation of production information, then the focus of the cost consultant should shift from projecting what the cost of the scheme should be, to ensuring that the design, as it develops, remains within the set budget. In these circumstances, the cost consultant will produce detailed estimates of specific elements or trade packages, which will confirm whether or not the architect's scheme can be delivered within the disciplines of allowances stated in the Cost Plan.

7 WHOLE LIFE COSTS

7.01 Construction, maintenance and operation costs

Buildings are long-lived assets, and often have quite high-operational costs, related to heating, ventilation and lighting, repair maintenance and so on. Research undertake by CeBe, referred to above has identified that the cost of maintenance over a building's lifetime can equate to three times the original construction cost. Furthermore, the costs of the operation, including the salaries of occupants, equate to 35 times the build cost.

7.02 Productivity

What these findings illustrate is that the lifetime costs of running and occupying a building dwarf the initial design and build costs, so if the design can be changed to reduce operating costs or enhance staff productivity, the client may agree to invest additional capital costs to find these improvements.

7.03 Sustainability

Given these opportunities, it is surprising that whole life costing has not been adopted more widely, but with the sustainability agenda very high-up on many clients' agendas, designers can be expected in the future to demonstrate a greater appreciation of long-term performance issues of their building designs.

7.04 Life cycle analysis (LCA)

It is important to clarify the distinction between life cycle costs and LCA. The former is concerned with calculating the costs associated with the operation and occupation of an asset, and is the subject of this chapter. By contrast, LCA is concerned with the full range of environmental impacts of a building, covering embodied impacts, construction and operational effects, together with those associated with asset disposal. As well as greenhouse gases, the scope of LCA will include impacts on landfill, water, biodiversity and so on.

7.05

The whole life cost agenda is potentially a very powerful tool for designers to create the case for investment in design, which promotes greater productivity, flexibility, durability or longer operational life. However, as with all forms of analysis, the whole life cost assessment needs to be prepared in a way which meets the client's objectives and provides an accurate representation of future performance. Amongst the problems affecting the take-up of whole life cost analysis include difficulties in obtaining unambiguous and corroborated performance and durability data, together with widespread confusion surrounding the use of discounted cash flows.

7.06 Important considerations

Architects should be aware of the following considerations:

- The purpose of the assessment, as whole life cost studies are typically produced for three purposes:
  - *An estimate of the operational cost of an asset*. In this instance, the whole life cost study should cover all potential sources of cost associated with the occupation of a building. These cost centres might include energy, cleaning, insurances, maintenance and so on. Total operating cost assessments such as these are typically used by clients to confirm that they will be able to afford to run and maintain their assets.
  - *Capital asset replacement*. Whole life costs studies, which focus solely on modelling the operational life of durable assets such as mechanical systems; roof finishes etc., that require replacement during the life of the building, enabling the client to plan for long-term maintenance obligations.
  - *Option comparisons*. Option studies can be prepared to identify preferred options on the basis of long-term performance. The approach could be used to select alternatives that have either different energy use, maintenance or replacement profiles such as window systems, floor finishes, air conditioning options. In an extreme case, the choice between a leased building or a self-financed scheme could be supported. Option studies involve the comparison of alternatives, which might have different life spans, replacement cycles, income or expenditure profiles. As a result, in many instances comparison can only be undertaken using *discounted cash flow techniques*. The use of discounting enables cash flows, which occur in different time frames to be totalled and compared on a like for like basis, enabling a best value option to be selected on the basis of *net present cost/value*.

When reviewing the results of option studies based on life cycle cost methodologies, the architect should ensure that the following aspects of the study have been properly taken into account:

- Discount rate, the selection of the discount rate should take into account the client's requirements. In the case of the public sector, discount rates are published by the Treasury, and in the private sector, discount rates generally reflect the client's cost of finance or expectations for rates of return. As it can have such an impact on the end result, the discount rate must always be confirmed by the client.
- That costs for all options have been consistently calculated. Where appropriate both cost and income streams associated with each option should be considered. For example, all cleaning and maintenance costs should be included in a floor finishes assessment together with some revenues associated with the disposal of high value, long-life assets such as stone finishes.
- *Presentation*. The presentation of a whole life cost study based on discounted cash flow should make it clear that the reported cost does not reflect what the client or end user will actually pay. Furthermore, if the *net present cost* differential between two or more options is relatively small, the team should ensure that other criteria, such as the initial capital expenditure, are considered in the selection of the preferred option.
- *Accuracy*. The report should clearly state how accurate and reliable the source information upon which it is based is.

4.2 is a simple worked example of a whole life cost-based option study examining the capital and maintenance costs of softwood and aluminium windows over an extended period of 50 years. The comparison illustrates that the aluminium windows, installed at a £20/m^2 cost premium have lower life time costs.

Features of the example that are worth noting include:

- *Total cost*. This example is based on a discounted cash flow and the results are presented as a 'Net Present Cost'. This is the cost of all expenditure over the 50-year period, discounted to the present day at a rate of 8% per annum.
- *Effects of discounting*. The costs of all future work are discounted to comparison on a like for like basis. This has the effect of reducing the significance and cost of future expenditure. The higher the discount rate, the lower the value of future expenditure. On this basis, high-discount rates favour projects with lower initial capital costs. The

WINDOW WHOLE LIFE COSTS – WORKED EXAMPLE

	Life expectancy	Capital Cost of Installation £/m²	Annual cost of Maintenance £/m²	Redecorations interval (years)	Redecorations cost (£/m²)	PERIODIC COSTS replace gaskets/beads interval (years)	replace gaskets/beads cost (£/m²)	Repair sills/frames interval (years)	Repair sills/frames cost (£/m²)
PC Aluminium	55	£320.00	£3.00	5 after 25	£24.00	15	£22.00	n/a	£0.00
Painted Softwood	30	£300.00	£2.50	5	£12.00	15	£25.00	5 after 20	£15.00

Year	Discount Factor	Powder Coated Aluminium						Painted Softwood					
		Installation £/100 m²	R&M £/100 m²	Periodic Redecs £/100 m²	Periodic Replacement £/100 m²	Periodic Repairs £/100 m²	Periodic Total £/100 m²	Installation £/100 m²	R&M £/100 m²	Periodic Redecs £/100 m²	Periodic Replacement £/100 m²	Periodic Repairs £/100 m²	Periodic Total £/100 m²
0	1.000	32,000						30,000					
5	0.681		204						170	816.70			816.70
10	0.463		139						116	555.83			555.83
15	0.315		95		693.53		693.53		79	378.29	788		1166.39
20	0.215		64						54	257.46		322	579.28
25	0.146		44	350.44			350.44		37	175.22		219	394.25
30	0.099		30	238.51	219		457.14	3,876	25				
35	0.068		20	162.32			162.32		17	81.16			81.16
40	0.046		14	110.47			110.47		12	55.24			55.24
45	0.031		9	75.19	68.92		144.11		8	37.59	78		115.91
50	0.021		6						5	25.59		32	57.57
TOTAL £/100 m²		32,000.00	3,670.05	936.93	981.08	0.00	1918.02	33,875.72	3,058.37	2,383.08	866.42	572.83	3822.33
NET PRESENT COST £/m²							£375.88						£407.56

4.2 *Whole life cost comparison. Source: Davis Langdon LLP*

effects of the discount factor can be seen in the declining cost of repair and maintenance over the study period. Even by year 5, at a discount rate of 8%, the present day cost of £300 is discounted to £204.

- *Inclusion of relevant costs only*. Other operational costs that would be the same for the two options, cleaning, for example, are excluded from the study.
- The importance of the length of the study period. In the worked example, the requirement to replace timber windows at 30 years is the key driver behind the differences in Net Present Cost. If the duration of the study were limited to 25 years, painted softwood would emerge the preferred option.

8 CONCLUSION

8.01

Clients will judge the success of their capital projects by many criteria, and there is no doubt that the imagination shown by the design team in delivering a carefully targeted solution to their client's requirements, together with a commitment to achieving a good level of finished quality will be very high on most client's agenda. Delivery on budget is also usually a high priority, and unlike other aspects of project delivery is easy to monitor and measure. Design teams need to work closely with their cost consultants to make sure that budgets are appropriate, and that design solutions directly address aspects of the clients brief which deliver greatest value.

Techniques such as whole life costing and value management can be used by the cost consultant and design team to help to identify design solutions which best meet the client's requirements.

8.02

By collaborating closely from the earlier stages of a project to establish an appropriate capital cost budget, and by maintaining the discipline of working within the budget set by the client and project team, the design team will give itself the best opportunity of delivering a project, which meets the design team's expectations, the client's requirements and provides all parties with an appropriate financial reward.

5 Design basics: Buildings and movement

CI/SfB: 66, 94
UDC: 621.876, 696.1

KEY POINTS:

- *The needs of wheelchair users increasingly predominate in the design of both aids to movement and sanitary facilities*
- *Women require twice as many sanitary facilities as the same population of men*
- *Unisex sanitary facilities providing for babies and small children are essential*

Contents

1 INTRODUCTION

This chapter contains basic information about the design and space requirements for some of the fundamental elements of building design – movement of pedestrians, basic sanitary facilities and space for simple activities and objects. Legal – and moral – obligations exist to design for the needs of the disabled, children and those that do not otherwise fit the definition of 'average'.

2 LIFTS

2.01 Traction systems

There are two common types of traction: electric and hydraulic.

2.02 Electric traction

In this system, the car is supported by cables passing over a drum and balanced by counterweights, **5.1**. The drum is driven by an electric motor, which can be one of a variety of types depending on the use and standard of service. The whole is controlled by an elaborate system which is now almost completely electronic.

The machine room is normally placed on top of the shaft, and, as shown in the figures and tables, requires additional space. In cases where there are restrictions on the height of the building, the machine rooms can be situated adjacent to the shaft at any convenient level (such as in the basement, **5.2**), with the cables carried on diverter pulleys. The overrun height above the top level served is increased by the small amount needed for these pulleys. This type of system is best avoided if possible, as it will cost more and the cables, being much longer, will need to be adjusted for stretch at more frequent intervals.

2.03 Hydraulic traction

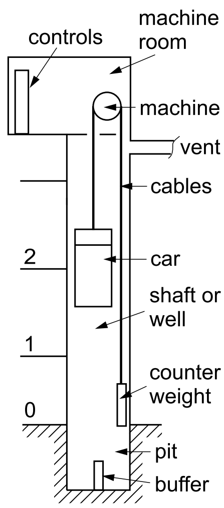
Despite its name, nowadays this is driven by oil-power. There are different types of installation, but the most common consists of a cylinder driven into the ground below the liftshaft to a depth slightly more than the height of the building. The car is directly attached to a ram raised in this cylinder by pumping oil into its base, **5.3**. The depth of the bore can be reduced by using a telescopic ram.

There are two major advantages to a hydraulic system:

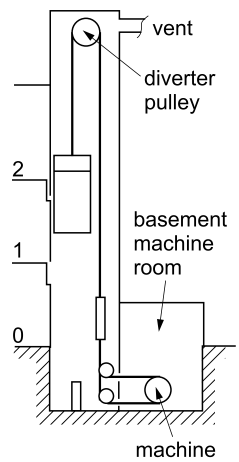
- There are fewer moving parts; therefore, in theory a more reliable performance is given, and
- There is almost complete freedom in the placing of the machine room and its size is smaller than for traction machines.

2.04 General considerations

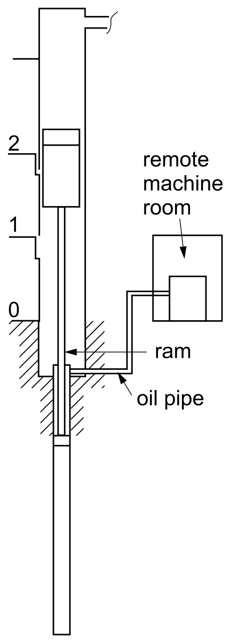
Below the lift shaft, a space used by people should be avoided wherever possible. Where there must be such a space, even a large duct, the necessary safety provisions will involve a wider or deeper well, additional structural support and/or additional lift equipment.



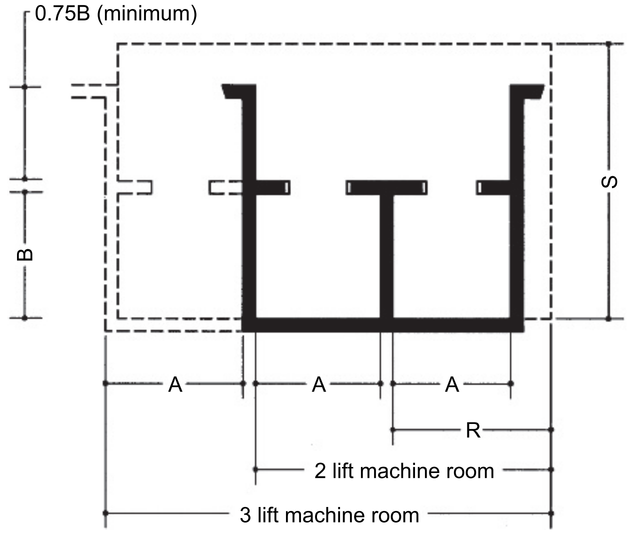
5.1 *Schematic diagram of a conventional electric traction lift with high-level machine room*



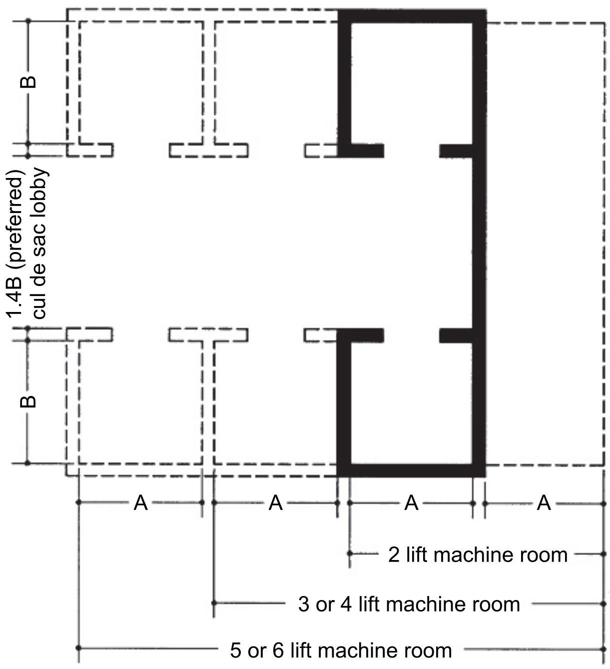
5.2 *Schematic diagram of an electric traction lift with semi-basement machine room*



5.3 *Schematic diagram of a direct-acting hydraulic lift with remote machine room*



5.4 *Plan of recessed lobby and machine room for multi-lift installation*



5.5 *Plan of cul-de-sac lobby and machine room*

Lift shafts have to be vented at the top, directly or by duct to external air (not into machine rooms) for smoke-dispersal purposes. There should be safe and convenient access to the machine room for lift maintenance and for the handling of replacement assemblies. Access via a ladder and trapdoor should be avoided. No services installation or access route other than those provided for lift equipment and lift personnel should share or pass through the machine room or lift shaft.

3 PASSENGER LIFTS

3.01 Location

Passenger lifts should be within a reasonable walking distance from the furthest part of the floor areas served (say, 70 m maximum) and, where they are the only or main lifts, near an entrance but with the stairs nearer to the entrance. A shorter walking distance (say, 50 m maximum) is desirable in an office building where interfloor journeys are to be catered for. The location of goods and service lifts will depend on their function, but they should not open into passenger lift lobbies or public areas.

3.02 Single lift installations

Ideally, lifts should not be installed singly. No installation can be guaranteed to give service at all times, and in most buildings there are people who rely totally on using lifts. In addition, the life of a normal lift in constant use is about 20 years; major overhaul or replacement can take several months. In long blocks, lifts can be spaced out to ensure that when all are working the 60 m limit is achieved, but another lift is usable at the cost of a longer walk. Alternatively, an additional shaft can be provided when the block is built into which a replacement lift can be installed when necessary, maintaining the original lift service until it is finished. Temporary floors and doors are often fitted in this shaft so that it can be used for storage until it is required.

3.03 Planning passenger lifts

Cul-de-sac or recessed lobbies, **5.4** and **5.5**, are essential to get the maximum performance from lift groups. Clearly, having called for lift service the waiting passengers should not have to walk further than necessary to the responding lift car, and should not be obstructed by passers-by. The lobbies for separate lifts or groups should be adequately separated in order to promote the channelling of their respective traffic and to discourage the duplication of calls on the landing buttons.

Within a group, it is preferable for all the lifts to serve all levels in order to avoid a particularly annoying inconvenience to the users. If only one or some lifts of a group serve a basement car park, for example, a normal pushbutton system cannot ensure (at a higher floor) that the responding lift car will be one that is able to travel to the basement.

It used to be common practice for two lifts in tall social housing blocks each to serve alternate floors. This proved most unsatisfactory, and should not be used today.

In very tall buildings (such as Canary Wharf), it is normal to provide 'sky lobbies' near the halfway point. These are served by non-stop express lifts from entrance level, and passengers can then be carried on to upper floors; or more commonly change to a second bank of normal lifts.

3.04 Lift cars

A standard eight-person car is the minimum size normally acceptable as it is necessary to have sufficient door width to pass self-propelled wheelchairs. It is also the minimum suitable size for moving furniture.

Controls should be low enough to be operated from a wheelchair, and should be duplicated for those unable to stoop. Buttons should be clearly marked, and have raised figures (not necessarily Braille) to assist those with visual impairment. There should be both visual and audible notification of floor level (this facility is now generally available at small additional cost).

3.05 Selecting type, size, speed and number

The standard passenger lifts are shown in **5.6** and Table I. Types 1–5 are inappropriate to the main lift service of such as a large office building, especially in the single-speed motor form (speed 0.5 or 0.63 m/s), but their robust single-panel doors and associated specification package makes them particularly suitable for municipal housing and hostels. The doors of types 1–5 (which close relatively slowly from the side) are particularly suited to the infirm or for goods traffic. The quicker doors of types 6–8 maximise handling capacity and service quality, by minimising journey and waiting times.

The quality and quantity of the lift service needed by buildings other than offices is essentially a matter for individual assessment with the assistance of specialist advice and comparison with similar cases. However, for preliminary purposes, it may be assumed that passenger lifts suited to an office building can be stretched (in terms of population and visitors served) up to 100% for a hospital, hotel or shop. The passenger lift service (if any is required) for a two- or three-storey building, including offices but excluding hospitals and the like, will usually need to be only nominal, i.e. not related to the population figures.

3.06 Lifts in offices

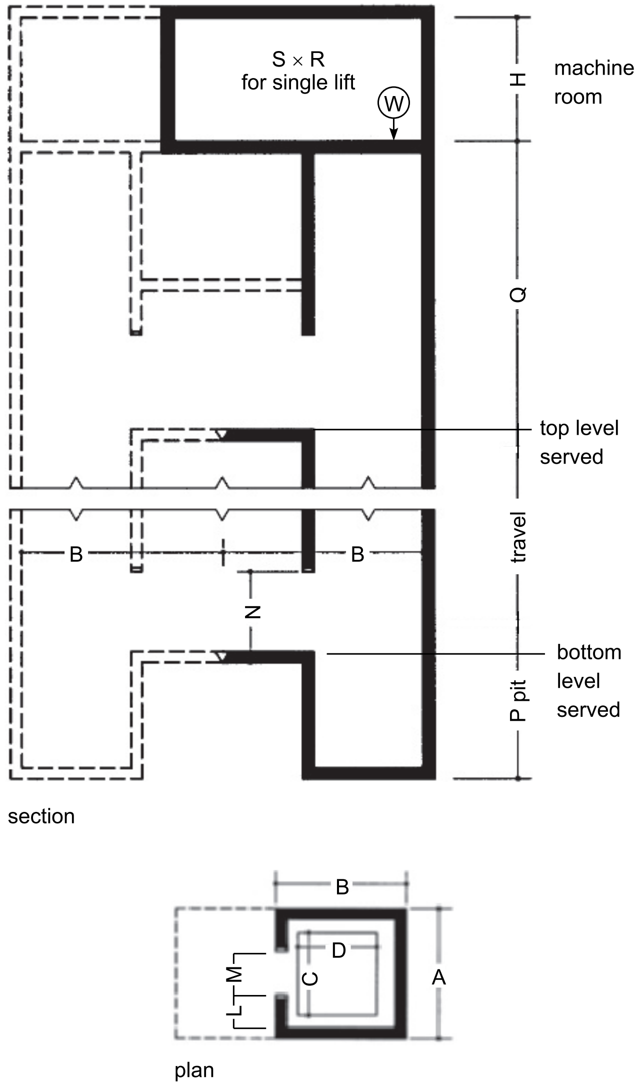
For lift types 6–8, Table II gives the configurations for a good service when dealing with typical office building traffic. Table III gives single-lift schemes for situations where the previous table cannot be applied; as, for example, where only two lifts can be justified and have to be separated for functional reasons instead of being placed in the more efficient two-lift group.

The second column in Tables II and III gives the population per floor (averaged) for which the lift or group of lifts is suitable. For example, the second scheme in Table II is suitable for a population averaging over 60 per floor, and up to and including an average of 69 people per floor. The third column is an extension of the previous column, allowing 10 m^2 per person, and therefore gives some indication of the total net area for which the lift or group is suitable. Dividing the area figure by 10 will give an indication of the total population for which the lift or group is suitable.

The seventh column gives an indication of the likely costs, excluding builders' work, of the specific lift installation: based on 1 for a single eight-person, 1 m/s lift serving ground floor and three upper levels.

It is advisable to work within the tabulated population figures until any conditions that would reduce the suitability of the lifts can be assessed with specialist advice. These conditions include situations where:

- The floor-to-floor heights average more than 3.3 m.
- There is more than one main floor, i.e. the lifts populate the building from the ground floor and another level or levels.
- There are levels below the ground floor requiring normal service for passengers.
- The distance from ground floor to first floor exceeds 3.3 m and/or the stairs are located so as to be unattractive to people entering the building.
- There is a canteen above the ground floor, especially where it is used by people not counted in the population served by the affected lift or group.



5.6 *Passenger lifts, dimensions as in Table I. Prefer machine room floor on one level with lift-shaft capping. (Also see* **5.2** *and* **5.3***)*

- There are large numbers of visitors.
- There is a significant amount of goods traffic or other 'requisitioning' which restricts availability for normal passenger traffic.

Firemen's lift service, where required (unusual under seven storeys), can usually be provided by the most suitably located passenger lift of at least 8-person capacity.

3.07 Lifts in social housing

Lift access is recommended for dwellings where there is a climb of more than two storeys to reach the front door **5.7**. The climb is measured from the ground, or from a main pedestrian deck. Where there are dwelling entrances on storeys up to the sixth storey (counting the ground or pedestrian deck as the first), one lift is usually sufficient. Where there are dwelling entrances above the sixth storey, two lifts are provided to serve not less than 20 dwellings each, or more than 50. These numbers include the numbers of dwellings at ground or deck level.

In order to avoid the provision of lifts in three-storey blocks of flats, or four-storey maisoneties, it is frequent practice to have a further storey-height climb beyond the dwelling entrance.

Blocks in hilly areas (or with well-used pedestrian decks as principal access) can be provided with street access above the lowest habited level; in this case, a maximum of two storeys below the street is acceptable without a lift. A lift-less block with six levels of flats is therefore possible, **5.8**. However, it is likely that

Table I Passenger lift dimensions

Type	Load capacity (persons/kg)	Speed (m/s)	Car size (Internal)		Shaft size (nominal)			Doors		Pit	Machine room				Load
			A	B	C	D	E	M	N	P	Q	H	R	S	W
1 Light traffic electric traction	5/400	0.5 and 0.63 1.0	1800	1600	1100	950	2200	800	2000	1400 1500	3900 4000	2300	3200	2500	48
	8/630 ♿	0.5 and 0.63 1.0 1.6	1800	2100	1100	1400	2200	800	2000	1400 1700 1700	4000 4000 4200	2600	3700	2500	76
	10/800 ♿	0.5 and 0.63 1.0 1.6	1900	2300	1350	1400	2200	800	2000	1500 1700 1700	4000 4000 4200	2600	3700	2500	96
	13/1000 ♿	0.5 and 0.63 1.0 1.6	1800	2600	1100	2100	2200	800	2000	1500 1700 1700	4000 4000 4200	2600 2600 2700	4200	2500	120
2 Light traffic hydraulic	5/400	0.5 and 0.63 1.0	1800	1600	1100	950	2200	800	2000	1400 1500	3900 4000	2300	2000	1800	–
	8/630 ♿	0.5 and 0.63 1.0	1800	2100	1100	1400	2200	800	2000	1500 1700	4000	2300	2000	1800	–
	10/800 ♿	0.5 and 0.63 1.0	1900	2300	1350	1400	2200	800	2000	1500 1700	4000	2300	2000	1900	–
	13/1000 ♿	0.5 and 0.63 1.0	1800	2600	1100	2100	2200	800	2000	1500 1700	4000	2300	2000	1800	–
3 Residential electric traction	8/630 ♿	0.5 and 0.63 1.0	2000	1900	1100	1400	2200	800	2000	1400 1700	4000	2600	3700	2200	76
	13/1000 ♿	0.5 and 0.63 1.0	2000	2600	1100	2100	2200	800	2000	1500 1700	4000	2400	4200	2400	120
4 Occasional passenger electric traction	5/400	0.5 and 0.63	1600	1700	900	1250	2200	800	2000	1400	3900	2300	3200	2200	48
	8/630 ♿	0.5 and 0.63	1600	2100	1100	1400	2200	800	2000	1400	4000	2600	3700	2500	76
5 Occasional passenger hydraulic	5/40	0.63	1600	1700	900	1250	2200	800	2000	1400	3900	2300	2000	1600	–
	8/630 ♿	0.63	1600	2100	1100	1400	2200	800	2000	1400	4000	2300	2000	1600	–
6 General-purpose passenger traffic – electric traction	8/630 ♿	1.0 1.6	1800	2100	1100	1400	2200	800	2000	1700	4000 4200	2600	3700	2500	76
	10/800 ♿	1.0 1.6	1900	2300	1350	1400	2200	800	2000	1700	4000 4200	2600	3700	2500	96
	13/1000 ♿	1.0 1.6	2400	2300	1600	1400	2300	1100	2100	1800	4200	2700	4900	3200	120
	16/1250 ♿	1.0 1.6	2600	2300	1950	1400	2300	1100	2100	1900	4400	2700	4900	3200	150
	21/1600 ♿	1.0 1.6	2600	2600	1950	1750	2300	1100	2100	1900	4400	2800	5500	3200	192
7 Intensive passenger electric traction	13/1000 ♿	2.5 3.5	2400	2300	1600	1400	2300	1100	2100	2800 3400	9400 10 400		4900	3200	120
	16/1250 ♿	2.5 3.5	2600	2300	1950	1400	2300	1100	2100	2800 3400	9500 10 400		4900	3200	150
	21/1600 ♿	2.5 3.5	2600	2600	1950	1750	2300	1100	2100	2800 3400	9700 10 600		5500	3200	192
8 Bed and passenger electric traction	21/1600 ♿	0.5 and 0.63 1.0 1.6 2.5	2400	3000	1400	2400	2300	1300	2100	1700 1700 1900 3200	4600	2800	5500	3200	192
	24/1800 ♿	0.5 and 0.63 1.0 1.6 2.5	2400	3000	1600	2400	2300	1300	2100	1700 1700 1900 3200	4600 4600 4600 9700	2900 2900 2900	5800	3200	216
	26/2000 ♿	0.5 and 0.63 1.0 1.6 2.5	2400	3300	1500	2700	2300	1300	2100	1700 1700 1900 3200	4600 4600 4600 9700	2900 2900 2900	5800	3200	240
	33/2500 ♿	0.5 and 0.63 1.0 1.6	2700	3300	1800	2700	2300	1300	2100	1800 1900 2100	4600	2900	5800	3500	300

Table II Selection table for a good passenger lift service

Levels served	Population per floor	Net area served (m^2)	No. of lifts in group	Load (persons)	Speed (m/s)	Cost level index
4	60	2400	1	8	1.0	1.00
	69	2760	1	10		1.07
	76	3040	1	13		1.13
	147	5880	2	8		2.00
	176	7040	2	10		2.13
	202	8080	2	13		2.27
5	33	1650	1	8	1.0	1.07
	37	1850	1	10		1.13
	88	4400	2	8		2.13
	105	5250	2	10		2.27
	147	7350	2	10	1.6	2.67
	168	8400	2	13		2.80
	199	9950	2	16		2.93
6	51	3060	2	8	1.0	2.27
	58	3480	2	10		2.40
	63	3780	2	13		2.53
	86	5160	2	8	1.6	2.67
	100	6000	2	10		2.80
	109	6540	2	13		2.93
	121	7260	2	16		3.07
	151	9060	3	10		4.19
	168	10 080	3	13		4.40
	199	11 940	3	16		4.61
7	69	4830	2	10	1.6	2.93
	75	5250	2	13		3.07
	109	7630	3	10		4.40
	122	8540	3	13		4.61
	138	9660	3	16		4.80
	152	10 640	3	21		5.08
	163	11 410	4	13		6.13
	184	12 880	4	16		6.40
	207	14 490	4	21		6.78
8	51	4080	2	10	1.6	3.20
	84	6720	3	10		4.80
	94	7520	3	13		5.00
	109	8720	3	16		5.20
	119	9520	3	21		5.48
	125	10 000	4	13		6.67
	146	11 680	4	16		6.93
	165	13 200	4	21		7.31
	183	14 640	5	16		8.67
	206	16 480	5	21		9.14
9	75	6750	3	13	1.6	5.20
	85	7650	3	16		5.41
	92	8280	3	21		5.68
	100	9000	4	13		6.93
	116	10 440	4	16		7.20
	131	11 790	4	21		7.58
	146	13 140	5	16		9.00
	164	14 760	5	21		9.47
	175	15 750	6	16		10.80
	197	17 730	6	21		11.36
10	61	6100	3	13	1.6	5.41
	68	6800	3	16		5.60
	73	7300	3	21		5.88
	82	8200	4	13		7.20
	96	9600	4	16		7.47
	107	10 700	4	21		7.84
	120	12 000	5	16		9.33
	134	13 400	5	21		9.80
	144	14 400	6	16		11.20
	161	16 100	6	21		11.76
11	51	5610	3	13	1.6	5.6
	56	6160	3	16		5.8
	61	6710	3	13	2.5	7.4
	69	7590	3	16		7.8
	73	8030	3	21		8.8
	81	8910	4	13		9.9
	93	10 230	4	16		10.4
	103	11 330	4	21		11.7
	112	12 320	4	24		12.0
	129	14 190	5	21		14.7
	140	15 400	5	24		15.0
	155	17 050	6	21		17.6
	168	18 480	6	24		18.0
12	53	6360	3	13	2.5	7.6
	61	7320	3	21		9.0
	71	8520	4	13		10.1
	80	9600	4	16	10.7	
	89	10 680	4	21	12.0	

Table II (Continued)

Levels served	Population per floor	Net area served (m^2)	No. of lifts in group	Load (persons)	Speed (m/s)	Cost level index
	96	11 520	4	24	12.3	
	111	13 320	5	21		15.0
	120	14 400	5	24	15.3	
	134	16 080	6	21		18.0
	144	17 280	6	24		18.4
13	46	5980	3	13	2.5	7.8
	52	6760	3	16		8.2
	61	7930	4	13		10.4
	70	9100	4	16		10.9
	77	10 010	4	21		12.3
	82	10 660	4	24		12.5
	97	12 610	5	21		15.3
	105	13 650	5	24		16.7
	116	15 080	6	21		18.4
	126	16 380	6	24		18.8
14	40	5600	3	13	2.5	8.0
	54	7560	4	13		10.7
	61	8540	4	16		11.2
	68	9520	4	21		12.5
	71	9940	4	24		12.8
	77	10 780	5	16		14.0
	85	11 900	5	21		15.7
	92	12 880	5	24		16.0
	102	14 280	6	21		18.8
	110	15 400	6	24		19.2
15	48	7200	4	13	2.5	10.9
	54	8100	4	16		11.5
	60	9000	4	21		12.8
	68	10 200	5	16		14.3
	76	11 400	5	21		16.0
	82	12 300	5	24		16.3
	91	13 650	6	21		19.2
	98	14 700	6	24		19.6
16	44	7040	4	13	2.5	11.2
	50	8000	4	16		11.7
	53	8480	4	21		13.1
	62	9920	5	16		14.7
	68	10 880	5	21		16.3
	74	11 840	5	24		16.7
	82	13 120	6	21		19.6
	89	14 240	6	24		20.0
17	40	6800	4	13	2.5	11.5
	45	7650	4	16		12.0
	47	7990	4	21		13.3
	56	9520	5	16		15.0
	62	10 540	5	21		16.7
	64	10 880	5	21	3.5	18.7
	77	13 090	6	21		22.4
18	42	7560	4	16	3.5	13.8
	45	8100	4	21		15.2
	53	9540	5	16		17.3
	59	10 620	5	21		19.0
	71	12 780	6	21		22.8

Based on the handling capacity of lift types (Table I) for typical office traffic

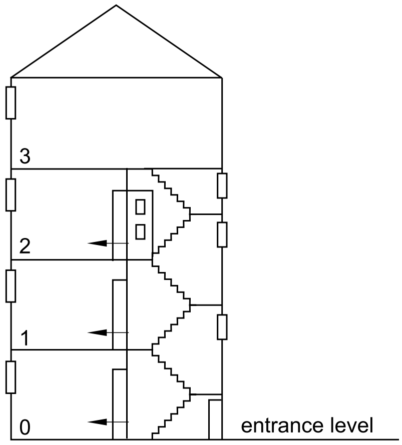
Table III Selection table for separated lifts

Levels served	Population per floor	Net area served (m^2)	Load (persons)	Speed (m/s)	Cost level index
5	64	3200	8	1.60	1.27
	70	3500	10		1.33
	77	3850	13		1.40
6	40	2400	8	1.60	1.33
	44	2640	10		1.40
	47	2820	13		1.47
7	29	2030	10	1.60	1.47
	31	2170	13		1.53

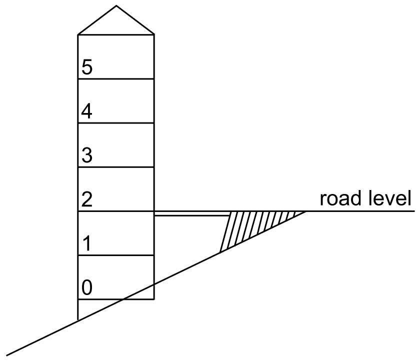
Based on estimated handling capacity of lift types 6 and 7 in Table I

regulations regarding accessibility to residential accommodation of all kinds for wheelchair users may eventually prohibit this practice.

There should be no direct lift access to enclosed underground or underdeck garage spaces for safety reasons. An open area should be provided between lift and garage. Stair access from the lift is



5.7 *A block of flats on four levels without lift service. The entrance door of any flat is no more than two levels from the entrance to the block*



5.8 *A block of flats on six levels with no flat door more than two levels from the entrance*

acceptable unless there are parking spaces for the cars of wheelchair users in the garage.

For blocks not higher than 11 storeys including ground or deck level, the type of lift normally used is the eight-passenger (630 kg) lift with standard speed 0.5 m/s (Table I). For higher blocks, a faster speed may be necessary. For example, in a 20-storey block, a person on the top floor calling the lift from the bottom and returning there, assuming four other 15-s stops en route, will take approximately 5 min at a speed of 0.5 m/s, 4.5 min at 0.63 m/s and 3 min at 1 m/s. In large blocks, the slow speed may well encourage overloading. If our passenger had just missed the lift, trip times will be increased by half as much again.

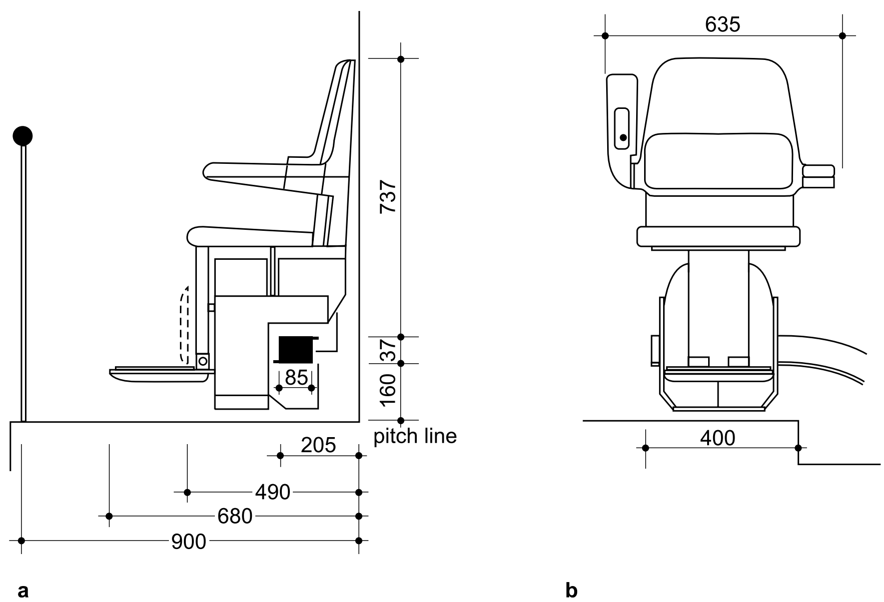
Lifts should be located in the block so that the walk to the dwelling entrance does not exceed 60 m. Habitable rooms, particularly bedrooms, should not abut liftshafts or machinery rooms as these often generate noise and vibration.

The standard lift car size is 1.1×1.4×2.2 m, and the door width is 0.8 m. It will be seen that this will accommodate a wheelchair and most items of furniture except the largest. It will not accommodate a stretcher or a coffin unless this can be stood on end. For this reason, in the past, a stretcher recess was sometimes provided in one lift of a tall block. This projected into the shaft for only part of the car height, but usually for the full width. However, stretcher recesses were a problem where vandalism was concerned. They have mostly been taken out of use and are never used in modern installations. Patients are now always strapped to stretchers, which can then be tipped. Coffins are very rarely taken into or out of flats; body shells are used whenever a corpse is removed.

3.08 Lifts in special housing for elderly and disabled people

It is now considered unsatisfactory to segregate people who are less able-bodied, and all housing schemes should take their requirements into account. However, where there is likely to be a preponderance of such people, or some with more severe disabilities, it may be necessary to provide accommodation specifically for them.

There is some difference of opinion on the desirable scale of provision in these cases. The Greater London Council did not accommodate these people above the fifth storey from the normal pedestrian or vehicular level, whichever is the lower. However, the Department of the Environment permitted only one lift up to four storeys, and two lifts for five- and six-storey buildings only if there are at least 12 dwellings above fourth storey level.



5.9 *A domestic stairlift. Such a device can usually be fitted to any domestic staircase. While normally used against a wall, it could alternatively be installed on the side of the banisters. This one has a fixed seat, but a swivelling seat is available for where there is insufficient space at the top or bottom of the flight for easy access to the seat. Note that the rail on which the lift travels projects into the staircase width by 205 mm. This may affect the ability of the staircase to pass larger furniture items. (Courtesy of Stannah Stairlifts Limited,* **a** *section,* **b** *elevation)*

Where a reliable lift service is provided, high-rise accommodation is both suitable and appreciated by the elderly, as ground-floor flats can be subject to noise and security problems.

3.09 Private sector housing

The standards of lift accommodation in the private sector are not usually markedly more generous than in social housing. A faster speed might be provided, and the standard of finishing will probably be more luxurious and less vandal-resistant.

3.10 Hostels

Where students and nurses are accommodated, it may be assumed that they are generally younger and fitter than the general population. It is therefore uncommon to install lifts unless more than four storey heights have to be climbed. However, a goods hoist should be provided for linen, etc. over two storeys. For blocks higher than four storeys, one lift will probably be sufficient. Given that no communal facilities are provided on upper floors, there is no need at present for access by students in wheelchairs who are accommodated at ground level; in the future, this may become an unacceptable limitation.

3.11 Hotels

Provision in hotels should be based on the scale laid down for office buildings; although, depending on the facilities provided (such as conference suites) and the grading of the hotel, the capacities may be adjusted upwards to a maximum of 100%. Hotel bedrooms should not abut shafts or machinery rooms.

4 WHEELCHAIR AND STAIR LIFTS

4.01

Details of a simple stairlift to transport someone from ground to first floor in a common type of house are shown in **5.9**. Staircases in houses should be designed with the possible future need to install such a lift borne in mind, and legislation is likely to reinforce this. A more elaborate stairlift suitable for a public building is shown in **5.10**; this type will also take a wheelchair.

4.02

Wheelchair lifts are used in a variety of situations. They can be used in public and semi-public buildings to transfer a wheelchair between minor changes of level. In domestic property, they can be installed where a stairlift is not possible, or appropriate for the user. They differ from standard lifts in that, moving relatively slowly, they commonly have no permanent enclosure, and require minimum pit depth. Motive power is often hydraulic.

5 GOODS LIFTS

Except for heavy industrial use (e.g. self-propelled trucks), standard goods lifts as in **5.11** and Table IV are usually satisfactory. The selected lift car size should allow for a person to accompany the largest item or batch of goods to be catered for in normal use (to operate the controls at the side of the car).

For over eight storeys, a requirement for a separate goods lift service is usually met by a lift of the passenger type having automatic side-opening doors, e.g. type 8 in Table I.

6 SERVICE LIFTS AND HOISTS

There is no standard range from which to select service lifts, and makers' preferences on general arrangement, size and speed vary considerably; but most makers can provide lifts similar to those shown in **5.12** and **5.13**. Where there are other lifts in the building or associated buildings, a service lift by the same maker assists management and minimises maintenance costs.

A maker's own standard pre-assembled and clad unit might be advantageous for such as an existing building where minimum builder's work and quick delivery are overriding factors. These packages do have disadvantages for some applications, however, e.g. insufficient fire resistance of cladding, unsafe for location above a space used by people.

7 ESCALATORS AND PASSENGER CONVEYORS

Dimensions, speed and finishes vary but a 30° incline is available from all makers, **5.14**. For preliminary purposes or an approximate comparison with lifts' performance (Tables II and III) allow a handling capacity of 1600 people in 30 min per 600 mm of step width. In many buildings, of course, a lift or lifts will also be needed for the infirm, wheelchairs, prams and/or goods traffic.

If space permits a conveyor, **5.15** may be installed. This is able to take prams and suitably designed trolleys, and so is appropriate for supermarkets and air terminals, etc. A more elaborate type is shown in **5.16**.

8 SANITARY INSTALLATIONS

8.01 Installation standards

Public and semi-public conveniences are places where one is obliged to perform the most private functions in public with strangers of the same sex.

Quite different gangways are needed on a Tube train where to brush closely against Mr X is acceptable, as opposed to between two urinal rows where to brush against the same Mr X is almost criminal. The fundamental point of planning spacing in public installations is that psychological not just physical clearances and spacing are required.

8.02 Types of installation

Installations can be:

1 Public conveniences, provided by municipalities, transport undertakings (including motorway service stations), shopping centres, etc. Use of these facilities are generally open to any member of the public
2 Semi-public conveniences: theatres, stadia, refreshment houses, etc. where use is restricted to patrons of the provider
3 Private multiuse installations for staff in offices, factories, etc. and in hostels and old persons' homes
4 Domestic facilities.

Types 1 and 2 tend to differ only in superficial ways such as the standard and type of finishes.

8.03 Activity spaces

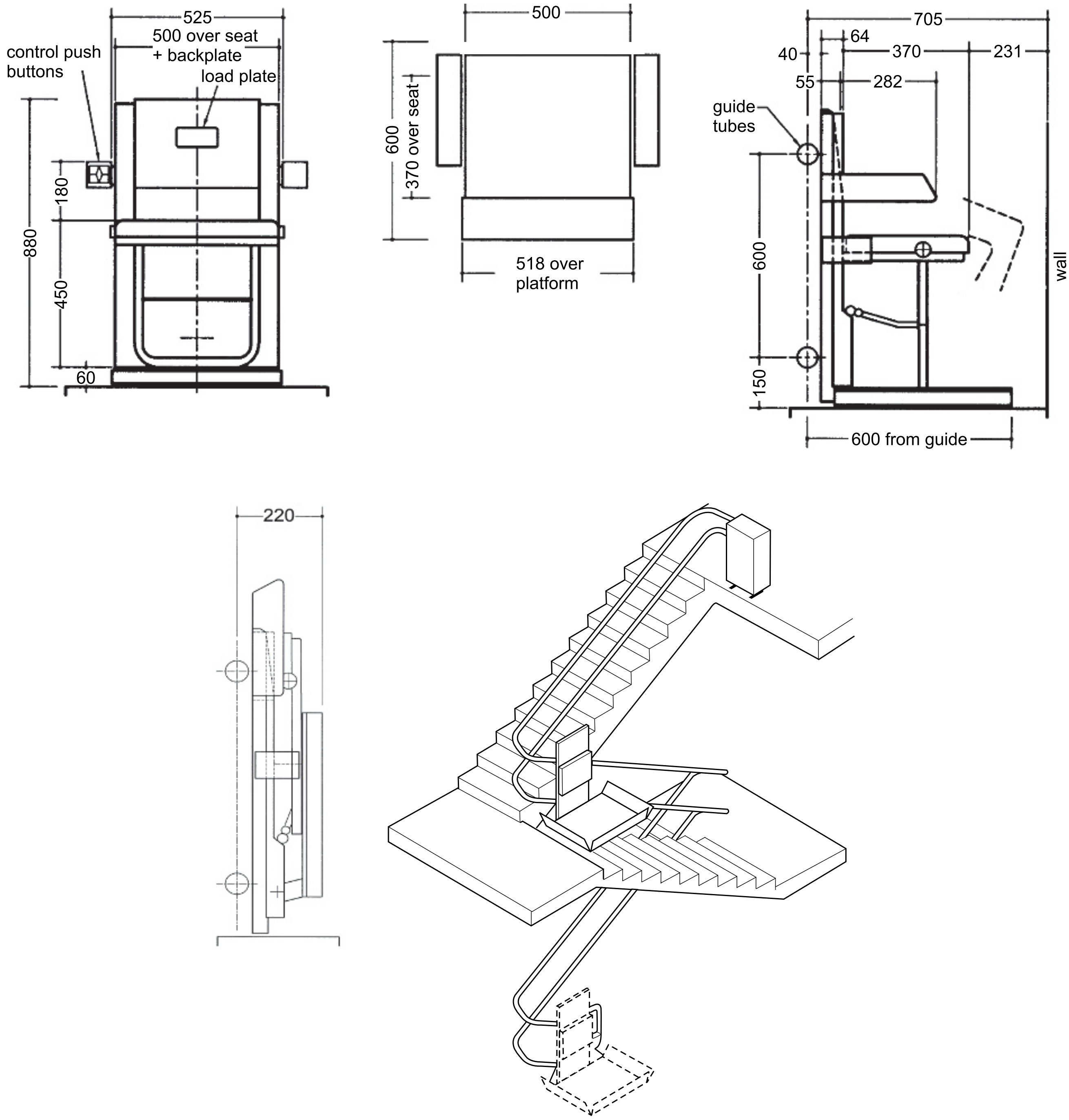
A number of different spaces are shown in the diagrams: space occupied by the appliance itself, additional space required by the user (the activity space) and further space required for luggage or circulation. In many cases, these latter spaces may overlap on occasion. Common sense will dictate when this is appropriate, and when it is not.

8.04 Number of appliances required

The recommendations given in Tables V–XVII are derived principally from BS 6465: Part 1:1994, and are the minimum requirements.

In all situations, attention is drawn to the necessity to provide facilities for the disabled, baby changing and also for the disposal of sanitary towels and continence aids.

A common mistake is inadequate numbers of WCs for females, leading to long queues. Always err on the generous side.



5.10 *Details of stair lift for wheelchair, or for seated passenger. (Courtesy of Gimson Stairlifts Ltd)*

Table XVIII gives figures for various building types of the numbers of appliances to be provided for a total of 100 people evenly divided between the sexes. Toilets for wheelchair users are not included.

8.05 Planning the space

The planning of installations of types 1, 2 and 3 in paragraph **8.2** above requires sensitivity to the requirements of privacy and discretion. It is desirable that circulation of people through the sanitary area space is essentially one way, **5.17**. Single entry/exit plans can, however, work satisfactorily, provided that the paths of users do not cross each other and the entry is wide enough. Placing the appliances in order of use simplifies circulation and reduces the distance walked. Hygiene should be encouraged by placing washing and drying facilities between the WC and/or urinal and the exit.

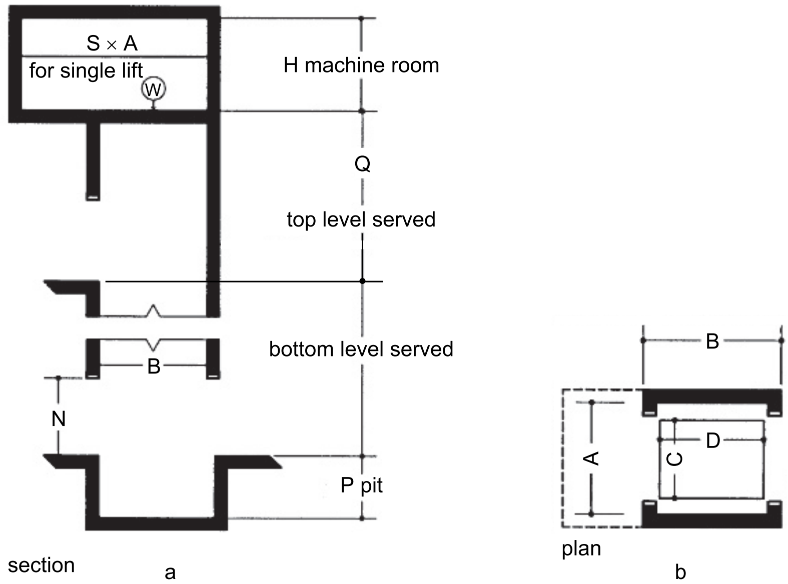
Vision is traditionally seriously considered in the planning of lavatories, although sound and odour are sources of considerable concern for many people and should also be considered, particularly in larger installations.

8.06 Vision

In larger installations, vision should be obstructed by the configuration of the entrance and in principle, entrance doors should be avoided, **5.18**. In smaller installations, doors should open inwards and be hung so as to screen the appliances and the user as far as possible when opened. The doors to adjacent male and female rooms should not be close to each other as this is psychologically disturbing and aggravates vision problems. Consideration should also be given to positioning of mirrors and to the gap created by the hinges. Doors should be self-closing wherever possible.

8.07 Noise

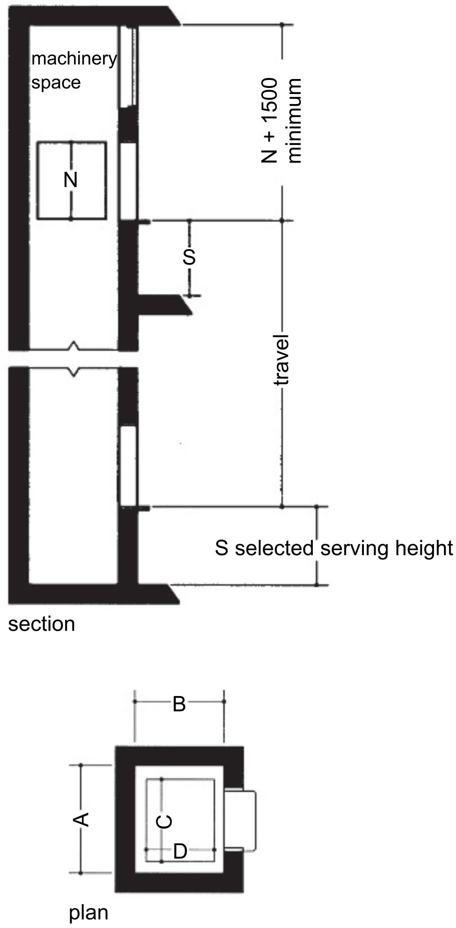
It is difficult and costly to satisfactorily insulate lavatories acoustically and this problem should be tackled by planning isolation if possible.



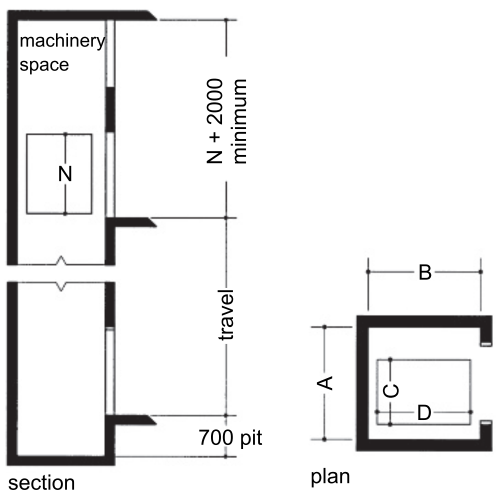
5.11 *Goods lift, dimensions as in Table IV. Entrances can be front only or front and back. Prefer machine room floor on one level with lift shaft capping*

Table IV Goods lifts

Type	Load capacity (persons/kg)	Speed (m/s)	Shaft size (nominal)		Car size (internal)			Doors		Pit		Machine room			Load
			A	B	C	D	E	M	N	P	Q	H	R	S	W
9 General-purpose goods lifts, electric traction	500/6	0.5 0.63 and 1.0	1800	1500	1100	1200	2000	1100	2000	1400 1500	3800	2400	3700	2000	60
	1000/13	0.25 0.5 0.63 and 1.0	2100	2100	1400	1800	2000	1400	2000	1500	3800	2400	4300	2100	120
	1500/20	0.25 0.5 0.63 and 1.0	2500	2300	1700	2000	2300	1700	2300	1500 1700 1800	4000 4100 4200	2700	4500	2500	180
	2000/26	0.25 0.5 0.63 and 1.0	2500	2800	1700	2500	2300	1700	2300	1500 1700 1800	4100 4300 4500	2900	5100	2500	240
	2000/26	0.25 0.5 0.63 and 1.0	2800	2400	2000	2100	2300	2000	2300	1500 1700 1800	4100 4300 4500	2900	4700	2800	240
	3000/40	0.25 0.5 0.63	3000	3300	2000	3000	2300	2000	2300	1500 1700 1800	4200 4400 4500	2900	5600	3000	360
	3000/40	0.25 0.5 0.63	3500	2700	2500	2400	2300	2500	2300	1500 1700 1800	4200 4400 4500	2900	5000	3500	360
10 Heavy-duty goods electric traction	1500/20	0.25 0.5 0.63 and 1.0	2600	2400	1700	2000	2300	1700	2300	1500 1700 1800	4800	2700	4800	2600	180
	2000/26	0.25 0.5 0.63 and 1.0	2600	2900	1700	2000	2300	1700	2300	1500 1700 1800	4800	2900	5400	2600	240
	2000/26	0.25 0.5 0.63 and 1.0	2900	2500	2000	2100	2300	2000	2300	1500 1700 1800	4800	2900	5000	2900	240
	3000/40	0.25 0.5 0.63 and 1.0	3000	3400	2000	3000	2300	2000	2300	1500 1700 1800	4800	2900	5900	3000	360
	3000/40	0.25 0.5 0.63 and 1.0	3500	2800	2500	2400	2300	2500	2300	1500 1700 1800	4800	2900	5300	3500	360
	4000/53	0.25 0.5 0.63	3500	3400	2500	3000	2500	2500	2500	1500 1700 1800	5200	2900	6200	4000	480
	5000/66	0.25 0.5 0.63	3600	4000	2500	3600	2500	2500	2500	1500 1700 1800	5200	2900	6800	4000	600



5.12 *Medium-size service lift, dimensions as in Table IX. Note: speed up to 0.5 m/s but prefer 0.38 m/s. Shaft size includes 25 mm allowance for out-of-plumb. Openings can be front and rear as required. Car can be fitted with shelves*



5.13 *Large service lift suitable for trolleys, dimensions as Table X. Note: speed 0.25 or 0.38 m/s. Shaft size includes 25 mm allowance for out-of-plumb. Openings can be front and rear as required*

8.08 Odour

Except in extremely well-naturally ventilated installations, some form of forced ventilation or air conditioning is desirable, particularly so in confined areas. Manually switched fans which continue to run for a set period after being switched off are useful in domestic situations.

8.09 Vandalism

No unsupervised installation can resist vandals. Even with the most vandal-resistant equipment (which would have to exclude all ceramics), an unsupervised facility will inevitably become substandard. In such situations, the use of an attendant will result in a high standard being maintained, possibly with reduced costs. A well-designed installation, easily kept clean, with an open layout, a high level of general lighting and robust equipment securely fixed will reduce the problem. Where vandal-resistant appliances are thought necessary, stainless steel is considerably less prone to damage than ceramics, but all designs should allow for individual items to be replaced. Pipework, traps, cisterns, electrical supplies, etc. should all be fully concealed and this is, of course, also highly desirable for hygiene and appearance. The modular plastic panel is not desirable in areas likely to be vandalised.

8.10 Ducts

As it is equally unacceptable to have pipes inside a room or outside it, ducts are an inevitable detail of sanitary installations. Although pipes are frequently buried into wall structures, notably in Germany where appropriate pipework fittings exist, the UK situation is that we consider access is needed to critical points such as traps and cisterns. To achieve this access, ducts may be walk-in or have access from one or other sides. For hygiene, cleaning maintenance, structural soundness and planning flexibility, plan **5.19** is superior to **5.20**.

Although if the appliance could be part of the wall, plan **5.20** would be very useful, in practice this plan usually results in the adoption of a standard ceramic appliance on a sheet plastic panel with its attendant impractical problems, details and module (which, in addition, seldom correctly relate to required activity spaces or correct operational heights).

On the other hand, **5.19** demands more detailed work from the architect, and it is not always possible to utilise adjacent room areas for access.

Once the duct is provided, it is logical and more hygienic to bring the water supplies directly through the duct wall to wall-mounted valves, rather than the pipework passing through the wall, sanitaryware, then on to deck-mounted valves.

It is similarly illogical to have traps hanging from appliances in the room if there is space in the duct for them, although some sanitaryware makes this unavoidable. Ducts should avoid maintenance problems and not have ferrous metal in their construction.

8.11 Tiles and modules

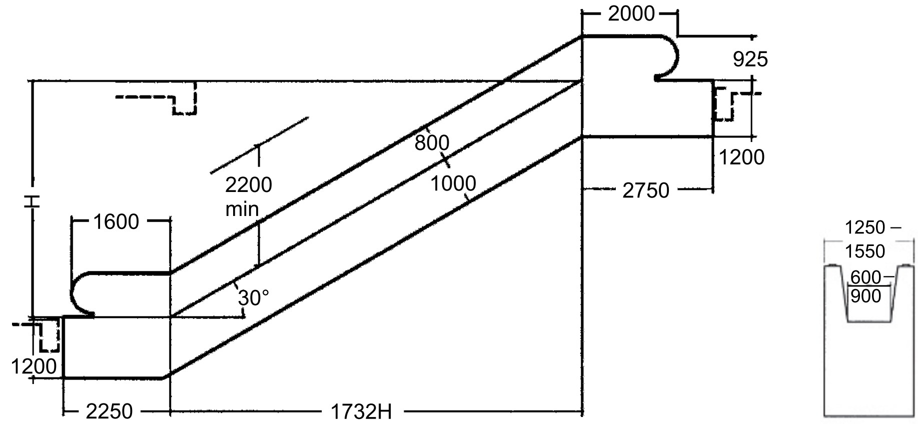
As UK manufacturers have never accepted the 100 mm modular tile (except as a special) and as UK manufacturers will not make sanitaryware modular, it is difficult to find a reason for choosing one module or another for the sanitary installation. It is, however, obvious, in view of the quite differing requirements of the various appliances and the individual situation, that any module should be as small as practicable. The best module is probably that used in Alvar Aalto's office of 1 mm!

9 SANITARY APPLIANCES

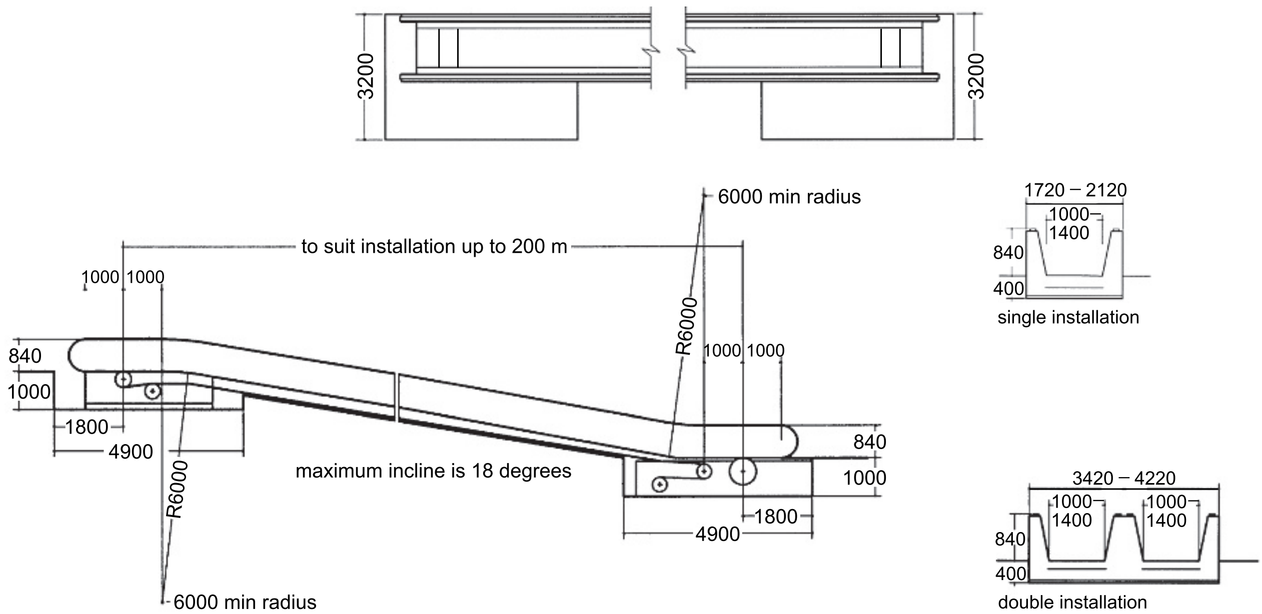
9.01 WCs

The principal appliance in any installation is the water closet or WC. This may be free-standing within a bathroom, or placed in a compartment or cubicle by itself, or with a hand-rinse basin.

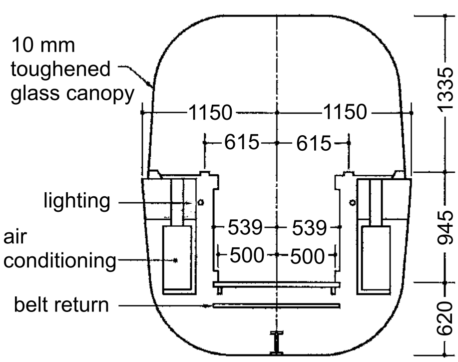
A WC compartment is totally enclosed by walls that reach down to the floor and up to the ceiling, and has its own lighting and ventilation system. A cubicle is enclosed by light partitions that do not reach floor or ceiling. It shares the lighting and ventilation of the larger space of which it is a part.



5.14 *Dimensions of 30° escalator, elevation and section*



5.15 *A one-speed mechanised passenger conveyor system, may be flat, or up to 12° for prams, shopping trolleys, etc., or up to 15° for special installations. Other systems available permit 'valley' and 'hill' longitudinal profiles; also surface laying of conveyor on drive motor on existing floors. Capacity of system shown is 7200 persons per hour. Systems are available up to 8000 pph. Speed range is 0.45–0.6 m/s. Tread widths, 1000–1400 mm*



5.16 *Section through passenger conveyor at Charles de Gaulle Airport, Paris*

5.21 shows the appliance, complete with cistern, and its normal activity space. If the cistern is at high level, or situated within a duct, the space for the appliance is correspondingly reduced. However, it may then be found difficult to accommodate a sanitary bin in a place acceptable to the user. **5.22** shows a bidet and its activity space.

In the UK, it is normal for a WC cubicle door to open inwards (see **9.03** below). This causes difficulties in entering some cubicles because there is nowhere to stand clear of the door swing. There is also a danger of clothes soiling by contact with the edge of the WC pan. BS 6465 now asks for a cylindrical volume 450 mm in diameter clear of all obstructions such as WC pan, door swing or toilet paper holder.

There are three basic types of WC compartment and cubicle (excluding those also containing a hand-rinse basin):

- A compartment in a house or flat where the user will be in indoor clothing and without impedimenta
- A cubicle in an office or factory, where the user is likely also to be in light clothing with no impedimenta
- A cubicle or compartment in a public place, such as a shopping centre or an airport, where the user may be in a coat and have heavy luggage, shopping or even a baby carrier that cannot, for security, be left outside.

5.23 shows a 'standard' WC cubicle with inward-opening door, the leaf of which is 700 mm wide. It is seen that with a normal pan central in the cubicle width, the cubicle is 1640 mm in depth. **5.24** shows an alternative where the pan is offset towards the door hinge

Table V Staff toilets in offices, shops, factories and other non-domestic premises used as place of work

Sanitary appliances for any group of staff		
Number of persons at work	**Number of WCs**	**Number of washing stations**
1–5	1	1
6–25	2	2
26–50	3	3
51–75	4	4
76–100	5	5
Above 100	One additional WC and washing station for every unit or fraction of a unit of 25 persons	

Alternative scale of provision of sanitary appliances for use by male staff only		
Number of men at work	**Number of WCs**	**Number of urinals**
1–15	1	1
16–30	2	1
31–45	2	2
46–60	3	2
61–75	3	3
76–90	4	3
91–100	4	4
Above 100	One additional WC for every unit or fraction of a unit 50 men provided at least an equal number of additional urinals are provided	

If public also use staff toilets, add 1 to each number of conveniences above

If work involves heavy soiling of hands and forearms	
Number of persons at work	**Number of washing stations**
1–50	1 per 10
more than 50	1 additional per 20 or part of 20

Table VI Sanitary facilities for customers in shops and shopping malls having a net sales area more than 1000 m^2 and assuming equal numbers of male and female customers

Sales area of shop	Appliances	Male	Female
1000–2000 m^2	WC	1	2
	Urinal	1	Nil
	Wash basin	1	2
	Toilet for disabled people	1 unisex	
	Baby-changing facilities	1 unisex *not* in disabled toilet	
2001–4000 m^2	WC	1	4
	Urinal	2	Nil
	Wash basin	2	4
	Toilet for disabled people	1 unisex	
	Baby-changing facilities	2 unisex	
Greater than 4000 m^2	In proportion to the size of the net sales area		

Table VII Sanitary provision in restaurants, cafés, canteens and fast food outlets assuming equal numbers of male and female customers

Appliances	For male customers	For female customers
WC	1 per 100 up to 400 males. For over 400 males, add at the rate of 1 per 250 males of part thereof	2 per 50 up to 200 females. For over 200, add at the rate of 1 per 100 females or part thereof
Urinal	1 per 50 males	–
Wash basin	1 per WC and in addition 1 per 5 urinals or part thereof	1 per WC
Toilets for disabled people	1 unisex compartment should be reasonably close by but may be shared by other facilities (such as shops)	
Bucket/cleaners' sink	Adequate provision should be made for cleaning facilities including at least one cleaners' sink	

Table VIII Sanitary provision in public houses and licensed bars

Appliances	For male customers	For female customers
WC	1 for up to 150 males plus 1 for every additional 150 males or part thereof	1 for up to 12 females plus 1 for 13–30 females plus 1 for every additional 25 females or part thereof
Urinal	2 for up to 75 males plus 1 for every additional 75 males or part thereof	
Wash basin	1 per WC and in addition 1 per 5 urinals or part thereof	1 per 2 WCs
Toilets for disabled persons	1 unisex	
Bucket/cleaners' sink	Adequate provision should be made for cleaning facilities including at least one cleaners' sink	

Assume 4 persons per 3 m^2 of EDA (effective drinking area) and 75%/25% male/female in public houses without public music and singing licences, 50%/50% elsewhere.

Table IX Sanitary provision in buildings used for public entertainment

Appliances	Males	Females
WC	In single-screen cinemas, theatres, concert halls and similar premises without licensed bars: 1 for up to 250 males plus 1 for every additional 500 males or part thereof	In single-screen cinemas, theatres, concert halls and similar premises without licensed bars: 2 for up to 40 females 3 for 41–70 females 4 for 71–100 females plus 1 for every additional 40 females or part thereof
Urinal	In single-screen cinemas, theatres, concert halls and similar premises without licensed bars: 2 for up to 100 males plus 1 for every additional 80 males or part thereof	
Wash basins	1 per WC and in addition 1 per 5 urinals or part thereof	1, plus 1 per 2 WCs or part thereof
Toilets for disabled people	1 unisex minimum	
Bucket/cleaner's sink	Adequate provision should be made for cleaning facilities including at least one cleaner's sink	

Assume, unless otherwise indicated, equal numbers of male and female customers.
In cinema, multiplexes, etc. where use is spread over all the time the building is open, assume 75% of total capacity, otherwise use 100%.
If premises include a licensed bar, additional provision as Table VIII will be needed.

Table X Sanitary provision in swimming pools

Appliances	For bathers	
	Male	**Female**
WC	2 for up to 100 males plus 1 for every additional 100 males or part thereof	1 per 5 females for up to 50 females plus 1 for every additional 10 females or part thereof
Urinal	1 per 20 males	
Wash basin	1 per WC and in addition 1 per 5 urinals or part thereof	1, plus 1 per 2 WCs or part thereof
Shower	1 per 10 males	1 per 10 females
Toilets for disabled people	1 unisex minimum	

Assume 50% male and 50% female users.
Toilets for spectators should be provided as Table IX and for staff as Table V.

Table XI Sanitary provision in Stadia

	Urinals	WCs	Wash hand basins
Male	1 per 70 males	1 for every 600 males, but minimum of 2 per toilet area	1 per 300 males, but minimum of 2 per toilet area
Female		1 for every 35 females, but minimum of 2 per toilet area	1 per 70 females, but minimum of 2 per toilet area
For disabled people	Where there is provision for more than 10 spectators with disabilities, provide at least 2 suitable unisex compartments within 40 m travel distance. Generally, 1 unisex special WC per 12–15 disabled spectators		

Table XII Minimum sanitary provision in stadia for different male:female ratios

Capacity of stand/ area	Type of provision	Male:female ratio			
		90/10	85/15	80/20	75/25
500		450:50	425:75	400:100	375:125
	Male urinals	7	7	6	6
	Male WCs	2	2	2	2
	Male WHBs	2	2	2	2
	Female WCs	2	3	3	4
	Female WHBs	2	2	2	2
1000		900:100	850:150	800:200	750:250
	Male urinals	13	13	12	11
	Male WCs	2	2	2	2
	Male WHBs	3	3	3	3
	Female WCs	3	5	6	8
	Female WHBs	2	3	3	4
2000		1800:200	1700:300	1600:400	1500:500
	Male urinals	26	25	23	22
	Male WCs	3	3	3	3
	Male WHBs	6	6	6	5
	Female WCs	6	9	12	15
	Female WHBs	3	5	6	8
3000		2700:300	2550:450	2400:600	2250:750
	Male urinals	39	37	35	33
	Male WCs	5	5	4	4
	Male WHBs	9	9	8	8
	Female WCs	9	13	18	22
	Female WHBs	5	7	9	11
5000		4500:500	4250:750	4000:1000	3750:1250
	Male urinals	65	61	58	54
	Male WCs	8	8	7	7
	Male WHBs	15	15	14	13
	Female WCs	15	22	29	36
	Female WHBs	8	11	15	18

side to provide space for a sanitary bin. In this case, the depth is reduced to 1550 mm. These two designs are suitable for the first two situations above.

5.25–5.27 show designs appropriate where there is likely to be luggage, etc.

It is seen that the width of a 'standard' cubicle is 800 mm. This width is also preferred by ambulant disabled people (see **9.05**).

However, many women find this width too narrow for them, and prefer a width of 900 mm as minimum, with a door opening 800 mm. A wider cubicle may also be needed for people who are oversize.

WC compartments and cubicles may also have to accommodate the following:

- Hand-rinse basin (see **9.03**)
- Large toilet roll holder and dispenser
- Bin for the disposal of sanitary dressings or continence aids
- Dispenser for disposable toilet seat covers
- Brush
- Shelf
- Clothes hooks.

9.02 Height of WCs

There is no standard height of pan, but most are around 400 mm to the top of the pan, allow a further 25 mm for the seat. There was a vogue for pans as low as 250 mm at one time, because of medical advice that more of a squatting attitude was beneficial. However, there now seems to be little movement towards the 'health closet', as it is hampered by Western tradition, the difficulty of the elderly or infirm to use a low-level WC and the uselessness of a low WC as a seat or urinal which are common functions in domestic bathrooms.

A pan of height 355 mm is available for use in junior schools. Slightly higher pans are recommended for WCs for disabled people, and these are 450 mm to the top of the seat. People who find a WC seat too low can use removeable seat raisers which are available in a number of different heights.

9.03 Doors

Traditionally, in the UK, doors to WC compartments and cubicles open inwards. The advantages claimed for this are:

- Privacy, particularly when the door lock is missing or broken
- Elimination of hazard to those outside the cubicle
- The doors are hung so that empty cubicles have open doors and are easily found.

The disadvantages are:

- Restriction of space within the compartment
- Difficulty of reaching anyone taken ill within (a not-uncommon situation).

Inward-opening doors can be designed so that they can be lifted off their hinges should access be necessary when someone has fallen against one.

9.04 Squatting WCs

Some people prefer a squatting WC, **5.28**. These are common in continental public conveniences, and also where there is a substantial Asian population. They can be accommodated in a 'standard' cubicle, although there should be grip handles fixed to the side walls. When intended for use by Muslims, the compartment should not face or back in the direction of Mecca, and a low-level cold water tap should be provided in addition to the flushing cistern.

9.05 WC compartments with hand-rinse basins

It is often desirable, and may be mandatory, for a compartment or cubicle to incorporate hand-rinsing facilities. **5.29** shows such an appliance with its activity space – which may overlap that of the WC. Where space is tight, a very small inset design may be used as shown in **5.30**.

5.31–5.35 show alternative designs of compartments with standard hand-rinse basins.

9.06 WC compartments for wheelchair users

Disabled people are remarkably adaptable and often of necessity extremely determined to manage for themselves in buildings designed primarily for able-bodied people. For many ambulant disabled people, the difficulties are surmountable, but for wheelchair users the problems are more serious. If an area is not negotiable by a wheelchair, the user is forbidden entry; this is intolerable, and may be illegal, in any new building.

Therefore, proper consideration should be given to the provision of WC and washing facilities for disabled people. Selwyn Goldsmith's book *Designing for the Disabled* is the most comprehensive study available. There is hardly any ergonomic evidence on this subject and the standard plans shauld be regarded as principles rather than unalterable working drawings.

Table XIII Sanitary provision in schools

Type of school	Appliances	Number recommended	Remarks
Special	Fitting	1/10 of the number of pupils rounded up to the next nearest whole number	
	WC only	Girls: all fittings	
	Urinal and WC	Boys: not more than 2/3 of fittings should be urinals	
	Wash basin	As for secondary school	
	Shower	Although not required by statute, it is suggested that sufficient showers should be provided for physical education	
	Toilet for disabled person	At least 1 unisex depending on nature of special school	
	Bucket/cleaner's sink/slop hopper	At least 1 per floor	
Primary	Fittings	Aggregate of 1/10 of the number of pupils under 5 years old and 1/20 of the number of others. Not less than 4. Rounded up to the nearest whole number	
	WC only	Girls: all fittings	
	Urinal and WC	Boys: not more than 2/3 of fittings should be urinals	
	Wash basin	As for secondary school	
	Shower	Although not required by statute, it is suggested that sufficient showers should be provided for physical education	
	Toilet for disabled person	At least 1 unisex unless number of disabled pupils exceeds 10. Then provide 1 per 20 disabled pupils or part of 20	
	Bucket/cleaner's sink/slop hopper	At least one per floor	
Secondary	Fittings	1/20 of the number of pupils. Not less than 4. Rounded up to the nearest whole number	
	WC only	Girls: all fittings	
	Wash basin	1 in each washroom. At least 2 basins per 3 fittings	See clause 7
	Shower	As for primary school	
	Toilet for disabled person	As for primary school	
Nursery and play	WC	1 per 10 pupils (not less than 4)	
	Washbasins	1 per WC	See clause 7
	Sink	1 per 40 pupils	
Boarding	WC	1 per 5 boarding pupils	Where sanitary accommodation for day pupils is accessible to, and suitable for the needs of boarders, these requirements may be reduced to such an extent as may be approved in each case.
	Wash basin	1 per 3 pupils for the first 60 boarding pupils; 1 per 4 pupils for the next 40 boarding pupils; 1 for every additional 5 boarding pupils;	
	Bath	1 per 10 boarding pupils	
	Shower	May be provided as alternative to not more than 3/4 of the minimum number of baths	
	Toilet for disabled person	As for primary school	

Table XIV Sanitary provision in dwellings

Type of dwelling	Appliances	Number per dwelling	Remarks
Dwellings on one level, e.g. bungalows and flats	WC	1 for up to 5 persons 2 for 6 or more	Except for single person's accommodation, where 1 WC is provided, the WC should be in a separate compartment. Where 2 WCs are provided, 1 may be in the bathroom
	Bath/shower	1	
	Wash basin	1	
	Sink	1	
Dwellings on one or more levels e.g. houses and maisonettes	WC	for up to 4 persons 2 for 5 or more	Except for single person's accommodation, where 1 WC is provided, the WC should be in a separate compartment. Where 2 WCs are provided, 1 may be in the bathroom
	Bath/shower	1	
	Wash basin	1	
	sink	1	

Table XV Sanitary provision in accommodation for elderly people and sheltered housing

Type of accommodation	Appliances	Number per dwelling	Remarks
Self-contained for 1 or 2 elderly persons, or grouped apartments for 2 less-active elderly persons	WC	1	An additional WC may be provided in the bathroom
	Bath/shower	1	Bathroom within apartment
	Wash basin	1	
	Sink	1	
Grouped apartments for less-active elderly persons	WC	1	
	Wash basin	1	
	Sink	1	
	Bath/shower	Not less than 1 per 4 apartments	Some may be Sitz baths or level access showers.
Additional provisions for communal facilities. Common room for self-contained or grouped apartments	WC	1	Minimum number required. Should be available for use by visitors
The pantry or kitchen for self-contained or grouped apartments	Sink	1	Adjacent to common room
Laundry room for grouped apartment schemes	Sink	1	
	Washing machine	1	
	Tumble drier	1	
Cleaner's room	Bucket/cleaner's sink		1 in each cleaner's room

Table XVI Sanitary provision in residential and nursing homes

Type of accommodation	Appliances	Number recommended	Remarks
Residents	WC	1 per 4 persons	An adjacent wash basin is also required
	Bath	1 per 10 persons	
	Wash basin	1 to each bedsitting room	
Staff	WC	At least 2 for non-residential staff	
	Wash basin	1	In WC compartment
Visitors	WC	1	
	Wash basin	1	In WC compartment
Kitchen	Sink	As appropriate	
Toilets for disabled people		A minimum of 1 depending on the number of disabled persons	
Cleaner's room	Bucket/cleaner's sink	1	In each cleaner's room
Other	Bed pan cleaning/disposal	As appropriate	Service area
	Wash basin	1	In each medical room, hairdressing, chiropodist, non-residential staff toilets and kitchen areas

Where en-suite facilities are provided, toilets for visitors and staff should also be provided.

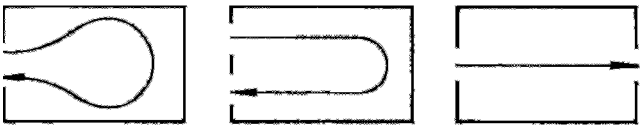
Table XVII Sanitary provision in hotels

Type of accommodation	Appliances/facilities	Number required	Remarks
Hotel with en-suite accommodation	En-suite	1 per residential guest bedroom	Containing bath/shower, WC and wash basin
	Staff bathroom	1 per 9 residential staff	
	Bucket/cleaner's sink	1 per 30 bedrooms	At least 1 on every floor
Hotels and guest houses without en-suite accommodation	WC	1 per 9 guests	
	Wash basin	1 per bedroom	
	Bathroom	1 per 9 guests	Containing: bath/shower, wash basin and additional WC
	Bucket/cleaners' sink	1 per floor	
Tourist hostels	WC	1 per 9 guests	
	Wash basin	1 per bedroom or 1 for every 9 guests in a dormitory	
	Bathroom	1 per 9 guests	Containing: bath/shower, wash basin and additional WC
	Bucket/cleaners' sink	1 per floor	
All hotels	Toilet for disabled person	All hotels should provide at least 1 unisex compartment for disabled people	

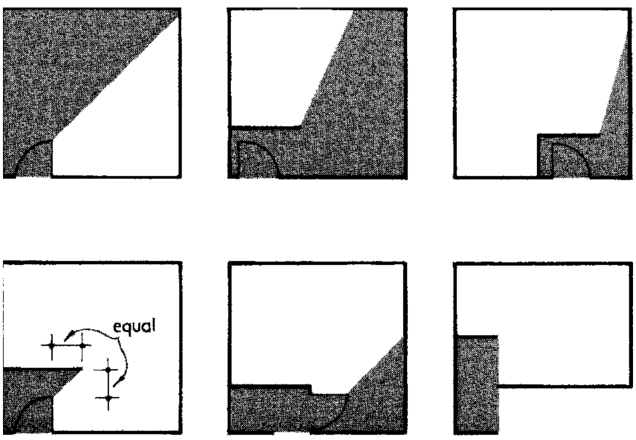
Hotels incorporating other uses such as conference entertainment facilities, bars and restaurants may need additional provision as previous tables.

Table XVIII Comparison of requirements in different building types for 100 people evenly divided between the sexes

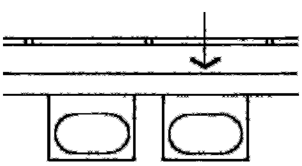
	For men			For women	
	Urinals	WCs	WHBs	WCs	WHBs
Workplaces	2	3	3	3	3
Workplaces where more dirty conditions are met	2	3	5	3	5
Shop customers:					
1000–2000 m^2	1	1	1	2	2
2000–4000 m^2	2	1	2	4	4
Restaurants, etc.	1	1	2	2	2
Pubs, etc.	2	1	2	3	2
Entertainment buildings	2	1	2	3	3
Swimming pools	3	2	3	10	6
Stadia	1	2	2	2	2
Schools:					
Special	3	2	2	5	2
Primary and secondary	1	1	2	2	2
Nursery	10 WCs and 10 WHBs for all				
Boarding	20 WCs and 30 WHBs for all				



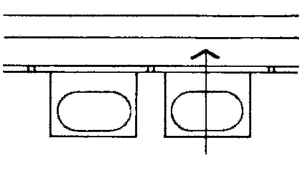
5.17 *Circulation through sanitary installation*



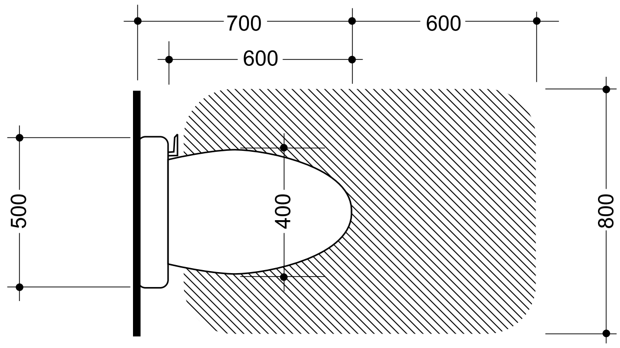
5.18 *Various screening arrangements for small installations, showing the area visible from outside in each case*



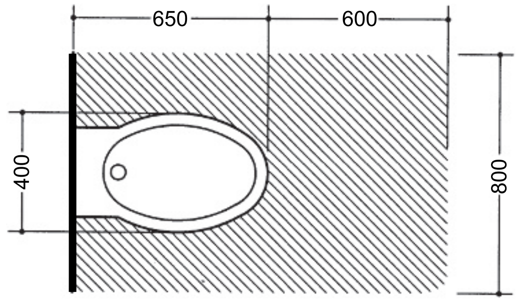
5.19 *Service duct, access from rear*



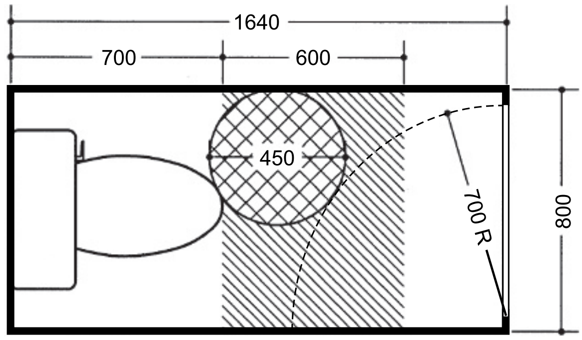
5.20 *Service duct, access from front*



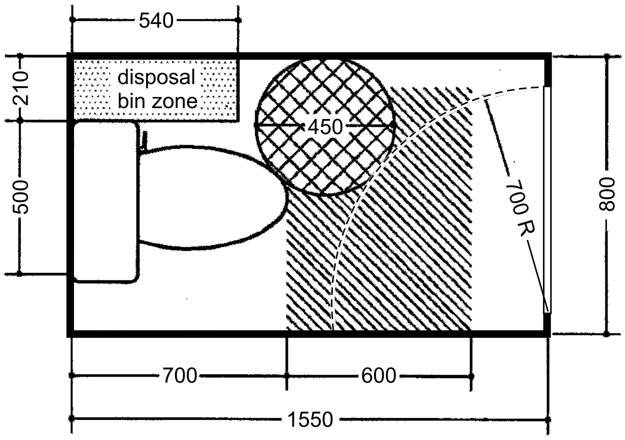
5.21 *WC and activity space. A duct mounted or high-level cistern would allow the WC pan to be placed closer to the wall*



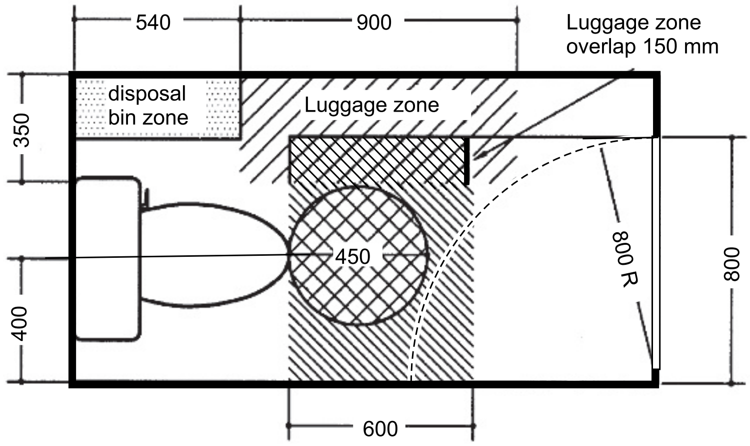
5.22 *Bidet and activity space*



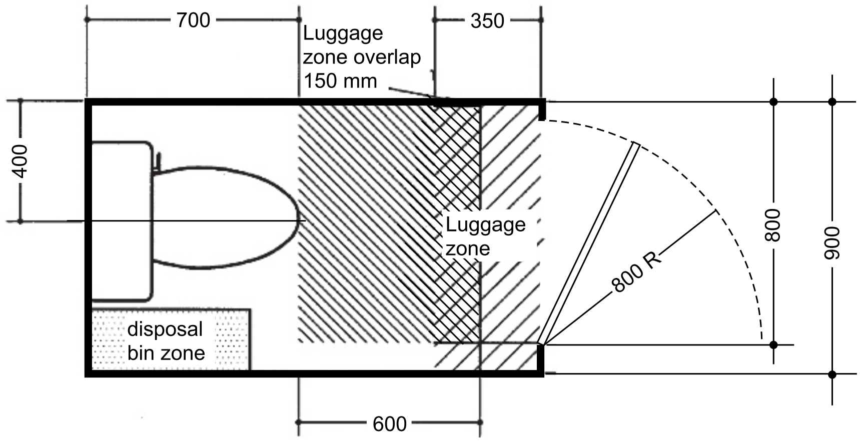
5.23 *WC cubicle, inward-opening door, no sanitary bin zone*



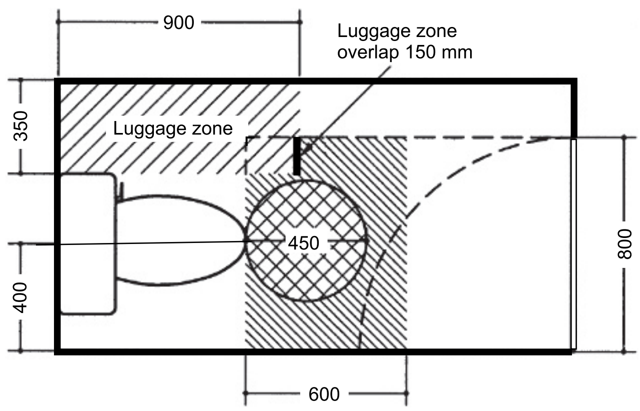
5.24 *WC cubicle, inward-opening door, sanitary bin zone*



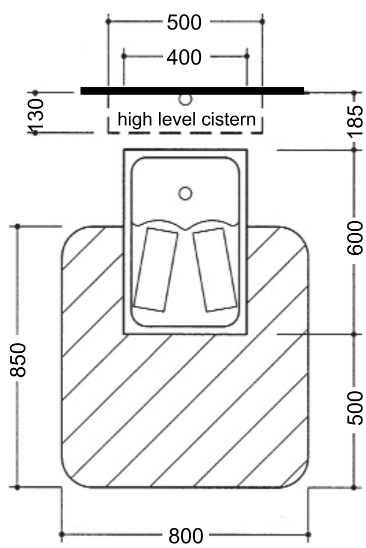
5.25 *Public WC cubicle, inward-opening door*



5.26 *Public WC cubicle, outward-opening door*



5.27 *Alternative public WC cubicle, inward-opening door, no sanitary bin*



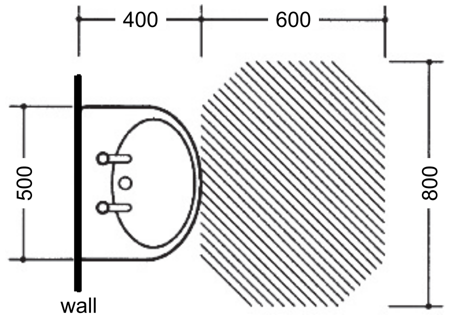
5.28 *Squatting WC and activity space*

WC compartments for disabled people are usually unisex; situated outside male and female multiuser facilities; this has several advantages:

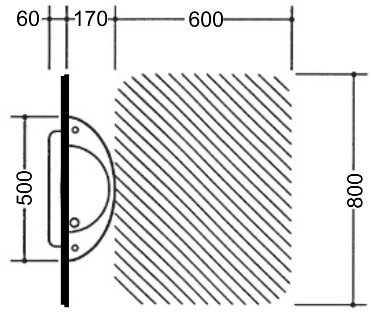
- Husbands and wives can assist each other which is not possible in single-sex compartments
- They avoid the cost of duplicated facilities; one decent unisex facility is more economic than two inadequate single-sex units
- They simplify signposting and access for disabled people.

A WC compartment for general use by disabled people should allow for frontal or lateral transfer from the wheelchair, with space for an attendant to assist. **5.36** shows the various means of transfer that a wheelchair user might have to employ.

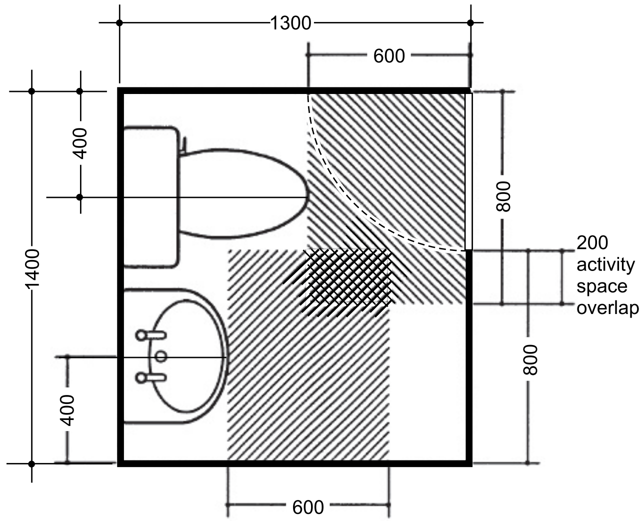
In WCs for wheelchair users, a hand-rinse basin should be installed where it can be conveniently reached by a person seated on the WC. However, it is desirable that the basin is also usable from the wheelchair. These opposing criteria together with the



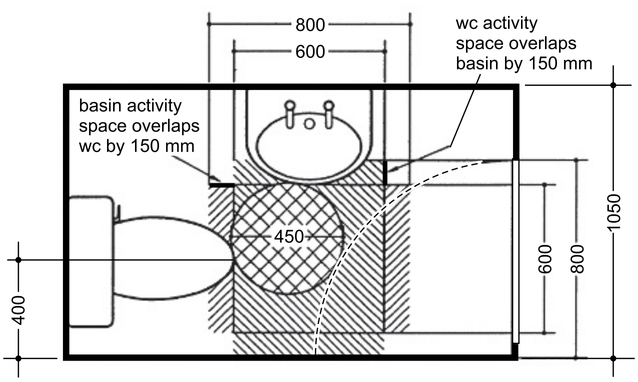
5.29 *Hand-rinse basin and activity space*



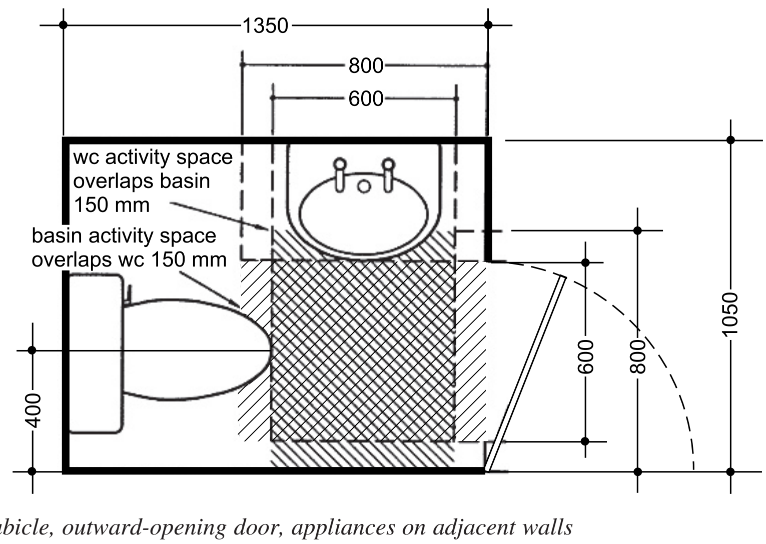
5.30 *Recessed hand-rinse basin and activity space*



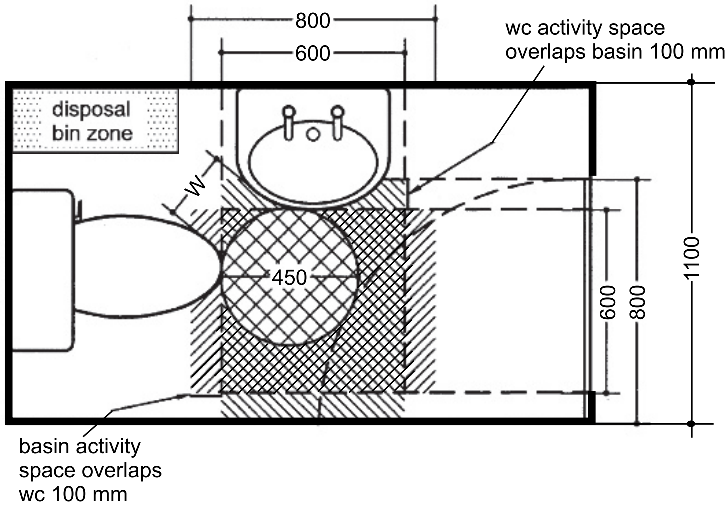
5.31 *WC and washbasin compartment, appliances on same wall*



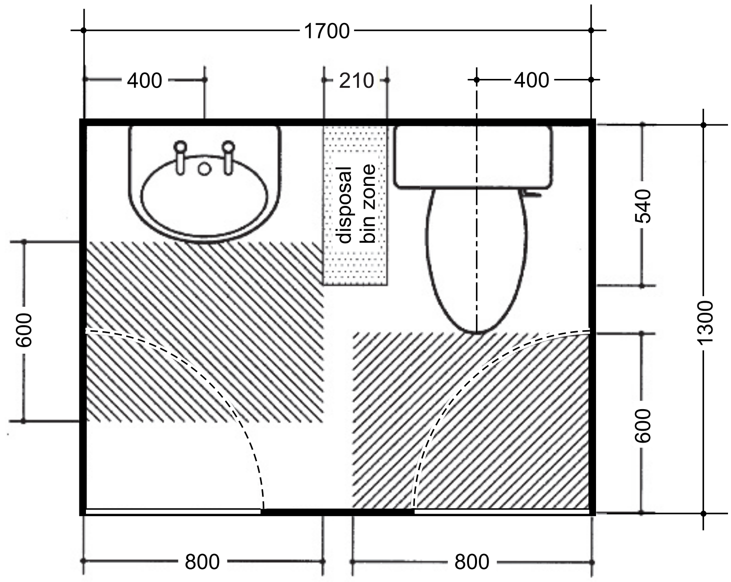
5.32 *WC and washbasin compartment, inward-opening door, appliances on adjacent walls*



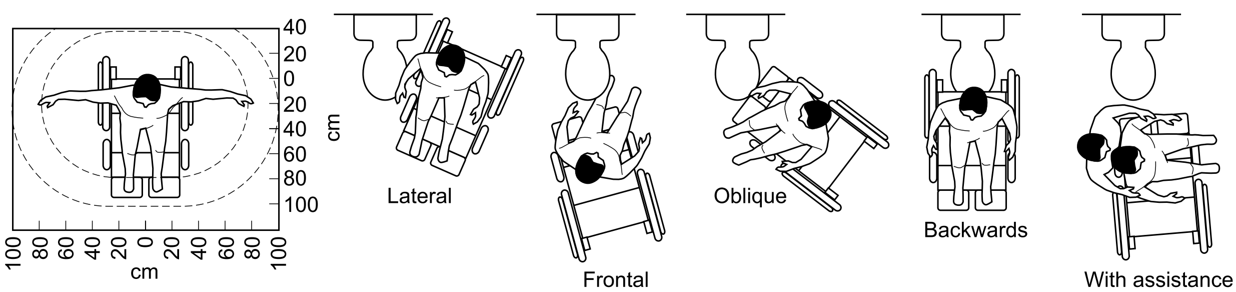
5.33 *WC and washbasin cubicle, outward-opening door, appliances on adjacent walls*



5.34 *WC and washbasin cubicle, sanitary bin zone, appliances on adjacent walls*



5.35 *WC and washbasin cubicle, sanitary bin zone, appliances on same wall*



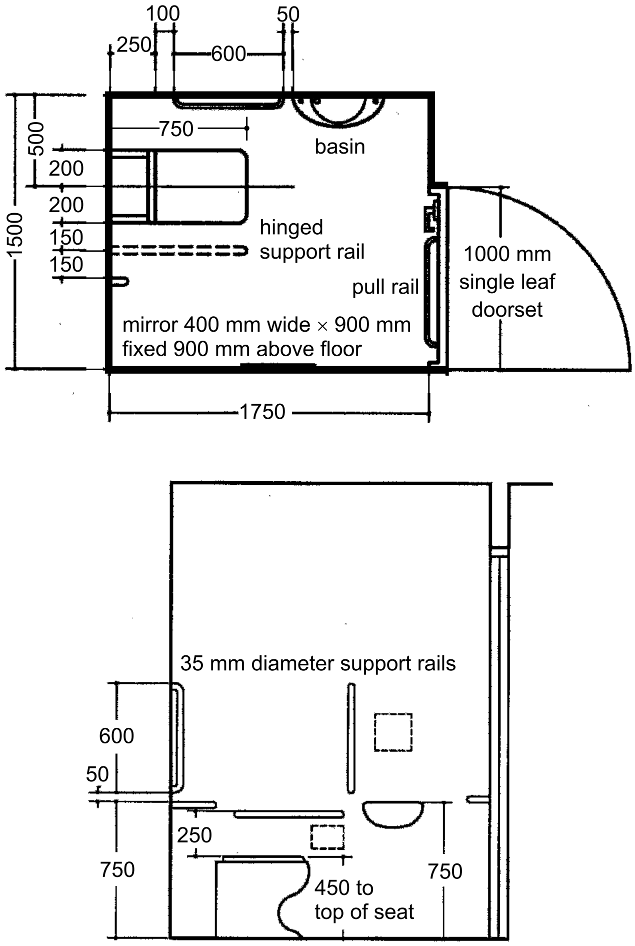
5.36 *A disabled person can transfer from a wheelchair to a sanitary appliance in a variety of ways. Toilets and bathrooms likely to be used by them should allow for a wheelchair turning circle of 1500 mm*

requirements for handrails and supports present a difficult problem often resulting in a poor or even unworkable compromise.

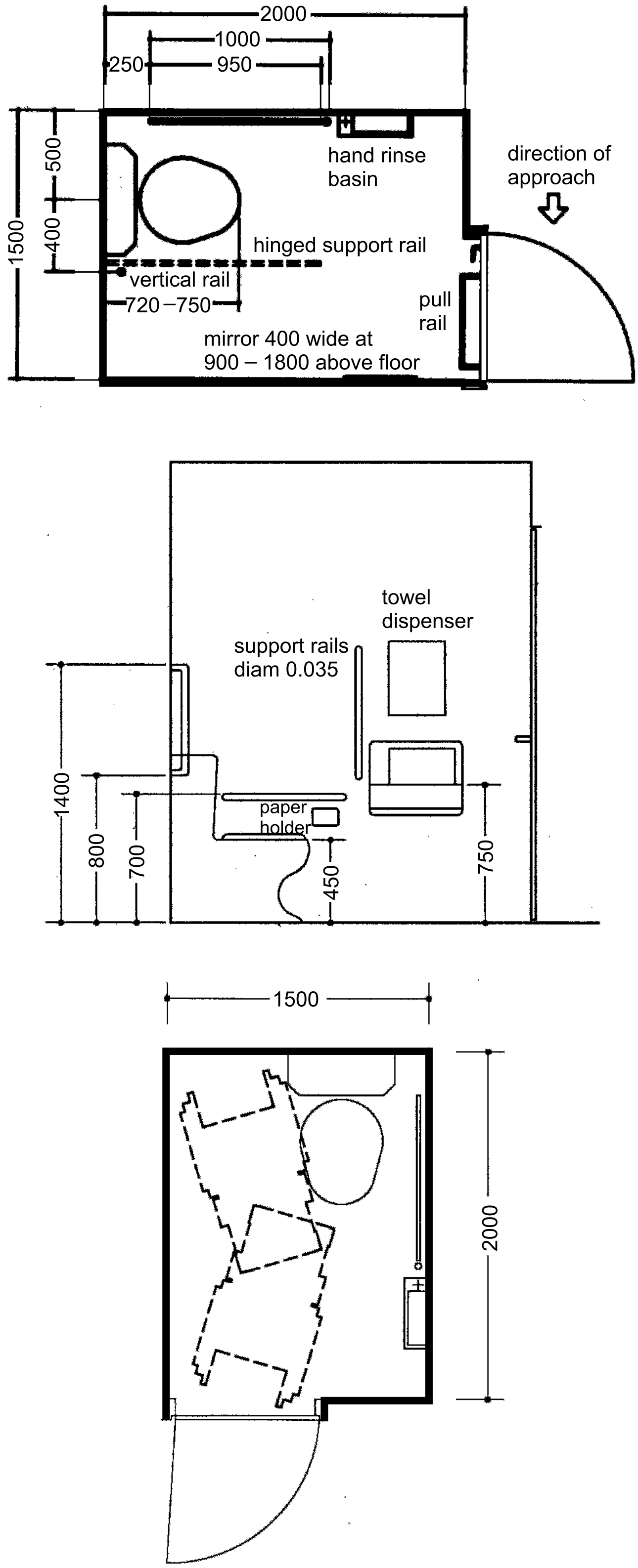
Part M of the Building Regulations gives a standard design of compartment for a wheelchair user, **5.37**. Such standardisation is recommended because of use by visually impaired people. The handed version is permissible.

Selwyn Goldsmith's recommended WC compartment for chair-bound users, **5.38**, may be compared to an alternative plan by Alan Tye Design, **5.39**, embodying the principles of Selwyn Goldsmith's recommendations in a neat and pleasant facility.

There is controversy over the use of wheelchair-accessible WCs by other people such as the ambulant disabled and pregnant women. In some cases, access to the WC is restricted to registered disabled people with a RADAR key. Since many people are temporarily disabled at some time in their lives, and are therefore not eligible for registration, this should only apply where constant abuse makes



5.37 *Wheelchair-accessible WC compartment from Approved Document B*



5.38 *WC cubicles for the wheelchair user (from Designing for the disabled)*

it essential. On the other hand, the combination of wheelchair accessible toilet and baby-changing facility should be deplored.

9.07 WC compartments for ambulant disabled

The standard facility for ambulant disabled people as given in Building Regulation Approved Document M is shown in **5.40**. The difference from a standard facility is principally in the provision of support and grab rails. People with visual impairment appreciate a standardised layout.

The narrow width is desirable as it allows the user to use the support rails on both sides of the compartment to raise themselves. In large public or semi-public conveniences, at least one cubicle should provide for ambulant disabled people.

Alexander Kira points out that grab rails, **5.41**, for able-bodied people, the elderly and children would virtually obviate the need for special provision for the disabled.

9.08 WC provision in domestic property

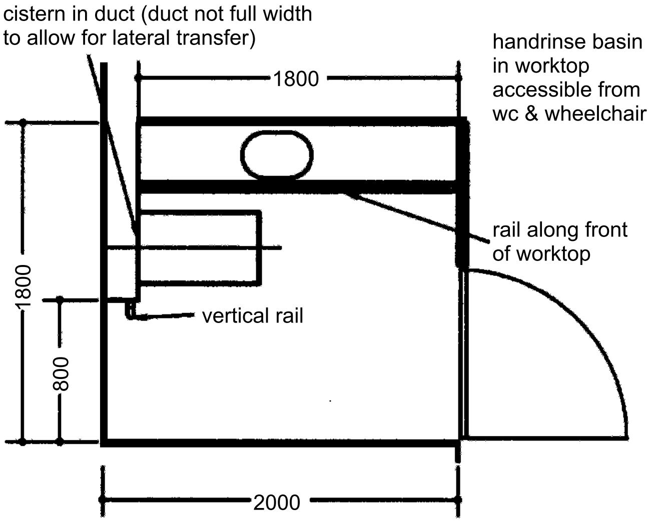
It is becoming clear that many people wish to stay in their own homes as long as possible when increasing disability or age occurs. Also, wheelchair users would like to make visits to their friends. This has led the Access Committee for England to recommend that all new houses and flats should be wheelchair accessible if possible, and that they should have WCs at entrance level which can be used by a wheelchair user, although the chair itself may not be able to be fully accommodated inside the WC compartment with the door shut. **5.42** and **5.43** show three ways of achieving this.

9.09 Urinals

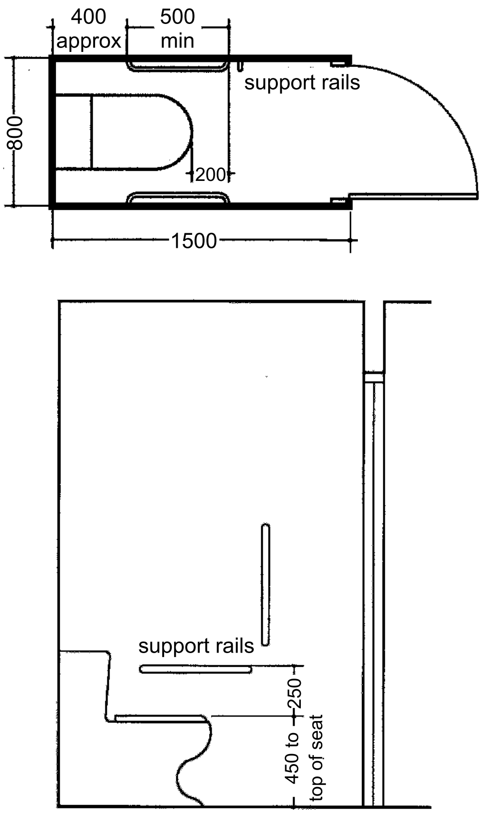
Although a number of female urinal designs have been produced, none have been successful. However, they are ubiquitous in public and semi-public facilities for men, and research shows that there is often over-provision of WCs for men.

Urinals are of two types: slab and bowl. Slabs are rarely used these days because they are more difficult to service and repair than bowls. A bowl and its activity area are shown in **5.44**.

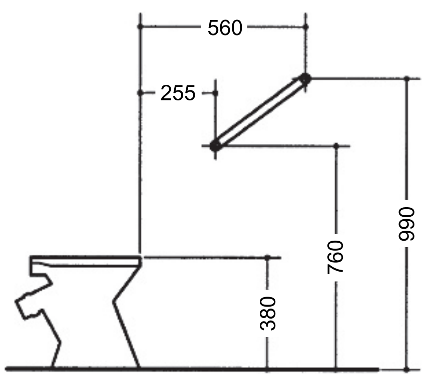
Urinals are usually provided in ranges. In the past, a centre-to-centre dimension of 600 mm was common, but it is now



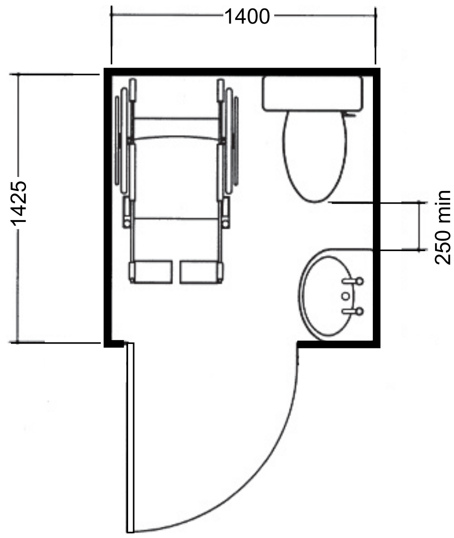
5.39 *An alternative facility (by Alan Tye Design)*



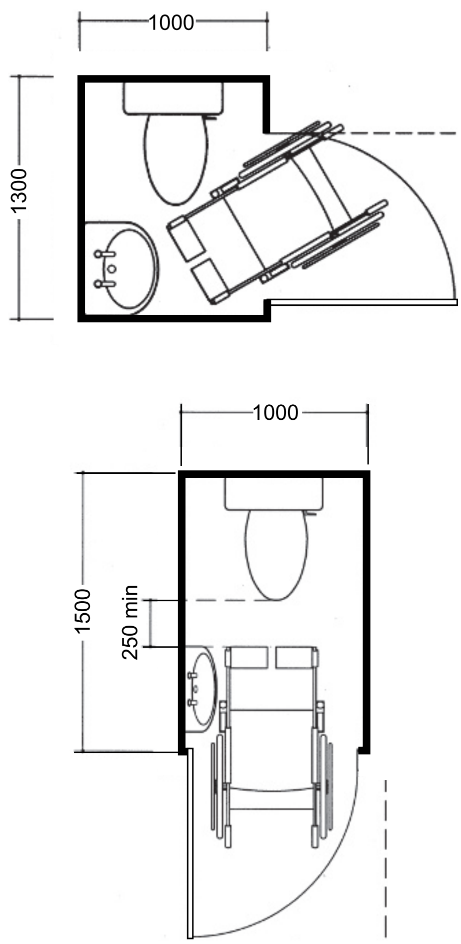
5.40 *WC compartment for ambulant disabled person from Approved Document M. The outward-opening door is preferred for people using crutches, but an inward-opening door can be used if the compartment is at least 200 mm deeper*



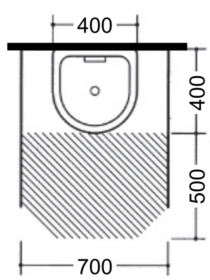
5.41 *Inclined rails mounted on walls of WC*



5.42 *Small wheelchair-accessible WC compartment at entrance level in a family house*

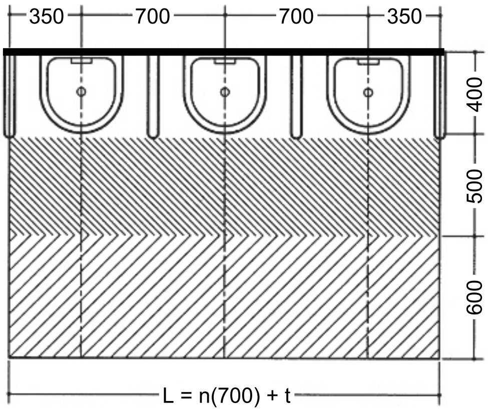


5.43 *Even smaller WCs for entrance level WCs in family houses. In these, transfer cannot be achieved with the door shut*



5.44 *Single urinal and activity space* accepted that this is too close. It is also desirable to have small modesty screens between bowls. **5.45** shows a range of urinals with activity and circulation spaces.

Urinal bowls are usually fixed with their forward rims 610 mm above floor level. One in each range should be lower at 510 mm for use by small boys.



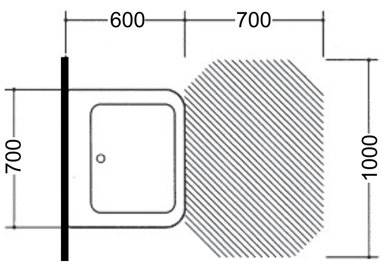
5.45 *Range of urinals, activity and circulation spaces*

9.10 Washbasins

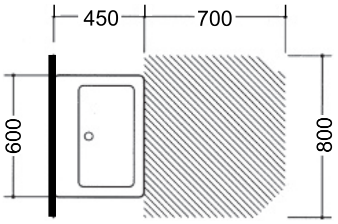
Washbasins come in a variety of sizes. The standard domestic washbasin, **5.46** is for washing the face and the upper part of the body and for wet shaving as well as hand-rinsing. A slightly smaller washbasin, **5.47**, is common in non-domestic situations such as factories, offices and schools where they are often used in ranges **5.48**. Sometimes, washbasins are set into a flat top forming a vanitory unit, and the dimensions of these do not vary significantly from the standard.

Hand-rinse basins have already been mentioned in connection with WC compartments. When they are used in a range the dimensions in **5.49** should be followed.

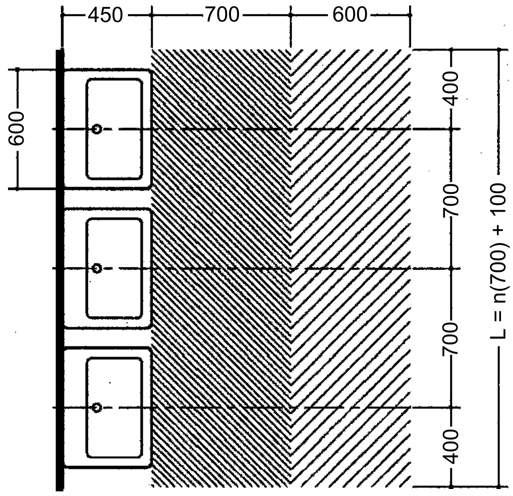
The traditional fixing height of basins is 785 or 800 mm to the rim. For adults, this height requires considerable bending as one is actually washing one's hands below the rim height. Alexander Kira suggests a height of 865–915 mm, but for normal use by a wide range of users 850 mm is preferred. The Department of Health recommends 760 mm in hospitals.



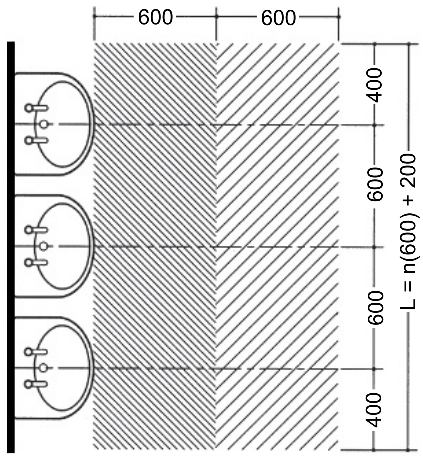
5.46 *Domestic washbasin and activity spaces*



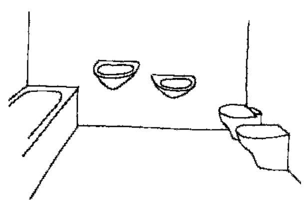
5.47 *Non-domestic washbasin and activity space*



5.48 *Range of non-domestic washbasins, activity and circulation spaces*



5.49 *Range of hand-rinse basins (non-recessed), activity and circulation spaces*



5.50 *Family bathroom incorporating second washbasin for children's use*

In any case, these heights would be unsatisfactory for small children, who need to be encouraged to wash their hands. A washbasin fitted at 700 mm could be provided for them, and **5.50** shows a family bathroom provided with a second basin for the children. A common alternative to provide a small step-up for children to use the standard basin. This would not be appropriate in a public convenience, where a lower washbasin should be provided unless a dedicated children's facility such as described in **9.15** is nearby. Children also deserve and appreciate consideration in the placement of dryers, towels, coat hooks and mirrors, etc.

As already shown, basins specifically for wheelchair users have rims 750 mm high. Plumbing, etc. underneath such basins should be arranged not to obstruct the knees of the user in the chair.

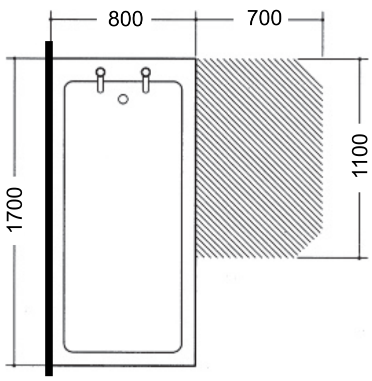
9.11 Baths and bathrooms

Baths are also available in many sizes, shapes and types; but the standard one and its activity area are shown in **5.51**. Baths are now rarely found outside bathrooms; and bathrooms normally also include at least a washbasin. The minimum width of a domestic bathroom is illustrated in **5.52**. All bathrooms should ideally be large enough for undressing and dressing, and for someone to lend a hand. Three domestic bathroom arrangements are shown in **5.53–5.55** and variations on these are also appropriate in nondomestic situations such as hotels, schools, etc. A matrix of virtually all possible arrangements will be found in BS 6465: Part 2.

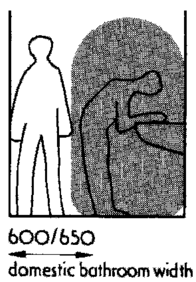
Baths can be provided for disabled people which have rims at 380 mm above the floor instead of the normal 500 mm. Alternatively, the bath may be set with the trap below floor level. It should have as flat a bottom as possible and should not be longer than 1.5 m; lying down is not encouraged.

Other special baths tip up or have openable sides. However, a standard bath with a mobility aid is usually more practical, particularly in the home. Lifting and lowering devices are available that can be fixed to a floor, wall or ceiling – or can even be simply sat on the floor. As suggested above, all bathrooms should ideally provide for handrails; a pole is invaluable for anyone less than fully agile, **5.56**. Adaptation of the standard bathrim to make it easier to grasp is shown in **5.57**. A seat at rim height is useful for sitting on to wash legs and feet.

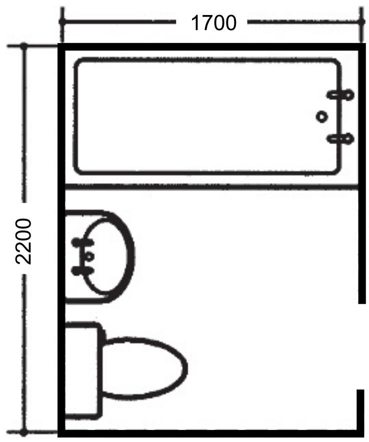
Bathroom and lavatory doors should preferably open out, with locks operable from the outside in emergencies.



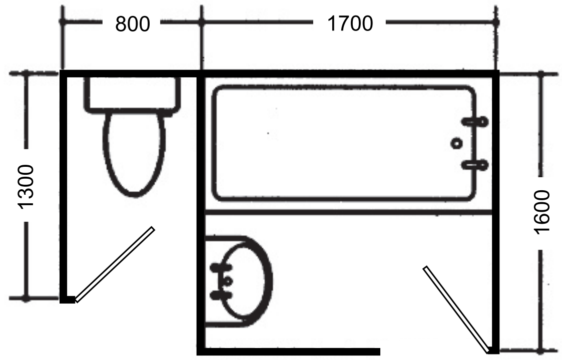
5.51 *Bathtub and activity space*



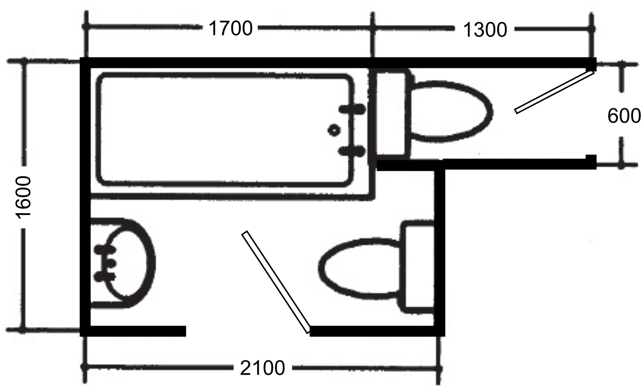
5.52 *Minimum width in domestic bathroom*



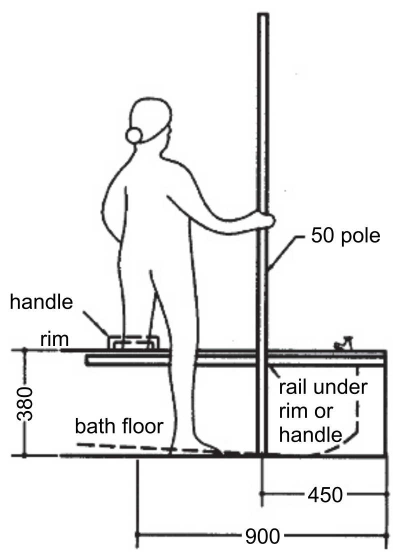
5.53 *Minimum bathroom including WC*



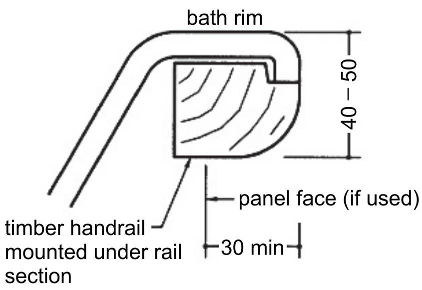
5.54 *WC in separate compartment adjacent to bathroom*



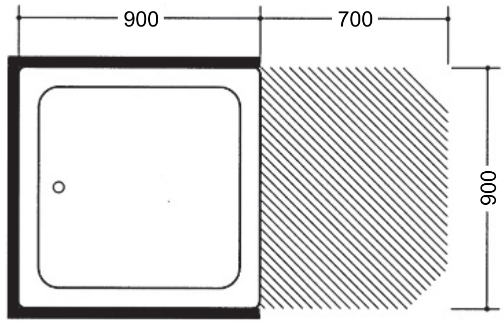
5.55 *WC in separate compartment adjacent to bathroom also containing WC*



5.56 *Aids for getting in and out of the bath: pole, handle and rim. Maximum height of rim from floor 380 mm*



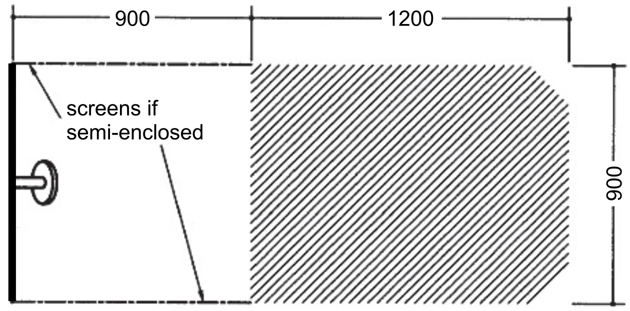
5.57 *Bath rim adapted for easy gripping*



5.59 *Enclosed shower with tray, and activity space adequate for drying. A nearby dressing space is presumed*

9.12 Taps

Choose taps that can be manipulated by small and arthritic fingers. Surgeons' taps are not recommended, however, as in extreme cases ordinary taps can be modified to provide similar facility. Under a European standard, it is now obligatory in new installations for the cold tap to be on the right and the hot on the left, unless there are compelling reasons otherwise: this is in order to assist visually impaired people. Tops should be boldly colour-coded.



5.60 *Unenclosed shower without tray, and activity space for drying and dressing*

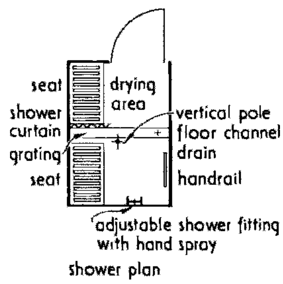
9.13 Showers

It is becoming common to install showers which are more economical in water and energy use than bathtubs. Disabled people in particular often find it easier to shower than to get in and out of a tub.

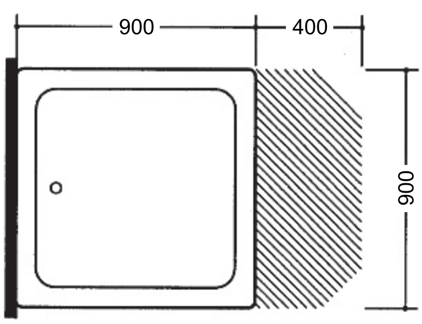
Showers come with and without trays and enclosures, **5.58–5.60**. Trays are not altogether suitable for disabled people unless they can be installed with the rim level with the floor and provided with a duckboard. Continental practice of an impervious non-slip bathroom floor laid to fall to a gulley has not been traditionally followed in the UK, although this can be ideal for a wheelchair user. A shower installation specifically designed for an elderly or disabled person is shown in **5.61**. The compartment should be well heated, with a fold-away seat and with pegs for clothes on the dry side, divided from the wet with a shower curtain. The water supply should be automatically controlled to supply only between 35 and 49°C. The shower head should be on the end of a flexible hose, with a variety of positions available for clipping it on.

In sports centres and swimming pools, showers are provided in ranges as **5.62** or **5.63**.

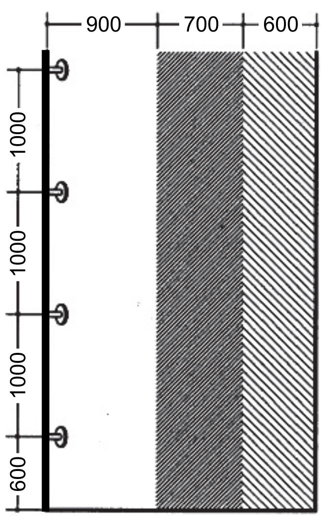
BS 6465: Part 2 recommends 900 mm^2 as the minimum size for a shower enclosure, but most of the shower trays and enclosures manufactured are between 700 and 800 mm^2.



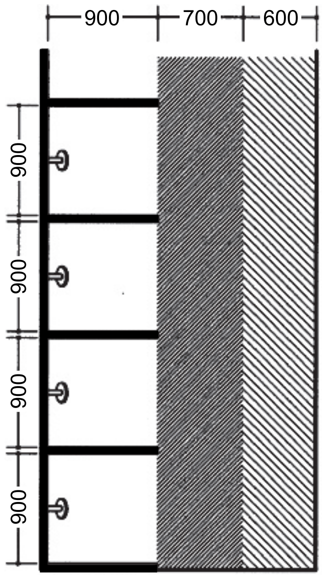
5.61 *Plan of shower room for elderly or disabled person, showing seats and aids*



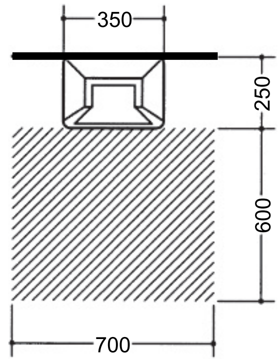
5.58 *Unenclosed shower with tray, and activity space. This is for access from one side of the tray, and to facilitate initial drying within the shower. A nearby area of 1100×900 will be needed for final drying and dressing*



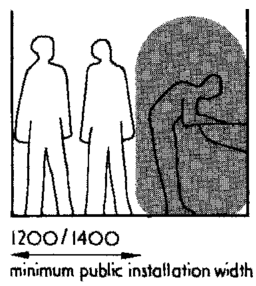
5.62 *Range of unenclosed showers, activity and circulation spaces*



5.63 *Range of semi-enclosed showers, activity and circulation spaces*



5.65 *Sanitary towel or continence aid disposal appliance not in a cubicle and activity space*



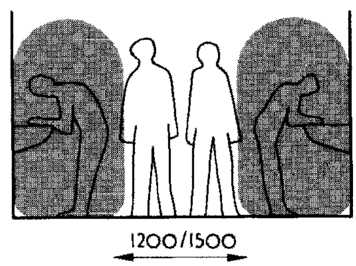
5.66 *Minimum width in a public installation with appliances on one side*

9.14 Public conveniences

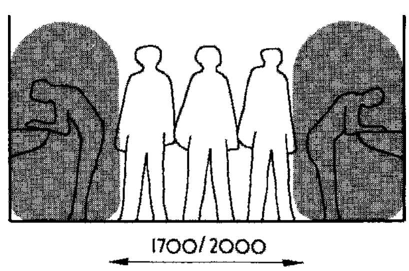
In addition to the appliances covered above, public installations also include drying facilities, **5.64**, which could be electric hand dryers or roller towels. Occasionally, disposal for sanitary towels and continence aids is provided outside cubicles, **5.65**, although this is not recommended practice.

The factors affecting the widths of public conveniences are covered in **5.66–5.68**. Appliances should be arranged so that the space is concentrated into larger areas, as it is psychologically and practically preferable to be able to see the whole of the room on entering. Narrow dead ends and corridors should be avoided and the circulation pattern planned to ensure that washing facilities are provided between WC/urinals and the exit to encourage hand washing.

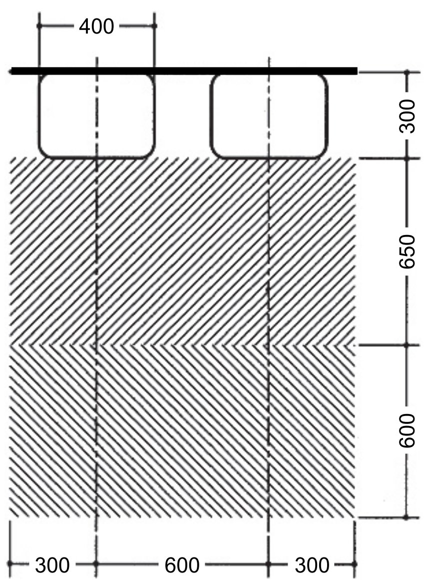
Circulation areas must be considered as being around both appliance and activity spaces rather than merely around appliances, although some encroachment of the circulation area into the appliance/activity space will normally be acceptable depending on the likelihood of full use of appliances.



5.67 *Minimum width in a public installation with appliances on both sides*



5.68 *Width of a larger public installation*



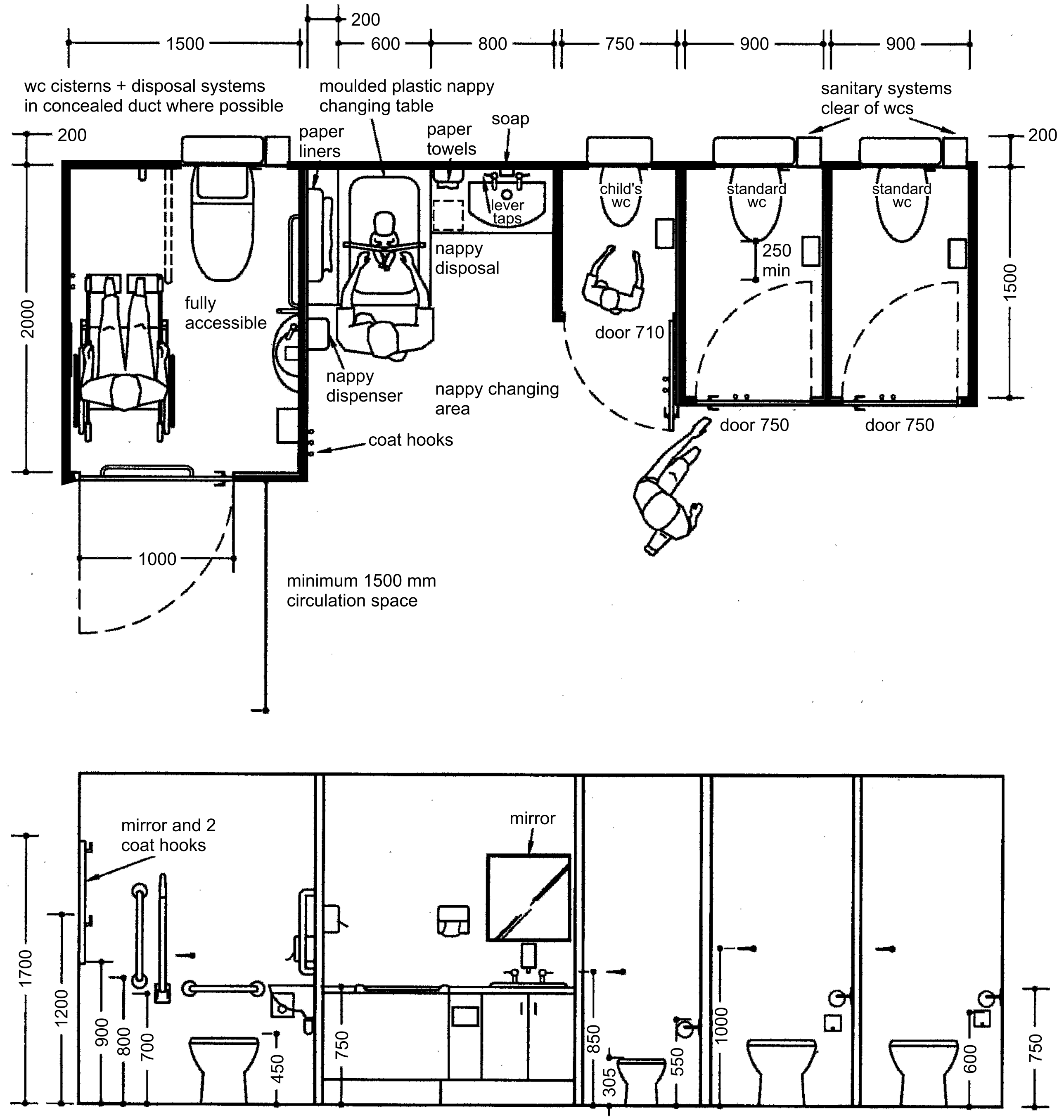
5.64 *Range of hand dryers, activity and circulation spaces*

9.15 Baby changing

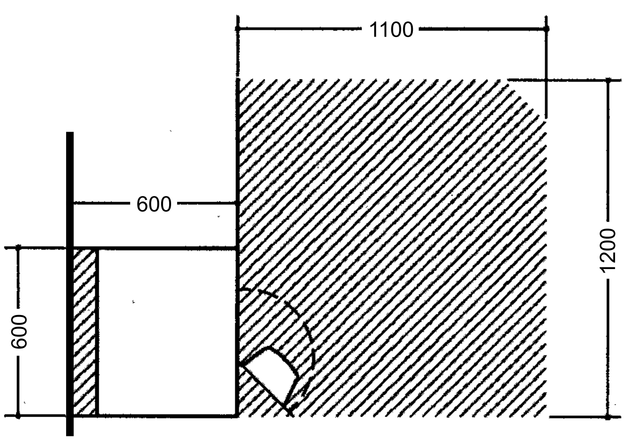
A full public installation should include a baby-changing facility and a child's WC. An arrangement recommended by The Continence Foundation and All Mod Cons, and designed by the Women's Design Service is shown in **5.69**.

9.16 Miscellaneous sanitary appliances

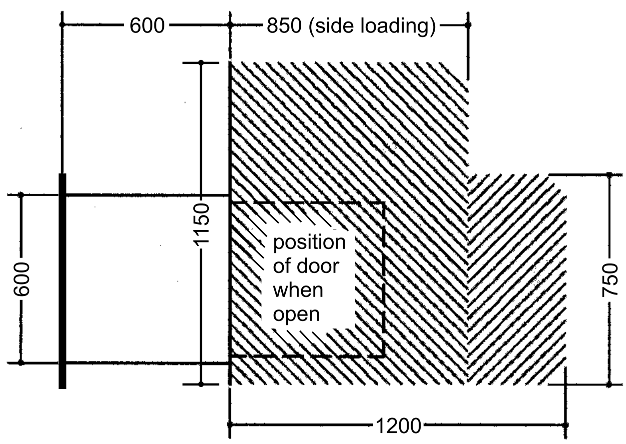
Some other water-using appliances and their activity spaces are shown in **5.70–5.73**.



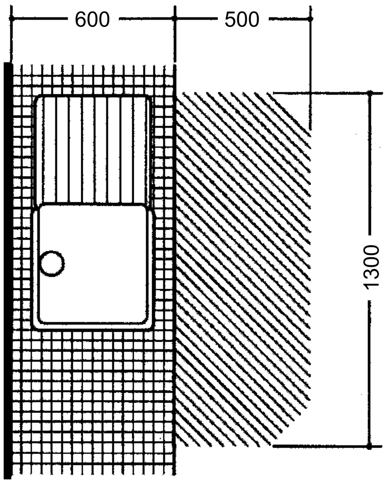
5.69 *Layout for a public convenience including wheelchair access compartment, child's WC and nappy-changing facility. This design is suitable for a ladies' facility, although nappy changing, child's WC and wheelchair access should be unisex*



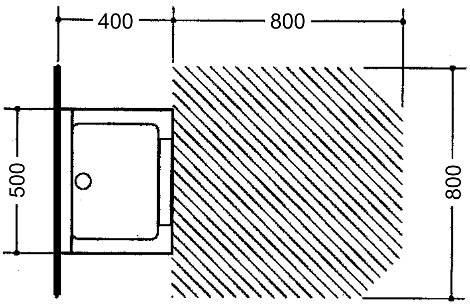
5.70 *Clothes washing machine and activity space*



5.71 *Dishwasher and activity space*



5.72 *Kitchen sink and activity space*



5.73 *Bucket/cleaners sink and activity space*

9.17 Cleaning manual/mechanical

Cleanliness can either be visual or bacteriologically sterile or both. Most people are happy with visual cleanliness and would be unhappy with a dirty-looking though sterile installation. Good design and detailing therefore plays a vital part in sanitary accommodation cleanliness.

Cleaning is rarely considered very seriously in sanitary areas, for most proprietary appliances are badly designed and uncleanable, producing dark shadows around down-to-floor appliances, cubicle feet, etc. and too often one sees pipes and cistern exposed.

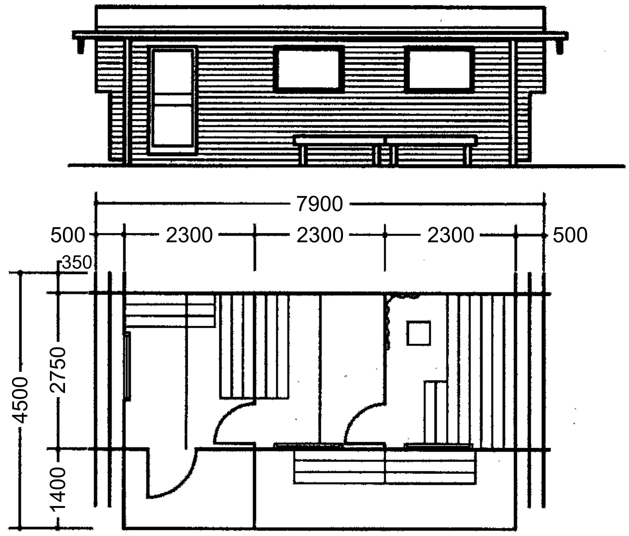
Consider carefully the cleaning method to be employed, and be critical of what manufacturers supply; for besides hygienic and aesthetic factors, dirty installations encourage sloppy use and vandalism. One should ensure that all surfaces are capable of thorough cleansing; floor details should be coved wherever possible and all possible interruptions of the floor, such as legs, pedestals and pipes, avoided.

Wall-mounted appliances are preferred, although many wall-mounted WCs leave so little floor clearance as actually to aggravate the cleaning problem. Appliances designed to eliminate uncleanable areas should be chosen; they should be cleanable not only in the appliance itself but also at its junction with the structural surfaces. Generally, the appliance is cleaned but the wall is not, so all appliances need upstands. Appliances should not be placed so close together that cleaning between them is hampered. Wall-mounted valves over washbasins promote better cleaning than deck-mounted ones.

10 SAUNAS

10.01 Origin of the sauna

The sauna, **5.74**, is essentially Finnish and in its original form is a one-room hut built of logs, with a rudimentary furnace or stove, over which rocks are piled, in one corner. Steps lead up to a slatted wooden platform along one side of the room where naked bathers sit or lie in the hot air under the roof. The stove heats the room by convection and the rocks reach a high temperature. After sitting in the dry heat for some minutes, the bather produces steam from time to time by throwing small quantities of water onto the hot rocks.



5.74 *Outdoor sauna with verandah, changing room, washing room and sauna room*

The temperature varies from 88 to 110°C and, provided that the moisture is properly absorbed by the wooden walls of the room, the air will not become saturated. Because the human body can stand a higher degree of dry heat than wet heat, the temperature is higher in a sauna than in a Turkish bath. After perspiration, bathers beat themselves with leafy birch twigs, wash and plunge into a nearby lake or take a cold shower. The cycle is repeated a few times until finally there is a period of rest while the body cools down completely. The time taken for the complete operation varies from 90 to 120 min.

10.02 Dimensions

The sauna room should be between 2.3 and 2.6 m high and have a minimum floor area of 1.8×2.1 m. Benches should be 600–760 mm wide and the platform at least 460 mm wide. The stove will take up 0.560–0.650 m^2 of floor area and will stand about 1.070 m high. Outside the sauna room, showers are required and if possible a cold 4–10°C plunge bath. Space for dressing and resting should be provided. Cubicles will strictly limit the maximum number of bathers, and an open layout is more flexible. Provision should be made for clothes lockers and a few dressing cubicles, and the rest of the area is occupied by resting couches/chairs and small tables.

Of the total number of bathers in an establishment at any time, 20–25% are likely to be in the sauna room, an equal number in the shower/washing room and the remainder in the dressing/resting areas.

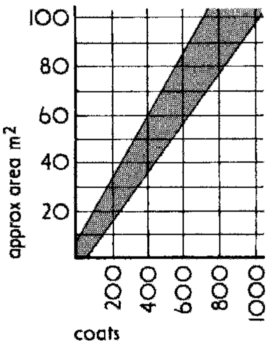
11 HYDRO-THERAPY SPA BATHS

This new development in bathroom equipment is an alternative to the sauna. Spa baths or ‘hot-tubs’ are small hydro-therapy pools that provide turbulent hot water as massage for the relief of aches, tensions and fatigue or simply for pleasure. These pools are usually of one-piece glass-fibre construction, available in a variety of sizes and shapes which are relatively easy and low-cost to install and are used indoors or out.

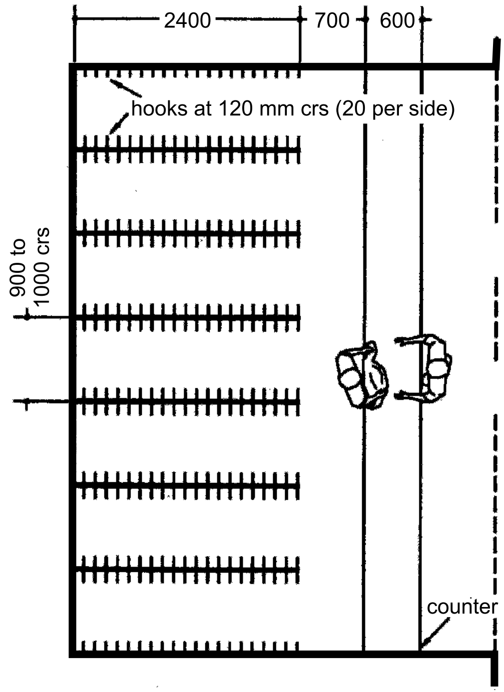
12 PUBLIC CLOAKROOMS

12.01 Calculating cloakroom areas

In the early planning stages, if you merely wish to establish an overall cloakroom area, you can obtain the size of a cloakroom to suit any number of coats from the graph, **5.75** (courtesy of G. & S. Allgood Ltd).



5.75 *Approximate guide to areas of cloakroom accommodation for use in early planning stage*



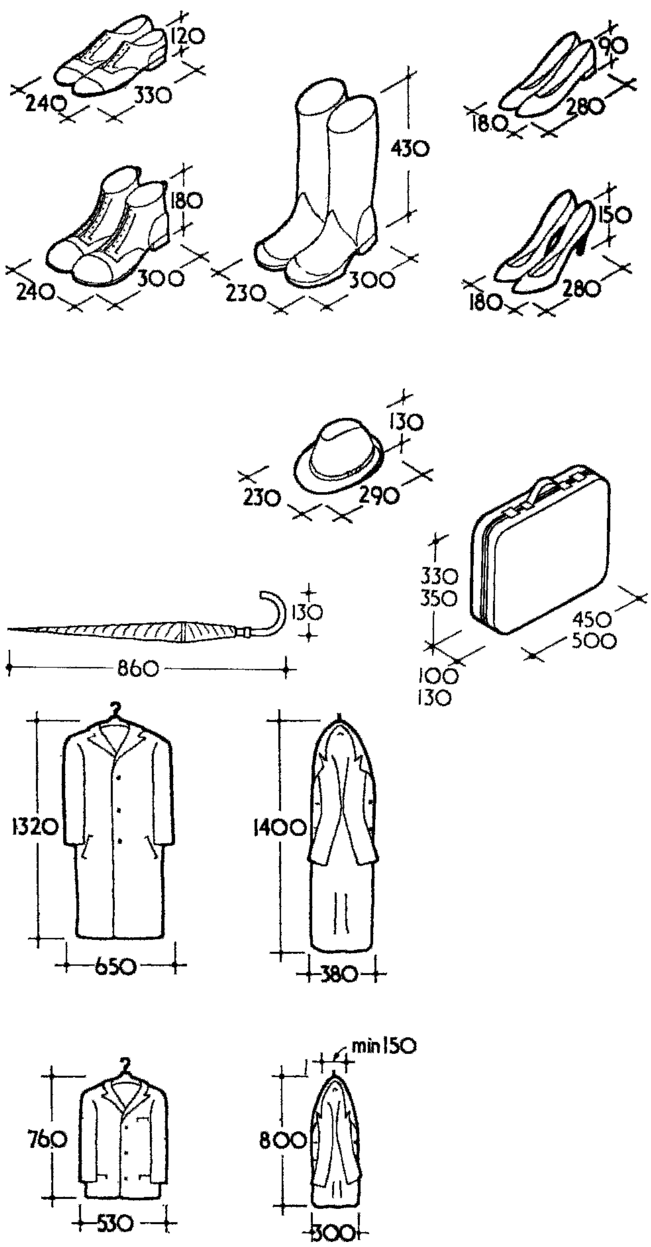
5.77 *Fixed rows of hooks. 0.08 m² per user including counter, 0.1 m² including 1200 mm on public side*

12.02 Items commonly stored

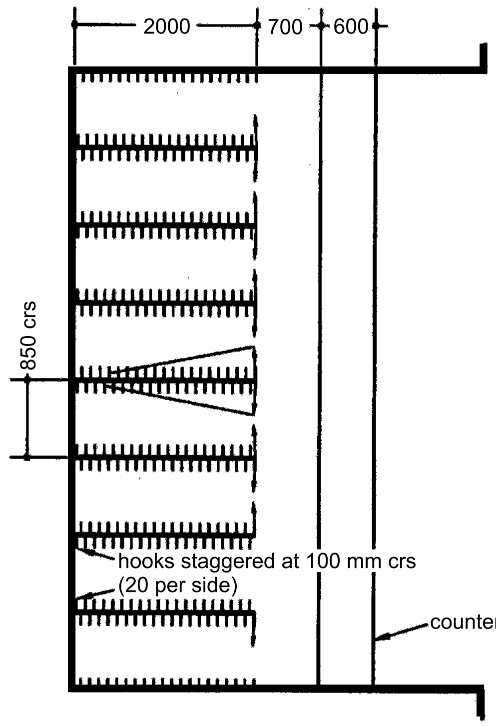
Typical sizes of items stored are given in **5.76**.

12.03 Attended storage

Typical arrangements and space requirements per user are shown in **5.77** and **5.78**.



5.76 *Sizes of items commonly stored in cloakrooms*



5.78 *Hinged rows of hooks, 0.007 m² per user incuding counter, 0.09 m² including 1200 mm on public side*

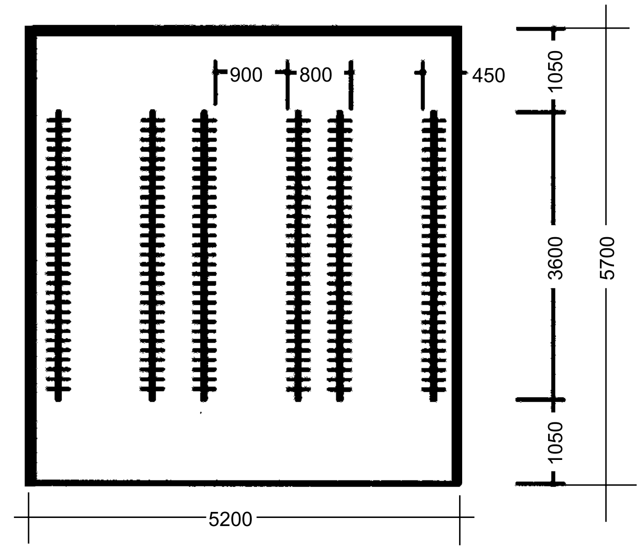
12.04 Unattended storage

The space allowances per user in **5.79–5.83** are based upon hangers or hooks at 150 mm in rows 3600 mm long with 1050 mm clear circulation space at ends of rows.

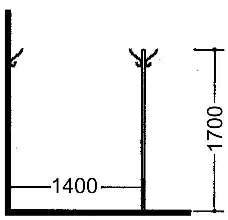
The proprietary system given in **5.84** provides unattended locked storage for coats and umbrellas.

12.05 Mobile storage

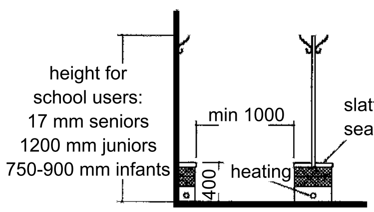
These are proprietary units and the measurements shown in **5.85** are approximate.



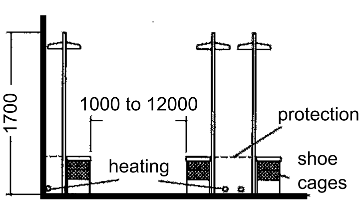
5.79 *Method of calculating space required by each user: six rows each 3600 mm long of double tier hangers at 150 mm centres = 300 hangers area of room = 5.7×5.2 = 29.6 m^2. Hence space allowance 0.098 m^2 per user*



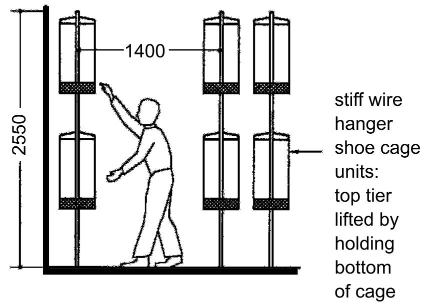
5.80 *Hooks in line: 0.16 m^2 per user including circulation*



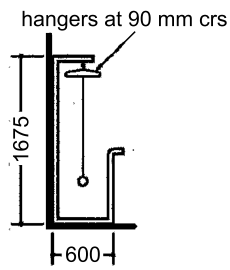
5.81 *Hooks with seating: 0.02 m^2 per user including circulation*



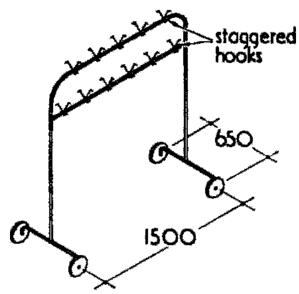
5.82 *Hooks with seating: 0.26 m^2 per user including circulation*



5.83 *Double tier hangers: 0.13 m^2 per user including circulation*



5.84 *Proprietry system affording security: 0.16 m^2 per user including circulation*



5.85 *Mobile coat rack*

12.06 Lockers

Lockers may be full height with a hat shelf and space to hang a coat and store shoes or parcels; or half height to take a jacket; or quarter height to take either parcels or folded clothes, **5.86** and **5.87**. Combination units such as **5.88** are also available.

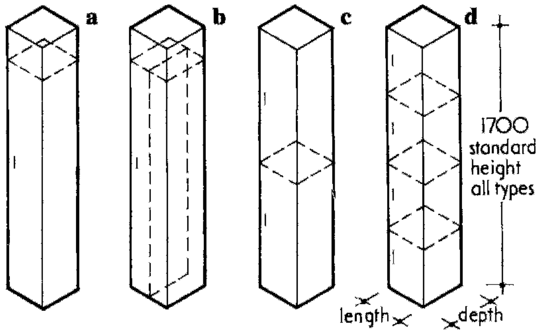
Note: Many of the units shown in this chapter are proprietary systems and metric measurements are only approximate. Manufacturers should be consulted after preliminary planning stages.

13 DOMESTIC ACTIVITIES

5.89–5.101 illustrate the space requirements of a number of domestic activities; these are derived from data in *Activities and spaces* by John Noble.

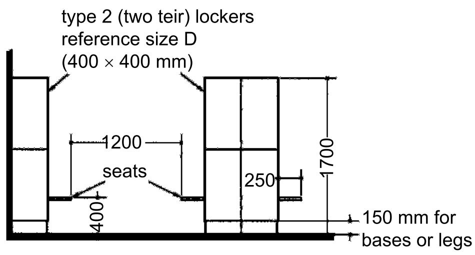
14 DOMESTIC FURNITURE

The sizes of a number of common items of living room furniture are given in **5.102**. A number of different dining room arrangements are shown in **5.103**. Items of bedroom and kitchen furniture are covered in **5.104** and **5.105**, respectively.

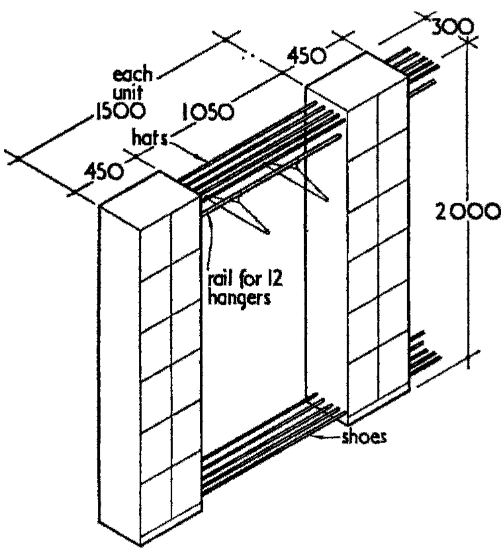


	reference size (mm)					
	A	B	C	D	E	F
length	300	300	300	400	400	500
depth	300	400	500	400	500	500

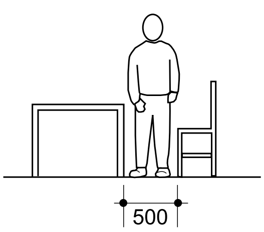
5.86 *Lockers:* **a** *type 1a with hat shelf;* **b** *type 1b with hat shelf and vertical divider. Not available in A, B or C;* **c** *type 2, two tier;* **d** *type 3, three, four, five or six tier*



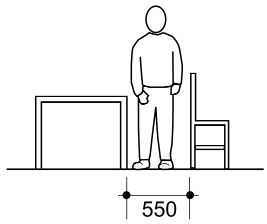
5.87 *Cross-section of lockers with seats*



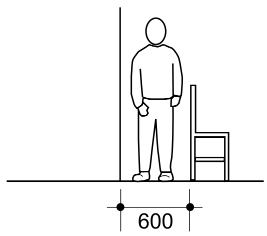
5.88 *Lockers with coat rail, hat and shoe racks*



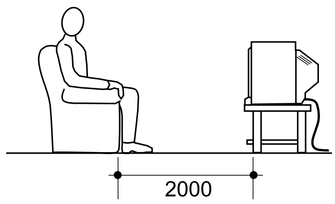
5.89 *Passing items of furniture, each table height or lower*



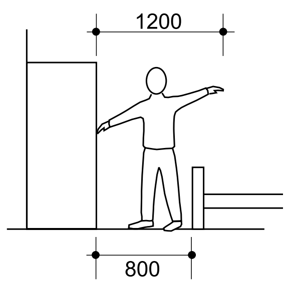
5.90 *Passing between two items of furniture, one table height or lower, the other higher on the wall*



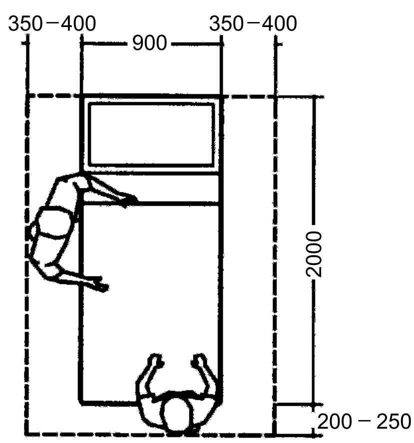
5.91 *Passing between the wall and tall furniture*



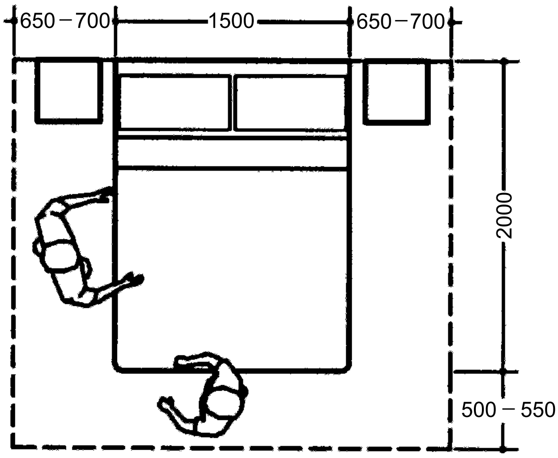
5.92 *Watching television. Most people prefer to sit a distance of more than eight times the height of the picture*



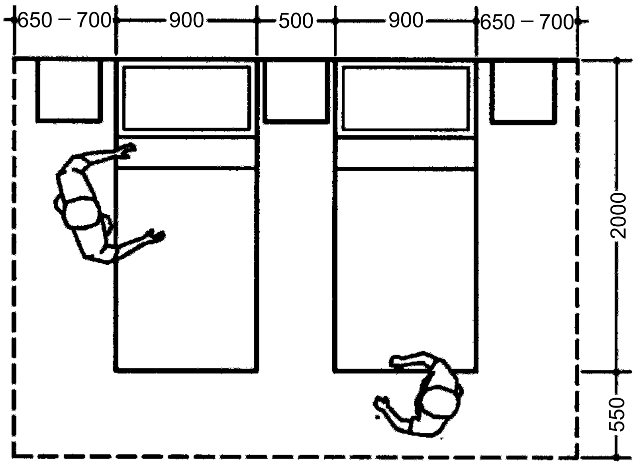
5.93 *Dressing in front of wardrobe*



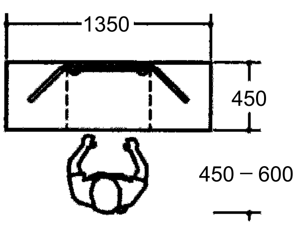
5.94 *Making single bed*



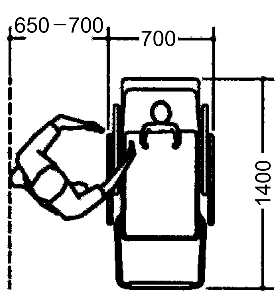
5.95 *Making double bed*



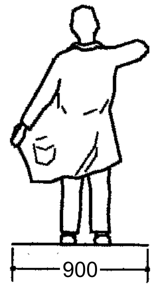
5.96 *Circulation around twin beds*



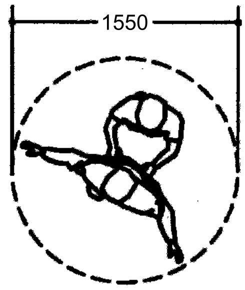
5.97 *Sitting at a dressing table*



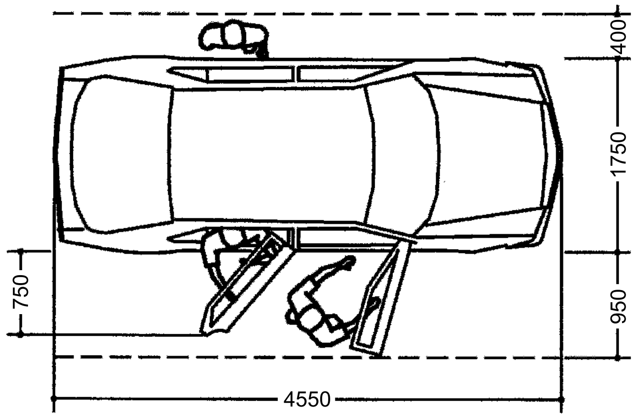
5.98 *Getting a pram ready*



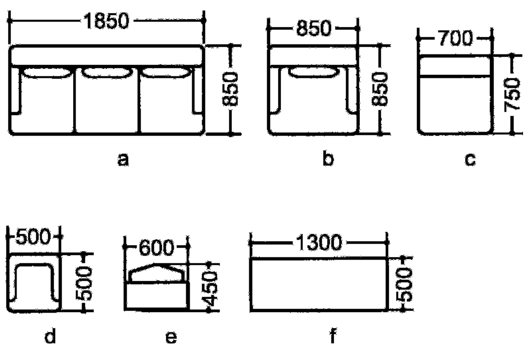
5.99 *Putting on coat*



5.100 *Helping on with coat*



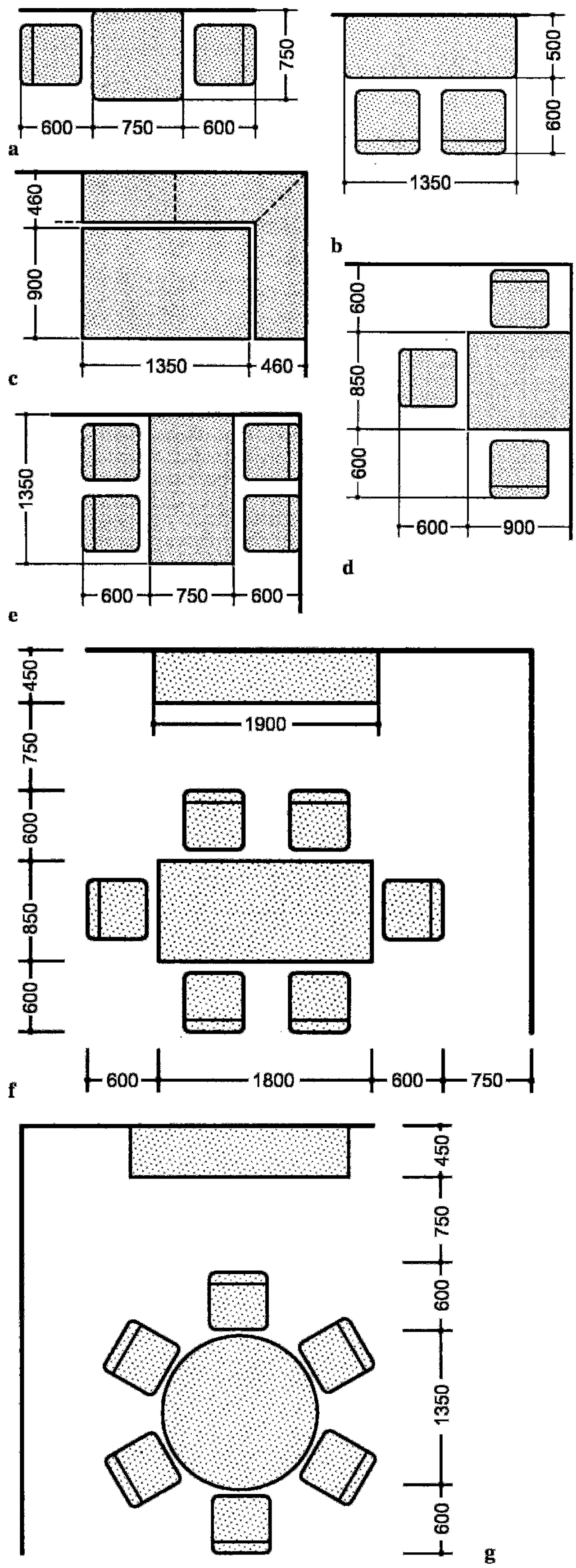
5.101 *Getting in and out of cars*

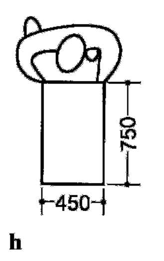


5.102 *Living space:* **a** *three-seater sofa,* **b** *easy chair with arms,* **c** *easy chair without arms,* **d** *occasional chair,* **e** *television set,* **f** *coffee table*

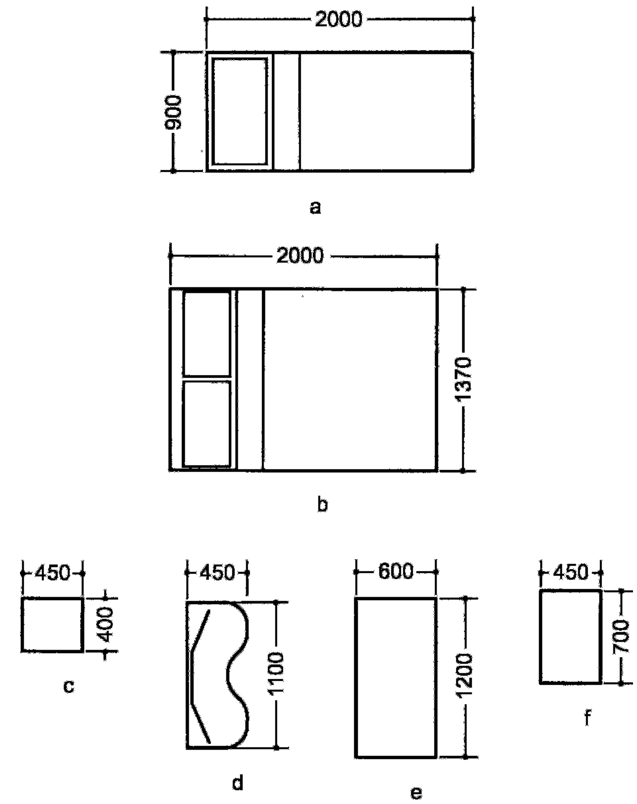
15 STORAGE

The spaces required to store domestic items and materials are shown in **5.106–5.118**. Various fuel storage facilities are covered in **5.119–5.121**, and refuse containers are shown in **5.122**.

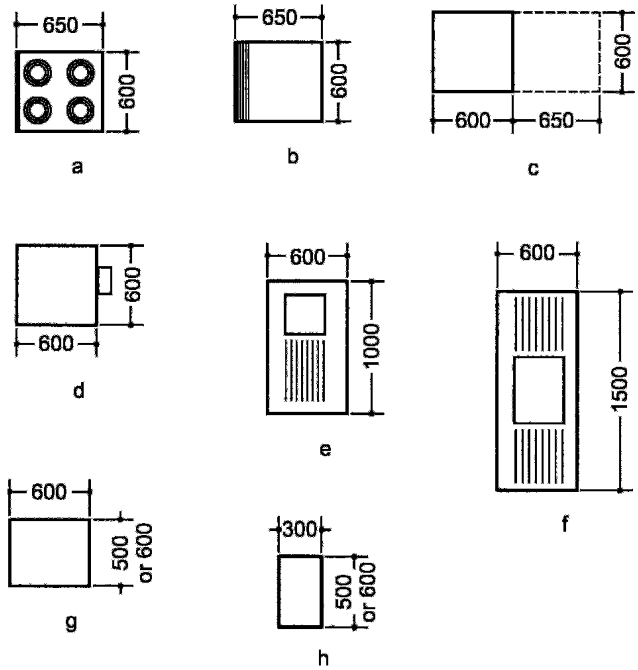




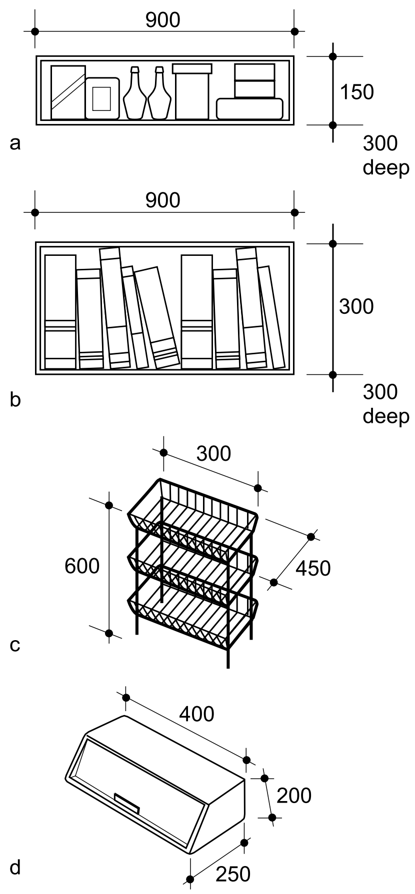
5.103 *Dining spaces:* **a** *two people facing,* **b** *two people side by side,* **c** *three people on banquettes,* **d** *three people on chairs,* **e** *four people,* **f** *six people and sideboard,* **g** *six people and round table,* **h** *serving trolley*



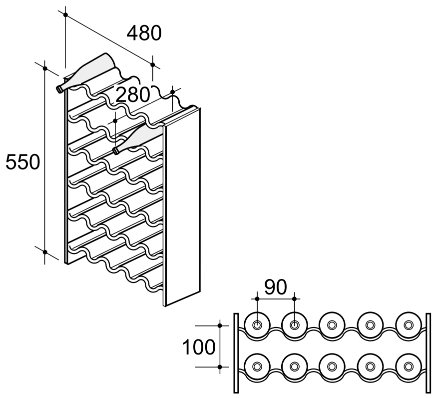
5.104 *Bedroom furniture:* **a** *single bed,* **b** *double bed,* **c** *bedside table,* **d** *dressing table,* **e** *wardrobe,* **f** *chest of drawers*



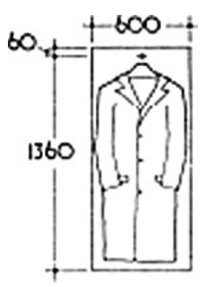
5.105 *Kitchen:* **a** *cooker,* **b** *fridge-freezer,* **c** *dishwasher,* **d** *washing machine,* **e** *sink with single drainer,* **f** *sink with double drainer,* **g** *large storage cupboard,* **h** *wall-hung storage cupboard*



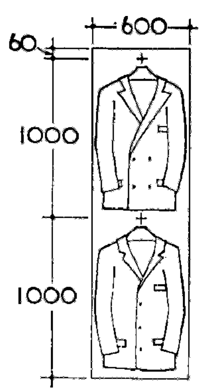
5.106 *Food storage:* **a** *tins and jars,* **b** *packets,* **c** *vegetable rack,* **d** *bread bin*



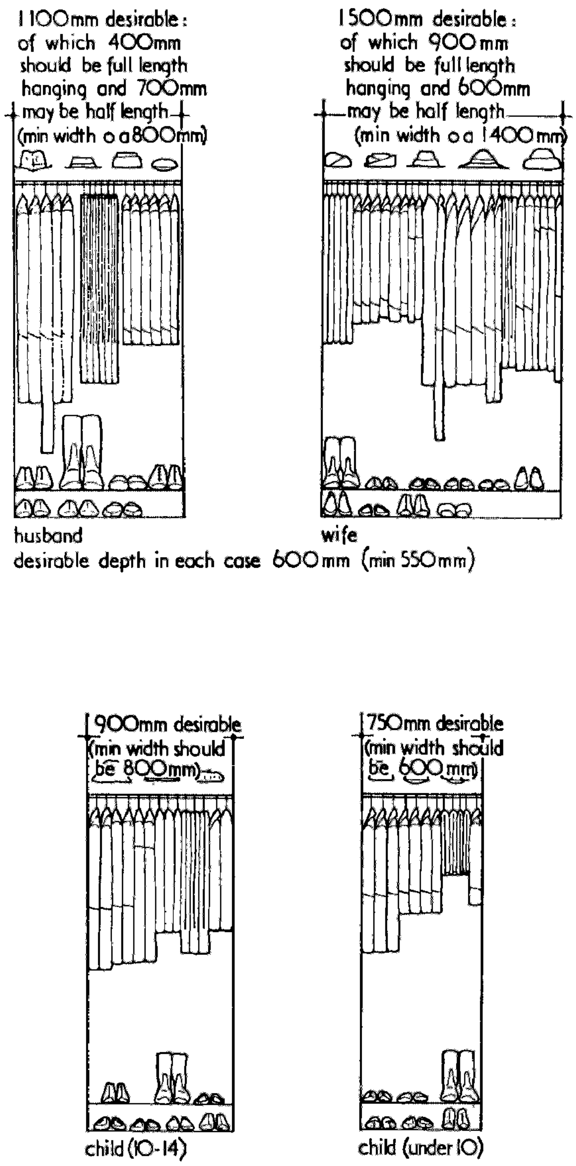
5.107 *Wine storage: a metal rack for 75 bottles*



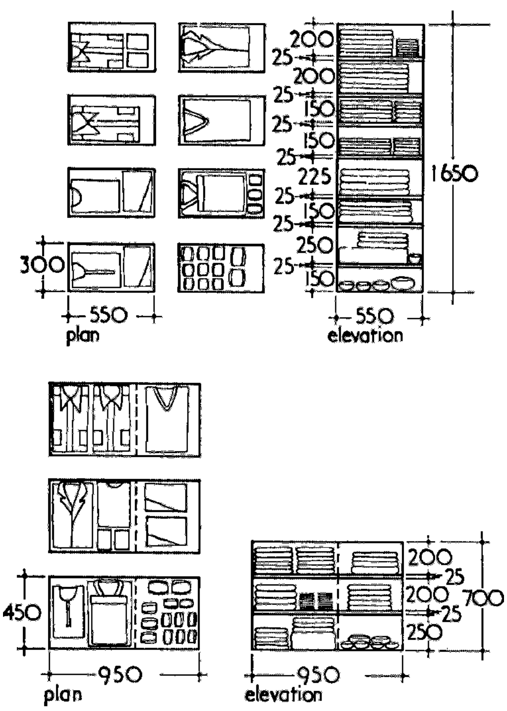
5.108 *Wardrobe for long coats and dresses*



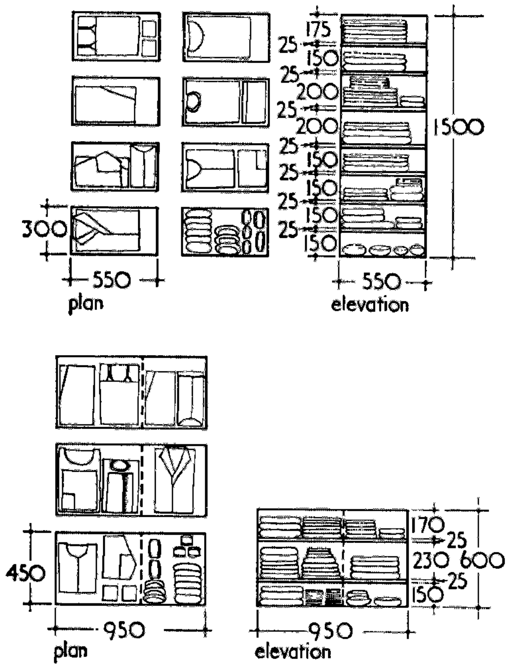
5.109 *Half-height hanging for jackets, etc.*



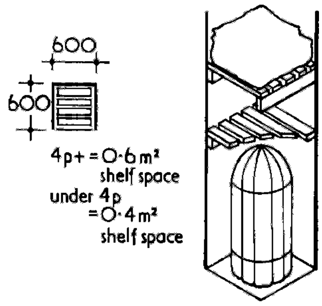
5.110 *Optimum hanging space for a family of four people*



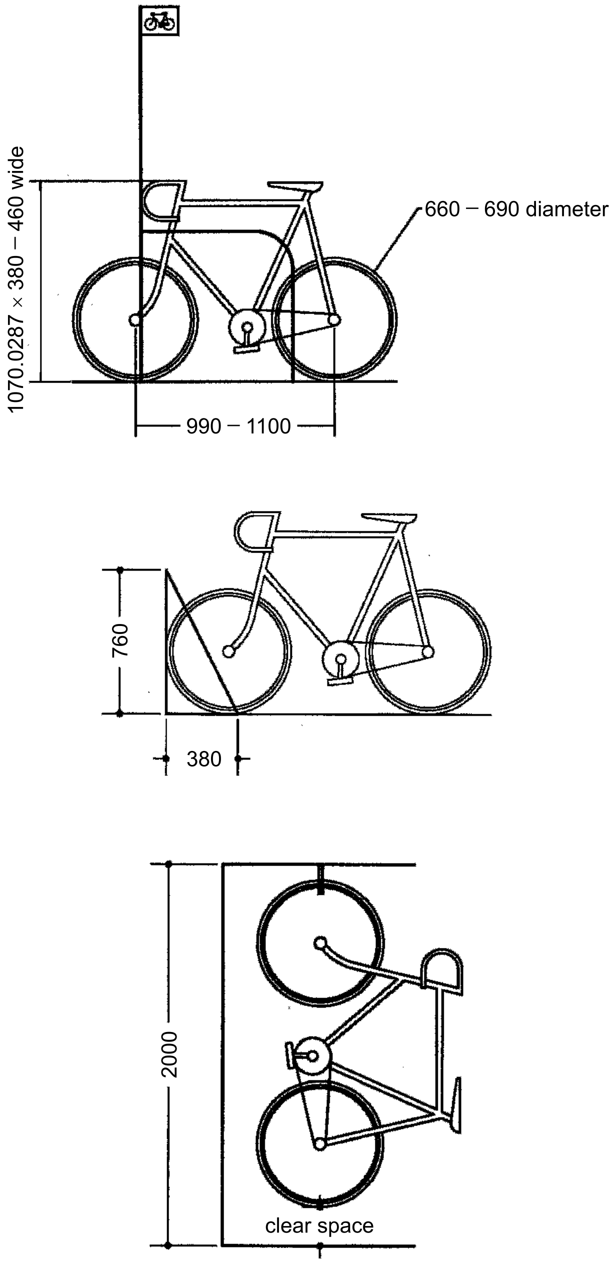
5.111 *Alternative storage arrangements for mens's clothing*



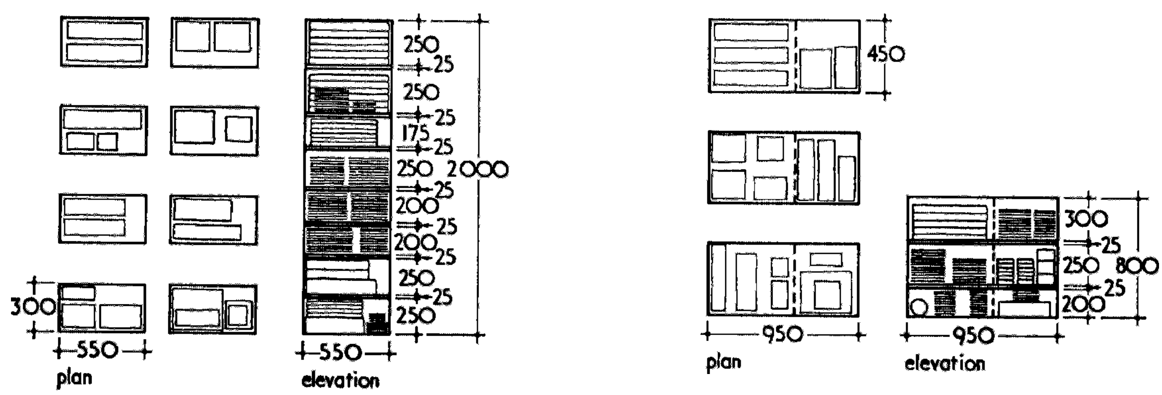
5.112 *Alternative storage arrangements for women's clothing*



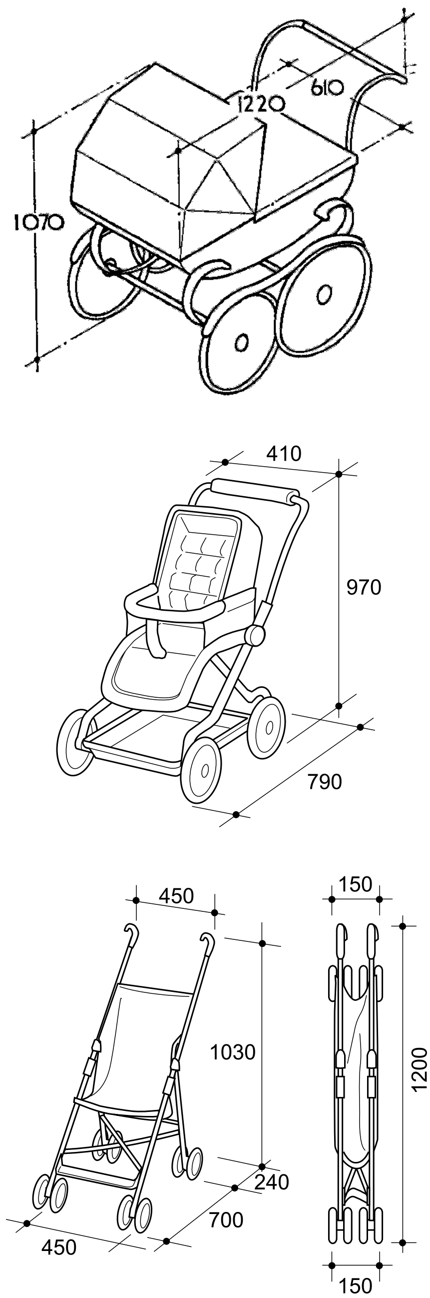
5.113 *Airing cupboard for linen including hot-water storage cylinder (not heavily lagged)*



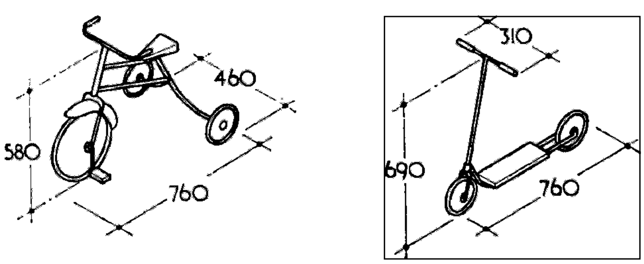
5.115 *Bicycles*



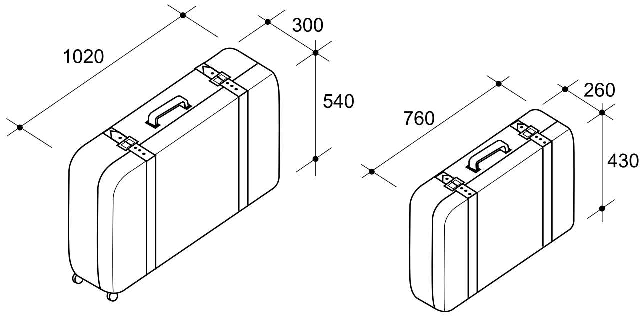
5.114 *Alternative storage arrangements for household linen for a five-person family*



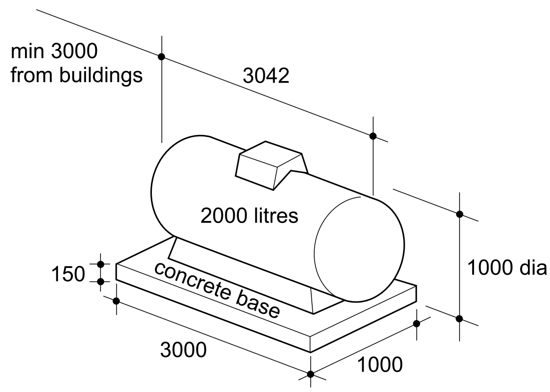
5.116 *Prams*



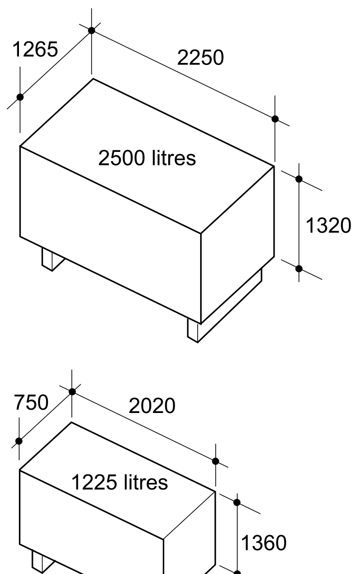
5.117 *Large toys*



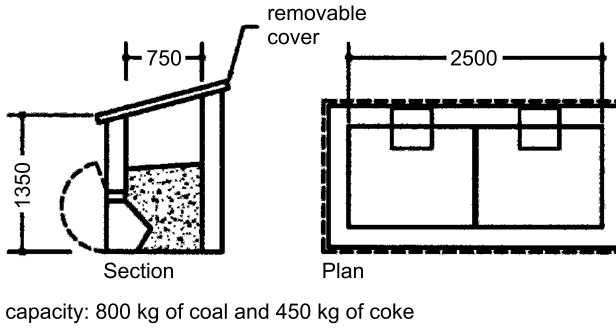
5.118 *Luggage*



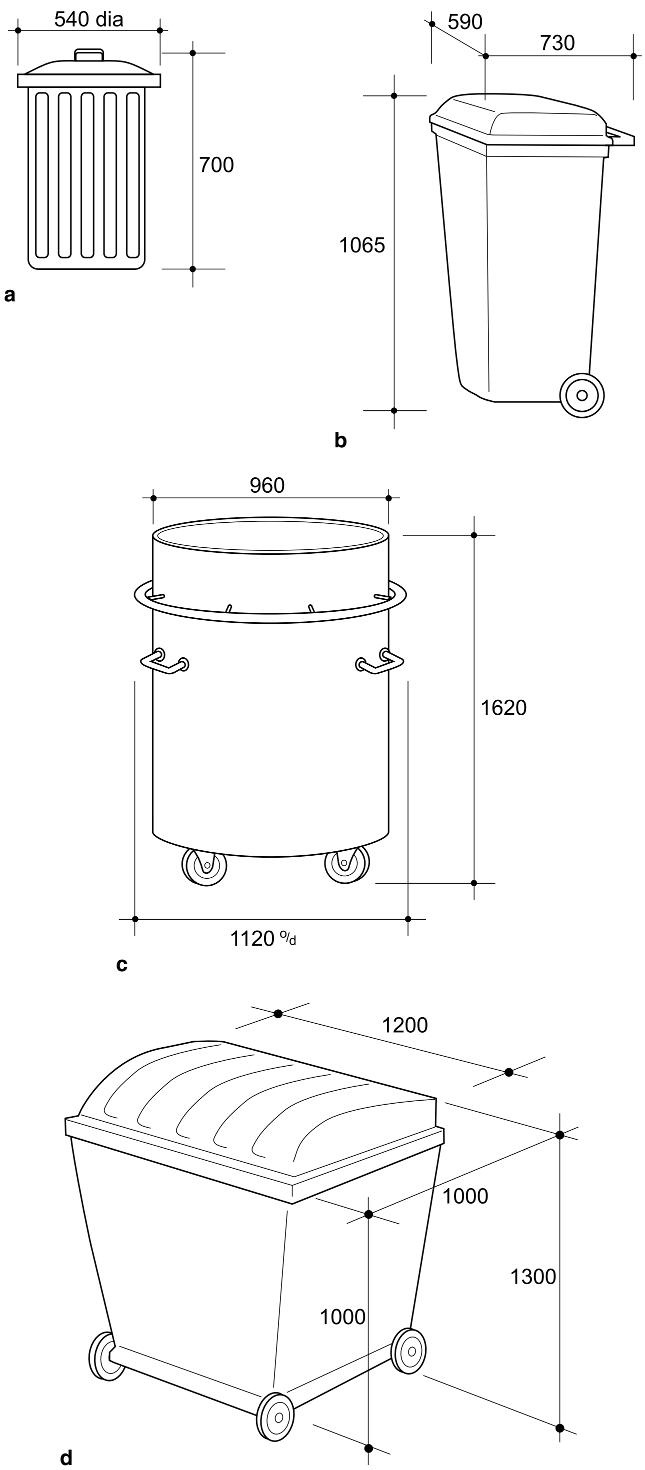
5.119 *Domestic gas storage for rural area (propane gas). Cylinders may now be buried if desired*



5.120 *Domestic oil storage tank. This may need a bund in certain circumstances. The oil flows to the boiler by gravity so the tank bottom needs to be sufficiently elevated. If this is not possible, the fuel can be pumped, but the boiler must then be a pressure jet type*



5.121 *Solid fuel storage*



5.122 *Refuse storage:* **a** *dustbin,* **b** *wheely bin,* **c** *paladin bin,* **d** *large bin*

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6 Master planning and urban design

Stuart Foley

Urbio Masterplanning and Urban Design

KEY POINT:
- *Teamwork is crucial to the masterplanning process, with different professional perspectives required*

Contents

1 INTRODUCTION

Spatial master planning is the process whereby existing and proposed land use of a specific site is considered in terms of environment, economic, social, political and technical matters. A master planner is the individual who collaborates across these five principles to direct the origination of a site-planning strategy that embodies the findings of this collaborative process. A master plan is most likely to be set out in several documents, written and visual, identifying how a site-planning strategy of this type can be applied to a site.

This chapter concentrates on the master planning of large or complex site-planning projects. It looks at some issues likely to require consideration by master planners and designers (architects, landscape architects and urban designers) operating in the core team.

2 MASTER PLANNING TYPOLOGIES

2.01

Exercises in master planning are undertaken in urban, suburban and rural contexts. Master plans may be undertaken for several forms of development (Table I), with differing scales of detail, for distinct purposes and all vary individually from project to project. The range and level of information used to generate a master plan proposal will be matched with its intended purpose.

2.02 Master plans for marketing

These master plans are aimed at raising the profile of a potential project, primarily to attract funding. They seek to inform potential investors about a development opportunity. They show broad detail and aim to identify a vision for the project. Some investigation into important issues will be considered, though for reasons of practicality these may not cover the entire site. Many aspects of the proposals will potentially be under review in later stages. The master plan documentation will usually cover some or all of the following:

- *Project description.* Concept plans and drawings of the proposal, outline information on environment, transport and infrastructure requirements, land use and project phasing.
- *Market information.* Regional and domestic background data and a description of aspirations for the project.
- *Strategic business plan.* Covering accomplishments to date, future development strategy and a project programme or timeline.

Table I Project forms

FORM	EXAMPLE
Residential	Housing.
Retail	Retail parks and shopping centres.
Commercial	Business parks and office campuses.
Civic	Parks, public squares and plazas.
Health	Hospital campuses and health retreats.
Education	School, university and staff training establishments.
Industrial	Research and production facilities.
Transport	Air, sea and rail terminals.
Leisure	Beach resorts, adventure parks and ski resorts. e.g. Figs **6.1** and **6.2**
Mixed	New towns, urban extensions and renewals.

- *Project economics.* Including initial information on investment returns, development opportunities within the proposal and project cost assumptions.
- *Company profile.* Details of senior management personnel, the project team and office contact particulars.
- *Preliminary development programmes.* Tabling facilities, units numbers and areas and capacity details.

Though not all, these projects are often proposed on green field sites and can be prepared for any project form (Table I). It will be very clear what form of development is to be proposed for the site at the outset. They are often lightweight, high-impact documents. Example projects may include **6.1** and **6.2** exclusive residential developments, golf courses, theme parks and leisure resort master plans.

2.03 Forward planning and management

All master plans are concerned with the future; however, this typology is particularly concerned with strategic aims and objectives of governance and large organisations.

There are a range of scales of operation with this type of master plan related to site area. Smaller more complex projects may also require a master plan. At the largest scale, master plans may consider the future development of an entire urban area and sometimes are called strategic frameworks in those instances.

Large institutions and international corporations require forward planning involving land use. The large property portfolios often controlled by these groups periodically require consideration for capital construction programmes and future investment purposes, calling for a master plan.

In the UK, Area Development Briefs and Master Plans are prepared as Supplementary Planning Documents and used by local government in their Local Development Framework. They are assembled on behalf of a landowner or developer, in liaison with local planning authorities. They are included in the Local Development Framework as a future guide to the general form of development or use that would be acceptable on a particular site.

All varieties show a broad level of detail for the entire site and are backed up with survey and analysis data. They aim to identify and rationalise the range of structural issues a development will hinge on during later stages. Because of the large areas with potential new uses involved, for some cases part of the actual process will involve establishing potential final uses.

2.04 Master plan competitions

Master plan competitions can be set up if enough baseline information is readily available. They are often appropriate for high-profile international projects and other situations where design ideas and quality are particularly important. Competition submissions offer a valuable ideas resource for a client. The selection process may include interviews in front of a technical panel for finalists. Here, a client team can examine other factors besides design talent. It is also a moment to clarify project methodology and previous project experience.

2.05 Design and construction master plans

These master planning projects usually arise from initial work prepared as part of one, or occasionally working through all of the previously outlined typologies. The form of development will be clearly understood though may undergo refinement. Project work can cover single sites if large enough. Occasionally, it will cover zones of larger scale strategic framework projects or perhaps a component of the proposed phasing of a strategic project. A plan will identify site layout and cover considerably more detail in comparison to all the other typologies and for the entire site. In most cases, the necessary information required to seek permissions and licenses to build are presented, requiring comprehensive documentation.

3 MASTER PLANNING PRINCIPLES

3.01

An effective master plan should establish the means by which valuable places for living, work and play can be created. Creating these surroundings is an interdisciplinary act, achieved through cooperation between client, professionals, communities and users. A successful master plan can be viewed in broadly similar terms to an ecological system, where apparently independent elements combine to set conditions that enable life to evolve and sustain activity. Ecology is the branch of biology that deals in relations of organisms to one another and to their physical surroundings. Unlike in the natural world, undertaking the creation of surroundings for human activity draws other variables in addition to physical ones. The master planning process involves consideration of both the physical issues of environment and technology or 'Visible' (Hard Information), along with economic, social and political matters or 'Invisibles' (Soft Information). Together, these terms outline five tectonic axioms, or the 'ecology' of the master planning process (Table II). This 'ecology' must be considered whole if a master plan is to have substance. In the same way, the ecology of a naturally occurring habitat will require the complimentary elements for growth to be in place in order to establish and thrive.

Of the five axioms, the title containing most relevance to design disciplines is environment. However, the equal impact of all five axioms on a deliverable master plan is vital. Each axiom will establish prominence at one time or another, through various stages, in the course of a project.

4 CONSULTANT TEAMS

4.01 Spatial master plan document

Evolving a strategy for the creation of changes of land use is the focus of the master planning process. A key image that illustrates the outcome of this effort is the spatial drawing or spatial master plan and this is invariably drafted – with several iterations – among the designers (architects, landscape architects and urban designers) in the core team.

4.02 Design team make-up

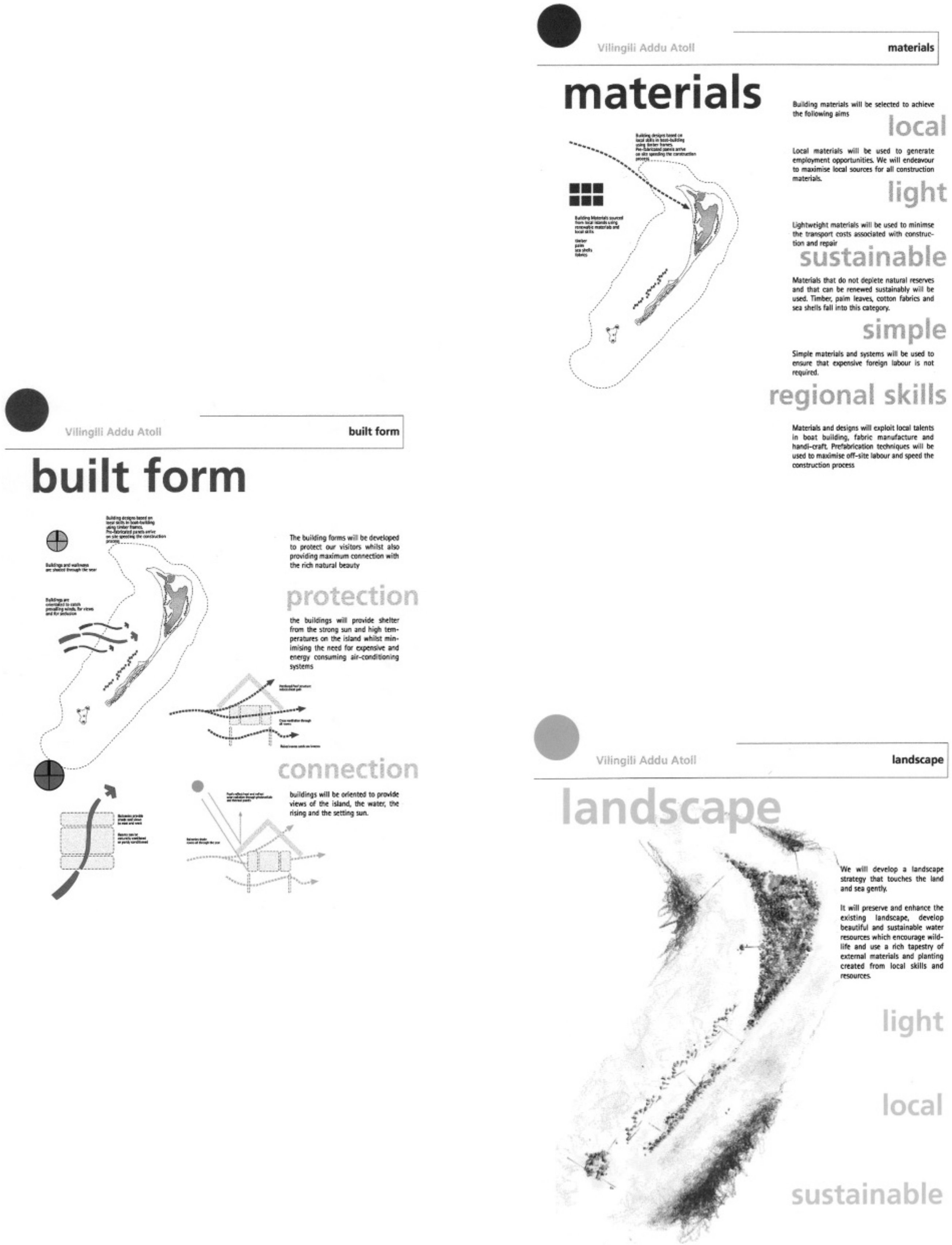
The involvement of design professions provides considerably more than a beautiful final image. The opportunity for a more complex discussion takes place when planning and engineering are integrated together with spatial design. The work of designers should add substance to the ambiguous realm of planning and esthetic value to the system basis of engineering via synthesis across disciplines. Master planners often come from design backgrounds in architecture, landscape architecture or urban design.

4.03 Master planner

For certain projects, a large team of consultants will need assembling, each prepared to contribute expertise within their particular discipline (Table III). The consultant list will vary according to each project, in relation to 'Visible' and 'Invisible' demands of the project. A master planner will be in control of the core team of consultants – and therefore project direction. Their project knowledge will be drawn from across the core consultant team. It is in this pivotal role that the master planners are able to offer direction to the core team and interact with the client concerning project progress. When dealing with a client, this individual will be looking to compress and interpret the volume of detailed information being considered by the core team into digestible summaries.

4.04 Smaller projects

For smaller projects, the master planner may take multiple responsibilities, e.g. master planner, architect, urban designer and project

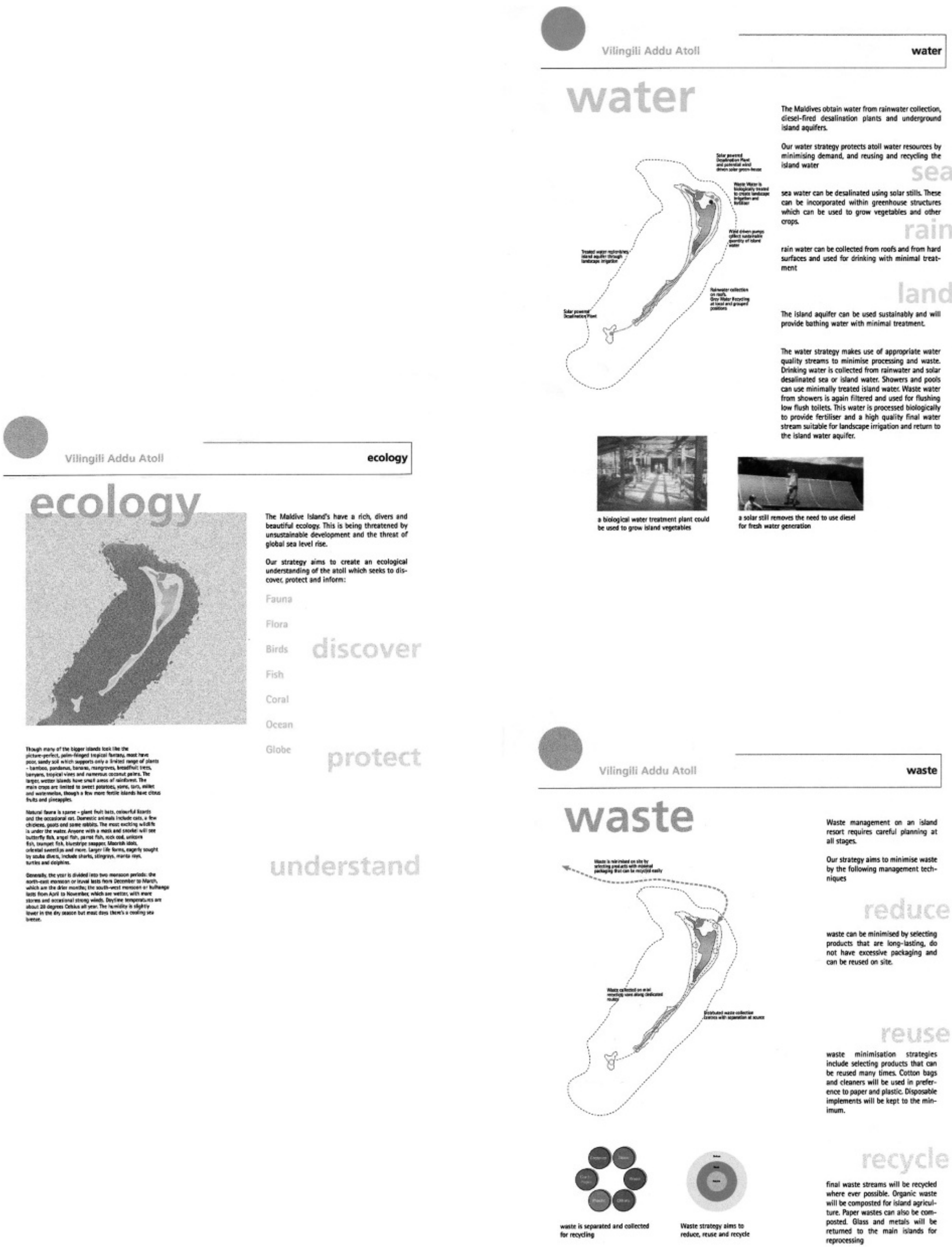


6.1 *Master Plan Typology: Marketing. Island resort design strategy, illustrated with themes that address the enhancement and protection of local environmental capital (Vilingili Addu Attol resort. Maldives)*

manager, as individual experience sometimes allows for this. It may not always be necessary or financially viable to commission the full list of consultants (Table III) in all master planning projects.

4.05 Consultant 'Territories'

Master planning projects vary in many ways, nevertheless the range of consultant groupings or 'Territories' (Spatial Design, Conservation and Protection, Engineering, Costs, Legislation,



6.2 *Master Plan Typology: Marketing. Island resort design strategy, illustrated with themes that address the enhancement and protection of local environmental capital (Vilingili Addu Attol resort. Maldives)*

Organisation and Public Consultation) are likely to be consistent (Table IV).

To assist with briefing of the master planner and core team organisation, senior professionals from each consultant group can be appointed responsible for a 'Territory'. The headings shown in Table IV assist with the identification of subteams and aid inter-disciplinary communication through ensuing stages. The range of skills making up a territory may not all be in-house.

This is also a useful division when considering the structure of meetings and its attendees. The duration of master planning

Table II Five tectonic axioms

VISIBLES	1. Environmental
	2. Technological
INVISIBLES	3. Economic
	4. Political
	5. Social

Table III Consultant team

	AXIOM	CONSULTANT
VISIBLES	Environment	Architect Landscape Architect Urban Designer Environmental Consultant Ecology Consultant Archaeologist
	Technological	Transport Engineer Building Services Engineer Civil & Structural Engineer
INVISIBLES	Economic	Quantity Surveyor Property Agent
	Political	Town & Country Planning Project Management
	Social	Community Mediation

projects may be a minimum of a year and expand into several. Territorial divisions help if members leave the team, by rooting experience within associated professional areas, thereby helping replacements to consolidate preparation during staffing transitions.

4.06 Territories in smaller design teams

Smaller design teams are often structured to allow responsibility for multiple 'Territories' to be held where experience allows; for example, Spatial Design and Organisation or Planning and Public Consultation. Care must be taken in these circumstances, as individual workloads start small and tend to increase substantially through the term of a project. Primarily because a characteristic of the process is discovery, an attribute that clearly invites uncertainty in workloads. Issues reveal themselves unexpectedly; require attention and

Table IV Project 'Territories'

CONSULTANT	TERRITORY
Architect Landscape Architect Urban Designer	Spatial Design
Environmental Consultant Ecology Consultant Archaeologist	Conservation & Protection
Transport Engineer	Movement
Building Services Engineer	Services & Drainage
Civil & Structural Engineer	Engineering
Quantity Surveyor Property Agent	Costs
Town & Country Planning	Planning
Project Management	Organisation
Community Mediation	Stakeholder Consultation

insertion into the process. Duties can become unmanageable, and availability of key individuals problematic, invariably causing difficulties when time is short. Unless planned in advance, enlarging the team in order to redistribute responsibilities will result in reductions in work quality and impact on project programme. The impact of reducing a team's size will inevitably lead to increases of individual responsibility for one or more team members. This also has negative effects on quality and programme, unless planned correctly.

4.07 Indisciplinary communication

There is significant overlap between the thinking developed by each individual consultant and between the territories that make the core team. Allowing time for interdisciplinary communication of the core team as a group is vital for these areas of similar interest to receive discussion. Views can then be cross-referenced between consultants, discussed and agreed prior to decision-making. Aim to establish regular consultant team meetings where tabling of rough and early draft ideas and outline information is encouraged. At consultant team meetings, avoid using elaborate graphic presentation techniques, they take comparatively more time to draft and often encourage the view that things are fixed. Amendments to this work can be fiddly and time consuming, and with tight fees and tighter time budgets, always come at the expense of face-to-face communication. Consider using presentation graphic work primarily for client meetings, there are likely to be many time consuming changes and amendments to these formal documents alone. Make room for interdisciplinary communication between the core team whenever possible.

5 PROCESS AND ACTIVITIES

5.01 Project evolution

The process of master planning is inherently prone to change, as the variables contributing to the process are multifarious. Unless viewed as a ‘living’ process, changes that enter during the evolution of a project are likely to be considered an encumbrance, when in fact they are important developmental stages of the endeavor. Experienced design teams will be constantly scanning for new issues with potential to alter the project bearing in both negative and positive ways. Any opposing effects on workload – and robustness of the process – can be reduced by reporting issues early. Clients will often be tied to fairly strict delivery programmes but even so, the impact of unforeseen issues on delivery, e.g. seasonal windows for environmental studies cannot be ignored (Table V). Structuring a master plan around incomplete or unchecked information will impact on its credibility. This reflects badly on the team and may affect implementation.

5.02 Background material

In most cases, the process of master planning will expose the largest volume of background material ever collected and considered for the particular site concerned. Placed in a position to direct outcomes from this material, it is important for the master planner to take a flexible approach and maintain a broad view of the issues as initial objectives may change when levels of project knowledge increase.

5.03 Master planning process phases

There are three basic phases in the master planning process: Devising, Design and Delivering. Designers are mostly active in the first two, but continue involvement throughout alongside the master planner and other core team members. Contributions are required from all territories of the core team both before and after the period when they are individually most active. For the duration of the project, a regular process of testing options and ideas takes place as decisions are taken.

5.04 Devising phase

This phase establishes of a strategic context for the project by collecting together information related to each of the five axioms (Table II) – environment, technological, economic, political and social. Designers will engage mainly with environmental and technological issues initially, when beginning site study work. This work should be carried out while keeping a watching brief on developments with the remaining three axioms.

For designers in the core team, the final aim of the ‘Devising’ phase is usually to assemble and order all the reference information into a Master Plan Brief. The brief will define requirements, set initial objectives and establish the framework that will inform the preparation of the spatial master plan in the following ‘Design’ phase. The design team will often rationalise this information through text and graphics, and combine this work into one document on behalf of all the consultants in the core team. During this phase, resist value judgments, as they will often presume knowledge that has not been qualified. Report facts and observations and note ideas (to incorporate later in the Design and Access Statement) separately, for use in the ‘Design’ phase.

5.05 Submission to the client

After completion, the document will be submitted to the client for consideration. The details of this brief will be subject to amendment, e.g. surveys may be due to be commissioned or still underway. Overlooked information may appear and new issues will arise. This new information will need to be incorporated into the brief as and when available. The mutable nature of the brief is to be expected and the client should be made aware of this and why it is so.

5.06 Work areas for master planners and designers

1. Identify initial aims and objectives for the project:
   a. Set out in a document
      i. Build detail up from client discussion with core team input.
2. Produce the master planning brief:
   a. Collect and Analyse Readily Available Information
      i. These are desk studies that can be attended to without visiting the site (Table VI). Undertaking some of these before visiting the site will help establish a mental map of the project area.
   b. Site-Based Analysis and Commissioning Studies
      i. This work provides up-to-date information. Consultants will undertake site surveys and carry out various types of analysis (Table VII). Threshold and capacity studies for funding, transport and services are particularly important.
   c. Portray the Project Vision
      i. State aspirations and elaborate with images in a reference document.
   d. Collate and Present the Master Planning Brief
      i. Present initial analysis documents. Chapters may include Project Vision, Environment, Landscape, Built Fabric, Transport, Services and Planning. A final chapter may cover initial ideas.
3. Maintain watching brief:
   a. *Economic*. Consider the outline business case
   b. *Social*. Identify main stakeholders. Review consultation and communication strategy
   c. *Political*. Consider project delivery issues

Table V Habitat surveys – optimal periods

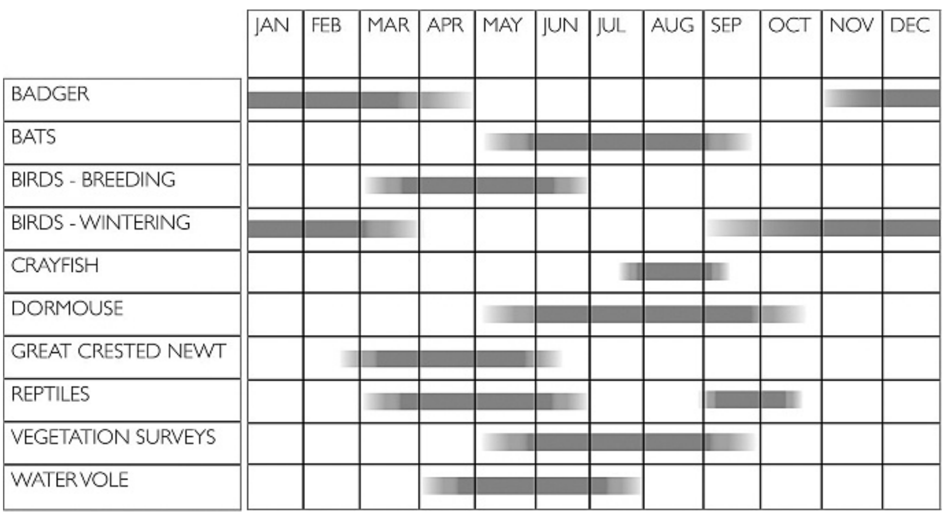


Table VI Secondary sources – collect and analyse readily available information

AXIOM	CONSULTANT
General	• *Design Team* Base plans Review existing site surveys Ordnance Survey plan (with contour information) Strategic area 1:25,000 medium scale map Site area 1:1250 large scale map Topography analysis Scheduled Monuments World Heritage Sites Land use patterns Figure Ground Precedent studies Project team contact list
Environment	• *Architect* Review relevant existing data and material provided by client Architecture related Policy Review National, Regional and Local Architectural Constraints: Desk Review Map relevant designations and other information
	• *Landscape Architect* Review relevant existing data and material provided by client National or International landscape designations Landscape Policy Review National, Regional and Local Landscape Classification Tree Preservation Orders Landscape Constraints: Desk Review Map relevant designations and other information Web sites: Natural England. www.naturalengland.org.uk Scottish Natural Heritage. www.snh.org.uk Wales Environment Link. www.waleslink.org Environment & Heritage Service. www.ehsni.gov.uk
	• *Urban Designer* Review relevant existing data and material provided by client Urban Design Policy Review National, Regional and Local Strategic Access & Permeability (Public roads & Rights of Way) Urban Design Constraints: Desk Review Map relevant designations and other information
	• *Environmental Consultant* Review relevant existing data and material provided by client National or International nature conservation designations Environmental Policy Review National, Regional and Local Map relevant designations and other information Environmental Constraints Desk Review: Water Waste Biodiversity Air & Climate Pollution Web sites: Magic. www.magic.gov.uk EnviroCheck. www.envirocheck.co.uk Environment Agency. www.environment-agency.gov.uk UK Air Quality Archive. www.airquality.co.uk Natural England. www.naturalengland.org.uk Continues...

Table VI (Continued)

AXIOM	CONSULTANT
Environment	• *Ecology Consultant* Review relevant existing data and material provided by client Draft scope of potential habitat surveys: Badger Bats Birds - Breeding Birds - Wintering Crayfish Dormouse Great Crested Newt Reptiles Vegetation surveys Water vole Web sites: Natural England. www.naturalengland.org.uk
	• *Archaeologist* Review relevant existing data and material provided by client Scope for potential archeological issues Map regression exercise of site and context
Technological	• *Transport Engineer* Review existing traffic modelling data and material provided by client: Private vehicles Public Transport Cyclists Pedestrians Web sites: Department for Transport. www.dft.gov.uk
	• *Building Services Engineer* Review relevant existing data and material provided by client
	• *Civil & Structural Engineer* Review relevant existing data and material provided by client
Economic	• *Quantity Surveyor* Review relevant existing data and material provided by client Demography (economic)
	• *Property Agent* Property market demand & supply
Political	• *Town & Country Planning* Planning overview Planning permissions & proposals Ownerships Legal constraints Listed buildings
	• *Project Management* Review relevant existing data and material provided by client: Project Finance Time and Delivery Issues Quality Issues Human Resources
Social	• *Community Mediation* Demography (social) Community information Cultural facilities Cultural identity Amenity location Consultation and communication strategy

Table VII Primary information requirements: site analysis visits and commission studies

AXIOM	CONSULTANT
General	• *Design Team* Site checking of desk studies Topography analysis Scheduled Monuments World Heritage Sites Land use patterns Figure Ground
Environment	• *Architect* Site checking of desk studies: Architectural Constraints: Desk Review Building identification and Photo survey Building entrances Building heights/storeys Building of Interest Commission Studies E.g. Building condition surveys
	• *Landscape Architect* Site checking of desk studies: Landscape Classification Landscape Constraints: Desk Review Landscape character assessment Views - See accompanying text Analysing Views – Section 5.12 Commission Studies E.g. Tree surveys
	• *Urban Designer* Site checking of desk studies: Strategic Access & Permeability (Public roads & Rights of Way) Urban Design Constraints: Desk Review Urban Analysis. E.g. Permeability Legibility Vitality Variety Robustness Views - See accompanying text Analysing Views – Methodology Commission Studies E.g. Space syntax surveys
	• *Environmental Consultant* Site checking of desk studies: Water Waste Biodiversity Air & Climate Pollution Commission Studies E.g. Pollution monitoring
	• *Ecology Consultant* Habitat surveys. For optimal survey periods see (Table 7) Badger Bats Birds - Breeding Birds - Wintering Crayfish Dormouse Great Crested Newt Reptiles Vegetation surveys Water vole Continues...

Table VII (Continued)

AXIOM	CONSULTANT
Environment	• *Archaeologist* Carry out archaeological surveys
Technological	• *Transport Engineer* Desire line studies Travel Isochrone Maps. Threshold studies
	• *Building Services Engineer* Threshold studies
	• *Civil & Structural Engineer* Threshold studies E.g. Ground conditions: Water absorption capacity
Economic	• *Quantity Surveyor* Capacity studies E.g. Retail Survey
	• *Property Agent* Site checking of desk studies
Political	• *Town & Country Planning* Initial Planning Strategy Report
	• *Project Management* Initial assessments of: Project Finance Time and Delivery Issues Quality Issues Human Resources
Social	• *Community Mediation* Develop report material Demography report (social) Community information report Cultural facilities Cultural identity assessment Amenity location Consultation and communication strategy

5.07 Design phase

This is the start of this site-planning phase. Designers once again will engage mainly with environmental and technological issues. The structural components of the site will not always be immediately evident but must be established. These are opportunities and constraints or desirable components that collectively identify site character.

5.08 Study layers

Separating the site-planning study into five layers or headings covering Street blocks, Streets, Public and Communal spaces, Buildings and Landscape will permit study of all the main components that go to make a place. Each design profession (architecture, landscape architecture and urban design) will consider the headings from their own particular attitude. They will establish the important characteristics that make up the structure of a site to them professionally and to some extent personally. These considerations will require discussion and clarification in drawings. Each consultants approach to site planning is considered in various items of published reference material. Of particular value to the designers of the core team is urban design site-planning reference material (See Bibliography). In all master plans, the source of site-planning ideas and direction is mostly extrapolated from successful existing urban environments.

The synthesis of environmental and technological information with knowledge from other disciplines of the core team will be focused through preparation of various drafts of the spatial master plan. A procedure of testing and refinement is undertaken, until a final draft of the spatial master plan emerges.

5.09 Some considerations for master planners and designers

Street blocks

- Identify each street block. Roads and pathways usually define the edges of these. Study the block sizes looking for signs of local scale and patterns of development.

- Grid orientation may be important if the ‘Project Vision’ includes sustainable building techniques, e.g. proposals for north–south building facades.
- Street block edges have a high level of permanence. For larger projects, a method of subdividing the site may be required to make things manageable. Divide the site into zones using major street block edges.
- Teams covering areas or zones of study can then be set up.
- Avoid arbitrary zone subdivisions or plot layouts. This often leads to extra land area calculation work in later phases.

Streets

- Consider roads, cycle routes and footpaths. Movement desire line studies will have indicated where traffic is coming from and most likely to enter and cross the site.
- Set out these access points, and consider what can be seen along them in addition to what destinations they may lead to and how busy these routes are likely to be. Busy routes will usually remain so. These are all linear features that historically cut across various boundaries.
- New movement corridors require new boundaries to be crossed and construction will often have a disruptive environmental impact.
- Increasing widths of existing movement corridors also attracts environmental impact, but it is often reduced by comparison and may lead to the strengthening of existing links and movement networks.

Public and communal spaces

- Hard and soft types will probably feature and they may be located on nodes, where streets cross. Locate the interesting ones and the reasons why the are valuable.
- For urban settings, some public space may exist, that is civic space the public have a right to freely occupy. However, in many newly proposed situations, outside space will be privately owned and therefore more accurately termed communal space.
- Distinguish between the two types of outside space. Communal space can operate very differently both immediately following project construction and in the more distant future. It may be subject to material change by a land owner, without recourse to its users.

Buildings

- Buildings do not need to be designed in detail for a spatial master plan. Simple outline forms are enough, with an indication of storey numbers and entry points.
- Massing studies should take into account the scale of immediate surroundings and the impact of buildings on the nearby community; particularly in terms of interference with valuable views.
- Though generally buildings do not need designing, there can be advantages in showing features of some for one reason or another. Develop a quick, 1:500 sketch plan of these and then change this drawing scale to match the scale of the spatial master plan. This will identify a simple set of lines in plan that can be reproduced to show an architectural intent.

Landscape

- Consider valuable landscape features, local connections with open space, streets scene and important views. Orientating streets to compose views, and using buildings to enclose squares and plazas, will set up situations for landscape to play its part in the structure of the spatial master plan.
- Often sites – or their surroundings – hold evidence of native landscape character that is particular to the locality, e.g. tree groupings, hedgerows, wall construction, etc. Identify these characteristics, find and record them in photographs. Consider ways of introducing these features into the proposed landscape strategy of the site. Native plant species thrive in their home surroundings and using local crafts also assists with sustainable objectives.

5.10 Analysing views

Identify important viewpoints and divide them into two groups: long range and short range. Identify each vantage point, the direction, length, width and elevation of each view and set them out on base plans; one showing long range and another short range:

- Long Range 1:10 000 (Street names should be readable)
- Short Range 1:2500.

Use a 50 mm or equivalent digital image lens and shoot viewpoints at eye level, i.e. 1.67 m above street level. Photograph the views that are obscured (by trees or buildings) for reference.

5.11 Finding viewpoints

Identify easily accessible public places where people pause and take-in the view. These are unlikely to be traffic islands, road crossings or the views from the insides of buildings. Consider bridges, public parks and hillsides as these places provide particularly good vantage points. Aim to review all the viewpoints that will be affected by the proposed development from:

- Conservation areas
  - Existing individual or groups of interesting buildings
  - Important public open spaces
  - Key entry points
  - Listed buildings
  - Local landmarks
  - Movement corridors (vehicular and pedestrian)
- Prominent escarpments.

5.12 Delivery phase

Delivery addresses how new development will take place on the ground. Delivery issues such as realistic market demand assumptions should be considered from the introductory stages and regularly tested through the master planning process. Designers also have an important role in developing structures that help clients safeguard the aspirations of master plans.

6 MASTER PLANNING AND URBAN DESIGN

6.01 Urban renaissance

The relatively large resident population of urban and suburban city projects is the common factor separating urban master planning projects from a range of comparatively less complex master planning exercises. Since the publication of the Urban Task Force Report Towards an Urban Renaissance in 1999, master planning of urban and suburban areas is an idea that has increased in importance. The term has entered into UK planning debate and now finds itself integrated with the current planning system.

6.02 Urban designers

Master planning in an city context is likely to involve the skills of a qualified urban designer. The profession is concerned with mechanisms that drive and create valuable places to live, work and play. Their work involves the incubation of ideas in urbanism, under the headings ‘urban studies’ (i.e. Urban economics), ‘urban planning’ (i.e. City planning) or social sciences (i.e. Urban sociology or geography). Urban studies and urban planning work are primarily applied or practice-based problem solving. These two subjects are concerned mainly with the structuring of ideas into public spaces, layouts of roads and car parks, with the use of hard and soft landscape, and use of street furniture, lighting and signage. There are strong similarities between topics that interest urban designers and landscape architects, but the chief distinction is the urban designers intimate knowledge of the city environment, its land economics and social issues.

6.03 Urban master planning

Urban design has become recognised as a vital ingredient in successful urban master planning. In fact, it can be illustrated that successful urban space can and does exist without great architecture. Conversely, good architecture will suffer in a poor urban setting.

6.04 Urban design perspective

The subjects of architecture and landscape architecture provide input to the origination of site plans, but connect directly with particular specialisations that shape a particular perspective, i.e. buildings and their operation or exterior space and horticulture, respectively. Similarly, urban design is not a subject solely focused on site planning, as important facets of urban debate are bonded to the master planning process by the presence of an urban designer in the design team. There will be separate detailed considerations that do not reliably arrive through the perspectives of architecture or landscape architecture. Incorporating a concerted urban design perspective within the aims and objectives of the project brief – for many contemporary projects – is necessary for it to be considered complete and robust.

7 OVERVIEW

7.01

Though the following two descriptions were prepared with urban master planning in mind, they usefully set out the various roles required of a master planner:

> A master planner will need to communicate ideas and proposals clearly and succinctly through words, diagrams and three dimensional illustrations, present research, evaluation and proposals clearly to a wide range of audiences, explain design decisions to stakeholders, think holistically about a site, prepare urban design proposals, coordinate a diverse range of technical inputs and evaluate the relative importance of different elements, address how proposals are going to be delivered, manage the team, manage client input, budget and program effectively and bring together key stakeholders interests into a coherent whole. (Creating Successful Masterplans, CABE 2004)
>
> A master plan at its best, is a description (both visual and written) of the potential of a place. It sets down the different layers of physical change (the buildings, public spaces, roads, pedestrian routes, etc.), and is able to assimilate the aspirations of key stakeholders in the public and private sectors and moderate their impact on the natural environment. Its outcomes are usually a set of policies and approaches for interventions in the physical environment, with a clear mechanism for delivery. (Design Reviewed Masterplans, CABE 2004)

As this is an introduction to the master planning process, what can probably described as a traditional approach is discussed here. Most groups, professional, student and client find this approach logical to follow. However, it is worth pointing out that this method can cause unnecessary costs and low maneuverability in certain cases as the labour involved can be substantial. For instance, studies can be expensive and prove what was already understood intuitively, and as potentially interesting new opportunities emerge, quick alterations to the trajectory of a project can prove difficult. The potential for more 'lightweight' models exist, but these are not considered here.

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7 Landscape design

Michael Littlewood

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KEY POINT:
- *The design of space between buildings is as important as that of the buildings themselves*

Contents

1 INTRODUCTION

1.01
The design of external spaces outside and between buildings, whether urban or rural, public or private, covers a wide variety of elements and requires considerable knowledge of the location, materials and construction. All too often parsimony results in schemes which are unsatisfactory both aesthetically and practically.

1.02 Basic human dimensions
The space requirements of people outside buildings are generally similar to those inside as illustrated in Chapter 2. A family group of six people on a lawn or terrace occupy a rough circle 4 m diameter; for ten people (the largest convenient simple group) the dimension becomes 6 m, which is the minimum useful size.

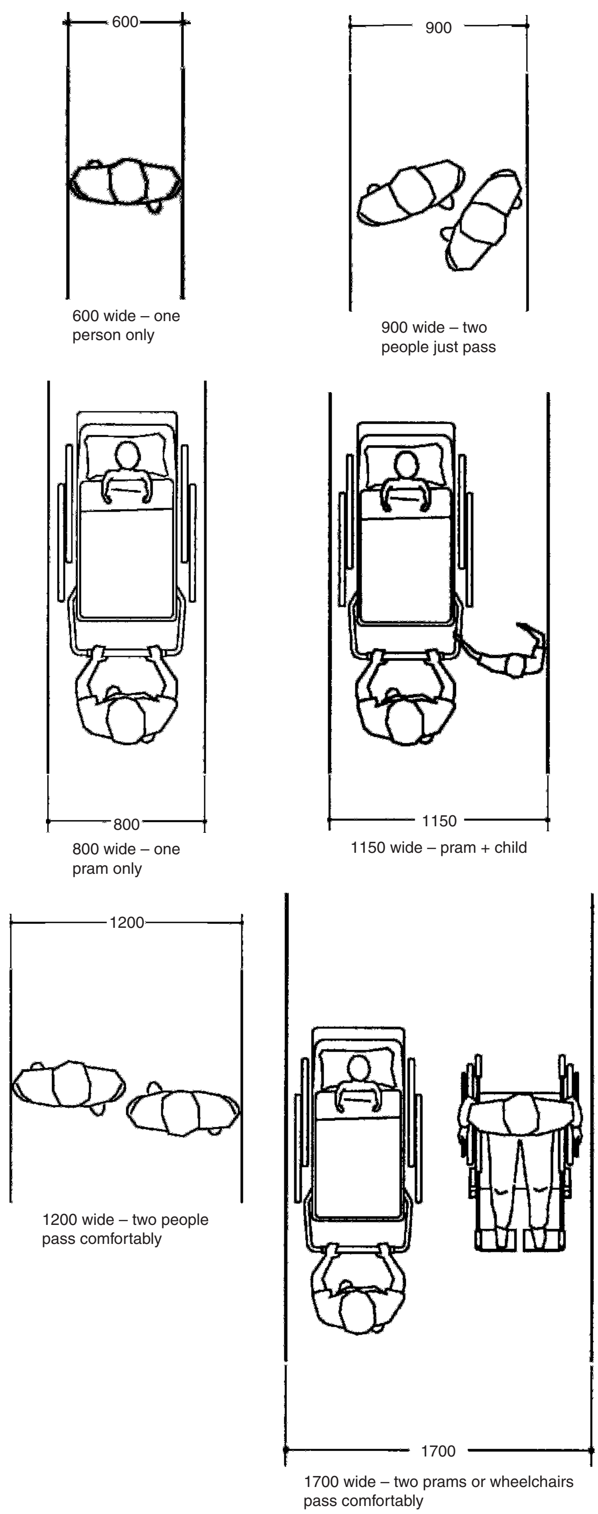
2 WALKWAYS

2.01
Full physical ability is a temporary condition. Most people become less than fully mobile at some time, perhaps carrying shopping or parcels; pregnancy; a sprained ankle; a dizzy spell; a broken high-heeled shoe; or just the normal course of ageing. Circulation routes should be planned bearing this in mind, integrating a design that is both functional and aesethetically pleasing, rather than adding on facilities for 'the disabled'.

2.02 Desire Lines
Pedestrian routes should follow desire lines as directly as possible.

The details are of secondary importance if the connections are incomplete. Routes should be chosen by analysing and responding to the context of the site. One way of achieving this is not to provide paths in a newly created landscape scheme but to wait until the users make worn tracks and then to pave these. Routes should include loops rather than dead ends, incorporating places to stop and rest. There should be coordination between parking, paved and rest areas, building entries, etc. with adequate seating, lighting and signage.

2.03 Widths of pedestrian routes
These vary with the purpose of the route, the intensity of use and with the situation. As a general rule of thumb, provide 600 mm width for each pedestrian walking abreast: which suggests 2 m minimum for public walkways. The requirements of others than pedestrians that use these paths must also be considered, **7.1**.

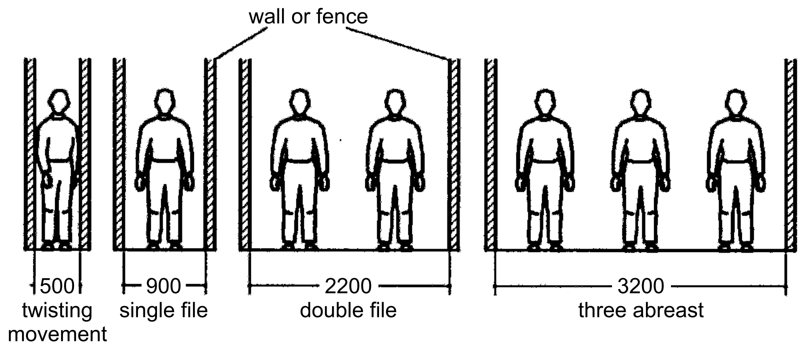


7.1 *Characteristics of various footway widths*

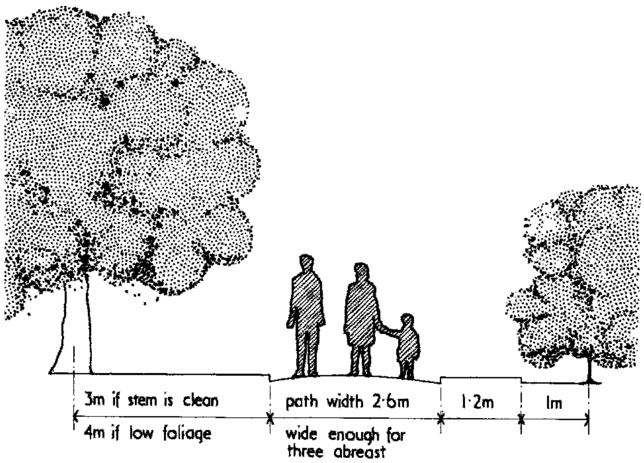
Minimum requirements between walls or fences are shown in **7.2**; **7.3** illustrates a path over open ground. Other situations are shown in **7.4** to **7.6**.

Pedestrians typically do not use the entire width of footpaths. The edge adjacent to a kerbed roadway about 75 m wide tends to be avoided, as is the 0.5 to 0.75 m width directly alongside a building, **7.7**. Only under conditions of congestion would these edges be used.

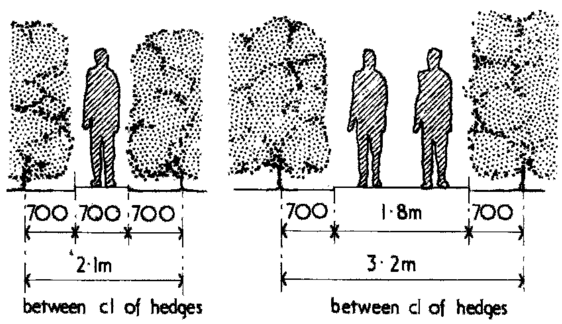
Street furniture such as trees, bollards, direction signs, parking meters, telephones, litter bins, fountains, sculpture and kiosks can also reduce footpath effective width. They should preferably be situated in the avoidance zones.



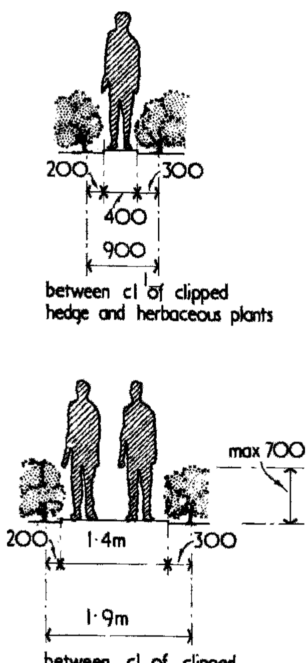
7.2 *Pedestrians between walls or fences, minimum dimensions. Add 25 per cent for free movement, prams, wheelchairs and bicycles*



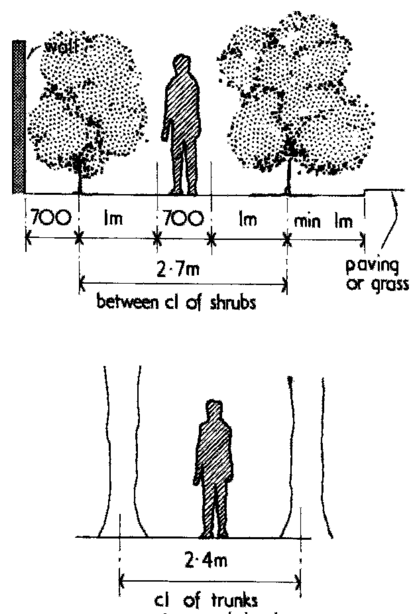
7.3 *Narrow path across open space*



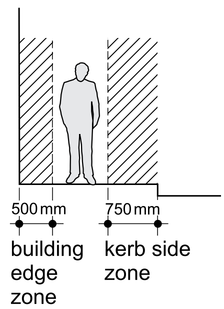
7.5 *Walking between clipped hedges with careful movement. Planting beds should be 400 mm wide for clipped hedges*



7.4 *Minimum path widths between low planting, but not suitable for prams. Planting beds should be 600 mm wide for herbaceous plants*



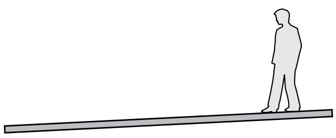
7.6 *Minimum dimensions for pedestrians between free-growing shrubs. Where there are prams allow 3 m between the centres of planting*



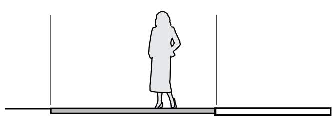
7.7 *Zones avoided by pedestrians*

2.04 Slopes

7.8 and **7.9** provide longitudinal and cross-slope criteria for footpaths under various circumstances. Longitudinal slope criteria or gradients are based on user abilities and design objectives. Cross-slope criteria are based on the need for positive drainage (depending on paving material). Porous paving, for instance, does not require as much of a cross-slope for drainage as does a nonporous paving material.



7.8 *Walking along a longitudinal slope: up to 3 per cent preferred, generally 5 per cent maximum, 5–10 per cent possible depending on climate. Between 5 per cent and 8 per cent slopes are considered to be ramps*



7.9 *Paths with cross-fall: 1 per cent minimum for drainage, depending on material of finish; 2 per cent is typical, 3 per cent maximum*

2.05 Surfacing

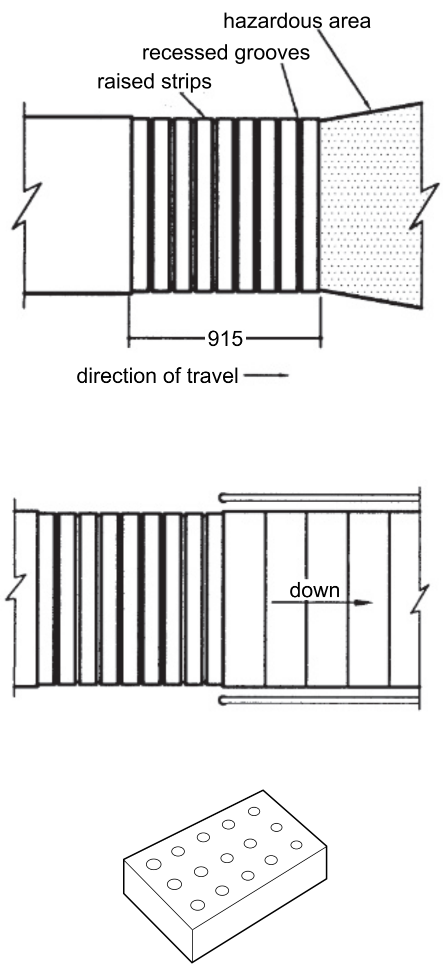
The location of the footpath and its intensity of use will determine the surfacing material and its thickness. Some paths are also used for service vehicles and should be designed accordingly, particularly the edge details. Several factors influence the durability of paving materials; even high-quality materials can wear out or disintegrate if subjected to extremes of heavy traffic or inadequate maintenance. Surfacing irregularities should be minimized.

Some footpaths or walkways are required to have high traction ratings for safety use. Highly textured surfacings usually require steeper slopes for drainage (i.e. 2 per cent minimum) but every footpath must seek to achieve its design purpose in all weather conditions. A multitude of design patterns is now possible with the current wide range of unit pavers. Colour affects the degree to which heat and light are absorbed or reflected, and requires consideration.

The edges of a footpath play an extremely important part in both its appearance and function. Flexible materials such as macadam or sprayed chippings particularly need the support of an edging; so do unit paving blocks and bricks.

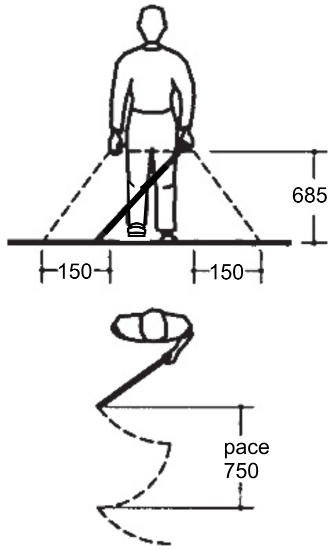
2.06 Tactile warning strips

These are used to give advance notice to people with impaired sight of abrupt grade changes, vehicular areas, dangerous exits, pools or water fountains, and the like **7.10**. They are recommended at the top and bottom of steps and in front of doors that lead to hazardous areas. However, such warnings should not be used at emergency exits, as they can inhibit their proper use.

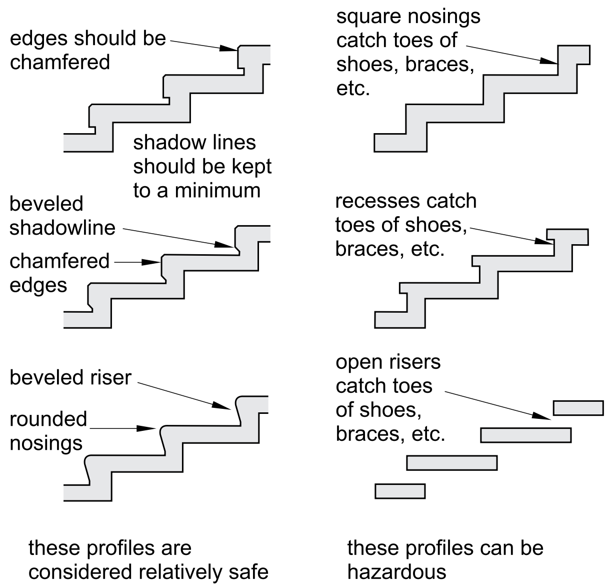


7.10 *Tactile warning pavings. These have value as devices to warn visually impaired people of hazards. They need to be in strips or areas large enough to be detectable*

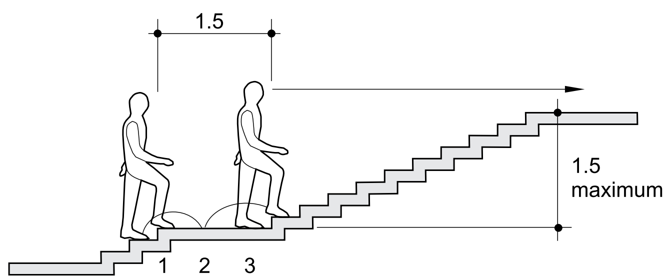
Street furniture, including trees, should be located within a defined zone along the outer edge of walkways, leaving a clear path without obstruction. A linear tactile warning strip can define this zone. **7.11** shows a blind person using a white stick.



7.11 *Visually impaired person walking. The Typhlo cane is primarily used by those with limited vision. It will detect objects only within a specific range. Nothing should project into a pedestrian pathway above a height of 680 mm*



7.12 *Various tread profiles*



7.13 *Stair height and landing proportions: at least two, preferably three steps to be provided. Longer flights should preferably be in multiples of five treads to alternate the feet. Landings should be long enough to allow an easy cadence, at least three strides. Longer landings should be in multiples of 1.5 m. The rise between landings should not exceed 1.5 m so that the next landing is visible: greater heights are psychologically uninviting. If it unavoidable, provide a landing at least every 20 treads to minimise fatigue*

3 STEPS

3.01

Steps provide great opportunities for creating character and drama; good examples abound. They can be divided into three main types:

- Those steps which are sculptural as they have been literally carved out of the ground: earth or rock
- Those which are part of an element or structure; a retaining wall of a building – usually a plinth – e.g. the steps of St Paul's, London
- The cantilevered kind, sometimes no more than a ladder between levels.

3.02 Design

The design and materials of steps should aim to reinforce the character of their site. However, steps constitute a formidable barrier and safety hazard for those with visual or mobility impairment. Forty-four per cent of all accidents to visually impaired people occur at level changes. Locate any unexpected level changes out of the main line of pedestrian traffic.

Never have a single step in a walkway, except for kerbs. Preferably, use flights of at least three steps; their presence should be announced conspicuously, with visual and textural warnings at the top and bottom.

3.03 Nosing and shadow line profiles

Shadow lines are often included in steps for reasons of appearance. They can be hazardous if large enough to catch the toes of pedestrians. Nosings can also catch toes unless they are rounded.

7.12 shows various nosing and shadow line profiles some of which are hazardous, particularly to disabled people, and are therefore not recommended. The nose of each step should be easy to see, not obscured by confusing surfacing patterns. Treads should be visually distant from one another. Open treads and shadow line recesses can cause tripping and should be used with discretion.

3.04 Tread/riser

The steepness of a flight of steps has a crucial influence on its character. Outdoor scale makes it difficult to have a rule for the tread/riser ratio, although some guidance can be provided. Interior standards such as given in Chapter 2 should not be used externally; steps with those ratios become precipitous when descending. Also, people tend to move faster outdoors than they do indoors.

Inherent to a particular tread–riser ratio is the ease at which the steps can be used in relation to the person's natural pace and his or her sense of rhythm, **7.13**.

In dimensionally tight situations an appropriate tread–riser ratio has to be determined that will allow a given number of steps (including landings if necessary) to fit the available space. Risers for outdoor stairways should be a minimum of 112 mm, a maximum of 175 mm.

Most examples show a more generous tread–riser than that achieved by formula. The steps to the Acropolis in Athens are 494 mm tread (going) × 173 mm rise; the Spanish Steps in Rome are 400 × 150 mm.

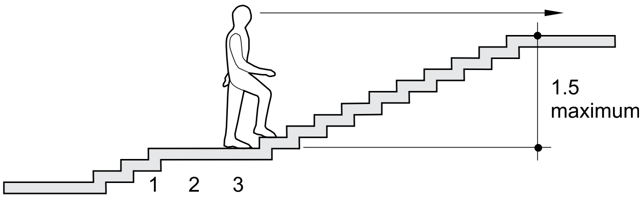
3.05 Surfacings

Textured materials are most suitable for treads as they provide a grip in wet and icy weather. It is also an advantage if they are in a lighter colour than the risers, as the nosings will contrast with their background.

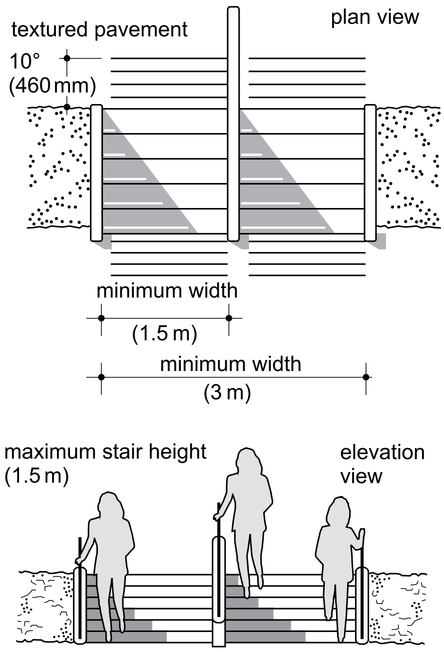
3.06 Abutments

While many steps will have no abutments, others will have one or two. In some instances they may be retaining walls, especially where treads cannot fade away into adjoining ground. Where the flight projects out from the slope or bank, the construction below the treads should be carefully considered.

3.07 Landings
Long flights of steps are frightening and exhausting. Landings should be provided after twelve to fourteen steps to provide a pause or a change of direction. The height between stairway landings is an important factor for psychological reasons as well as for human endurance. The maximum should be 1.5 m for visual coherence and invitation between adjacent levels. Lower heights are preferred **7.14** and **7.15**.



7.14 *Seeing over the landing from the bottom of the flight of steps*



7.15 *Vertical height between landings should be minimised to accommodate people with limited stamina. Note that the minimum widths do not include the wall thicknesses*

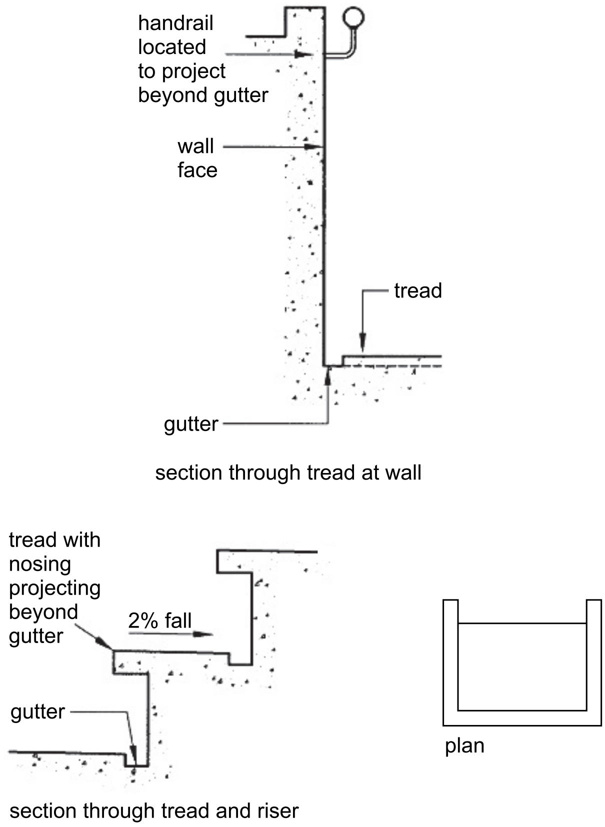
3.08 Landing widths
Landings should allow for the convenient movement of people, especially for those who need assistance negotiating steps. Except in the case of very wide steps, such as those in front of imposing buildings, they should be at least as wide in both directions as the flights they serve, and may be wider.

3.09 Drainage
Surface water must be shed off steps as quickly as possible, especially in winter, and treads should fall by at least 2 per cent. In areas of heavy rainfall a detail such as shown in **7.16** could be used.

Landings are needed to moderate the flow of water down stair flights, and should incorporate gullies.

4 RAMPS

4.01 Pedestrian ramps
These are used to allow wheeled vehicles such as trolleys, wheelchairs and buggies to change levels. The important criteria is the angle of slope, the type of surfacing and the drainage of surface water.



7.16 *In areas of heavy rainfall and/or hard frosts, the treads to a flight of steps might be given a slight backfall with tiny gutters which themselves fall to larger gutters at the flight edge*

Ramps are essential for those who use wheelchairs. The angle of slope may vary depending upon the location. A steep angle that is satisfactory for a short length will be unacceptable for a longer ramp. A zig-zag ramp which goes up a long bank needs to be almost level at its bends; otherwise the gradients on the insides of those bends will be very steep.

Ramps should have a landing at least every 9.0 m of length, **7.17**. Visual and textural indications should be provided at top and bottom.

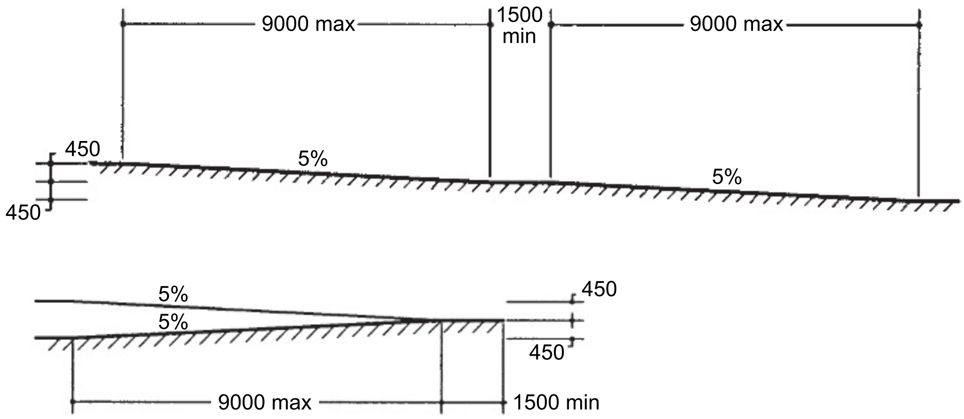
4.02 Slopes
Outdoor ramps should generally be no steeper than 5 per cent; when enclosed and protected the maximum gradient is 8.5 per cent. Dropped kerbs are an exception, 12 per cent being acceptable if the running distance less than 1 m.

4.03 Widths
These are determined according to type and intensity of use. Oneway travel requires a minimum width of 900 mm clear, whereas two-way travel needs 1500 mm, **7.18**. Where turns occur at landings adequate space for manoeuvring wheelchairs must be provided.

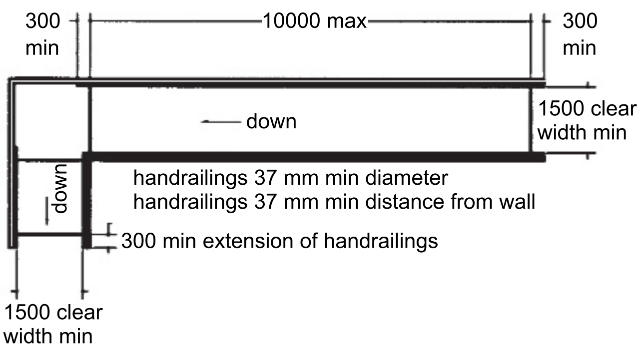
4.04 Edges
Usually one or both sides of a ramp will be higher or lower than adjacent ground. Where the side is lower than the ground, there will be a bank or a retaining wall. The base of a bank will need some form of kerbing.

Where the ramp is higher than adjacent ground, guarding will be necessary. See Section 5 of this chapter for details.

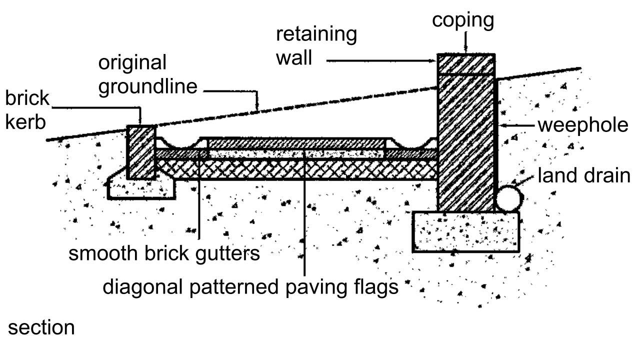
4.05 Surfacing
The surfacing of the ramp depends on its slope and location. A grassed ramp is suitable where the use is minimal and the slope is gentle as in a garden. In an urban situation with steep slopes a



7.17 *External ramps, straight and dog-leg*



7.18 *Dimensional criteria for a two-way ramp for wheelchairs. For one-way travel the minimum width is 900 mm*



7.19 *Diagonally rilled slabs can be used to pave a ramp surface. This provides grip, and rainwater drains to the side*

sealed surface of tarmac with chippings rolled in would be more appropriate. On extreme slopes bricks or blocks can be used, combined with drainage channels and gullies. A useful form of surface is shown in **7.19**.

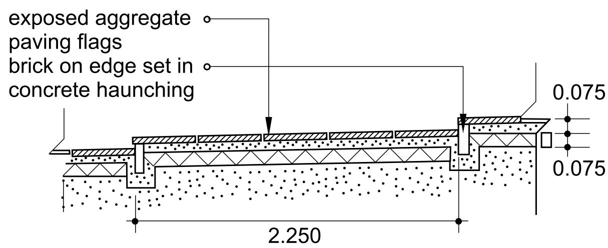
Surfacings should have grip, with low kerbs (at least 50 mm high) along the edges of ramps and landings for detection by cane.

4.06 Drainage

Unless checked, rainwater will run rapidly down a ramp: landings are used to break the flow. Gullies should be placed where they will not cause problems to people or wheels. Linear drains are helpful at the bottom of a ramp.

4.07 Ramped steps or perrons

These can be useful for long hills where a ramp would be too steep. They are not suitable for wheelchairs. 50 mm risers can be negotiated by prams and buggies. Allowing three paces on each tread (2.2 m) an overall gradient of 7 per cent can be achieved, **7.20**.



7.20 *A perron, or stepped ramp. May be used where prams, pushchairs and trolleys are expected but not suitable for most wheelchair users*

5 HANDRAILS

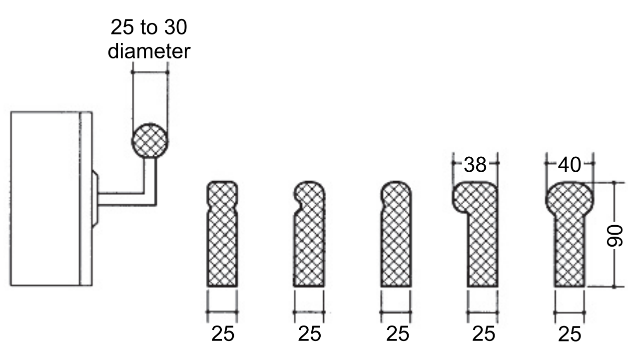
5.01

Handrails should be provided to all stairways and ramps, and may also be installed along paths to assist less mobile people. They are important for safety, for support and for guidance of those with visual difficulties.

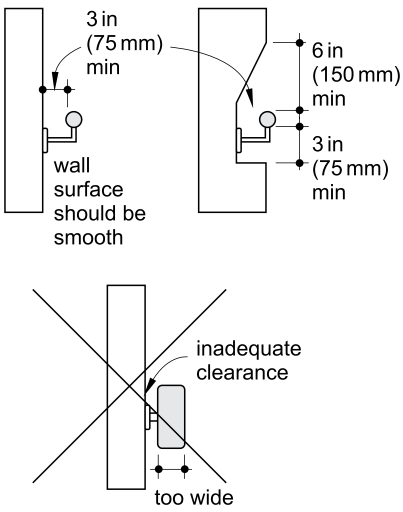
In recreational settings, ropes with periodic knots have been used as location devices enabling the visually impaired to enjoy areas and places which were previously inaccessible.

Handrails should not be an afterthought, or seen purely as a safety factor. It is preferable to provide handrails on both sides of a stairway or ramp because some people have one-sided strength. Extra-wide stairways should have centre railings no more than 6 m apart.

The ends of railings should extend beyond the top and bottom steps of stairways by 300 to 450 mm. They should be continuous across intermediate landings and should be capable of supporting 114 kg of mass. Handrails should be easy and comfortable to grip, **7.21**. There should be no sharp or protruding ends, edges or fixings. When fixed to walls they can obtrude or be inset, **7.22**.



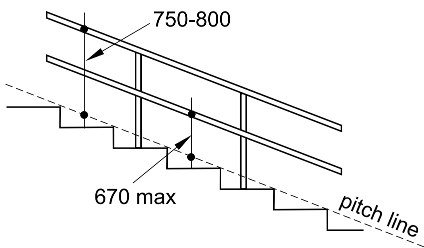
7.21 *Handrail profiles: preferred and deprecated. The preferred profiles allow a secure and comfortable natural grip*



7.22 *Fixing handrails*

5.02 Height

Handrailing heights for outdoor steps and ramps range from 750 to 850 mm, **7.23**. Below the top rail of handrailings there should be a second rail at a height of 670 mm or lower for children and for detection by cane users.



7.23 *Handrail heights*

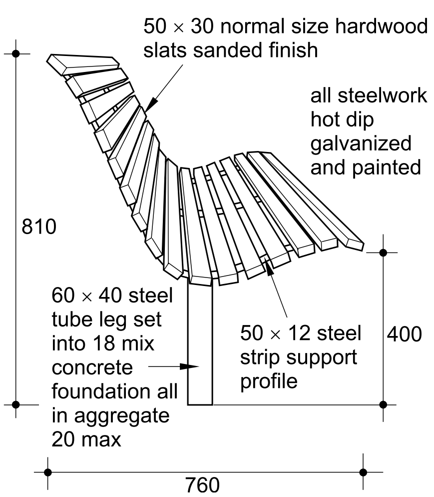
6 SEATING

6.01 Benches and other forms of outdoor seating

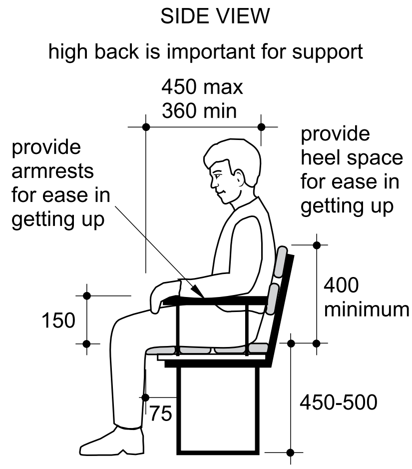
These are important. Reasons to sit vary widely, and many people find it essential to find a readily available place to rest.

The placing should be carefully considered. Avoid situations attractive to vagrants and alcoholics.

Benches should be designed for comfort. **7.24** illustrates preferred height and the seating angle for outdoor benches.



7.24 *A good park bench: from the GLC South Bank. Standard length modules 1 m, 1.5 m, 2 m, 2.5 m and 3 m. Longer lengths as special*



7.25 *Park bench seat, designed to suit people of limited strength. Armrests and heelspace are especially important*

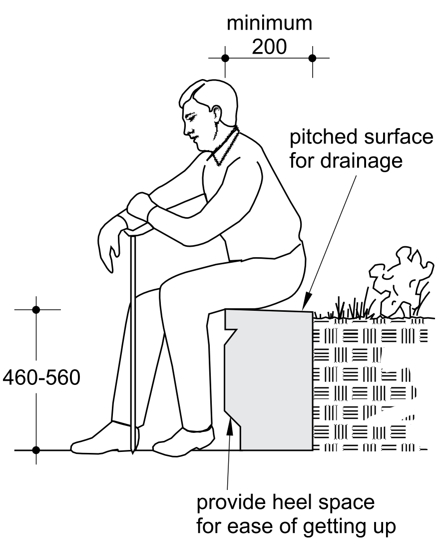
Consider the needs of elderly and disabled people. Some, for example, require armrests when getting into or out of a seated position. Heel space is necessary when rising from the seat, **7.25**.

Wheelchair users require places to stop and rest off the pedestrian flow, and somewhere to set packages. These should be adjacent to benches for their friends and carers.

Outdoor seating should be designed for easy maintenance and cleaning, and materials should resist vandalism. Surfaces should be pitched to shed water, but weep holes should not drain onto walking surfaces where wetness or ice may constitute a hazard.

6.02 Wall seating

Walls designed for sitting on are typically 400–450 mm wide, and between 350 and 550 mm in height, 400 mm being most common, **7.26**. For the elderly, a greater height is preferred.



7.26 *Wall seating. Although wall heights can vary, they should be designed for a range of users*

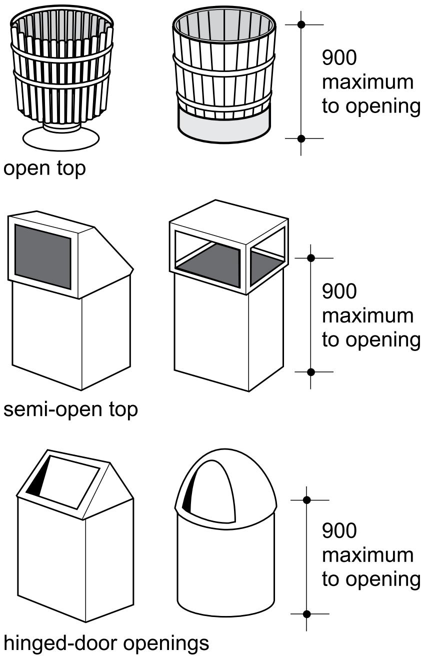
7 STREET FURNITURE

7.01

Street furniture should be carefully organised for safety and easier negotiation for those with visual impairments. Elements should be easily detectable by cane, either in themselves or by way of a hazard strip. A linear textured surface can be used to separate a zone with furniture from clear walking space.

7.02 Litter bins

Provide types that are usable by disabled people, **7.27**. Open-top varieties are the easiest but allow snow and rain to collect. Semi-open tops prevent entry of snow and rain and are relatively easy to operate. Hinged-door varieties prevent entry of snow and rain, but many people find them difficult to use.



7.27 *Litter bins*

8 BARRIERS

8.01

The purposes of barriers are

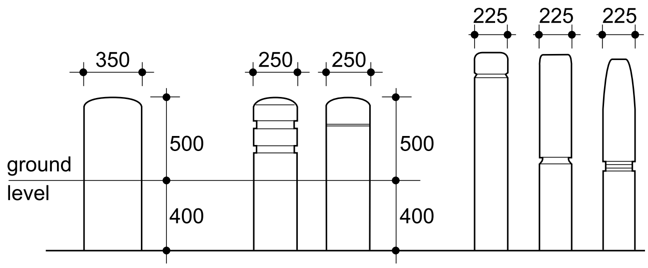
- Privacy
- Safety
- Security
- Boundary definition
- Circulation control
- Environmental modification – climate, noise, etc
- Appearance.

8.02

The type, size and the materials will largely be determined by the prime purpose (see Table I). The site and local character should influence the style, especially if it is not level. The design should also consider scale, proportion, rhythm, colour and texture. Practical matters, such as Building Regulations, accurate boundary surveys, easements, fire and safety access as well as economic factors, construction methods and maintenance, must not be overlooked.

8.03 Posts and bollards

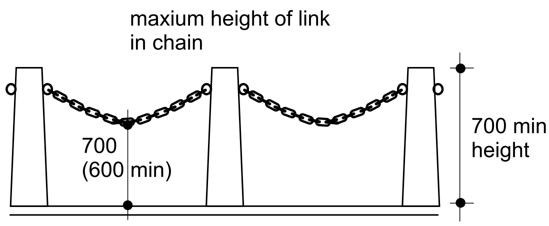
These are mainly used to prevent vehicles encroaching on pedestrian areas. They should preferably not be placed in the main line of pedestrian travel and should allow free pedestrian movement, **7.28**.



7.28 *Various styles of precast concrete bollards. Some of these can be supplied in alternatiove version with built-in lighting*

8.04 Chain barriers

These, especially when lower than 790 mm in height, are hazardous to pedestrians, cyclists, and motorcyclists since they are difficult to see, **7.29**. They are also difficult to detect by visually impaired cane users unless they are lower than 670 mm.



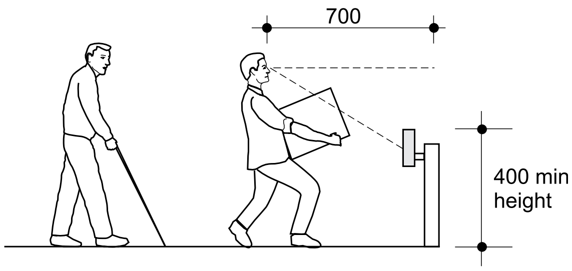
7.29 *Chain barrier*

Table I Choice of barrier related to function

Form of enclosure	Physical barrier (security)	Visual barrier (privacy)	Noise barrier	Windbreak	To define space	Durability	Climbable	Permanence	Remarks
Trees	×	✓	×	✓	✓	High	×	High	
Walls: brick, stone, concrete	✓	✓	✓ (i)	✓	✓	High	×	High	(i) If properly placed and sized
Fences: timber	✓	✓	✓ (i)	✓	✓	Low	X(ii)	Low	(i) If properly placed and sized
Fences: precast concrete with timber panels	✓	✓	✓	✓	✓	Med	X(i)	Med	(i) Depending on design
Fences: precast concrete with wires	✓	×	×	×	✓	High	✓	Med	
Metal: wrought iron and mild steel	✓	×	×	×	✓	High	X(i)	High	(i) Depending on design
Chain link and woven wire fence	✓	× (i)	×	×	✓	Med	✓ (ii)	Med	(i) Woven wire can be a directional visual barrier, e.g. glare fences on motorway (ii) Chain link if large mesh
Strained wire fence	✓	×	×	×	✓	Med	✓	Med	
Guard rails	✓ (i)	×	×	×	×	Med	✓	Low	(i) Only for the law abiding
Hedge bank	✓	× (i)	×	✓ (ii)	✓	Med	✓	Med	(i) Unless very high (ii) If high enough
Ha-ha	✓	×	×	×	×	High	✓	Low	
Cattle-grid	✓ (i)	×	×	×	×	High	×	High	(i) For animals
Hedges, shrubs	✓ (i)	✓	×	✓	✓	Med	×	Med	(ii) If spiky, e.g. hawthorn, blackthorn
Bollards	×	×	×	×	✓	High	✓	Med	

8.05 Guardrails

These can also be hazardous. They should be constructed high enough to be easily seen, but should also be designed for easy detection by those who are visually impaired, **7.30**.



7.30 *Low barriers and the hazards they present*

8.06 Fences

The various types of fences are shown in Table II and **7.31** to **7.39**. They come in small, medium and tall heights (Table III), in closed, open, ornamental and security types, and in various styles. Higher fences should be designed with wind forces in mind – a plastic-coated wire chain link is 14 per cent solid.

8.07 Walls

Walls, whether free-standing, retaining or screen, can be built *insitu* in concrete, concrete blocks, bricks, stone, timber and even metal, either on their own or in combination. Table IV and **7.40** to **7.48** list the main types.

Careful attention to detail is necessary for pleasing appearance, especially brick walls. Damp-proof courses and copings must be provided.

Heights should not exceed the safe limits given in Table V, based on the wind strength zones in **7.49**. Piers at intervals along a wall can increase its capacity to withstand wind, but staggering the wall as in **7.50** is more efficient. By this method a half-brick wall can be built up to 2.25 m high in Zone 1.

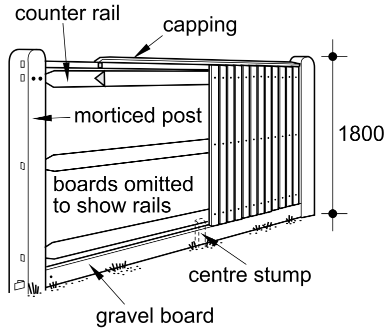
8.08 Open-screen walls

Scale, texture and pattern should decide the type of open-screen unit required. Since any large area would become boring, an open screen is usually more successful when used sparingly as a decorative element in a solid wall or in short lengths. These walls look their best when there is strong contrast of light and shade and especially when used with large foliage plants.

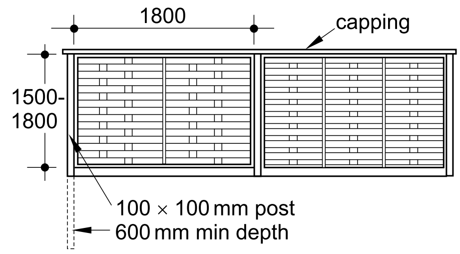
This type of walling is quite easy to erect and reinforcement is not usually necessary. Concrete blocks are available in several standard designs, but in general they are approximately 300 mm square, and 90 mm thick.

8.09 Stone walls

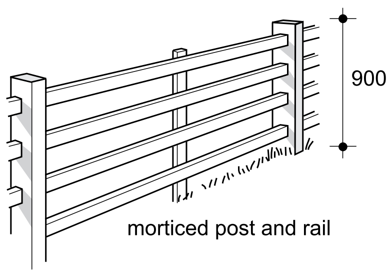
The two basic methods of stone wall construction are dry wall and mortar-laid. Dry stone walls have no mortar, the stones are irregular in shape, and the stones are laid flat. Mortar-laid stone walls have continuous footings (and therefore are stronger and can be higher) and require fewer stones than dry walls.



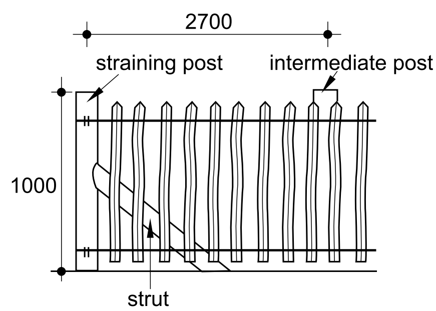
7.31 *Close boarded fence with capping and gravel board*



7.32 *Woven wood fence*



7.33 *Morticed post and rail fence*



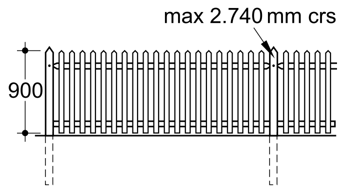
7.34 *Fence of chestnut palings supported on straining and intermediate posts*

Stonework patterns

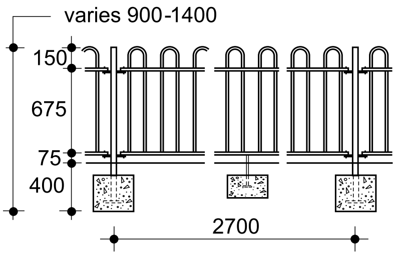
Stonework can be random rubble or ashlar. The former has the stone as found, or cut by the mason in the field, while for the latter the stones are pre-cut and dressed before delivery to the site. Stones for a wall should be similar in size, or, if in a variety of shapes and sizes, should be evenly distributed to give a balanced appearance to the wall.

Table II Fencing

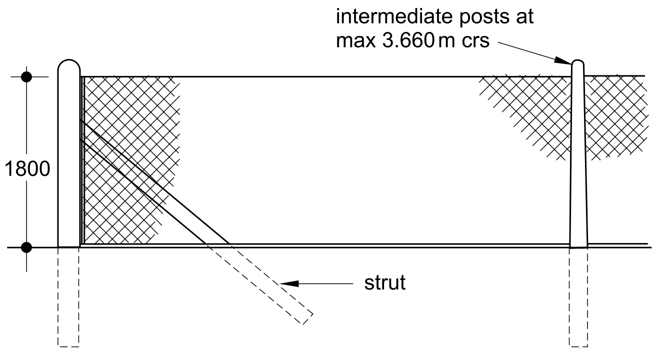
Material style	Timber		Metal		
	Closed	**Open**	**Ornamental**	**Security**	**Open**
	Close boarded **7.31** Woven panels **7.32**	Post and rail **7.33** Chestnut pale **7.34** Palisade/picket **7.35**	Steel bar railings **7.36**	Chain link **7.37** Steel palisade **7.38**	Post and wire **7.39**



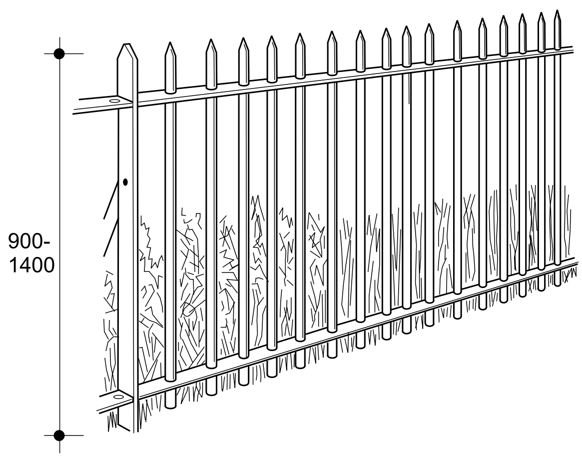
7.35 *Timber palisade fence*



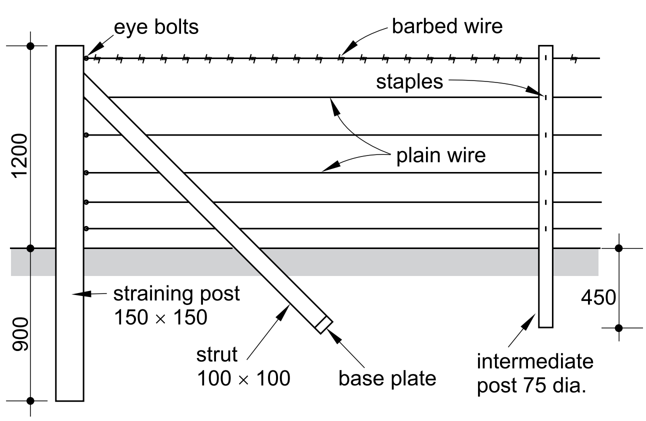
7.36 *Mild steel railings, hairpin top*



7.37 *Chain link fencing on precast concrete posts*



7.38 *Pointed top round bar fencing*



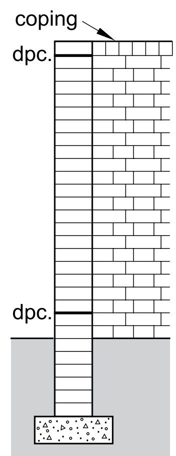
7.39 *Strained wire fence, end and corner posts braced*

Table III Heights of fencing

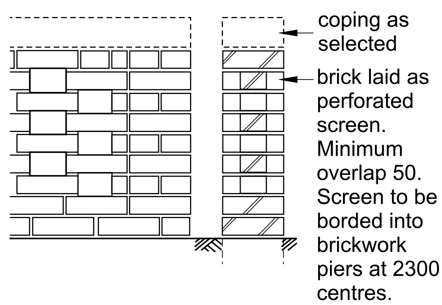
Type	Height in (m)
House garden fronts and divisions	0.9
Minimum for children's playgrounds; general agricultural	1.2
House gardens; playing fields; recreation grounds; highways; railways	1.5–1.8
Commercial property	1.8
Industrial security fencing	2.1

Table IV Walls

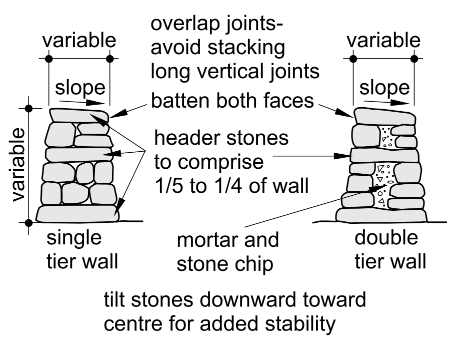
Material	Solid	Screen
Brick	**7.40**	**7.41**
Stone	Drystone **7.42** Random rubble **7.43** Ashlar **7.44**	Not common
Concrete block	**7.45**	**7.46**
Composite	Stone hedge **7.47**	Ha-ha **7.48**



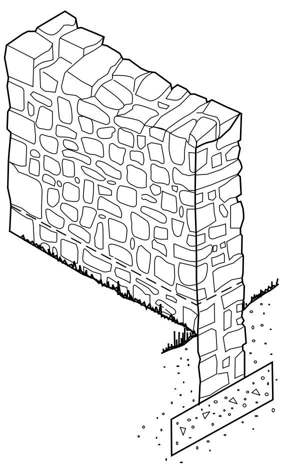
7.40 *Brick wall (showing various bonds and pointing details)*



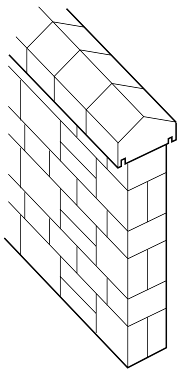
7.41 *Brick perforated screen wall*



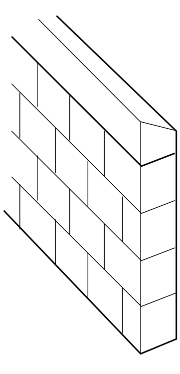
7.42 *Drystone wall*



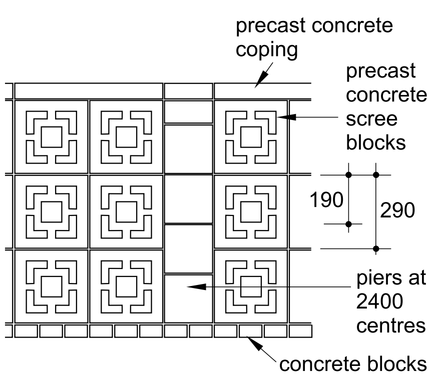
7.43 *Random rubble stone wall*



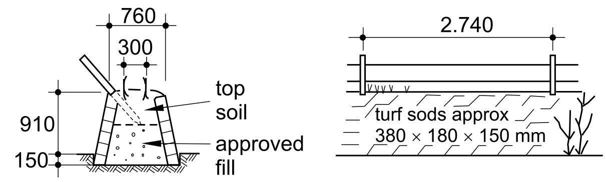
7.44 *Ashlar stone wall*



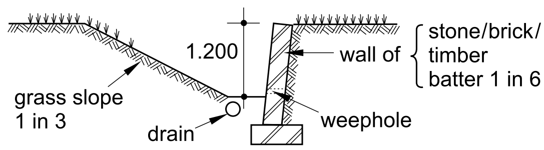
7.45 *Concrete block wall*



7.46 *Perforated concrete block screen wall*



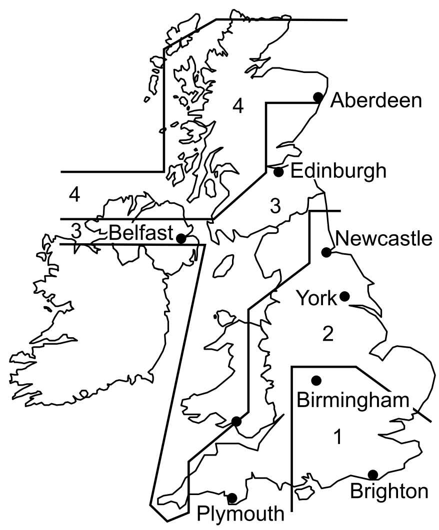
7.47 *Hedge bank, appropriate in a rural context*



7.48 *Ha-ha*

Table V Heights of masonry garden walls (from DoE leaflet Your garden walls)

Zone →	Maximum height (mm)			
Wall type and thickness ↓	1	2	3	4
Half brick (104 mm)	525	450	400	375
One brick (220 mm)	1450	1300	1175	1075
One and a half brick (330 mm)	2400	2175	2000	1825
100 mm block	450	400	350	325
200 mm block	1050	925	850	775
300 mm block	2000	1825	1650	1525



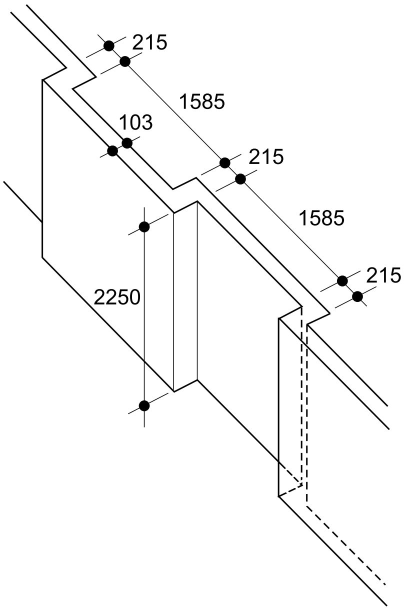
7.49 *Map of the United Kingdom showing zones for design of garden walls*

Styles

The British Isles is fortunate in having a variety of styles for stone walls based upon geographical regions. For new walls it is best to retain the local character.

8.10 Stone and hedge banks

Stone hedges are built with two faces of battered rubble stonework bedded on thin grass sods, with the centre filled with rammed earth. With time a stone hedge disappears behind naturalising vegetation. The construction of a hedge bank follows the same principle as a stone hedge but using turf instead of stone to form the faces. This limits height and so a simple post and wire fence is often incorporated when stock has to be contained.



7.50 *Staggered brick wall*

8.11 Ha-has

These are useful devices for separating formal gardens from livestock without a visual barrier, using a retaining wall in stone, brick or timber with a link batter and the opposite ground graded to a 33 per cent slope.

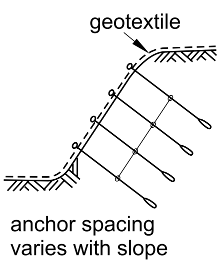
9 RETAINING WALLS

9.01

These are used to make an abrupt change of level where there is insufficient room for a slope. Table V shows the principal types. In general they require careful structural design combined with an efficient drainage system.

9.02 Reinforced earth

This is a recent innovation consisting of a geotextile membrane tied back into the soil with anchors, **7.51**.



7.51 *Reinforced earth retaining structure*

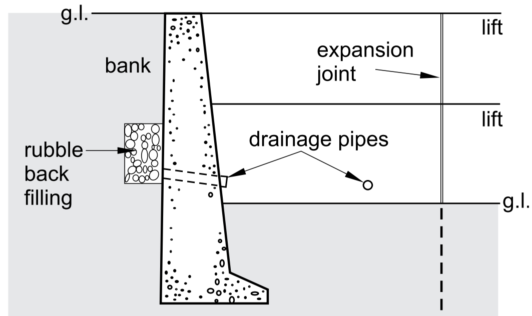
9.03 Masonry

Masonry structures for retaining ground can be constructed in many materials, both on their own or reinforced with steel bars:

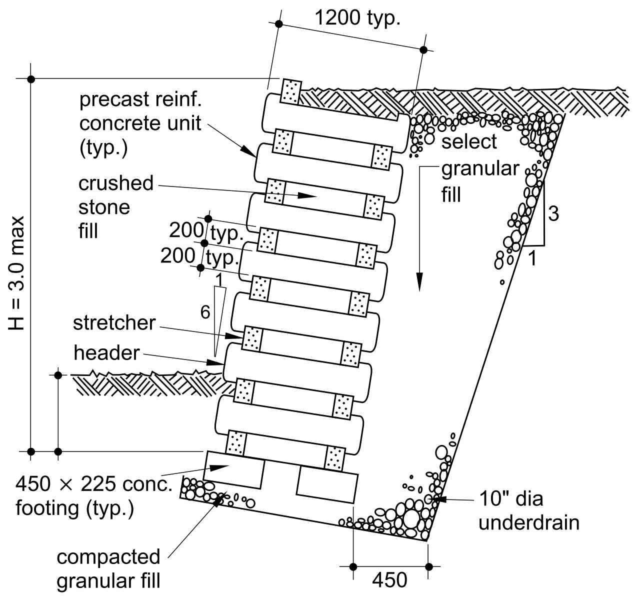
- In-situ concrete, **7.52**
- Concrete blocks
- Precast concrete
- Brickwork
- Natural stone.

9.04 Concrete crib

This is constructed of precast reinforced concrete units laid in interlocking stretchers and headers to form vertical bins which are filled with crushed stone or other granular material, **7.53**.



7.52 *Mass concrete retaining wall. Note rubble backfill and through pipes to facilitate drainage. Failure can occur if water pressure is allowed to build up behind the wall*

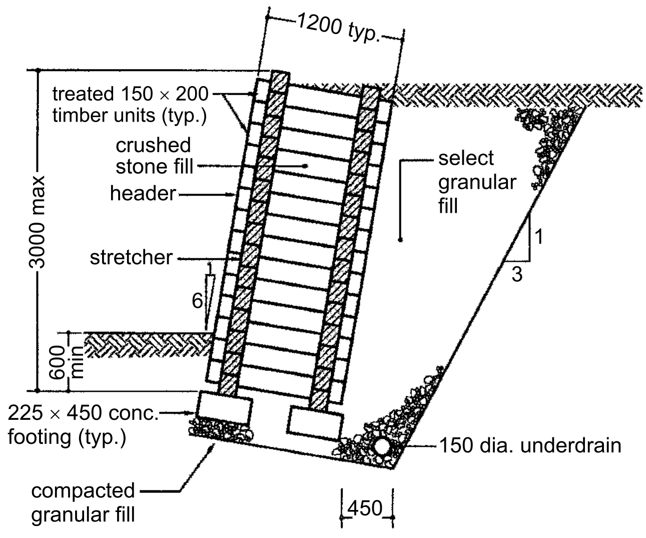


7.53 *Precast concrete crib wall*

They are a particularly utilitarian solution for retaining fills in situations where excavation is not necessary. Reinforced projecting lugs on the headers are typically used to lock the headers and stretchers together.

9.05 Timber crib

Crib walls may be built of timber when a more natural appearance of wood is desired, **7.54**. All units should be pressure-treated with a



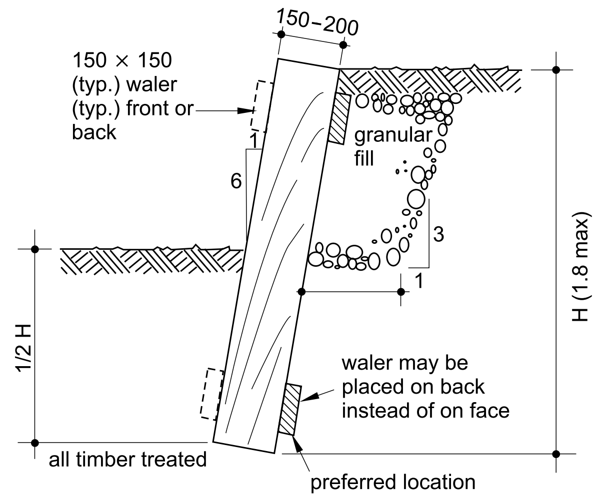
7.54 *Timber crib wall*

preservative. Used railway sleepers were commonly used in early crib wall construction and continue to be employed for low walls. However, timber units cut to size and pressure-treated with copper salts or other non-bleeding preservatives are now widely available.

9.06 Timber

Retaining walls can be constructed using timbers driven into the ground, **7.55**. Since the wall's resistance to overturning depends upon one-half of its height being below finished level, it is often not economical or practical to use this type for retained heights greater than 1.5 m. The timber units in the horizontal wall can be of variable lengths over 1.5 m. The retained height should be less than 10 times the thickness of the timbers, and at least 50 per cent of their overall length should be buried below the lower ground level in average soil.

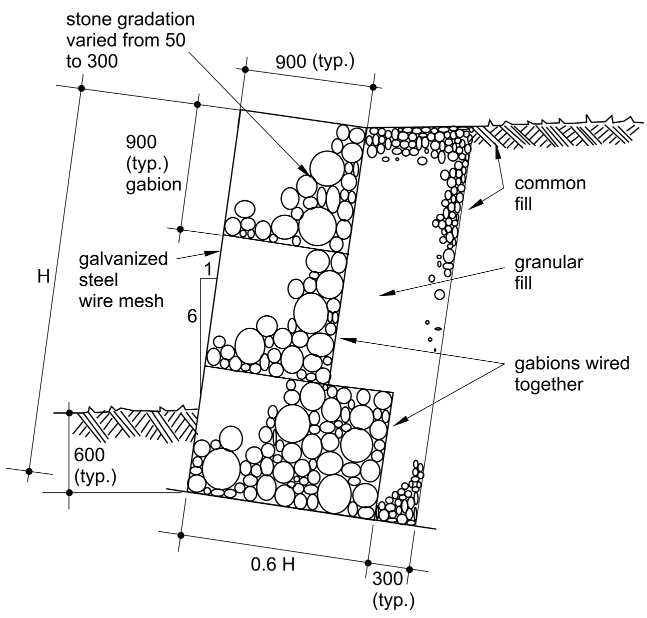
A structural engineer will need to be consulted.



7.55 *Timber retaining walls of vertical railway sleepers*

9.07 Gabions

Gabions are rectangular baskets in standard sizes made of galvanised steel wire or polyvinyl-coated (PVC) wire hexagonal mesh which are filled with stone and tied together to form a wall. Each gabion has a lid and is sub-divided into 1 m cells. After being filled with stone, the lid is closed and laced to the top edges of the gabion. Each gabion is then laced to the adjacent gabions, **7.56**.



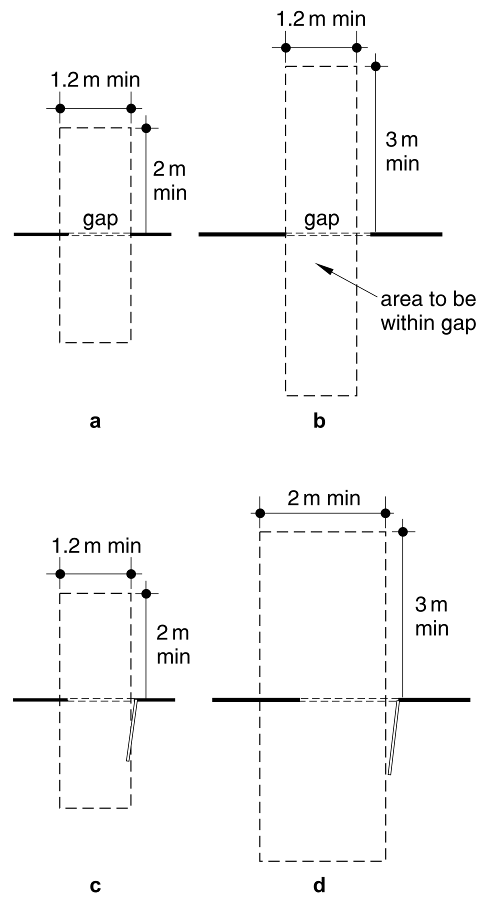
7.56 *Gabion wall*

Gabion walls, being flexible, can adapt to ground settlement. Their permeability allows water to drain through, making gabions especially suitable along stream and river banks where variations in water depths occur between flood and dry weather conditions. Volunteer vegetation establishes itself quickly in gabions, softening the structure's appearance in the landscape while also adding durability.

10 GATES AND DOORS

10.01

An increased awareness of the needs of disabled people has led to the need for consideration as to whether a landscape area can reasonably be made accessible, for example, to wheelchair users. A forthcoming revision of BS 5709 will incorporate new requirements. Gaps and gates should conform to the minimum dimensions in **7.57**.



7.57 *Minimum dimensions for gaps and gates. Latches, where fitted should be accessible from each side and at a height suitable for both mounted and unmounted users.* **a** *gap in pedestrian footpath,* **b** *gap in bridleway,* **c** *gate in pedestrain footpath,* **d** *gate in bridleway*

10.02

A gate must relate to the wall or fence in which it is placed, and state visually that there is an entrance or exit. Its construction and the supporting posts must be robust enough to withstand the effects of gravity and use, and it must be convenient to open and close.

10.03 Width

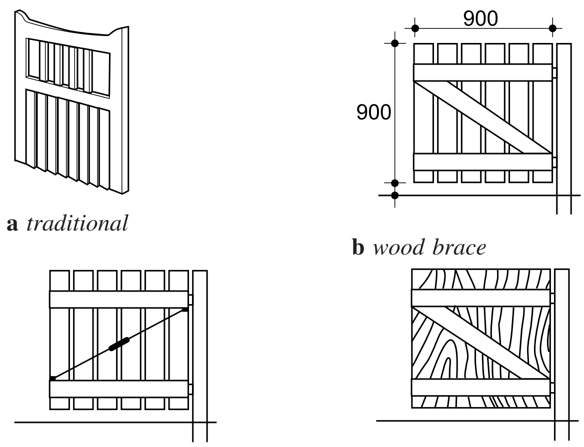
The appropriate width for a gate, or combination of gates, will be partially a matter of appearance and partially a matter of functional necessity: it must be wide enough for any vehicle needing to use it. A gate which, due to functional necessity, has to be large will also have a degree of presence, even if that function is relatively humble.

Table VI gives some minimal dimensions for the passage of people and vehicles. These dimensions will allow people and vehicles to pass through a gate and each other. Clearance is not necessarily simply between gate posts – the open gate may, itself, occupy some of the available space. The dimensions assume straight travel but if a vehicle is also negotiating a bend, then widths will need to be greater.

7.58 to **7.64** show gate designs of different sizes and in various materials.

Table VI Widths of gates

Passing	Width (mm)
One person	600
Pram, pushchair, bicycle	800
Two people (just)	900
Wheelchair	1000
Pram or pushchair plus a walking child	1150
Two people (comfortably)	1200
Two wheelchairs or prams	1700
Small or medium car	2100
Large car, ambulance, medium van, small or medium tractor	2400
Car and bicycle, large tractor	3000
Fire engine, dustcart, lorry	3600
Two cars to pass (just)	4100
Combine harvester, two cars (comfortably), car and lorry (just)	4800
Any (normal) combination of two vehicles	5500



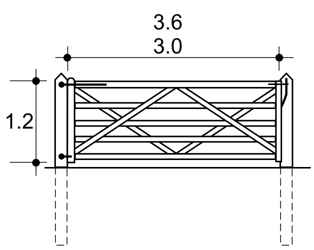
a *traditional*

b *wood brace*

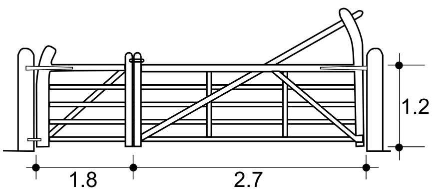
c *steel rod/wire with turnbuckle*

d *plywood panel*

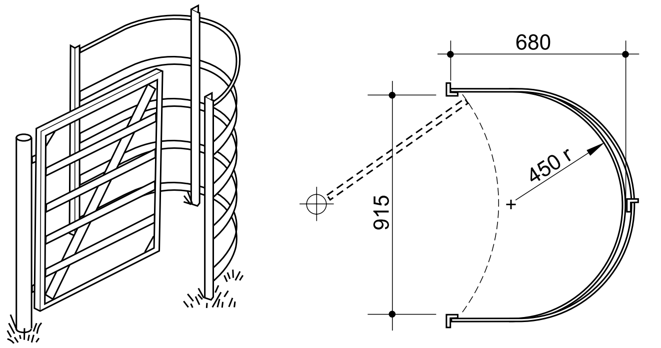
7.58 *Single garden gates*



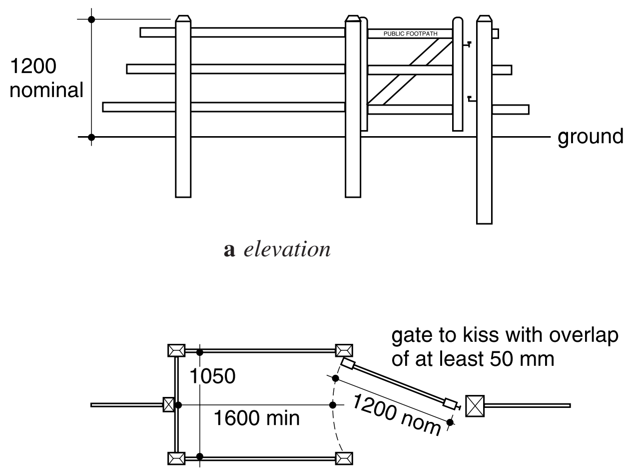
7.59 *Farm type gate*



7.60 *Single and double farm gates*



7.61 *Steel bow kissing gate*



a *elevation*

b *plan*

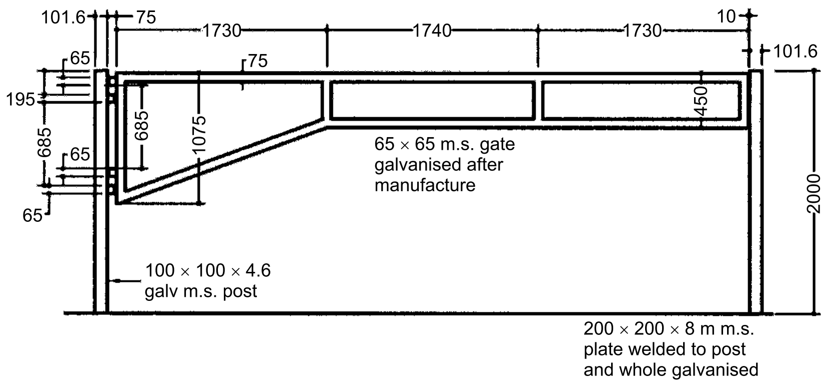
7.62 *Kissing gate usable by a wheelchair. This type will also pass prams and pushchairs. However, there may be a problem with bicycles also using it*

11 CHILDREN'S PLAY EQUIPMENT

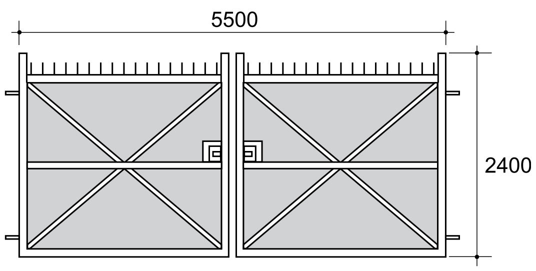
11.01

There are now many suppliers of play equipment whose design and appearance has changed dramatically over the last ten years. However, what has not changed is the need for the safety of children playing around the equipment.

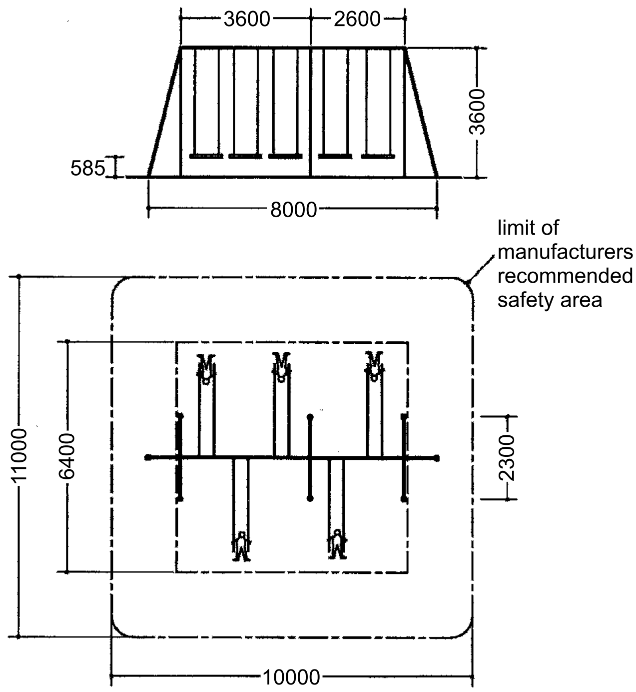
7.65 to **7.69** show the distances required for safety around conventional equipment. All equipment should have impact-absorbing surfaces wherever a child can fall. To a small child, falling on its head a distance of no more than 150 mm can be fatal. There are a



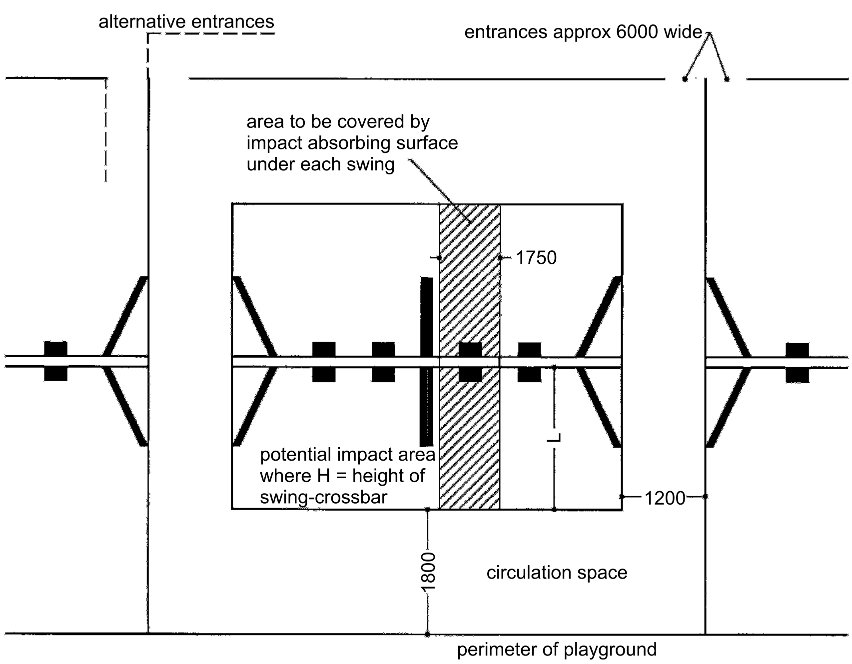
7.63 *Medium-duty car park barrier gate*



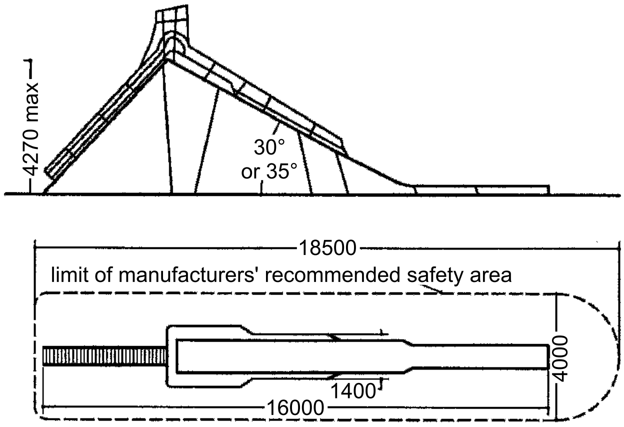
7.64 *Angle framed gates with spiked top*



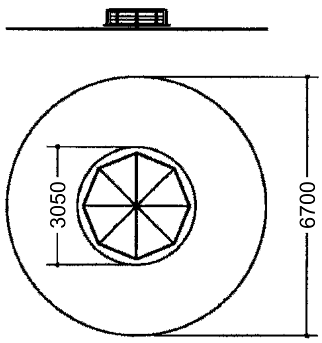
7.66 *Arrangement of full-size swing in a park. Smaller sizes are common*



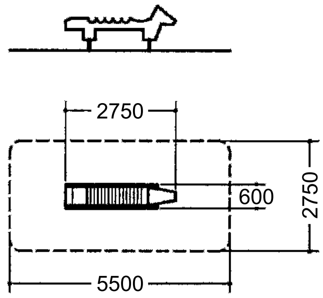
7.65 *Arrangement of barriers and impact absorbing surface for children's swings. $L = (0.866 \times \text{distance from swing pivot to swing seat}) + 1.75$*



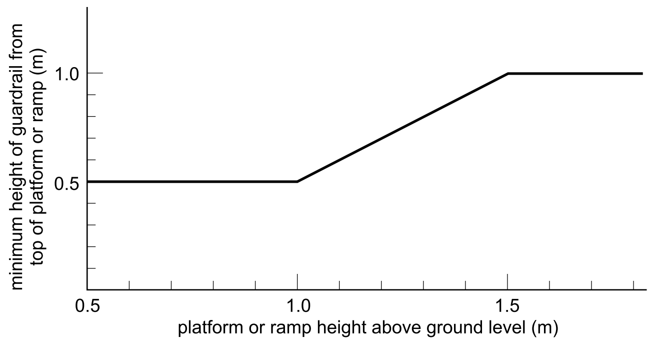
7.67 *Large slide for park. These are now normally installed on an earth mound to reduce the risk of falls*



7.68 *Roundabout*



7.69 *Rocking horse. Only safe designs of this device may now be used*



7.70 *Heights of guardrails for children's play equipment*

variety of impact-absorbing surfaces available, including loose materials, foam rubbers, etc., but each has disadvantages. Many are subject to damage by deliberate vandalism, some are prone to fouling.

Wherever possible, guardrails should be provided even where an impact-absorbing surface is used. **7.70** gives the recommended heights of such guardrails.

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8 Houses and flats

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KEY POINTS:
- *Low space standards lead to dissatisfaction, and*
- *Accommodation has to be tailored to numbers and characteristics of expected residents*

Contents

1 INTRODUCTION

1.01 Housing standards

Governments have made a number of attempts during this century to influence or impose standards in housing. The Tudor Walters Report of 1918 and the Dudley Report in 1944 reflected the ‘homes fit for heroes’ feeling of social optimism following each world war.

In 1961 the report ‘Homes for Today and Tomorrow’ was published by the Parker Morris Committee of the Ministry of Housing and Local Government (MHLG). The standards in this report, which have subsequently become universally known as Parker Morris Standards, were imposed as mandatory on local authority housing in 1967 and were converted to metric in 1968. They ceased to be mandatory in 1981.

It was the hope of the Parker Morris (PM) Committee that their standards would apply to all housing, whether publicly or privately funded. However, although the standards become the minimum for, initially, all local authority and, later, all housing association new-build schemes, the private sector remained aloof.

1.02 Public and private sector housing

In Britain, as in many other countries, housing is divided into privately and publicly funded sectors. In the early years of the century, the new local authorities increasingly took over from charitable foundations (such as the Peabody and Guinness Trusts) the provision of *social housing*. Such housing was promoted to keep the poor out of insanitary slums or even off the streets.

The growth of municipal housing became such that in some urban boroughs most of the housing was in their ownership. This has been reversed in the last twenty years by a number of government measures: *right-to-buy*, restriction of LA expenditure, and by the growth (or regrowth) of charitable Housing Associations (HAs), funded and subsidised through the Housing Corporation (HC). There is now an accelerating trend for local authorities to transfer some, or even all, of their stock to HAs, or other ‘Registered Social Landlords’.

While the privately funded sector used to be geared to the provision of housing for rent, it now almost exclusively provides for purchase through mortages, mainly from the banks and building societies. With the volatility of interest rates, the level of affordable payments is crucial for most of its customers; there is a therefore a tendency for standards in the ‘spec housing’ market to be cut to the bone.

There has until recently been a constant demand for small ‘starter homes’ – both flats and houses – at affordable prices. This reflects the demographic changes this century: household sizes have fallen dramatically, but the numbers of independent households have exploded; partly due to the steady growth of failed marriages and partnerships. Later, some of these initially small households, when they have more money, and perhaps a family, are able to sell and buy somewhere bigger. This may be a large, older house; or it may be one of the superior quality speculative houses that some developers are building at or even above PM standards. It is uncertain whether the demand for starter homes will continue. In some cases they have been found difficult to sell when the original owners have required more space. Even people living on their own are beginning to demand more generous accommodation.

The public sector is very different. It is a baleful symptom of the two very distinct systems of providing housing in the UK that tenants of social housing have less choice in their dwellings. Also, once the household is accommodated, their ability to move home is limited. Often the only opportunity is likely to be a mutual swap with another household. Clearly this does not happen very often, so the tenant is likely to be in his or her flat or house for a long time. Babies may be born, children may grow up, grannies may die, but the harassed LA Housing Department or small Housing Association Management Team is unlikely to have a larger (or smaller), dwelling coming available for a requested transfer. This is the argument for ensuring especially in the publicly funded sector that reasonable standards are maintained.

People must have the room to settle satisfactorily into what is likely to be their long-term home. Since 1981 the Parker Morris standards are no longer mandatory for new-build schemes. The Housing Corporation does not lay down space standards, preferring to leave these to the experience and judgement of the housing associations, and to their architects.

Instead, the HC funds HA schemes according to its Total Cost Indicators (TCI), which lays down cost allowances based upon 5 m^2 increment bands. These bands (see Table I) are related to probable occupancies, but these are also very broad and approximate, so that the bands vary from well below to well above PM dwelling sizes. The use of HC *TCI space standards* does not therefore mean that housing associations can no longer build to PM standards, as is sometimes suggested. Larger dwelling plans tend to attract greater cost allowances (but higher rents can then follow).

1.03 Housing for different users

A significant proportion of the population is disabled in some way. While many of these people are able to cope in normal dwellings, other people such as those in wheelchairs require substantial modifications to enable them to live satisfactorily. Housing to *special needs* standards is now being built, both for *mobility* and more onerous *wheelchair* use. Housing not specifically designed for people with disabilities is known as *general needs* housing. The new 1999 Part M of the Building Regulations extended the requirements for disabled access to all new dwellings, although the requirements do not go as far as those for wheelchair using residents.

1.04 Parker Morris standards

For the reasons given above, it is important that public sector housing, at least, is not allowed to slip below the standards that

Table I Housing Corporation floor area bands, for use with Total Cost Indicators (1998)

NB: Probable occupancies in persons are noted, but this table is *not* intended to be used as a guide to appropriate floor areas for households of given numbers. It includes accommodation for frail and elderly.

Dwelling floor area	Probable occupancy
Up to 25 m^2	1 person
Exceeding 25 m^2 and not exceeding 30 m^2	1 person
Exceeding 30 m^2 and not exceeding 35 m^2	1 and 2 persons
Exceeding 35 m^2 and not exceeding 40 m^2	1 and 2 persons
Exceeding 40 m^2 and not exceeding 45 m^2	2 persons
Exceeding 45 m^2 and not exceeding 50 m^2	2 persons
Exceeding 50 m^2 and not exceeding 55 m^2	2 and 3 persons
Exceeding 55 m^2 and not exceeding 60 m^2	2 and 3 persons
Exceeding 60 m^2 and not exceeding 65 m^2	3 and 4 persons
Exceeding 65 m^2 and not exceeding 70 m^2	3 and 4 persons
Exceeding 70 m^2 and not exceeding 75 m^2	3, 4 and 5 persons
Exceeding 75 m^2 and not exceeding 80 m^2	3, 4 and 5 persons
Exceeding 80 m^2 and not exceeding 85 m^2	4, 5 and 6 persons
Exceeding 85 m^2 and not exceeding 90 m^2	4, 5 and 6 persons
Exceeding 90 m^2 and not exceeding 95 m^2	5 and 6 persons
Exceeding 95 m^2 and not exceeding 100 m^2	5 and 6 persons
Exceeding 100 m^2 and not exceeding 105 m^2	6 and 7 persons
Exceeding 105 m^2 and not exceeding 110 m^2	6 and 7 persons
Exceeding 110 m^2 and not exceeding 115 m^2	6, 7 and 8 persons
Exceeding 115 m^2 and not exceeding 120 m^2	6, 7 and 8 persons

Table II Parker Morris minimum floor areas (square metres) (mandatory for publicly funded housing from 1967 to 1981)

		Number of person (i.e. bedspaces)						
		1	2	3	4	5	6	7
HOUSES								
1 storey	N	30	44.5	57	67	75.5	84	–
	S	3	4.0	4	4.5	4.5	4.5	–
	Total	33	48.5	61	71.5	80	88.5	–
2 storey	N	–	–	–	72	82	92.5	108
(semi or end	S	–	–	–	4.5	4.5	4.5	6.5
terrace)	Total	–	–	–	76.5	86.5	97	114.5
2 storey	N	–	–	–	74.5	85	92.5	108
(intermediate	S	–	–	–	4.5	4.5	4.5	6.5
terrace)	Total	–	–	–	79	89.5	97	114.5
3 storey	N	–	–	–	–	94	98	112
(excluding	S	–	–	–	–	4.5	4.56	6.5
garage if built-in)	Total	–	–	–	–	98.5	102.5	118.5
FLATS	N	30	44.5	57	70	79	86.5	–
	S	2.5	3.0	3	3.5	3.5	3.5	–
	Total	32.5	47.5	60	73.5	82.5	90	–
MAISONETTES	N	–	–	–	72	82	92.5	108
	S	–	–	–	3.5	3.5	3.5	3.5
	Total	–	–	–	75.5	85.5	96	111.5

Net space is the area enclosed by the walls of the dwelling, measured to unfinished faces, including the area occupied in every floor by staircases, partitions, chimney breasts, flues and heating appliances. It excludes the area of general storage space, dustbin stores, fuel stores, garages, balconies, areas with sloping ceilings below 1.5 m height, and porches or lobbies open to the air.

General storage space should be provided in addition to the net space. It excludes the areas of dustbin stores, fuel stores, pram space, and, in a single-access house, any space within a store required as access from one side of the house to the other (taken as 700 mm wide).

In houses, at least 2.5 m^2 should be at ground level, and on upper floors it should be separated from linen or bedroom cupboards or wardrobes. If there is an integral or adjoining garage, any area over 12.0 m^2 can count as general storage space.

In flats and maisonettes no more than 1.5 m^2 may be outside the dwelling (e.g. in a lockable store off a common area) and, if there is an integral or adjoining garage, any area over 12.0 m^2 can count towards the 1.5 m^2.

Fuel storage is excluded from the table. If it is needed, then the following areas should be provided in addition to Net space and General storage space:

For houses	1.5 m^2 if there is only one appliance
	2.0 m^2 if there are two appliances or in rural areas
For flats and maisonettes	1.0 m^2 if there is no auxiliary storage

N = Net space
S = General storage space

came to be accepted as reasonable during the period when Parker Morris ruled by statute. Research into housing built to PM standards has shown that, while there may be much wrong with other aspects of estate design, such as the confused and insecure arrangement of external spaces, there is usually a good level of satisfaction with the internal layout and space standards. And, conversely, where public sector housing has been designed to lower than PM standards, or where PM housing has been over-occupied, the tenants have responded by consistently expressing dissatisfaction.

This edition of the *Metric Handbook* therefore continues to include the essential parts of the Parker Morris standards as its basic minimum recommendations. These recommendations start with the areas of net floor space and general storage space, given in Table II. Other important recommendations included by Parker Morris are integrated into the following subsections of this chapter.

It should be stressed that Parker Morris did *not* lay down minimum areas for *rooms*. The report simply stated that the dwelling had to be furnishable with a specified amount of furniture (Table III) which had to be shown on the plans. It also required reasonable storage space, and this has proved to be a popular and successful feature of Parker Morris housing.

1.05 Room area standards

In the housing association sector an additional set of space standards has come to be widely accepted for the minimum sizes of individual rooms. These are quite commonly but erroneously referred to as 'Parker Morris'. As stated above, the PM committee went out of their way to avoid being prescriptive about individual rooms. The origin of these figures given in the table of room areas (Table IV) is understood to have been the Greater London Council, which funded many housing association projects in the capital in the 1970s and early 1980s. They were particularly applied to refurbishment or rehabilitation projects, to which Parker Morris standards were never mandatorily applied.

Since the demise of Parker Morris as statutory minima, these room sizes have been increasingly seen as reasonable minimum design standards for social housing; many housing associations now include them in their briefing documents to architects. It is our opinion that these should be taken as *absolute minima* for public sector houses and flats. In addition, if total dwelling areas are based on PM standards, these room sizes can be exceeded. Some London boroughs have included these minimum room areas in the standards sections of their Unitary Development Plans, published in the early 1990s, as minima which must be achieved in any housing schemes, public or private, for which planning approval is being sought. This is potentially controversial, as it is debatable whether planning authorities have the power under Town and Country Planning Acts to lay down minimum space standards. Private developers have a long tradition of resisting space standards imposed other than by the market.

1.06 Room-by-room commentary on room area standards

Table IV, in addition to these minimum standards, gives recommended areas based on experience, the Housing Corporation's lists of required furniture.

- *Living rooms*: Provided a proper dining kitchen is included, the sizes given in the 'absolute minimum' table can be acceptable. We give guidance under 'recommended' for preferable room areas, where this is possible.
- *Kitchens*: These are no longer places solely for the preparation of food and washing up. Most households now spend a considerable time in their kitchens, and they tend increasingly to be treated as living rooms. Just watch one episode of a TV soap opera! We do not therefore recommend galley kitchens as normally appropriate except in single-bedroom dwellings. The minimum sizes recommended for dining kitchens are reasonable, however.

Table III Parker Morris standards for fittings and space for furniture (mandatory for publicly funded housing from 1967 to 1981)

1 WCs and washbasins
(a) 1–2-and 3-person dwellings: 1 WC (may be in bathroom)
(b) 4-person houses and maisonettes, and 5-person flats and single-storey houses: 1 WC in a separate compartment
(c) 5-or more person houses and maisonettes, and 6-or more person flats and single-storey houses: 2 WCs (1 may be in bathroom)

(PM also required a separate WC to have a washbasin; this is now required under Building Regulations)

2 Linen storage (not counting as general storage space)
(a) 1–2-or 3-person dwelling: $0.4\,m^3$
(b) 4-or more person dwelling: $0.6\,m^3$

3 Kitchen fitments
(a) 1-or 2-person dwellings: $1.7\,m^3$
(b) 3-or more person dwelling: $2.3\,m^3$

including ventilated 'cool' cupboard (now less relevant) and broom cupboard (need be in kitchen). Standard fittings measured overall for depth and width, and from underside worktop to top of plinth for height.

Kitchens should provide an unbroken sequence: worktop/cooker position/worktop/sink/worktop

4 Electric socket outlets

(a) Working area of kitchen	4
(b) Dining area	1
(c) Living area	3
(d) Bedroom	2
(e) Hall or landing	1
(f) Bedsitting room in family dwelling	3
(g) Bedsitting room in 1 person dwelling	5
(h) Integral or attached garage	1
(i) Walk-in general store (in house only)	1

(These standards would now be considered low, but would be roughly appropriate if each number represented a double socket)

5 Space heating
Minimum installation should be able to maintain kitchen and circulation spaces at 13°C, and living and dining areas at 18°C, when outside temperature is –1°C.

(This standard would now be considered far too low, and all new and refurbished general needs housing should be able to be maintained at 18°C, with 21°C for day rooms, when outside temperature is –1°C.)

6 Furniture
All plans should be able to show the following furniture satisfactorily accommodated:

(a) *Kitchen:*	a small table, unless one is built in
(b) *Dining area:*	dining table and chairs
(c) *Living area:*	2 or 3 easy chairs a settee a TV set small tables reasonable quantity of other possessions such as radiogram (sic) and bookcase
(d) *Single bedroom:*	bed or divan 2000 × 900 mm bedside table chest of drawers wardrobe, or space for cupboard to be built in
(e) *Main bedroom:*	double bed 2000 × 1500 mm or, where possible: 2 single beds* 2000 × 900 mm as alternative bedside tables chest of drawers double wardrobe or space for cupboard to be built in dressing table
(f) *Other double bedrooms:*	2 single beds 2000 × 900 mm each bedside tables chest of drawers double wardrobe or space for cupboard to be built in** small dressing table

* Where single beds are shown, they may abut, or where alongside walls should have 750 mm between them.
** May be outside the room if easily accessible.

Table IV Room sizes, minimum and recommended (see text, areas in m^2)

Number of residents	1	2	3	4	5	6	7
Living room in a dwelling with a dining kitchen							
recommended	11	12	13	14	15	16	17
minimum	11	12	13	14	15	16	17
Living room in a dwelling with a galley kitchen							
recommended	14	15.5	17	18.5	20	21	22
minimum	13	14	15	16	17.5	18.5	19.5
Dining kitchen							
recommended	9	10	11	12.5	13.5	15	16
minimum	8	9	10	11	12	13	14
Galley kitchen							
recommended	5.5	6.5	7	8	9	10	11
minimum	5.5	5.5	5.5	7	7	7	9
Main bedroom (double)							
recommended	9	12	12	12	12	12	12
minimum	8	11	11	11	11	11	11
Other double bedrooms							
recommended	–	–	–	12	12	12	12
minimum	–	–	–	10	10	10	10
Single bedrooms							
recommended	–	*9	8	8	8	8	8
minimum	–	*8	6.5	6.5	6.5	6.5	6.5

* A flat for two single people should have two single bedrooms of recommended $9\,m^2$, minimum $8\,m^2$ each.
Notes: 'Minimum' room areas shown are those commonly required in social housing. They are sometimes but erroneously referred to as 'Parker Morris' room areas. PM in fact made a point of *not* laying down requirements for room areas. 'Recommended' room areas are shown as guidance for better provision, especially in social housing.

- *Main bedroom*: Master bedrooms of less than $12\,m^2$ should be considered tight, for double bed and large wardrobe, etc. Great care needs to be taken over single-person flats, especially for elderly people; a widow may well not want to dispose of her double bed and other familiar furniture.
- *Other double bedrooms*: The minimum of $10\,m^2$ can be acceptable in some circumstances, as this size of room can be used flexibly by a single person, by children in bunks or by two single beds set against walls. However, the furniture list now published by the HC for social housing makes $11\,m^2$ or $12\,m^2$ necessary, depending on shape.
- *Single bedroom*: There is evidence that $6.5\,m^2$ is too small for most single bedrooms. $8\,m^2$ is a more reasonable standard, and $6.5\,m^2$ should be regarded as the absolute minimum.

Although the SDSs do not lay down space standards, either for overall dwellings or for individual rooms, they do include requirements which impinge on room sizes. They also refer to the recommendations in the National Housing Federation's good practice guide 'Standards and Quality in Development', published in 1998, for furniture and activity spaces. They also cover issues such as general accessibility and mobility standards (requiring level thresholds and front doors giving minimum 800 mm clear openings) as well as standards for insulation that may exceed those in the Building Regulations. See Tables V, VI and VII for extracts from the HC Scheme Development Standards.

2 OTHER PUBLISHED SPACE STANDARDS

2.01

The MHLG, followed by the DOE published a number of Design Bulletins in the 1970s, a number of which refer specifically to housing. Additionally, the Housing Development Directorate of the DoE produced a number of Occasional Papers. All the useful publications are listed in the Bibliography at the end of this chapter, although you may have difficulty tracking down copies of some of them.

2.02 The Housing Corporation

In 1993 the Housing Corporation published new Scheme Development Standards. They were revised in 1995 and 1998.

Table V Housing Corporation standards, for housing association dwellings
(from HC Scheme Development Standards, August 1998)

1 EXTERNAL ENVIRONMENT

1.1 Location, site layout and orientation

Essential:
1.1.1 Location convenient for doctor's surgery, shops, post office and public phone, bank, school, play facilities, park, public transport, commercial centre, leisure and sports facilities
1.1.2 Integrated with surrounding area
1.1.3 Aesthetically compatible
1.1.4 Clear delineation of public, communal and private spaces
1.1.5 Public spaces connected by well-lit routes
1.1.6 Orientation and grouping to enhance privacy
1.1.7 Convenient, robust and inconspicuous refuse areas
1.1.8 Play areas suitable for a range of age groups
1.1.9 Soft and hard landscaping
1.1.10 Paved drying areas
1.1.11 Lockable external storage
1.1.12 Canopies or porches to front doors

Recommended:
1.1.13 Form, mass, detail and materials to improve appearance and views
1.1.14 Integrated art works and landmarks
1.1.15 Guidance from the National Housing Federation good practice guide *Standards and Quality in Development*
1.1.16 For high profile schemes, guidance from the Commission for Architecture and the Built Environment
1.1.17 Housing Quality Indicators (HQI) assessment

1.2 Vehicular access

Essential:
1.2.1 Access for service and delivery vehicles
1.2.2 Road layout to restrict speeds
1.2.3 Shared surface cul-de-sacs should serve no more than 25 dwellings
1.2.4 Shared driveways should serve no more than 5 dwellings

1.3 Parking

Essential:
1.3.1 Parking to reflect current and planned future needs
1.3.2 Parking located for natural surveillance
1.3.3 Individual spaces minimum 2.4 m × 4.8 m
1.3.4 On-plot spaces to have adjoining hard surface 0.9 m wide
1.3.5 One in ten of grouped spaces to be 3.3 m × 4.8 m
1.3.6 Grouped spaces to be identifiable with groups of dwellings served
1.3.7 Grouped spaces to be within 30 m of front doors
1.3.8 Grouped spaces and paths to be well lit

Recommended:
1.3.9 On-plot spaces for houses and bungalows
1.3.10 Grouped spaces to be allocated

2 INTERNAL ENVIRONMENT

2.1 General convenience, and accommodation of necessary furniture and activities (The Housing Corporation also refers to the National Housing Federation's good practice guide *Standards and Quality in Development.* See Table VII)

General within dwellings

Essential:
2.1.1 Layout to minimise noise transmission
2.1.2 Convenient relationship between rooms
2.1.3 Circulation space sensible for room activities
2.1.4 Adequate space for sensible furniture arrangements (see Table VII)
2.1.5 Space to move larger items of furniture
2.1.6 Space for whole family and occasional visitors to gather
2.1.7 Space for a small worktop or similar in single bedrooms
2.1.8 Space for an occasional cot in main bedroom (family units)
2.1.9 Space for a pram or pushchair (family units)
2.1.10 A bath, WC and basin
2.1.11 Additional separate WC and basin in units for 5 persons and over (but note that the Building Regulations Part M now require an entrance level WC in all dwellings)
2.1.12 Additional sanitary and kitchen provisions in extended family accommodation
2.1.13 Secure storage for medicines and harmful substances
2.1.14 Enclosed storage space for food, utensils, washing and cleaning materials
2.1.15 Enclosed storage for brooms and tall equipment
2.1.16 Enclosed storage for airing clothes and linen
2.1.17 Hanging space for outdoor clothes
2.1.18 Space and connections for cooker, fridge/freezer and washer
2.1.19 Adequately and sensibly located electrical outlets
2.1.20 Aerial point with conduit and draw wire
2.1.21 Whole house heating or low energy equivalent
2.1.22 Heating to provide suitable temperatures
2.1.23 Individual control of heating output

Recommended:
2.1.24 Living room not part of circulation
2.1.25 Storage not accessed only through living room
2.1.26 Two separate living areas
2.1.27 Direct access from living room to private open space
2.1.28 Dining room separate from kitchen

Table V (Continued)

2.1.29 More than one position in bedrooms for beds
2.1.30 All double bedrooms able to take twin beds
2.1.31 One or more bedrooms with direct access to washing and WC
2.1.32 Bottom of glazing to living rooms, dining rooms and bedrooms no higher than 810 mm
2.1.33 Restrictors on upper floor windows
2.1.34 Shower over bath, with wall tiling and screen
2.1.35 Space for two people to have casual meals in kitchen
2.1.36 Direct access from kitchen to private open space
2.1.37 Kitchen work surface continuous
2.1.38 Minimum 1.2 m kitchen work surface between cooker and sink
2.1.39 Minimum 0.5 m kitchen work surface each side of cooker, and minimum 0.1 m between cooker space and wall units
2.1.40 Space for extra kitchen equipment such as microwave, dishwasher etc.
2.1.41 Principles of *Accommodating Diversity* to be incorporated

Communal areas and landings

Essential:
2.1.42 Well lit halls and corridors
2.1.43 Passenger lift(s) if required for user group
2.1.44 Passenger lift(s) able to take a wheelchair and accompanying person
2.1.45 Lift controls operable from a wheelchair
2.1.46 Lift provided to any wheelchair dwelling above ground level
2.1.47 Lift provided to any frail elderly dwelling above ground level

Recommended:
2.1.48 Graffiti and dirt resistant finishes
2.1.49 Entryphone security to entrances to blocks of flats
2.1.50 Lift provided to any dwelling 7.5 m above ground level
2.1.51 Lift provided to any sheltered (category 1) unit 3.0 m above ground level
2.1.52 Lift provided to any sheltered (category 2) unit above ground level

All housing for the elderly

Essential:
2.1.53 Bathroom and WC doors to open out, where internal space is limited
2.1.54 Bathrooms to have external override door locks and handholds
2.1.55 As an alternative to a bath, a non-slip shower with side seat
2.1.56 Thermostatic mixing valves
2.1.57 Low surface temperature radiators, where space is restricted
2.1.58 Easy rise staircase (Max 35° or halfway landing). In Category 2, should have handrails both sides
2.1.59 Electrical outlets and switches positioned for convenient use by the elderly
2.1.60 24 hour alarm facilities

Supported housing

Essential:
2.1.61 Cooker and fridge/freezer to be provided
2.1.62 Furniture, fittings, fixtures, carpet, etc. to be provided

Communal facilities in housing for the elderly or self-contained supported housing

Essential in sheltered Category 2 or frail elderly
Optional in sheltered Category 1 or self-contained supported housing
2.1.63 Warden accommodation or 24-hour peripatetic cover
2.1.64 Common room, with space for sensible furniture for residents and visitors
2.1.65 Common room to be heated, comfortable and appropriately furnished
2.1.66 Common room to be wheelchair accessible
2.1.67 WC and basin near to common room
2.1.68 Chair store for common room
2.1.69 Tea kitchen for common room
2.1.70 Laundry room, with automatic washing machine, tumble-dryer, sink, bench and extract ventilation
2.1.71 Twin bed guest room with basin, heated and comfortably furnished, and near to a WC
2.1.72 Circulation areas to be heated and appropriately furnished
2.1.73 Office, close to main entrance
2.1.74 Pay phone and cloakroom

Frail elderly housing

Essential:
2.1.75 Resident manager or 24 hour emergency care cover
2.1.76 Individual parts or dwellings should meet sheltered Category 2 standards
2.1.77 Individual dwellings all to wheelchair user standards (see 3.2 below)
2.1.78 Communal facilities as listed above all to be provided
2.1.79 Communal areas all to be wheelchair user accessible (see 3.2 below)
2.1.80 Communal toilets near the common room and dining room
2.1.81 Central linen store
2.1.82 Laundry facilities
2.1.83 Sluice room
2.1.84 Room(s) for visiting special care service providers (hair dressing, chiropody, etc.)
2.1.85 Staff room, with toilets, changing room, and sleep-over room(s)
2.1.86 Fully equipped assisted bathroom
2.1.87 Wheelchair entry shower
2.1.88 Catering facilities, central and/or dispersed
2.1.89 At least one catering facility, if dispersed, to be wheelchair usable
2.1.90 Furniture, fittings, fixtures and floor coverings
2.1.91 Maintained garden or open area with seats

Table V (Continued)

Shared housing or shared support housing

Essential:
2.1.92 Appropriate balance of private and shared spaces
2.1.93 Individual bedrooms
2.1.94 Bathrooms and WCs to be conveniently located
2.1.95 1 bath, 1 shower, 1 WC and 1 basin per 5 persons maximum
2.1.96 Separate shower, if bathroom shared by more than 2 people
2.1.97 Separate WC, if bathroom shared by more than 2 people
2.1.98 Cooker, fridge/freezer and washing machine to be provided
2.1.99 24 hour access to shared kitchen
2.1.100 Furniture, fittings, fixtures and carpet etc.
2.1.101 In schemes for 6 or more sharing residents, located near main communal area: Catering facilities, laundry with coin-operated machine, small interview/reception room, pay phone and cloakroom, WC with basin

3 ACCESSIBILITY

3.1 General access, allowing for people with limited mobility (The Housing Corporation also refers to the Accessibility section of the National Housing Federation's *Standard and Quality in Development*)

Essential:
3.1.1 The approach to the dwelling needs to have:
slip-resistant, smooth paths, 900 mm wide, with max. cross-falls 1:40 and shallow crossings
ramps max. 5 m long at 1:12, or 10 m long at 1:15
protected edges to raised paths
1.2×1.2 m level area outside entrance door
where unavoidable, steps no steeper than 150 mm riser and 280 mm going
handrail to raised paths, where drop exceeds 380 mm
contrasting texture or kerb between pedestrian and vehicular access
dropped kerbs at roadway crossings
gates clear openings min. 850 mm, without a step
3.1.2 Main entrance to dwelling needs to have:
Clear door opening min. 800 mm
Nominally flat threshold (max. 15 mm upstand)
3.1.3 Other doors need to have:
secondary external doors, min. 750 mm clear
internal doors, min. 750 mm clear, but wider if off 900 mm corridors
3.1.4 Ground floor passageways need to be:
generally min. 900 mm wide (or 750 mm by limited intrusions, e.g. Radiators) wider where turning into 750 mm clear doors splayed at comer, or one passage 1200 mm wide, at 90° corners
3.1.5 An entrance level WC and basin in all units
3.1.6 Staircase width and landings suitable for future BS stair-lift

Recommended:
3.1.7 Level paving outside all external doors
3.1.8 All external doors wheelchair accessible
3.1.9 Fully wheelchair accessible ground floor WC
3.1.10 Living room at ground level
3.1.11 Ground floor space usable as bedspace
3.1.12 Space to turn wheelchair in kitchens, dining areas and living rooms
3.1.13 Lower pitch staircase; either 35, or 42° with a half landing
3.1.14 Door handles, switches etc. at between 900 mm and 1200 mm height
3.1.15 Sockets at between 450 mm and 600 mm height

3.2 Full accessibility in housing and wheelchair users
(The Housing Corporation refers to the *Wheelchair Housing Design Guide*, published by Habinteg HA and Home Housing Group, on behalf of the Wheelchair Housing Association Group)

Essential:
3.2.1 to 3.2.15 The Housing Corporation requires compliance with all of sections 1 to 15 of the *Wheelchair Housing Design Guide.* See Table X for a summary of key dimensions.

4 SAFETY AND SECURITY

4.1 Safety, internally and externally

Essential:
4.1.1 All windows to be safely openable
4.1.2 Reversible child-proof hinges to allow cleaning of upper floor windows from inside
4.1.3 Opening doors and windows not to be obstructive or hazardous
4.1.4 Lighting to be adequate for safety
4.1.5 Stairs and steps to be safely negotiable
4.1.6 Smoke alarm on every floor
4.1.7 Kitchen, bathroom, shower and WC to be safely laid out 1.2 m min. clear in front of all kitchen equipment slip resistant floor finishes in 'wet' areas

Recommended:
4.1.8 No winders or tapered treads on stairs
4.1.9 Switched lighting in stores of over 1.2 m^3
4.1.10 Low surface temperature radiators

4.2 Security, internally and externally

Essential:
4.2.1 Advice from local police design advisers, before detailed planning
4.2.2 Secure side and/or rear fencing, with full-height lockable gates
4.2.3 Layout to avoid unnecessary through routes and hiding places

Table V (Continued)

4.2.4 Layout to maximise natural surveillance
4.2.5 Opening window lights to be secure
4.2.6 External doors to be sturdy, and have min. 5 lever mortice deadlocks

Recommended:
4.2.7 Fused spur for security alarm
4.2.8 Certification under police 'Secured by Design' initiative.

5 ENERGY EFFICIENCY, SUSTAINABILITY AND NOISE

5.1 Energy efficiency

Essential:
5.1.1 SAP rating to meet minimum standards (see Table VI), or in buildings which cannot be SAP assessed (certain types of multi-residential buildings) evidence that energy efficiency measures have been incorporated
5.1.2 Housing for vulnerable users to allow for higher temperatures and extended heating periods as appropriate

Recommended:
5.1.3 SAP rating to exceed minimum standards by at least 6 (see Table VI)
5.1.4 Low energy light fittings in areas of high use
5.1.5 Low energy external lights
5.1.6 Any fridges, freezers and washing machines provided to have energy label A, B or C
5.1.7 Gas cooker point
5.1.8 Leaflets for tenants on energy efficiency and controls

5.2 Environmental sustainability

Essential:
5.2.1 Water metering, wherever new connections made
5.2.2 Low volume flush WCs
5.2.3 Written advice to residents on water saving
5.2.4 Any washing machines provided to be water efficient
5.2.5 Potentially harmful emissions minimised: restrictions on chemical treatment e.g. formaldehyde timber treated only when essential any treatment done industrially prior to use no asbestos or lead in paint avoidance of CFCs and HCFCs

Recommended:
5.2.6 Engineering to allow use of land with poor bearing: lightweight frame construction modular construction pile and beam construction
5.2.7 Scheme-specific water savings measures
5.2.8 Tenant's option of water butt
5.2.9 Separate container for collecting recyclable waste
5.2.10 BRE Environmental Standard Award

5.3 Noise abatement

Essential:
5.3.1 Where there is significant external noise: specialist sound survey with recommendations appropriate sound insulation measures to be incorporated
5.3.2 Sound insulating construction for party walls and floors
5.3.3 Opening window casements planned to minimise air-borne noise
5.3.4 Structure planned to minimise nuisance from door slamming
5.3.5 Handing of plans etc. in order to minimise shared walls and floors

Recommended:
5.3.6 Triple glazing, where high external noise levels
5.3.7 Testing after completion to check sound insulation

6 MAINTAINABILITY, DURABILITY AND ADAPTABILITY

6.1 Service installations

Essential:
6.1.1 Should be readily accessible for inspection
6.1.2 Should be accessible for routine maintenance and repair

Recommended:
6.1.3 Pipework and ductwork to be unobtrusive
6.1.4 Should be economical in layout

6.2 Suitability and durability of components and materials

Essential:
6.2.1 Durability and suitability to be appropriate for position of use
6.2.2 Regular site inspections to be carried out
6.2.3 Pre-handover inspections to be carried out

Recommended:
6.2.4 Finishes, fittings and equipment to be good quality
6.2.5 New fittings and equipment to be compatible with any existing
6.2.6 Availability of replacement parts and components to be taken into account
6.2.7 Work quality checked against BS8000
6.2.8 Contractors and consultants accredited under Quality Assaurance ISO9000
6.2.9 'Considerate Constructors Scheme' used
6.2.10 Scheme accredited under one of: Housing Association Property Mutual; National House-Building Council; Buildplan; Shield; or Zurich building guarantees

Table V (Continued)

6.3 Future adaptability

Essential:
- 6.3.1 Walls in bathrooms and WCs to be able to support aids
- 6.3.2 Ceilings in bathrooms and main bedrooms to be able to take hoists and rails

Recommended:
- 6.3.3 Ethnic diversity needs to be met
- 6.3.4 Facilitate future internal replanning by: full-span floor construction non-load-bearing internal walls floor and ceiling space service runs
- 6.3.5 Facilitate future extension into roof by: non trussed roof construction ceiling joists strength space for extra stairs and landings
- 6.3.6 Extra space for future provision of: side or rear extension in garden ground floor bedroom conversion wheelchair accessible ground floor WC or shower vertical lift
- 6.3.7 A 'Housing Quality Indicators' (HQI) assessment to be undertaken

These replaced previous standards as mandatory requirements for developments by housing associations and other 'Registered Social Landlords'.

2.03 National House Building Council

The National House Building Council publishes a comprehensive set of standards for private house builders. Most of these concern standards for construction, but they also include a limited number of specific space standards. Ones to watch out for are minimum kitchen dimensions and minimum loft hatch dimensions. The NHBC minimum standards for bedrooms are very small indeed, and generally unsuitable for the public sector. Some of the NHBC space and dimensional standards are given in Table VIII.

Table VI SAP ratings referred to in Table V, section 5

Floor area (m^2)	New-build SAP		Rehabilitation SAP	
	minimum	recommended	minimum	recommended
≤35	71	77	56	62
>35/≤40	72	78	57	63
>40/≤45	73	79	58	64
>45/≤50	74	80	59	65
>50/≤55	75	81	60	66
>55/≤60	76	82	61	67
>60/≤65	77	83	62	68
>65/≤70	78	84	63	69
>70/≤75	79	85	64	70
>75/≤80	80	86	65	71
>80/≤90	81	87	66	72
>90/≤100	82	88	67	73
>100/≤110	83	89	68	74
>110/≤120	84	90	69	75
>120	85	91	70	76

2.04 Building Regulations

Now that the Regulations are published in 'Approved Document' format, they are clear and easy to understand. We draw attention to

Table VII Housing Corporation requirements for furniture from *Standards and Quality in Development* good practice guide, published by National Housing Federation

Furniture	Sizes (mm)	Dwelling size						
		1p	2p	3p	4p	5p	6p	7p
Living space:								
Armchair	850 × 850	2	2	3	1	2	3	4
2 seat settee	850 × 1300	optional, in combinations to suit no. of residents						
3 seat settee	850 × 1850				1	1	1	1
TV	450 × 600	1	1	1	1	1	1	1
Coffee table	500 × 1050	1	1	1	1	1	1	1
Alternative coffee table	750 diameter	may be shown instead of rectangular						
Occasional table	400 × 500					1	1	1
Storage unit	500 × 1000	1	1	1				
(any combination with	500 × 1500				1			
total length shown)	500 × 2000					1	1	1
Visitor's chair	450 × 450	2	2	2	2	2	2	2
Focal point fire	150 × 500	1	1	1	1	1	1	1
Radiator	110 deep	1	1	1	1	1	1	1
(200 deep if low surface temperature, 250 deep if storage heater)								
Dining space:								
Dining chair	450 × 450	2	2	3	4	5	6	7
Dining table	800 × 800	1	1					
(can be circular, with	800 × 1000			1				
same surface area)	800 × 1200				1			
	800 × 1350				1			
	800 × 1500					1		
	800 × 1650						1	
Sideboard	450 × 1000	1	1	1				
(not required if dining	450 × 1200				1			
area is in kitchen)	450 × 1500					1	1	1
Radiator	110 deep	1	1	1	1	1	1	1
Double bedroom:								
Double bed	2000 × 1500	n/a	1	1	1	1	1	1
(Single beds option)	2000 × 900		2	2	2	2	2	2
Bedside tables	400 × 400		2	2	2	2	2	2
Dressing table and stool	450 × 1350		1	1	1	1	1	1
Chest of drawers	450 × 750		1	1	1	1	1	1
Double wardrobe	600 × 1200		1	1	1	1	1	1
Occasional cot	600 × 1200			1	1	1	1	1
(other furniture may be moved out to make space for cot)								
Radiator	100 deep		1	1	1	1	1	1
Twin bedroom:								
Single beds	2000 × 900	n/a			2	2	2	2
Bedside tables	400 × 400				2	2	2	2
Desk & stool	500 × 1050				1	1	1	1
Chest of drawers	450 × 750				1	1	1	1
Double wardrobe	600 × 1200	(or 2 wardrobes 600 × 600)			1	1	1	1
Radiator	110 deep							

Table VII (Continued)

Furniture	Sizes (mm)	Dwelling size						
		1p	2p	3p	4p	5p	6p	7p
Single bedroom:								
Single bed	2000 × 900	1	1	1	1	1	1	1
Bedside table	400 × 400	1	1	1	1	1	1	1
Desk & stool	500 × 1050	1	1	1	1	1	1	1
Chest of drawers	450 × 750	1	1	1	1	1	1	1
Single wardrobe	600 × 600	1	1	1	1	1	1	1
Radiator	110 deep	1	1	1	1	1	1	1
Bathroom:								
WC & cistern	500 × 700	1	1	1	1	1	1	1
Bath	700 × 1700	1	1	1	1	1	1	1
Wash hand basin	600 × 400	1	1	1	1	1	1	1
Shower tray	750 × 750	(if provided)						
Radiator	110 deep	1	1	1	1	1	1	1
Separate toilet (on ground floor):								
WC & cistern	500 × 700	in all houses, and flats for 5 persons or more						
Cloakroom basin	250 × 350	(larger size 400 × 350 preferred) in every separate WC						
Radiator	110 deep	in every separate WC						

Note: The NHF guide also gives extensive detailed guidance on zones needed between furniture.

Table VIII National House Building Council requirements for private sector dwellings
(normally those for which a mortgage is needed) summarised from NHBC Standards, chapter 12, operative 1995.

The NHBC does not set space standards, but requires that purchasers are provided with floor plans showing that bedrooms can accommodate bed or beds without obstructing the door swing. Other free-standing furniture such as wardrobes, chests of drawers etc. may be shown at the builder's discretion.

Furniture and activity spaces (mm)

Furniture	Furniture size	Activity space
Double bed	2000 × 1350	400 to sides, 450 at foot
Single bed	2000 × 900	400 to side, 250 at foot
Large chest of drawers	950 × 600	1000 deep (700 if space bounded by low furniture such as a bed)
Small chest of drawers	750 × 450	
Dressing table	1100 × 400	600 deep
Large wardrobe	950 × 600	1000 deep (700 if space bounded by low furniture such as a bed, or if wardrobe has sliding doors)
Small wardrobe	600 × 600	
Bedside table	400 × 400	None

the main parts affecting the planning of housing (see Table IX). All the parts of the Building Regulations, now including Part M (Access and Facilities for the Disabled) apply to housing. The extension of Part M of cover dwellings from October 1999 was an important development. Significant requirements now apply to for example downstairs toilets, level front door access, and corridor and door widths. These requirements are summarised in Table XI.

2.05 Other statutory controls

The *Underground Rooms Regulations*, published by some local authorities under the Housing Acts, cover lighting and ventilation of basement habitable rooms.

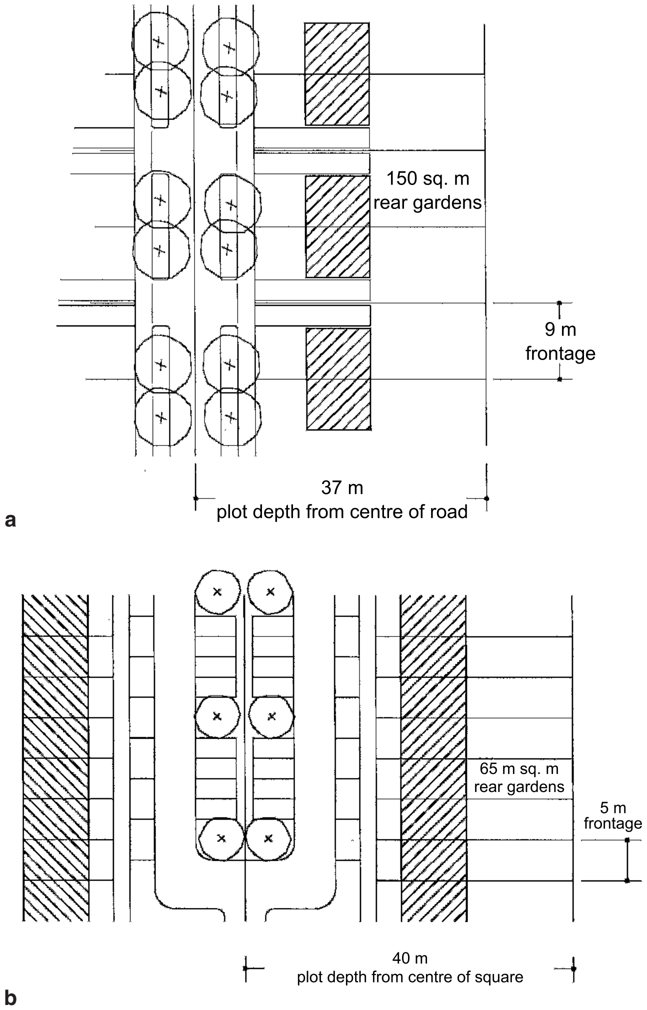
Planning Authorities publish Local Plans, or Unitary Development Plans, including standards for housing which are imposed through development control. These cover such areas as housing density, external design, car parking, and, in some cases, minimum room sizes.

Planning densities are normally expressed in *habitable rooms per hectare* (or acre). The definition of habitable rooms is normally taken to be all living rooms, bedrooms and dining kitchens (the latter commonly only if more than 13 m^2). Densities for new housing commonly vary from around 150 habitable rooms per hectare (60 habitable rooms per acre) to 250 habitable rooms per hectare (100 habitable rooms per acre), **8.1**, **8.2** and **8.3**. Some authorities allow higher densities for non-family housing, or for areas close to urban centres or good transport links. There have been recent moves from Central and Local Government to consider higher densities for residential (and other) developments, particularly since publication of the Urban Task Force report: 'Towards an Urban Renaissance' in 1999. External design generally covers minimum dimensions between habitable rooms facing each other directly or obliquely, and sizes of gardens and other external spaces, **8.4**.

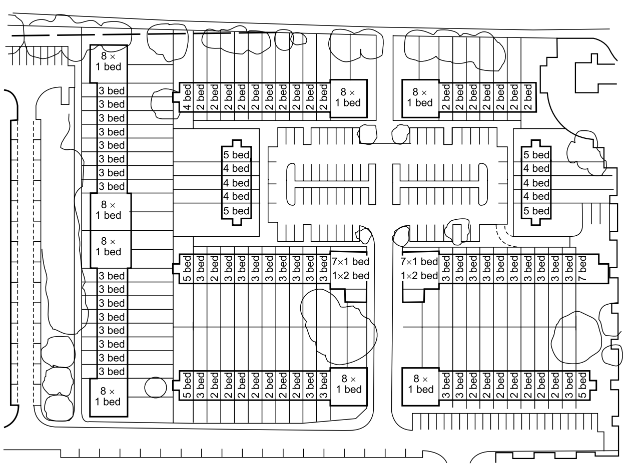
Car-parking requirements vary considerably between planning authorities. Inner-city planners may require only one space per house and less for a flat, but suburban areas may demand two or more spaces per house. Visitors' spaces need to be added at 10 to

Table IX Building Regulations 2000 (England and Wales) applying to dwellings

Approved Document		Last revision	Applies to housing	Relevant to planning of housing
A	Structure	2004	*	
B	Fire Safety (Means of Escape, etc.)	2006	*	*
C	Site preparation (resistance to moisture)	2004	*	
D	Toxic substances (cavity insulation)	1992	*	
E	Resistance to passage of sound	2003	*	*
F	Ventilation	2006	*	*
G	Hygiene (bathrooms, etc.)	1992	*	*
H	Drainage and waste disposal	2002	*	*
J	Combustion appliances and fuel storage systems	2002	*	*
K	Protection from falling, collision and impact (stairs etc.)	1998	*	*
L1A	Conservation of fuel and power (new dwellings)	2006	*	*
L1B	Conservation of fuel and power (existing dwellings)	2006	*	*
L2A	Conservation of fuel and power (new buildings other than dwellings)	2006		
L2B	Conservation of fuel and power (existing buildings other than dwellings)	2006		
M	Access to and Use of Buildings	2004		
N	Glazing materials and protection	1998	*	
P	Electrical Safety – Dwellings	2006	*	
Regulation 7 – Material and Workmanship		1992	*	

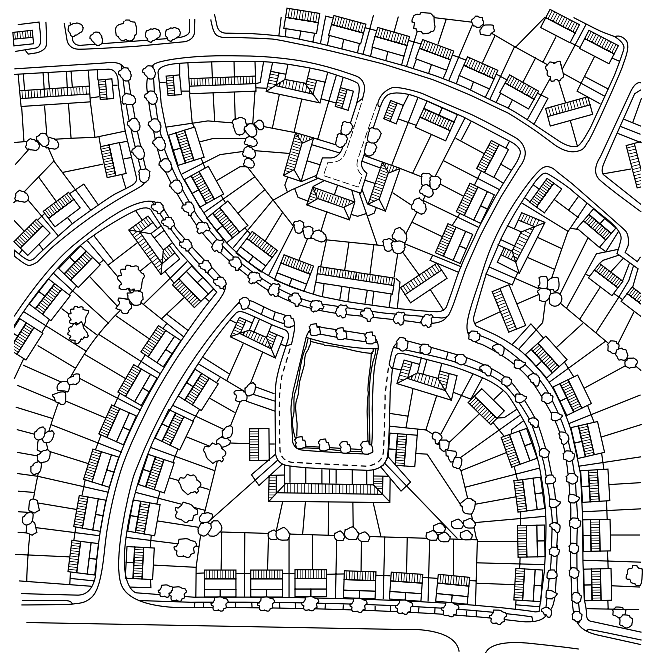


8.1 *Notional housing layouts at 150 and 250 hr/ha based upon typical houses of five habitable rooms.* **a** *Semi-detached houses with in-curtilage car parking: 30 dwellings per hectare (12 per acre); 150 habitable rooms per hectare (60 per acre).* **b** *Terraced houses around an urban square: 50 dwellings per hectare (20 per acre); 250 habitable rooms per hectare (100 per acre)*



8.2 *Housing layout at 250 hr/ha (100 hr/acre) in a typical urban location with open car-parking area*

20 per cent. Some authorities at present allow considerable relaxation of their requirements for social housing, on the basis of lower than average recorded car ownership. There is also a movement towards 'car free' developments, for some sites that are particularly well served by public transport.



8.3 *Housing layout at 150 hr/ha (60 hr/acre) in a suburban location*

3 OTHER DESIGN DATA

Several important dimensions and spatial requirements are not covered by statutory control.

3.01 Ceiling heights

These have not been covered by the Building Regulations since 1985, as the DoE has decided that they do not significantly affect health and safety. Despite this, the old standard of 2.3 m should still be considered the minimum reasonable ceiling height for domestic buildings. 2.4 m is preferable, **8.5**. For rooms in the roof, floor areas are calculated to include only those parts where the ceiling height exceeds 1.5 m.

3.02 Staircase widths

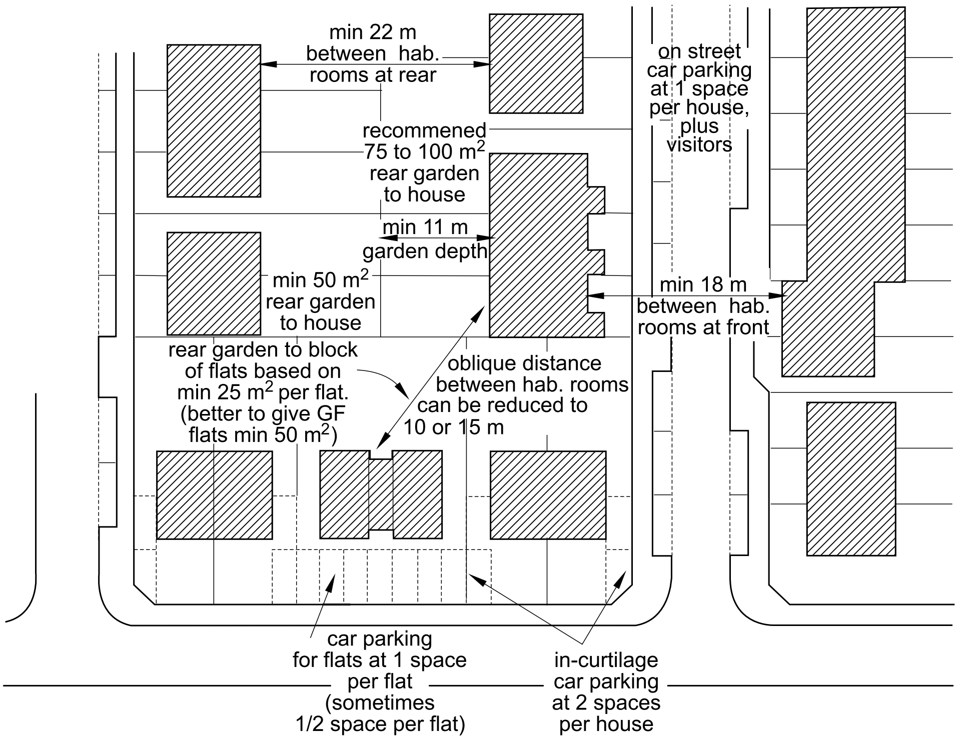
These have not been included in part K of the Building Regulations since 1992. For means of escape purposes, widths of staircases to blocks of flats are covered in part B; but this does not cover the majority of single family-houses. The movement of furniture should be considered, and 800 mm should be the minimum reasonable clear stair width in domestic building.

3.03 Kitchen units

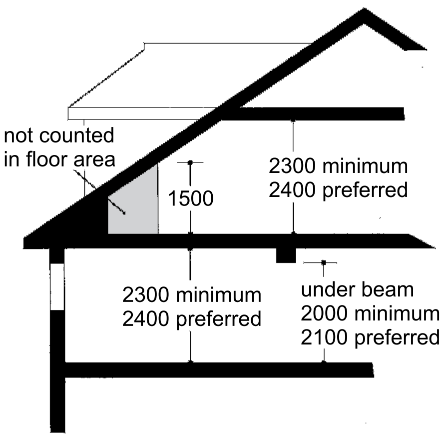
Previous editions of this Handbook included detailed graphs on comfortable heights for kitchen worktops, demonstrating that the common standard height of 900 to 914 mm is too low for the majority of both men and women. This height generally suits only women over 60. For the majority of women, worktops at 950 mm and sinktops at 975 mm are the most comfortable. For men, these heights can be increased further. So for fixed kitchens used by both sexes of able-bodied people, 950 to 975 mm is recommended. The use of lower worktops, at 850 mm, for housing for the elderly is not recommended, especially as 'white goods' will rarely fit underneath this height.

3.04 Space standards for housing in relation to people with disabilities

There has been a gradual change in thinking in the last few years, resulting in the current requirement that *all* housing should be accessible to people in wheelchairs, not least to permit them to visit friends and relations. This should also permit people to remain in their dwellings well into old age or infirmity, instead of having to move to more accessible accommodation. The requirements are contained



8.4 *Typical planning standards*. NB: *Different planning authorities have widely differing minimum dimension requirements*



8.5 *Ceiling heights and rooms in the roof, no longer covered by Building Regulations*

in the new Part M of the Building Regulations, parts 6–10, applying to dwellings (see 2.04 above). Table XI summarises these standards.

When planning dwellings for regular occupation by users of wheelchairs or walking frames, it might be supposed that recommended room areas would need to be augmented. This is not necessarily always the case. Much more important are linear dimensions across circulation areas and between fixed appliances or obstructions. For this reason the planning of kitchens and bathrooms is especially important. Ample guidance is given in Selwyn Goldsmith's *Designing for the Disabled.* The Wheelchair Housing Design Guide, published in 1997 by Habinteg Housing Association and HOME Housing Trust on behalf of the National Wheelchair Housing Association Group, has been endorsed by the Housing Corporation as the essential standard for wheelchair dwellings provided by Registered Social Landlords. A much-distilled summary of some of the main requirements is given in Table X. These recommendations will tend to lead to increases in the floor areas of kitchens and bathrooms, and widths of circulation spaces, which may in turn cause the overall dwelling area to exceed Parker Morris standards. PM standards should therefore be considered the absolute minimum.

Table X Key dimensional requirements for wheelchair and mobility housing: recommended minima in millimetres

	Wheelchair housing	Mobility housing
Entrance doorway clear width	800	800 (Housing Corp.) 775 (Building Regs)
Level threshold maximum upstand	15	15
Internal doorway clear width	775, off 1200 wide corridor	750, off 1200 wide corridor 775, off 1050 wide corridor 800, off 900 wide corridor
Space to side of door (on lock/latch side)	300	100–300
Corridor width	1200	900–1200 (with different door widths – see above)
Turning-circle diameter	1500	–
Space between kitchen fittings	1500	1200
Bedroom width	3000	2800
Wheelchair storage (may overlap hall space)	1200 × 700	–
Transfer space for WC:		
front	1200	–
diagonal	750	–
side	750	–
WC pan centre to adjacent wall	450	400

3.05 Lifetime Homes

A further recent initiative has been published and promoted by the Joseph Rowntree Foundation, in their concept of ‘Lifetime Homes’. The idea is to construct dwellings that can be more easily adapted to cope with residents’ future disabilities, should these arise. Such disabilities could be either temporary, such as resulting from an accidental injury, or permanent, from accident or illness. JRF’s recommendations take the form of 16 points covering the planning and construction of new dwellings. These 16 points are listed in Table XII. The standards for Lifetime Homes are not mandatory, but they relate to the requirements now in Part M of the Building Regulations, and in effect extend their scope, towards the same ends of improving accessibility. Housing Associations

Table XI Summary of key requirements for accessible general needs housing from Building Regulations Approved Document M, 1999 edition

Sections 6 to 10 apply to new dwellings

Section 6 Means of access to and into the dwelling
This section covers level, ramped ot stepped approach.
Level approach should be no steeper than 1:20
Ramped approach is allowed if the plot gradient exceeds 1:20, but not 1:15
Ramps must be min. 900 mm wide
Ramp flights no longer than 10 m at 1:15, or 5 m at 1:12
Top and bottom landings min. 1.2 m length
Stepped approach is allowed if the plot gradient exceeds 1:15
Steps must be min. 900 mm wide
Rise of flight between landings must not exceed 1.8 m
Top and bottom landings min. 900 mm
Suitable tread nosing profiles, and uniform rise of between 75 mm and 150 mm
Going of steps no less than 280 mm
Handrail to one side of steps with three or more risers, extending 300 mm at top and bottom
Thresholds should be accessible
In exceptional circumstances (a stepped approach) a stepped threshold of max. 150 mm rise
External entrance door min. clear opening 775 mm

Section 7 Circulation within the entrance storey of the dwelling
This section covers internal corridor and door widths.
Corridors should be minimum width 900 mm to 1200 mm, depending on door widths
Corridors can be min. 750 mm opposite obstruction such as radiator, for no longer than 2 m
Door clear opening widths should be minimum as follows:
750 mm at end of 900 mm wide corridor
750 mm off 1200 mm wide corridor when approach not head-on
775 mm off 1050 mm wide corridor when approach not head-on
800 mm off 900 mm wide corridor when approach not head-on
In exceptional circumstances (severely sloping plots) steps are allowed within the entrance storey. Such steps should be min. 900 mm wide, with handrails to both sides.

Section 8 Accessible switches and socket outlets in the dwelling
This section gives heights for fittings to assist people whose reach is restricted.
Switches and sockets in habitable rooms should be between 450 mm and 1200 mm height above floor level.

Section 9 Passenger lifts and common stairs in blocks of flats
This section gives requirements on lift dimensions, and on stair dimensions in blocks which do not have lifts.
Requirements for passenger lifts:
400 kg min. load capacity
1.5 m × 1.5 m landings in front of entrances
Lift door clear opening 800 mm
Car min. width 900 mm and min. length 1250 mm
Controls between 900 mm and 1200 mm above floor level.

Requirements for common stairs in blocks of flats without a lift:
Contrasting brightness step nosings
Suitable step nosing profiles (illustrated in the Approved Document)
Step max. rise 170 mm; max. going 250 mm
Non open risers
Continuous handrail on both sides of flights of more than 2 steps, extending 300 mm onto landings.

Section 10 WC provision in the entrance storey of the dwelling
This section requires a WC on the entrance floor of any dwelling, and gives dimensional guidance.
If there is a habitable room on the entrance floor, there should be a WC on that floor.
WC door should open outward, and opening should overlap WC pan by 250 mm
Door widths should observe the measurements described in Section 7 (with clear opening widths in accordance with Table 4 of the Approved Document)
In a front access WC, compartment should be 1000 mm wide (or min. 900 mm wide)
In an oblique access WC, compartment should be 900 mm wide (or min. 850 mm wide)
Transfer space 750 mm deep should be provided in front of WC.

Table XII Lifetime Home standards, published by Joseph Rowntree Foundation 1999 edition

Access

1 Where there is car parking adjacent to the home, it should be capable of enlargement to 3.3 m width.
2 The distance from the car parking space to the home should be kept to a minimum, and should be level or gently sloping.
3 The approach to all entrances should be level or gently sloping. (Building Regulations Approved Document M gives guidance on dimensions and gradients.)
4 All entrances should be illuminated, and have level access over the threshold (max. upstand 15 mm), and the main entrance should be covered.
5 Communal stairs should provide easy access. (Building Regulations Approved Document M gives dimensional guidance.)
Where homes are reached by a lift, it should be fully wheelchair accessible (min. lift car dimensions 1100 mm × 1400 mm)

Inside the home

6 The width of the doorways and hallways should conform to a table of recommendations. This is the same as the requirements in Building Regulations Approved Document M (see Table XI), except that doors opening off 900 mm wide corridors should be 900 mm clear opening width.
7 There should be space for turning a wheelchair in dining areas and living rooms, and adequate circulation space for wheelchair users elsewhere. A turning circle of 1500 mm diameter or a 1700 mm × 1400 mm ellipse is required.
8 The living room should be at entrance level.
9 In houses of two or more storeys, there should be space on the ground floor that could be used as a convenient bed space.
10 There should be a wheelchair accessible ground floor WC, with drainage provision to allow a shower to be fitted in the future. In dwellings with three or more bedrooms, or on one level, the WC should be fully accessible, i.e. with space for side transfer from a wheelchair with the door closed, and 1100 mm clear space in front of the WC.
11 Walls in bathrooms and toilets should be capable of taking adaptations such as handrails. Wall reinforcement should be located between 300 mm and 1500 mm from the floor.
12 The design should incorporate provision for a future stair lift, and a suitably identified space for a through-the-floor lift from the ground to the first floor, for example to a bedroom next to the bathroom. The stairs should be min. 900 mm clear width.
13 The design should provide for a reasonable route for a potential hoist from a main bedroom to the bathroom.
14 The bathroom should be designed to allow ease of access to the bath, WC and wash basin. There should be sufficient space for a wheelchair user to use the bathroom.

Fixtures and fittings

15 Living room window glazing should begin at 800 mm height or lower, and windows should be easy to open/operate.
16 Switches, sockets, ventilation and service controls should be at a height usable by all (i.e. between 450 mm and 1200 mm above floor level). This applies to all rooms.

are increasingly adopting Lifetime Homes as part of their design briefs, and there are signs that Local Authority planning departments are also starting to ask for them, at least for a proportion of new dwellings.

4 SINGLE FAMILY HOUSES

4.01

There is now a large consensus that families with children should be housed at ground level in single-family houses, or in ground-floor flats or ground- and first-floor maisonettes with direct entrances. It is not just that children need private gardens. Equally, if not more importantly, the shared entrances, staircases and corridors in blocks of flats, and the external spaces around them, have proved to be largely incompatible with family life. This is especially true in the public sector, where the resources to overcome the management and maintenance problems of communal areas are very limited.

4.02 Orientation and gardens

The relationship between the single-family dwelling and the adjacent public domain (i.e. the highway, the street, court, or – much less satisfactorily – the footpath) should be as clear and simple as possible. A private front garden, with front gate and front path leading to the front door, and with minimum depth of 2 to 3 m has proven benefits as *defensible space*, as promulgated by Oscar Newman and Alice Coleman. This is not to say that successful houses have not been built with no front garden, and the front door opening directly, or via an inset porch, from the public pavement. There are many thousands of quite satisfactory houses planned like this in the Victorian inner cities; but in these cases the pavement is clearly part of the publicly maintained highway. When there is an intervening ‘confused’ space that is neither public nor private but needs to be communally managed, this is rarely satisfactory, and often leads to tangible neglect. Similarly, rear gardens benefit from simplicity and clarity of relationship to the house and of enclosure. Communal space is best kept to a minimum or omitted altogether. Such is the concern about security these days that opinion is generally against any provision of rear access, especially from unsupervised rear pathways, even when these are of practical convenience, such as in uninterrupted terraces.

Orientation of the dwelling for best sunlight is probably taken less seriously now than twenty years ago, and should not normally take precedence over achieving simple clear relationships of private and public domains. However, within the dwelling it should normally be possible to arrange for one of the two day rooms (living room or dining kitchen) to get direct sunlight for a large part of the day. It is preferable for one day room to face the front permitting supervision of the street; and for the other to face the rear giving direct garden access. Another factor is the potential for passive solar gain in the winter through the simple expedient of larger double-glazed windows on the southern elevation.

4.03 Height

Although the majority of family houses are of two storeys, three storeys can be appropriate in urban areas. The expense of building taller is usually more than compensated for by savings in foundations and roofs, making this an economical type. Four-storey houses, however, are difficult to plan, because of the need for an alternative escape route from the upper floors (Building Regulations Part B1). Mutual escape is normally provided between adjacent houses via adjoining rooms or balconies; but this leads to potential security risks.

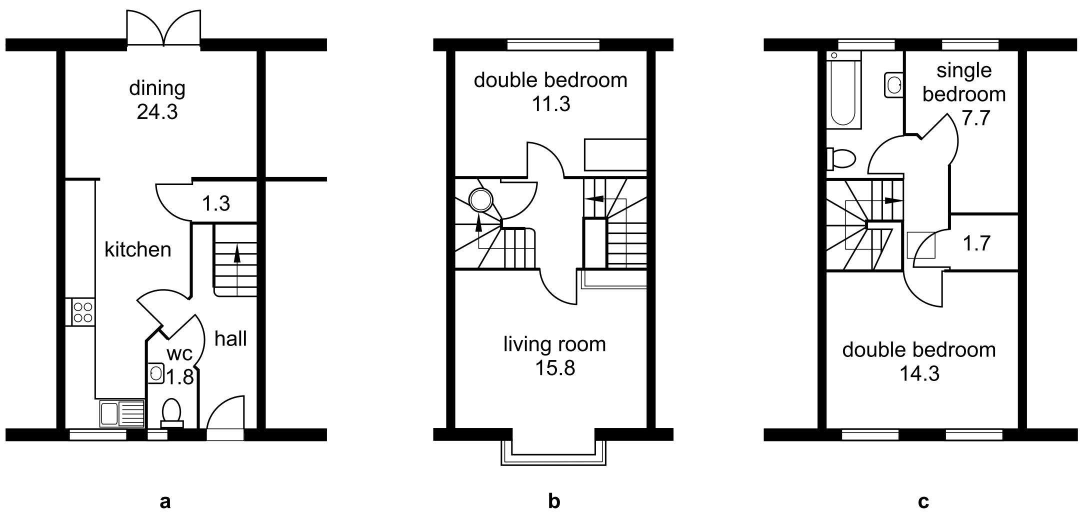
4.04 Frontage widths

Because of the costs of providing roads and services infrastructure, there is often pressure to build narrow-frontage houses – especially in urban areas. Anything less than 5.0 m width can be considered narrow frontage. Although reasonably satisfactory houses have been built with frontages of 4.0 m or even 3.5 m, the stresses on internal planning start to build up below approximately 4.5 m. A reasonable minimum could be taken to be 4.25 m frontage. Below this width, rear gardens also become apologetic. **8.6** shows a five-person, three bedroom, three-storey terrace house with a 4.5 m frontage.

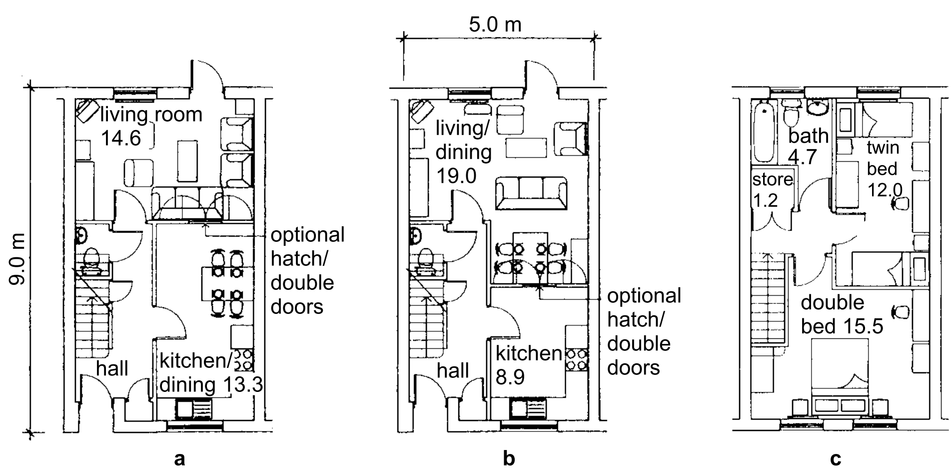
Taking 5.0 m as the normal terrace house frontage, **8.7** shows a two-bedroom, four-person, two-storey house; **8.8** a three-bedroom, five-person, two-storey house; **8.9** shows a four-bedroom, seven-person, two-storey house.

4.05 Internal planning

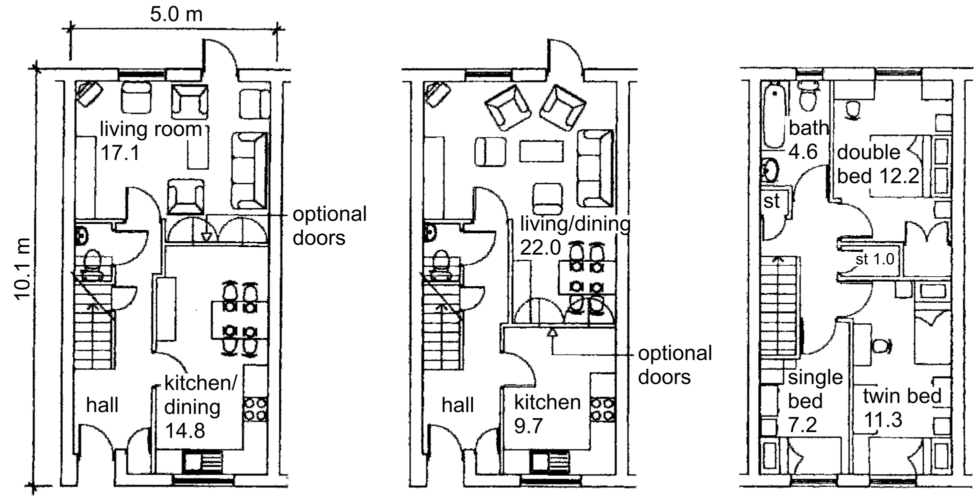
Opinions continue to differ over the relative positions of living room and kitchen, and therefore no recommendation is given here as to whether the kitchen is best at the front or the back. It is, however, rarely satisfactory for the only access to the rear garden to be via the living room: in fact Parker Morris ruled this out. In narrow-frontage houses where the living room needs to occupy most of the full width of the front of the house, the dining kitchen will therefore tend to be at the rear, where it can provide a route to the garden. In three-storey houses this sometimes works well in combination with a front living room at first-floor level as in **8.7**. Rooms can then be full width, and offer good outlook and supervision to both front and rear, as well as



8.6 *A five-person, three-bedroom three-storey terrace house with a 4.5 m frontage of 17 m*^{2}. **a** *Ground floor;* **b** *First floor;* **c** *Second floor*

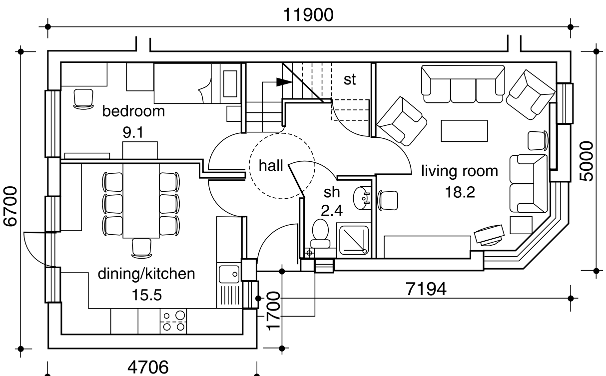


8.7 *A two-bedroom, four-person, two-storey terrace house of 79 m*^{2}. *Architects: PRP Architects.* **a** *Ground-floor plan with kitchen/diner;* **b** *Alternative ground floor with living/dining room;* **c** *First-floor plan*

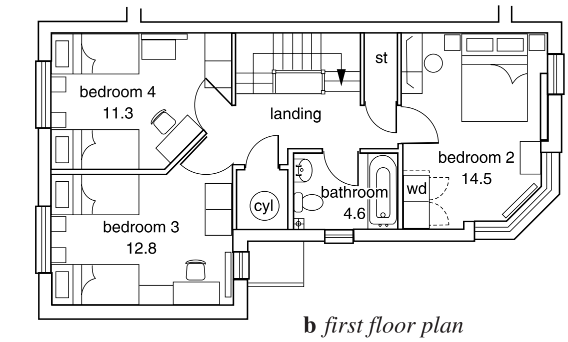


a b c

8.8 *A three-bedroom, five-person, two-storey terrace house of 85.9 m*^{2}*. Architects: PRP Architects.* **a** *Ground-floor plan with kitchen/diner;* **b** *Ground-floor plan with living/dining room;* **c** *First-floor plan*



a *ground floor plan*



b *first floor plan*

8.9 *Seven-person four-bedroom terrace house of 111 m*^{2} *to NHF standards. Architects: PRP Architects*

benefiting from sunlight with almost any orientation. **8.10** shows a seven-person semi-detached or end-of-terrace house; this achieves a full-width ground-floor front room by placing the entrance in the side wall.

4.06 Living/dining versus kitchen/diner

Several of the examples shown in this chapter give alternative ground-floor plans with the dining space in either the living room or the kitchen; also the possibility of opening the two spaces into one.

4.07 The main bathroom

This should preferably be located on the floor with the most bedrooms. In three-storey houses this might be the first or the second floor. A ground-floor WC is now a requirement in all family houses, however small. Although there is no longer a legal prohibition of WCs opening directly from kitchens, this arrangement is not normally either popular or advised. An exception might sometimes be a utility room containing a WC and forming the route to the garden. WCs must always have a handbasin (Building Regulations).

In larger family houses with four or more bedrooms, a second bathroom, or shower room, is recommended. This can be useful in three-storey houses, as it can mean having a WC on each floor. One bathroom or shower room can be en-suite with the main bedroom; however, this has not normally been considered to be appropriate in social housing. The Parker Morris standards for WCs were not especially generous, and have been overtaken by the new requirment for an entrance level WC.

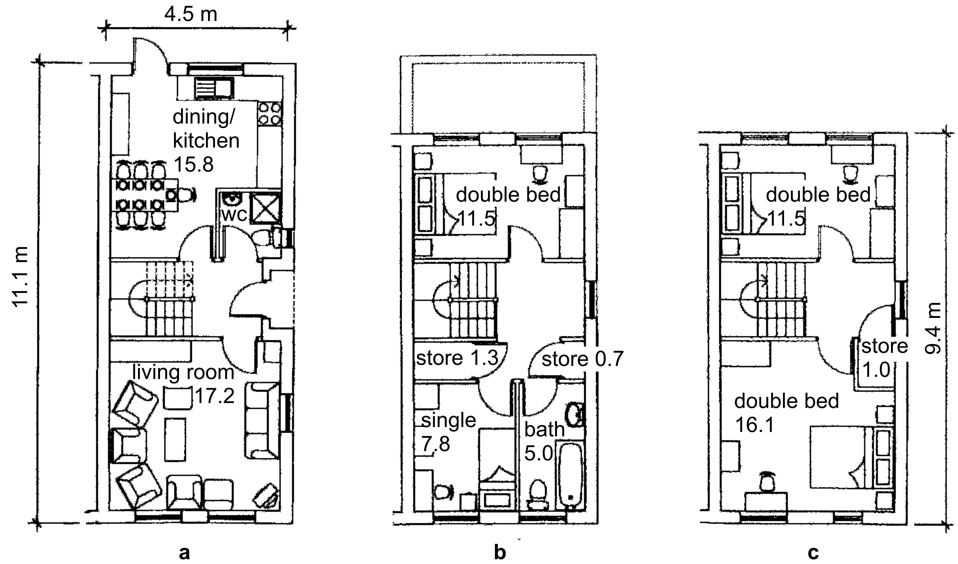
4.08 Storage

Where Parker Morris scored highly was in specifying good standards for storage. This has proved popular, and with people becoming more acquisitive all the time, real needs for storage space are increasing. General storage space is laid down in PM standards, over and above net floor space (see Table II). PM was specific that a large part (minimum 2.5 m^2) of the general storage space should be at ground level. All of it should normally be accessible from circulation areas rather than from rooms. It was not intended that the loft space should count, as this is not normally conveniently accessible (though a good-quality loft ladder will make it more so) and trussed rafter construction makes the space much less usable. Having said this, boarding to at least part of the loft will create valuable extra storage space for light objects such as empty packing cases, etc.

In addition to general storage space, Parker Morris stipulated the following storage spaces, *included* in the net floor area of the dwelling:

1 Space for hanging outdoor clothes in the entrance hall
2 Space for a pram (1400 × 700) in houses for three persons or more
3 Linen cupboard: 0.6 m^2
4 Kitchen storage: 2.3 m^2 (Parker Morris stipulated that part of this should be in a ventilated 'cool' cupboard, but this is less necessary now that virtually all households possess a refrigerator).

Bedroom cupboards such as built-in wardrobes were not stipulated. These can be valuable especially for low-income families; however, they need to be carefully planned in order to prevent them making the bedrooms less furnishable. If provided, built-in wardrobes also come out of the net floor space, and do not count towards general storage space. The figures in Table II should not include dustbin stores or spaces (which should be at the front of single-family houses), fuel stores if these are required, nor any space within a



8.10 *Seven-person four-bedroom house of 118.5 m^2. Architects: PRP Architects.* **a** *Ground floor;* **b** *First floor;* **c** *Second floor*

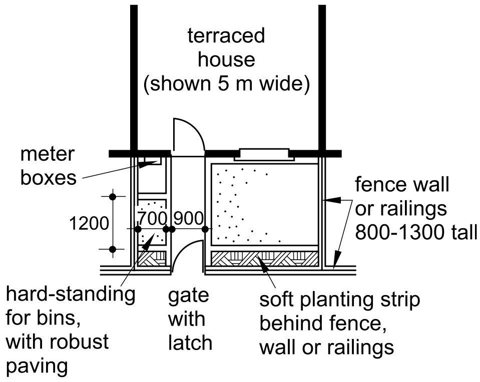
store which is needed for through access, such as to get to the rear of a single-access house. For this purpose Parker Morris stipulated a 700 mm width. Space in an integral or adjoining garage over and above 12.0 m^2 can count towards general storage space.

4.09 Stair configuration

Although the Building Regulations do not rule out winders provided certain minimum dimensions are met, winders are intrinsically less easily negotiated and more hazardous, especially for young children and older people. It is important that large wardrobes and other furniture can be taken up and down the stairs. This needs to be carefully planned for, especially in three-storey houses, where the soffit of the upper flight can restrict the head height over the lower flight, and winders make the problems worse.

4.10 External design

Refuse storage space is almost always needed at the front of the house, **8.11**. This can be over-designed, and there are many examples of ugly dustbins concealed inside even more ugly bin enclosures – sometimes little temples which make an inappropriate celebration out of storing refuse, with intricate and flimsy doors, hinges and catches that hardly survive the first visit by the dustman. The location for the dustbins or *wheelybin* needs to be clearly identified, for example by partial enclosure or change of paving surface. It needs to be close to the highway, the front gate and path, and not too far from the front or kitchen door. It should not be where smells would cause a problem, such as immediately under the window of a habitable room. It should always be copiously ventilated, and from this point of view the best form of enclosure is none at all.



8.11 *Front garden of a terraced house showing refuse storage*

Meter positions can sometimes be integrated with that of dustbins, so that one can partially mask the other. This is more the case now that the service companies increasingly ask for external or externally readable meters.

External enclosure by fences, walls or railings can dramatically influence the look of a housing development. The function of a front garden enclosure is different from that of the rear garden, and this should be reflected in the design, **8.11**. Front fences, railings or walls should allow easy visual surveillance, both ways. A height of between 800 mm and 1300 mm is usually appropriate, and it is useful if the enclosure can be seen through below this level, but does not let dogs through. Thus railings and paling fences score over walls. Front gates should be of roughly the same height. A closed gate effectively excludes dogs and makes a *defensible* space feel rather more so; but gates, gate posts and catches need to be sturdy and carefully designed. Probably a majority of existing front gates do not shut properly, because of historical movement of the posts.

Enclosure of rear gardens is simpler. An impermeable wall or fence of approximately 1.8 m height is normally recommended at the far end. The side (party fence) enclosures can be reduced to approximately 1.2 m. Most people seem to welcome some garden-to-garden contact with their neighbours, though not immediately next to the house, where a greater height is preferred. If gates *are* provided in rear garden walls or fences, these should be full height (at least 1.8 m) and lockable with security grade dead locks. Where against public or communal spaces, the security of rear fences and garden walls can be improved by the addition of timber trellis on top; between 450 mm and 600 mm in extra height.

5 PURPOSE-BUILT FLATS

5.01

A block of flats nearly always involves shared entrances, stairs, landings, balconies or lobbies, and often one or more lifts. It is these that make flats more difficult to manage, because someone has to clean and look after these common spaces. These features tend to make flats unsuitable for families with children, as already said above. Flats should therefore normally be considered only for single people and childless couples, In many developments, one would expect most flats to be single-bedroom, with a lesser number of double-bedroom. The latter can be popular with couples whose children have grown up, or are just being born; and with other smaller households.

The common areas and facilities become exponentially more difficult to manage with increasing numbers of flats in the block. Small blocks of four or six flats are easier to manage than those where the numbers get into double figures. Shared systems such as entryphones rely upon responsible behaviour; this is more achievable with a small number of households who know each other.

5.02 Height of blocks

Parker Morris stipulated the maximum walk-up to a flat front door to be two storeys. Although the Housing Corporation no longer rules out four-storey blocks without lifts, these are on the limit of acceptability. For five storeys and above, a lift is essential (although – despite expectations – the new Part M of the Building Regulations does not make the provision of lifts a legal requirement).

5.03 Common stairs, corridors and balconies

Essential criteria for common parts of blocks of flats are laid down clearly in the Building Regulations Part B1 and in BS 5588 Part 1. Direct entry to flats is permitted without intervening lobbies in low blocks (up to four storeys) with no more than two flats per floor if the entrance halls within the flat are fire-protected routes with fire doors and door closers. If lobbies are provided, then within small flats (less than 9 m maximum travel distance from the furthest point in the flat to the front door) a protected route is not stipulated.

Common, or semi-public, staircases are usually best located at the front of the block, where the stair windows can look over the highway or public domain, rather than over private gardens provided for the ground-floor flats.

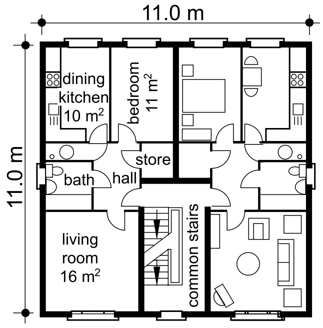
5.04 Stacking of similar rooms

All party floors have to provide sound insulation; but the levels of insulation that are mandatory cannot prevent all noise nuisance, and it is best if similar rooms are stacked one above the other. The worst combination is one flat's living room directly above another flat's bedroom.

5.05 Configuration of rooms around the common stairs

The minimum levels of sound insulation specified in the Building Regulations between all habitable rooms in flats and the common parts of the block are less than fully satisfactory. It is preferable therefore to situate bedrooms away from the common stairs **8.12**; and particularly, well away from any liftshaft.

It is usually preferable to plan day rooms at the front and bedrooms at the quieter rear, perhaps alongside the kitchen. There are however, many examples of small blocks of flats with bedrooms at the front alongside the stairs, and living rooms at the rear. The banal reason for this is that the bedrooms are narrower than the living rooms which make use of the extra width behind the stairs. This plan form combines the worst exposure of the bedrooms to noise nuisance from the common stairs with the least satisfactory orientation of day and night rooms.



8.12 *Small block of one-bedroom, two-person flats, bedrooms located away from stairs. Each flat 52 m². Lobbies between stairs and flats are required in larger blocks*

5.06 Balcony access

This is no longer common, having been largely discredited by the social failures of much of the deck-access medium-rise local authority housing built in the 1960s and 1970s. However, some of the smaller self-contained balcony access flat blocks built between the wars have proved quite satisfactory in long-term use. Open-air balconies can sometimes avoid the squalor associated with wholly internal common circulation areas, but they can also enable the planning of large extended blocks, with too many flats using a single entrance and stair. This should be resisted.

A problem with balcony access flats is the dual aspect; some windows are directly onto the balcony. These are not popular, owing to lack of privacy and the security risks. Kitchens and bathrooms tend to be placed on the balcony side, but residents dislike strangers passing close to their kitchen sinks.

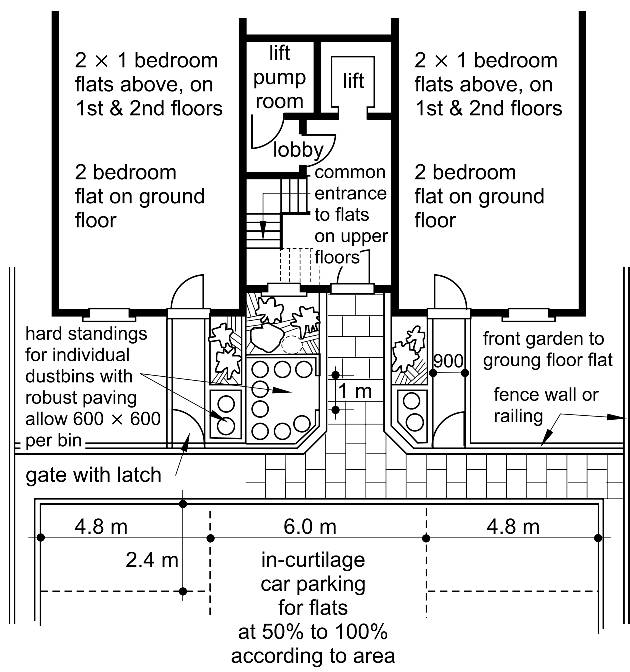
5.07 Lifts

In blocks of flats these should always be capable of taking a wheelchair; preferably an eight-person lift as defined by BS 5655 (see Chapter 5). The new Part M of the Building Regulation does however allow rather smaller lift car dimensions, equating to a five person lift. A thirteen-person lift should also be capable of taking a horizontal stretcher. Lifts in medium-rise flat blocks have become rather easier to plan, using hydraulic lifts with pump rooms at or near the base, as opposed to electric lifts with motor rooms at the top. Hydraulic pump rooms can be very compact and flexibly positioned, as shown in **5.3**. Also refer to **5.6** for dimensions for an electric traction lift.

5.08 Refuse

This is always a problem with flats. Traditionally, public sector housing has used chutes. These cause a noise nuisance, tend to get blocked, and the inlet points can become particularly unsavoury. Additionally, the chambers at the base of the chutes, with paladins or skips, collect overflowing rubbish, vermin, and general mess and squalor. If blocks of flats can be kept small (up to six or eight flats) then it is quite possible to provide a discreet but easily accessible area containing a separate rubbish bin for each flat, clearly and individually marked, **8.13**.

For large or tall blocks, there is little alternative to refuse chutes – in fact, they are required under the Building Regulations for blocks



8.13 *External planning for typical three-storey block of ten flats showing refuse storage* of more than five storeys. The base area needs to be carefully designed, with robust and easily cleaned surfaces, good access for cleaning and copious ventilation.

5.09 External areas

Unless there is a very competent management regime, shared external areas should be minimised or abolished. Clearly the latter is not entirely possible, as access is needed to the common front door. The route to this entrance should be as simple as possible: broad and short. Areas to the sides of this access can be given to the ground-floor flats as front gardens; and these will be much more successful if these flats have separate front doors independent of the common entrance. Similarly, the best use for the ground behind the block is normally as rear gardens for the ground-floor flats. Communal gardens sound good but rarely work, unless there is an exemplary system of management by residents' association or landlord. (As residents of Georgian squares know, this does not come cheap!) External space for upper-floor flats is often provided by private balconies. The enclosure of front and rear gardens to ground-floor flats should be similar to that for single-family houses (see para **4.09**). The shared approach to the main entrance door should be treated rather differently. If there is no unallocated garden space there will, naturally, be no fencing except on either side of this approach.

If there is any soft landscaping along the shared approach route, it needs to be carefully planned to withstand rather less tender loving care than in private gardens. If flanked by well cared-for private gardens, then the common approach path is best left as good quality hard landscaping and paving.

6 HOUSE CONVERSIONS

6.01

The conversion of large houses into self-contained flats in the 1970s and 1980s used to be the stock-in-trade of inner city housing associations, as well as private developers. There is evidence of a falling off of this type of rehabilitation project, partly because of a gradual shift in demand, but also because housing associations have been turning more towards new-build schemes since the Housing Act 1988.

6.02 Planning

Splitting up a single-family house involves creating at least one new dwelling, and thereby constitutes 'Development' under the Planning Acts. Unlike extending a single-family house by an allowed percentage of its volume, this is not 'Permitted Development', as defined by the General Development Order and its various amendments. Therefore house conversions require planning permission, and this allows planning authorities to control this type of development if they feel that it is eroding the balance of single-family houses in the district.

Houses that are statutorily listed have more onerous constraints; for example, requiring Listed Building Consents for any demolition (however small). Certain restraints also apply to all properties within Conservation Areas, possibly depending on what Article 4 directions have been approved. Conservation Area Approval is no longer required for a small amount of demolition, such as of an outhouse; but a proposal of this nature might well lead to a spot-listing, when a Listed Building Consent would then be required. In many of these cases the planning authority and/or English Heritage may then get very involved in detailed design and aesthetics.

This introduces the first discipline when dealing with an existing house, which is to respect its existing qualities and character. A natural conversion should aim to keep well-proportioned rooms intact wherever possible. This commonly means at least the main front rooms at ground- and first-floor levels. Avoid boxed-in lobbies in the corners of previously good rooms: they can make nonsense of original decorative elements such as cornices and picture rails, and also make the rooms more difficult to furnish. Another implicit aspect of natural conversions is the aim to keep similar rooms stacked over each other. Day rooms of one flat should not be planned over bedrooms of another flat; and bathrooms and kitchens are best stacked, thereby simplifying drainage and plumbing.

The same considerations about accommodation for families with children apply as for new-build. Family dwellings should be at ground and/or basement level, or at least have direct street entry and garden access. This will usually mean only one large unit in the conversion of a house, with one or more smaller units (preferably one-bedroom) over it. In an understandable wish to reduce the common areas, many conversions have been built the 'wrong way up' with a large unit over a one-bedroom flat at ground-floor level. This is unsatisfactory, especially in social housing. Family life is noisy, and does not fit well over single people or couples.

Having said this it should be the aim to abolish or minimise common areas and stairs wherever possible, as these often cause continuing management problems. New external stairs may be added in some cases to achieve the objective of a separate direct entrance for each dwelling.

6.03 Building Regulations

Creating new dwellings constitutes building work and is controlled by the Building Regulations. Most of the same parts (see Table IX) apply to conversions as to new-build. The main exception is Part L, in recognition of the fact that it may not be reasonably possible to add thermal insulation to all elements of the existing fabric to the standards required for new buildings.

Some elements such as top-floor ceilings, though, are quite simple to insulate, and could be upgraded to a higher level than required for new-build to compensate for not insulating the walls. Thermal insulation can also often be added to the walls of rear extensions, where there is a greater proportion of exposed wall surface to floor area, and decorative features, which would be lost, are absent. The replanning of rear parts of the house to provide new service rooms may also give opportunities to add insulating linings. Also worth considering (subject to planning restrictions) is external insulation, as this can theoretically give a better thermal performance and reduces cold bridging. Parts B1 (Means of Escape) and E (Resistance to the Passage of Sound) apply to conversions as for new-build, and can impose significant requirements.

6.04 Loft conversions

If habitable rooms are converted out of loft space, the resulting floor area is measured over those parts that are more than 1.5 m high. A two-storey house is covered by Part B1 of the Building Regulations only for escape from upper floor windows. However, when its loft is converted, extra requirements of Part B1 come into force.

Under Part K, alternating-tread stairs are specifically allowed up to single rooms and bathrooms in a loft. Despite this, there are considerable reservations about the safety of alternating-tread stairs, and they are not recommended, especially in social housing. A reasonable width for a staircase leading to a single habitable room in a loft is 800 mm, with a minimum of 700 mm.

6.05 External areas

Similar considerations apply as to purpose-built flats. The best answer is often the simplest: to give both front and rear gardens to the lowest dwelling, which is likely to be the largest. Balconies to upper-floor units are less likely to be feasible than with new-build, unless a low rear extension provides an opportunity for a roof terrace. Some planning authorities deprecate these as prejudicing the privacy of neighbouring gardens. In cases of detached, semidetached and end-of-terrace properties with easy access to the rear, plots for the upper flats can be provided by dividing the rear garden. There are also examples where first floor flats have been given access by means of external stairs. There is however evidence that small subdivided rear gardens can lead to neglect, because residents feel less well 'connected' to them.

7 ACCOMMODATION FOR SINGLE PEOPLE

7.01

In DoE Design Bulletin DB29 *Housing single people*, published in 1975, a distinction was drawn between the space requirement for *middle-aged permanent residents* and for *young mobile workers*. This led to a recommendation for small (25 m^2) bedsitting room flats for the latter category. The trouble is young mobile tenants turn into middle-aged permanent ones quicker than housing managers can respond. This has resulted in a great degree of dissatisfaction with bed-sit flats for single people.

The four principal types of accommodation provided for single people are:

- Self-contained one-bedroom flats, for which Parker Morris standards are recommended without change
- *Cluster flats* providing a number of bedsitting rooms for individuals, with shared dining kitchens, living rooms and sanitary facilities, **8.14**, and
- Sheltered housing for elderly single people (see para **8** below)
- That which is suitable for students, nurses, etc.

7.02 Cluster flats

Because of the space needed for the individual bedsitting rooms, the floor areas for cluster flats should be rather greater than for the equivalent size of a general needs household, for three-person units and larger (see Table XIII).

Even more than with Parker Morris general needs housing, storage space is important for single persons sharing a dwelling. DB29 therefore laid down minimum storage spaces,

Table XIII Housing for single people from DB29

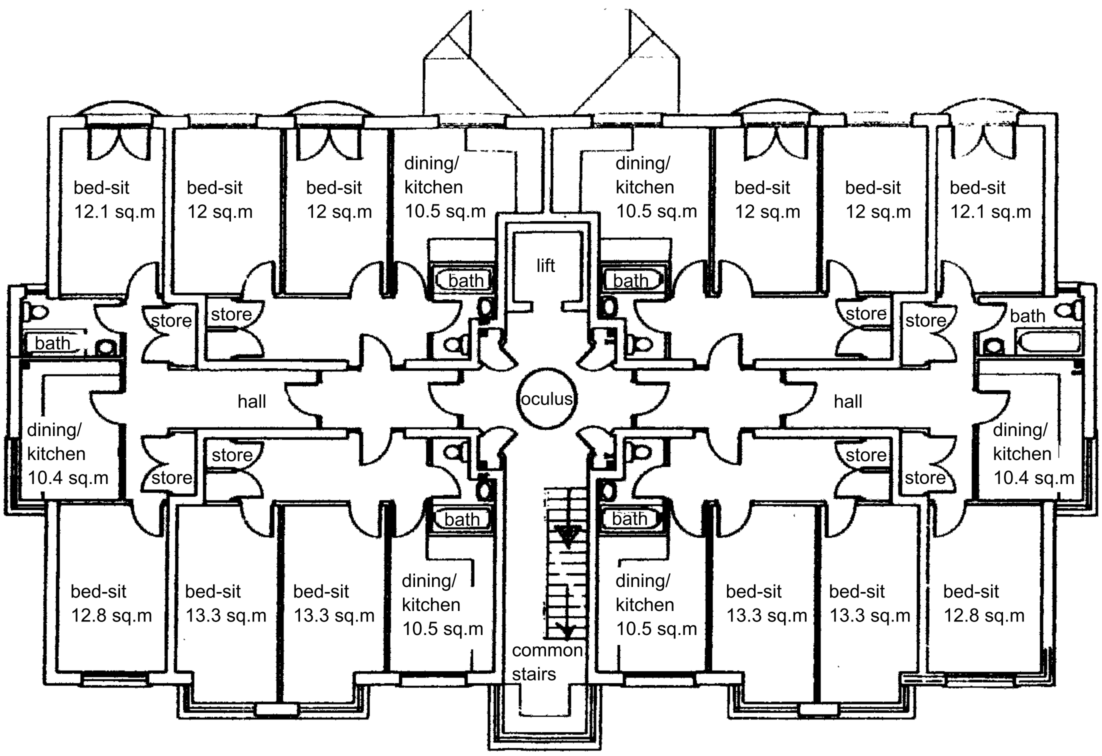
Numbers of single people sharing	1	2	3	4	Each additional person
Minimum areas (including storage) in:					
single-storey houses	33 m^2	48.5 m^2	65 m^2	85 m^2	20 m^2
houses more than 1 storey				90 m^2	
flats	32.5 m^2	47.5 m^2	65 m^2	85 m^2	20 m^2
maisonettes				90 m^2	
Personal storage	3 m^3	6 m^2	9 m^2	12 m^3	3 m^3
including shelves or drawers with area not less than:	2 m^2	4 m^2	6 m^2	8 m^2	2 m^2
Dwelling storage	0.5 m^3	0.5 m^3	0.5 m^3	0.5 m^3	
including shelves or drawers with area not less than:	0.8 m^2	0.8 m^2	0.8 m^2	0.8 m^2	
Kitchen storage	1.4 m^3	2.1 m^3	2.8 m^3	3.5 m^3	0.7 m^3
including shelves or drawers with area not less than:	5 m^3	7 m^2	9 m^2	11 m^2	2 m^2
Electric socket outlets	9	12	15	18	3
Bath or shower	1	1	1	1	
Washbasin	1	1	1	2	
WC separate	1*	1*	1	2*	

* one may be in the bathroom.

distinguishing between that for individuals and that for the dwelling as a whole (see Table XIII). The minimum area for the individual bedsitting rooms within a cluster flat was not laid down in DB29, and does not equate directly with any classification in Table IV. A minimum bedsitting room is 12 m^2, the recommended size for a medium to long-stay resident is 15 m^2, and a washbasin should be provided in each.

7.03 Common rooms

Where these are provided, the areas should be at least 20 m^2 for the first 25 persons (*young mobile*) plus 0.4 m^2 for each additional person. However, it is now less common to provide common



8.14 *First floor of a block containing six flats of 51 m^2, each with two bed-sitting rooms for single people sharing (see* **8.15** *and* **8.17** *for other floors of this block)* rooms, as schemes tend to consist of self-contained flats, either for one-person households, or of clusters, who share integral day rooms. There is one exception that should be noted.

7.04 Foyers

A concept introduced from France in the early 1990s is the *foyer*, consisting of a complex containing accommodation for young single people either in one-person flats or more usually a number of cluster flats, or a mixture of the two types. It also includes substantial training and other facilities such as cafeterias, laundries and common rooms. To make it economically feasible, a foyer may need to house about 100 young people. Although successful in France, it is still too early to assess how well foyers work in the UK.

8 SHELTERED HOUSING

8.01

The design standards for accommodation specially designed for elderly people were first set down in the forms of *Category 1* and *Category 2* in MLHG Circular 82/69. This did not refer to *sheltered housing*, which is the name now generally employed for separate flats or bungalows for the elderly within a scheme that also has shared facilities such as common rooms and a warden.

8.02

The standards in Circular 82/69 were mandatory for publicly funded sheltered housing schemes from 1969 until the parallel demise of Parker Morris in the early 1980s. The circular has now been withdrawn, but the standards in its Appendix 1 remain a reasonable guide to what should normally be included in a sheltered scheme. The one exception is the small one-person *grouped flatlets*, which have proved neither popular nor suitable for elderly people.

8.03

The Housing Corporation, in its Scheme Development Standards for Housing Associations, continues to define sheltered housing as *Category 1* and *Category 2*, or frail elderly. These Standards require most of the facilities listed in Circular 82/69, but give no space standards. The following guidance is taken from Circular 82/69 (Tables XIV and XV) and from the Housing Corporation current Standards (Table V).

Table XIV Sheltered housing for the elderly Minimum floor areas in m^2 from Circular 82/69. Mandatory for publicly funded schemes from 1969 until 1981

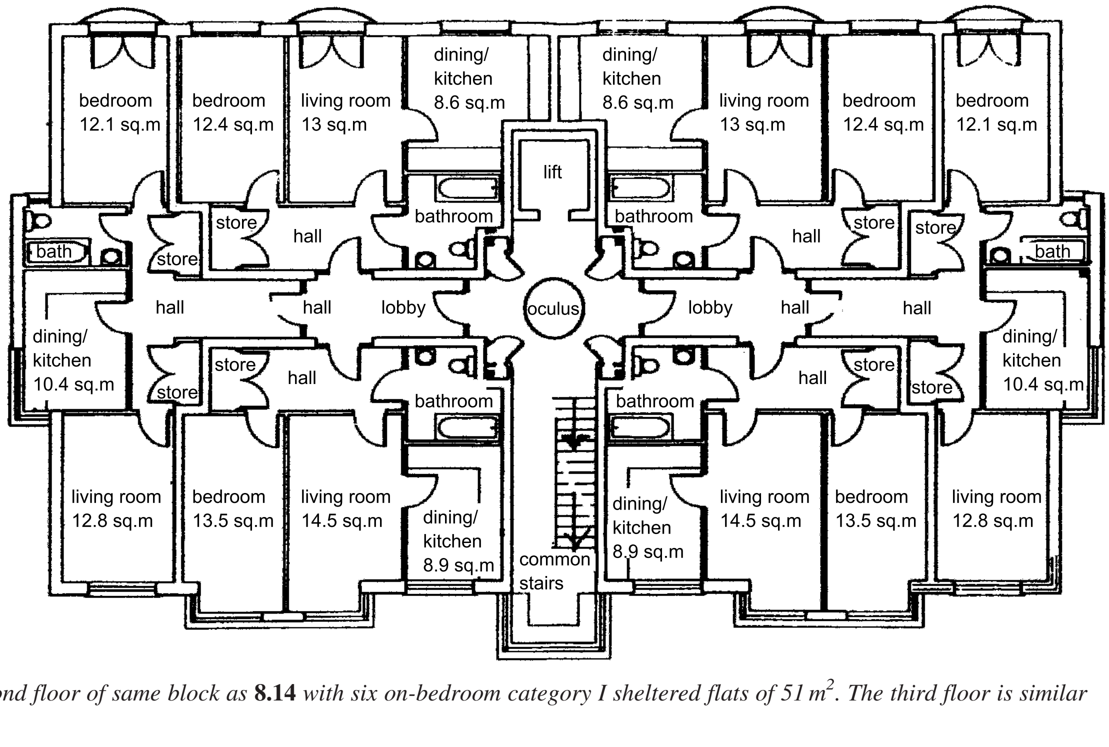
	No. of persons (bedspaces)	Net area	General storage area	Total
Category 1 bungalows	1	30.0	3.0	33.0
	2	44.5	4.0	48.5
Category 1 flats	1	30.0	2.6	32.6
	2	44.5	3.0	47.5
Category 2 'flatlets'	1	28.1	1.9	30.0
	2	39.0	2.5	41.5

Notes:
1 Category 1 standards were the same as in Parker Morris, Table II.
2 In Category 1 bungalows no more than 1.5 m^2 of general storage space should be outside the dwelling. In Category 1 flats, all should be inside.
3 In Category 2 flatlets for one person, up to 0.8 m^2 of the general storage space may be outside the flatlet in internal communal storage; in two person flats, up to 1.2 m^2.
4 The Circular recommended caution in providing a bath in a one-person flatlet. It suggested a very short 1350 mm bath. This excessive caution was probably misplaced.
5 The Circular also recommended smaller 'grouped flatlets' for single persons with bedsitting rooms and small kitchens sharing a bathroom. These proved neither popular nor suitable and the Housing Corporation now requires every flat to be self-contained with its own bath or shower.

8.04 Category 1

It will be seen from Tables XIV and XV that Category 1 dwellings need not be radically different from general needs one- and two-person units, **8.15**. The minimum recommended floor areas (Table XIV) are identical to Parker Morris equivalents (Table II). The main additional requirements concern access (maximum of one storey up enclosed stairs with a gentle pitch unless a lift is provided), full central heating (which should be universal in any case), and baths suitable for the potentially infirm.

The stipulation of short (1550 mm long) baths, previously made by the Housing Corporation, is questioned by some physiotherapists. Nowadays many types of special baths are available, some with mechanically assisted immersion. Some of these are based on normal domestic sizes, of approximately 1700 × 700 mm, and are designed to replace ordinary baths without much difficulty.



8.15 *Second floor of same block as* **8.14** *with six on-bedroom category I sheltered flats of 51 m^2. The third floor is similar*

Table XV Sheltered housing for the elderly Minimum standards from Circular 82/69 for plans, fittings and facilities. Mandatory for publicly funded schemes from 1969 until 1981

1 *Plan arrangements*
(a) enclosed staircases
(b) maximum climb of 1 storey, without a lift
(c) 2 lifts, and all access enclosed, if more than 4 storeys high
(d) convenient, covered and lit access to refuse storage
(e) entrance lobbies or halls with clothes hanging space
(f) kitchens should provide unbroken sequence: worktop/cooker/worktop/sink/draining board
(g) in 2- and 3-person dwelling; space in kitchen for 2 persons to eat

2 *Furniture*
Plans should be able satisfactorily to accommodate the following:

(a)	Kitchen	in Category 1, a small table
(b)	Living room	small dining table and chairs 2 easy chairs, or 1 settee and 1 chair TV set small table reasonable quantity of other possessions, e.g. bookcase
(c)	Bedroom (single)	single bed bedside table small dressing table and chair built-in cupboard 600 mm wide, or space for single wardrobe
(d)	Bedroom (double)	2 single beds (or double bed alternative) 2 bedside tables small chest of drawers small dressing table and chair built-in cupboard 1200 mm wide, or space for a double wardrobe
(e)	Bed recess	same as single bedroom

3 *Kitchen fitments*
(a) Storage capacity minimum 1.7 m^3 including refrigerator minimum capacity 0.07 m^3 or space for a refrigerator, and a broom cupboard.
Fittings measured overall for depth and width, and from underside of worktop to top of plinth for height. Maximum height of worktops 850 mm. (Note: this is no longer recommended, see sections above.)
(b) In Category 2 flatlets; a gas or electric cooker, adapted for safe use by elderly people.

4 *Linen cupboard*
(a) storage capacity 0.4 m^3
(b) at least 2 shelves, at minimum height 300 mm, and maximum height 1520 mm.

5 *Electric socket outlets*

(a)	Kitchen	4
(b)	Living room	3
(c)	Bedroom	2
(d)	Hall or lobby	1
(e)	Bedsitting room	5

(These standards would now be considered low, but would be roughly appropriate if each number represented a double socket.)

6 *Space heating*
(a) The installation should be able to maintain:
flats and communal rooms (if provided) at 21°C
circulation areas in Category 2 schemes at 15.6°C
when outside temperature is –1°C
(b) The temperature should be controllable by the resident.

7 *Bathrooms*
(a) Baths should be flat bottomed and short (1550 mm) to prevent an elderly person becoming competely immersed. (Note: this guidance on short baths is not agreed with by all occupational therapists.)
(b) All baths and WCs should have at least one hand-hold in a convenient position.
(c) Doors to bathrooms should open outwards and have locks openable from outside in an emergency.
(d) One in four bathrooms may be replaced by a shower room. The shower compartment floor should be non-slip and free of hazards, with a secure hand-hold and wall-mounted seat. The hot water should be thermostatically controllable to a maximum 49°C, with a height adjustable outlet.

(Note: All Category 1 and 2 flats should now be provided with a full bathroom, with WC, washbasin and bath or shower.)

8 *Communal facilities for Category 1 schemes*
Common rooms (e.g. lounge, TV room, workshop or hobbies room) are optional in Category 1 schemes. If they are included, then the following should be provided:

(a) floor area 0.95 m^2 per resident
(b) short route from the dwellings (not necessarily covered)
(c) one WC and handbasin, near the common room
(d) small tea kitchen, next to the common room
(e) space for hats and coats
(f) small cupboard for cleaning materials
(g) store next to the common room, at least 2 m^2.

A Category 1 scheme may have an emergency call system, which should be linked to a reception point. (It is general to include this in current schemes.)
A Category 1 scheme may also include a guest bedroom. This should be near a communal toilet. (An en-suite bathroom is preferable.)

9 *Communal facilities of Category 2 schemes*
The following should be provided:

(a) a common room or rooms, floor area 1.9 m^2 per resident
(b) a WC and handbasin, near each common room
(c) a small tea kitchen, next to the common room
(d) space for hats and coats
(e) a store next to common room, at least 2 m^2
(f) a warden's self-contained dwelling, designed to general needs standards (see Tables II to V) (or, for schemes of less than 15 flats, adjoining a residential home, a warden service provided from the home)
(g) an emergency call system linked to the warden,
(h) a laundry room, with minimum of:
1 automatic washing machine
1 tumble-drier
1 sink
1 table or bench for folding clothes
(i) a cleaner's cupboard, minimum 1 m^3
(j) a telephone and seat
(k) enclosed and heated circulation areas
(l) the possibility of door-to-door goods delivery
(m) a warden's office near the main entrance
(n) a Category 2 scheme may also include a guest bedroom, which should be near a communal toilet. (An en-suite bathroom is preferable.)

It would be normal for a larger Category 1 scheme to include a number of two-bedroom units, which should be to Parker Morris three- or four-person size. Category 1 dwellings tend to follow certain recognised patterns:

1 Small two-storey blocks of flats, containing, for example, from four to eight dwellings
2 The lower two storeys of a general needs block of flats, up to four storeys tall, without lifts. (This can conflict with the policy of putting family housing at ground-floor level.)
3 A group of bungalows, perhaps forming part of a larger sheltered scheme.

8.05 Category 2

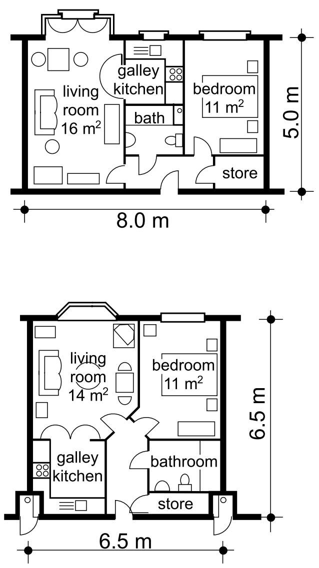
These dwellings are more clearly distinguished from general needs housing by their need to be grouped in a single scheme or block. The size of the scheme will be constrained by the the requirement for a resident warden in his or her own dwelling on the site. It will need to have enough flats to contribute to the salary and costs of the warden; this normally means a minimum of about 20 flats. But the scheme should not be so large that the warden's time and care are too stretched to cope; and this imposes a maximum size of around 40 flats. Category 2 schemes therefore tend to contain about 30 flats, **8.16**.

A number of the ground-floor flats should normally be designed for residents in wheelchairs, **8.17**. Also, although most Category 2 flats have one bedroom, a small number of two-bedroom flats can be included. These are valuable for elderly siblings, for example. Such flats should be approximately 10 m^2 larger than the standard one-bedroom two-person flatlets in Table IV, i.e. 50 to 55 m^2.

Of one-bedroom flats, it has been found that the greatest demand is for nominal two-person units. Many single elderly people are fairly recently widowed, and still have furniture, e.g. double beds, from their marriages. For these, a double bedroom is very desirable (see Table IV).

Sheltered flats' bathrooms should be better equipped and rather larger than for general needs, to allow space for assistance with bathing or showering, when necessary. The advice in 'Lifetime Homes' is also relevant here.

Category 2 schemes should include the communal facilities listed in Tables V and XV, all accessible indoors, via heated common circulation areas. The planning of the communal facilities



8.16 *Category 2 sheltered flats, two-person one-bedroom flats at 41.5 m² each*

will vary greatly from scheme to scheme, but some general principles apply. If more than one common room is provided, one can be planned at the front of the building to face the street and approaching visitors; and another overlooking the rear garden. One might be planned as an evening room; and the other to suit more daytime activities, with perhaps a conservatory linking it to the garden. Every common room should have a WC to mobility or wheelchair standard (see Chapter 3) as close as possible, and a furniture store. One of the common rooms should have a kitchen. The laundry is best sited at ground-floor level, with direct access to a drying area in the garden, even if it is equipped with tumbler-driers.

Many Category 2 sheltered schemes, and all schemes for the frail elderly have a bathroom suitable for assisted use, as some residents will be or become too frail to bathe themselves. This is not necessary where the sheltered scheme is linked to a adjacent residential home whose facilities can be used.

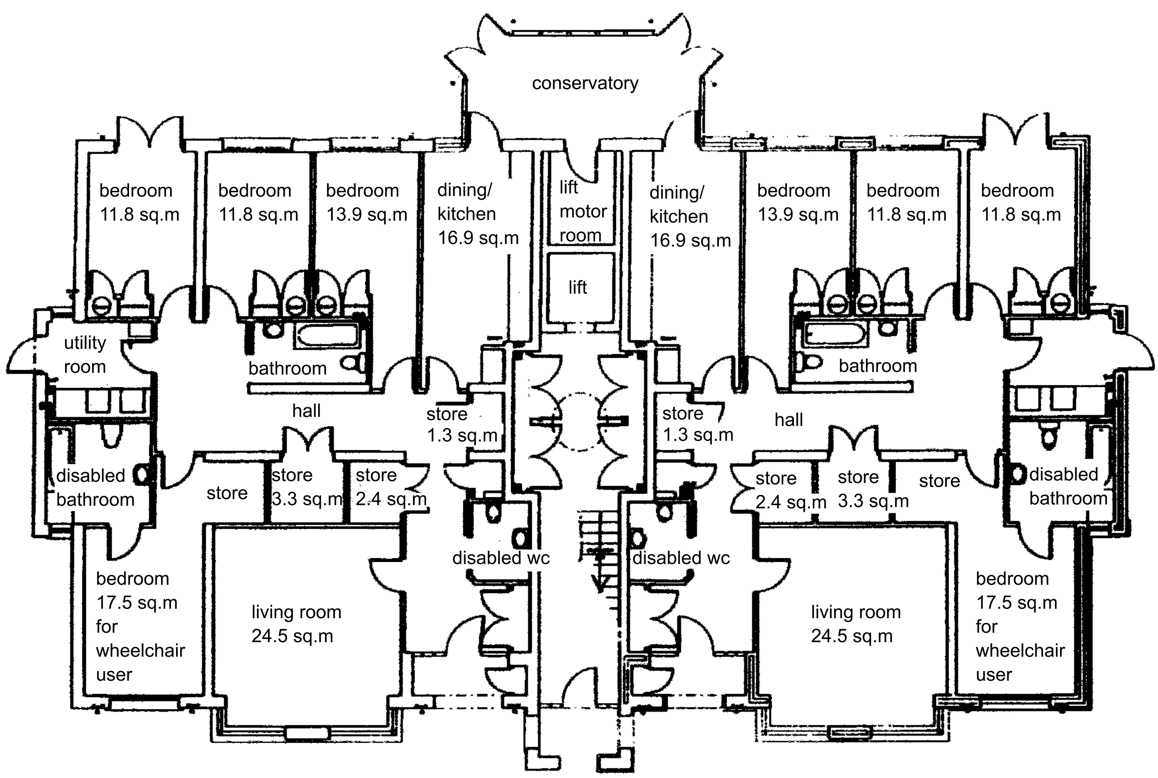
The warden's dwelling may be a flat, a house or a maisonette, and should be to general needs standards (see Tables II–VIII). Since the warden may well have a family, it should preferably be a three-bedroom family unit meeting all the normal criteria for family dwellings (see above), i.e. be at ground level, with its own independent front and rear gardens and separate front door. Additionally, there should be a discreet direct link to the common circulation area of the flats. The warden's dwelling need not be near the warden's office, which should be close to the main entrance of the scheme. Indeed, it is preferable if the dwelling is in a more private location.

Some residents of sheltered housing will be or become frail, while others will retain their full fitness for many years. To cater flexibly with a varied population of elderly people, a larger development could contain a mixture of Category 1 dwellings (perhaps free-standing bungalows), a Category 2 scheme of around thirty flats, and a Frail and Elderly Home.

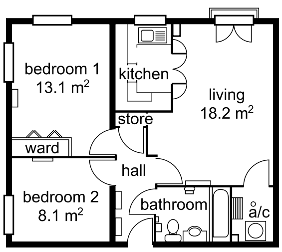
Against this, geriatric ghettos should be avoided. A comprehensive housing development should aim sensitively to integrate housing for older citizens with general needs family houses and flats. While some elderly people enjoy the noise and activities of children, others are irritated by them. A proportion of units for elederly people should be located at a distance from general needs housing. When shops and other facilities are included or nearby, the sheltered housing should be sited reasonably close to them.

8.06 Private sector

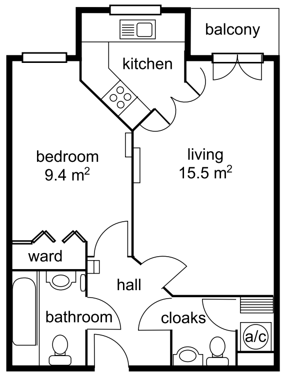
Housing for elderly couples and singles provided by the private sector are referred to as *retirement homes.* The facilities are similar to Category 1. Usually, there is no resident warden although there may be a manager on-site during office hours, and a system of calling a private emergency service when he or she is not there. Typical examples are shown in **8.18** and **8.19**.



8.17 *Ground floor of same block as* **8.14** *and* **8.15** *containing two flats each of 165 m² with four bedrooms, one of which is for a wheelchair user*



8.18 *Private sector retirement home with two bedrooms, Note the tiny kitchen and the lack of adequate storage space*



8.19 *Single-bedroom retirement home. For one bedroom, this has very generous sanitary arrangements, but again a singular lack of space to store a lifetime's possessions*

9 ESTATE MODERNISATION

9.01

Local authorities have recently been building little new housing, but they still own an enormous stock of existing estates built over the last hundred years. Many of these are now decrepit and out of date. Significant funds and initiatives are therefore being directed towards the special problems of these estates. These initiatives have included government-financed Estate Action Programmes, City Challenge projects, and Housing Action Trusts; and more recently Estate Renewal Challenge Funding, Single Regeneration Budgets, and New Deal for Communities Initiatives. Funding via the Housing Corporation for stock transfers to housing associations has also been available.

9.02

Many flat blocks built before the First World War, often by philanthropic organisations or Model Dwelling Companies, are characterised by too small floor areas, outdated internal planning with inadequate kitchens and bathrooms, and unsatisfactory means of escape. The building services are probaby obsolete, and central heating and thermal insulation absent. Some of these blocks, however, possess considerable architectural character, and have stable and supportive communities of residents.

9.03

Blocks built between the wars may also be lacking in modern services, heating, and insulation; but can be better planned internally and well-built structurally. Floor areas improved between the wars, but kitchens were usually still too small for modern requirements. External planning was simple, but with more communal space than is now desirable. Blocks from this period represent a vast investment in housing stock, with enormous potential for improvement into good-quality modern housing.

9.04

Since the Second World War, social housing has suffered from too many well-intentioned attempts to rethink design and planning from scratch. Consequently the last fifty years have seen widely differing forms of housing, many of which have proved dramatically unsuccessful. High-rise blocks of flats are only the most prominent and publicised of mistakes. Some of the medium-rise (five or six storey) deck access estates have proved even less satisfactory.

It is ironic that the dwellings in these large usually inner-city estates were built to comply with the good internal standards of Parker Morris. It is the external estate design that is often hated and feared by the residents. Over-imaginative networks of decks, footpaths and confused and potentially dangerous open spaces present intractable problems of estate management, and fail to provide private and public open spaces appropriate for families with children.

9.05

Estate modernisation presents many varied, peculiar and acute problems. First, an investigation to establish what the problems really are has to be carried out. These are rarely simple, and may vary widely from estate to estate. The people who understand the problems best are the residents, but they may need help to articulate them. Careful approaches and techniques under the general description of *community architecture* should be adopted to identify and address the tenants' concerns.

Architectural teams usually move onto the estate to conduct surveys, set up design surgeries, hold open meetings and distribute newsletters to reach their social clients.

9.06

After this consultation, designs and proposals can be worked up in close collaboration with the residents. The works needed to improve estates will be different in each case; but may include some or all of the following:

- Moving family units down to ground level, perhaps by combining flats on ground and/or first floors into larger flats or maisonettes, and subdividing large flats on upper floors into small ones
- Using unwanted external space to provide private gardens for the ground-floor units, with separate direct access from the public highway or estate road
- Remodelling the flat interiors, giving larger dining/kitchens and better bathrooms
- High-rise blocks that cannot be split up or effectively use entryphones can be provided with *concierge* systems; using a combination of electronic and human portering to provide 24-hour security
- Improving refuse arrangements, aiming to disperse rather than concentrate collection points
- Improving the fabric; adding thermal and sound insulation; adding pitched roofs on top of flat roofs; replacing windows with double glazing and controllable trickle ventilation
- Renewing the mechanical and electrical services; adding central heating; improving ventilation by putting extract fans into kitchens and bathrooms. Where there is district heating with a central boiler house and a history of problems, replacing with unit systems in each dwelling. Consider heat-retrieval systems
- Consider converting some blocks to integrated sheltered housing. In these cases, entrances and gardens must be clearly distinguished and separated
- Communal external spaces to be reduced to a minimum or abolished
- If all family flats and maisonettes have their own private gardens, there is an argument that communal children's play space within the estate may be unnecessary. If not, it must be carefully sited as it may cause nuisance to neighbouring dwellings. Playspace in local parks is preferable if they are nearby; or situated in clearly

public spaces such as the squares that might feature in some large estates. A lack of security is often perceived; ideally, family accommodation without sufficient private open space should be avoided. (The 1998 edition of the Housing Corporation's Scheme Development Standards now requires 'appropriately located play areas suitable for a range of age groups'.)

- Estate roads, car parking and emergency vehicle access often need to be replanned. Parking within the curtilage may be possible if the front gardens are deep enough; otherwise provide small parking bays in clear view of the dwellings they serve. Basement parking and car courts at the rear of blocks are best avoided because of the security risks they pose
- Replan pedestrian routes in order to eliminate unnecessary footpaths and to maximise natural supervision from the dwellings of all routes
- Adding lifts if over three storeys high
- Perhaps enclosing open balconies and staircases, and splitting up long balcony access buildings into smaller more manageable blocks, preferably with no more than 10 or 12 flats in each
- Adding entryphones to privatise staircases

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MHLG/DoE Circulars

36/67 Housing Standards
1/68 Metrication of Housebuilding
82/69 Housing Standards for Old People

DoE Bulletins and Papers

Design Bulletins

DB1 Some aspects of designing for old people (1968)
DB36 Space in the home (1968)
DB12 Cars in housing (1971)
DB13 Safety in the home (1976)
DB14 House planning; a guide to user needs (1968)
DB23 Housing for single people 1 (1971)
DB24 Pts 1 & 2 spaces in the home, bathrooms, WCs and kitchens (1972)
DB25 The estate outside the dwelling (1972)
DB26 New housing and road traffic noise (1972)
DB27 Children at play (1973)
DB29 Housing for single people 2 (1974)
DB30 Services for housing; sanitary plumbing & drainage (1974)
DB31 Housing for the elderly; the size of grouped schemes (1975)
DB32 Residential roads and footpaths. Second edition (1992)
DB33 Housing single people (1978)

HDD Occasional papers

2/74 Mobility housing
2/75 Wheelchair housing

Housing Corporation

Scheme Development Standards (1995)
Good practice guide, incorporating design & contracting Guidance (1990)

National House Building Council

Standards, vol 1, chapter 1.2
The home – its accommodation and services (1991)

The Building Regulations 2000

See Table IX for a list of Approved Documents and their relevance to housing.

British Standards

Many British Standards are cited in the Approved Documents to the Building Regulations. Many more BSs that are not statutorily cited apply to housing. These cannot all be listed here, but especially important (and cited in Approved Document B) is:

BS 5588 Part 1 1991: Means of escape in case of fire for houses and flats.

Local Authorities

Each planning authority is obliged to publish a Unitary Development Plan. The first of these have now been published and many others are in Draft consultative form. UDPs incorporate planning standards for housing density and other matters.

Wheelchair Housing Guide, 1997 Habinteg Housing Association and HOME Housing Trust, on behalf of the Wheelchair Housing Association Group
Selwyn Goldsmith, *Designing for the Disabled*, 4th Edition, Architectural Press, 1997
Alice Coleman, *Utopia on trial*, Hilary Shipman Ltd, 1985
Oscar Newman, *Defensible space*, The Architectural Press Ltd, 1973
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Joseph Rowntree Foundation, *Meeting Part M and Designing Lifetime Homes*, 1999

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9 Student housing and housing for young people

Liz Pride

CI/SfB: 856
UDC: 728.4
Uniclass: F856

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KEY POINTS:
- *Student housing is usually designed down to a budget that relates to the rent charged*
- *The quality and availability of accommodation is a factor in attracting students to particular universities and students are more discerning now that they have to pay fees*
- *Student housing that is used for conference accommodation is likely to be designed to higher standards*

Contents

1 INTRODUCTION

1.01

This chapter deals with the design of accommodation for students, but is also relevant to other groups who are mobile (in respect of the length of time they stay in accommodation), single and young, such as nurses. 'University' is used to refer generally to higher education establishments (HEEs), colleges and other similar institutions.

1.02

Government legislation has resulted in considerable expansion in the number of students attending university with a corresponding increase in the provision of student housing. Students come from a wider range of economic and social backgrounds, and many universities have a significant number of students from overseas. Students now pay fees and are becoming more discerning in their choice of university and of accommodation. There is more competition between universities to attract good students, and the availability of well-designed residences is a criterion in attracting students. Universities usually give priority to specific groups, such as first year students or students from overseas, who need more help to settle into the university community.

1.03

Student accommodation is owned and managed in a variety of ways, which have implications for design. Universities provide communal rented accommodation on or off campus, which they own and/or manage. A small, but expanding, number of students live in purpose-built accommodation provided by private sector commercial operators (Commercially Operated Communal Establishments, COCEs). To be financially viable, these developments usually accommodate a large number of students (200 plus). They may be managed in liaison with the university. A large proportion of students live in individual shared houses or flats within the community. Many also live at home.

1.04

The government does not fund student accommodation and schemes are normally self-funding through the rent that is charged for the rooms. Project budgets are, therefore, determined by the level of rents that students can afford, and this is directly reflected in the size of the study bedrooms, which are therefore normally small. Projects will generally be programmed to complete construction in time for a new academic year.

1.05

Universities are generally active in promoting sustainability and consideration should be given in the design of residences to reducing energy consumption and provisions for renewable energy, recycling and transportation. Provision for future flexibility should be incorporated into the design where possible, as student requirements and aspirations change – two examples in recent years are the huge increase in the use of computers and IT, and the increasing preference for en-suite bathrooms.

Issues relating to social sustainability include fostering a sense of community, and incorporating amenities and access to student support services – some universities have systems of pastoral care with wardens living among the students. The building form can help students to feel part of the university by, for example, arranging accommodation around shared courtyards, which provide a focus and sense of ownership for residents.

1.06

Consideration should be given to the relationship of the accommodation to the local community, particularly where it is located within a town rather than on campus. The design of the building and landscape can help to integrate the university with the community, although potential problems also need to be considered. Students can cause nuisance to neighbours, particularly where there are large areas of student accommodation within one neighbourhood. There can also be risks to the students for personal safety and theft of property.

2 STUDENTS

2.01

Conventionally, students are perceived as young, single, mobile, adaptable and with little money to spend. While this is still largely true, there is also an increasing need to cater for a broader range of people from different economic and cultural backgrounds, and for students with different needs: students with disabilities; mature and married students and those with families, including single-parent families. Postgraduate students in particular, are older and require a quieter and more 'adult' living environment. Many universities have a significant number of international students from outside Europe. Many students have part time jobs and there is an increasing demand for convenience and flexibility in the way that services, including accommodation, are provided to them.

2.02
The characteristics which differentiate student accommodation from other housing and which should be addressed in its design are:

- An appropriate environment in which to study as well as to live.
- Creating a university community, with opportunities for informal academic and social interaction.
- Privacy where people are living in close proximity and are sharing facilities – most students will not have the opportunity to choose their neighbours.
- Design, including the selection of materials and fittings, must be appropriately robust for student use and easy to maintain.
- Student accommodation can easily feel institutional, as it must be planned for efficient management and inevitably incorporates a large degree of repetition in the study bedrooms.
- For many students, living in student accommodation will be their first experience away from home, managing for themselves. Well-designed student accommodation gives young people an experience of architecture that may raise their awareness for the rest of their lives.

2.03
Research into student requirements reveals the following preferences and concerns:

- Rent levels and value for money.
- Proximity to other parts of the university, the town and to friends.
- Availability of IT and Internet access.
- Low noise levels.
- Comfort on a basic level – heat, light, hot water and clean communal facilities.
- Reasonable room size.
- Private en-suite bathrooms.
- Facilities for self-catering.
- Safety and security.

3 TYPES OF ACCOMMODATION

3.01
The main components of student accommodation are the study bedrooms, which are inevitably modestly sized, repetitive units. Care should be taken to ensure that this does not lead to a dull, institutional character in the internal layout or elevations of the building. Providing a mix of room types introduces variety and offers students choice in the standard and cost of rooms. The mix will reflect the different needs of undergraduates, postgraduates and staff and may include single and shared rooms, rooms with and without en-suite bathrooms, 'studio' rooms with en-suite bathroom and kitchen area, and shared or conventional self-contained flats.

3.02
The design of student accommodation is largely determined by the number of study bedrooms that are grouped together and the way that catering and other facilities are provided. These factors affect the degree to which the students are treated as independent or part of an institution.

3.03 The number of students in each unit
In traditional 'halls of residence' or hostels, several hundred students might be accommodated in one building in rooms off a common corridor. At the opposite end of the spectrum, accommodation is arranged in self-contained flats serving groups of five or six students.

It is generally agreed that small groups of students function best socially, and are more likely to behave responsibly, thus reducing potential management problems. However, smaller groups may not get on where they have not chosen to live together. With larger units, there is usually a greater level of supervision and pastoral care by university staff.

3.04 The facilities provided in each unit
Traditionally, central catering facilities are provided in larger halls of residence, with only minimal facilities for cooking close to the study bedrooms. However, for reasons of economy, culture and convenience, most students prefer the freedom of catering for themselves or, increasingly, of eating out. As a consequence, in most new accommodation – whether in the form of hostels, flats or houses – kitchen–dining rooms are provided for self-catering, each serving a group of study bedrooms, and effectively defining the social groups.

A significant proportion of study bedrooms are now provided with en-suite bathrooms, and where it is intended that the rooms will be used for conference accommodation out of term time, en-suite bathrooms are virtually obligatory. However, en-suite bathrooms increase costs and therefore rents, and groups of study bedrooms with shared bathrooms still provide a popular, cheaper alternative in some universities.

Other facilities – common rooms, seminar rooms, leisure facilities, etc. – will be provided where the student numbers are large enough to support them, or where there is a demand associated with teaching or conference uses.

4 BUILDING FORM

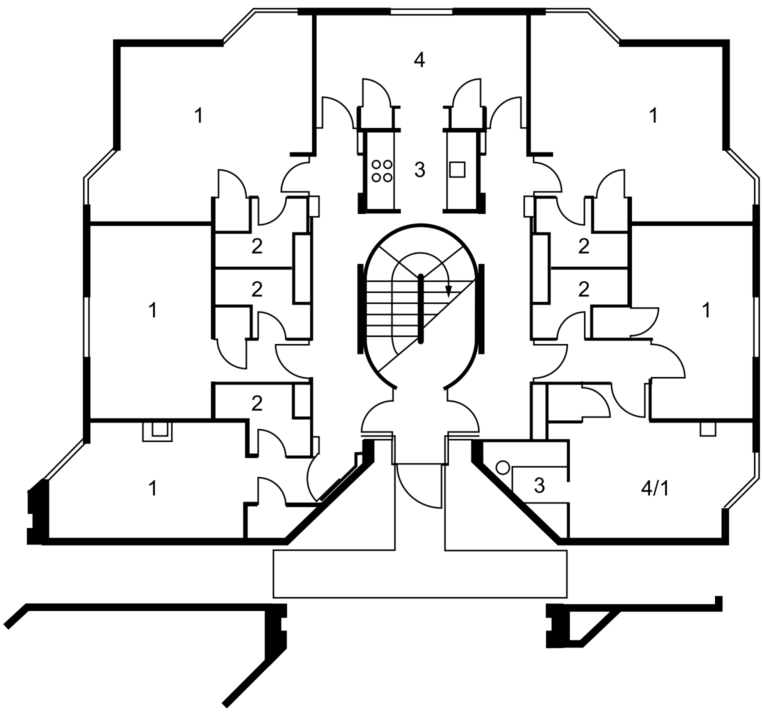
4.01 Principal types
Study bedrooms form the basic building block of student accommodation and can be arranged in a number of ways:

- *Staircase*: In the traditional 'Oxbridge' model, buildings are divided into 'staircases' each with a limited number of study bedrooms at each level served by a single stair, **9.1**. The arrangement is good for forming social groups. However, it is difficult to incorporate lift access economically if separate lifts have to be provided for each staircase.
- *Corridor*: Rooms arranged off a corridor, **9.2–9.4**. This is the most common arrangement as corridor schemes allow for large numbers of rooms to be served economically by lift, providing easy access for people with disabilities, conference guests and cleaning staff, as well as students. Corridor access schemes tend to have a higher proportion of circulation area than staircase schemes. It is difficult to bring natural light and ventilation into double-loaded corridors, and their design requires careful handling to avoid monotony and an institutional character.
- *Flats*: Rooms grouped into self-contained flats with a number of study bedrooms and shared common facilities, **9.5**. This arrangement is also very common. In some schemes, it is combined with a corridor arrangement where the corridors are subdivided to create separate flats.
- *Individual flats or houses*: Accommodation can be provided in conventional flats or houses, **9.6**. This is more usual for mature students or staff who have families.

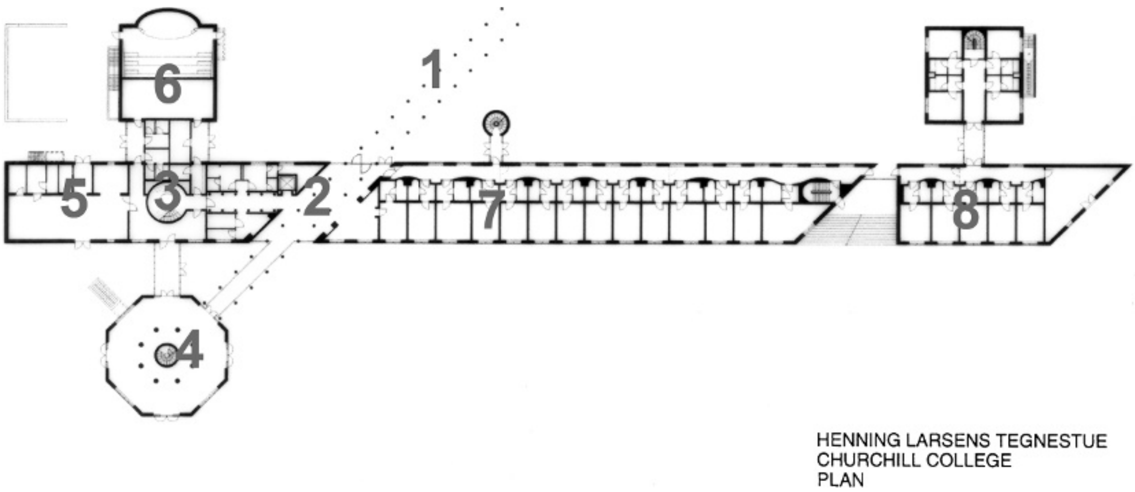
4.02 Depth of plan
Deeper plans are more economical and are achieved by increasing the depth of the student room or by providing internal bathrooms (whether en-suite or shared) in the centre of the plan.

5 STANDARDS AND REGULATIONS

The standards and legislation referred to are current at July 2007. Designers should check that these have not been superseded by subsequent standards and legislation.



9.1 *Generic type: Hall of residence with a staircase arrangement, Jowett Walk, Balliol College, Oxford. Architects: MacCormac Jamieson Prichard. 1, study bedroom; 2, en-suite bathroom; 3, kitchen; 4, dining room*



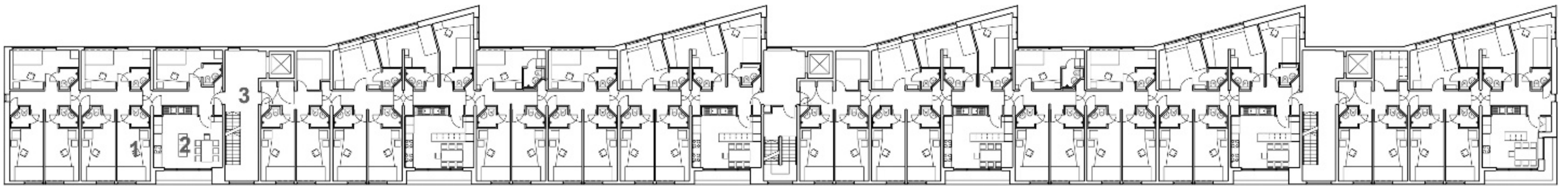
9.2 *Generic type: Hall of residence with a corridor arrangement: The Maersk McKinney Moller Centre, Churchill College, Cambridge. Architects: Henning Larsen Architects. Undulations and views provide visual interest along corridor. 1, entrance colonnade; 2, double-height entrance lobby; 3, stairs; 4, dining room; 5, kitchen; 6, lecture theatre; 7 and 8, student bedroom*

5.01 Planning permission
Most student accommodation will fall into Town and Country Planning Use Class C2 'Residential Institutions' where it is for educational use. Some other types of accommodation for young people, such as hostels and houses in multiple occupation (HMOs), have no specific Planning classification and discussion with the Planning Authority will be required to clarify requirements.

5.02 The Housing Act and HMOs
The 2004 Housing Act came into force in 2006. Part 1 applies to all accommodation and provides a system for assessing housing conditions – the Housing Health and Safety Rating System.

Part 2 of the Act is concerned with licensing of HMOs and generally relates to private rented accommodation rather than that provided by universities (see below). The Act essentially defines HMOs as accommodation occupied by more than one household and where households share one or more basic amenity, such as a kitchen. Licensing is mandatory for larger HMOs (this includes those that are three stories or more, five or more people of two or more households). Part 3 of the Act allows for selective licensing by the Local Authority, for example, where landlords are not taking appropriate action to resolve problems.

Student accommodation that is managed or controlled by HE or FE establishments, where people are attending full-time courses, is specifically 'excepted' from the definition of an HMO for the purposes of licensing, provided that it is managed in conformity with an approved code of practice. Three codes were approved in 2006: The Universities UK 'Code of Practice for University Managed Student Accommodation', ANUK/Unipol's 'Code of Practice for Student Accommodation Managed by Higher Educational Institutions' and ANUK/Unipol's 'Code of Practice for Student Accommodation Managed by Undertakings Subject to HMO Licensing'. The codes deal with a range of standards and management practices with requirements equivalent to those that would need to be met if the properties were subject to licensing



9.3 *Generic type: Hall of residence with a corridor arrangement: Pooley House, Queen Mary University of London. Architects: Fielden Clegg Bradley Architects. 1, study bedroom; 2, shared kitchen; 3, communal circulation area*

9.4 *Generic type: student and key-worker housing with a corridor arrangement: Friendship House, London. Architects: MacCormac Jamieson Prichard. The corridor arrangement is wrapped around a courtyard to provide a focus for residents. 1, study bedroom; 2, study bedroom for disabled residents; 3, shared kitchen; 4, common room; 5, courtyard; 6, garden; 7, railway viaduct*

under the Housing Act. They include fire safety, maintenance of gas and electric appliances, water supply and drainage, toilets, sinks, washbasins, storage of food, disposal of refuse, maintenance of common areas, windows and ventilation, repairs and postboxes.

5.03 Local Authority requirements in relation to HMOs

Local Authorities develop their own codes of practice for HMOs and the Environmental Health Officer should be consulted at an early stage. The requirements may vary for different types of student accommodation – bedsits, hostels, flats, etc. They are likely to cover:

Storage and preparation of food – safety, convenience and hygiene:

- *Equipment*: One sink, one full-size cooker and a fridge is typically required for up to five students.
- *Storage*: Refrigerator space and storage for dry goods per person.
- Provision and arrangement of worktops.
- Number of sockets.

WCs, baths and showers – proximity to rooms, privacy and hygiene:

- Provide one WC, one washbasin and one bath or shower for each unit (i.e. each flat) or for up to five individuals. If five people share a WC it should generally be separate from the bathroom.
- Maximum distance of shared WCs and bathrooms from bedsitting rooms.

Means of escape and fire precautions

Space standards – fitness for human habitation, over-crowding:

- Minimum room areas for bedrooms/bedsitting rooms, with and without cooking facilities
- Minimum room areas for kitchen/dining rooms and common rooms, depending on the number of rooms served
- Appropriate supplies of mains, hot and cold water
- Drainage
- Space heating
- Natural lighting
- Artificial lighting
- Refuse.

5.04 The building regulations

Part B: Fire safety

Most schemes will be classed as 'Residential (other)', (2(b) in the relevant table). The requirements for escape and fire safety should be considered in relation to the site plan, the building height, the size of the floor plate (max travel distances and number of escape stairs) and the planning of corridors and lobbies, including provision for escape for wheelchair users. Fire-detection systems, extinguishers and fire blankets will be required. Dry or wet risers may be required.

Fire doors and fire glazing, positions for extinguishers, detectors, call points, etc. should be designed to avoid an institutional feel and to reduce potential vandalism (extinguishers being let off, fire doors wedged open, etc.).

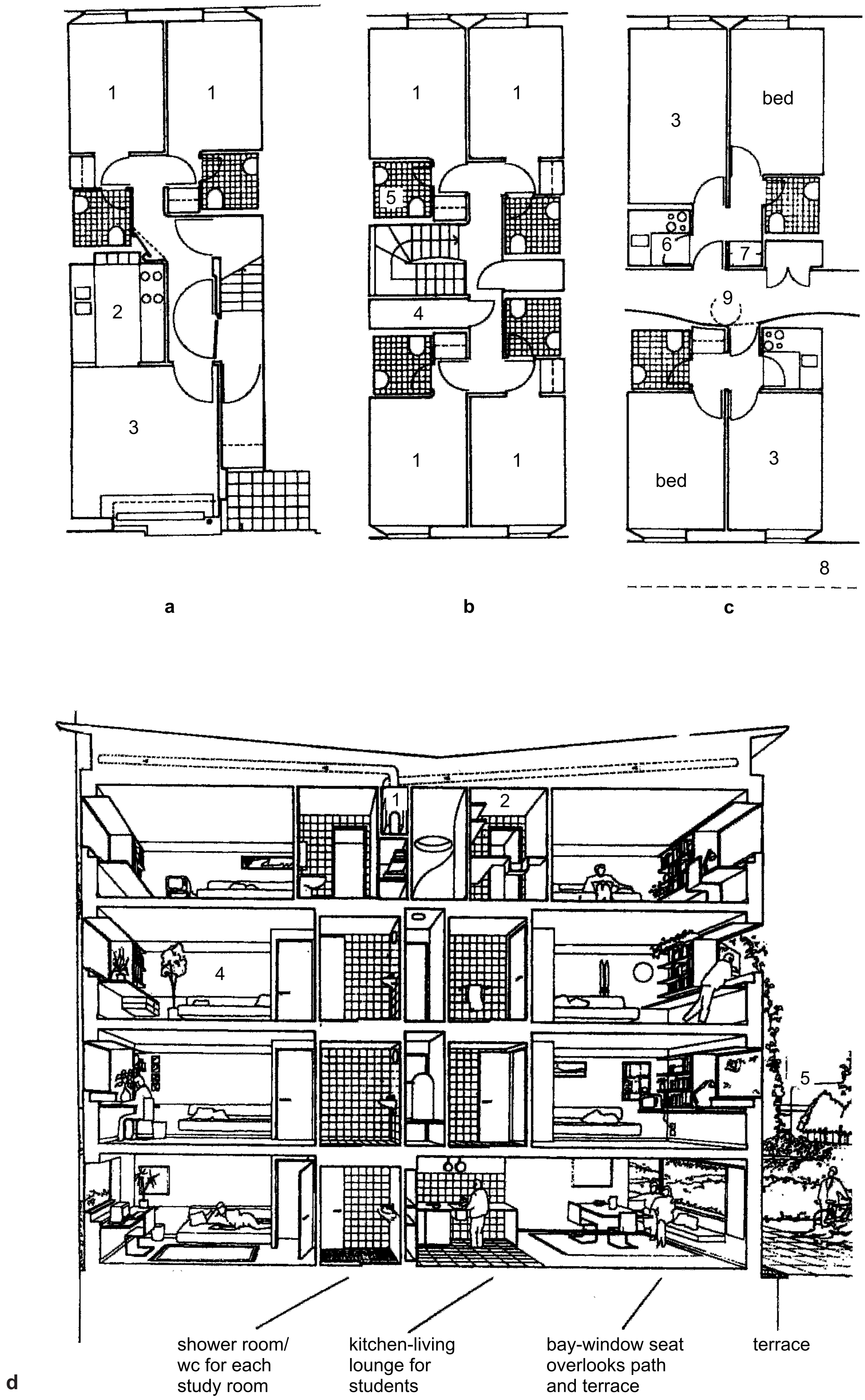
If it is intended to use accommodation for conferences, a Fire Certificate will be required and more onerous standards will apply. Conference attendees, unlike the students, will not be familiar with the layout of the building. It is arguable that the Fire Certificate Standards provide for an appropriate safety level and should be met in any case.

Means of escape in case of fire is also covered by the Housing Act and by the approved codes of practice that apply to educational institutions (see above). A fire safety risk assessment should be carried out in consultation with Fire Authority or Local Authority.

Part E: Resistance to the passage of sound

Part E applies to 'Rooms for Residential Purposes' and includes requirements for different parts of the construction. Noise is a major source of annoyance in student residences, because the uses of

9.5 *Generic type: student flats, Newington Green, London. Architects: Haworth Tompkins. Shared kitchens are adjacent to communal circulation area with individual flats beyond. 1, study bedroom; 2, shared kitchen; 3, common circulation area*



9.6 *Generic type: terrace house plus self-contained flats. Constable Terrace, University of East Anglia. Architects: Rick Mather Architects. 1, study bedroom; 2, kitchen; 3, living/dining room; 4, services/storage/cleaners; 5, shower/WC; 6, kitchenette; 7, ventilation cupboard; 8, line of roof overhang; 9, rooflight to continuous corridor.* **a** *Ground floor plan*, **b** *Plan of first and second floors,* **c** *Plan of third floor containing corridor accessed self-contained flats for two persons,* **d** *Isometric sectional view. (Note: scheme designed prior to recent DDA legislation.)*

neighbouring study bedrooms rooms for leisure, study and sleep contains inherent conflict. Students do not keep regular hours and, in nurses' accommodation, shift working exacerbates the problem. There may also be noise from other students, both inside and outside the building, from service ducts, lifts, badly adjusted door closers, common areas, telephones, etc. It is important to consider the location of potentially noisy areas in planning the accommodation, separating noisy uses from student bedrooms as well as insulating each individual study bedroom to a high standard.

Part F: Ventilation

The regulations apply to student accommodation. Shared bathrooms and kitchens are used intensively. In student accommodation, bathrooms are often internal, so problems of condensation are common. Student bedrooms may be left unoccupied for long periods during the holidays and adequate background ventilation is important.

Part M: Access and facilities for disabled people

Part M includes requirements for student accommodation. Refer also to BS 8300:2003 and to the Disabilities Discrimination Act 1995 and the Disability Discrimination (Employment) Regulations 1996.

Disabled people may be discouraged from attending university if there is inadequate or inappropriate provision for them. Their accommodation should be integrated with other students, and the need to visit friends should also be considered. This will normally mean that accommodation for people with disabilities should be distributed throughout the residences, and that access for wheelchairs should be provided into all student rooms and all shared facilities. The Planning Authority will set the requirement for the percentage of study bedrooms to be designed for disabled people. Early consultation regarding requirements is essential. There may also be a requirement for accommodation to be provided for a carer close by.

Provision for wheelchair users and for ambulant disabled people will increase the area required for stairs and corridors, and for the doors and corridor areas within individual study bedrooms. Provision will be required for disabled WCs for visitors and for appropriate design of fittings and equipment in areas such as kitchen/dining rooms and laundries. Other requirements could include provision of induction loops in common areas.

6 THE STUDY BEDROOM

6.01

This is the most important element in the project: it has to facilitate a range of functions in a small space – sleeping, studying, relaxing and socialising. The room must feel private and secure, with good light and ventilation and, ideally, with a reasonable view. The student should preferably be able to control the environment – heating, lighting, etc. – and should be able to impose her or his own personality on the room without damaging it. The room must be easy to clean and maintain. The design should seek to include variety in the room types on offer and in the way that furniture can be arranged within them to avoid the institutional character that can easily arise with large numbers of repetitive units.

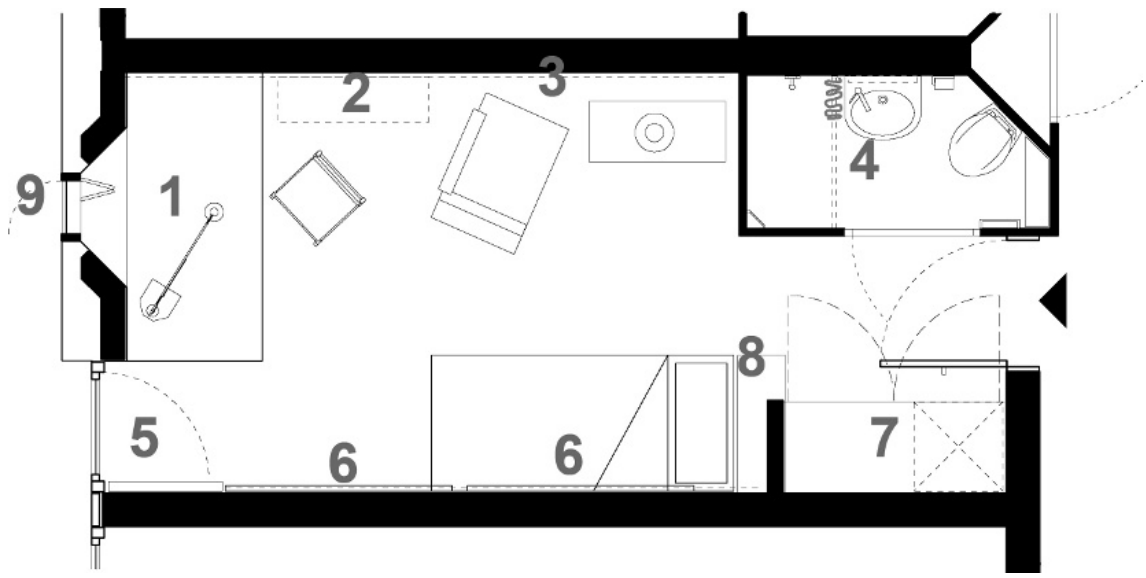
Study bedroom types include rooms with or without en-suite bathrooms and rooms (sometimes called 'studio' rooms) with en-suite bathroom and kitchen area. Rooms may be single or shared. The most common type is the single, en-suite study bedroom.

6.02 Room size and shape

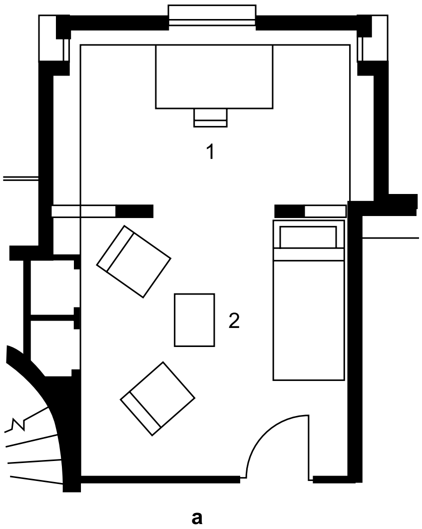
Study bedrooms (without en-suite bathrooms) can be as small as $8\,m^2$, but an appropriate minimum area for one person is $10\,m^2$. Rooms with en-suite bathrooms are typically $13\,m^2$ minimum, **9.7**.

Carefully consider the proportions of the room – alternative furniture layouts, the position of the door, window, built-in cupboards, sockets and fixed lighting to ensure that the room will accommodate different functions and moods. The larger the floor area, the easier this becomes, and the design should aim to provide alternative furniture layouts even with a room of minimum area. En-suite rooms will need to be approximately 2.8 m wide to allow for wheelchair access past the bathroom and a turning circle. Provide variety by changing the proportions, orientation or window positions in the rooms. Features such as window seats, built-in furniture, alcoves, etc. add to the character.

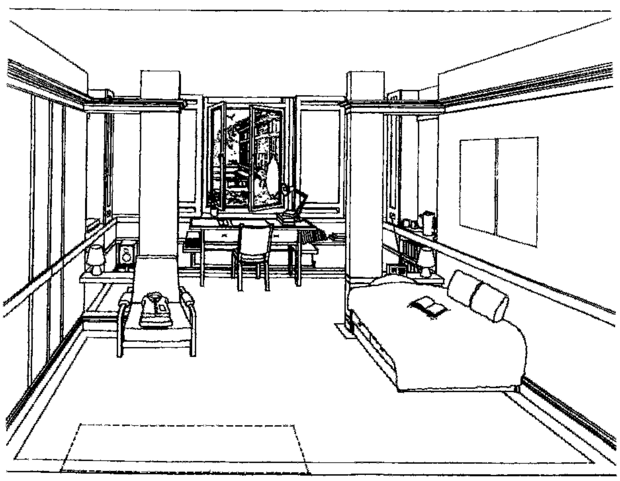
Where it is feasible to provide larger rooms – for example, where students have a choice of rents – it is possible to design for greater adaptability and to zone the different functions of the room, **9.8**.



9.7 *Room with en-suite bathroom. St Hugh's College, Oxford. Architects: David Morley Architects. 1, desk; 2, movable shelf; 3, hanging rail; 4, bathroom pod; 5, full-height window; 6, movable pinboard; 7, wardrobe; 8, built-in bedhead shelf/storage; 9, window with shutter in splayed opening*



a *Plan*



b *Perspective*

9.8 *Study bedroom with zones. The Garden Quadrangle, St John's College, Oxford. Architects: MacCormac Jamieson Prichard. The larger study bedroom can be zoned. 1, study area; 2, sleep and relaxation*

6.03 Furniture and finishes

The careful design of built-in furniture and the careful selection of loose furniture are essential to the success of the room. The furniture should allow units to be used together – for example, a chest of drawers the same height and depth as the desk can be used to extend the desk. Furniture and fittings should be robust, not institutional in character.

Typical provision:

Bed:	900 mm × 2000 mm May have storage drawer under. Usually doubles as a sofa. Wider beds of 1280 mm × 2000 mm are provided in some schemes.
Desk:	800 mm × 1200 mm minimum to take a computer, with drawers. A larger desk of approximately 1800 mm length is better. If the window cill is at, or slightly above, desk height it can be used as an extra shelf, although items stored on window cills can look messy from outside the building.
Chest of drawers:	Height and depth as desk – 800 mm wide with full depth drawers.
Wardrobe:	Often built-in. Full-height hanging space 600 mm × 900 mm minimum, with storage above. Lockable storage space may be provided at high level for the student to use when rooms let out for conference use.
Shelving:	Approximately 300 mm × 3600 mm minimum run.
Bedside table:	May not be needed if shelves can serve the purpose.
Easy chair:	
Desk chair:	A comfortable chair, without arms.
Pinboard:	Generous provision to discourage use of walls.
Washbasin:	Where en-suite bathrooms are not provided, a washbasin is often provided in the study bedroom and should be separated from the main area of the room, by containing it in a section of the wardrobe unit or behind a room divider.

6.04 En-suite bathrooms

En-suite bathrooms add approximately 2.7 m^2 to the room area. Bathrooms are often supplied as prefabricated 'pods', which allows the intricate work involved in the finishes and in waterproofing showers and floors to be carried out under factory conditions, and avoids delays to other trades on-site.

6.05 En-suite kitchen facilities

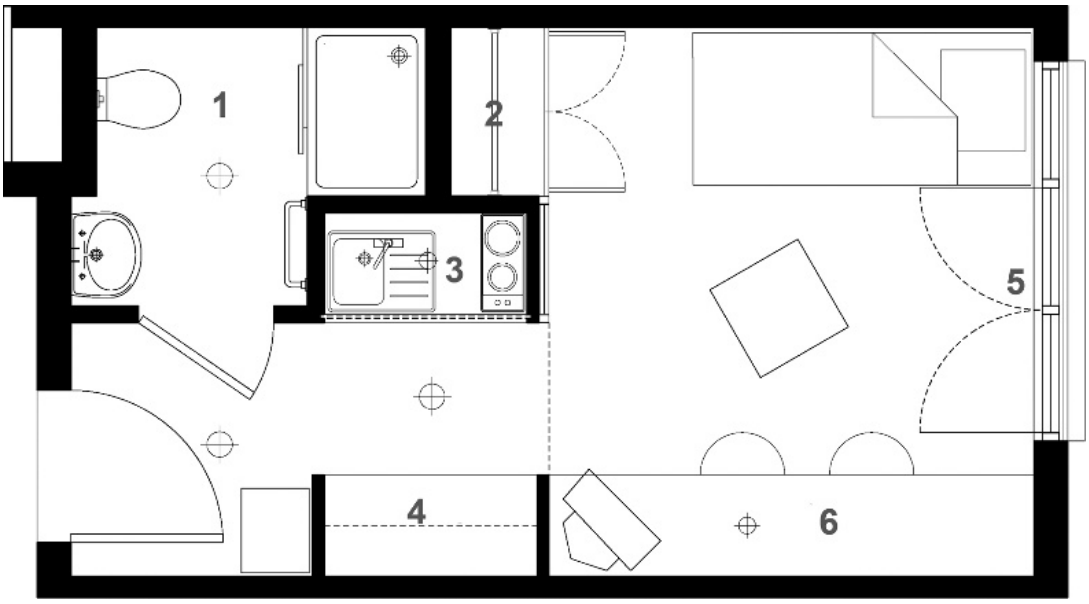
These are not generally provided for undergraduate accommodation, although there is demand from more mature students, nurses and single people who want greater independence. A room with an en-suite kitchen and bathroom is approximately 18 m^2. Additional fire provisions are required, including a heat detector in the kitchen area, **9.9**.

6.06 Services

Students should be able to control their environment, but consideration should also be given to erratic patterns of use and occupation of study bed rooms, and the tendency by some students to leave lights and heating on when they are out. Access for maintenance and meter reading should be arranged where possible from corridors to avoid the need for access to the student rooms.

- *Lighting*: Provide good natural light. General artificial lighting should be supplemented by task lighting to serve desk, easy chair and bed positions.
- *Electric power*: A minimum of three double sockets will be required for equipment, which may include computer/printer, television, stereo, charger for phone or other equipment, kettle, hair drier, light fittings, clock, etc. The location of sockets should be considered in relation to alternative furniture arrangements. Sometimes there is a limitation on the maximum current to prevent electric fires being used. The supply may be via a prepayment meter.
- *Internet and communications*: Students place high importance on Internet access and their courses are increasingly delivered partially in this way, so that it is important to provide connections in all study bed rooms. Technology for Internet access and also for telephone and TV is constantly advancing, so that the most appropriate system should be agreed as each project is designed. Where trunking and data sockets are used, positions should be coordinated with furniture arrangements.

  The vast majority of students have mobile phones, so that the provision of shared phones in common areas may be unnecessary, other than for emergency use.



9.9 *Room with en-suite shower/WC/basin and kitchenette. Architects: MacCormac Jamieson Prichard. 1, bathroom pod; 2, wardrobe; 3, kitchenette; 4, kitchen storage; 5, full-height window; 6, desk. The kitchenette must be provided with a heat detector*

- *Heating*: The system and controls will depend on the university's strategy for energy conservation and for charging. Background heating may be provided within the rent, with the facility to boost heat within each room for an extra charge.
- *Ventilation*: Natural ventilation should be provided with opening windows fitted with restrictors to prevent students from falling out.

6.07 Students with disabilities

Current legislation and implications for the design of the building are discussed above. Study bedrooms for wheelchair users require larger rooms, which can accommodate a free turning circle to manoeuvre between furniture of 1500 mm, and provision of an appropriate en-suite bathroom. Rooms should be designed with space to store the unused wheelchair without obstruction. Disabled study bedrooms may require additional adaptations to meet the specific needs of individual students, as these will vary depending on the nature of the disability.

Other variations to standard rooms for people with disabilities may include:

- Height of desk (may be adjustable), shelving, sockets, switches and ironmongery to suit wheelchair
- Design of en-suite bathroom
- Appropriate window-opening gear and ironmongery
- Levels of lighting and choice of colours for people with visual impairments
- Induction loop
- Provision of telephone, emergency call point and special fire alarm
- Provision of disabled parking space close to building entrance.

7 KITCHEN/DINING ROOMS

7.01

In student accommodation, kitchen/dining rooms provide a social focus for the group of rooms that they serve, with opportunities for casual encounters, conversation and friendship. This fosters a sense of ownership of the accommodation and of being a part of the university, which tends to encourages responsible behaviour. One kitchen/dining room will typically serve 5–8 students, although in some universities they may serve 10 or more students, particularly if the university wants to encourage the use of central catering facilities.

Kitchen/dining rooms can be arranged to overlook common areas such as entrances, stairs and halls, providing further opportunities for interaction and a degree of security/informal policing. They should be located to avoid noise and nuisance to study bedrooms. The dining areas should be designed to allow all the students in the unit to eat at the same time, preferably with some room for guests. Furniture should not be fixed to avoid creating an institutional character.

The trend is towards self-catering and kitchens will be heavily used and should allow several people to prepare food simultaneously. They must be designed to be functional, robust and easy to clean. As a guide, a minimum length of work surface of 3600 mm, including cooker and sink, will be sufficient for six people. Circulation space between units should be 1200 mm minimum. Where kitchens serve larger numbers of students, the provision of cookers, sinks, fridges and storage will need to be increased to meet Environmental Health requirements (see above). A microwave oven should be provided as well as a conventional cooker, and a freezer in addition to a refrigerator. Lockable cupboards should be provided for each student for storage of tins, dry goods, etc. Shared kitchens are often untidy and windows cills that are used for storage will look messy from outside.

7.02 Services

- *Electric power*: Provide sockets at worktop and at low level. Some universities meter and charge for cookers separately from rents to discourage wasteful use of energy. Cookers can have a time switch in case they are left on by mistake.
- *Lighting and mechanical extract*: These should be good. Provide generous opening windows with restrictors, positioned to avoid nuisance from noise and smell to neighbouring study bedrooms.
- *Fire*: Use heat detectors and provide fire blankets and extinguishers.
- *Refuse and recycling*: Place bins for easy cleaning and emptying. Separate recycling bins should be provided in line with university systems.

Kitchen/dining rooms may be extended to incorporate a living area with sofas and a television.

7.03 Disabled access
Where the kitchen serves disabled study bedrooms, it should be designed with appropriate equipment and fittings and sufficient area to allow for wheelchairs to manoeuvre in the kitchen and dinning areas. Some duplication of equipment may be necessary.

7.04 Sanitary accommodation
Bathrooms, showers and WCs are usually designed to the minimum practical area. Simpler arrangements will be easier to construct to a good standard and are less likely to cause problems in cleaning and maintenance. Students are not always careful in the way they use the facilities: overflowing and leaking showers are a common problem. Service ducts should be carefully located and detailed, with access from corridors. Factory-assembled bathrooms 'pods' are often used.

Provide good mechanical ventilation, especially in showers, and moisture-resistant light fittings. Include a shelf, towel rail and hooks in the shower area but out of the way of the shower itself. A mirror, with a light/shaver socket over may also be required. The layout of WCs should take account of the type of toilet rolls and holders and sanitary towel disposal units used by the university, all of which can be bulky. Even where a shower tray is used, the floor in any shower room should drain to a floor gully. Thermostatic balanced pressure mixers should be provided to showers, to avoid risk of scalding.

Where bathrooms are not en-suite, consider proximity to study bedrooms and acoustic and visual privacy. Numbers of facilities should be in accordance with the Environmental Health Officer's requirements: typically one WC, washbasin and bath or shower for every five students. Some people prefer baths to showers: provide a mixture to allow choice. WCs should be separate from bathrooms unless serving very few people. Where facilities are shared, additional washbasins are usually provided in study bedrooms.

8 OTHER FACILITIES
Provision will depend on the number of students living in the accommodation and on the availability of facilities elsewhere. They may include the following:

8.01 Laundry
Where accommodation is in independent flats or houses, provide washing and drying machines in the kitchen. In larger residences, include a laundry with washing and drying machines of a robust commercial type and emergency cut-off switch, plus a sink for hand-washing clothes, facilities for ironing and folding clothes and seats for waiting. Sometimes a common room is provided near by.

Laundries can be noisy, smelly and humid and are liable to flooding. There is also a risk of theft where clothes are left unattended. Choose the location carefully and provide good lighting, ventilation and a floor gully. Fittings and equipment should allow easy maintenance. Services such as electricity supply, hot water, etc. must be adequate for the level of use.

8.02 Cleaners' storage
Where accommodation is in independent flats or houses, cleaning is the students' responsibility and a tall cupboard will be sufficient. Where the university arranges cleaning, provide central stores for the cleaners within a reasonable distance of all the accommodation. In larger schemes, there should be a store on each floor. Provision may also be required for the cleaning staff to leave belongings, take breaks, etc.

8.03 Circulation areas
Entrances should be light and welcoming and avoid a minimal, institutional character. Provision may be required for a term-time or conference reception, and a place for mailboxes.

8.04 Other possible facilities
- *Central common room/television room/party room*: These are often poorly used if insufficient thought has been given to demand. Common rooms should be located so that any activity is visible from main circulation routes to encourage use. Party rooms need to be located to reduce nuisance to study bedrooms
- *Seminar, IT suites*: Central computer rooms can provide a sociable alternative to working in study bedrooms and a place for group working
- Music practice room
- Games room
- Trunk store
- Guest bedrooms.

8.05 Refuse and recycling collection
Consult the collectors at the preliminary design stage about their requirements for access. The size of any bin store will depend on the number of students and the frequency of collection. Bins filled by staff may be cleaner and tidier than those used by students, but all are potentially untidy, smelly and attract vermin. Stores should be easy to access, clean and maintain. Locate to reduce nuisance to residents, and provide good ventilation. Separate bins will be required for recycling.

8.06 Parking
The requirement for parking will partly depend on whether the residences are located on campus or within a town. The Planning Authority and the university will have policies for the provision of parking, and the allowance for parking is generally minimal in towns. Spaces will be required for disabled parking. To encourage use of sustainable modes of transport, there should be good provision of covered cycle parking. To guard against theft and for personal safety, parking areas should be overlooked and relatively close to entrances.

Each student arrives at the start of the academic year with quantities of luggage and sufficient space should be provided near to entrances for unloading several vehicles simultaneously.

8.07 Safety and security
The design should address potential risks of attack, vandalism and theft. Personal safety is a major issue in student housing, especially in accommodation for women. Nurses are particularly vulnerable because they work in shifts and return home late at night. Theft is also a common problem, as students own computers and other valuable equipment, and it is difficult to control people entering residences. The building should be designed so that external areas, such as entrances, paths and car parks, and common areas within the building are overlooked providing informal supervision – for example, kitchens can overlook stairs. Good external lighting is essential. CCTV and alarm points may also be required in external areas.

Swipe card systems are often used for doors instead of keys, which are expensive to replace when lost. Where there is a sufficient number of residents there may be a staffed reception. Where this is not possible entry phones may be provided, with handsets in each study bedroom. Provide spy holes in study bedroom doors.

The design should avoid features that encourage vandalism or dangerous behaviour.

9 CONFERENCE USE

9.01

Some universities use student residences for conferences or as holiday lets during the vacations and this has implications for design:

- A Fire Certificate will be required and higher standards will apply
- Rooms with en-suite bathrooms will be preferred
- A higher standard of fittings and finishes may be required
- Central linen stores will be required with easy access to study bedrooms for cleaning
- A term-time store for equipment that is provided to conference guests, such as kettles
- Lockable storage may be provided for students' possessions and/or a safe for conference guests
- Reception area, seminar rooms or other facilities to support conference activities.

10 Homes for older people

Ian Smith (updated by David Littlefield)

Before his retirement Ian Smith was a partner in Hubbard Ford and Partners

CI/SfB 44
Uniclass: F442
UDC: 725.513

KEY POINTS:
- *Because of other available accommodation, the people needing care are increasingly infirm*
- *There is a need for activities for residents other than watching TV*

Contents

1 MAIN ELEMENTS OF THE PLAN

1.01

The design of homes for old people should create a homely, comfortable and friendly atmosphere. The importance of avoiding an institutional character is stressed in most design guides and instructions to architects.

1.02

This chapter deals with the design of homes in which the residents are in need of special care and attention. The special facilities provided may vary, depending on the degree of infirmity and mobility of the residents, but the basic relationship between the main elements of the plan are common to all homes for old people. Latterly, the concept of very sheltered housing (VSH) has been developed which can provide tenants with a home for life, offering them a choice of different levels of care and support which changes according to need. This removes the need for residents to move to other forms of supported housing. Independence is encouraged; residents can develop a sense of ownership over where they live and can be as self-sufficient as they choose.

1.03 Elements of VSH

A VSH development will likely include the following elements:

- Independent self-contained flats designed to wheelchair-user standards. Flats would contain fully fitted kitchens, a shower room, bedroom and lunge
- Main catering kitchen and dining room providing at least one hot meal each day
- Communal lounge, often linked to the dining room
- Lift access to all floors
- Assisted bathrooms, usually one per floor
- Communal laundry
- Wheelchair/scooter recharging store
- Guest accommodation
- Non-resident building manager
- Separate care team based on site offering 24-h care. Facilities for staff and carers to include office, rest, meeting, changing and sleepover accommodation
- Extra community services, such as hairdressing, chiropody, shop, etc.

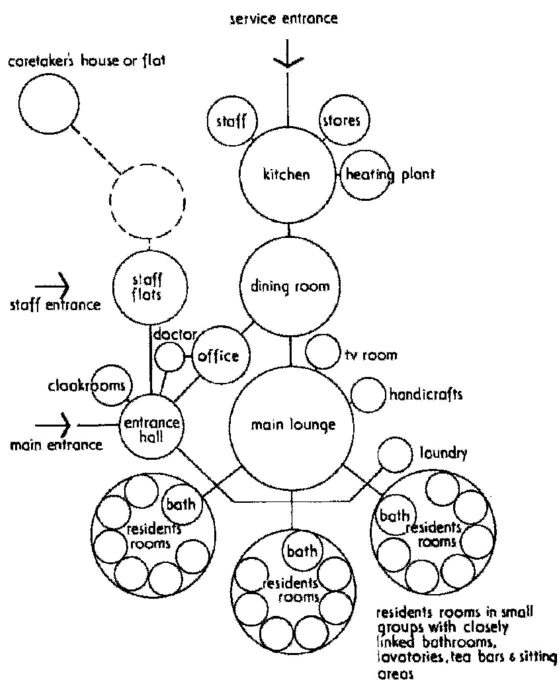
Design elements of a VSH development would include:

- Full wheelchair standards
- Adequate passing points in circulation areas for wheelchairs and scooters
- Removal of obstructions such as fire compartment doors, which can be held open on magnetic pads
- Free swing door closers to residents' front doors and other doors regularly used by residents
- Centrally located lift and communal facilities to enable unobtrusive care delivery and minimise walking distances and possible feelings of isolation
- Centrally located staff facilities away from residential areas
- Clear separation between areas for residents, staff and visitors
- Good natural and artificial lighting particularly on circulation routes
- Good visual access throughout
- Carefully considered use of tone, colour and tactile materials to assist residents who are partially sighted or disorientated
- Interesting corridors, ideally naturally lit from windows or rooflights. Avoidance of long, dull vistas
- Handrails along both sides of circulation routes that are appropriately scored, and snag-free, to assist way-finding for those with visual impairments
- Appropriate ironmongery, taps, etc. for older people with limited dexterity
- Protected, sunny, sheltered outdoor spaces with design features appropriate for residents.

2 RELATIONSHIP BETWEEN ELEMENTS OF THE PLAN

2.01 Relationship structures

10.1 shows how the main areas of the building are interrelated. The aim should be to encourage social contact, but at the same time to preserve individual privacy. The residents' rooms are often grouped



10.1 *Relationships between elements of the plan* round a small sitting room and services area containing a bathroom and lavatories. Circulation routes to the communal lounges and dining room should be as short as possible, although routes through the residents' groups should be avoided. Communal areas may either be centralised or divided between the residential groups, but most homes have a main dining room, which should be close to a sitting area. The administrative offices should be close to the entrance hall, and, if possible, within easy reach of the kitchen. Staff accommodation should be provided in self-contained flats with separate outside entrances.

2.02 Lighting and materials

Internally, developments should seek to create an uplifting experience that is welcoming, non-institutional and friendly for both residents and visitors. Particular attention must be paid to the building's entrance. Careful lighting, colour schemes and use of materials can help create a special environment, although they should remain domestic in character and specified with consideration for the sensory impairments suffered by older people.

2.03 Circulation planning

The general arrangement of circulation spaces in a VSH scheme should be clear and 'rational' to assist people who are suffering from dementia or memory loss. Complicated planning of circulation routes must be avoided: they will confuse and disorientate. Breaking down the building into identifiable clusters and the provision of visual clues (through pictures and graphics) and signage will greatly assist easy way-finding. Careful planning can reduce the length of corridors, thus reducing the travel distances and minimising an institutional feel. Corridors should have contact with the outside at some points along their length to help people orientate themselves within the overall building and to provide some natural daylight. Windows in the end wall of corridors are not ideal as they create glare, making the corridor appear dark in contrast. A window in the sidewall, near the end of the corridor, will still provide daylight and ventilation while avoiding the glare problem.

3 PLANNING ALLOWANCES

Typical accommodation allowances are given in Table I.

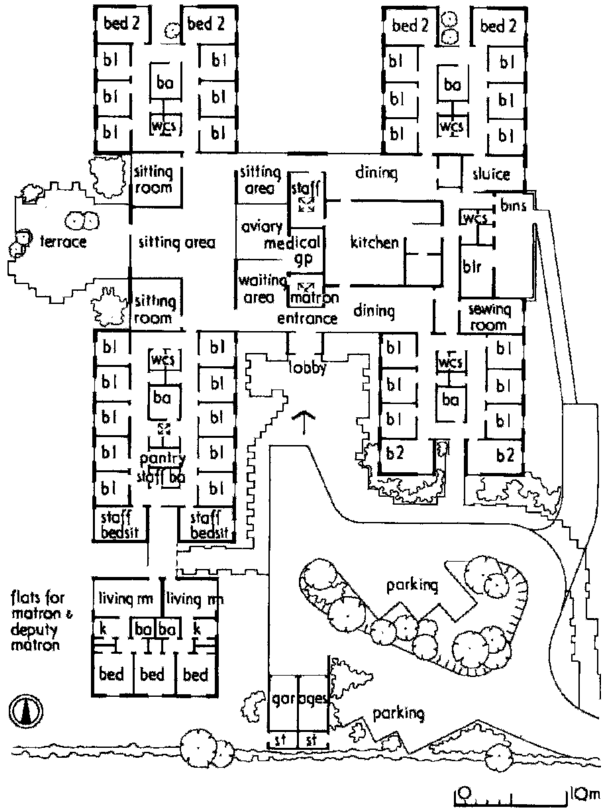
Table I Planning allowances

Accommodation and facilities		
Residents	Single bedsitting rooms	9.6–12 m^2
	including private WC	15.3 m^2
	Double bedsitting rooms	14.8 m^2–16 m^3
	Bathrooms and lavatories	8.8 m^2
	Sitting areas and tea bars Stores	
Communal rooms	Entrance hall and visitors' cloakroom	
	Lounges	2.3 m^2 per person
	Dining room	1.5 m^2 per person
	Handicrafts or sewing room	15 m^2
Kitchen	Larder and dry store	12.15 m^2
	Food preparation and cooking	42.50 m^2
	Washing up	15 m^2
	Cloakroom and non-resident staff room	12 m^2
Administration	Matron's office	11 m^2
	Doctor's room	10 m^2
	Visitors' room	10 m^2
Ancillary rooms	Sluice rooms	6 m^2
	Laundries	20 m^2
	Linen storage	8 m^2
	Cleaners' stores	4 m^2
	Box rooms	8 m^2
	Boiler and plant room	25.30 m^2
	Garden store and WC	10 m^2
Staff accommodation		
Self-contained flat for matron		70 m^2
Self-contained flat for assistant matron		60 m^2
Two-staff bedsitting rooms		12 m^2
Staff bathroom		
Staff kitchen		6 m^2
Two-staff garages		
Staff lounge		12 m^2

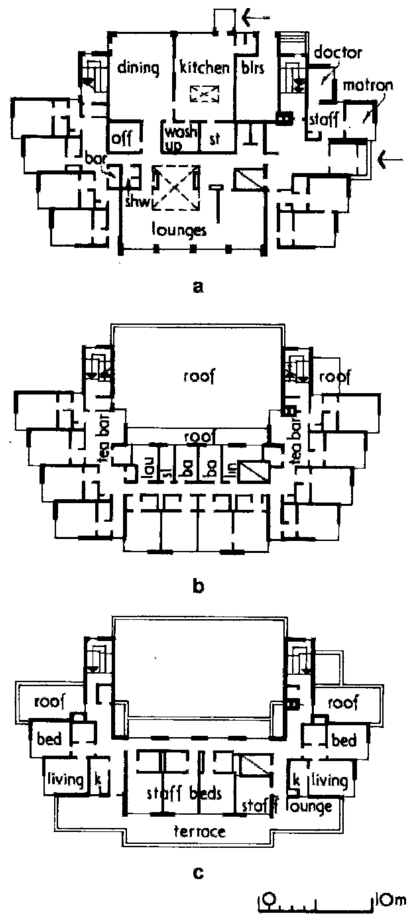
NB Room areas on typical 40-person home

4 PLANNING EXAMPLES

The plans of two typical homes are shown in **10.2** and **10.3**.



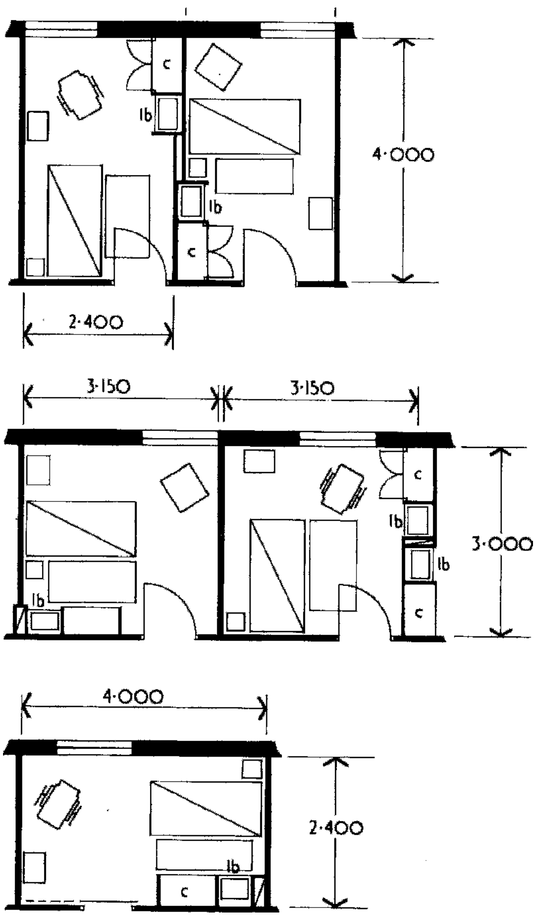
10.2 *Plan of glebe house, Southbourne*



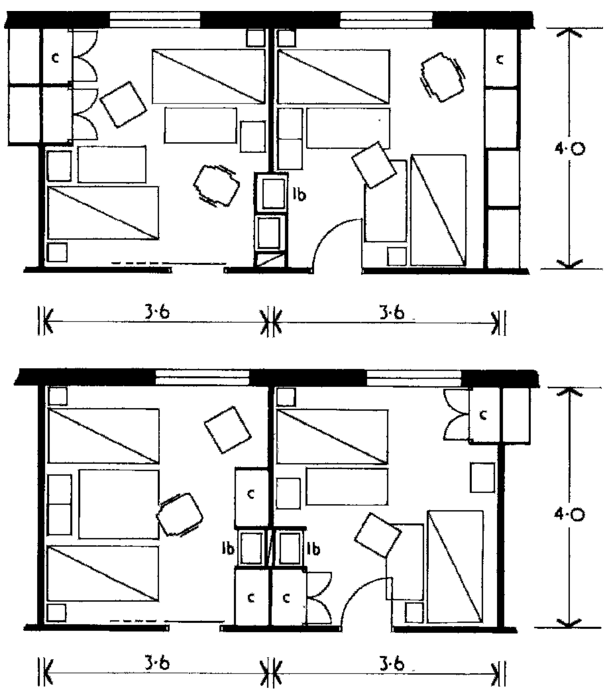
10.3 *Maidment court, Dorset.* ***a*** *ground-floor plan.* ***b*** *plan of first and second floors.* ***c*** *third-floor plan*

5 ROOM DATA AND SPACE REQUIREMENTS

Typical layouts are given for single rooms, **10.4**, and double rooms, **10.5**. These layouts, from DHSS Building Note 2, with rooms of varying proportion, show ways of providing a flexible arrangement within clearly defined sleeping/sitting areas. With narrow rooms, corridor circulation is reduced to a minimum, but other types may well be suitable where a different overall planform is chosen.



10.4 *Room data and space requirements for single rooms*



10.5 *Double room requirements*

6 BUILDING EQUIPMENT AND FITTINGS

6.01

Some of the information below repeats material in previous chapters. It is also included here because of its importance for this building type.

6.02

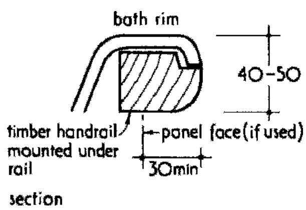
Elderly people should be encouraged to do as much as possible for themselves. To facilitate this, the design of the accommodation and appliances should take into account the limitations imposed by age.

6.03 Taps

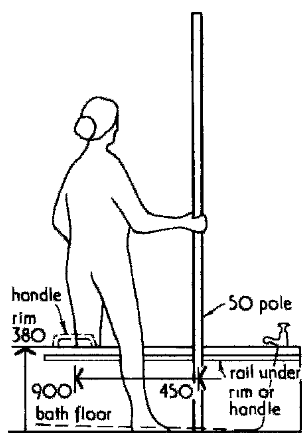
Choose taps that can be manipulated by arthritic fingers. Surgeon's taps are not recommended, however, as in extreme cases ordinary taps can be modified to provide a similar facility. Within one building, it is sensible to maintain consistency as to the location of hot and cold, e.g. hot always on the right as is now provided in current standards. In addition, the tops should always be boldly colour-coded. It is hoped that in the near future a standard for additional tactile identification will be introduced.

6.04 Washhand basins and baths

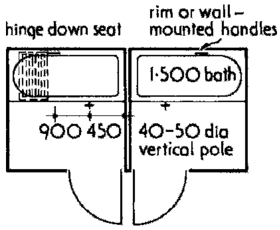
Washhand basins should be fitted with their rims between 800 and 850 mm high. Bathrooms should be large enough for undressing and dressing, and for someone else to lend a hand. Low-sided baths are available, as the rim, which should be easy to grip, **10.6**, should not be higher than 380 mm from the floor. Alternatively, the bath may be set with the trap below floor level. It should have a bottom as flat as possible and should not be longer than 1.5 m; lying down is not encouraged. Grab handles and poles should be provided as in **10.7** to help getting in and out. A seat at rim height is useful for sitting on to wash legs and feet. Bathroom and lavatory doors should open out, with locks operable from the outside in emergencies, **10.8**.



10.6 *Bath rim adapted for easy gripping*



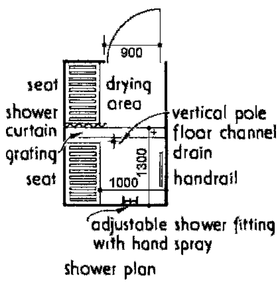
10.7 *Aids for getting in and out of the bath: pole, handle and rim. Maximum height of rim from floor 380 mm*



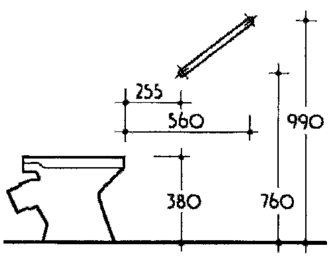
10.8 *Plan of bathrooms showing handing to suit people with disability of either right or left leg, and position of pole aid*

6.05 Showers

Some old people find showers more convenient to use than baths, **10.9**. If the floor of the compartment is of smooth non-slip material with a fall to a drain of 1:40, there is no need for a tray with an upstand to be stepped over. The compartment should be well heated, with pegs for clothes on the dry side, divided from the wet with a shower curtain. The water supply should be automatically controlled to supply only between 35°C and 49°C. The shower head should be on the end of a flexible hose, with a variety of positions available for clipping it on. WCs should have a seat height of 380 mm, and handles provided as in **10.10**.



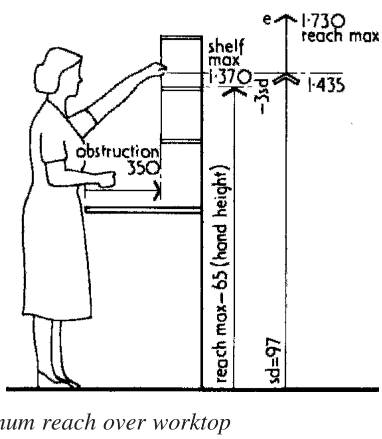
10.9 *Plan of shower room showing seats and aids*



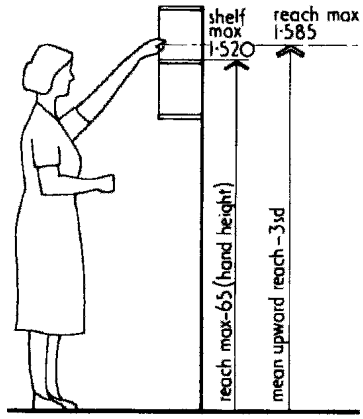
10.10 *Inclined rails mounted on walls of WC*

6.06 Cupboards

Shelves and cupboards should acknowledge the limitations of elderly people. The clothes cupboard rail should be mounted 1.5 m from the floor, and the cupboards should be at least 550 mm deep, **10.11** and **10.12**.



10.11 *Maximum reach over worktop*



10.12 *Maximum reach to unobstructed wall-mounted cupboard*

7 FURNITURE

7.01 Easy chairs

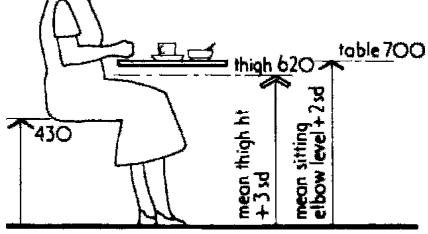
A variety of chair types should be provided in sitting and common rooms, to ensure maximum comfort for all the old people. Seats should not be too low, as this makes the chair difficult to get out of; but if too high, the feet may end up off the floor. A height between 400 and 430 mm is about right, with footstools available for those with extra-short legs. A seat depth between 410 and 470 mm is ideal: any more and cushions become necessary. The back should be angled at 28° to the vertical, and high enough to support the head, for which an adjustable pad is useful. Armrests 230 mm above the seat at the front facilitate getting up, but if lower at the back, make sewing and knitting easier. There should be a gap under the seat to allow the heels to be drawn right back when rising. Generally, the padding should not be too soft and generous, as this can put strain on the tissues rather than allowing the bone structure to support the body.

7.02 Tables and dining chairs

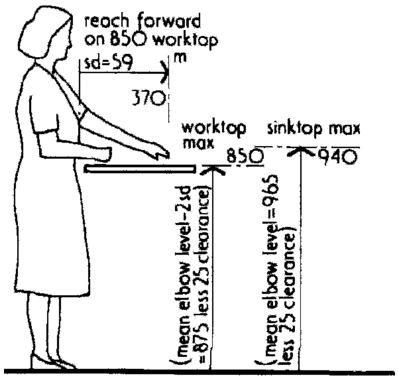
Occasional tables in common rooms should not be lower than chair seat height. Dining tables should be 700 mm high and used with chairs having a seat height of 430 mm and a depth of 380 mm. There should be a gap for the thigh between the chair seat and the underside of the table top of at least 190 mm, **10.13**.

7.03 Worktops

Comfortable reach to worktops are shown in **10.14**.



10.13 *Table and sitting worktop design, giving height and thigh clearance*



10.14 *Standing worktop design, giving height of working surface and reach forward to fittings (scale consistent with 3613)*

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11 Hotels

Fred Lawson and John Rawson

CI/SfB: 85
UDC: 728.51
Uniclass: F852

KEY POINTS:
- *Standards are tending to rise all the time*
- *Value for money is a prime concern*
- *Ancillary facilities are a major generator of business*

Contents

1 INTRODUCTION

1.01

Hotels provide a service to their customers whose requirements are:

- Clean, quiet and comfortable rooms
- Good food
- Good service, and
- Value for money.

The financial viability of the project depends on keeping capital requirements and operating costs to a minimum. This depends largely on the standards of planning, construction and equipment of the building. For the architect the two most important technical decisions are:

- Location of the main kitchen, and
- Provision of an efficient duct system.

Hotel staff requirements are substantial and the payroll absorbs about one third of the turnover. The designer must ensure maximum working efficiency in order to minimise their number. The ratio of staff to guests varies from 1:10 in a budget hotel to 1:2 or more in a luxury hotel. Facilities are required for staff changing, toilets, canteen, security and personnel offices; in some cases even some living accommodation may be required. Designing the hotel needs to be done in the closest consultation with those who will run it, in order to maximise their efficiency.

1.02 Hotel classification

Virtually all countries classify hotels but in different ways: most have some sort of symbol or 'star' system, as proposed by the World Tourism Organisation. The grading defines the space and facilities available. There are several broad categories:

- Hotel: including city, resort and sport hotels, defined by star category
- Motel: originally simple low-rise developments suitable for the motorist
- Inn, auberge, gasthof: originally a bar with some rooms attached
- Boarding house: with simple rooms generally let for a week or more
- Bed and breakfast establishment: accommodation with no restaurant and
- Holiday villages: often with self-catering accommodation.

2 GENERAL CONSIDERATIONS

2.01 Orientation

During the preliminary design stage consider the relationships of different parts of the hotel and the effects of noise and pollution. However, restrictions imposed by the site, particularly in a town, may determine the building's orientation regardless of other considerations. See para **3.04** for orientation of bedrooms.

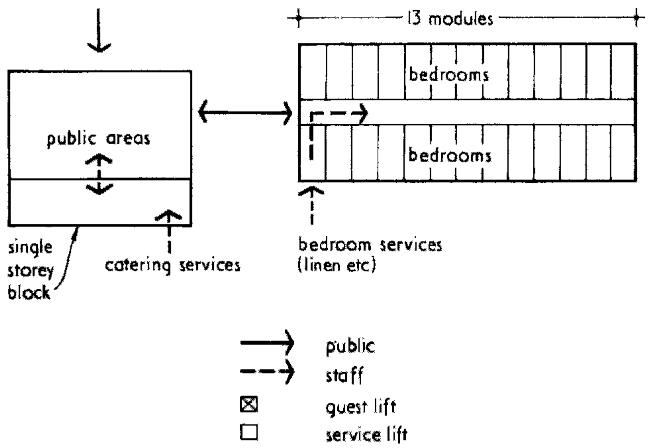
2.02 General arrangement

Determine and agree pedestrian and vehicular access at an early stage. The main hotel entrance is a critical commercial feature determining the location of the main frontage.

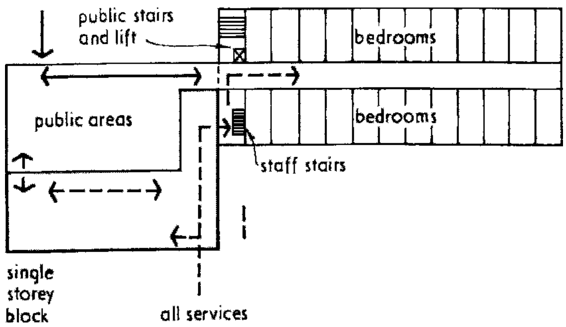
Site value usually determines the height of the development. In a cheap rural setting, costs favour a low building. There are savings in foundation and structural work, lifts are not currently obligatory up to three storeys (although this may change with disabled access regulations, and could incur considerable later costs). There may be also be savings in maintenance costs. On the other hand, long corridors with more staircases are needed, and engineering services may be more expensive. On a town site, cost may dictate a high building. A compromise has to be arrived at, taking into account planning restrictions, rights of light and any legal restrictions caused by adjacent properties. The most common arrangement is a tall bedroom block over a larger area of low public rooms. High site costs may lead to the high-value frontage being let as commercial space such as shops. Bedrooms can be located above another such as offices or flats. Various relationships between the two sorts of accommodation – bedrooms and public areas – are shown diagrammatically in **11.1** to **11.4**.

2.03 Circulation

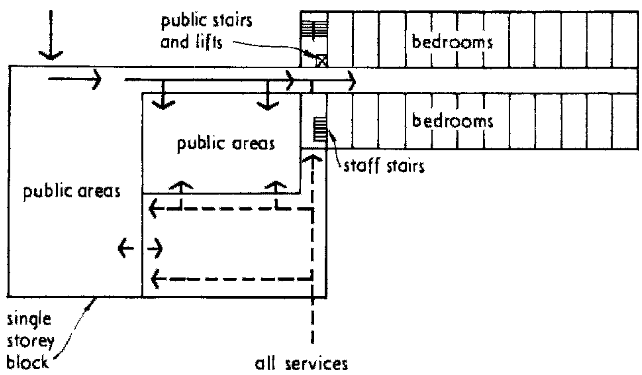
The general circulation layout should facilitate movement and, as far as possible, provide for the separation of guests, staff and maintenance personnel. This is not just to avoid disturbing the guests, but also to enable efficient servicing. Separate the



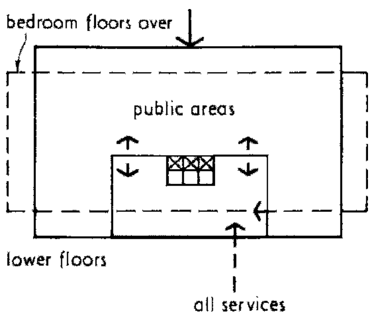
11.1 *Simple bedroom block with detached single-storey catering building as in primitive motels. No cohesion or rationalisation of circulation*



11.2 *Simple rationalisation of circulation. All bedroom and catering services collected in controllable zones and routes. Public areas are single storey*



11.3 *11.2 after extension. More public and function rooms added, still single-storey. These may be appropriately subdivided. Guest and staff circulations should not mix*



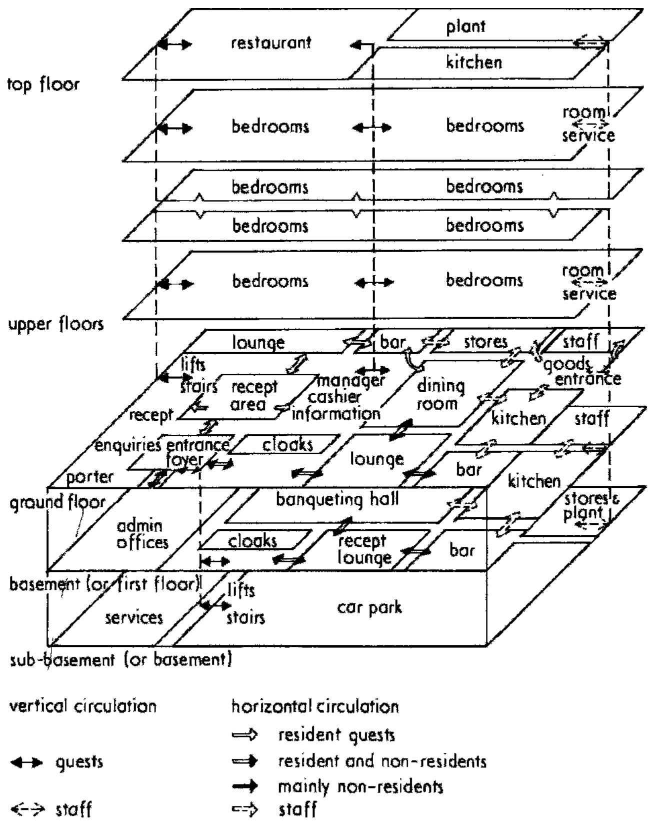
11.4 *The same circulation principles apply where bedrooms are built over public areas. It is simpler to plan with vertical rather than horizontal circulation. Note grouping of lifts to serve guests on one side and staff on the other*

circulation of resident and non-resident guests; for instance, by providing direct access to restaurants and banqueting halls. This avoids congestion in the main reception area and gives better control and supervision. A diagram of main circulations is given in **11.5**, although this is not to be taken as a layout in itself. General relationships covering the whole hotel are shown in **11.6**.

Corridors are wasted space. Circulation in public spaces should wherever possible be through areas of other use such as lounges or shopping precincts, or have a special use, such as lobbies.

2.04 Staircases

Staircase design is dictated by fire escape requirements. The main stairs should be beside the lift bank to enable guests to find them easily, with secondary stairs at the end of each corridor. Some ramps may be required for guests using wheelchairs.



11.5 *Circulation diagram showing desirable relationships, not intending to imply any particular layout*

2.05 Lifts

Lifts are expensive. They should be wider than they are deep to facilitate entry. Tough surfaces are required to resist damage by baggage. The main lift bank must be visible on entering the reception area. Specialist design of the lift system may be necessary. Additional service lifts may also be required for housekeeping and room service. There are often one or two service lifts to every three guests' lifts, and these open onto service lobbies on each floor. At least one lift should be large enough to take furniture such as a bed or bath, or a stretcher case as accidents and illness occur in hotels, and it may be preferable not to use the public areas in such event.

2.06 Environment

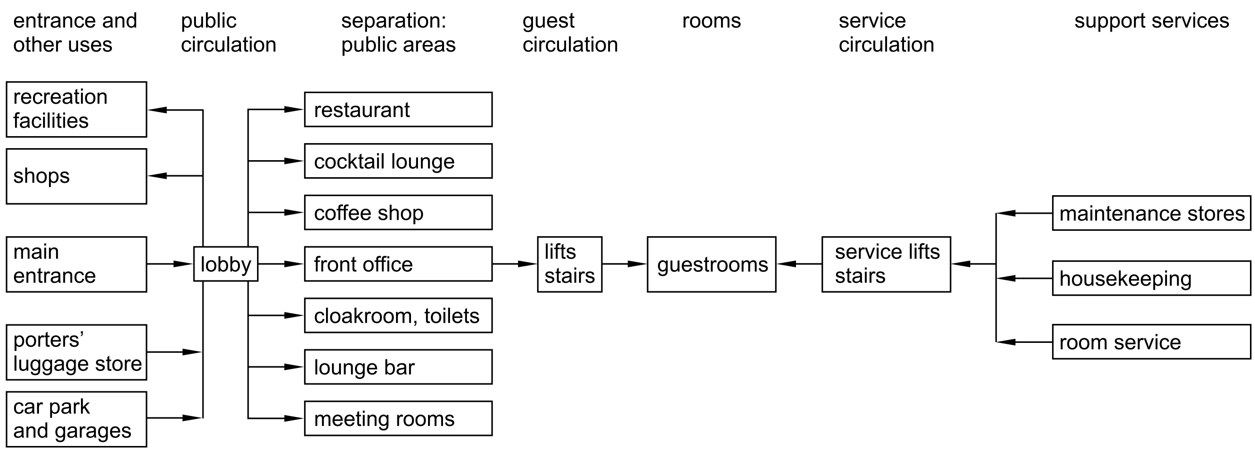
The internal environment must be attractive, engender confidence in the operation and leave a memorable impression. It must be safe, resist damage and be easy to clean and repair. It must provide maximum space and facilities at minimum cost.

2.07 Lighting

Lighting should assist in providing the appropriate environment, differentiate spaces, and illuminate signs and hazards, etc. as appropriate. It may change with time of day. Light sources are likely to be incandescent in areas used by guests. Spotlights and coloured sources may be used. Fluorescent tubes will be used in work areas for economy.

2.08 Noise

Noise will be generated both outside and inside a hotel, and the rooms within will need to be protected from it. External noise comes from highways, low-flying aircraft (near airports), building sites, car parks, swimming pools and play areas, and hotel servicing such as refuse collection and even guests arriving to stay or to attend conferences, etc. Internal noise comes from public rooms such as discos, service areas such as kitchens, televisions and telephones in



11.6 *Circulation and relationship diagram*

bedrooms, and from mechanical services. Doors can bang and keys are rattled in locks. All piped services are liable to create or transmit noise, ventilation ducting such as bathroom ventilation can reduce sound insulation, and lifts should not be next to bedrooms.

The first line of defence against noise is careful planning: placing noisy areas away from quiet ones. The second, insulation, generally depends on heavy construction of walls and double windows. The third is the reduction of reverberation to lower sound levels, the absorption of impact noise with soft finishes, and the prevention of door slamming. Machinery should be on resilient mountings.

2.09 Safety

Safety covers not only design but also how buildings are maintained and used. Accidents are likely to occur when these are poor. As hotels are used by the young, old and infirm, designers must be specially careful in detailing and in choice of materials. Some points to check are:

- Planning: safe positioning of equipment, with adequate working space
- Floors: non-slip, easily cleanable, effective marking of steps and edges
- Doors: check door swings for clearance and visibility
- Windows: must be safe to clean, and not open accidentally
- Lifts: level properly, landings adequate
- Bathrooms: correct positions of fixings, non-slip floors, electrical safety
- Kitchens: ditto, work areas to be well lit, and
- Machinery: properly guarded, and maintained.

2.10 Fire precautions

There have been many tragic accidents in hotels in recent years. Take fire precautions very seriously for the following reasons:

- The occupants will be transient, and unfamiliar with the building
- Many guests will be elderly, very young, disabled, tired or inebriated
- Large numbers of people will be asleep in separate bedrooms, each needing to be warned and evacuated separately
- There may be large numbers of people in the public rooms, creating crowd-control problems
- Fire loading may be high, due to the furnishings present, and kitchens, garages, boiler houses, etc. are high risks, and
- Staff are on duty intermittently, and few may be there at night.

The common causes of hotel fires are kitchens, smoking, and electrical. The three principal precautions are as follows.

Structural protection

This is to ensure that the building does not collapse before people can escape from it; also that escape routes are protected from fires in adjacent rooms. Combustible materials may be prohibited in escape routes.

Active protection

This covers the installation of fixed equipment to detect fires, raise the alarm, and put them out. There must be access for fire brigade vehicles and appliances, and provision of firemen's lifts. Special water storage tanks and fixed fire mains and hydrants may be required. Automatic sprinklers, electromagnetic door releases, dampers in ventilation ducts and portable fire extinguishers may all be required.

Means of escape

Current building regulations require:

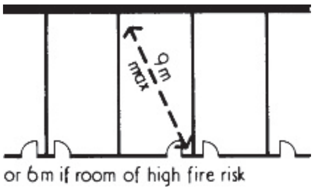
- Maximum travel distances from bedrooms or points in public rooms to a protected escape route
- Alternative directions of escape, normally at least two from any point
- Protected escape routes to be of adequate width and unobstructed
- Final escape must be free; not into a closed courtyard, and
- Maximum times are laid down for the complete evacuation of the building.

11.7 illustrates the main requirements of the regulations.

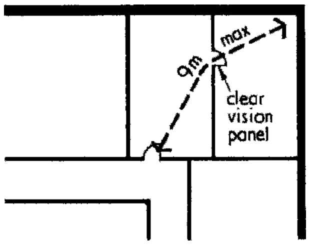
2.11 Security

Security involves the protection and control of property, and the safety and supervision of all persons occupying, entering or leaving. In planning, consider the following:

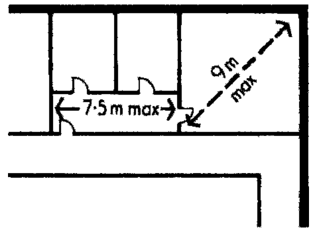
- Control of property, i.e. prevention of theft. This covers strength of construction of doors and walls, burglar alarms, CCTV, and controlling unauthorised exit through fire escapes
- Control of entry to bedrooms. This covers access to windows and balconies, and the lock mastering system. Access of guests, cleaners, manager and security personnel have to be controlled, and locks have to be changed regularly to prevent later access using old keys. Electronic card key systems facilitate frequent code changes
- Provision of safes and strongrooms for valuable items, both in bedrooms and centrally
- Surveillance of everyone entering or leaving. Entrances must be planned so that they are always watched. Side or garage entrance routes must not by-pass reception desks. Goods entrances should have roll-down shutters



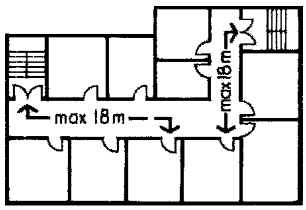
a *Maximum allowable travel distance to the doorway from the most remote corner of the room*



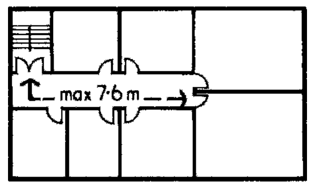
b *In multi-room suites no single cross-room dimension should exceed 9 m*



c *In multi-room suites any associated private corridor limited to 7.5 m long*



d *Stage 2 escape; no room exit further than 18 m from entrance to protected escape route*



e *Dead-end corridors limited to 7.6 m long*

11.7 *Requirements for means of escape*

- Baggage handling and checking. Baggage rooms should be isolated and have explosion relief
- Security of hotel grounds. Motels, holiday village or condominium developments may have substantial grounds. Unclimbable perimeter fences and floodlighting are common. Intruder detection appliances may be used
- Ensure that criminals cannot escape by setting off fire alarms and using unsupervised fire exits.

2.12 Hygiene

Failure to maintain a proper standard of hygiene can lead to a hotel being closed down. The designer should specify:

- Impervious easily cleaned surfaces
- Facilities to prevent cross-contamination of food
- Control of ventilation and temperature
- Protection against flies, rodents or smells
- Means of washing food, utensils, and surroundings
- Sanitary, washing and changing facilities for staff, and
- Proper refuse storage and disposal.

2.13 Piped services

A hotel depends on having an economical ducting system. It must be of generous size, as short as possible, and with easy access to every part without going into bedrooms.

Large quantities of water are used for catering, boilers, swimming pools, cleaning, fire fighting and irrigation of grounds. Storage equal to 100 per cent of daily use is recommended. Drainage must be provided to carry all this away. The repetition of bathrooms lends itself to prefabrication of pipework. Heating systems for bedrooms must have local control.

2.14 Communications

Space requirements for communications equipment are constantly changing. Equipment tends to get smaller, but services provided increase in number.

Telephones

A hotel will have separate groups of lines for guests and administration. They will normally go to a private automatic branch exchange (PABX). All bedrooms usually have a telephone; incoming calls via the operator, outgoing calls direct dialled, but metered and charged for by the hotel. There will be payphones in public areas and staff rest rooms. Internal extensions will be located in plant rooms, kitchens, serveries and bars, etc. and in escape routes. A direct line will be required for a fax machine. Phone systems will provide automatic morning alarm calls.

Public address

Public areas are often covered by a public address system for paging guests. Individual public rooms, such as discos or conference spaces need their own equipment. These can be used for background music.

Radio and TV

Normally by a central aerial system and coaxial cables to all rooms.

Computer systems

These are constantly changing, but many hotels have terminals in restaurants, room service areas, etc. so that the guest's bill is constantly updated and immediately available. Quick settlement of guests' bills is very important in business executives' hotels, where most of the guests check out at the same time in the morning.

Staff paging

There is usually some radio-based method of locating and contacting staff.

3 BEDROOMS

3.01

Bedrooms are the core of the hotel industry. For flexibility most rooms have a double bed or twin beds. Bedrooms normally have en-suite bathrooms. It may be assumed in preliminary calculations that the capital cost of a room will approximate to 1000 times its nightly rate.

3.02 Areas

Corridor widths and bedroom sizes are greater in more expensive hotels. In the preliminary design stage allow the following overall bedroom areas:

2-star: 20–22 m^2
3-star: 25–27 m^2
4-star: 30–34 m^2
5-star/exclusive 36 m^2min.

The ancillary areas that will be required to service these rooms are shown in Table I.

Table I Service areas in m^2 according to number of guest rooms

	100 rooms	250 rooms	500 rooms	1000 rooms	Notes
Housekeeping and general storage	1.40	1.11	0.93	0.74	Hotel laundry requires a similar area. Most hotels use off-site laundry services
Administration department	0.46	0.46	0.37	0.28	

3.03 Bedroom corridors

Corridors in bedroom areas should be minimised. Widths vary from 1.3 m wide for 2-star to 1.8 to 2.0 m wide for 5-star. Costs usually dictate bedrooms both sides of corridors. Though a number of city hotels have been built high with central service cores surrounded by bedrooms, this is not economical owing to the quantity of circulation space.

To avoid an institutional appearance corridors should not appear too long. Fire regulations determine the positioning of escape stairs.

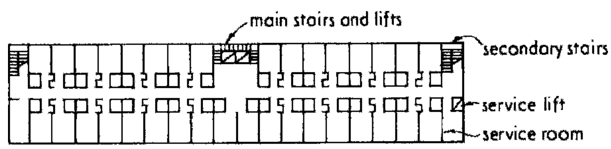
Access to all guests' bedrooms should be free of steps. At least 50 per cent should be accessible to disabled people.

3.04 Orientation

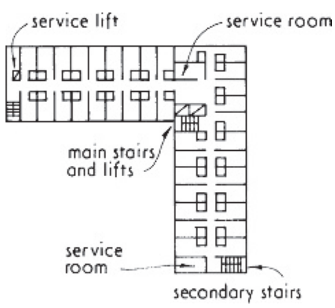
Take account of sunlight. Bedroom blocks with the long axis nearer north–south than east–west are preferable. Position bedrooms to minimise noise from traffic, machinery, kitchens, and the hotel's public rooms.

3.05 Form

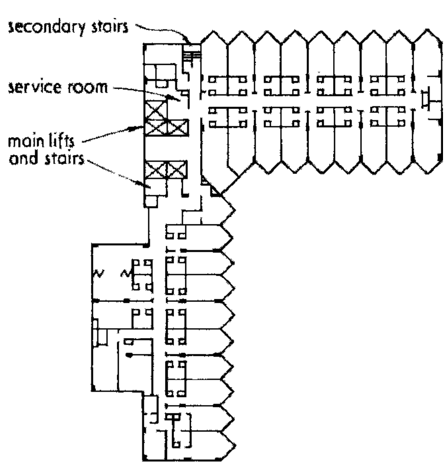
The bedroom areas are formed from relatively small units divided by separating walls, with many service ducts. On plan the block often forms an elongated rectangle, which can be straight or curved, or bent around a corner, or surrounding a rectangular or round courtyard. Various forms of bedroom blocks are shown in **11.8**.



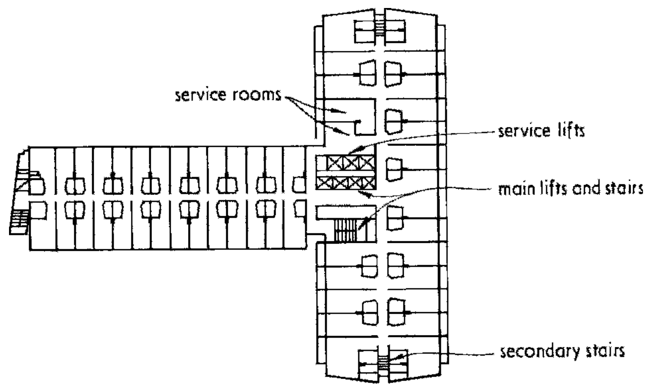
a *Linear room arrangement*



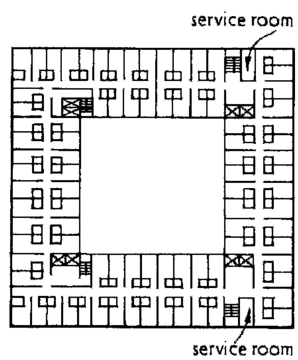
b *L-shaped room arrangement*



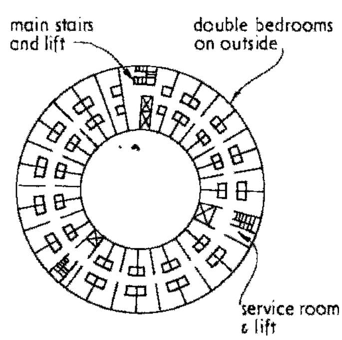
c *A US example of L-shape at Chicopee Motor Inn*



d *T-shaped arrangement at Royal Garden Hotel, London*



e *Rooms around a square court*



f *Rooms around a circular court at Ariel Hotel, Heathrow*

11.8 *Generic block plan forms*

3.06 Structural grid

Apart from site constraints, the structural framework and vertical services (including lifts) have to be related to the public rooms below, which will have a quite different structural grid. The structural module for the bedroom block will depend on the bedroom sizes required.

Bedroom layout should be related to staff capacities. One chambermaid can cope with about six bedrooms in luxury hotels and up to twenty or even more in lower-grade premises. Designing in multiples of her capacity per floor will minimise staff costs.

The length of each wing will be determined by the maximum escape distance in case of fire to a protected stair. Lifts and stairs are usually placed together as structural cores. Do not have lifts against bedroom walls because of noise transmission.

Bedroom sizes must be correct as they cannot be altered after construction. The structural design of high blocks is usually post and beam, while low blocks are usually cross-wall. Cross-walls have good inherent sound insulation, while post and beam save weight and therefore foundation costs.

3.07 Services

As standards are constantly rising, provide easily renewable fixed services in generously sized ducts. Preferably design bedrooms in handed pairs, so that the bathrooms are adjacent. This saves on duct space and reduces noise transmission, but take care to avoid noise through adjacent bathroom vent extracts or details such as recessed soap dishes.

3.08 Types of room

The ratio of singles to doubles will be decided by the client depending on expected use. Most hotels have 100 per cent doubles, but some hotels for business executives require many singles. Communicating doors between rooms maximise flexibility as suites can be formed; but fit two lockable doors in each wall for sound insulation. Ease planning problems at corners of blocks by having suites with a common lobby for two or more rooms.

Five per cent of rooms must be suitable for wheelchair users. This includes providing a much larger bathroom so that there is room to turn inside it in a wheelchair and transfer to the WC.

Be aware of the terminology used:

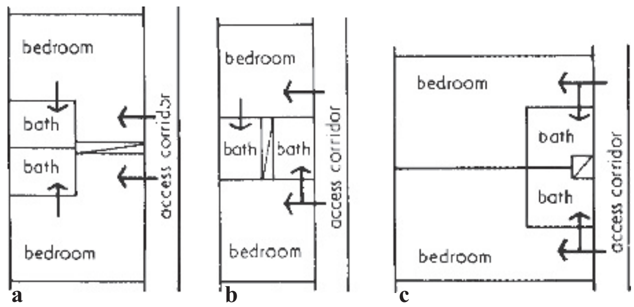
- Module: a single space, based on the structural grid, which can be used for any purpose including business. Used for financial feasibility calculations
- Bedroom: a single module containing a bedroom with its own bathroom
- Suite: two or more modules incorporating bedrooms, bathrooms and a separate sitting room
- Keys: total number of bedrooms and suites.

3.09 Bedroom planning

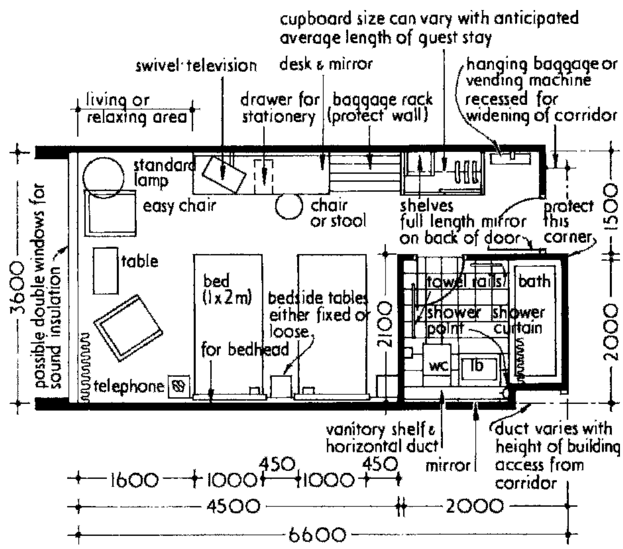
Rooms must be designed and furnished to facilitate access, cleaning, making up and servicing. The shape and to some extent the size will be governed by the placing of the bathroom. Most new hotels have individual bathrooms for each bedroom. There are three common arrangements:

- *Bathroom on external wall:* This gives natural ventilation to the bathroom, **11.9a**. The greatest disadvantage is that the service duct can only be inspected by passing through the bedroom. Also with bedrooms on both sides of the corridor two separate drainage systems are necessary. The amount of external walling is increased, the bedroom window is often recessed and light to the bedroom may be lost.
- *Bathrooms between bedrooms:* The main disadvantage is the elongation of the corridor and the increased external wall, **11.9b**. If the bathrooms are adjacent one of them is internal, so the ventilation problem is only half solved, and access to the service duct is still through a bedroom. Few arguments commend this arrangement, but it may be unavoidable in conversions.
- *Internal bathrooms:* These necessitate a lobby, **11.9c**, but it is generally used for the furnishings and so can be subtracted from the bedroom area. It can help with sound insulation from corridor noise. The bathrooms will require artificial lighting and ventilation. But the external walling and the corridors are minimised. This is the most common layout.

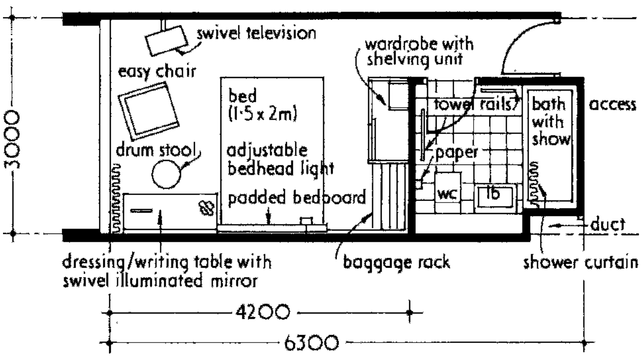
11.10 and **11.11** show typical double and single rooms in more detail, while **11.12** shows a twin-bedded room of non-conventional shape.



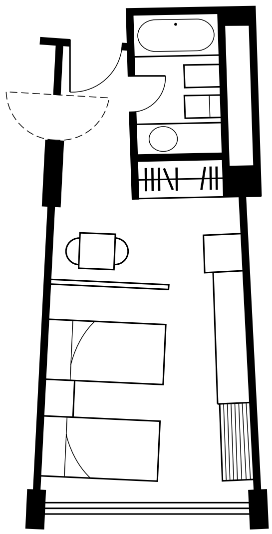
11.9 *Generic plan arrangements:* **a** *Bathrooms on external walls;* **b** *Bathrooms between bedrooms;* **c** *Internal bathrooms*



11.10 *Twin-bedded room with clothes storage and dressing table along party wall. Size varies according to site constraints and standard of accommodation*



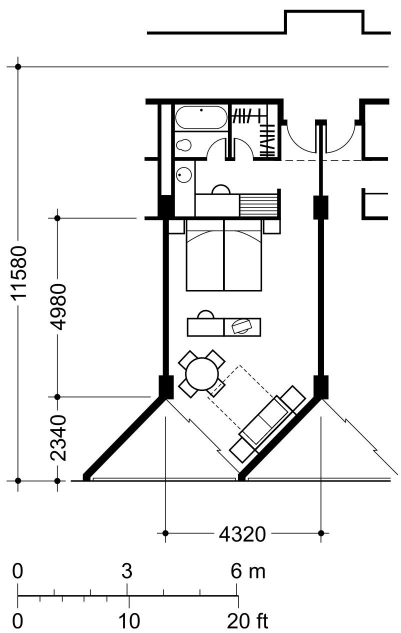
11.11 *Layout for single bedroom. Note double bed for use as double room if required*



11.12 *Twin-bedded room*

3.10 Terraces and balconies

These are pleasant but costly. They lead to an increase in the volume of the building, and to problems of security, wind and waterproofing. A raised threshold is always needed, and guests may slip or trip, causing claims for damages. It is wise to restrict them to rooms with outstanding views, and to those in higher price ranges only. **11.13** to **11.15** shows examples of hotel rooms with such features.



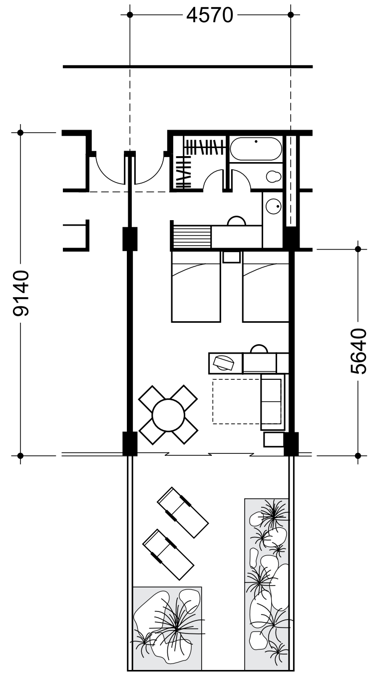
11.13 *Bedroom in a saw-tooth facade hotel*

3.11 Furniture and fittings

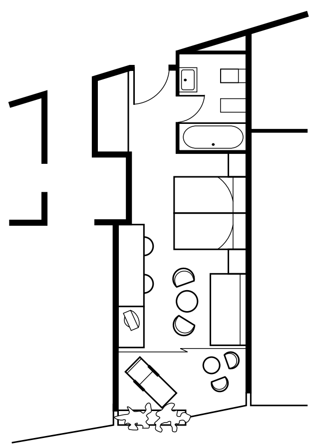
General

Furniture can be free-standing or built-in, and it can be bought from the domestic market or specially commissioned. Requirements will vary depending on the length of stay of the guests, and on the prices to be charged.

Free-standing furniture, particularly if of standard design, is cheap, flexible, easy to maintain and available in many varieties. Fixed furniture saves space and can facilitate cleaning by being fixed clear of the floor. It can help with sound insulation between rooms, but, on the other hand, it may transmit noise from doors,



11.14 *Bedroom with large terrace*

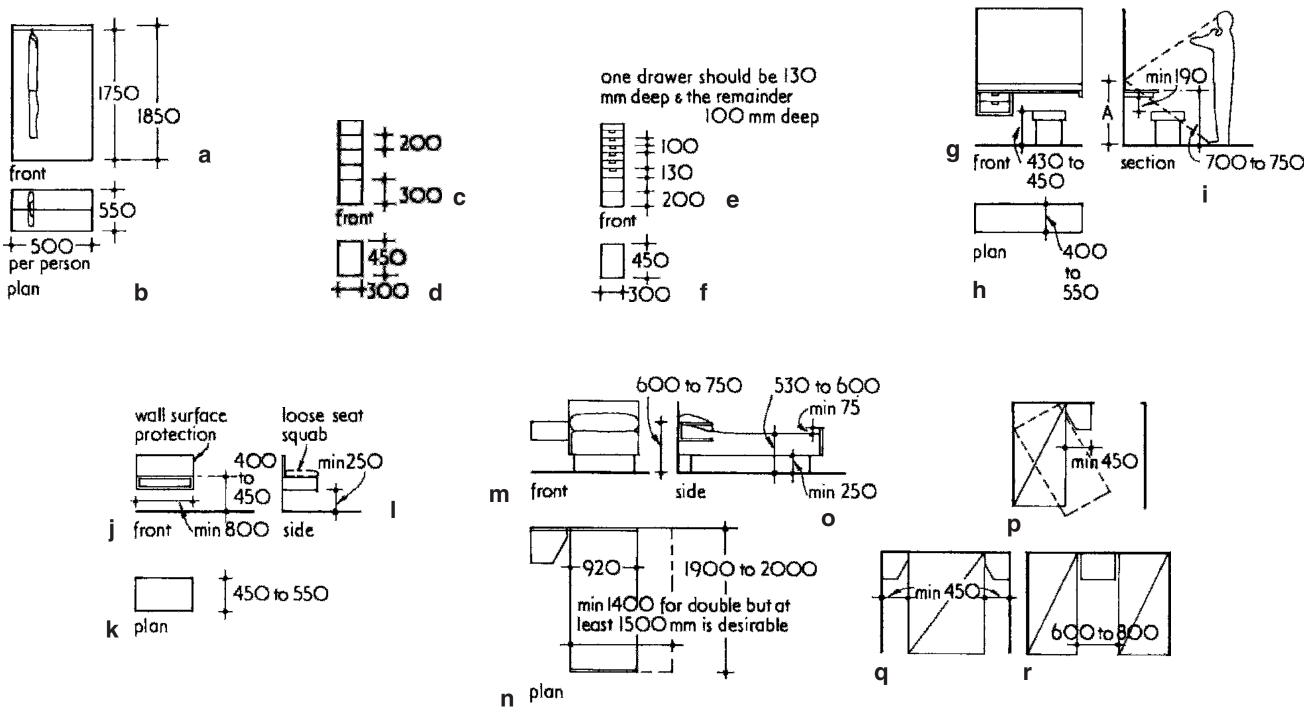


11.15 *Bedroom with small terrace*

drawers and hangers being moved. It is regarded as a fixture and hence as a capital investment.

Hotel furniture must be robust, and if fixed, firm. Moveable fitments should be few, particularly in motels where control is more difficult than in conventional hotels with one entrance. It has been known for everything to be stripped from a room including the television set and beds. In any case electrical equipment, such as hair-driers, are usually permanently wired-in, and television sets can have all their controls in bedside fitments. **11.16** shows the space requirements of all the common items of furniture.

When a room needs to be redecorated it will be out of commission. Walls and ceilings should be of materials that can be easily cleaned. Carpets can be of modular squares so that worn areas can be replaced. A small increase in the cost of furnishings can be a good investment. The main types of accidental damage are cigarette burns and people sitting on wall-hung fixtures. Horizontal surfaces should be as heat-resisting as possible, and fixtures should be very firmly fixed, or provided with legs. Catches should be strong and simple, and doors may have to be prevented from opening too far. A large proportion of a hotel's income is spent on staff and maintenance. The designer should seek to reduce these.



11.16 *Space requirements for hotel bedroom furniture. Note: the dimensions for wardrobe, shelf and drawer units are minimum clear internal dimensions.* **a** *Wardrobe front – per person;* **b** *Wardrobe plan;* **c** *Shelf unit front;* **d** *Shelf unit plan;* **e** *Drawer unit front;* **f** *Drawer unit plan;* **g** *Dressing/writing table front;* **h** *Dressing/writing table plan;* **i** *Dressing/writing table section. Dimension A must not exceed half eye height to achieve full-length view. For combined dressing and writing use the minimum table top area is 0.6 m*^{2}*;* **j** *Luggage rack front;* **k** *Luggage rack plan;* **l** *Luggage rack side;* **m** *Bedside table and single bed front;* **n** *Bedside table and single bed plan;* **o** *Bedside table and single bed side;* **p** *Bedside table for single bed;* **q** *Bedside tables for a double bed;* **r** *Bedside table for twin beds*

One of the chief reasons for needing cleaning and eventual redecoration is smoking by the guests. Modern practice is to maintain some rooms solely for smokers, to minimise the problem for the other rooms.

Beds

These must satisfy a number of requirements:

- Comfort
- Adequate dimensions
- Durability
- Ease of movement for making up
- Ease of dismantling for storage
- Absence of creaking, and
- Good appearance, including bedhead which may be a fixture.

Positioning is important: generally singles are located parallel to a wall and doubles have the bedheads against one of the party walls. The opposite, singles with the head to the party wall, or doubles with the beds parallel to walls, the so-called studio room layout, use more space.

Beds are now 1 m wide for a single and 2 m × 1.5 m for a double, but the size varies with the degree of luxury. For appearance, a height of 300 to 400 mm, including mattress, is best. For ease of making, however, as low beds cause fatigue and backache, a height of 530 to 600 mm or even 700 mm is better. Including the bedhead the bed is therefore 2.10 m long. A minimum of 0.8 m is needed as passageway at the foot of the bed, so the minimum width of a double bedroom is 2.9 m.

If the associated bathroom has a full-length bath, basin and a WC it also needs to be 2.1 m overall. There is consequently no space in the entrance lobby for furnishings, so wasting this space completely. If a further 0.6 m is allowed in the lobby for furnishing, the room width becomes 3.5 m. This is a fairly common module in modern medium-priced bedroom wings. It balances the need for shortening corridors with the provision of reasonable space in individual rooms.

Fittings

A long hanging wardrobe space with 300 mm and 500 mm width is required for the first person, plus 300 mm more for each extra person, with preferably a short hanging space somewhat smaller. Provide at least two shelves or drawers for the first, and one more for each extra person, with a width of 300 mm and a depth of 450 mm.

A luggage rack, which could have a space for a trolley underneath, 800 to 900 mm long, is needed. There must be guards against abrasion by metallic objects such as studs on suitcases, and it should be high enough to avoid fatigue for those packing.

Provide a dressing table at least 900 mm long, doubling as a writing table, and with at least one drawer. Fix a mirror above it, ideally with two side mirrors. It must have a good light, with separate switches. There should also be a full-length mirror with suitable lights.

There should be separate reading lights over the bed or beds, a general light and a light in the entrance lobby as well as those in the bathroom.

The bedhead is normally built in, but may need to be moveable to allow change of bed position. It holds bedside tables large enough for books, spectacles, water and a telephone. All lights, radio and television should be controlled from the bedhead, also any mechanical equipment such as curtain controls, heating and ventilation or tea maker. In the best hotels there will be a drink dispenser, a refrigerator, and sometimes a safe.

Loose furniture
Each bedroom should have one or two occasional chairs, at least one easy chair per person, a swivel dressing table chair, an occasional table, standard or table lamps, ashtrays, maybe a trouser press, and usually a television set.

4 PUBLIC AREAS

4.01
These areas usually need long-span construction and vary greatly from one hotel to another. They are usually located at ground level for convenience. Roof-top restaurants are only built to take advantage of quite exceptional views – the costs of servicing them can be substantial.

4.02 Entrance
The impression created by the main entrance is important and defines the type of hotel. It must always be obvious and lead directly to reception. Something more than a canopy is desirable to provide protection from wind and rain. A porte-cochère should be wide enough to allow two cars to pass and possibly high enough for coaches. Special lighting may be needed to accentuate the entrance.

Provide doors wide enough for a porter with bags, 900 mm clear. With revolving doors, side-hung escape doors will also be required. A draught lobby should normally be provided. Consider automatic doors.

All public entrances must be accessible to ambulant disabled people, and at least one to those in wheelchairs. At least one entrance from the hotel garage must be accessible to wheelchair users.

A transition area of flooring is required at the entrance before fine floor finishes are approached. There will be dirt and wear from foot traffic.

4.03 Reception
The reception desk should be visible to the guest immediately on entry, and it should be on the route to the lifts and stairs. Sometimes clients will require it to be visible from the street, alternatively they may decide that privacy for guests may be more important. This will influence the type of glazing and curtains. Occasionally a hotel is located above another street-level use. If the reception itself is on an upper floor, the stairs and lifts must be exclusive to the hotel.

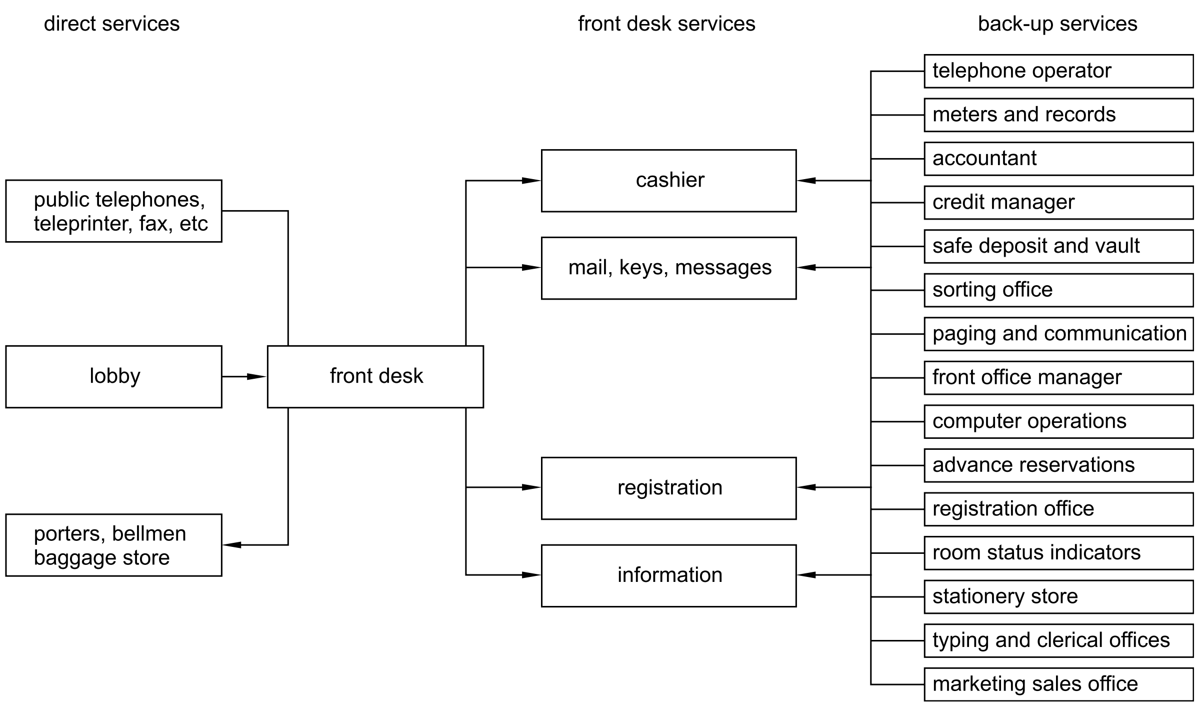
In any reception, the following facilities are required:

- Counter, suitable for writing, with a 'bag shelf'
- Space for receptionist
- Key racks, often associated with letter racks behind counter
- Cashier and accounting equipment, computer, etc. Foreign currency service may affect storage requirements
- House telephone, for visitors to speak to guests in their rooms
- Call boxes: if there are phones in rooms only a few will be needed. They must be visible to reception staff but have some privacy
- Space for timetables, tourist leaflets, brochures, etc.
- Postbox, stamp machines, etc.
- Telephone meters for recording the cost of calls from guests' rooms
- Clocks and calendars visible to staff and guests
- Stationery and records store
- Strongroom or safe
- Parcel or baggage storage
- Room call system, and
- CCTV monitors, etc.

The relationships between the reception desk and other facilities are shown diagramatically in **11.17**.

There is often a separate head porter's station, which may include an enquiry counter. It should be in a strategic position to control the entrance, the coming and going of guests, call boxes, and any external taxi rank or valet parking system. The head porter will control porters and messengers, and will look after baggage. He or she will be able to communicate with the garage, luggage room, reception, and cashier and will monitor fire alarms and service bells.

The client must decide on baggage handling. If not carried by the guest, there may be a separate baggage entrance, especially if tour buses bring mass deliveries of luggage. A lift, baggage room and a



11.17 *Relationship diagram for administration services* foolproof method of identifying luggage may be necessary; guests are nervous if they are separated from it. Provide some space for trolleys. Access to those public rooms mainly for nonresidents (including conference, banqueting suites, etc.) is often separate from the main reception. Another entrance foyer will be needed, plus cloakrooms.

4.04 Lounges

The traditional image of a lounge as a separate room is changing. Isolated lounges earn no revenue. They are more likely to be part of an irregular area joining public rooms to the entrance area, or part of a bar. If there is a bar the room should not look dead when the bar is closed. Resort hotels may have a lounge for entertaining guests' friends. A rough planning figure is 1.1 to 1.4 m^2 per seat. Furniture is normally easy chairs and low coffee tables, and the atmosphere should be informal and relaxing.

The design of bars is influenced by the areas that they serve: lounge, restaurant, coffee shop, banqueting rooms, room service, etc. and the degree to which waiter service is employed. Bar design is dealt with in detail in Chapter 17 of this Handbook.

4.05 Dining rooms

The dining room is usually open to non-residents, so there should be convenient access from outside the hotel in addition to access for resident guests. Most larger hotels will have dining rooms on several levels, such as a breakfast room on the first floor. The main dining room must be directly adjacent to the main kitchen. Details are in Chapter 17. Table II gives areas required according to the number of seats, and includes the areas that are more fully covered in section 5 below.

Table II Food service areas in m^2: according to numbers of seats

	Area per seat (m^2)	Notes
a Food services		
A-la-carte restaurant	1.8 to 2.0	Seating area in restaurant
Brasserie Coffee shop	1.7 to 1.8	Gross factor, allowing for circulation
Lounge and bar	1.8 to 2.0	Cloakrooms, etc. typically add 20%
Functions, banquet style	1.2	
Functions, conference style	1.6	
Foyer to banquet hall	0.3	
Staff canteens	0.7 to 0.9	
b Service facilities		
Main kitchen	0.9 to 1.0	or 60% of dining room
Coffee shop kitchen	0.6	or 45% of coffee shop
Food, liquor and china storage	0.5 for diners 0.3 for coffee shop	or 50% of kitchen
Banquet kitchen	0.24	or 20% of banquet room
Banquet storage	0.05	or 8% of banquet room

4.06 Function rooms

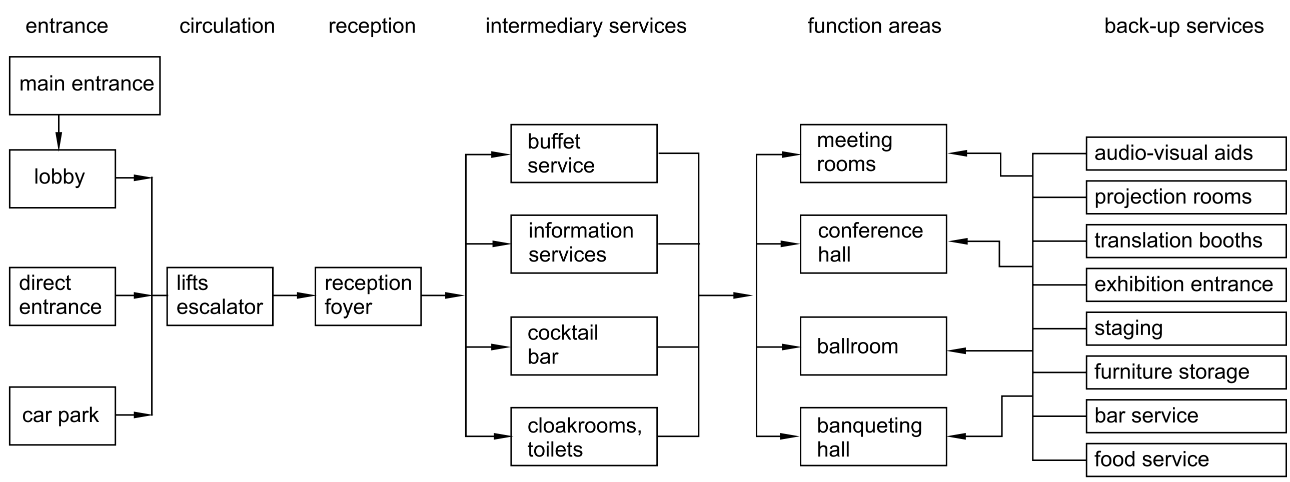
Function rooms tend to be linked to the business facilities as they are also used for conferences, etc. But these large rooms have to be designed to be multi-functional as the cost of providing them is high and so they have to be in frequent use.

They may need to be adaptable for banqueting, dancing, conferences or exhibitions. Floors may have to be changed, e.g. by changing the covering. Considerable space adjacent will be needed for furniture storage. It may be necessary to be able to divide the room with sliding screens, but ineffective soundproofing may not allow use of both parts at the same time. A separate entrance from outside is usually needed. There must be at least two emergency exits. Very good sound insulation is vital both to prevent sound entering and escaping to bedrooms, etc. Excellent environmental services are necessary.

4.07 Checklist of requirements

- Ante-rooms
- Food and liquor service
- Method of dividing room
- Soundproofing and acoustic treatment
- Storage of moveable walls
- Furniture storage
- Crockery and equipment storage
- Dance floor, with removable carpet
- Protection of walls against chair damage
- Air-conditioning
- Toilet and cloakroom facilities
- Cine projection
- External access for heavy equipment for exhibitions
- Exhibition services, e.g. gas, water, drainage, phones
- Dimmable lights
- Electronic equipment: TV, audio
- Changing rooms for temporary staff or performers
- Bandstand or dais, temporary or permanent
- Theme motif or name
- Press box
- Fire exits, lighting, etc.

A diagrammatic representation of these relationships is shown in **11.18**.



11.18 *Relationship diagram for non-residential functions*

5 SERVICE AREAS

11.19 is a relationship diagram for the service functions.

5.01 Bedroom servicing

Table I gives service areas required according to number of guest rooms. Take particular care where room service areas are concerned, as much work is done while guests are still asleep.

5.02 Catering servicing

The most important element to get right is the location of the main kitchen. This has to serve the main restaurant three times a day, 365 days a year, and needs to be immediately adjacent. It also serves, directly or by satellite kitchens, other catering outlets, functions, banquets, bar food, room service, staff restaurant, etc. Its location is critical for back-of-house circulation. Site kitchens and rooms used for food and wine storage on the north or northeast side if possible, to facilitate temperature control. Areas required are given in Table II.

5.03 Offices

The manager's office is usually adjacent to reception for reasons of control. Other offices, accounting, records, etc. can be elsewhere as long as communication to reception is good. In a large hotel accounting is computerised for speed and staff economy. While office sizes vary greatly, a rough indication is 7.5 to 20 m^2, and Table III gives some further details.

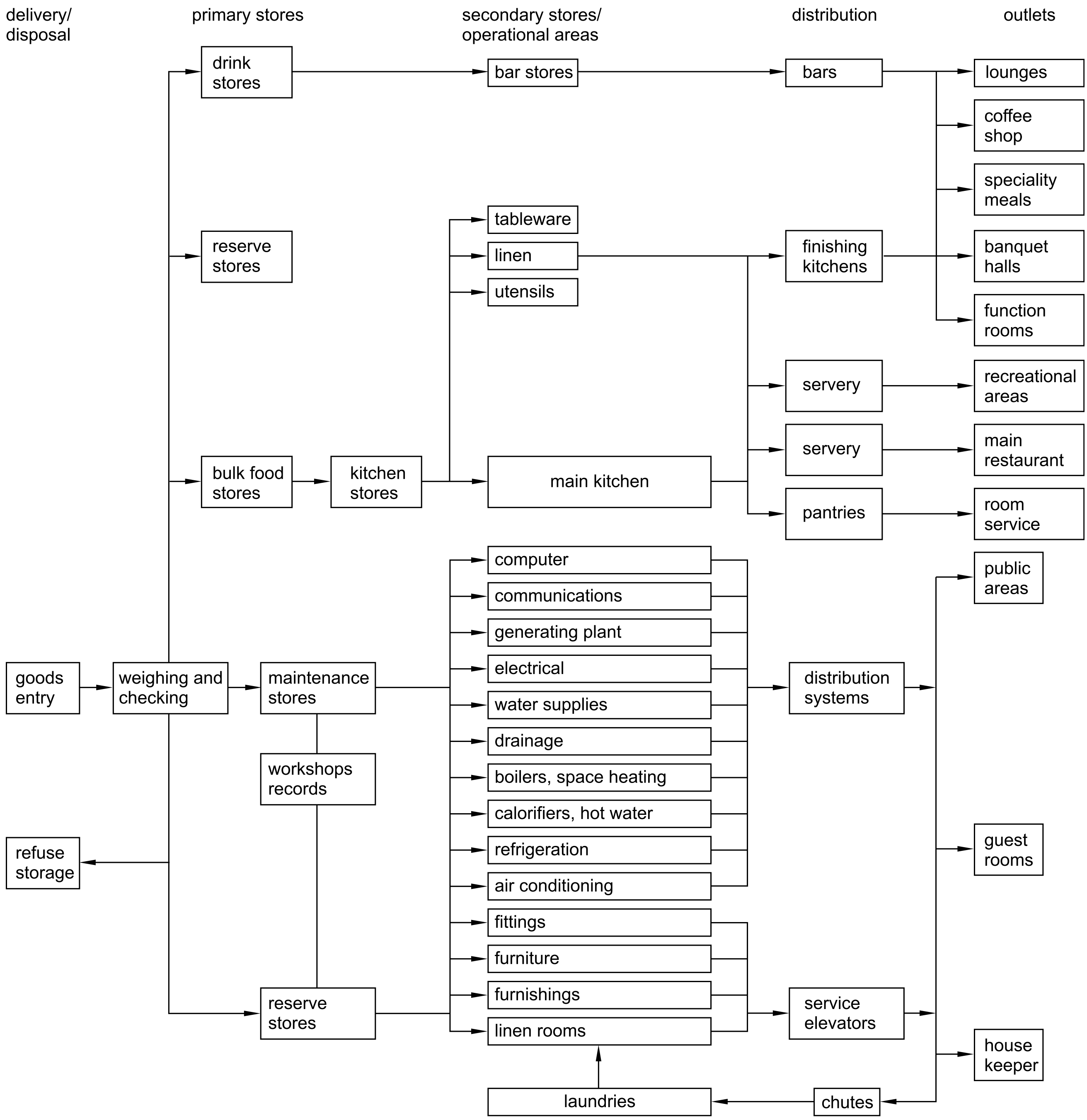
6 OTHER SPACES

Table IV covers area requirements for various other spaces.

6.01 Special accommodation

The other facilities that may be required are:

- Staffroom for guests' chauffeurs or other staff
- Day nurseries (especially in resort hotels)
- House doctor or nurse, and sick bay
- Business executives secretarial facilities or offices



11.19 *Relationship diagram for technical and catering services*

Table III Office areas required in m²

	100 guest rooms	200 guest rooms
a Administrative		
Manager	9.5 to 11.5	11.5 to 14.0
Assistant manager	7.5 to 9.5	9.5 to 11.5
Financial	not required	7.5 to 9.5
Secretaries (area for each, two required)	7.5 to 9.5	11.5 to 14.0
Sales and catering	not required	11.5 to 14.0
Purchasing	not required	11.5 to 14.0
Personnel and auditing	not required	7.5 to 9.5
General office	14.0 to 18.5	18.5 to 23.0
b Food and beverage department		
Catering manager	7.5 to 9.5	9.5 to 11.5
Chef	not required	9.5 to 11.5
Banquet manager and waiter	not required	7.5 to 9.5
Room service	not required	7.5 to 9.5
c Housekeeping		
Housekeeper	7.5 to 9.5	7.5 to 9.5
Receiving clerk and timekeeper	7.5 to 9.5	7.5 to 9.5
Engineer	7.5 to 9.5	7.5 to 9.5

Table IV Areas for various spaces

Function	Area
a Circulation and reception	
General allowance	Gross factors: 25–35% added to room areas
Lobby areas	2-star 0.6 m^2 per room to 5-star 1.2 m^2 per room
b Cloakrooms	
Fixed rows of hooks	0.1 m^2 per user including staff circulation and space around counter
Hooks plus seats or lockers	0.2 to 0.3 m^2 per user
c Health and fitness clubs	
Swimming pool	15.0 × 7.0 × 1.4 m plus 2 m surround plus changing rooms
Gymnasium	15 m^2 for a small fitness room to 65 m^2 for a large complex
d Public assemblies	
Conferences (theatre style)	0.6 to 1.0 m^2 per person plus stage, plus translation booth or 1.0 to 1.2 m^2 overall
Dances	0.6 to 0.9 m^2 per person plus band space up to 12 m^2 for a 6-piece band
Recreations	See elsewhere in this Handbook

- Gymnasium or fitness centre
- Sauna or Turkish baths
- Cinema
- Meeting rooms
- Press, interview or lecture rooms
- Casino or card rooms
- Changing rooms for swimming pools
- Night clubs
- Kosher kitchens
- Manager's flat
- Service flats or suites
- VIP rooms, and
- Chapels.

6.02 Cloakrooms and lavatories

These should be on main circulation rooms near public rooms. They must be discreetly conspicuous, and male and female must be separate. It must not be possible to see in even when all the doors are open, nor must they communicate directly with rooms used for food.

Women's lavatories should include a powder room of appropriate size. Women prefer the cloakroom to be within the lavatory area, but men prefer it to be outside. The number of fitments depends on the maximum number of people to be served.

7 ACCESS AND CAR PARKING

7.01 Access

Pedestrian and vehicular access to the hotel needs to be determined and agreed at an early stage. Access for guests and hotel servicing must be clearly separate. Provision must be made for:

- Guests: arriving by private car, taxi, public buses, coaches or on foot
- Staff: arriving by car or public transport
- Goods deliveries: food, laundry, furniture may need to be separate
- Refuse: separate from food supplies.

Roads must have curvatures related to the size of vehicle, space must be available for waiting, and approaches should be visible from inside the building.

7.02 Signage

External signage is always required. Consider the proper integration of illuminated signs on the building at the design stage, not as an afterthought. Flagpoles, floodlighting and other feature entrance signage may be required, as well as remote off-site direction signs.

7.03 Lighting

External lighting needs to draw attention to the hotel and highlight an inviting entrance. It should banish dark corners and enhance security.

7.04 Car parking

Planning requirements vary according to the type and size of hotel and its location. The planning authority will advise.

A common operational requirement is 1.2 to 1.3 spaces per room. Inside London it may be less, but space for conference parking may be greater. The biggest problem is usually fly-parking by outsiders where the site is desirable.

Provision must be made for cars to drop off passengers easily at the main entrance, and then go to the car park; the driver must then be able to return easily on foot to the entrance to rejoin guests. Afterwards, it must be equally easy for the car to return to pick up at the entrance. In a town the parking may have to be in the basement, and mechanical plant may be displaced to a subbasement or upper floor.

7.05 Servicing

Secondary access is required for goods and service vehicles with adequate provision for turning, loading and unloading. It is normally from a road different from the main entrance. Staff access is usually through the service entrance to simplify control. It is necessary to make separate provision for receiving and handling different types of goods, taking into account their nature and storage requirements. The main divisions are:

- Beers, wines, spirits: needing beer and wine cellars, spirit stores and crate storage
- Food: needing cold stores, vegetable stores and dry goods stores
- Laundry and soft furnishings: linen stores
- General: crockery and cutlery stores, cleaning equipment stores, storage for maintenance plant, furniture and general goods and
- Fuel: oil storage tanks and solid fuel enclosures.

7.06 Refuse

Refuse collection vehicles will normally use the service entry. There must be space for:

- A compactor, about the size of one car-parking bay
- Crushing machines and containers for glass bottles
- Containers or skips for large dry items
- Bins for food waste intended for animals
- Space for returnable containers
- Material intended for incineration.

Rubbish is a potential source of nuisance as decaying residues of food attract rats and flies, and rubbish clearance operations can be noisy. Bins and containers should be situated in an impervious enclosure equipped with means of hosing down and drainage.

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12 Offices

CI/SfB 32
UDC 725.25

Frank Duffy with Jay McMahan and Jack Pringle

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KEY POINTS:
- *Changing expectations*
- *Occupants' demands*
- *Space standards*
- *Time sharing*
- *Atria, and their fire safety*
- *Floor loadings*
- *Building services*
- *Information technology*
- *Refurbishment*

Contents

NOTE
Some important aspects of design relevant to offices will be found elsewhere in this handbook.

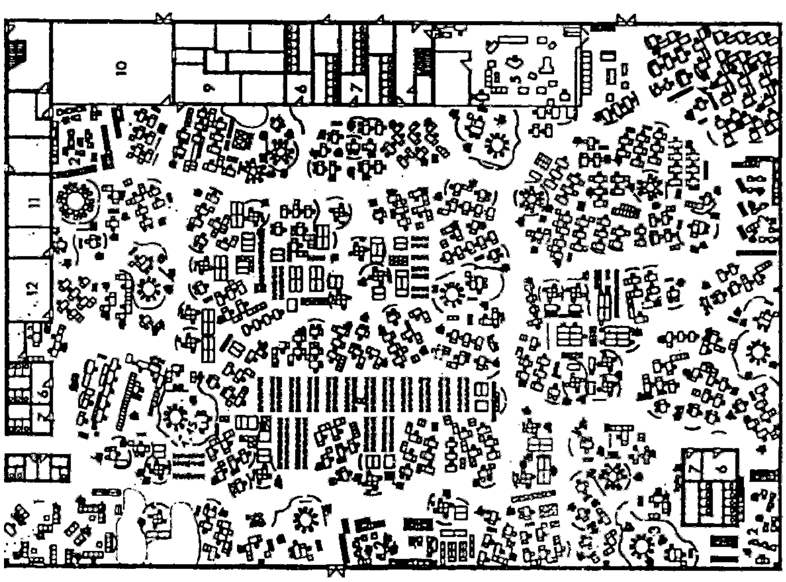
1 INTRODUCTION

1.01
Office design is at a turning point. For many decades, especially in the developer-dominated Anglo-Saxon world, office users have been passive. Vendors have concentrated on perfecting the delivery of buildings at most profit, least risk and maximum convenience for themselves. The buildings that result can satisfy the relatively simple demands of highly routinised and unchanging organisations. The key question is whether such office buildings are capable, without substantial modification, of accommodating the emerging requirements of organisations.

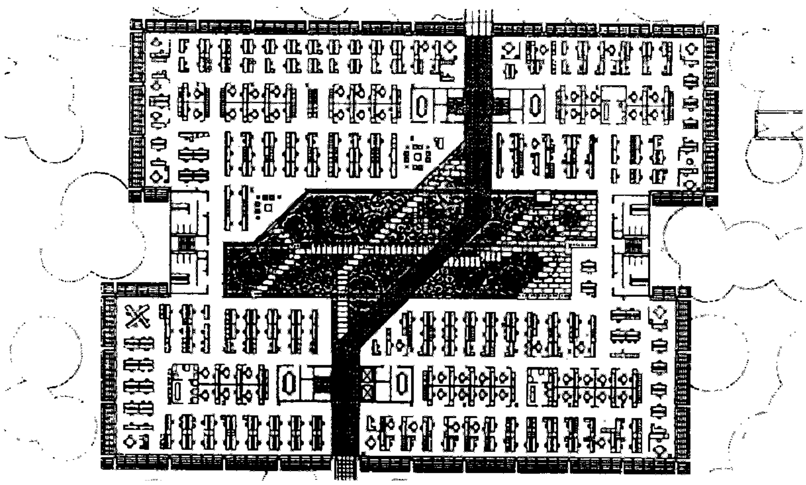
1.02
This is particularly relevant to the UK. British office buildings were until the early 1980s a provincial variant of the North American developer system, financed in much the same way but much smaller, far less efficient in construction as well as plan form, less serviced, and much more influenced by external considerations forced upon the developers by the British town and country planning system.

1.03
The contrast between the best new, North Americanised London offices such as Broadgate or Canary Wharf with the best North European offices such as SAS Frösundavik or Colonia – the sort of buildings produced when the developer's influence on office building design is relatively weak – is very striking.

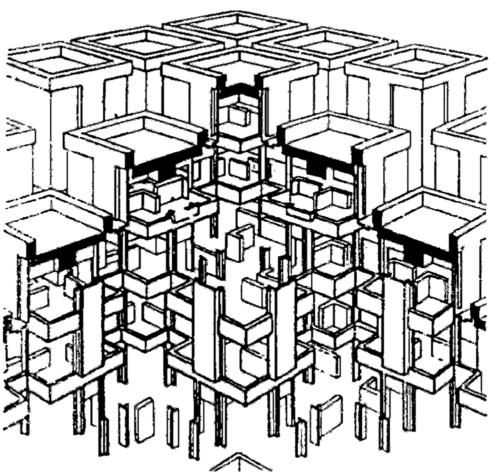
1.04
User influence on recent office design in Scandinavia, Germany, and the Netherlands has been direct and considerable, resulting in narrow and complex rather than deep plan forms, in very high degrees of cellularisation, and above all in extremely high standards of space, amenity and comfort for office workers. Buildings which have been shaped by direct user influence – through highly professional programming, through the competition system, and above all through Workers' Council negotiation – are sufficiently different from the supply-biased, developer-oriented offices of the USA and the UK to demonstrate that an alternative kind of office is achievable, but at a cost, **12.1** to **12.4**. A comparison of the types is given in Table I.



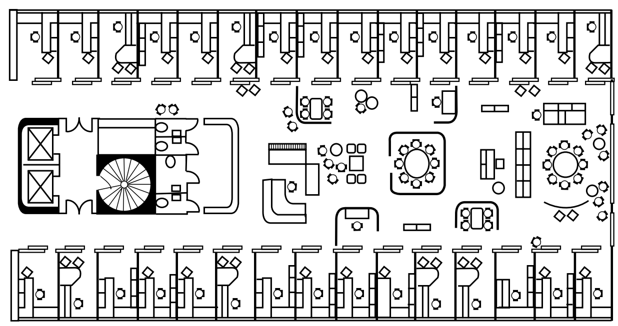
12.1 *The scientifically planned bürolandschaft office (1950s)*



12.2 *The American influenced open plan with centralised space standards and single status workstations (1960s)*

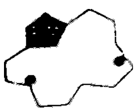
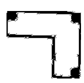
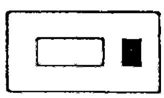
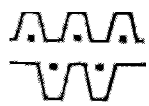


12.3 *Robust office shell designs, self-regulating structural grids (1970s)*



12.4 *The demand for higher standards, personal privacy – the 'combi-office'*

Table I Planning and design criteria for different types of office building

	Bürolandschaft	**Traditional British speculative**	**New 'Broadgate' type of British speculative**	**Traditional North American speculative**	**New north European**
					
No. of storeys	5	10	10	80	5
Typical floor area (m^2)	2000	1000	3000	3000	multiples of 200
Typical office depth (m)	40	13.5	18 and 12	18	10
Furthest distance from perimeter aspect (m)	20	7	9 to 12	18	5
Efficiency: net to gross		80%	85%	90%	70% (lots of public circulation)
Maximum cellularisation (% of usable)	20%	70%	40%	20%	80%
Type of core	Semi-dispersed	Semi-dispersed	Concentrated: extremely compact	Concentrated: extremely compact	Dispersed: stairs more prominent than lifts
Type of HVAC service	Centralised	Minimal	Floor by floor	Centralised	Decentralised: minimal use of HVAC

1.05 The new office

In the last years of the 20th Century offices suffered the effects of the first wave of distributed intelligence. Cable management, bigger heat gains, finer zoning of air conditioning were the symptoms; the major underlying problem was, and still is, how to accommodate accelerating organisational change within long-term architecture. Today it is the indirect consequences of ubiquitous and addictive information technology that is reshaping organisations, changing their demography, and above all rescheduling their use of time. Whereas in the early 1980s what mattered was the obsolescence of particular office buildings, what matters now is the growing obsolescence of the nine-to-five office work – and of all the patterns of employment, location, and commuting that have shaped our cities for a hundred years.

1.06
Re-engineering (or changing the organisation of) office work is leading already to experiments in the intensification of space use-time sharing the office. This is hardly good news for developers whose enthusiasm in the late 1980s modernised the British office stock, but led also to overbuilding. While office users are intent on driving office space harder than ever before to succeed (or even to survive), developers are considering whether to offer more services to attract tenants (the intelligent building), to take secondary office space out of circulation (change of use), or to tailor-make offices to suit particular tenants.

1.07
Architects must get closer to the users, at both tactical facility management level and at a strategic level. Users are now where the real power lies – certainly no longer in the old, discredited, institution-dominated real estate market – and users' needs are changing faster and more spectacularly than ever before.

2 MATCHING SUPPLY AND DEMAND

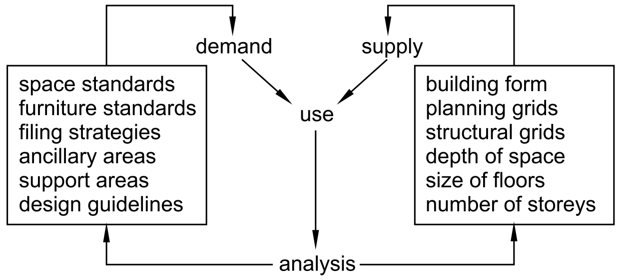
2.01
The design of office buildings has suffered from oversimplified generalisations by architects, developers and clients, who have preferred to use a 'rule book' providing easy answers, rather than thinking the problems through. There is no such thing as the all-purpose building, a hard lesson for architects in the modern movement tradition of 'universal space'. Equally, speculative developers and funding institutions still have difficulty in coming to terms with the fact that the different sectors of the market have different requirements, and that those requirements are constantly changing.

2.02
We need to examine the frame of reference for designing office buildings. Those looking for premises have a choice between the new and the old. There are additional options – even for those seeking new, large, high-performance buildings which until recently did not exist. Buildings must be designed to reflect the requirements of the different sectors – horses suited to courses.

2.03
At one end of the spectrum are very large, rich and complex organisations which have spent considerable sums on computing and telecommunications. In recent years these firms have been able to move offices at short intervals to ensure that their accommodation kept pace with their growth and technological requirements.

2.04
The demand for space from professional firms with distinct usage and layout requirements puts them in the middle range. At the other end of the spectrum are the many small service firms which need only the simplest and cheapest accommodation. No one design can accommodate equally well such a wide spectrum of demand.

2.05 Supply and demand
The essence of the design brief for office space is in the balance of the economic model of supply and demand, **12.5**. Producing a viable statement of requirements for a client is begun by investigating the demand for space. Depending on whether the project involves existing space or whether it is being built to suit, the final area requirement will be arrived at by reconciling space demands, such as workspace standards, furniture and filing strategies, with the supply issues of building form, planning and structural grids and depth of space. Table I covers planning and design criteria for various types of office.



12.5 *Reconciling demand and supply*

2.06 Improving user satisfaction, health and comfort
A good building is an elusive thing, but it is one which satisfies organisational needs at reasonable cost and without unnecessary effort, and in which the inhabitants are happy to work. This brings us to a good brief, good design, and good management. There must be four key features:

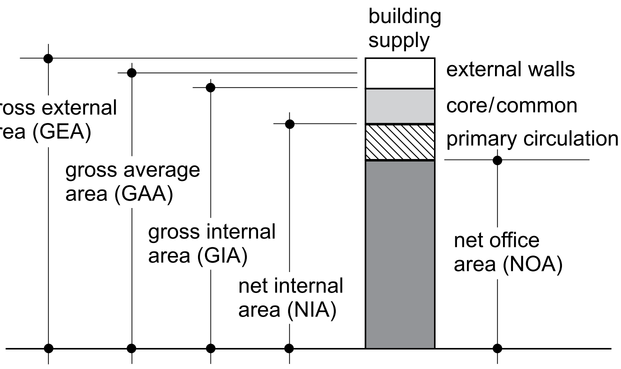
- Adaptability to meet a range of space and servicing requirements. The building should not make it difficult for occupants to do what they want. For example, in addition to the current shell-and-core facilities, offices might accommodate a wider range of choice in internal environmental services, from natural ventilation and lighting upwards.
- Contact with the outside world. People like being near a window with clear glass. In Scandinavia and Germany this is now almost a right, and is having a major influence on office design, with deep open plans giving way to more diverse buildings with offices of a more domestic scale around a core or 'street' of common facilities. The degree to which similar views and solutions will prevail in the UK is not yet clear. Cultural and climatic differences make building types and their services difficult to export, however international they may feel, and new icons are just as likely to prove false gods as others have in the past.
- Better, healthier and more productive internal environmental quality. In all its aspects: heat, light, sound, colour, and air quality. This last is the most difficult as natural ventilation is more psychologically acceptable than any mechanical system, however poor the outside air. And, of course, delight: a building which both works and feels good to be in will be a much better investment in the long run than one which is functional but unloved.
- User control. Psychologists have observed that the human factor – for example, the openable window – is disproportionately significant to perceived wellbeing. The reasons may include social as much as design and health issues. For example, one writer observes that 'individuals measure their worth within an organisation as much by the control they possess over their environment (in the broadest sense) as by expenditure, however lavish, from an invisible and unfeeling corporate exchequer'. Not nearly enough is known about the behavioural aspects of both simple and advanced environmental control systems in buildings.

3 STANDARD METHOD OF BUILDING MEASUREMENT

3.01
An understanding of the terms used by clients to specify floor areas, **12.6**, **12.7** and **12.8**, is essential:

Gross External Area (GEA): the floor area contained within the building measured to the external face of the external walls *Gross Internal Area (GIA)*: the floor area contained within the building measured to the internal face of the external walls.

In all the above gross measures features such as atria are measured at the filled floor level; the clear voids are not included in the total area. Enclosed plant rooms on the roof are included in all gross measures.



12.6 *The standard method of measurement in the Code of Measuring Practice published by the Royal Institution of Chartered Surveyors and the Incorporated Society of Valuers and Auctioneers*

Net Internal Area (NIA): is GIA less the floor areas taken up by:

- Common lobbies and foyers
- Enclosed plant on the roof
- Stairs and escalators
- Mechanical and electrical services plant areas
- Lifts

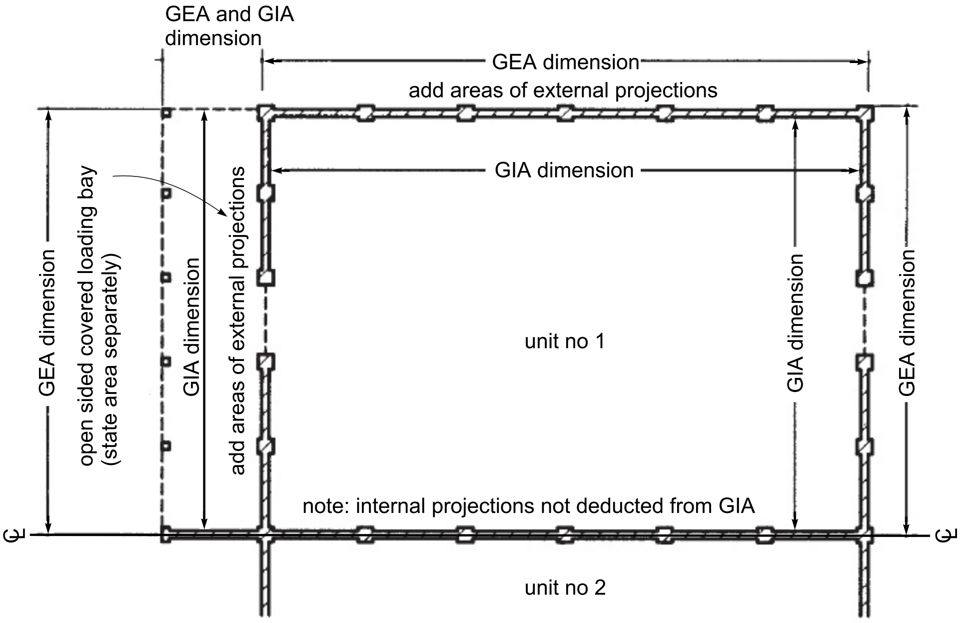
Internal structure, such as columns

- Toilet areas
- Functions within the core enclosure
- Ducts and risers
- Car parking which was included in gross area

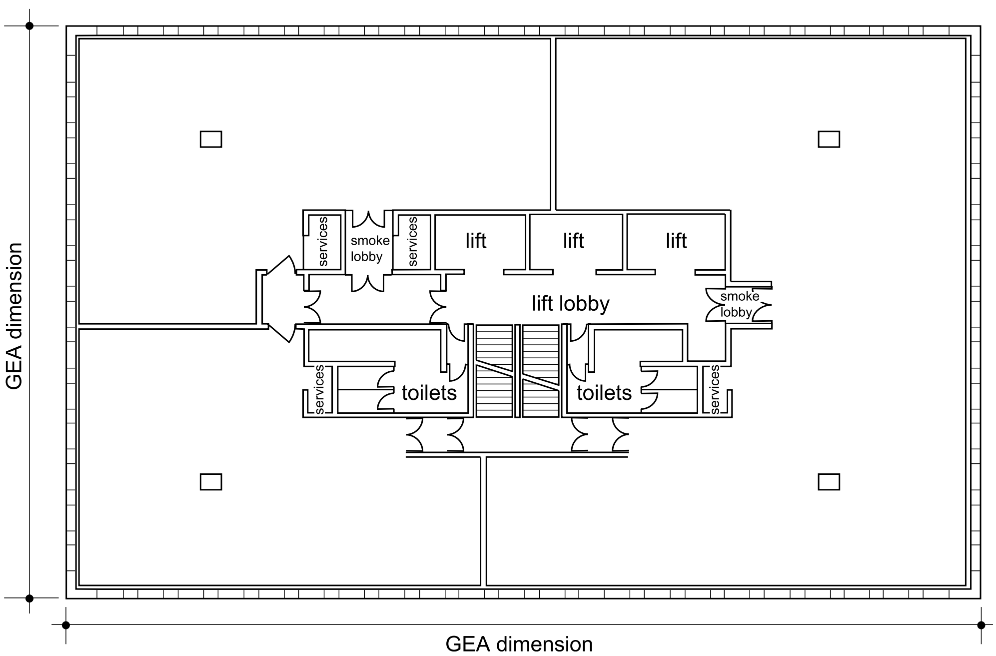
These areas are often referred to as core and/or common areas.

3.02

An additional non-standard term encountered is *Net Office Area (NOA)*. This is the NIA less the main corridors or primary circulation



12.7 *An example of dimensions for GEA and GIA for an industrial/warehouse end terrace unit*



12.8 *An example of a multiletting office floor showing NIAs* (as it is often called). These corridor routes are required to maintain life safety in emergency situations such as a fire, but do not include the routes used to access workstations off the main corridor (i.e. secondary circulation is included in NOA).

3.03 The space budget

The components of the space budget, **12.9** are as follows:

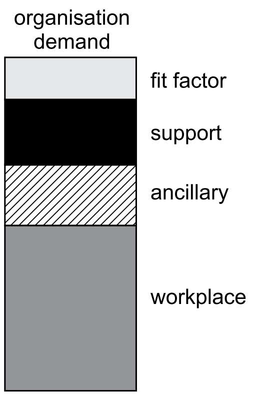
Workspace: the area given over to workstations and their immediate requirements, such as personal filing

Ancillary: the area given over to functions that are managed by and support a section or working group, including local meeting places, project rooms, storage areas, shared terminals, refreshment and copy areas

Support: the area given over to functions that are centrally managed and support the whole organisation or building, including mail, reprographics, network rooms, switchboard rooms, library, conference, central meeting etc. The areas may be on separate floors or otherwise distant from individual departments or groups

Fit factor: buildings can rarely be 100 per cent efficient, for two prime reasons:

- Building configurations, grids and obstructions
- Departmental integrity.



12.9 *The space budget represents the organisation's requirement for net usable area*

4 THE TIME-BASED NATURE OF THE OFFICE ENVIRONMENT

4.01

Buildings are relatively permanent, while the organisations and activities within them are continuously changing. To allow for maximum flexibility, different time scales of building briefing and design can be distinguished into separate functions of:

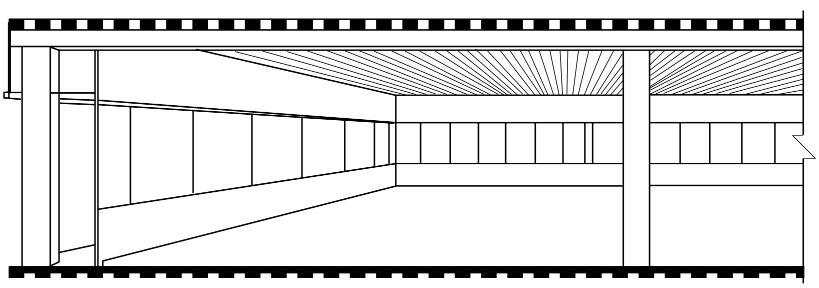
- **The building shell** – the structure and enclosure of the building, **12.10**, lasting 50–75 years, while the functions within change many times over. The ability of the shell to allow for change is reflected in the depth of space, location of cores, floor-to-floor height to allow capacity for services, and the floorplate configuration.
- **Building services** – the heating, ventilation, and cabling infrastructure of a building, **12.11**, which have a life span of 15 years or less before the technology becomes obsolescent.
- **Scenery** – the fitting-out components of a building, such as ceilings, lighting, finishes, **12.12**, which adapt a building to a specific organisation's requirements. The life span of a fit-out is between 5 and 7 years.
- **Setting** – the day-to-day re-arrangement of the furniture and equipment, **12.13**, to meet changing needs.

4.02

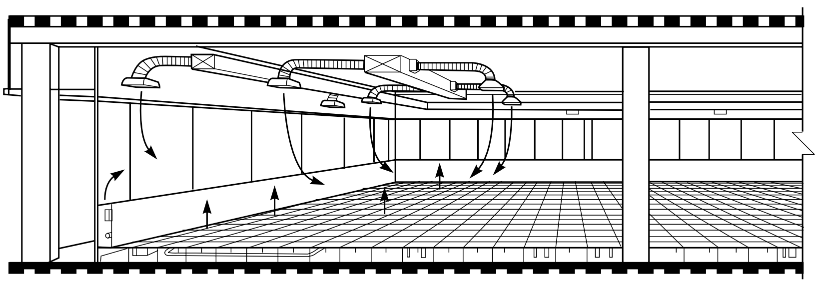
The traditional role of the office building has been to accommodate people and their (largely paper) files. It has also provided a meeting place for customers, suppliers and consultants, as well as for the organisation's own staff. To this role, developments in technology have added the need to accommodate a wide variety of new equipment.

4.03

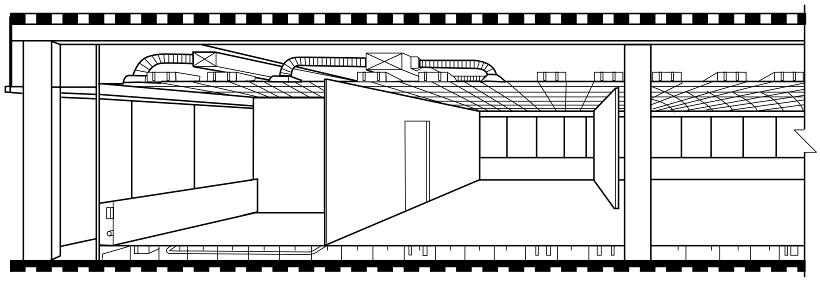
Information technology is changing the role of the office building. Computers make it possible for an increasing proportion of staff to work away from the office, which becomes a communications centre for the organisation. This has implications for the location and aesthetics of the building; and other implications, too. For instance, there is likely to be more travel outside rush hours. Office buildings should provide more meeting rooms, and a less



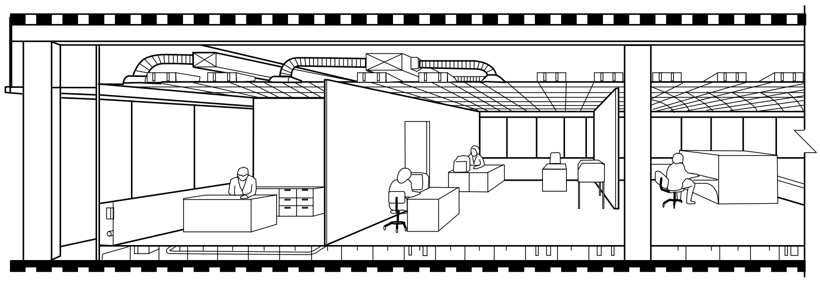
12.10 *The building shell, expected life 60 years*



12.11 *Building services, expected life 15 years*



12.12 *Scenery, replaced after 7 years*



12.13 *Setting, changing from day to day*

ordinary desk space. Some of the office space will be allocated to staff on a temporary rather than a permanent basis.

4.04
Many organisations, particularly in the services sector, already find that up to 40 per cent of their staff are away from the building at any one time, **12.14**. It is not therefore appropriate to plan for 100 per cent occupancy by all employees. This leads to the concept of 'free addressing': an employee does not have a personally assigned desk, but uses any convenient free desk when he or she is in the office, and with mobile phones or new PABX technology they keep their own extension numbers.

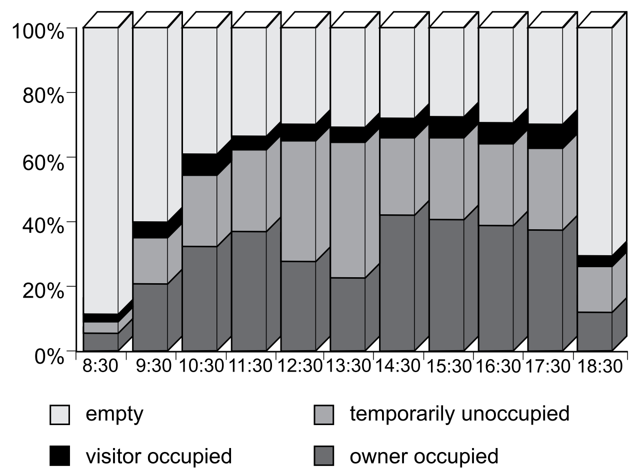
5 THE OFFICE SHELL

5.01
Research into the requirements of building owners and facilities managers provides useful feedback into specification requirements which are high priority. These are:

- The ability to absorb change and minimise operating costs
- The freedom to address users' expectations for:
  - Opening windows
  - Environmentally friendly working spaces
- Local environmental control
- Ease of maintenance
- Opportunity to participate fully in design decisions.

5.02
The dimensions provided in this section are guidelines based on European case studies and good practice. In some circumstances, such as inner-city sites, a different approach may be necessary to stay within planning restrictions or to ensure financial viability.

5.03 Floor depth
This determines the quality and types of space available on each level. Aspect, natural ventilation and lighting, zoning of space, and support space should all be considered. Building depths are generally described as being predominantly 'glass to core' or 'glass to glass'.



12.14 *Time utilisation of traditional desks*

- Glass-to-core depths of 9–12 m allow room for cellular office space or open plan plus storage.
- Glass-to-glass depths of 13.5–18 m allow two or three zones of office and support space.

5.04 Storey height (floor-to-floor height)
Related to floor depth and floor plate size, this has a major effect on air conditioning, cable distribution, ability to use natural ventilation and light, and on visual comfort.

- Floor-to-floor heights of 4–4.5 m provide maximum flexibility and good visual comfort.

5.05
Floor depth and storey height are interrelated and assuming glass-to-glass depths of 13.5–18 m should be thought of together. For example, narrower buildings do not require such generous storey heights because of the different servicing strategies that they use.

5.06 Floor size and configuration
These affect internal communications and circulation routes around the building. Small floors are inefficient in terms of the

ratio between core space and usable floor area. Large departments have to be split over a number of floors, which is also inefficient. Very large floors, on the other hand, produce circulation routes with long distances between departments.

- Contiguous floor sizes between 500 m^2 and 2500 m^2 provide the most usable spaces. Landlord efficiency, expressed by the ratio of Net Internal Area to Gross Internal Area, should be 84–87 per cent if the building is mid- to high-rise, or 90 per cent + if low-rise. Tenant efficiency, expressed by the ratio of usable area to Net Internal Area, should be 85 per cent or above.

5.07 Floor loading

This determines the amount of equipment and storage that can be placed in the work area, and the overall stability of the structure. The tendency in the UK and certain other parts of Europe is to overspecify floor loading, which can add significantly to the construction costs of the building.

- A floor loading of 4 kN/m^2 is sufficient for general loading. If necessary, specific areas can be designed for higher loading to support heavy items.

5.08 Planning and partition grids

These determine how the organisation uses its space. The size of the planning grid is less important in a completely open-plan office. If part of the space is enclosed, however, the planning grid will determine the size of the office modules and the overall efficiency in the use of space.

- A 1.35 m grid allows 2.7 m wide offices; a 1.5 m grid will provide 3 m wide offices, and relates better to building components in 600 mm modules.

5.09 Building skin

The role is shifting from being a barrier to the environment to being an integral part of the servicing strategy. Natural ventilation is becoming increasingly important in Europe. See Section 6.

5.10 Communications infrastructure

Local- and wide-area communications are important, and the base building shell should be designed to accommodate them. Of particular significance are the entry points for external communications services including satellite services, and also the size and positioning of vertical risers.

- Risers for voice, data and other services, should not take up less than 2 per cent of Gross Floor Area (GFA), and there should be the capacity to knock through another 2 per cent easily if the need arises. The cores containing the risers should be widely distributed to avoid cable bottlenecks. A communications room measuring 2 × 1 m should serve each 500 m^2 of GFA.
- There should be space for dual-service entries into the building.
- Provide space on the roof, or nearby, with good sight-lines for satellite or microwave dishes.

5.11 Access for goods and materials

Ease of access for the entry of goods must be at least as good as for people to conflicts and bottlenecks. A clear strategy of entry supported by appropriate signage should keep people and goods separate. Typical materials which are regularly delivered are:

- Stationery and office supplies
- Office equipment, machinery and furniture
- Food and supplies to dining areas, vending machines, etc.
- Post and couriers
- Building maintenance supplies and equipment.

5.12

A summary of considerations in the design of shells is given in Table II.

Table II Summary of building shell considerations

Depth of building	• Flexibility of layout options • Amount of cellularisation • Need for mechanical ventilation • Spatial efficiency
Location of cores	• Ease of sub-letting • Security • Spatial efficiency
Floor-to-floor heights	• Method of cable distribution • Type of servicing
Floor size and shape	• Spatial efficiency • Planning flexibility • Size of working groups
Perimeter detail and planning grid	• Flexibility of sub-division • Efficient use of space • Solar gain/heat loss/condensation
Construction	• Base of adaptation • Space for services • Image

6 BUILDING SERVICES

6.01 Natural ventilation or air conditioning?

It is usually a straight choice between natural ventilation and full air conditioning for both speculative and purpose-built offices. In the UK many organisations choose the latter, although they get twice the building services energy costs, and dearer maintenance and management. Not all these are directly related to the air conditioning system, but to the characteristics of the type of buildings which are air conditioned. Apart from improved comfort (not always realised), reasons for choosing air conditioning include:

- Prestige
- Standard requirements, particularly for many multinationals
- Deeper plans, partly for alleged organisational needs and partly to maximise usable area
- Flexibility to accommodate changing requirements, seldom achieved except at a high cost
- Higher rents giving a better rate of return for landlords
- Poor external environment, particularly traffic noise.

6.02

Recent trends in offices have moved from traditional climate-responsive forms, which were designed as coarse climate modifiers, to climate-rejecting, sealed designs where the internal environment is created largely or entirely artificially. This trend is now being questioned and some pointers to the future are:

- Communications systems question the need for large, deep spaces.
- Occupants are asking for environments to be more natural, with greater outside awareness, more daylight, natural ventilation, and better individual control, but often with mechanical and electrical systems available on demand for when the natural ones cannot cope. In essence, this includes opening windows and solar control linked to a computerised building management system. This system monitors the opening of windows so that heating, ventilating and air-conditioning systems are reconfigured accordingly.
- In difficult conditions it may not be possible to have opening windows, but some form of solar protection should be incorporated to minimise the cooling load.
- New materials, systems and design techniques permit closer integration of natural and mechanical systems with intelligent user-responsive controls, allowing buildings which are not fully air conditioned to provide a higher level of environmental control than hitherto.

- Concern for the global environment implies greater energy efficiency; ways of doing this are to use natural ventilation, light and solar heat where possible in place of mechanical and electrical systems.
- The energy consumption by desktop IT equipment will soon fall, reducing cooling loads in the general office though not necessarily in equipment rooms.

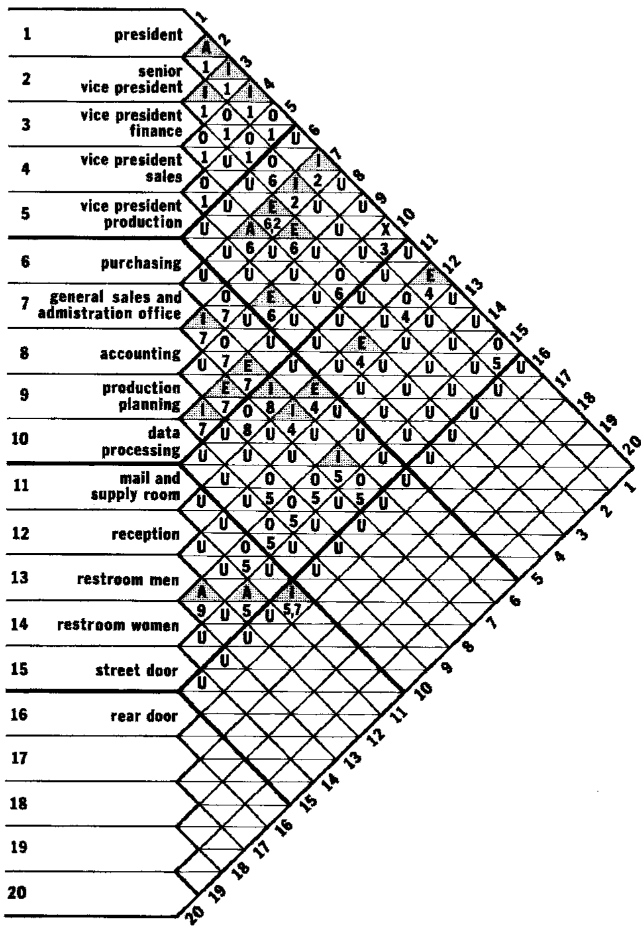
7 SCENERY AND SETTING OPTIONS

7.01

The arrangement used by an organisation depends on who needs to be close to whom, and what facilities are better at a distance from, for example, the directors' suite. **12.15** shows a relationship chart that is used to design the allocation of space.

7.02

The scenery and setting of the workplace need to be highly adaptive, **12.16** to **12.22**. They are also the least constrained area of procurement, and one with the fastest turnover. Furniture is a highly accessible tool which can add value to performance, of doing the most with the least.



reason

code	reason
1	personal contacts
2	use of steno pool
3	noise
4	number of visitors
5	convenience
6	supervisory control
7	movement of paper
8	use of supplies
9	share same utilities

(reasons which govern closeness value)

importance

value	closeness
A	absolutely necessary
E	especially important
I	important
O	average satisfies
U	unimportant
X	undesirable

(closeness rating)

12.15 *Relationship chart for a small company*

7.03 Key features

- Less provision of workstations for full-time individuals
- Furniture and settings for groups, project teams, and space shared over time
- Furniture to support varied and intensive IT use
- Ability to support different users over time.

7.04

Layouts must balance the desire for cellularisation (common in Germany and Scandinavian offices) against the need to keep costs down and to add value with strongly interactive work patterns in open-plan settings. Open areas should be designed and managed to allow quiet and reflective work, and the flexible use of space at different times. Using IT to allow mobile working within the office suggests entirely new ways of planning space.

Managing the balance between:

Maximising communication and	Need for quiet and reflection
Need for group/team and /project work	Confidentiality and individual work
Provision of open areas and for group work	Access to daylight, aspect, ventilation

7.05

12.23 to **12.38** give dimensions relevant to clerical-type workspaces. Standard dimensions for computer workspaces can be found in Chapter 2. Drawing offices nowadays are nearly all run with computer aided design (CAD) workstations, but where drawing boards are still used **12.39** to **12.42** indicate the required dimensions.

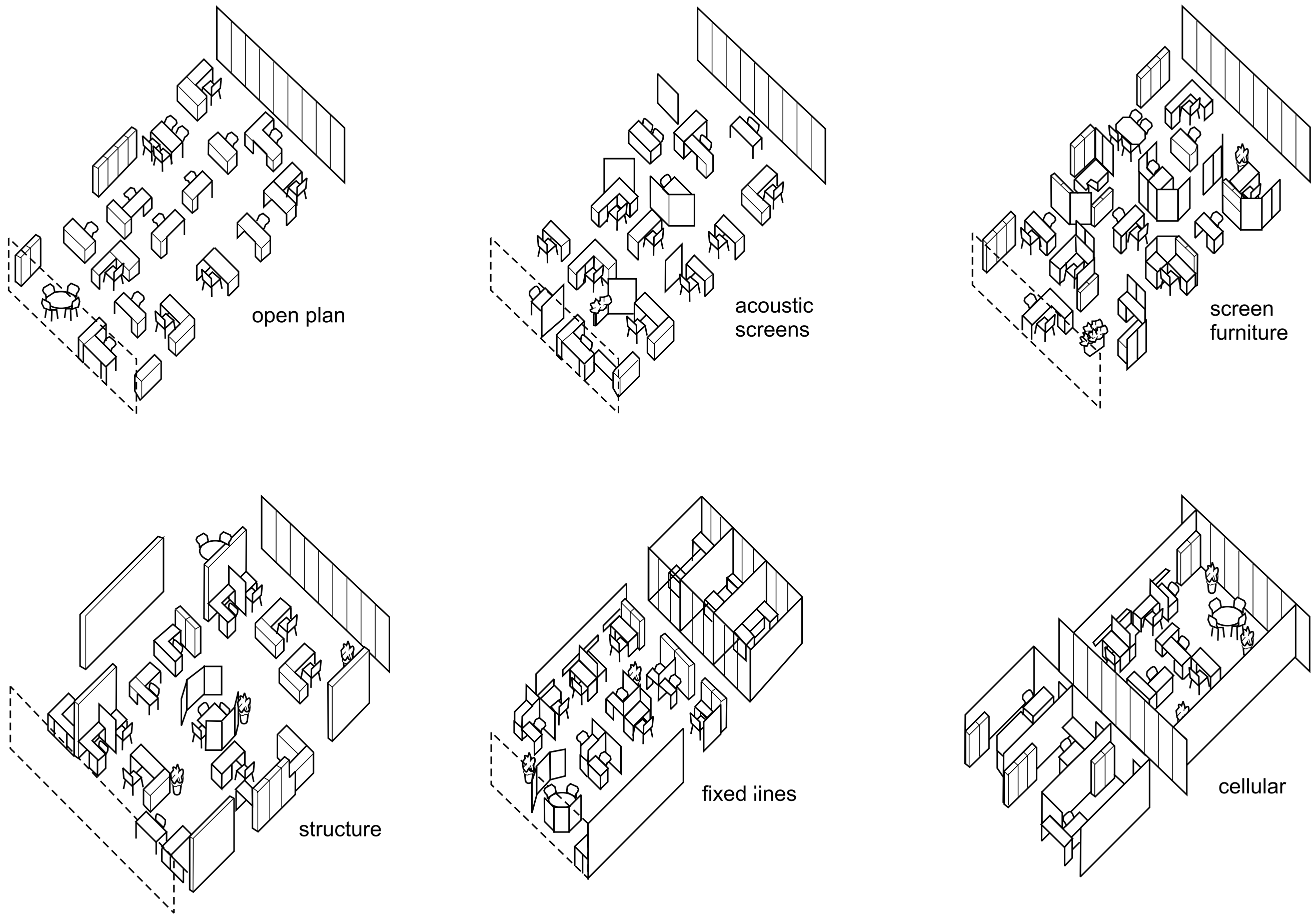
7.06 Meeting rooms and spaces

These are key areas in any organisation. **12.43** to **12.45** cover a number of configurations. Some provision may be needed for televisual connection to remote sites.

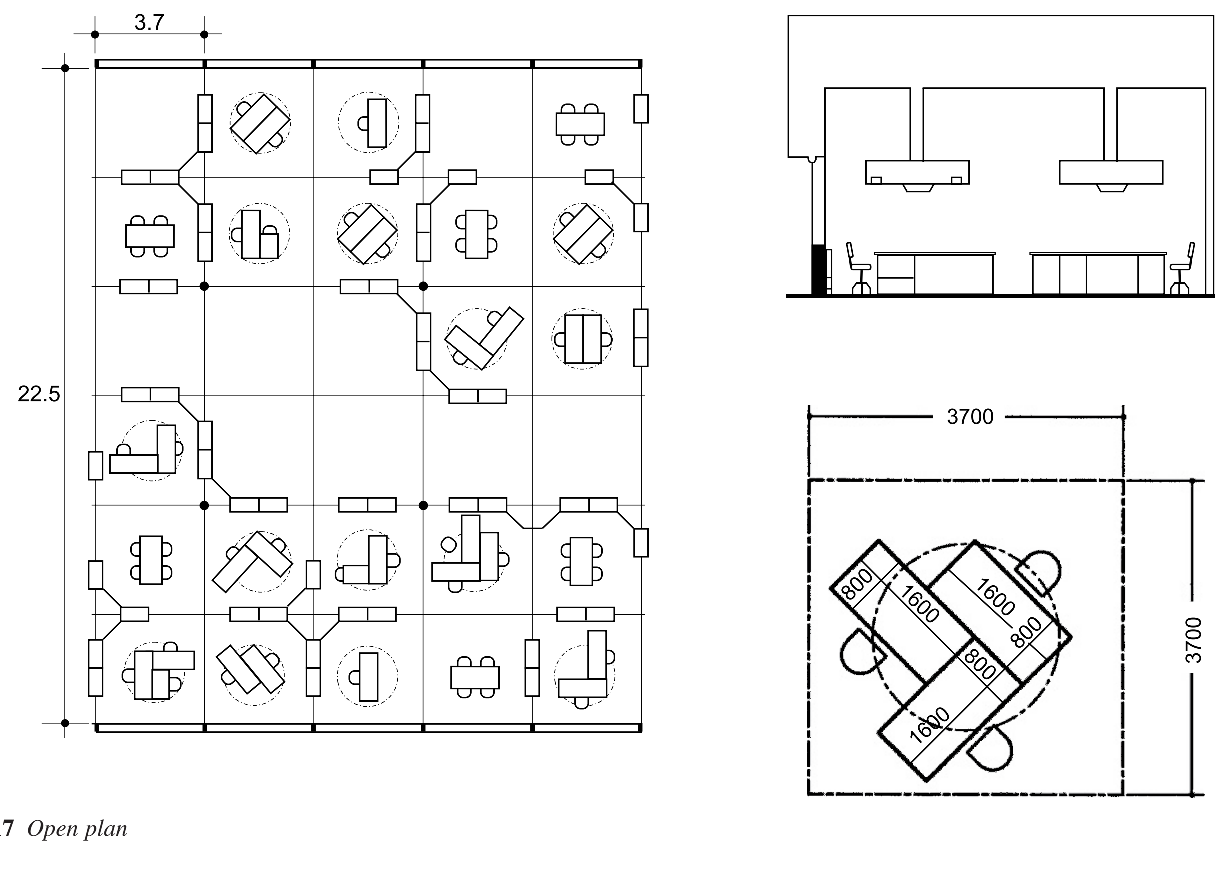
7.07 Servicing strategy

Power and communication services can be taken to each workstation and meeting place in one of three ways:

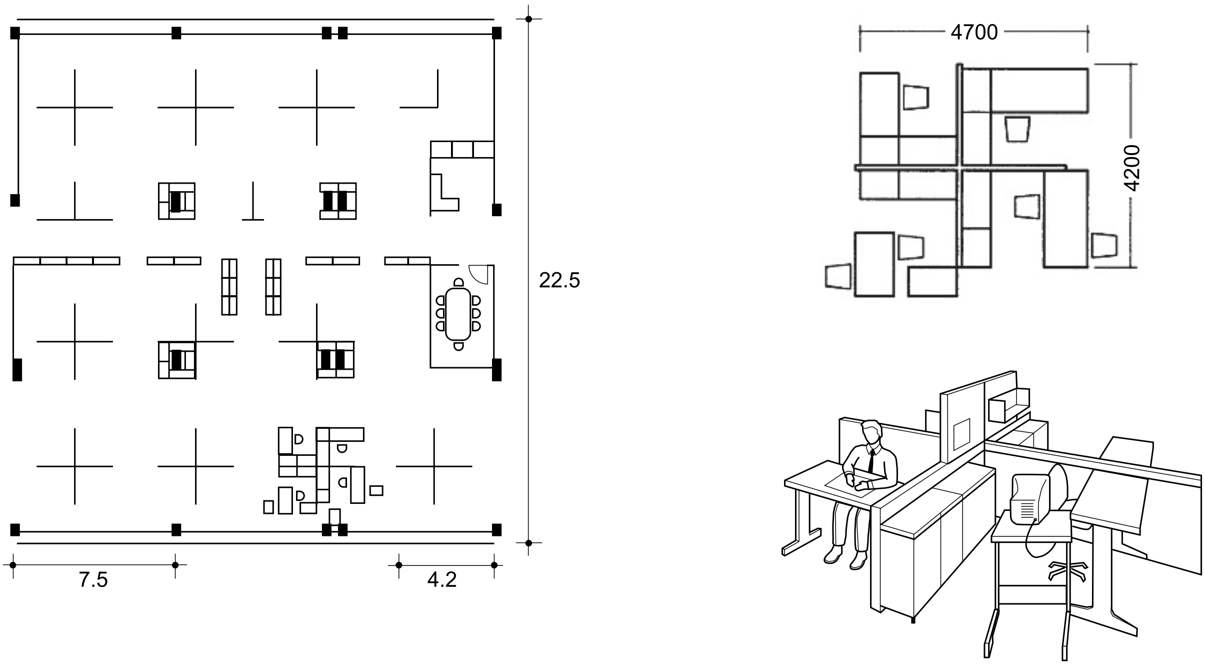
- *In raised floors*, **12.46**
  This is a popular arrangement for developers, which is surprising as it is the most expensive method. Unless an unacceptably low ceiling is provided, it means that the floor-to-floor height is increased by the depth of the raised floor. Power and telecommunication outlets are in sunken boxes accessed through flaps with slots for the flexes. These boxes have a capacity limited by their size, and usually only have room for three power sockets and a double telephone socket. It is not that easy or cheap to provide more boxes, or to move the ones that are there, so that furniture and screen arrangements tend to be fixed in relation to them. Sometimes boxes find themselves within major traffic routes, where they cause a hazard.
- *In suspended ceilings*, **12.47**
  Usually suspended ceilings are only half-full of air conditioning or ventilation ductwork, so the increase in depth to accommodate cabling is minimal. Power and telecommunication outlets can be accommodated in 'service poles'. These have room for up to twenty miscellaneous outlets. They can be positioned virtually anywhere, and easily moved, as they are kept in place by simply being braced between the floor and the concrete soffit of the floor above. The disadvantage is that a multitude of service poles, apparently randomly placed, can appear unsightly.



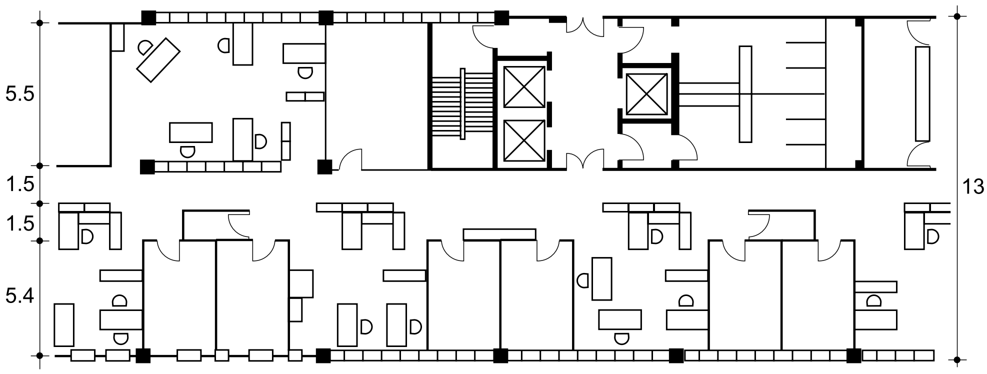
12.16 *Comparison of layout types. Layouts vary depending on: degree of enclosure, density of people, distribution of space*



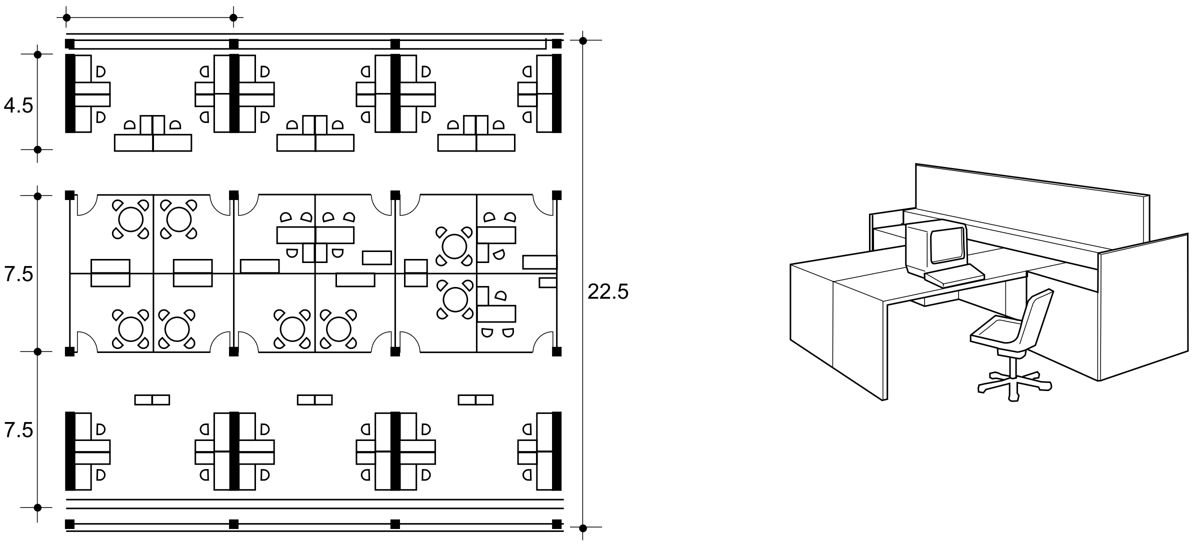
12.17 *Open plan*



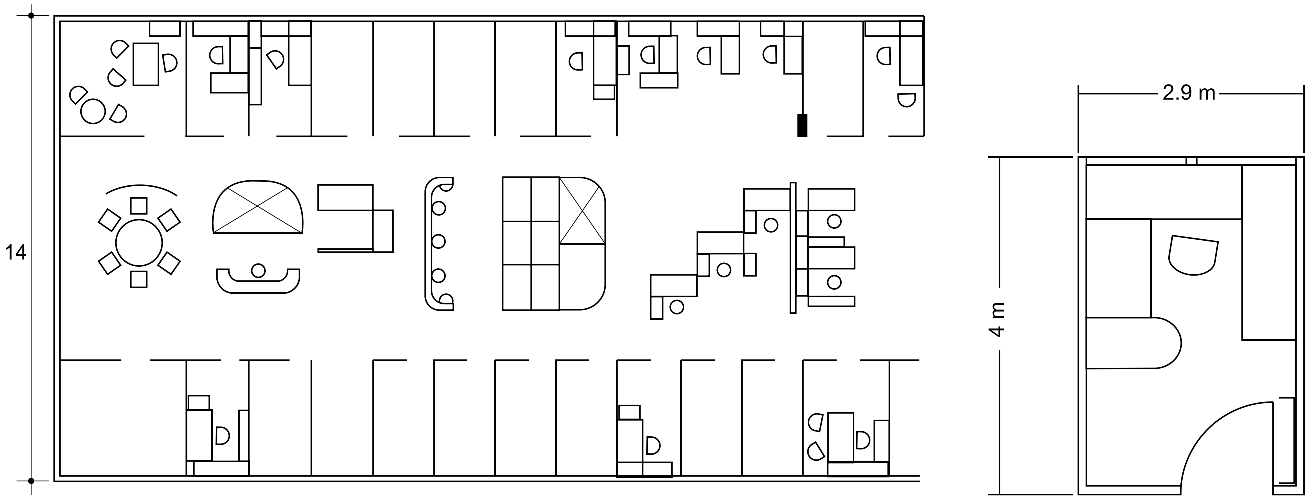
12.18 *Structured open plan*



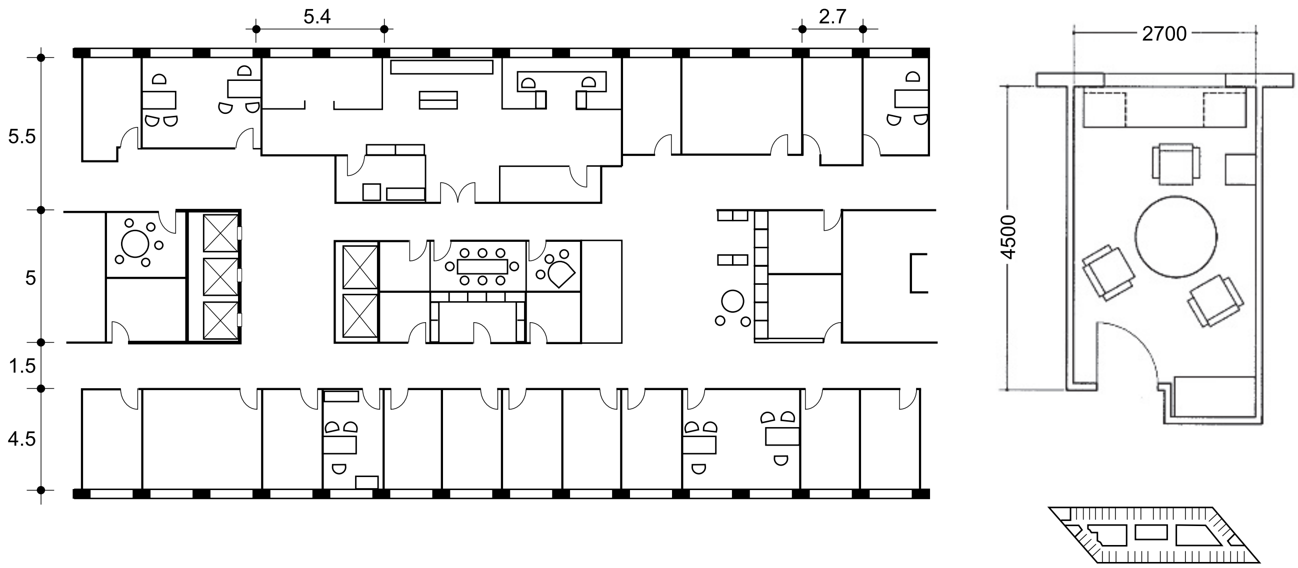
12.19 *Group space*



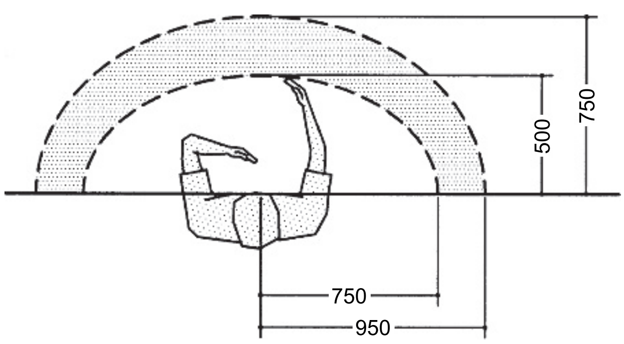
12.20 *Self-regulatory – mixed*



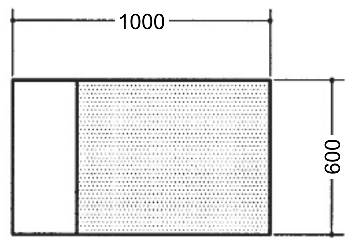
12.21 *Combi-office*



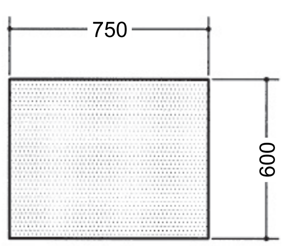
12.22 *Cellular*



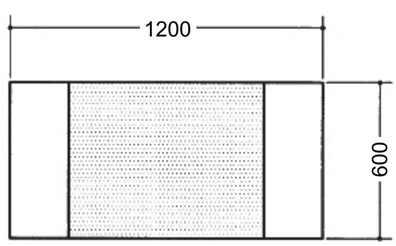
12.23 *Average reach of a person sitting at a desk. To reach outer area user has to bend, but not stand up*



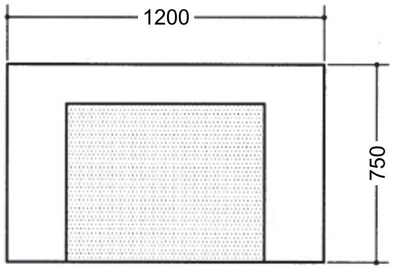
12.25 *With space for paper on one side*



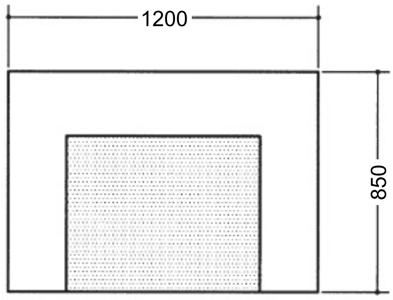
12.24 *Basic space for writing and typing*



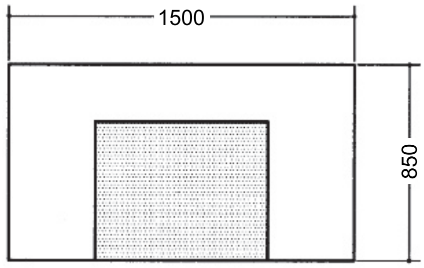
12.26 *With space for paper on both sides*



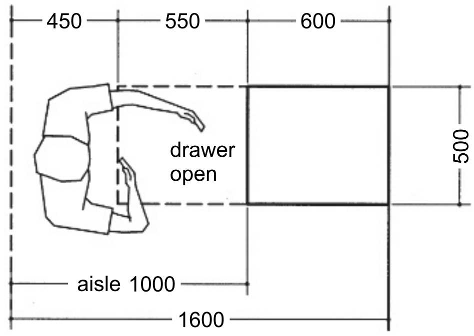
12.27 *Paper plus space for pens and telephones*



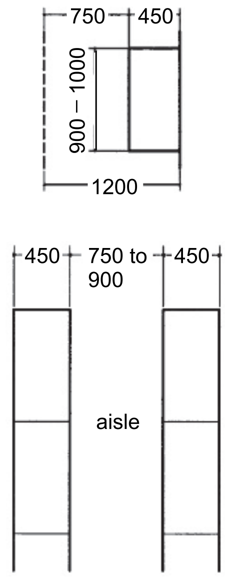
12.28 *Generous amount of space for paper*



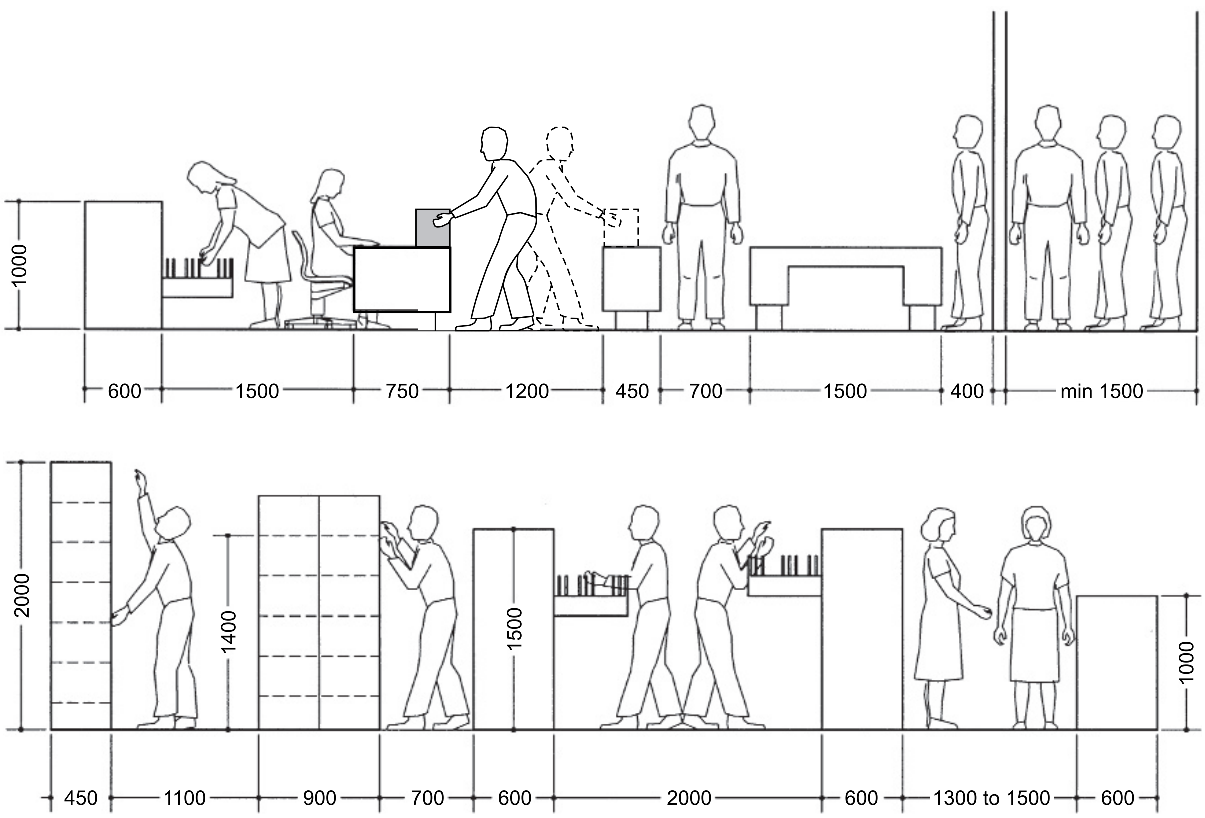
12.29 *Space for papers plus area for references*



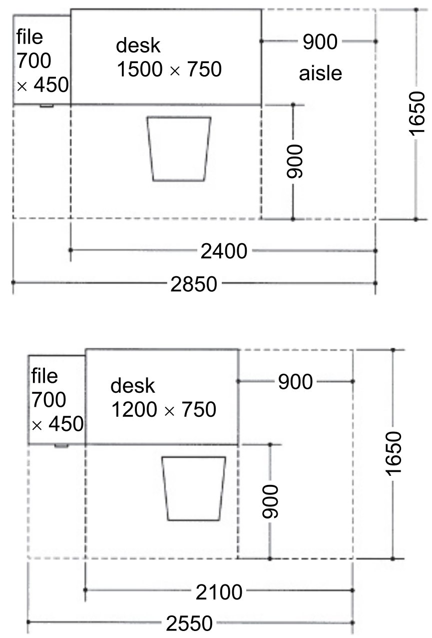
12.30 *Space requirements of drawer filing cabinet*



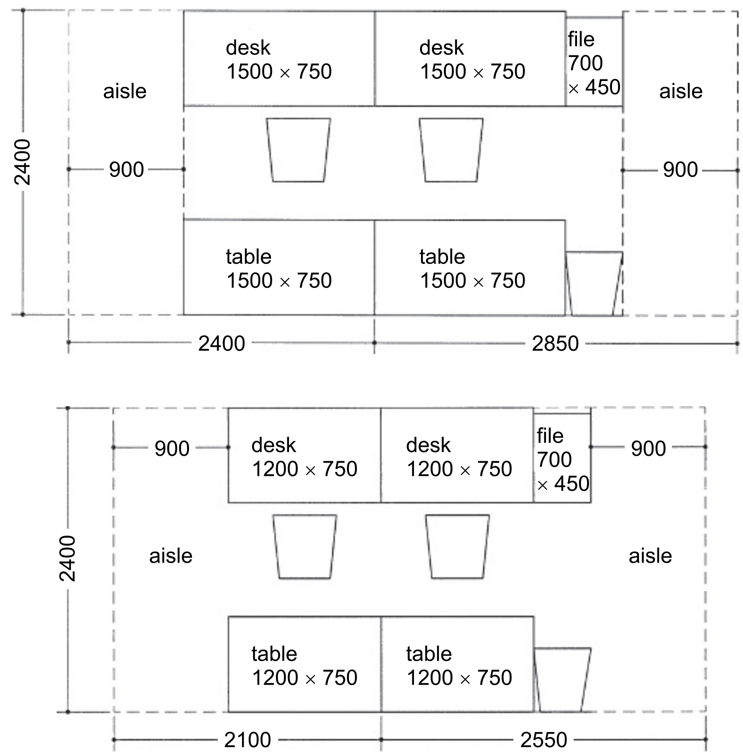
12.31 *Space requirements of lateral filing units*



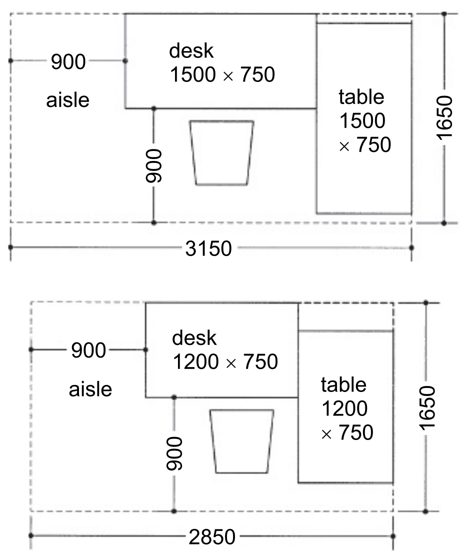
12.32 *Space and circulation requirements of filing and other office equipment*



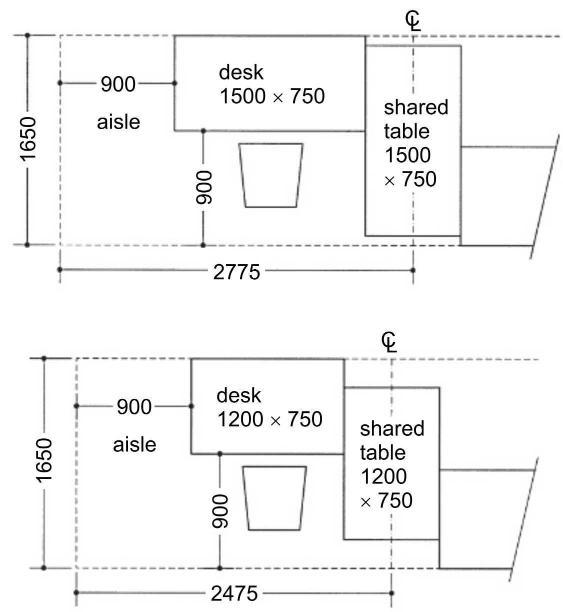
12.33 *Desk and file spacing and layout*



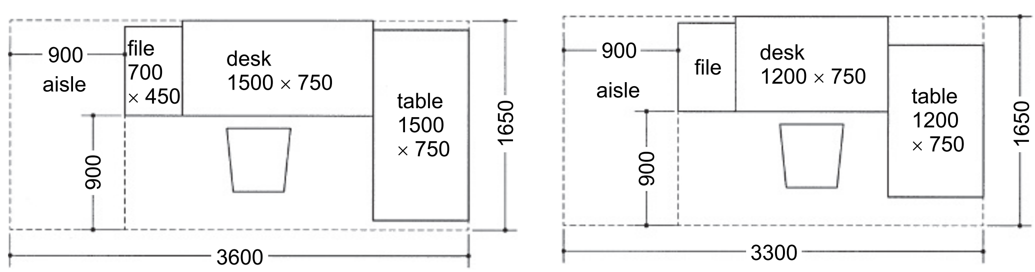
12.34 *Desk with tables, file and chair, spacing and layout*



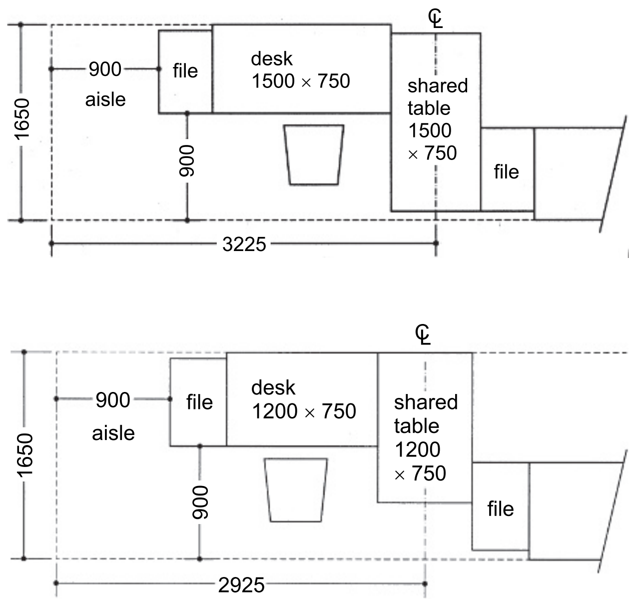
12.35 *Desk with adjacent table, spacing and layout*



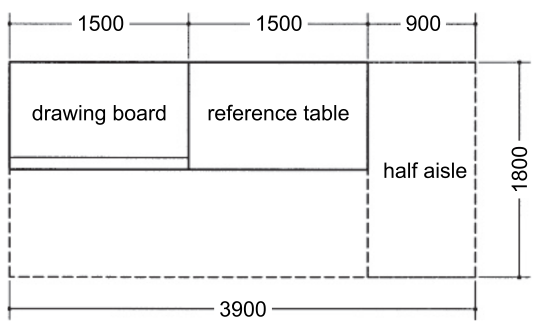
12.36 *Desk with shared table, spacing and layout*



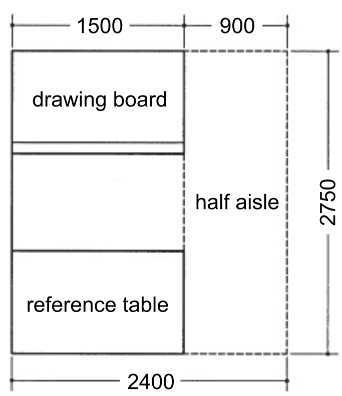
12.37 *Desk, table and file, spacing and layout*



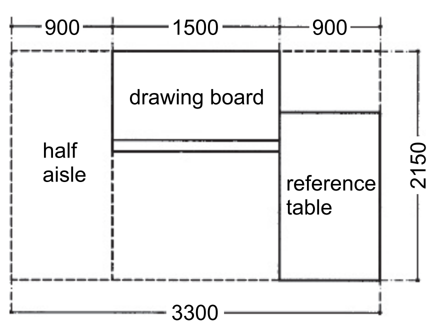
12.38 *Desk, shared table and file, spacing and layout*



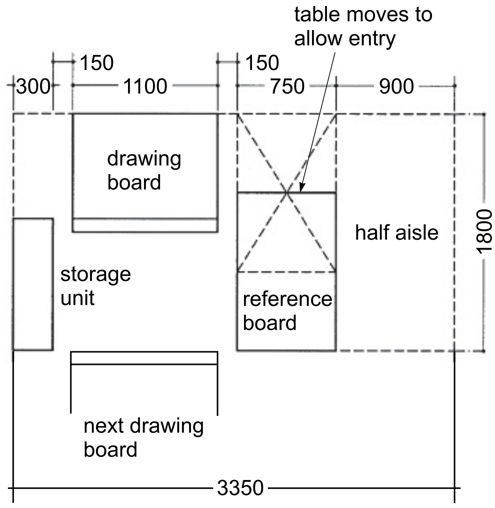
12.39 *Drawing board with front reference: area 7.0 m²*



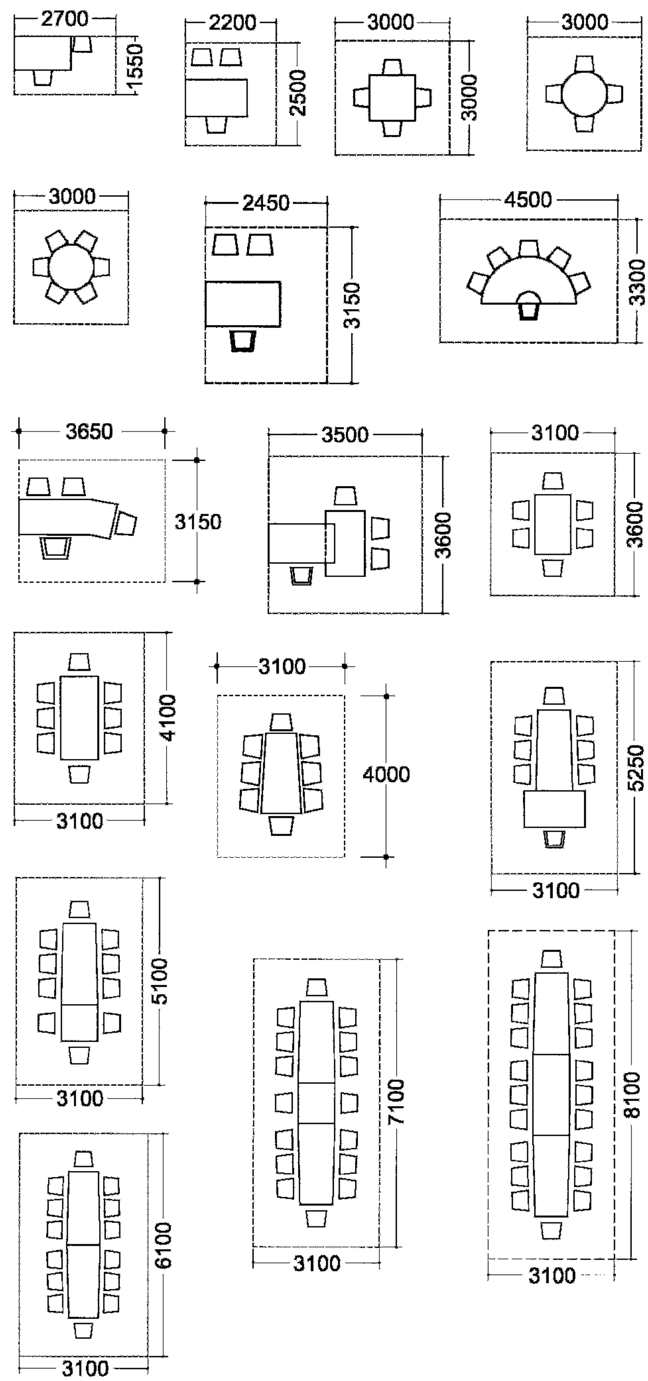
12.40 *Drawing board with back reference: area 6.6 m²*



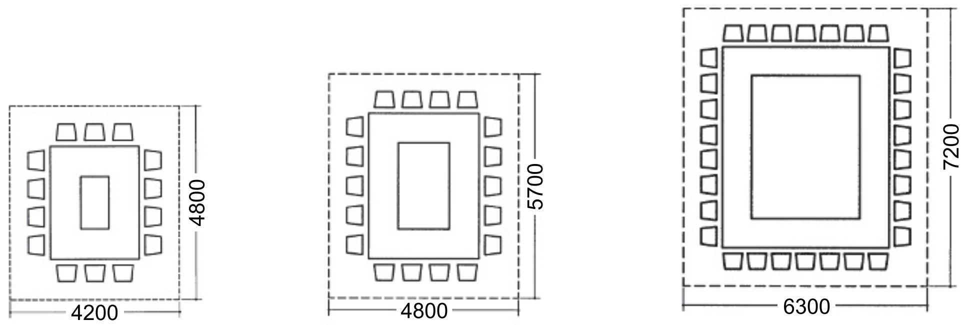
12.41 *Drawing board with side reference: area 7.1 m²*



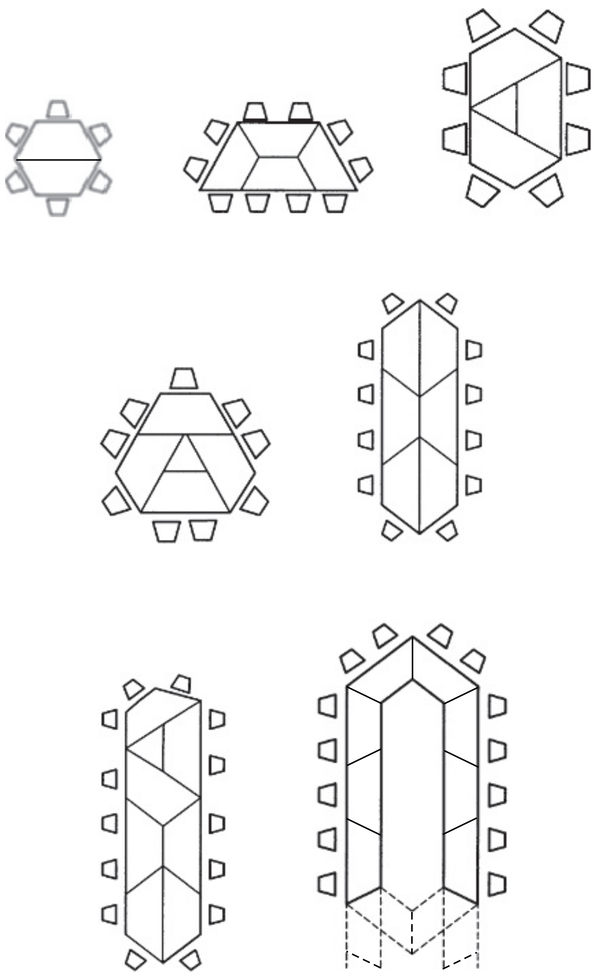
12.42 *Drawing board with mobile reference: area 6.0 m² (Building Design Partnership design)*



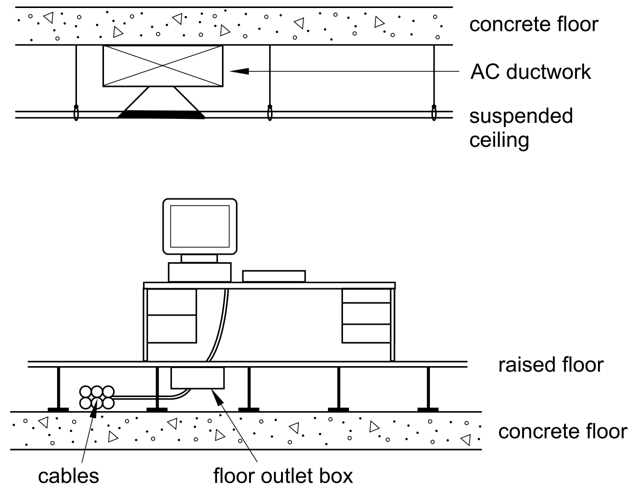
12.43 *Space requirements for informal meetings*



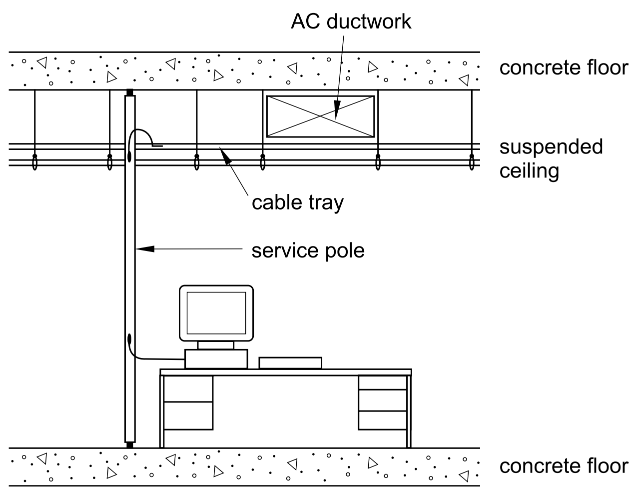
12.44 *Space requirements for formal meetings*



12.45 *Modular furniture designed to allow for alternative configurations*



12.46 *Power and communication servicing through raised floor*



12.47 *Power and communication servicing through suspended ceiling*

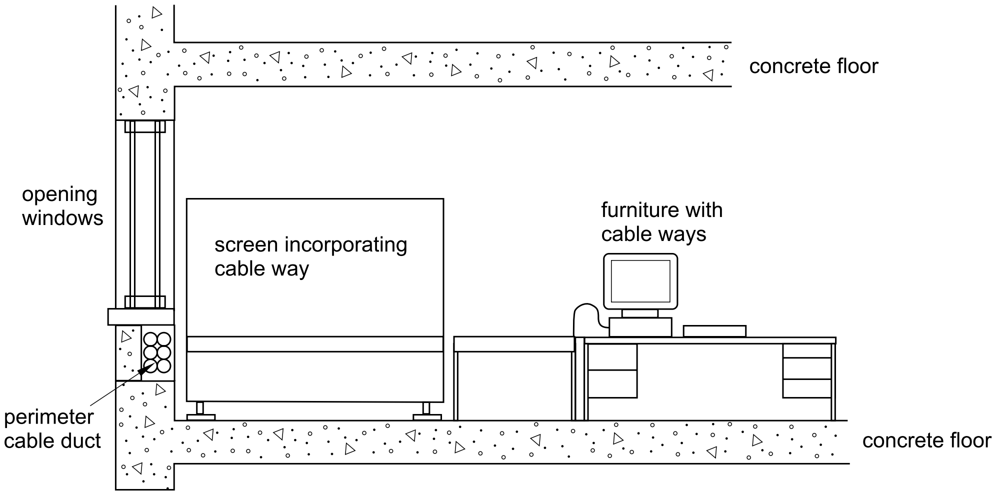
- *In perimeter ducting connected to cable management systems within furniture and screens*, **12.48**
  This is a system particularly suitable for naturally ventilated offices without suspended ceilings. It does make moving the furniture and screens difficult, and can inhibit easy movement between workspaces.

Two other methods have been used in the past, but are no longer recommended. Ducts in the thickness of the floor screed require service outlets above floor level; and these can only be adjacent to the duct positions. These totally control the placing of furniture and pedestrian routes. An even worse system is to have the cables in the suspended ceiling below the floor in question. This means that when changes have to be made, work is done on a different floor which may be occupied by a totally different organisation!

8 TRADING FLOORS

8.01
Until about thirty years ago, trading floors such as the Stock Exchange were spaces with crowds of traders wheeling and dealing with each other amid a hubbub of noise and hand-signals. The last of these 'open outcry pits' have passed into history. They have been replaced by floors with large numbers of computer screens, mostly on desks, with the traders operating on these.

8.02
Although some individual traders operate independently, mostly from their front rooms, those in organisations still need to be able



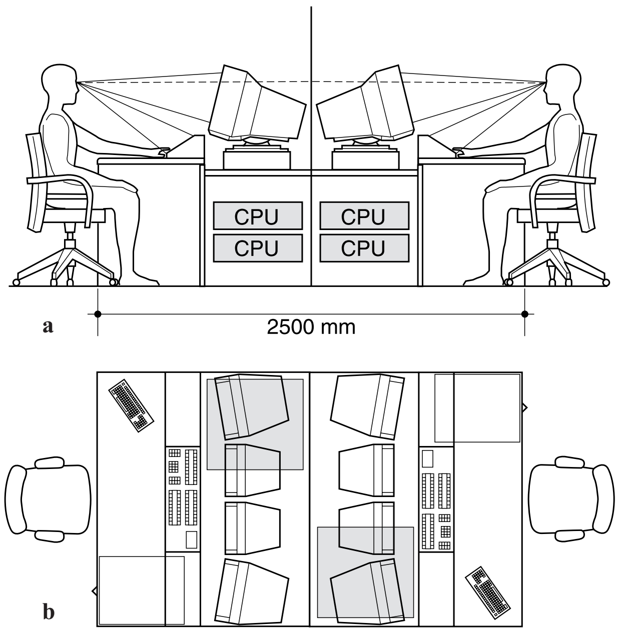
12.48 *Power and communication servicing through perimeter cable ducts, and cable management furniture*

to interact face-to-face with each other. Hence computerised trading floors tend to be large to accommodate substantial numbers of them working in close proximity.

8.03

A radical change has occurred with the advent of the flat panel display (FPD). Previously all computer screens were in monitors incorporating cathode ray tubes (CRTs). These necessarily occupied substantial space on the desktop, and also produced considerable heat. FPDs employ liquid crystal displays (LCDs). These used to be much more expensive than CRTs, but this is no longer the case. They have a number of advantages:

- their reduced depth (while screen size is maintained) means that they occupy considerably less worktop space, allowing the desk size to be reduced with resulting increases in density and flexibility of layout;
- they are lighter and more easily moved for installation and in use, potentially allowing screen positions to vary for different tasks, which is not possible at present. New forms of desk top or above desk top screen mountings can be achieved.
- Desk sizing becomes purely dependent on the requirements for housing CPUs and other under-desk equipment, and ergonomics/user comfort.



12.49 *Back-to-back traders' desks for CRTs:* **a** *section,* **b** *plan*

8.04 Desk analysis

Drawings of desk options are shown in **12.49–12.51**. These illustrate a pair of desks back-to-back for CRT, FPD and a mixture of the two. Recent changes to the recommended standards for desk ergonomics may impact on some of the dimensions quoted here and in *20/20 vision* and *Net effect* (see Bibliography).

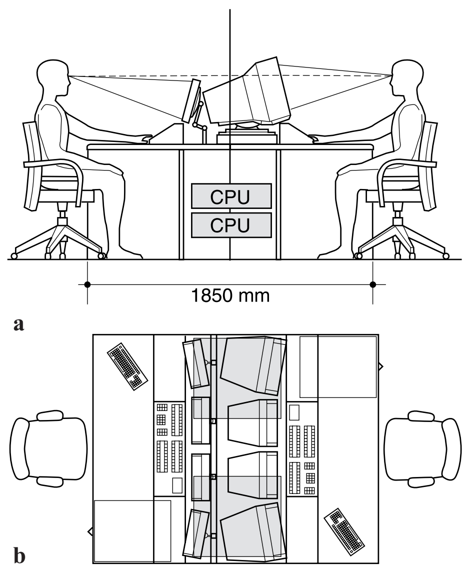
The key issues related to each type of installation are:

CRT desks:

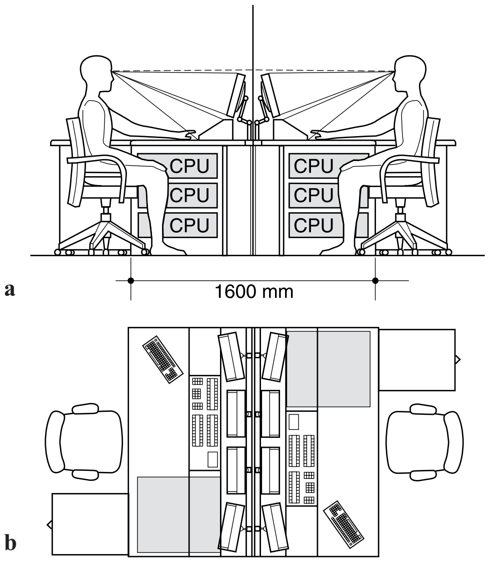
- Face to face contact and trading is difficult because of distance and screen height
- Huge desk footprint if 21 in screens are to be accommodated with full equipment flexibility
- Good accommodation for CPUs and services because of above
- Health and Safety issues related to large, heavy CRT monitors and microwave emissions

FPD desks:

- Good face to face contact and trading
- Desk size is reduced (up to 36% if other technical issues are resolved)
- Trader density increase (up to 24%)
- New flexibility in screen locations and desk layouts is possible



12.50 *Back-to-back traders' desks with mixed CRTs and FPDs:* **a** *section,* **b** *plan*



12.51 *Back-to-back traders' desks for FPDs only:* **a** *section,* **b** *plan*

- Screen tiling options are improved
- Health and Safety concerns of CRTs are eliminated
- New approach may be required to CPU housing or provision (critical issue)
- Services co-ordination becomes more critical with smaller desk footprint
- Simplified desking is possible, moving away from bespoke trading room furniture.

FPD/CRT desks:

- Compromise on improvements of FPD desk (footprint reduction, density improvement and face to face trading)
- CPUs and services can be more easily accommodated
- With desks back-to-back CRTs can be used on one desk and FPDs on the other

8.05 Central processing units (CPUs)

The drawback of a smaller desk footprint is less space in the desk for the equipment, principally the CPUs. Future desk designs will require careful integration of CPUs. **12.49** to **12.51** illustrate how CPUs could be accommodated in equipment towers under the desk.

An alternative approach would be to set up a centralised processing area in an equipment room, although it is recognised that there are advantages and disadvantages with this approach depending on the technology platform.

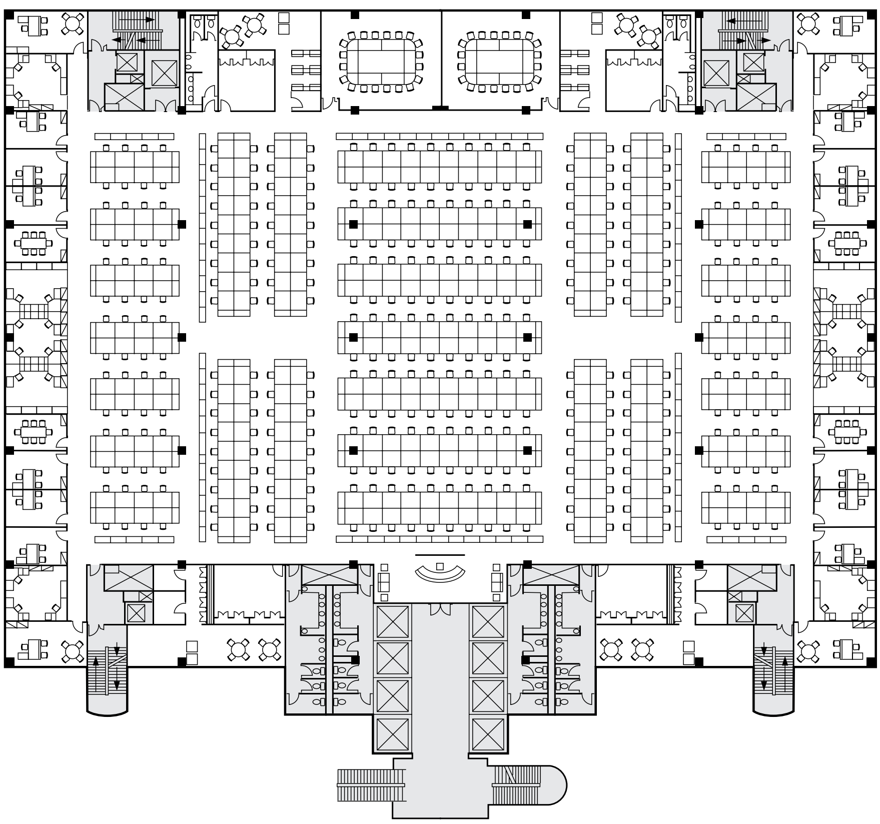
Using network computers (NCs – smaller, cheaper alternatives to the PC, designed to connect to a network or the Internet) instead of PCs would eliminate the requirement for a number of large CPUs to be housed in the desk, consequently reducing the necessary size of the under-desk void. However, it is likely that semi-independent CPUs will still be required for some applications and to reduce unnecessary network traffic.

8.06 Future desking

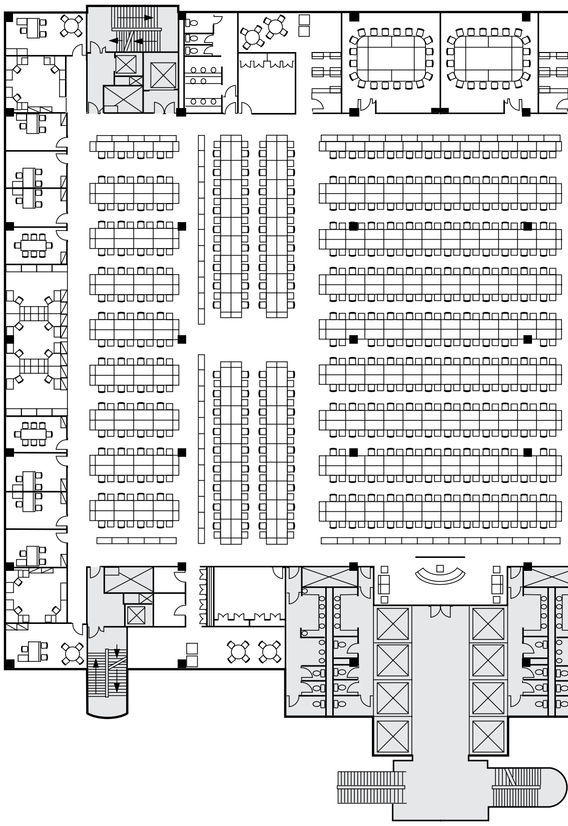
Standard office workstations, which used to be small, simple, low-cost, flexible desks, have become bigger, L-shaped and highly engineered to accommodate increasingly large CRT monitors.

At present trader desk design is complicated as vendors have to accommodate the requirements of current technology. Some are building in collapsible frame devices to 'future proof' for FPDs by allowing conversion to a smaller desk. The highly bespoke and inflexible trader desk will soon be a thing of the past.

It seems likely that many businesses will adopt FPDs (possibly as well as NCs) for general office areas and trading rooms over the next few years. As this happens, we should see a convergence of the trading desk and general workstation into a standard, non-modular, linear bench arrangement. An ideal solution would be to provide mobile docking pedestals and a technology trench (a linear void within the desk zone to accommodate cabling, back boards, connections and NCs) to maximise linear flexibility.



12.52 *Plan of trading floor using CRTs. Desk size 1500 × 1250. Headcount: 384 traders, 16 offices, 29 sec/support: total 429*



12.53 *Plan of trading floor using FPDs. Desk size 1500 × 800. Headcount: 478 traders, 16 offices, 29 sec/support: total 523. A design using mixed CRTs and FPDs would be a compromise between these two*

This set-up will provide a highly flexible office environment, offering variable density desking (individual workspace can be varied to suit functional requirements) to accommodate business churn and change at low cost and high speed.

8.07 Office layout

The use of smaller trading desks allows the trading room architect much more scope to achieve an effective, innovative concept layout in restricted spaces, as well as trader orientated layouts if desired to suit business adjacencies. All this can be achieved along with density increases over CRT desk layouts. **12.52** and **12.53** show desk layouts for use respectively with CRTs and FPDs.

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13 Retail shops and stores

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CI/Sfb(1976): 34
UDC: 725.21 & 725.26

KEY POINTS:

- *Retail trading is affected by marketing, competition, polarization, and store locations*
- *Market research of customers and focus groups is highly developed*
- *New concepts, innovations and efficiencies in operation are continuously being introduced*

Contents

1 INTRODUCTION

1.01

Retail outlets consist of buildings or rooms where goods or services are sold to the public. They include shop and store premises and also concessionary space.

1.02 Scale and polarisation of business

A total of 33.7 per cent of consumers' overall expenditure in Great Britain in 2004 was spent in retail outlets. This proportion has progressively reduced from 37.5 per cent in 1995, showing the benefits of scale and sourcing made possible by polarisation of retail business into large groups serving particular segments of the consumer market. In 2004 the total turnover in predominantly food stores was over £112 billion and in non-food stores £128 billion.

Polarisation of retail business has also had a dramatic impact on shop numbers and the retail landscape. In 2005, 6487 multiple grocers with 10 or more stores commanded over 70 per cent of the total grocery turnover. This compares with 76 440 individual and other small grocery outlets that together achieved less than 30 per cent. A similar concentration of business has occurred in non-food retailing with some 90 000 stores belonging to multiples now dominating this sector. With corporate finance to pay increasing rents and building conversions to represent the brands, the character of High Street shops has lost much of the variety of individual tenancies.

1.03 Changes in space and location

Total shop floor space has grown with the penetration of chain stores into further market catchment areas as well as to extend individual store space for more product lines, customer choice and self-service checkouts. In 1992, following extensive development of shopping centres, retail warehouse parks and standalone superstores in the 1980s total shop floor space had risen to 93 million m^2. By 2004 this total is estimated to be over 100 million m^2, much of the increase arising from large-scale regional shopping centres.

2 TERMINOLOGY

2.01 Shopping activities

Shopping activities vary with different needs and may be described as essential, convenience, comparison, purposive (specific), leisure or remote (mail order, teleshopping, internet retailers).

2.02 Selling methods

Personal service: individual service, usually over counters or desks by staff in attendance. (Examples: high-value goods, technical equipment, specialist boutiques and salons, delicatessen shops, financial and travel agency services.)

Self-selection: by customers who handle, compare and select goods prior to taking them to cash points for payment and wrapping. (Examples: department stores, variety stores.)

Self-service: of prepackaged groceries and durables collected in baskets or trolleys and taken to checkout points for cashing and packing. (Examples: supermarkets, superstores, discount stores.)

Assisted service: self-selection by customers combined with despatch of similar goods from stockroom to collection point or home delivery. (Examples: hypermarket, warehouse stores, furniture stores.)

2.03 Stock

Forward or displayed stock: held in sales area.

Support or reserve stock: in stockrooms ready for replenishing sales. The method of replacing displayed stock is a critical consideration in planning and organisation.

Amounts of stock in reserve are related to the stock-turn (average time held prior to sale), weekly turnover, delivery frequency and stock control. Electronic point of sale (EPOS) monitoring is used to predict sales patterns, reduce reserve stock and coordinate distribution and manufacture.

2.04 Areas

Gross leasable area (GLA): total enclosed floor area occupied by a retailer. This is the total rented space and includes stockrooms, staff facilities, staircases, preparation and support areas. It is usually measured to outside of external walls and centre line between premises.

Net sales area (NSA): internal floor space of a retail unit used for selling and displaying goods and services. It includes areas accessible to the public, e.g. counter space, checkout space and window and display space. Net areas are used to calculate the density of trading turnover (sales per m^2 or ft^2).

The ratio of sales to ancillary space ranges from about 45:55 in small shops and departmental stores to 60:40 in supermarkets.

2.05 Rents

Rents are based on gross floor area measured in ft^2 or m^2 ($1\ ft^2 = 0.0929\ m^2$). Three main types of rental agreement are used:

Guaranteed rent: with minimum annual rent guaranteed by the tenant irrespective of sales.

Percentage rent: based on a stated percentage of the gross sales of the tenant.

Turnover lease: the rent being related to the actual gross turnover achieved by the tenant, based on the total trading receipts less stated allowable deductions.

Rents are normally subject to review every four or five years.

Leases usually include the right to assign after an initial period (five years) and may provide a landlord's option to buy back. Premiums may be charged when leases are sold for premises in good trading positions with favourable lease and rent review conditions.

2.06 Retail operations

Independent: Shops and stores operated by individual or sole trader with less than ten branches (usually one or two). May be affiliated to a collective marketing and purchasing association.

Multiple: Mainly joint stock companies, with ten or more branches operated as a chain of shops and stores including large space users. Goods may include own-branded products.

Cooperative societies: Development has polarised into large supermarkets/superstores and small convenience shops serving local communities. Goods may be sourced through the Cooperative Wholesale Society or competitive suppliers.

Concessions: Granted rights to use land or premises to carry on a business – which may involve selling or promotion. The agreement may be based on rent, fees or profit sharing. (Examples are department stores, concourses in shopping centres, and catering operations.)

Franchises: Contractual relationships between two parties for the distribution of goods and services in which the franchisee sells a product designed, supplied and controlled by and with the support of the franchisor. (In the UK franchising has been mainly used in fast-food brands, launderettes, car maintenance, bridal wear and some electrical trading.)

3 MARKETS

3.01

A market is a public area, open or covered, provided with stalls, where traders may sell their wares on recognised market days subject to payment of a statutory charge. This franchise confers sole and exclusive market rights over a distance of 10.73 km.

Markets make up less than one per cent of total retail sales in the UK, but attract potential customers to the town area. The character of markets relies on variety, mix of traders, simplicity and liveliness.

3.02 Open markets

Markets may be set up in streets, squares and open spaces, **13.1**. Stands comprise erected stalls and fitted-out vans and trailers set out in line along kerbs or back to back between aisles. Key considerations are:

- Vehicle parking and loading (near stalls)
- Traffic control
- Garbage storage and collection
- Washing facilities
- Protection of exposed food.

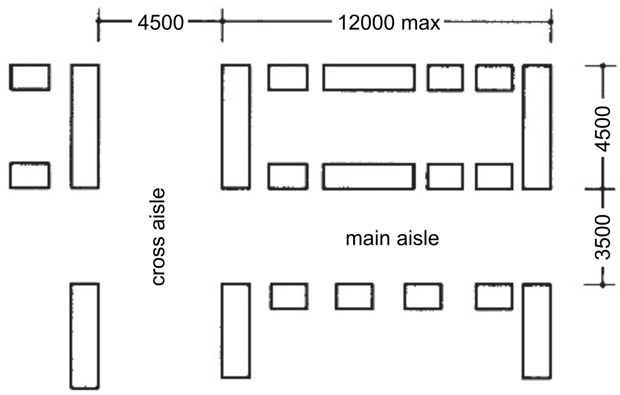
3.03 Covered markets

Permanent market stalls are sited in town centres and fringe areas (associated with auction rooms). New projects include craft markets (permanent or temporary) combined with workshops or forming part of shopping centres. Redevelopment of existing market halls often involves linkages with shopping centres and car parks.

3.04 Planning

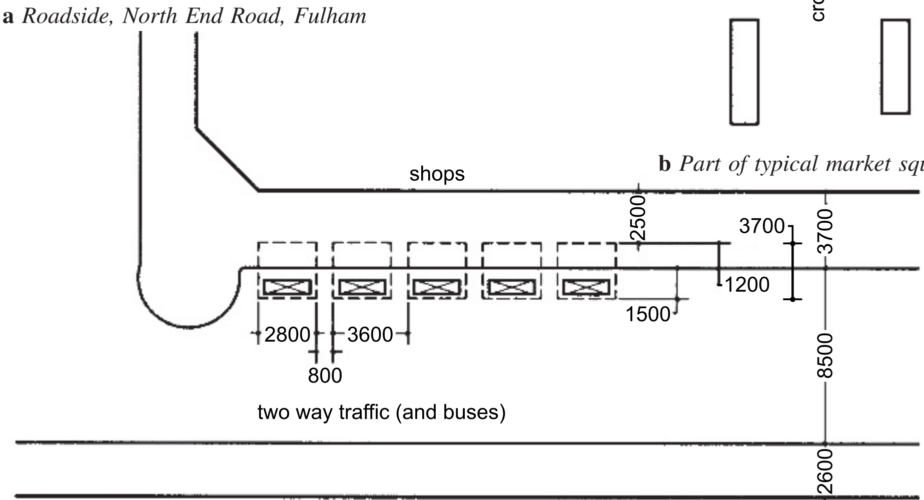
Halls are usually designed to give a large-span open space having natural roof lighting, good ventilation and service connections. One-floor trading is preferred. Any upper floor is usually limited to a perimeter balcony served by escalators, stairs, goods and disabled lifts. Perimeter stalls and other grouped layouts have service corridors. Fish, meat and food stalls are sited in zoned areas with more sophisticated ventilation, drainage and services.

Key considerations: Access and linkage to car parks, shopping areas, goods delivery and parking bays. Mix of traders. Risk of fire (incombustible materials, fire-resistant construction smoke evacuation) and means of escape.



b *Part of typical market square*

a *Roadside, North End Road, Fulham*



13.1 *Markets*

4 SHOPS AND STORES

4.01 Locations

Main locations for retail development in the UK are:

High street: inner cities and towns, including backland development of shopping centres, shopping malls and street frontages

Urban fringes: industrial wasteland, redevelopment areas (superstores, retail parks, discount stores)

Out-of-town: near motorway/main road junctions, easy access to large population catchment (retail complexes, regional centres, discount warehouses)

Neighbourhood: association with estate development, filling stations (convenience shops), nurseries (garden centres), tourist attractions (souvenir shops, cáfes)

Out-of-town retail developments generally allow much lower rents, easier access and parking, economical purpose-built ‘shed’ designs with flexible large-span spaces. Retail parks and complexes also generate mutual benefit from association of stores and services. Planning guidelines in the UK have stiffened resistance to development on greenfield sites with policies directed towards town-centre shopping and sensitive integration of new frontages.

4.02 Range of shops and stores

Retail outlets can be broadly divided into small shops (less than 280 m^2 sales area) and large space users. The latter include supermarkets and stores which may specialise in food or non-food lines or sell a wide variety of products (composite shops, variety shops, departmental stores).

Distinctions between stores tend to become blurred with:

- *Retail polarisation*: trends towards both larger (one-stop shopping) and smaller retailers (speciality and convenience shops, financial, etc. services, franchised units, workshop-craft outlets).
- *Competition*: innovation, market penetration and development of new merchandise and selling methods, creaming of popular lines.
- *Acquisition*: merger of competing outlets, focusing of business and market positioning of company products, rationalisation of lines of goods and resources.
- *Image and service improvement*: extension of added value and high-profit value lines. Improved customer services and design environment.

4.03 Planning guidelines

Structural models	*Width(m)*	*Notes*
Small shops	5.3 to 6.0	Mostly 5.4 m
Large-space users	7.3 to 9.2	Depending on beam depth. Single-storey buildings – larger spans

Clear ceiling	*Height(m)*	*To underside of beams*
Small shops	3.3 to 3.8	Sales area
	3.2 to 3.6	Non-sales area
Large-space users	3.6 minimum	With floor: floor spacing 4 to 5 m

Typical floor loading	*kN/m^2*	
Shop sales area	5	
Shop storage	10	Increase in loading docks

Car parking	*Car spaces per 100 m^2 gross retail area*
Supermarkets, superstores	10–12
Shopping centres	4–5

Goods and service docks	*m*	*Notes*
Typical provision for large-space user		
Two 15 m articulated lorries: width	10.7	Allowing 1.5 m each side
Minimum clearance height	4.7	Approach road – 5.00 m
Design load for service yard	20 kN/m^2	

(See also Chapter 4)

Deliveries may be controlled or random. Provision must be made for manoeuvring space and waiting bays, for separate refuse storage with compaction equipment, refrigerated garbage and collection skips.

Staff facilities (general guide only)

Staff numbers: net sales areas, 1:50 m^2 to 1:80 m^2

Additions to the net sales area

	Net areas	*Gross areas*
Staff facilities	10–15 per cent }	25–30 per cent
Offices	5–8 per cent }	

Staff facilities include: restaurant with kitchen and servery, coffee and recreation rooms, changing areas, toilets, personnel and training and reception/control area.

4.04 Shop fittings

Shop fittings may be individual bespoke designs, fabricated or modular units. While the range and style vary widely, fittings must satisfy functional needs (including ergonomics) and be compatible with the design, versatile, durable, stable and safe in use.

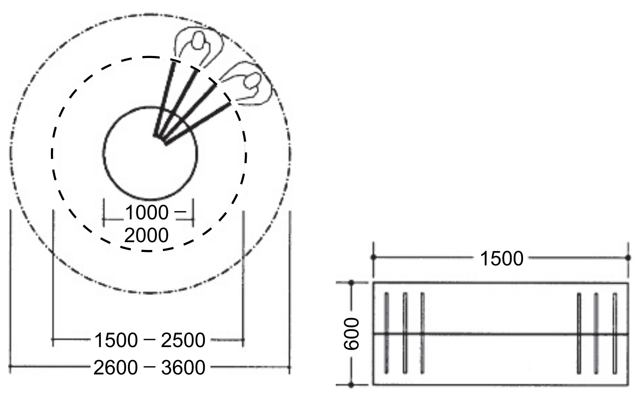
Display units can be broadly divided into wall-anchored fittings and free-standing units, the latter being designed for perimeter or central locations.

13.2 and **13.3** are examples of mobile display units, while **13.4** to **13.6** show units suitable for supermarkets.

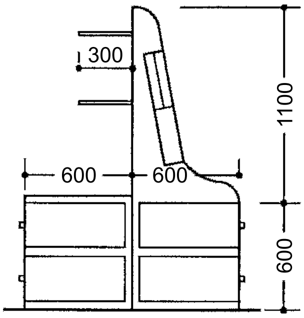
Examples:

- Wall systems (slotted panels, frames, suspensions)
- Fitted furniture (cupboards, wardrobes, trays)
- Free-standing racks and garment rails
- Gondolas and island displays
- Cases (counters, showcases, wall cases)
- Cabinets (front or top access)
- Shelving systems (modular, adjustable)
- Forms, mannequins, displays (counter or free-standing)
- Bins, tables, risers
- Counters (cash and wrap, checkout, service)

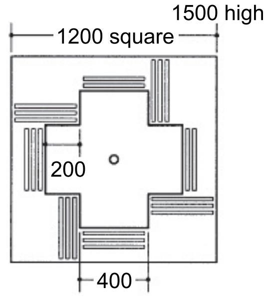
Construction materials include hardwoods, laminates (lipped) acrylics, toughened glass, polycarbonate, UPVC, chrome-plated and stainless steel, anodised aluminum.



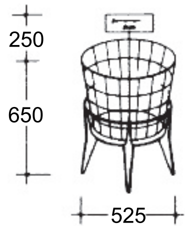
13.2 *Storage and display racks for clothing shops*



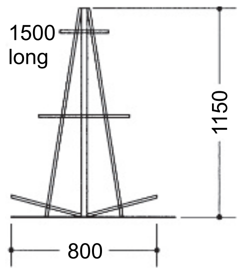
a *Greetings cards*



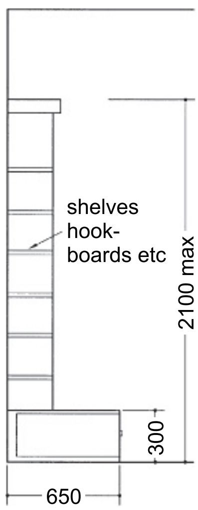
b *Paperback books*



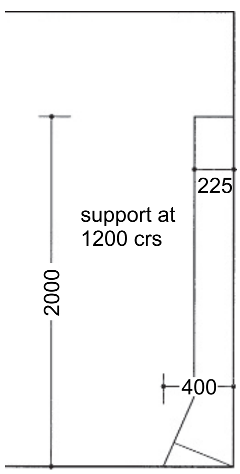
c *Bins, used everywhere*



d *Island display of books*

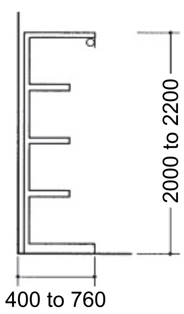


e *Wall units for stationery and books*

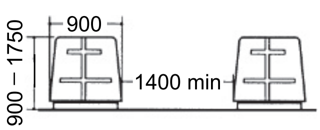


f *Wall units for books*

13.3 *Storage and display fittings for stationery and bookshops*



13.4 *Section through supermarket wall shelving*



13.5 *Section through supermarket shelving*

4.05 Environmental Standards

Lighting	*Standard service illuminances* (lux)	*Notes*
Conventional shops	500	Concentrated over displays
Supermarkets	500	Usually increased to 700–800 lux with three levels of control: 100 per cent – sales, 50 per cent – stacking, 30 per cent – security
Covered shopping centres	100–200	Malls, arcades, precincts
Lifts, main circulation	150	
Staffrooms	150	
External covered ways	30	

Luminaires include low-voltage units (displays), colour-balanced fluorescent (sales areas), metal halide (high intensities).

Temperatures: Design conditions

	Temperature (°C)	*Air infiltration (Changes/ hour)*	*Ventilation allowance ($W/m^{3\circ}C$)*
Small shops	18	1	0.33
Large shops	18	½	0.17
Department stores	18	¼	0.08
Fitting rooms	21	1½	0.50
Store rooms	15	½	0.17

Recommended outdoor supply rates for airconditioning spaces

Recommended	*Minimum*
8 per person	5 per person, 3 per m^2 of floor area

Occupancies in large stores: average: 1 person per 5–6 m^2; peak areas: 1 person per 1.8 m^2

Air conditioning is usually designed for 18–21°C at 50 per cent ± 5 per cent RH (below-risk of static) pressurised to + 5 per cent actual air volumes

Fresh air regulated by CO_2 sensing.

In shed-type buildings design temperatures are 18°C with 10 per cent fresh air. Air cooling used 18–22°C and mechanical cooling above.

Display of food	*Cabinets (°C)*
Fresh products (chilled)	+8
Dairy products, cooked meats	+3
Fresh meats, poultry, fish	0
Frozen foods (subject to EU regulations)	−18

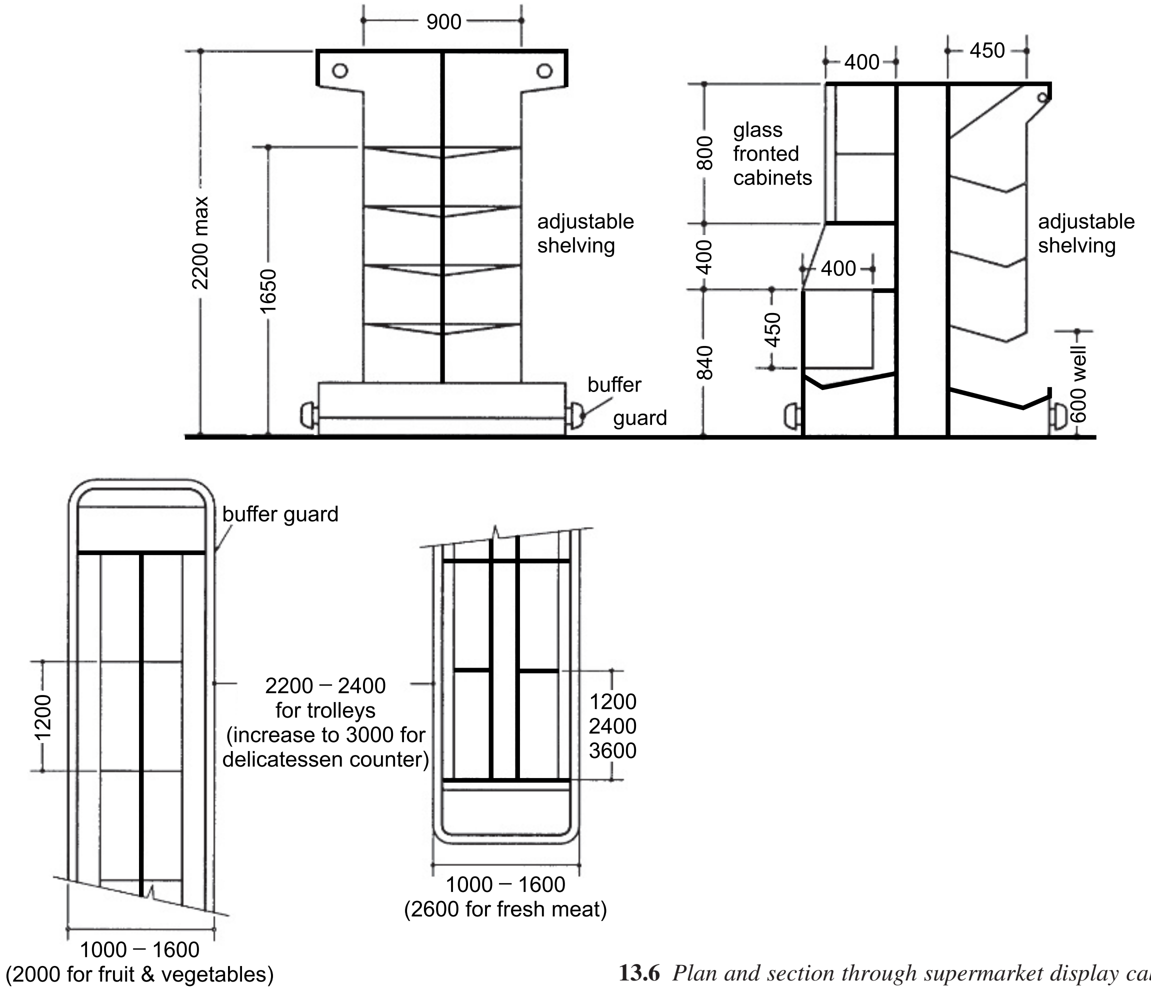
4.06 Energy management

Most multiple and large stores use energy management systems with remote station monitoring. Waste heat is recovered from refrigeration for hot water supplies and cool air recycled from refrigerated display areas. Refrigerants are changing to hcfc's (non-ozone reactive) with leakage-detection systems.

5 SMALL SHOPS

5.01

These are shops having a sales area less than 280 m^2 and not more than three stores, one of which may be a basement. Shops employing fewer than 20 people or 10 above the ground floor do not normally require a fire certificate.



13.6 *Plan and section through supermarket display cabinets*

5.02 Location

Convenience shops need to be near populated areas or stopping places (filling stations, airports, railway stations).

Speciality shops are best grouped with other shops and large space users to increase market exposure or in speciality areas associated with tourist attractions, etc.

Financial, etc. services: shop units usually combined with offices and ancillary rooms above.

5.03 Planning

Typical small shop plans are given in **13.7** to **13.10**.

	Typical	*Minimum*
Width of frontage	5.4 to 6.0 m	4.0 m
Depth	18.0 to 36.0 m	12.0 m
Height (depending on services)		3.0 m
Sales: ancillary areas	50:50	45:55
Staff facilities	1 wc plus 1 washbasin for each sex (minimum)	
	Changing area with individual lockers	
	Restroom with small food-preparation area	
Office	Files, safe, desk, terminals	

5.04 Servicing arrangements

- Stock replenishment and waste removal usually through a rear service road
- In a shopping complex this may be accessed through a service corridor and goods lift
- Some pedestrianised precincts allow vehicle access to front of shops outside restricted hours.

5.05 Design

The design of the shop frontage, graphics and window display is a major consideration. Multiple and franchised outlets usually reflect a uniform brand image. In environmentally sensitive areas, the scale and character of existing facades may need to be retained.

Interior layouts, fittings and design features depend on the nature and volume of goods sold.

6 DEPARTMENTAL STORES

6.01

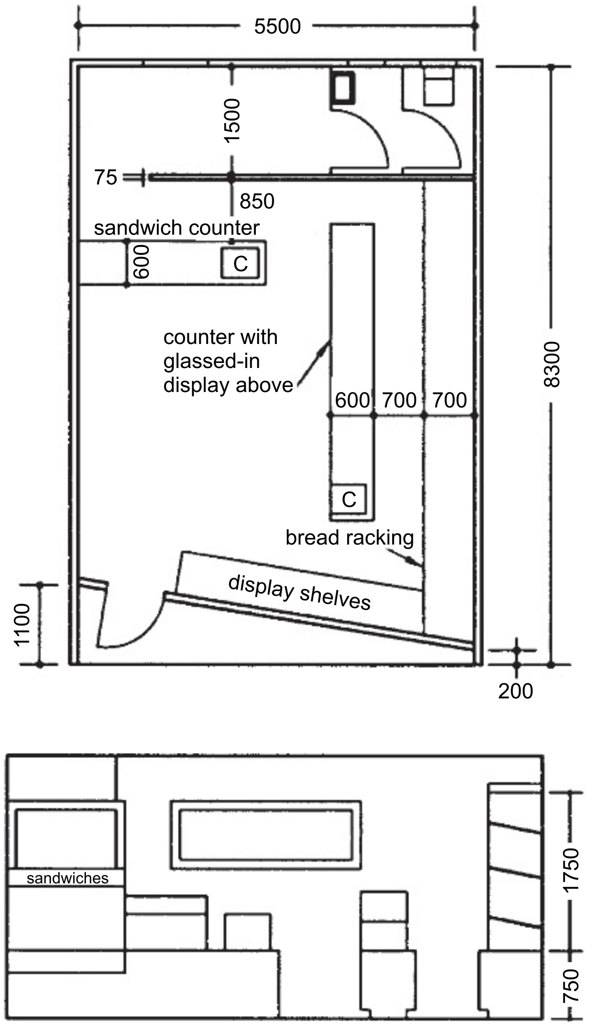
Department stores are large complex shops, invariably extending over several floor levels, selling a wide variety of goods, particularly clothes. Sales areas are grouped into departments corresponding to different categories of shops but are flexible in size and position. Departments may be operated directly by the store or let to other traders and franchisees.

Main high street stores usually have more than 20 000 m^2 sales areas but 'Junior' department stores in new shopping centres are less than 10 000 m^2 over two floors. Sales:gross area ratios are relatively low, 45:55.

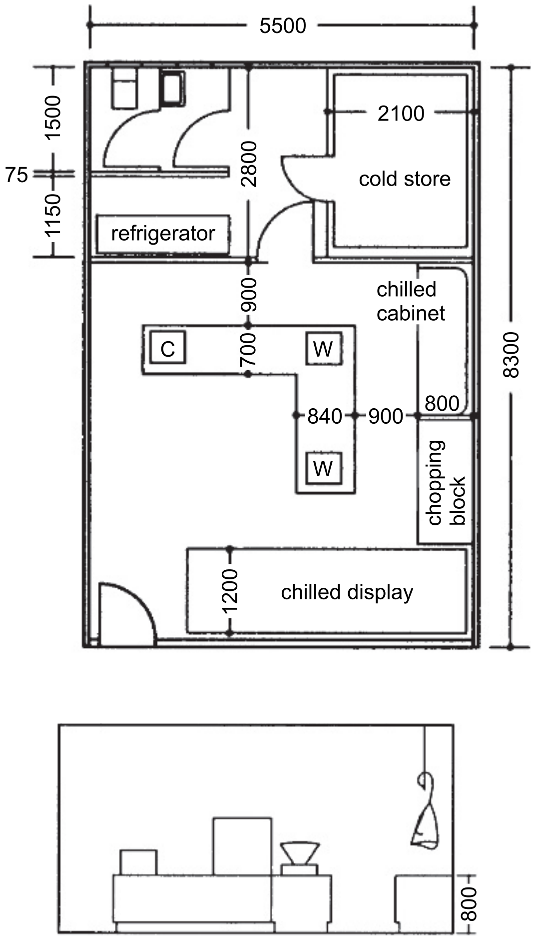
6.02 Planning

A frontage to more than one street or mall is preferred for extended window displays, customer entrances and emergency exits. Separate staff entrances and goods delivery and despatch areas (with customer collection bay) are essential.

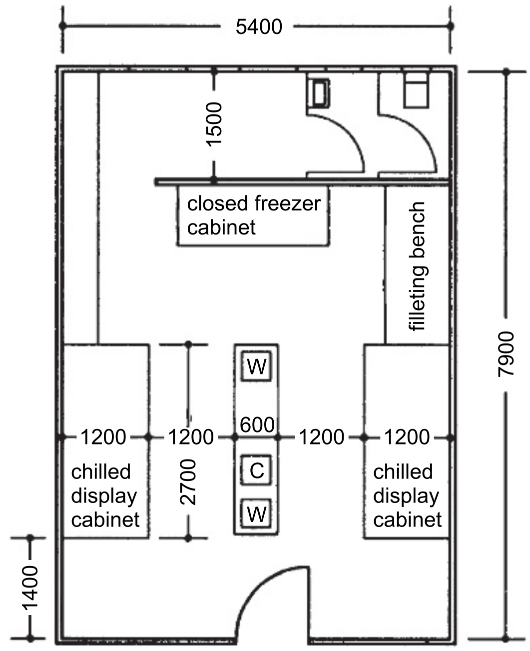
Internal areas must be planned for maximum clear space to allow for changes in seasonal sales and tenancy arrangements.



13.7 *Baker's shop, plan and section C cash register, W weighing machine*



13.8 *Butcher's shop, plan and section*



13.9 *Fishmonger's shop, plan*

Exceptions are food areas (food halls, food-preparation kitchens) which require permanently fitted equipment and special services.

6.03 Fire requirements

Compartmentation: most regulations permit up to 2000 m^2 and 7000 m^3 or twice this size (4000 m^2) with automatic sprinkler system.

Smoke evacuation: reservoir space with exhaust ventilation and controlled airflows.

Construction: fire-resisting structures and limitations on surface flame spread of lining materials.

Isolation: sprinklers, water curtains and physical separation of escalators, lift shafts and voids.

Means of escape: travel distances to protected staircases and adequate exits to street.

6.04 Locations

Locations for departments is rationalised by floor levels of related goods but influenced by turnover values and unit selling times. The ground floor is used for quick sales or small items to attract customer interest.

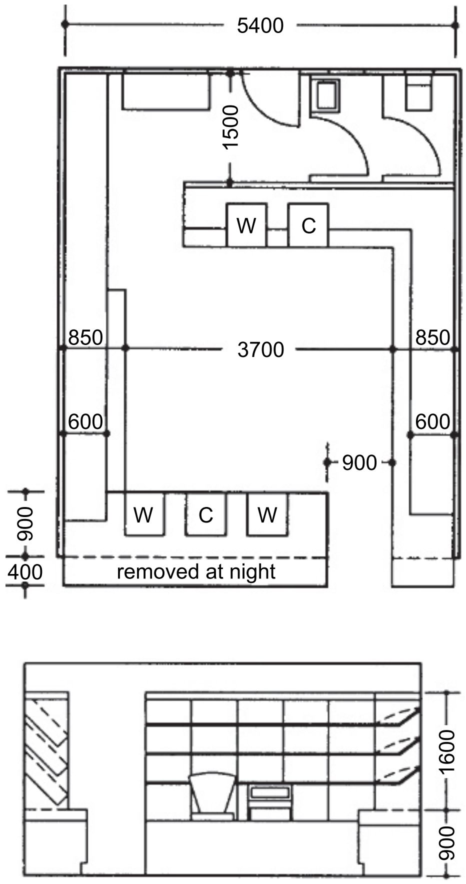
Restaurants, toilets and customer services are usually accessed through selling areas.

Subsidiary accommodation is needed to service departments on each floor but main stock rooms, staff facilities and administration are located in lower-value areas (rear, basement or upper floor).

Escalators and lifts are usually centrally positioned to create a focus and draw customers through departments.

6.05 Trends

Department stores have relative high staffing and operating costs. Life-cycle renovation may be used to remodel, divide and/or extend stores as shopping centres. Junior department stores are also sited in airports and regional shopping complexes.



13.10 *Greengrocer's shop, plan and section*

7 VARIETY STORES

7.01

These are large-space users selling a wide range of non-food goods, mainly by self-selection in an open sales area. In some stores part of the area is used for self-service food sales. Includes independent and multiple chain stores (Woolworths, Marks & Spencer, John Lewis etc.).

7.02 Size and location

Sales areas range from 500 to 15 000 m^2, most major stores being between 10 000 and 15 000 m^2 with sales:ancillary area ratios of 50:50.

Locations

- Prime high streets: serving sizeable catchment populations
- Shopping centres: multi-level links to upper and lower floors
- Regional shopping complexes and retail parks (space allowing introduction of wider ranges of goods).

Major stores require catchments of 80 000 to 100 000.

7.03 Planning

A rectangular plan with one-level trading is preferred with frontages on the high street and shopping mall. Sales floors in large stores are on two levels (sometimes three) with food areas having access to parking or collection points. Escalators, stairs and lifts for the disabled and goods distribution are kept to the perimeter to allow uninterrupted space for display and circulation planning.

7.04 Layout

Main aisles with distinctive flooring lead from entrances to assemblies of display fittings and cash and wrap points positioned for visibility and convenient access.

Displays include both perimeter and island fittings with related goods grouped together for easy location and comparison. Stores selling clothes and fashion goods must provide changing rooms and multiple mirror points. The self-service areas for food goods are planned on supermarket lines.

7.05 Facilities

Some stores provide a café or restaurant for customer use usually located on the upper floor to promote other impulse buying. Toilets and other customer services are in this vicinity.

Ancillary areas for staff and reserve stock are at the rear or on a higher floor, with separate staff entrance, reception and control leading to changing and associated facilities.

8 SUPERMARKETS

8.01

Supermarkets sell food and regular domestic necessities on self-service lines. The sales areas of large-space users range from 1000 to 2500 m^2 although many small grocers also use self-service.

8.02 Planning

Sales are invariably on one floor, planned to allow trolley circulation from car park through the store. Where required, upper floors are limited to non-food goods. A simple rectangular plan is preferred with 30 to 60 m frontage. (Minimum frontage (18 m) may require double-banked checkouts.)

The position and layout of the checkout points govern entrance, exit and circulation plans. Sales areas have large unobstructed spaces with structural grids of 9.0 m or more (to suit stand spacing) and 3.66 m clear ceiling heights.

8.03 Layout

A standard arrangement of parallel shelf racks and cabinets on each side of circulation aisles is invariably adopted. The main aisles are 2.2 to 2.5 m wide increasing to 2.8 to 3.2 m in front of delicatessen counters and fresh/frozen meat cabinets. 3.0 m across aisles are provided at the end of turns and a clear area 2.2 to 3.0 m deep on each side of the checkout line.

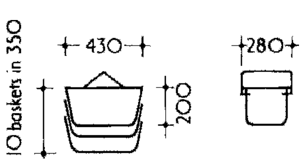
Displays are grouped into food, non-food and off-licence sections. Delicatessen, bakery and perishables prepared on the premises need to be adjacent to the preparation areas, with easy access to stores (refrigerated).

As a rule, refrigerated display cabinets are grouped together to facilitate service connections and airflow recovery.

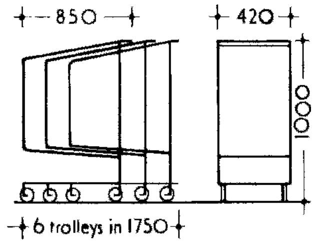
Demand goods (vegetables, fruit) are usually placed near the entrance to initiate buying and promotional items displayed in bins and in racks at the end of rows and checkout stations.

Space has to be allocated for customers to collect and restore baskets and trolleys, **13.11** and **13.12**. Where virtually all customers arrive by car, trolley parks are normally situated within the car parking area, often in lightly covered kiosks; and few (if any) baskets are provided. In urban areas, substantial areas within the store curtilage have to be provided, and many customers will use baskets.

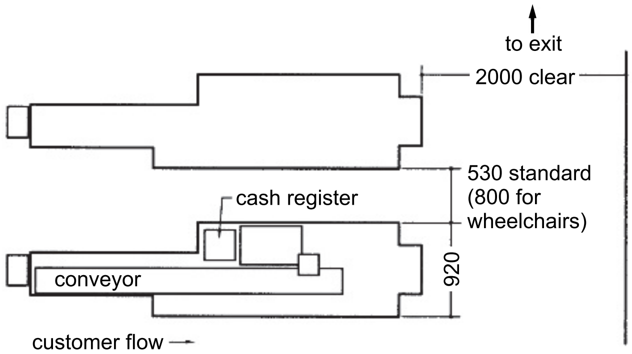
In self-service shops, supermarkets and hypermarkets the customer pays for his or her purchases at a checkout. These vary greatly



13.11 *Supermarket baskets*



13.12 *Supermarket trolleys*



13.13 *Typical check-out*

in design, depending on the type and quantities of merchandise, and the policies of the company concerned. Some contain automatic price-checking equipment and semi-automatic packing arrangements. **13.13** shows a fairly standard basic design.

Separate shop units (newsagents, florist, chemist, café) may be sited independently of the checkout and direct access is required to public toilets, public telephones and management offices.

8.04 Trends

The intensity of sales/m^2 is a critical consideration with trends towards increase of high added value (own-preparation bakery, butchery) and profit margins (delicatessen, wines, plant sales, made-up goods).

Technical equipment includes barcode scanning, EPOS monitoring and stock control, cheque printing and the introduction of liquid display shelf edge/labelling, robot packing and self-checkout facilities.

With opposition to out-of-town location, some multiples are developing convenience stores in town centres selling a limited range of goods.

9 HYPERMARKETS AND SUPERSTORES

9.01 Hypermarkets

These are very large stores on supermarket lines but with at least 2500 m^2 sales floor. Examples include Savacentres which provide 11 000 m^2 sales halls with 50 checkouts and gross floor areas of 20 000 m^2.

Compared with supermarkets the range of non-food lines is extended up to 50 per cent of the area. Hypermarkets tend to be built on derelict industrial land and urban fringes within large catchments, **13.14**.

Superstores are similar but tend to be larger with 5000–10 000 m^2 of selling space. Located out of town, they occupy large sites, with extensive parking, a petrol-filling station and an associated square or arcade of small shops, **13.15**. The overall development often combines out-of-town shopping with community facilities such as a village hall, public house, sports ground or/and leisure centre.

Discount stores and warehouse clubs concentrate on lower costs by limiting the range of goods (e.g. 650 compared to a supermarket's 3500 brand lines) and using simpler warehouse-style buildings and fittings.

9.02 Planning

Large stores are basically constructed as large rectangular boxes having large-span clearances to allow mainly one-level trading. If required, upper storeys are confined to part of the building and used for non-food sales, and ancillary services. The sales: ancillary ratio is high 60:40, with maximum goods on display and highly mechanised stock replenishment.

Compared with supermarkets, the stores use larger trolleys, wider and level circulation routes and easier transfer to car park areas (some with prepacking and mechanised conveyors).

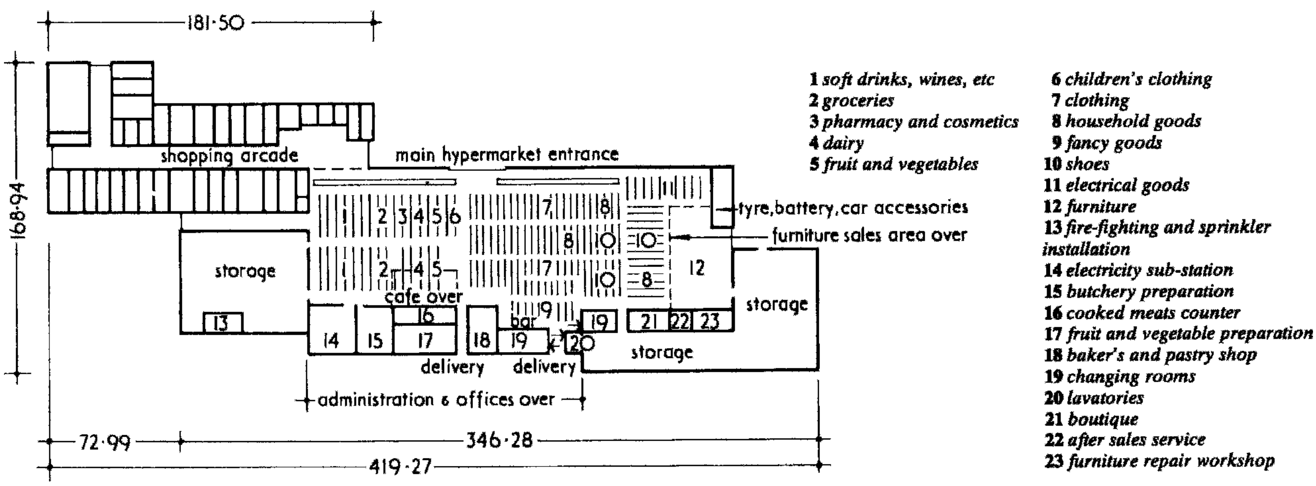
10 SHOPPING CENTRES

10.01

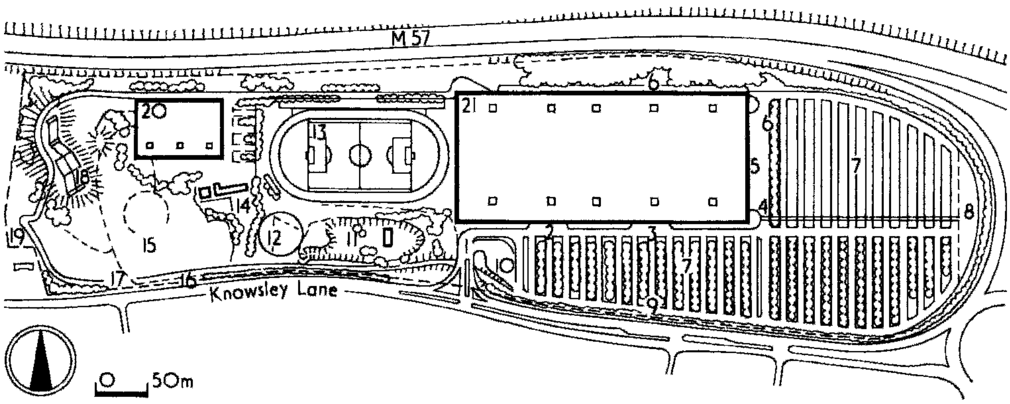
These are planned as a shopping complex under one central management which has a high degree of overall control, leasing units to individual retailers.

Shopping centres may be:

- *Open*, in terraces, squares, piazzas or village-style groupings
- *Partially covered*, with canopies over frontages (3.6 m high for clearance) or setbacks creating arcades
- *Fully covered*, single-level or multi-level shopping malls, converted warehouses, etc.



13.14 *General layout of a major hypermarket*



13.15 *Superstore at Knowsley, Lancashire: site plan Architects: Foster Associates*

10.02 Locations

New centres

- in new towns and expanding residential areas
- out-of-town regional shopping centres

Integrated centre

- in existing high street areas, to
- open up backland for commercial use
- provide linkages with other developments, carparks, etc.
- extend pedestrianised areas.

10.03 Planning

Centres should, where practicable, follow existing street patterns and be sensitively integrated into the existing street architecture.

Commercial and operational considerations

- Number, size and locations of large space users and other attractions (magnets) which will increase pedestrian flows
- Distribution, number and size of small shop units, numbers of shopping levels
- Servicing needs and access for goods vehicles
- Entrances and links with parking, public transport and other shopping areas
- Focuses and features to provide an identity and sense of place
- Environmental control in the mall and individual shops
- Fire regulations, safety and security requirements.

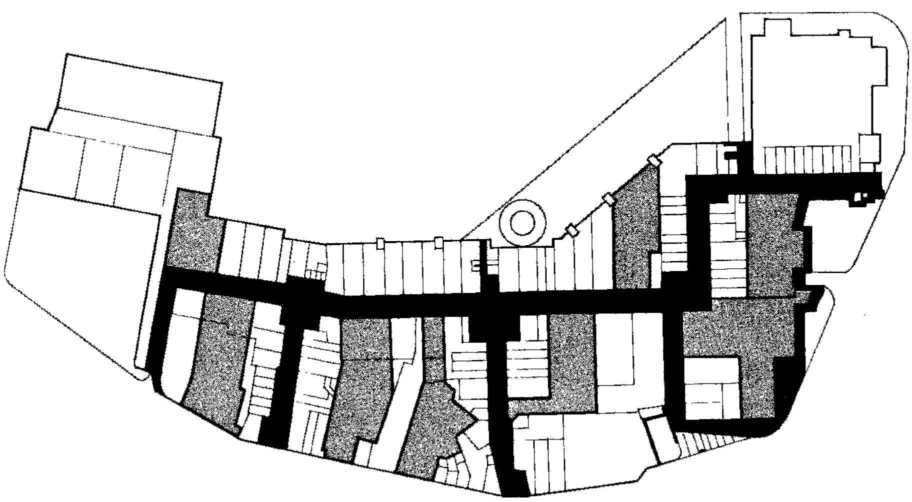
10.04 Plan forms

Shopping units are mainly one or two levels. Upper levels are usually required to join multi-storey variety and department stores and form galleries around a central square or atrium. Gross leasable areas vary, many infilling centres fall within 25 000 and 50 000 m^2 GLA providing 40 to 100 units. New regional centres may provide up to 100 000 m^2 GLA with 40 per cent allocated to large space users (magnets).

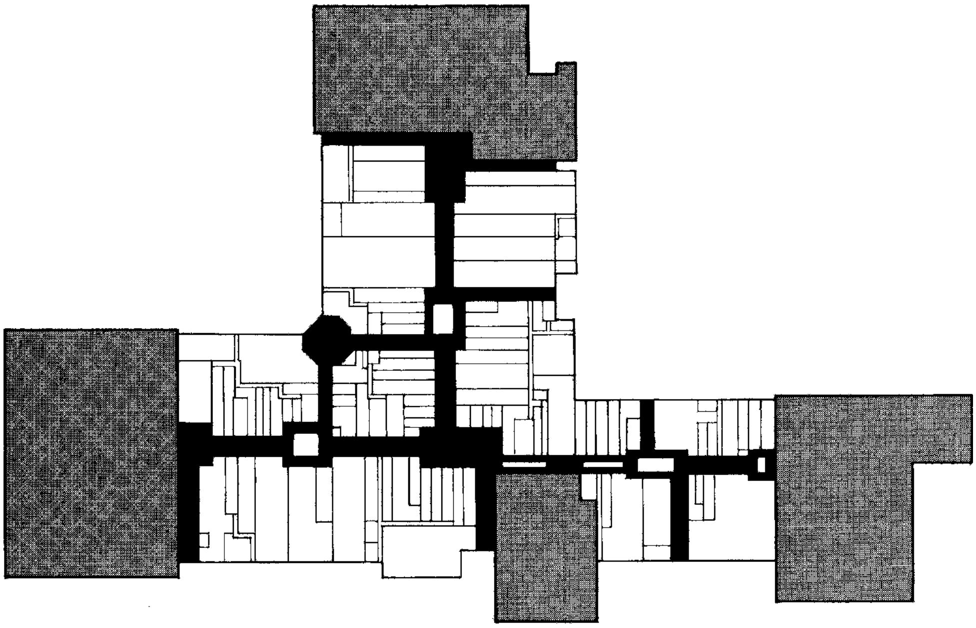
Magnets are sited near the ends of malls and branches to attract flows of shoppers past individual shops and have an effective range of 90 to 120 m. It is not practical to extend a mall more than 350 m and large developments calls for more than one level with concentrated plan forms. L, **13.16**, T, **13.17**, C and Square plans are common but out-of-town centres may use cruciform, **13.18**, pinwheel **13.19** and figure-of-eight, **13.20** layouts extending out from a central concourse.

10.05 Details

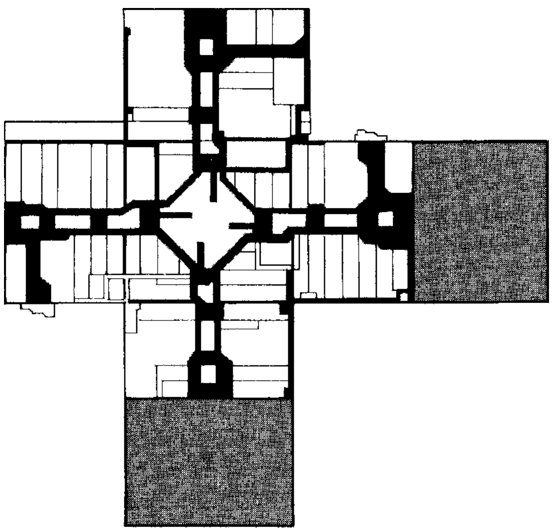
In the UK mall widths have progressively increased from 5.4 m to 8 m or 9 m. The average French centre uses a 16 m mall while



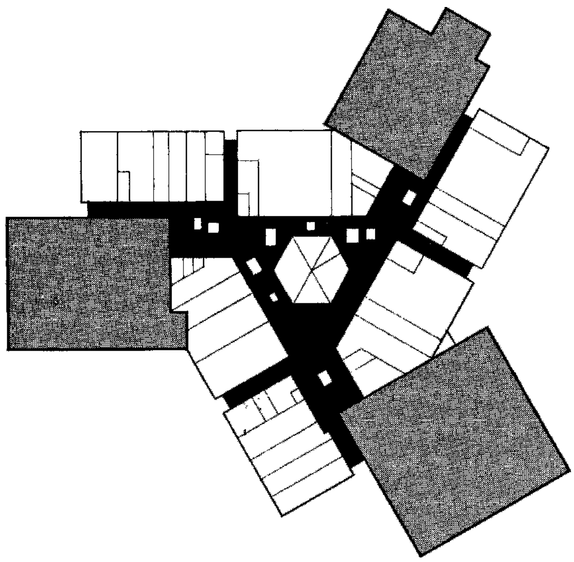
13.16 *L-shaped plan: Arndale Centre, Luton*



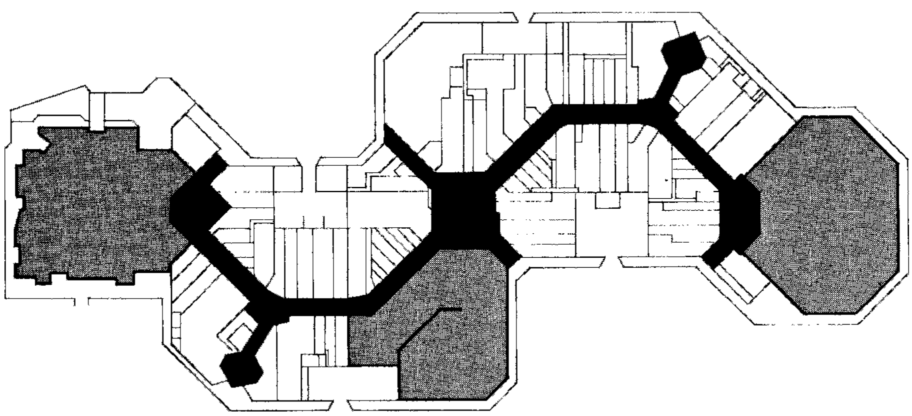
13.17 *T-shaped plan: Willowbrook Mall, New Jersey*



13.18 *Cruciform plan: La Puente, California*



13.19 *Pinwheel plan: Randhurst, Illinois*



13.20 *Figure-of-eight plan: Sherway gardens, Toronto*

North American malls vary from 12 to 27 m. Galleries around central courts are often 4 m wide. The preferred frontage for small shops is 5.4 m to 7.3 m with a depth of 13 m to 39 m but smaller units (1.8 × 3.6 m) are often required for service outlets and specialised trades.

Glazed frontages are necessary when the mall remains open to the public at night but otherwise Continental (fully or partly open) frontages are more convenient with latticework shutters or fire barriers (if required) to secure the shop at night.

10.06 Food courts and focuses

Large atria and glazed courtyards provide activity spaces which are often landscaped and used as revenue-generating open restaurants or food courts. Features such as water fountains, kiosks, planted containers and children's play centres also create focuses for interest and direction.

10.07 Fire precautions

The design of shopping centres does not conform with conventional compartmentation arrangements and specific requirements will be stipulated by each fire authority.

Fire control

Fire separation walls are required between shops in different tenancies, **13.21**. Malls must be of non-combustible construction, with incidental combustible material controlled, and have an automatic sprinkler system installed.

Specific requirements apply to adjoining or facing frontages of large space users (more than 2000 m^2).

Smoke control

Smoke reservoirs, **13.22**, are created by downstand beams on fascias at shop frontages and intervals along the mall. Smoke detectors activate exhaust fans in the reservoirs and lower fresh air supply fans to ensure clear escape routes. Further smoke ventilation and smoke control facilities are shown in **13.23** to **13.25**.

Escape routes

Maximum occupancy levels are estimated on the basis of:

- Shops, showrooms, supplementary areas – 7.0 m^2/person
- Supermarkets, department sales floors – 2.0 m^2/person

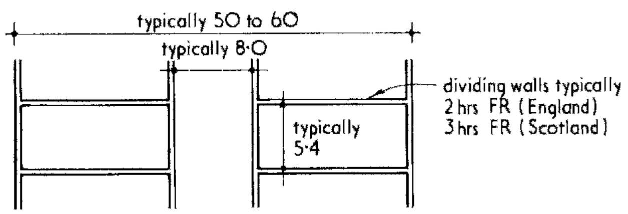
No more than 50 per cent of occupants should be assumed to escape through the rear of a shop, the rest using the mall. Escape routes from the mall must be provided at intervals with exits to open streets directly or via separated structures.

Controls

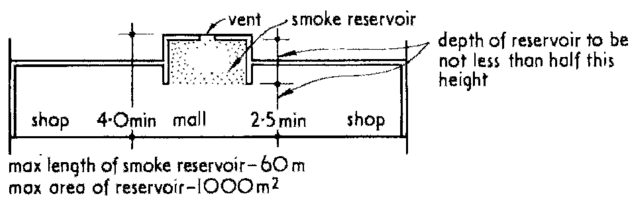
Automatic fire alarm and indication systems must be installed.

Access

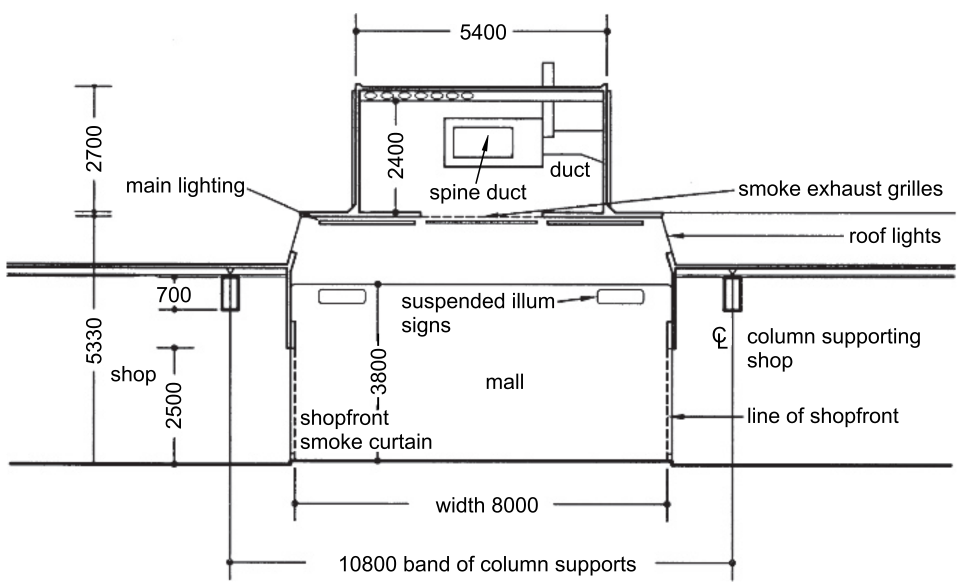
Requirements of the fire authority for appliance access into the mall must be adopted together with positions for hydrants, hoses and extinguishers.



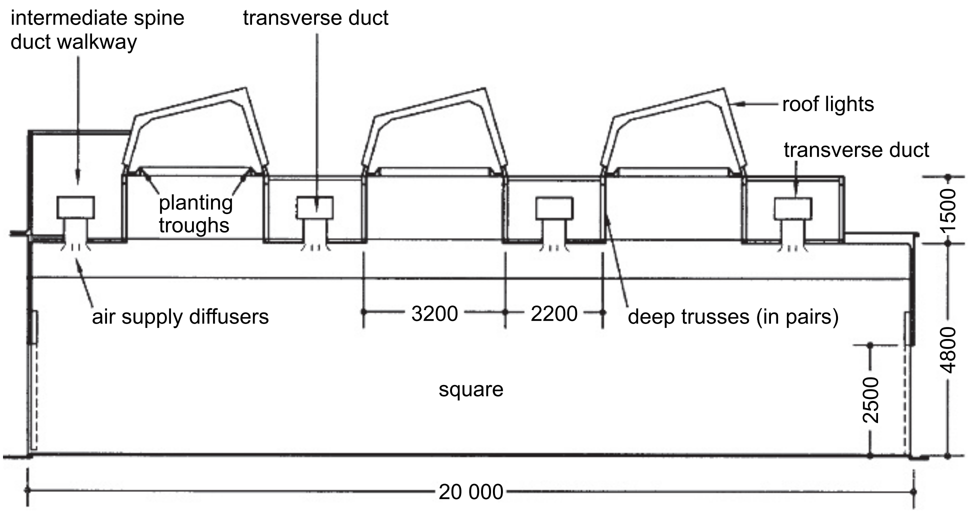
13.21 *Plan of a mall showing fire separation between shop units*



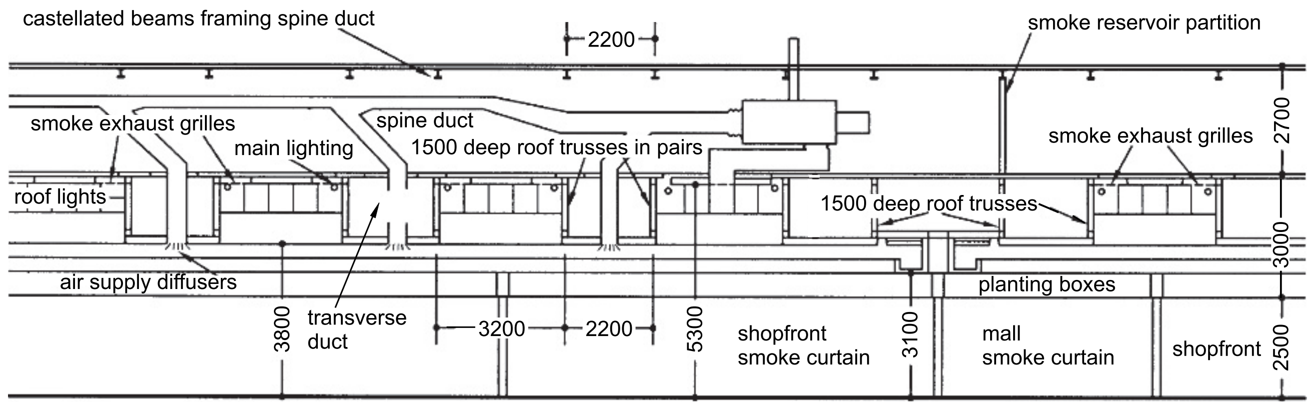
13.22 *Section showing smoke reservoir*



13.23 *Detail cross-section through a shopping mall*



13.24 *Detail cross-section through central square*



13.25 *Detail longitudinal section along mall*

10.08 Circulations
Vertical circulation between storeys requires escalators, featured lifts and stairs designed to stimulate interest. These are usually located in a spacious central concourse or atrium, at junctions or corners and within the large space users.

Servicing shops
Vehicular access is required to loading docks and waiting bays directly accessible to each of the larger stores, with service roads, goods lifts and tunnels extending to the rear of shops. Service entry is usually at basement and street level but may be at an upper level on sloping sites.

10.09 Engineering services
The landlord is normally responsible for installing mains and providing the communal services of the mall including comfort cooling and heating or air-conditioning, lighting, cleaning, fire control and security systems. As a rule, individual tenants instal their own services and equipment subject to agreement. Food-preparation areas, public toilets and plant areas require the installation of specific ventilation, drainage and electrical services.

Sections through a typical centre showing the complexity of structure and servicing are illustrated in **13.23** to **13.25**.

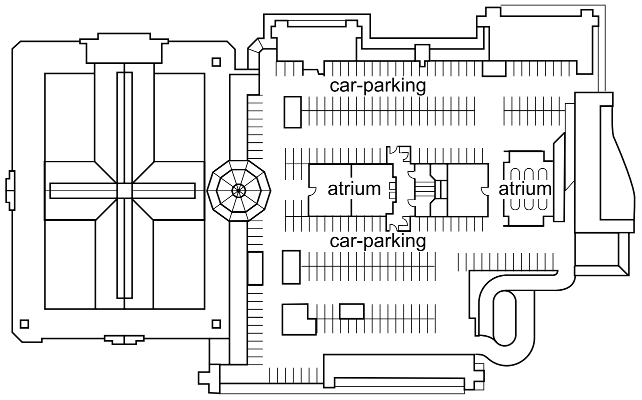
10.10 Other facilities
Public toilets including facilities for the disabled are installed and maintained by the landlord. Access to a public car park is often a primary consideration in letting units.

10.11
Some examples of town-centre shopping centres are shown in **13.26** and **13.27**.

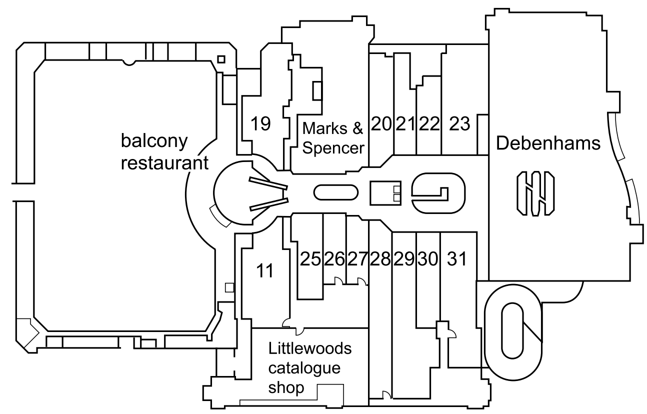
11 RETAIL PARKS
These are centres of at least 4500 m^2 sited outside a town consisting of at least three single-storey units of 900 m^2. Retail parks cover non-food goods (DIY, furniture, furnishings, consumer durables, etc.). Buildings are generally of warehouse design and benefit from the combined attraction, shared infrastructure, parking and extra facilities (café/fast food outlets).

12 REGIONAL CENTRES
These are large multiple shopping complexes, located near major highway junctions to serve a wide catchment area.

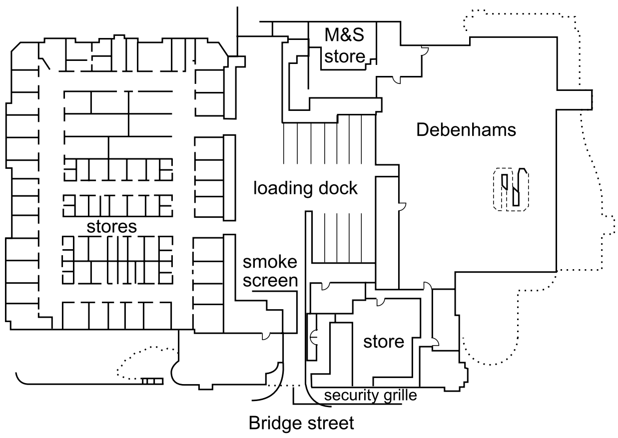
Examples include Bluewater, near Dartford, Kent, **13.28**, the Metro Centre, Gateshead – 250 shops; Meadowhall, Sheffield – 230 shops (23 million visitors/year), **13.29**; Brent Cross, London, Lakeside, Thurrock. A range of leisure facilities, restaurants and amenities is provided for family attraction.



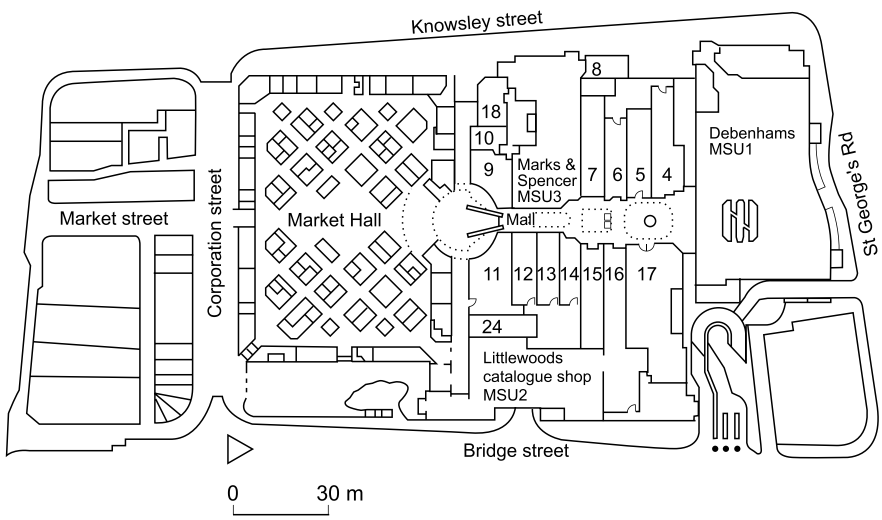
a *First-floor level*



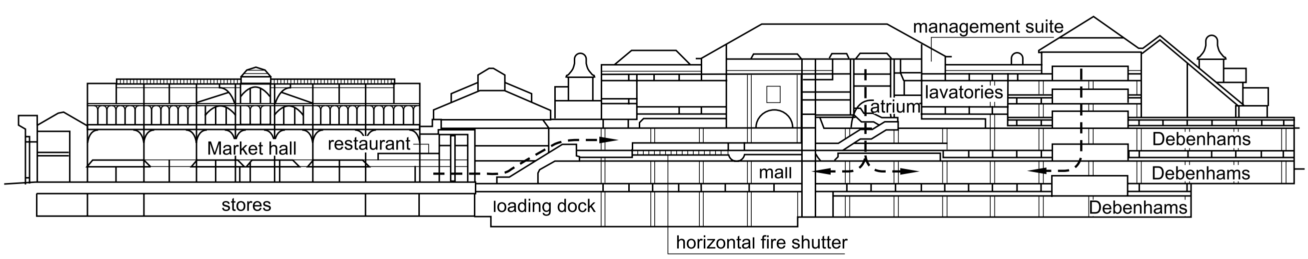
b *Upper ground-floor level*



c *Ground-floor level*

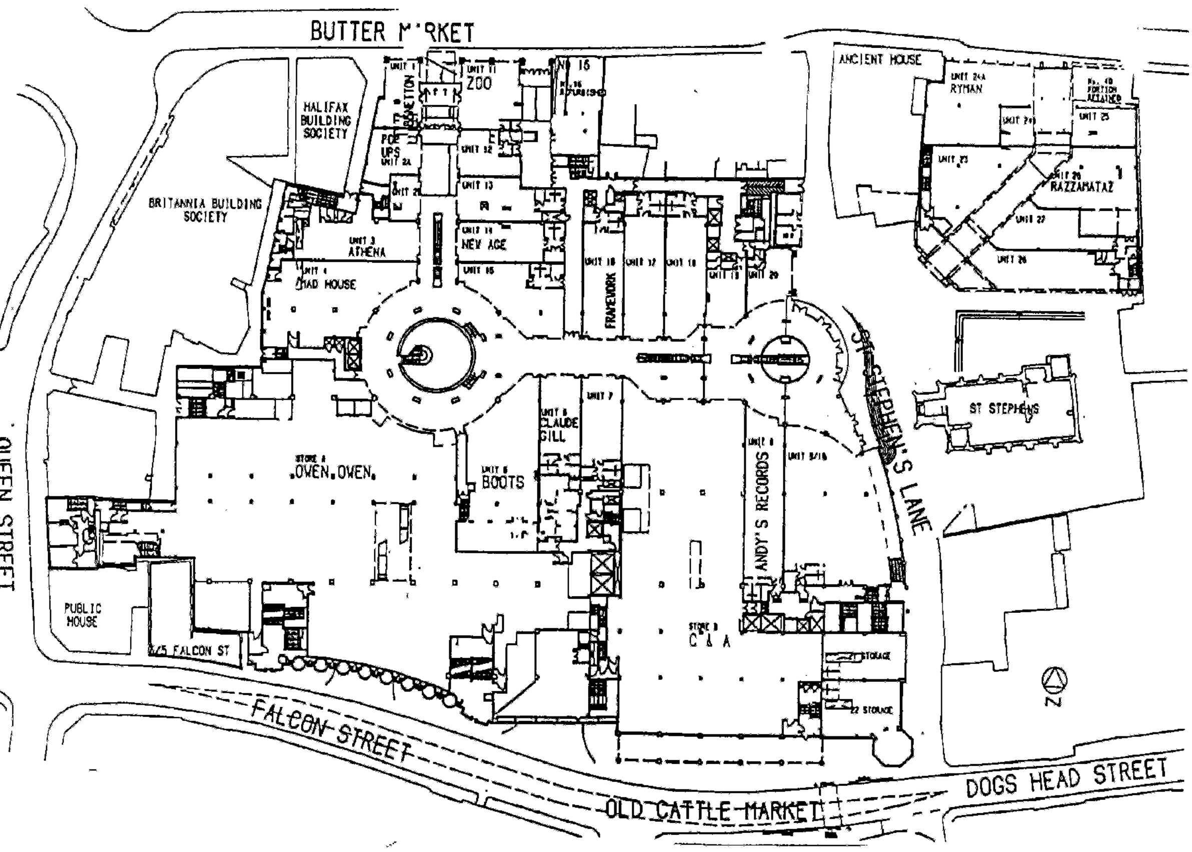


d *Lower ground-floor level*

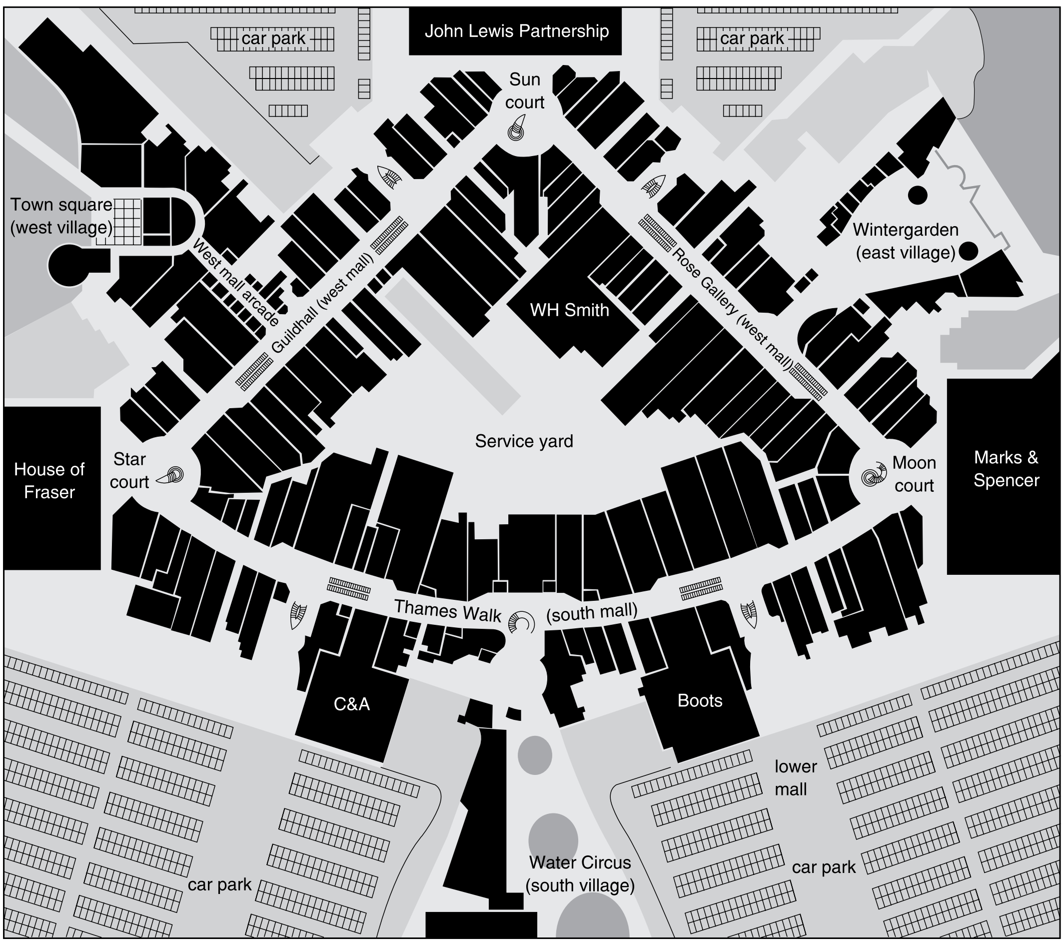


e *Section south–north*

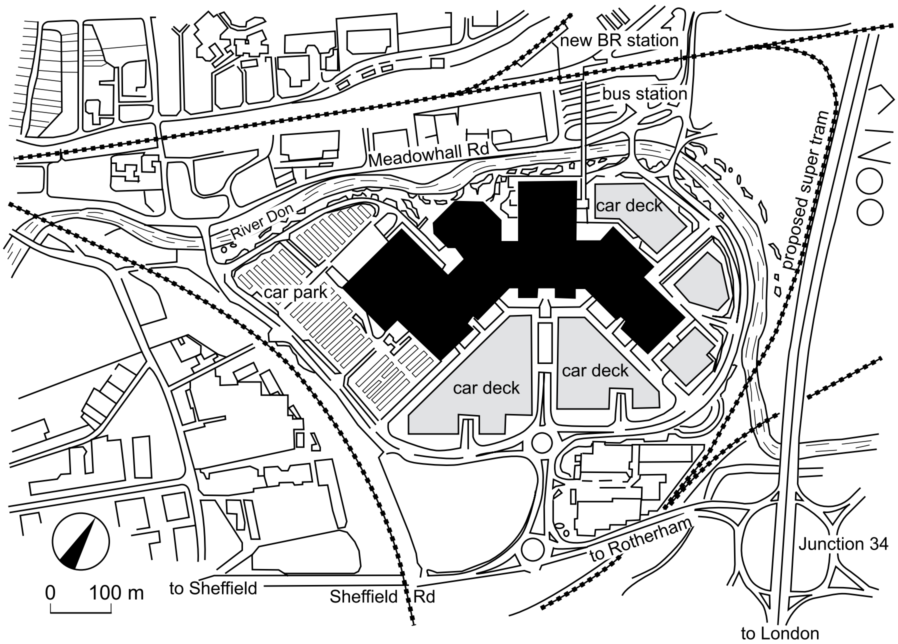
13.26 *Bolton Market Place: a shopping centre on two levels linked to the refurbished existing Market Hall. Deliveries and storage are in the basement, and car parking on three upper floors. Total area is 49 796 m*^{2} *Architects: Chapman Taylor & Partners*



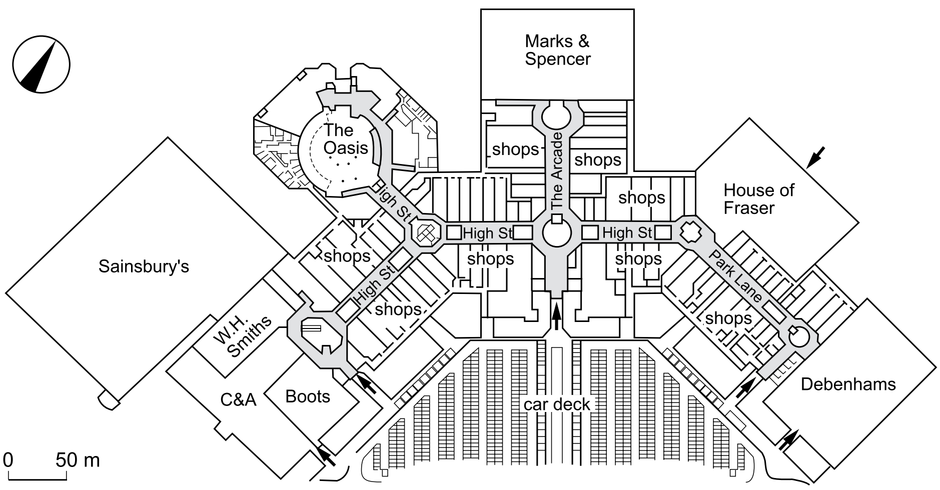
13.27 *Buttermarket, Ipswich. Development of a shopping centre in a sensitive historic area, incorporating a church restored as an amenity area, and two level basement parking. Completed in 1992 with 49 units. Built area 25 083 m², cost £37 million Ground-floor plan Architects: Building Design Partnership*



13.28 *Bluewater Park near Dartford, Kent. Europe's biggest retail centre to date. Architects: Eric Khune and Benoy*



a *Site plan of the regional shopping centre*



b *First-floor level of the dome's shopping mall with shops on two levels*

13.29 *Meadowhall Centre, Sheffield*

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14 Industrial facilities

Jolyon Drury and Ian Brebner

The Jolyon Drury Consultancy advises on the design of production, distribution and storage systems and facilities. Ian Brebner is a partner of architecture practice Austin-Smith:Lord

KEY POINTS:
- *Constant change is endemic*
- *Increasing demand for small units and starter accommodation*

Contents

1 INTRODUCTION

1.01 Industrial facilities

An Industrial facilty is a building enclosure and site within which goods are manufactured, assembled, stored or shipped/trans-shipped. Manufacturing processes continually develop, improve and evolve, but have generally been classified as either:

1 A transformation of elemental raw materials into a finished product or material that requires further manufacturing to become a finished product (commonly referred to as **Heavy Industry**). These are typified by traditional industries, such as Steel manufacture, Chemical manufactfure, Refining Plants, etc.
2 An assembly process which integrates finished components into a finished product (commonly referred to as **Light or Medium Industry**). These are typified by Automotive manufacturing, White Goods manufacturing, Electronics Manufacturing, etc.

A third category of **Technology** manufacturing is rapidly evolving from the development of artificial/assisted intelligence, communications and biotechnology. The intellectual capital required to sustain this third category is a step change from the more traditional light and heavy industries that have previously predominated in the developed economies. Developed economies are changing their manufacturing base to this third category as a means of generating added value to sustain the increasing income aspiration of their workforce and maintaining their global trading position. This category demands greater integration of further education and research with the actual manufacturing activity. It is generally recognised that clustering together research and manufacturing facilities produces a catalytic effect where the total output (physical or intellectual) can exceed the sum of the parts – even though they may be separate enterprises. This has significant implications on the nature of the enclosure which accommodates these new industrial facilities.

1.02 History of industrial facilities

The history of industrial development has been one of the continual changes following improvements in production equipment, management and techniques. The key stages of the development of manufacturing which have influenced the design and nature of industrial building have been:

1 Craft-based manufacture, where individuals or small groups of individuals created the finished product from elemental raw materials. The building which facilitated this were in the main, relatively small-scale workshops, or indeed, individuals dwellings. An industrial building typology was not generally identifiable.
2 Power-assisted manufacture, where production machines were powered rather than manually operated. Significantly, the use of power increased the capacity of the machine and allowed the subdivision of the production process, decreasing reliance on the skill of the individual. This, in turn, facilitated a greater concentration of manufacturing capacity in a single location. Early power systems relied on extended shaft drives with belt-driven power transfer to individual machines. Belt drives had a finite limit on their length and operated at right angles to the drive shaft. The buildings which accommodated these power systems were characterized by there distinctive long thin shape on multiple floors. The first distinctive industrial (factory) building typology had evolved amongst the earliest examples being Cromford Mill at Belper in Derbyshire by Richard Arkwright, 1771.
3 The assembly line. The development of compact individual electrical, fluid- or air-driven 'engines' released the production machine from the constraint of being tied to a central power engine. These new machines had relatively unlimited capacity and power. Together, these factors allowed machines to be located to match the assembly sequence needed to produce the final product. The assembly evolved. The buildings which accommodated this new form of mass production were typified by being single storey, comparitively large with clear internal spans to provide the flexibility to reconfiguration of the assembly line to suit changes to the product in a more rapidly evolving marketplace. The industrial building typology evolved into large enclosures, single storey with large internal spans.

2 CLASSIFICATION OF PRODUCTION BUILDING TYPES

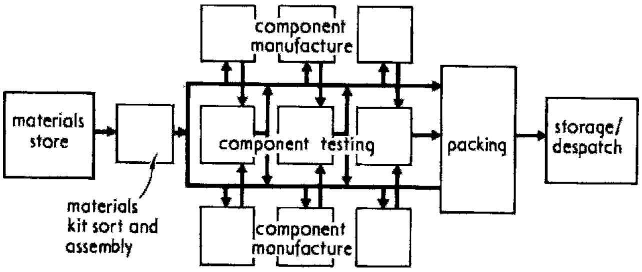
Factories can be broadly categorised as bespoke or generic.

2.01 Bespoke

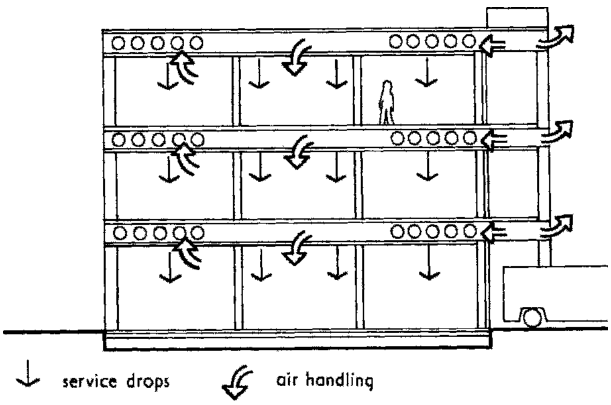
These include:

- High-precision work in controlled conditions, **14.1–14.3**.
- Highly tailored to a unique or very specialised process
- Primary manufacturing sites which double as headquarters or 'flagship' manufacturing sites.

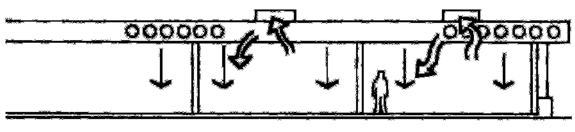
Design will depend on circumstances, but will tend to approximate to laboratory or office type design conforming to Planning B1 classification.



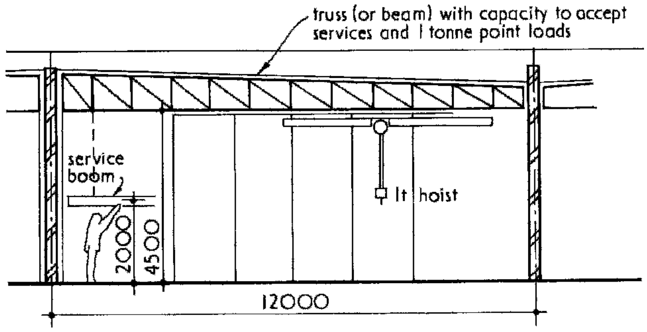
14.1 *Typical process flow diagram for light production and assembly such as small electronic components' manufacture, and similar high-technology processes. 'Kit sort' refers to the making up of kits of components for assemblers*



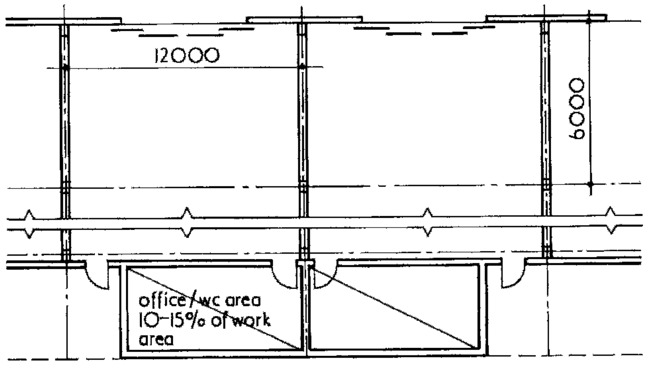
14.2 *Section through typical factories for light, high-technology production; multi-storey construction, as new or conversion of existing building: could be flatted units*



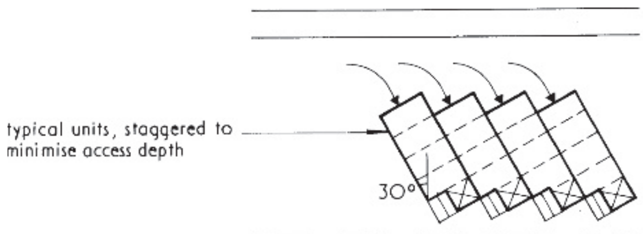
14.3 *Light production and assembly: single storey for small-scale and high-technology assembly. High degree of service freedom in roof zone*



a *Section through unit*



b *Part plan*



c *Units staggered in plan to reduce site depth required*

14.4 *Typical 'nursery' for light production and assembly, low technology, may be built speculatively*

2.02 Medium industries

The greatest need for careful and thoughtful design is in this field. These industries can be subdivided into:

- Light – medium small-scale engineering and assembly, clothing factories, paint shops, similar to **14.4**.
- General – medium batch production of components for other factories, medium-sized printing, **14.5** and **14.6**.
- Heavy – medium industries requiring intensive use of buildings and services as in mass production, **14.7** and **14.8**.

2.03 Heavy industries

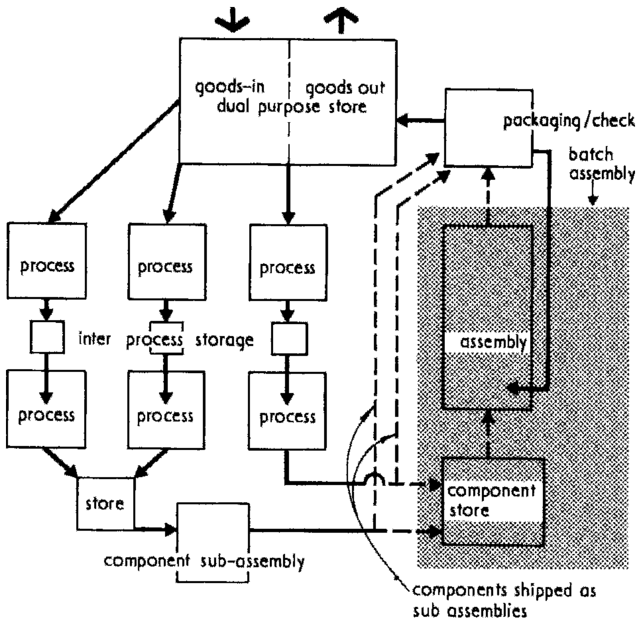
Industries such as steel-making and shipbuilding require spaces (not necessarily enclosed) designed around the work or the mechanical plant, **14.9**. Traditionally, it is difficult to build adaptable structures, **14.10**, but modern handling techniques enable 'loose fit' buildings to be designed **14.11**.

3 ADAPTABILITY

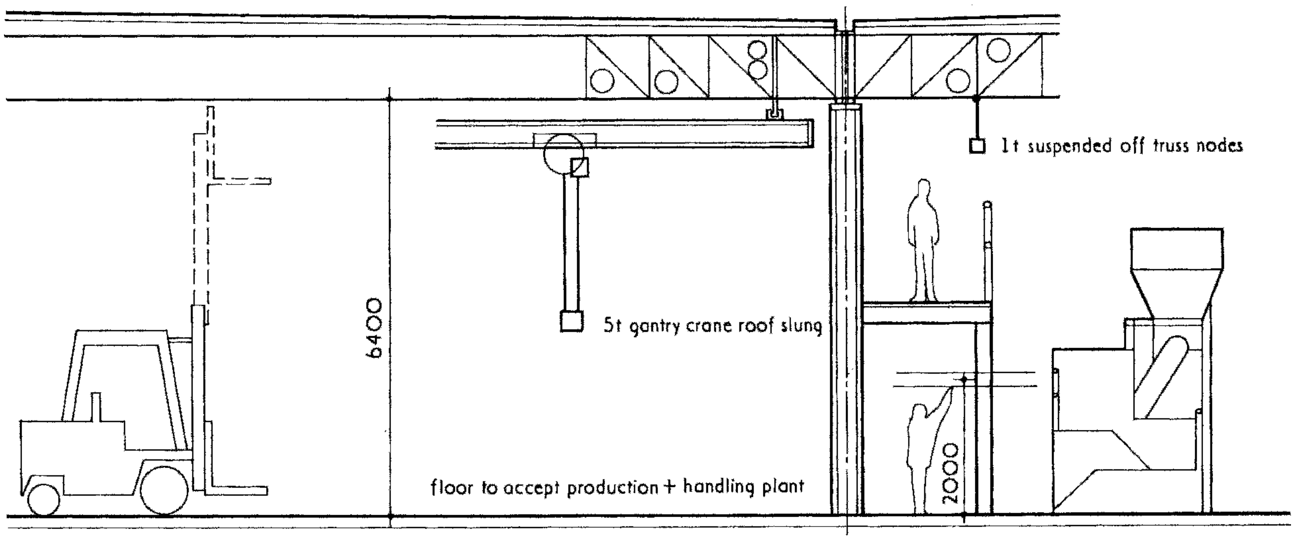
3.01 Design for change

An industrial facility is designed to either:

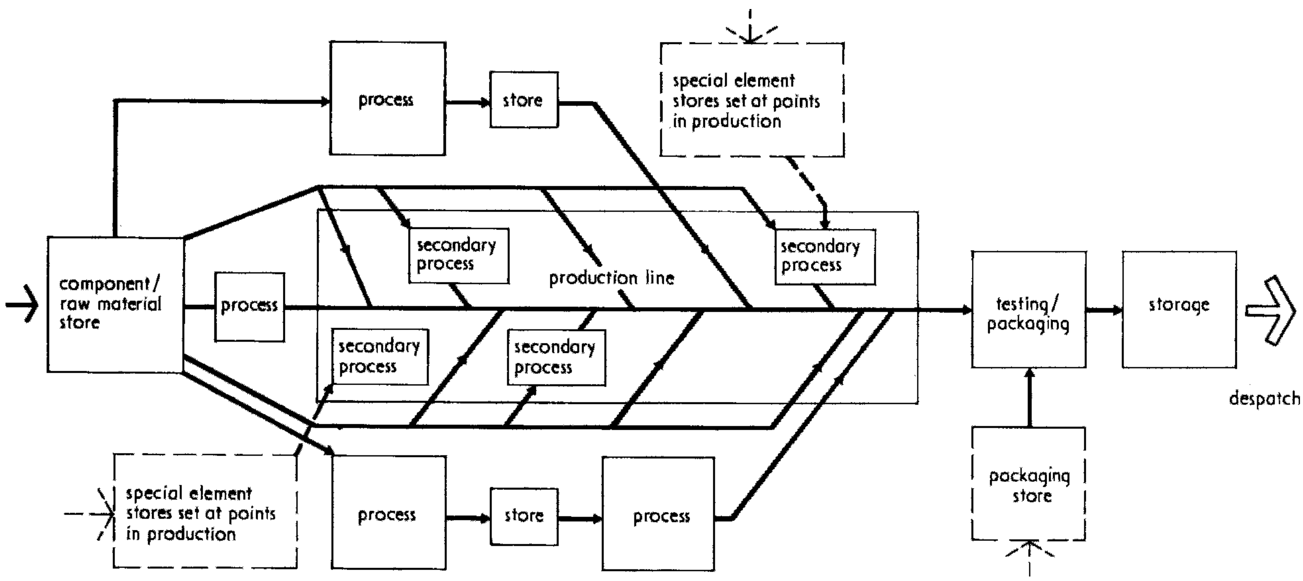
- 'institutional' standards, where the configuration of the building is geared to the requirements of the financial institutions who



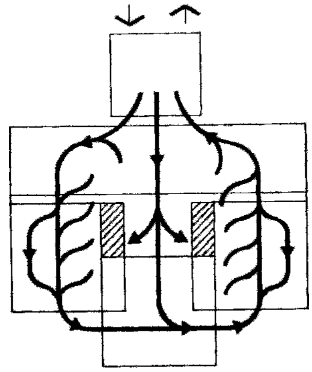
14.5 *Process flow diagram for batch production and assembly. Sometimes involves the assembly and shipping out of complete sub-assemblies, more commonly the production and dispatch of batches of discrete components*



14.6 *Section through typical purpose-built batch production building. The spans, typically 18 × 12 m and trussed roof construction are selected for cheap and rapid adaptation to a variety of uses. Floor loading 25 kN/m²*



14.7 *Process flow diagram for mass production and assembly. This applies to high-volume line assembly as in the motor industry, with some components being built into sub-assemblies before final assembly on the main line*

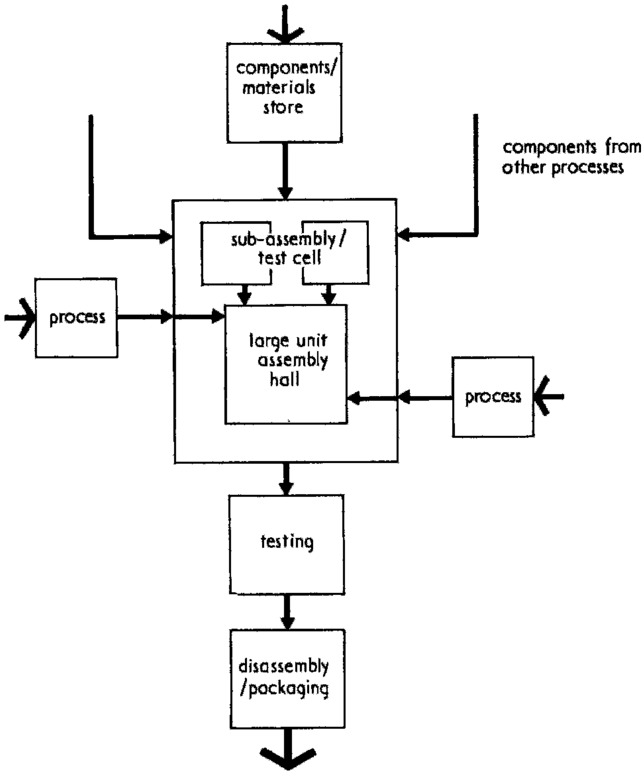


14.8 *Materials flow for mass production does not have to impose a predominantly linear building form. Group assembly 'cells' may feed onto a circulatory route, allowing personnel and services to be grouped into specifically equipped zones*

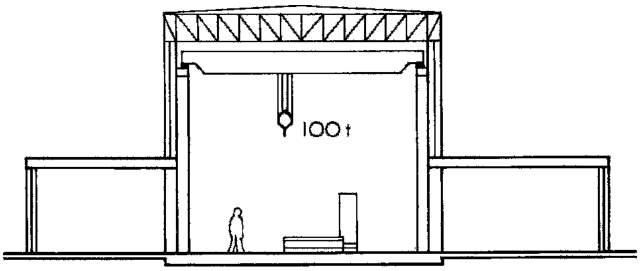
fund the development. These requirements manifest themselves in a very flexible building which can be adapted to other industrial process or distribution uses if the initial occupier vacates the building. Typically, the buildings are regular in shape (optimally around 2:1 to 3:1 ratio of length to width) with internal height related to the floor area (typically, 6 m clear to underside of structural obstructions for floor areas up to 2500 m² and up to 12 m clear to underside of structural obstructions for floor areas of 10,000 m² and above). Distribution facilities would normally start at a height of 12 m and rise to 18 m where automated 'picking' equipment is intended.

It is desirable to have the maximum clear internal spans. The most economic form of frame is the portal which can economically span up to 36 m and can be duplicated to increase the width of the building as required. The most economic primary grid spacing is between 6 and 7.2 m.

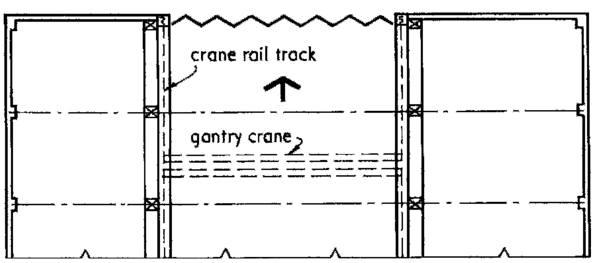
As proportion of the total floor area, the total of office and welfare accommodation will typically range from 10% in total floor areas of 1000 m² to 5% in total floor areas of 10 000 m² and more.



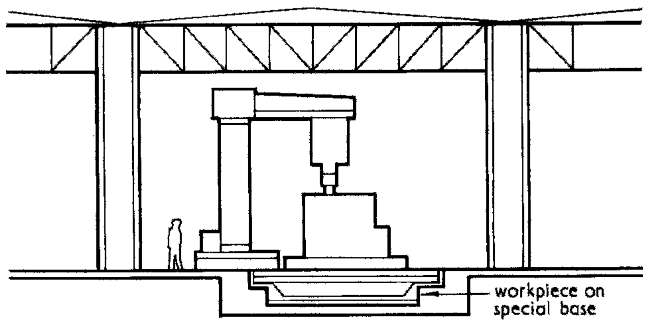
14.9 *Process flow diagram for typical heavy engineering. The workpiece is the centre to which sub-assemblies are routed. It is likely to be disassembled for shipment*



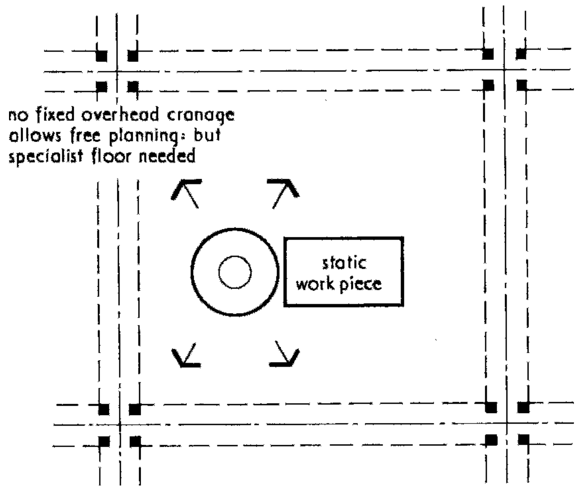
14.10 a *Section, and*



14.10 b *Part plan of traditional type. Heavy-duty gantry cranes move the workpiece to the appropriate machine tools and assembly areas*



14.11 c *Section, and*



14.11 d *Part plan of recently developed workshop where large workpieces remain static, being built up on special bases that are likely to be employed for transport and installation. Machine tools and components are brought to the workpiece, air-cushion techniques are widely used*

Recognising the needs of the occupier who is likely to require smaller floor areas, around 1000 m^2, the provision of dock levellers is much reduced in comparison with larger buildings of, say, 10 000 m^2, where as many as 6–8 may be desirable.

- Bespoke industrial facilities are usually required where the process is so unique that it is unable to fit within the simple flexible layout of the 'institutional' building, cannot be contained in a single building or does not require full enclosure. In these circumstances, the building enclosure effectively becomes part of the process. This will limit the future flexibility of the building, in the extreme, rendering it unusable for anything but its intended use. Bespoke buildings are usually associated with capital intensive processes where the process equipment is relatively immovable – in contrast to the type of process equipment that can be readily accommodated in the 'institutional' building. For the designer, a thorough understanding of the process requiring a bespoke solution can offer rich opportunity for expressive functional design.

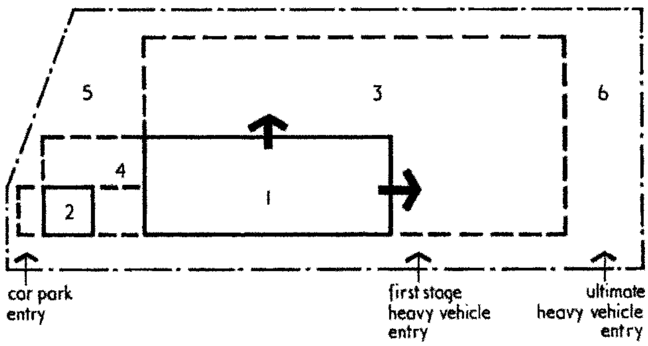
The evolving Technology industries tend to conform well to the 'institutional' building model which offers greater flexibility for change in the format and type of process. The extreme example being Biotech or Biopharma production processes which are organised as multiple production cells within a large uniform enclosure, each cell is capable of being stripped out and replaced with a completely different process without disruption to the remaining operating cells.

There is a reducing requirement for the bespoke industrial facility, at a practical level and resulting from the means of funding of modern industrial facilities.

Adaptability must allow:

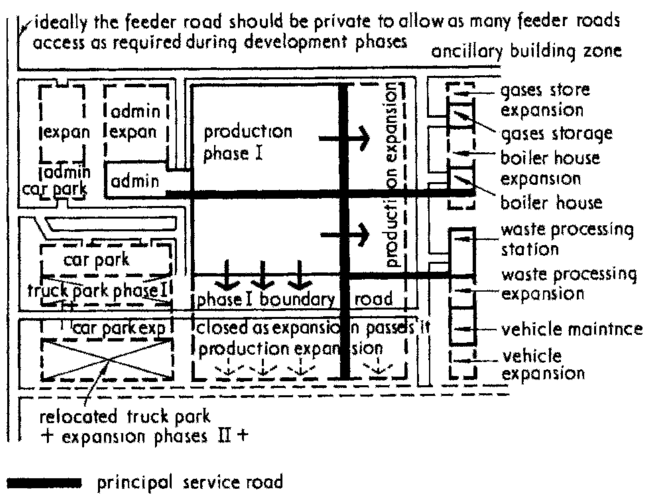
- Change of process to avoid obsolescence
- Change of process and product following change of ownership.

Changes will normally only be within the broad groupings of building types given in Section **2.02**.



1 *first stage factory*
2 *first stage office*
3 *factory expansion*
4 *various options for office expansion*
5 *car park*
6 *heavy vehicle area*

14.12 *Small or medium-size factory development, with a free-standing office building. The uneven boundary increases the possibility of conflict when the factory and offices expand simultaneously, and restricts commensurate expansion of car parking*



14.13 *A large plant with segregated development zones:*

- *The factory and associated car and truck parking. When the factory expands the truck park becomes the expanded car park and a new truck park is constructed adjacent to dispatch*
- *The administration block and associated car parking, separated from manufacturing by landscaping*
- *The ancillary area, incorporating individual growth provision for each element within the zone boundary.*

3.02 Design for extension

Apart from alterations within the envelope, there may also be requirements for extension; and the design should anticipate this, **14.12** and **14.13**.

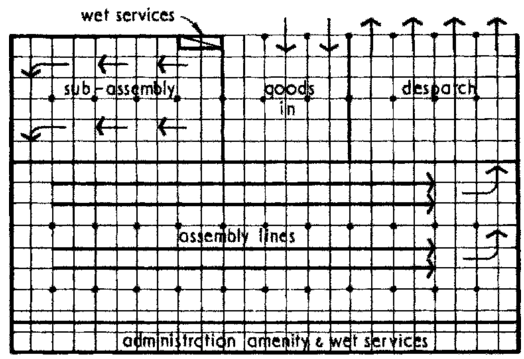
4 WORKING METHODS

4.01 Alternative methods

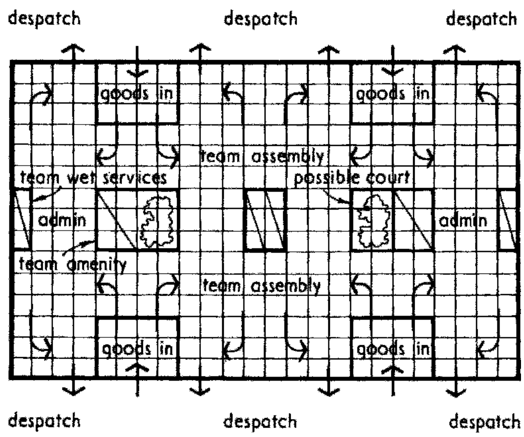
The alternative methods of work organisation are:

- Linear assembly
- Team technology.

While the latter is a more recent introduction, there is no indication that it will completely supplant the former. Consequently, production buildings must be able to accommodate either or even both in different areas, **14.14** and **14.15**.



14.14 *Mass production buildings have to accept changes in production technology. This plan shows a conventional line assembly that may be adapted to the form in* **14.15**



14.15 *The factory can change to team assembly due to new product. Note localisation of amenity and wet service areas to identify with teams. Chance of opening courts adjacent to amenity areas, though these may change position as production demands*

4.02 Linear assembly

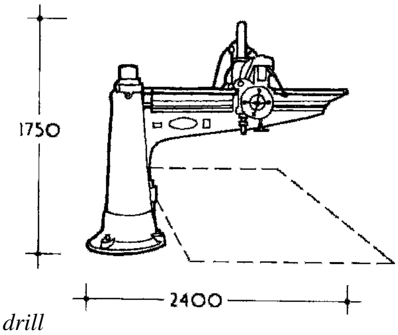
In this method, machines are arranged along work-travel routes. At each station, component are added until the work has been completely assembled and finished. Supplies of components and materials are needed at each station; and waste must be removed.

4.03 Team technology

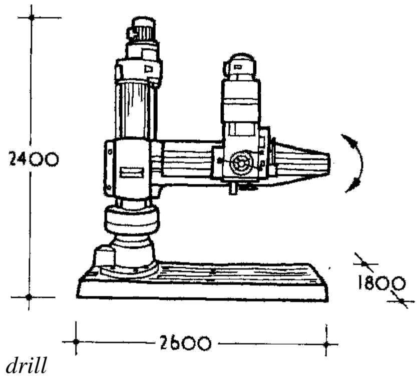
This appears to restore to the labour force a feeling of responsibility and achievement. The machines are arranged in groups, and all or a substantial part of the work is assembled within the group. There is a need for storage of materials and components. The main planning requirements are for unrestrictive space and strong floors to enable the machines to be relocated at will, with adaptable overhead services systems. Storage and assembly spaces should be interchangeable.

5 MACHINE SIZES

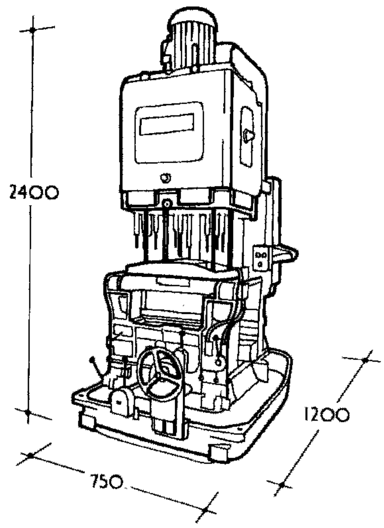
The sizes of typical machines for light and medium duty industries are shown in **14.16–14.21**. The majority of machine tools do not exceed 7.5 kN/m^2 in loading on the floor.



a *Plate drill*

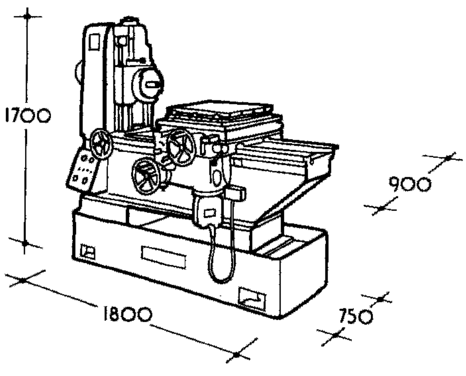


b *Radial drill*

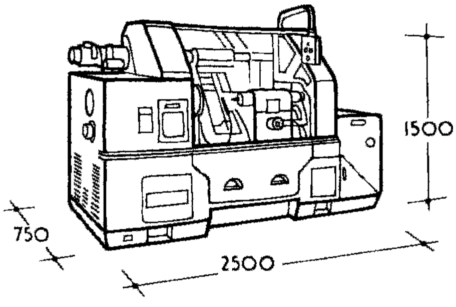


c *Adjustable multi-drill*

14.16 *Drilling machines*

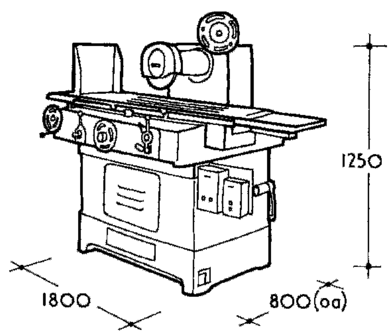


a *General purpose chuck lathe*

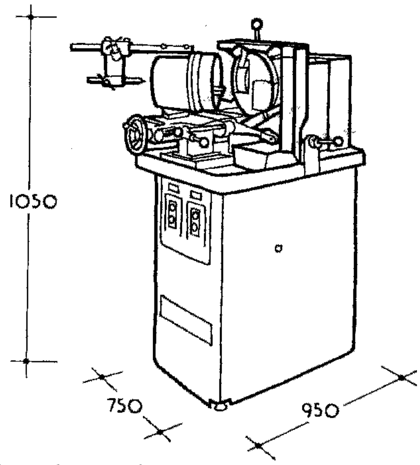


b *Hydraulic copying lathe*

14.17 *Lathes*



a *Surface grinder*



b *Twist drill grinding machine*

14.18 *Grinding machines*

6 OUTLINE SPECIFICATION OF A TYPICAL MULTI-STRATEGY FACTORY

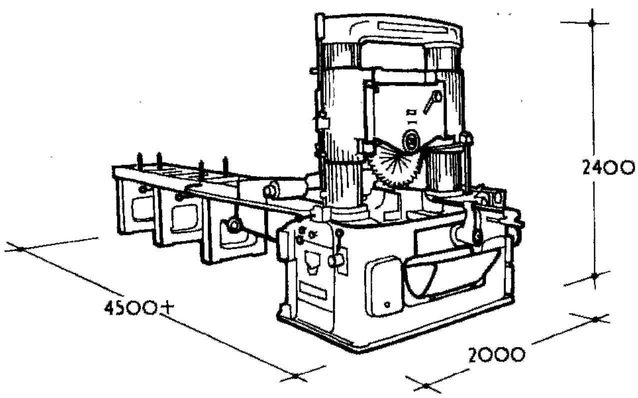
Scope

Type of industries for which appropriate	Buildings of this type are suitable for most manufacturing functions, excluding 'light', 'heavy' and 'process' industries.
Size of project	Total area of production space can vary widely. Average size of all projects is 2500 m^2, so most are smaller. This specification is suitable for projects from about 1000 m^2 upwards.
Type of project	40% of industrial projects are adaptations and extensions of existing premises. This specification sets out the general requirements of those projects, or parts of projects, free from special restraints.

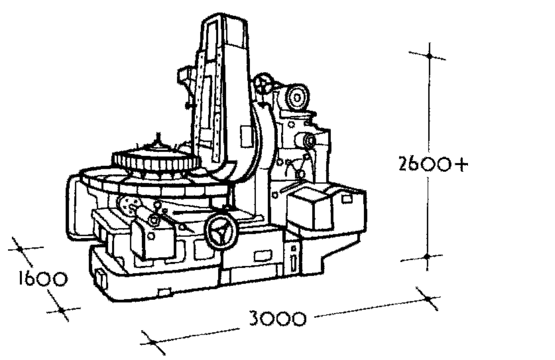
Criterion	Performance specification	Design notes
Requirements of the process		
Adaptability	Should be designed for general-purpose use and not around a particular process. General-purpose characteristics should be maintained wherever possible, e.g. in stores and production warehousing as well as in production space itself.	Building positioned on site leaving maximum possible room for extension, preferably in two directions. Single-storey building designed as a large open space. Standardised, mainly dry construction, easily extended or modified. Framework able to carry a variety of alternative roof and wall claddings, services and handling equipment. Those external walls not on or near site boundaries designed for easy demolition.
Plan shape	Probably not critical except where linear flow processes employed. Rectangular form maximises usable area, facilitates extension.	Rectangular plan form with ratio of long to short sides between 1:1 (minimises internal travel distances where no particular traffic routes are dictated by process) and say, 3:1 (average 2:1).
Physical environment	Process requirements will not usually be critical: workplace environment and energy efficiency are very important.	See under 'Environmental requirements of labour force'. In general, the production process will not require special dust-free conditions, nor will it create a dusty or especially dirty atmosphere. If there are toxic or corrosive hazards within the general production space, these should be isolated by local compartmentation and extraction equipment. High standards of cleanliness (e.g. very exact avoidance of foreign matter) or hygiene (e.g. avoidance of bacterial contamination) for some high-technology factories.
Structural dimensions	Exact plan dimensions rarely critical, except where flow processes employed. Aim should be to optimise convenience for production layouts provided by open space, e.g. the convenience of stanchions for locating small equipment, switches, etc. balanced against the potential adaptability: freedom for service drops and the location of equipment against the cost of greater spans and the loss of overhead craneage.	Span 18 m; bay spacing 12 m or even 18 m (which would permit production line to be turned at right angles if needed). These are proven dimensions in the USA but are greater than those found in many British factory buildings and (excluding 18 m square bays) are unlikely to increase costs significantly over smaller spans.
	Internal clear height probably most critical dimension, for once built can only be modified with difficulty. Height needed for high stacking, overhead equipment, possibly facility to install mezzanines (for works offices, lavatories, control gear, extension of production space, etc.), overhead conveyors, etc. Space for services needed above clear height level.	Internal clear height minimum 6 m. Main vehicle entrance doors (ground level loading) 5 m. For intensive manufacture, high stacking, overhead hoists or mezzanine floors a minimum height of 7.5 m is recommended.
Structural loadings	Within economic restraints, design for heaviest likely loads.	Ideally point loads of 36 kN, but 25 kN sufficient for general-purpose use for buildings less than 6 m high to eaves. For very dense storage, typically mini-load automated component stores, 30 kN/m^2 distributed loading.

Criterion	Performance specification	Design notes
Requirements of the process (Continued)		
Provision for services	Facility to take any production service (water, steam, gas, electrical power, etc.) to any point within production area with minimum disturbance to building, and therefore production.	Production and building services carried in roof space above level indicated by 'clear height', with vertical droppers as required to machine positions. This eliminates overhead craneage, but allows monorail hoists and conveyors. Roof structure designed appropriately. Drainage used to be below floor level, although alternative more costly but flexible arrangements are preferable. A permanent grid of drainage runs beneath the floor (a minimum of, say, one run in the middle of each 18 m span) will minimise disturbance.
Provision for movement of materials and equipment	It should be possible for the production engineer to use the type of material-handling equipment best suited to the product and production methods. Use of fork-lift trucks or similar wheeled materials-handling equipment will be general; overhead conveyors may be used. Cranes more usual in engineering than other industries. Heaviest floor loading is likely to result from wheels of fork-lift trucks (36 kN) and point loads from stacked storage cages and from pallet racking.	Separate foundations will be provided for any special or heavy equipment, especially that which vibrates. Wherever possible, the upper surface of such foundations will be at or below finished floor level. Much equipment is now 'stuck-down' to the floor. Conventionally, an RC floor slab with integral granolithic finish is used, although deterioration of the floor finish is a common problem in industrial buildings. Durable floors can be obtained, but they require a suitable base, good workmanship and close supervision. Particular finishes may be needed to resist attack from acids or oils used in certain processes.
Support for production loads	There are two opposed points of view about supports for such production loads as conveyors, local hoists and other overhead equipment. One is that since production loads cannot be predetermined, they should not be allowed to bear on the building structure, and should be loads carried either on the plant or on a separate structure, as and when this becomes necessary. This can lead to substructures inhibiting floor area and future flexibility. Although initially more expensive the preferred alternative is to design the roof structure to carry a general minimum of local loads, and to provide the facility to suspend conveyors, etc. at will.	Design assumptions might be that bottom boom of trusses (assumed spaced at 3–3.6 m centres) carry uniformly distributed load of 8 kN/m run, and a point load of 10 kN on any panel point at, say, 3 m centres. Structural supports for heavier loads are then provided on an *ad hoc* basis by the production engineer.
Environmental requirements of the labour force		
Visual environment	Practically all visual tasks will be met by illumination levels within the range of 200–750 lux; illumination in the middle of the range will be most common. Limiting values of glare index (as IES Code) are likely to be within 22–28. Colour schemes should be designed both to assist the distribution of light and to minimise fatigue. Natural light design levels: warehouse, packing, large assembly, heavy forging, casting, saw mills, Daylight Factor 2% (say 10–15% floor area) 300–500 lux: Bench and machine work, fine casting, motor repair, general office work, average general purpose lighting, Daylight Factor 4–5% (say 12–15% floor area) 500 lux: Drawing work, medium assembly, weaving, small typesetting, Daylight Factor 6% (say, 15–20% floor area) 500–750 lux: Small inspection and assembly, small bench and machine work, 1000 lux+Daylight Factor 10%.	Either daylight or 'windowless' design. If daylight design, 'north light' is a useful compromise between even light level and energy conservation. View windows in external walls. Fluorescent lighting installation arranged in regular pattern over whole production floor to give 300–500 lux consistent illumination level E_{min}/E_{max} must be at least 0.7 wired in three phases to reduce flicker, and in trunking for simple replacement. Point luminaires may be used in areas of higher headroom, or to provide a high and even intensity. Reflecting surfaces decorated with colours of high reflectivity (e.g. underside of roofs: Munsell value 9), but care that glare from surfaces does not disturb machine operators, e.g. fork-lift truck drivers. For 10% and over use PSALI (permanent supplementary artificial lighting installation). For a general purpose building and for resale the design level should not be below a Daylight Factor of 5%. The method of achieving this must be checked against insulation regulations.

Criterion	Performance specification	Design notes
Environmental requirements of the labour force (Continued)		
Thermal environment	Optimum values of temperature, air movement, etc. will depend largely upon nature of work – whether, for example, it is sedentary or active. Main environmental problem will be to avoid uncomfortable heat in summer. Minimum temperatures: heavy work 10°, light work 13°C sedentary 16°C.	For most light industry plant should be able to provide air temperature of 18–21°C. Mechanical ventilation, at least in factories of average or greater size. Air-change rate (fresh air supply) minimum 5 l/s/person
Acoustic environment	Production processes highly variable in noise output. Control by encapsulating machinery and by using interspersed storage stacks.	Thermal insulation material can give a measure of acoustic control, particularly in providing absorption.
Fire protection	Some industries are regarded as having 'abnormal' fire risk because of the process or materials used; building design will be affected by requirements for additional compartmentation. Generally, fire hazard is classed as 'moderate' to 'low'. The general requirement of fire safety, of a maximum division of the production area into self-contained fire-resisting compartments, is at variance with the general production need for open space, and should be carefully considered. The requirements of the occupiers insurers may be more onerous than the requirements of Building Control. The most common standards to refer to are FM Global and LPCB – Loss Prevention Certification Board.	Fire division walls may be required to obtain acceptable insurance rate. Areas will depend on process, etc. 'Fire curtains' in roof space. Fire vents in roof surface of total area not less than 1% of floor area. Avoidance of combustible materials in sheeted claddings. Sprinklers are also being increasingly required by insurance companies, both over the process and in the roof depth to protect services.
Explosion hazard	Not normally considered critical, but can be accommodated with blow-out panels, or placing part of process outside the main building.	
Building economics	The cost of using a factory building is an important element in the long-term cost of manufacturing. Nevertheless, without adequate justification, few managements are prepared to pay more than the minimum to obtain their essential specification, one reason being that investment in plant, equipment, perhaps labour is likely to show a higher return than investment in buildings (see Sections **3.01** and **3.02**).	A 'basic' specification: concrete floor slab; exposed structural framework and services; simple finishes, such as painted steelwork, untreated concrete, fairfaced brickwork; self-finished insulating materials forming roof lining.



14.19 *Cold sawing machine*



14.20 *Gear cutting machine*

7 NON-PRODUCTION ACCOMMODATION

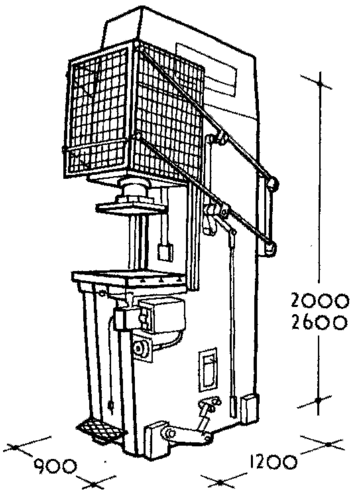
7.01 Offices

There is a tendency for administrative and production space to be interchangeable. Two types of offices will be required in close conjunction with the production space:

- Foreman's desk space in sight and proximity of work supervised. This is formed from easily demountable components to allow for rapid relocation. Sometimes to avoid floor obstructions this accommodation is raised to mezzanine levels where visibility is improved.
- Executive offices for the local administrative staff, or the company headquarters where these are not elsewhere. This type of accommodation is designed in accordance with Section 16, Offices, Shops and Railway Premises Act 1963, and will depend on the numbers to be accommodated. As a rough guide, allow 10–15% of the production floor area, or 5 m^2 per person.

7.02 Lavatories

For sanitary accommodation see Chapter 5. A first aid facility is normally provided in conjunction with this.



14.21 *Hydraulic pedal press*

7.03 Canteens

Staff are not allowed to eat in dirty or dusty surroundings. If the process demands a clean environment the reverse may apply, and the importation of food into the working area may need to be discouraged. Canteens are therefore nearly always now provided. See Chapter 17 for details of design.

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15 Industrial storage buildings

Jolyon Drury, updated with advice from Stephen George & partners

CI/SFB 284
UDC 725.35

KEY POINTS:

- *Modern warehouses need the height to use mechanical aids at maximum efficiency*
- *Scales have increased massively; a 'big shed' now is ten times the size of the largest building only 20 years ago*

Contents

1 INTRODUCTION

Few industrial storage buildings are designed to make a profit (steel stockholders and cash and carry stores are exceptions); the majority perform the function of a valve or pipeline, limiting the supply of a product to suit demand, to stabilise prices and allow steady and economic manufacture within fluctuating market conditions. Industrial storage is therefore a service at a cost that must be minimised.

The payback period most frequently chosen for such a building is 25 years. During that time, it is likely that the storage method will need to change at least three times, and that the type of goods handled will change even more frequently. Flexibility for expansion and manner of use are therefore important design considerations.

Large distribution buildings are now even larger than they have ever been. Twenty-five years ago, a large industrial 'shed' contained approximately 100 000 ft^2 of space. Industrial storage buildings are now being constructed 10 times that size.

At the time of writing, industrial storage buildings cost approximately £32 per square foot to build (£336 per square metre). This price regime and changes to building regulations (Part L in particular) may well make the purchase and reinvention (through recladding, etc.) of an existing building unviable, i.e. it would be cost effective to construct a new building.

2 IDENTIFICATION OF WAREHOUSE AND STORAGE TYPES

The three main types are:

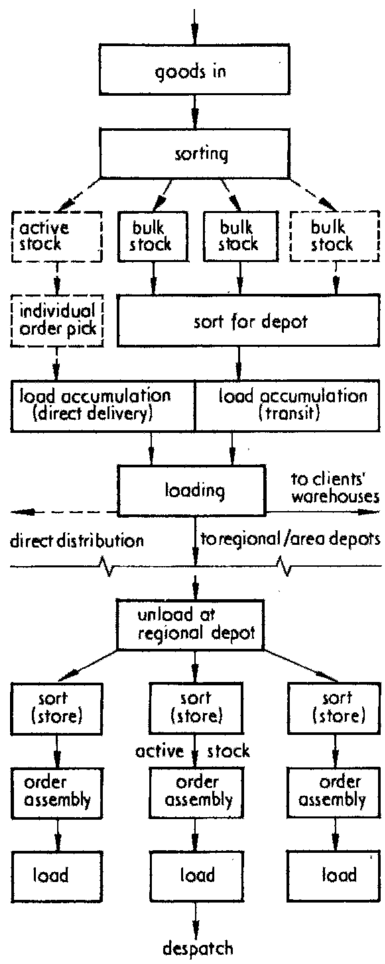
- Transit between manufacture and the market, **15.1**.
- Distribution: similar to a transit unit, but accepts a wide variety of goods from a number of manufacturers, sorts them into orders and distributes them to a number of outlets, **15.2**. A components warehouse for a factory performs a similar function.
- Repository: a warehouse used for stockholding, either as a service (e.g. a furniture repository) or within a company (e.g. a cold store), **15.3**.

3 PRELIMINARY DECISIONS

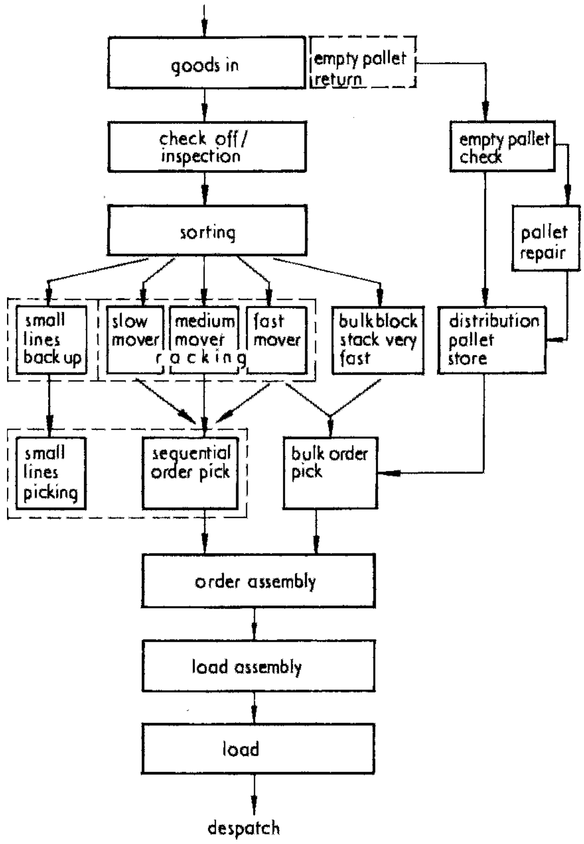
The initial decision about what type of building is required will involve a choice between these three types, dependent on the client organisation's needs. Such a study is generally undertaken in cooperation with a specialist consultant. Other factors to be considered at the pre-design stage are:

1 The orientation of the loading bays and the heavy vehicle marshalling areas. Future expansion must be taken into account.
2 The orientation of the goods sorting and load accumulation areas which must be related to the disposition of the storage area, i.e. block stacks or racking and loading bays.
3 Will the required bulk of the building be acceptable in terms of planning consent?
4 Are the existing roads suitable to meet increased demand?
5 Is there public transport for operatives?
6 Are there night operating restrictions which will entail special features to muffle night noise?

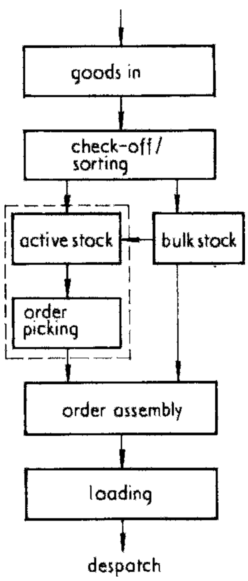
Can this be catered for by any design measures/configurations?



15.1 *Relationships in warehouse for transit between manufacturer and market*



15.2 *Relationships in distribution warehouse*



15.3 *Relationships in a stockholding warehouse. The bulk stock area is dominant*

Table I Typical internal clear heights for storage areas

Minimum clear internal height* (m)	Type of storage
5–5.5	Minimum-cost low-rise block stacking warehouse. Suitable for light industrial factory use
7.5	Minimum for any industrial storage building combining racking and block stacking
9+	When narrow-aisle trucks are used
15–30	Fully automatic, computer-controlled warehouses and stacker cranes are to be used

* Clearance for structural memvers, sprinklers, lighting must be added to obtain overall height of buildings

Table II Classification of materials for handling and storage as unit loads

Description	Examples	Storage method
Materials not strong enough to withstand crushing – not suitable as integral unit load	Automobile components, made-up textiles, electrical appliance components, manufacturing chemists' sundries, light engineering products, glassware	On pallet in rack
Materials strong enough to withstand crushing – suitable for unit loads	Casks and drums, sawn and machined timber, sheet materials	On pallet, or self-palletised and block stowed
Irregular-shaped materials, strong in themselves suitably packed into unit loads	Goods in cases, creates or cartons	On post pallets and stacked, on pallets in rack or self palletised
Bagged materials which form a flat surface under load	Grain, powder and similar	On pallet and block stowed
Bagged materials which do not form a flat surface under load or will not take pressure	Forgings, moulded or machined parts, nuts and bolts	On pallet in rack
Large irregular loose materials	Moulded plastics; sheet metal pressings	On post pallets and stacked
Small irregular loose materials	Machined and moulded parts, pressings, forgings	In cage pallets and stacked
Materials hot from production process	Castings and forgings	On post pallets and stacked
Materials too long to be handled other than by side loader or boom	Steel sections, tubes, timber	Horizontally in tube or bar racks
Materials strong enough to withstand crushing but subject to damage	Partly machined automotive parts, painted finished materials, books	Steel box pallets with special partitions
Perishable goods	Frozen meat, vegetables, drink	Cartons, soft packs pallets, box pallets, etc.

4 HEIGHT, AREA AND TYPE OF HANDLING SYSTEM

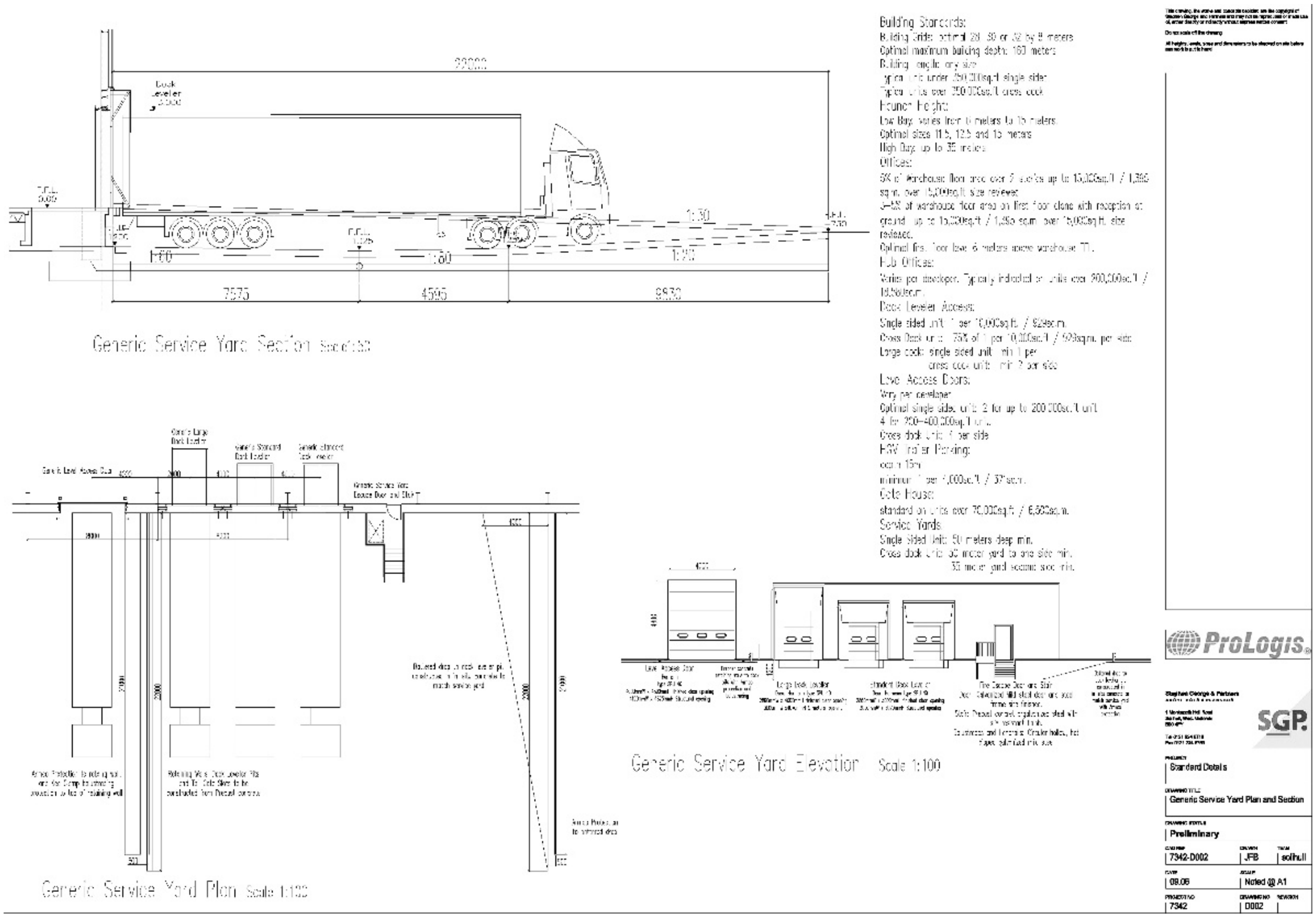
The most economical way of gaining volume for storage is to use height – Table I; this affects the choice of the handling system to be employed. Typical structures are shown in **15.4**. Consider also:

- The type of unit load to be handled and the physical characteristic of the goods – crushability, durability, the type of unit loads that will be assembled after sorting (Table II).
- The speed of turnover. This will determine what storage method is the most efficient.
- The position of the construction and movement joints within a concrete floor. Generally, columns should be hidden within the racking, as should the floor joints. Access widths should suit the selected loading mechanisms and racking should not obscure exits. In a portal frame construction, columns are typically set at 32.2 m centres. A grid of 8.2 m can accommodate two dock levellers.

5 STORAGE METHOD

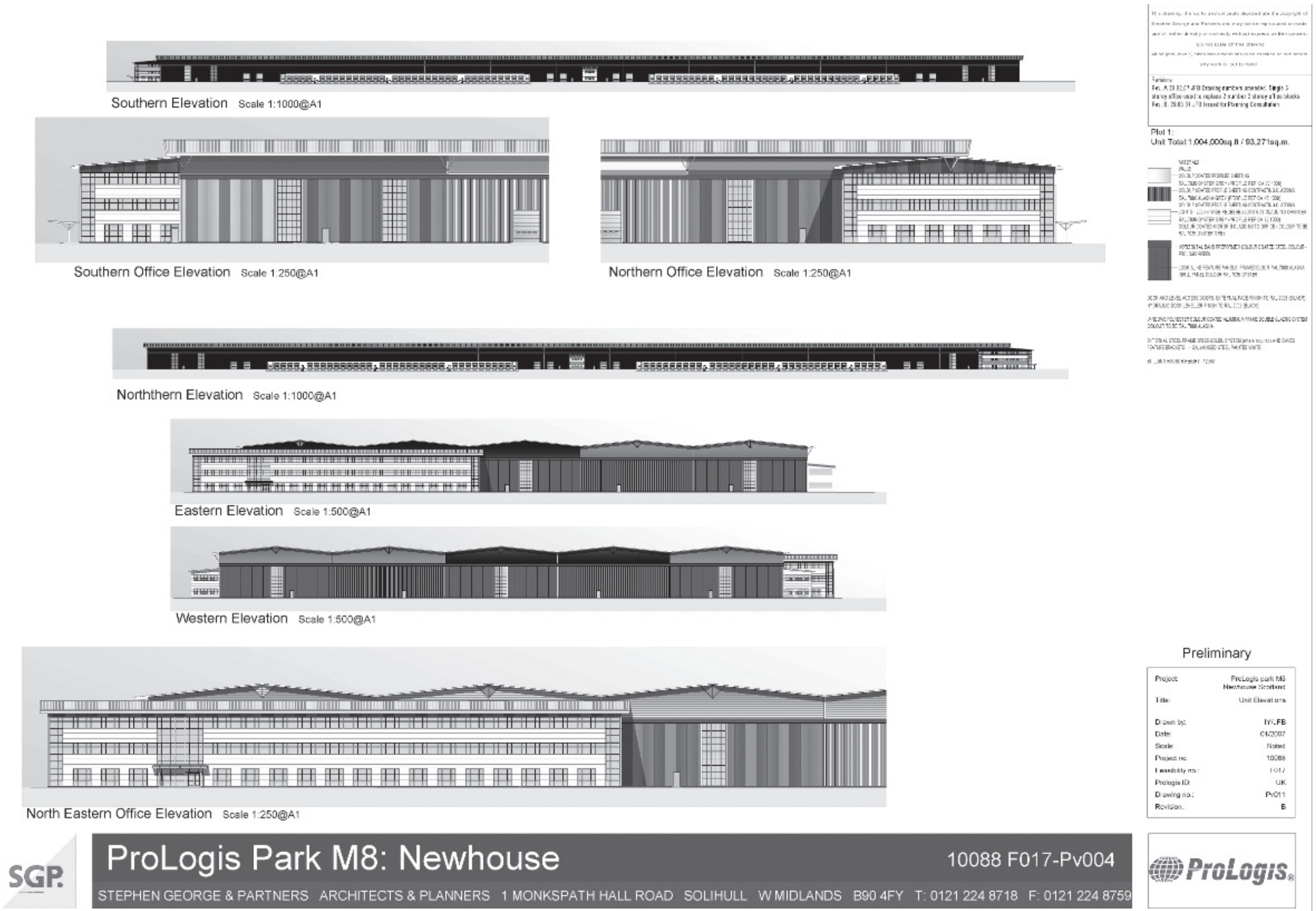
Storage methods (see Tables III–V) include:

1 Very fast throughput involving a limited number of products: block stacking, **15.5**, rather than racking. First in, first out, or first in, last out configuration, depending on the shelf life of the goods.
2 A wider variety of goods, but still with fast turnover: drive-in racking, **15.6**, or 'live' (roll-through) storage, **15.7**. Pallets are placed into racking up to four positions deep, with the pallets'



a *Generic service yard section and elevation*

15.4 *Examples of typical structures (continued over)*



b *Modern 'big box' warehousing – 520×170 m industrial storage unit for ProLogis by Stephen George & Partners. The unit contains 78 loading bays on its northern and southern sides, with 5000 m*^{2} *of office space*

15.4 *Continued*

Table III Mechanical handling

	Block stacking	Post pallets	Drive-in racking	Beam pallet racking	Gravity live storage	Powered mobile racking
						
Cubic space utilisation (%)	100	90	65	35–50	80	80
Effective use of installation capacity (%)	75	75	75	100	70	100
Accessibility of unit loads (%)	10	10	30	100	30	100
Order picking (%)	Poor	30	30	100	30	100
Speed of throughput	Fastest	Good	Poor	Good	Good	Quite good
Load crushing	Bad	Nil	Nil	Nil	Some	Nil
Stability of load	Poor	Fair	Good	Good	Fair	Good
Ease of relocation	Not applicable	Not applicable	Fair	Good	Difficult	Difficult
Speed of installation	Not applicable	Not applicable	Good	Fastest	Fair	Slowest
Rotation of stock	Poor	Poor	Poor	Good	Excellent	Good

Table IV Manual handling

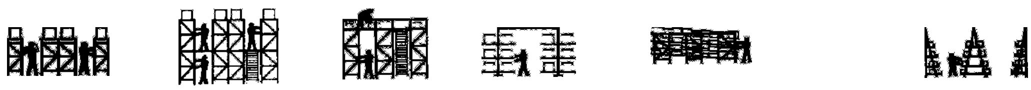
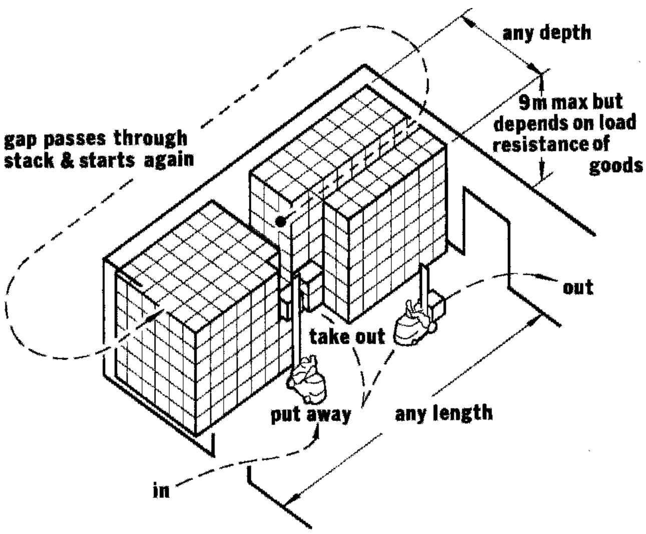
	Long-span Shelving	Tiered shelving	Raised storage area	Cantilever shelving	Lightweight live storage	Fir tree racking
						
Cubic space utilisation (%)	45	45	80	50	65	25
Effective use in installation capacity (%)	95	95	50	100	70	70
Accessibility of goods	Good	Good	Poor	Good	Excellent	Good
Ease of relocation	Good	Fair	Difficult	Fair	Very difficult	Best
Load range (kN/m^2)	2–9.5	2–9.5	2.8–11	2–4.7	Up to 0.2 kN/m run of track	2.6–4.4 kN/arm
Speed of picking	Good	Fair	Poor	Good	Very good	Good
Speed of installation	Very good	Good	Fair	Fair	Slowest	Fastest
Rotation of stock	Very good	Good	Poor	Very good	Excellent	Very good

Table V Load mounting

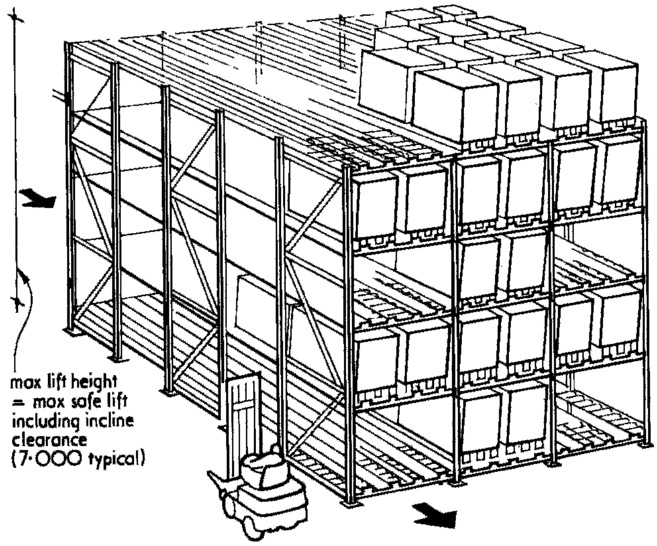
Load mounting	Type of load								
	Heavy unstable load	Flat cards/sheets	Sacked/ bagged loads	Small unit loads	Drums Reels Barrels	Coils	Casks	Bales	Textile Raw materials
									
Special cradle with/without pallet	*								
Standard pallet		*	*	*	*	*	*	*	
Flat board pallet + decking supports		*	*		*	*			
Direct mounting on timber panels		*	*	*		*	*	*	*
Drum supports					*				
Post pallets cage/bin			*	*		*	*		
Coil supports					*	*			*
Skips/skeds							*		
With skids									

edges resting on runners attached to the rack's uprights. First in, last out. Live racking involves inclined storage lanes. For heavy pallets and shock-sensitive goods, braking and separating equipment can be incorporated.

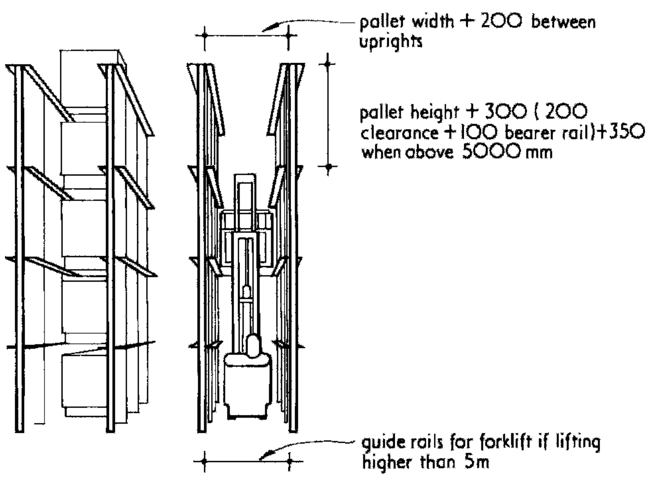
3 Pallet racking, **15.8** and **15.9**. For a wide variety of goods, the speed of throughput decreases. Pallet racking is the solution with a large variety of products, brands or pack sizes. Each pallet is normally allotted a unique position in the racking.



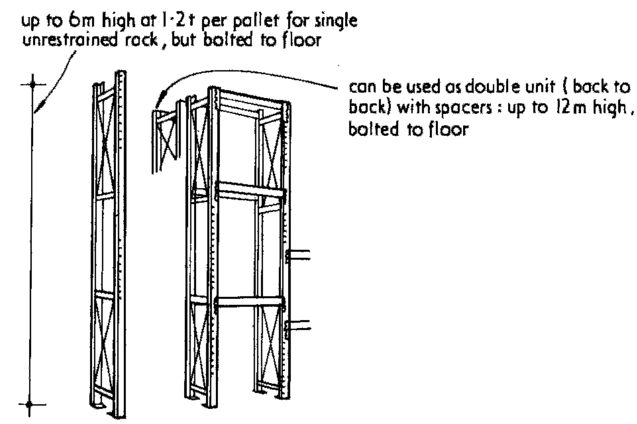
15.5 *Method of block stacking for stock rotation. Where cartons are being stacked on pallets, a height of three pallets is the normal maximum*



15.7 *Roll-through racking*



15.6 *Drive-in racking for fork-lift. A maximum depth of six pallets, with fluorescent lighting in the racking structure. Four-pallet depth is preferable*



15.8 *Pallet racking*

6 DISPOSITION OF THE RACKING

There are two common alternatives:

- The rack is oriented at 90° to the order assembly areas, with the fast turnover stock in the bays nearest to it or
- One complete racking face is oriented along one side of the order assembly area and reserved for very fast-moving stock.

7 RELATIONSHIP OF STORAGE METHOD, MECHANICAL HANDLING EQUIPMENT AND BUILDING HEIGHT

The effect of handling equipment on warehouse section is shown in **15.10–15.13**. These factors depend on site conditions:

1 For very constricted sites where a large volume of goods needs to be held high-bay, automated warehouses can prove the most economical solution. Such warehouses have been built up to 30 m high, the racking being used as the roof and wall cladding supporting structure. Handling machines run on fixed tracks, **15.13** and **15.14**.

2 For medium- and large-scale installations where full automation is not justified, storage areas up to 12 m high allow free-standing racking (bolted to the floor) with aisle widths marginally wider than the largest pallet, **15.15**. 'Narrow-aisle trucks' used in this type of plant are free path machines based on fork-lift technology, **15.16**.

3 Where the cost of high-bay stacking and high-lift machinery is not justified, fork-lifts and reach trucks are used, **15.17**. Reach trucks are suitable for conventional pallet weights (1 – 1.5 tonnes) over flat floors. They can lift to 9 m and operate in aisles of about 2.8 m. A fork-lift truck can carry heavier loads but requires aisles of 3.2–4 m width, **15.18**. Heavier trucks are required to lift greater heights and tend to require a greater aisle width.

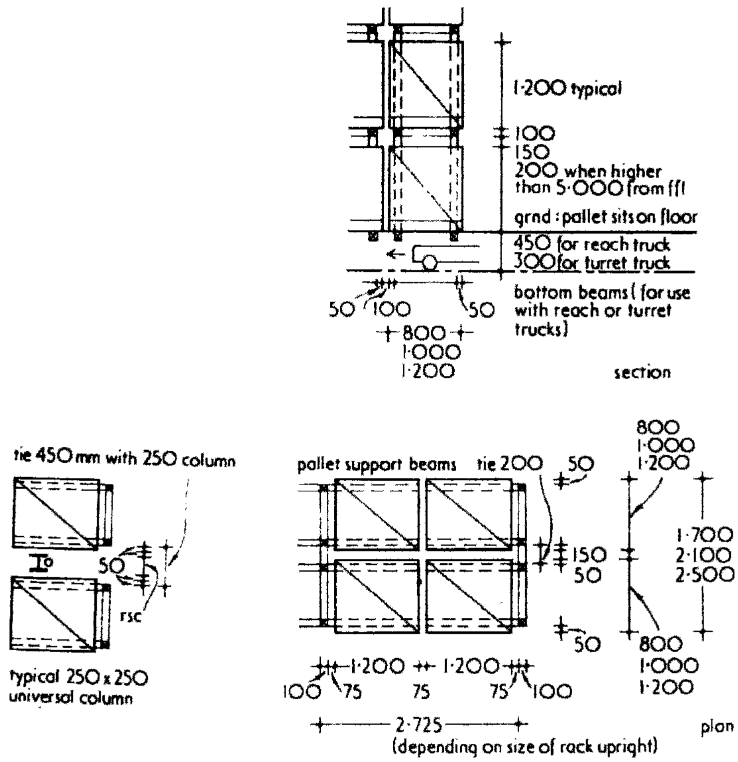
4 Mobile racking where pallet racking is mounted on mobile bases and rests face to face may be suitable where storage is to be installed in an existing structure or where the site is limited in area and the turnover of products comparatively low. It is costly to install and the floor slab has to accept double the normal distributed load.

8 OUTLINE SPECIFICATION

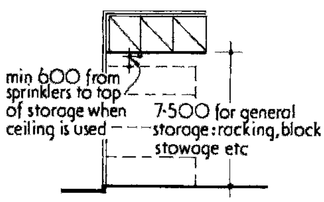
8.01 Storage area

Pitched roofs, though strong on first cost, waste storage volume and run the risk of being damaged by handling equipment: Three factors favour the flat or low pitch roof type:

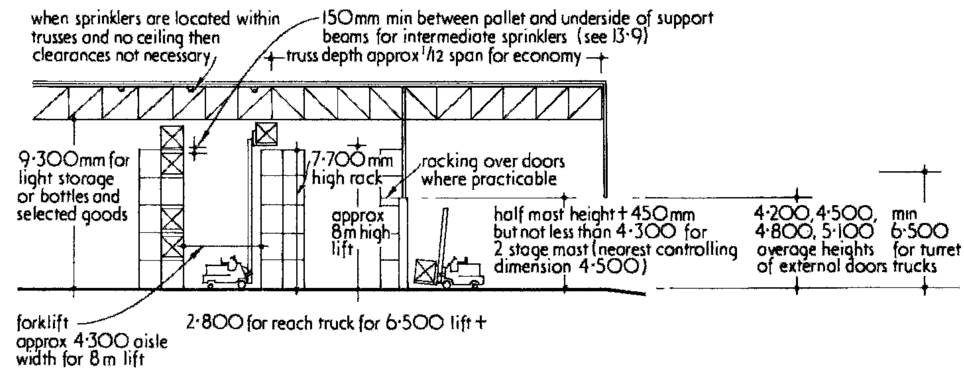
- The column pitch can be wide, **15.17** and **15.18**.
- They are more adaptable to a change of use or changes dictated by new processes.
- They are more suitable for the installation of services such as cooled air.



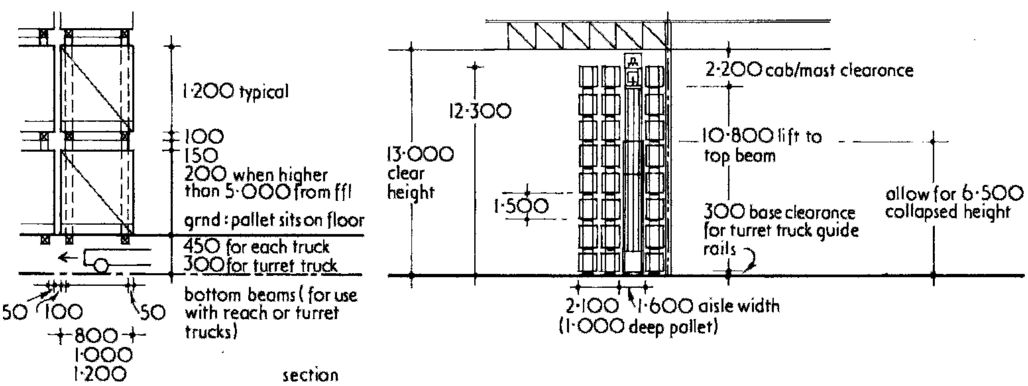
15.9 *Construction of pallet racking*



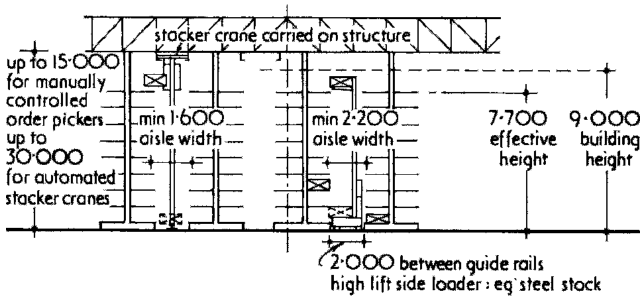
15.10 *Section through small warehouse for fork-lift operation*



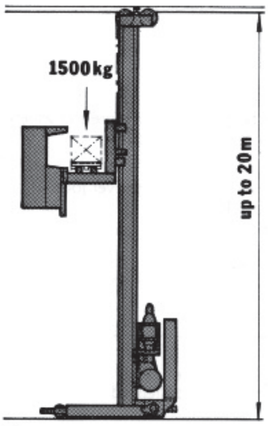
15.11 *Section through large warehouse for fork-lift or reach truck operation*



15.12 *Section through warehouse for narrow aisle truck operation. Floor tolerance ±3 mm in 3 m run*

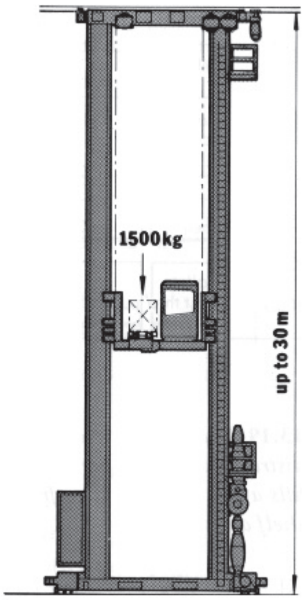


15.13 *Section through warehouse for stacker crane handling (left) and steel stockholding with side loader (right)*



a

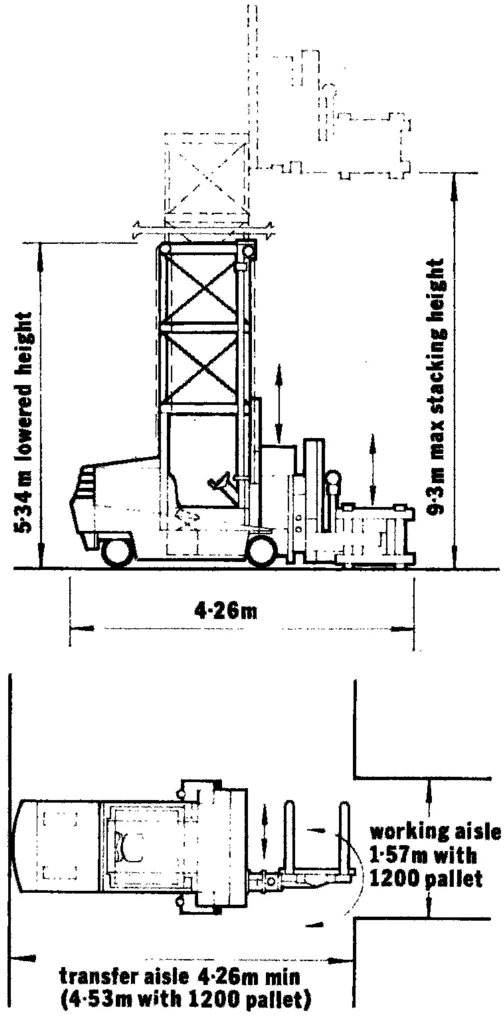
a *Order picker*



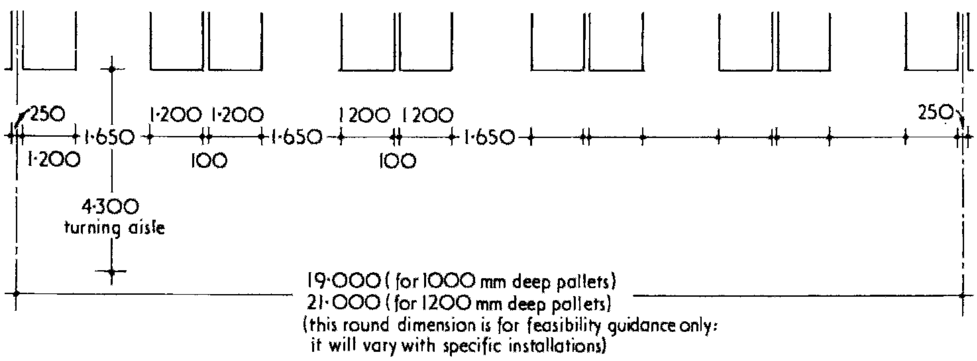
b

b *Stacker crane*

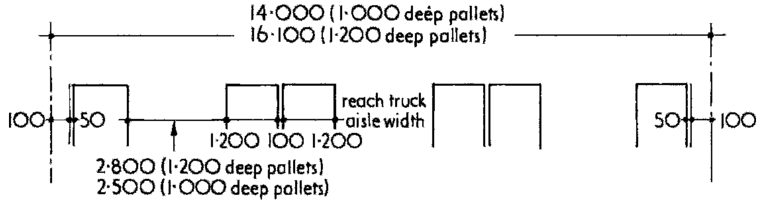
15.14 *Dimensions of:*



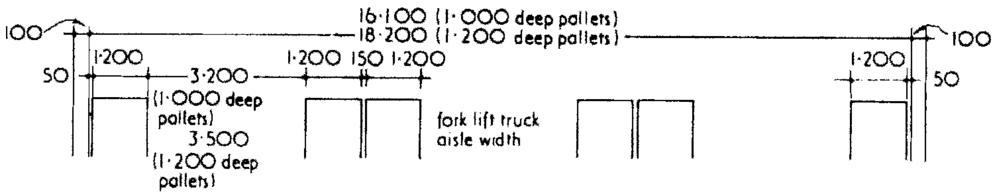
15.15 *Free path stacker/order picker with elevating cab, fixed mast and rotating fork. The four-post mast gives extra stability. Out of the aisle can also be used as a fork-lift truck. The free lift on the fork carriage also allows differential movement between the pallet and the picking platform. Minimum building height 2.2 m above top lifting level*



15.16 *Relationship to structure of narrow-aisle truck aisles*



15.17 *Relationship to structure of reach truck aisles*



15.18 *Relationship to structure of fork-lift truck aisles. Note: 16100 mm span is common to fork-lift and reach truck requirements*

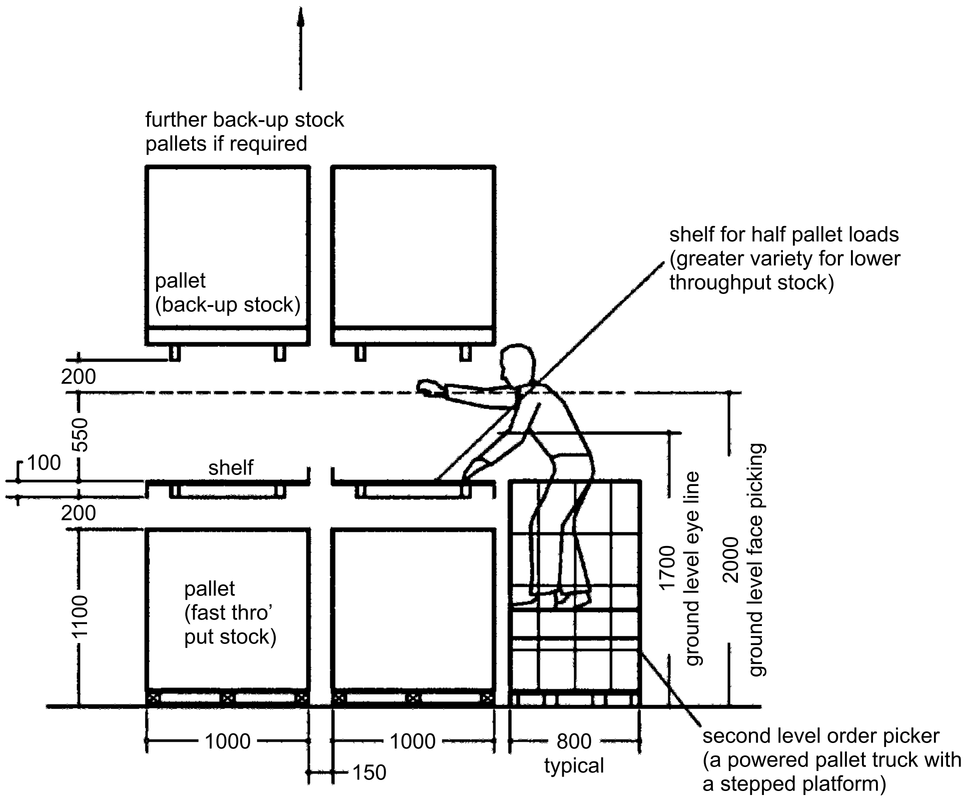
8.02 Order picking and assembly

Space demanded will vary with the type of business involved and the method of order assembly, in turn generated by the method of despatch and transport. For instance, a brewery warehouse may despatch whole pallet loads, **15.7**, but a pharmaceutical warehouse may handle and assemble a very large number of small items. Therefore, it may require a large area for order assembly, **15.19–15.21**.

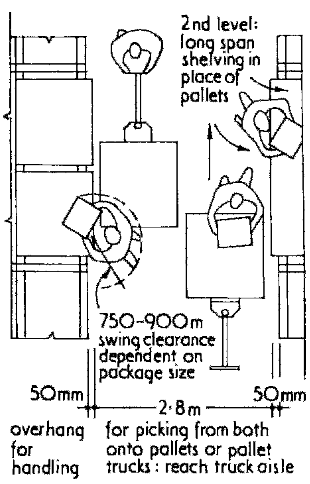
8.03 Loading bay and load accumulation area

The loading bay is the critical link between the storage and distribution system, **15.22**. It usually combines inward and despatch movements. It must provide sufficient space for:

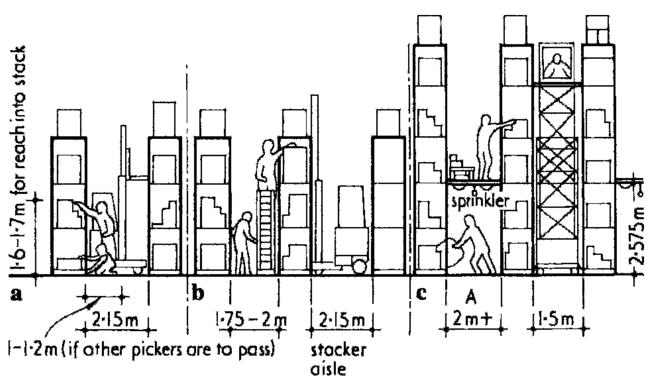
- incoming goods to be checked off;
- empty unit load devices to be removed; and
- despatch loads to be accumulated



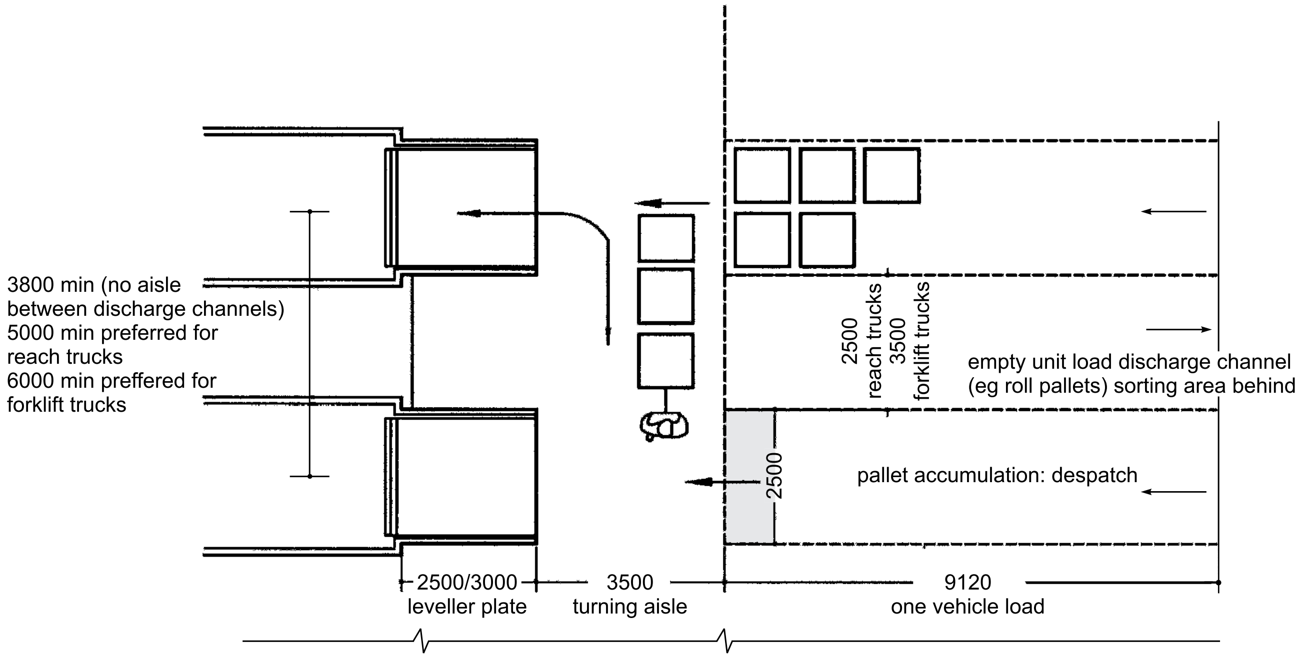
15.19 *Second level order picking, typically used for food distribution and supermarket replenishment. The operative fills a roll pallet or cage from the pallet on the floor and the shelf above it*



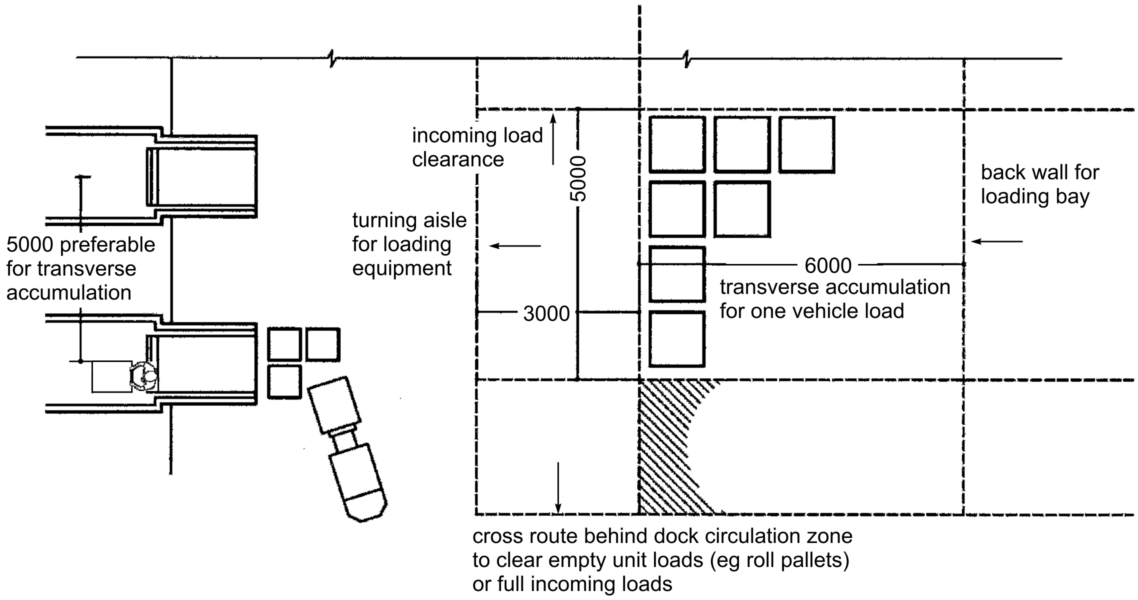
15.20 *Reach truck aisle for second-level order picking*



15.21 *Stacker aisles for order picking:* **a** *Pulling from lower levels – replenished by stacker truck* **(15.25)** **b** *Alternating pick-up and replenishment aisles* **c** *Multi-level alternative aisles, replenished by narrow aisle truck*



a *Where available*



b *Where depth is limited*

15.22 *Combined arrival/despatch loading bays*

A full vehicle length (12 m) should be allowed as the zone behind the loading dock.

8.04 Office and amenity areas

Large warehouses can employ more than 100 order-picking staff (mainly female) each shift. Extensive washing and changing facilities will be required. Also space for operatives to rest and smoke outside the storage area. See BS 6465-1:2006 (which supercedes BS 6465-1:1994) for full details of sanitary installations.

Clients and developers generally prefer the office element of a distribution building to face the main entrance to the site, leaving loading/unloading at the rear. If this means, offices facing south (taking advantage of sunshine) it may mean fixing brise soleil to the façade.

8.05 Equipment maintenance areas

Most mechanical handling equipment for internal use is battery-powered electric. The batteries need charging at night or after shifts of about 12 h. Requirements for maintenance areas are:

- a distilled water supply;
- 1 tonne hoisting tackle for removing batteries;
- fume extraction; and
- acid-resistant floor.

Major services and repairs tend to be done off site.

9 SECURITY

Warehouses are, by definition, prone to theft. Most thefts are carried out during working hours. This can be minimised by ensuring that:

- There is no direct access from loading bays to the warehouse, especially through the order-picking zone, without supervision.
- Access from office accommodation to the warehouse should be visible from the office area.
- The changing rooms, showers (necessary in cold stores) and WCs should not have direct access from the warehouse, and

equally, should not be accessible from outside. Visiting drivers should have segregated WC facilities.

- If small, valuable goods are involved, a search room may be required.
- Operatives' parking should be well separated from heavy vehicles' parking and away from the loading area.

10 HANDLING EQUIPMENT

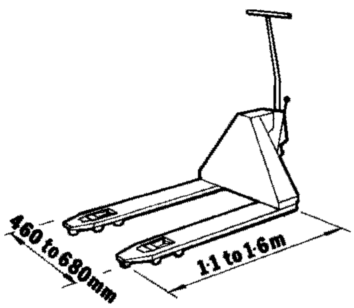
Goods handling systems are now highly specialised and only their general layout falls into the architectural remit. Computerised and robotic handling systems, controlled from a central database, can represent half the build cost.

Some typical handling equipment is shown in **15.23–15.27**.

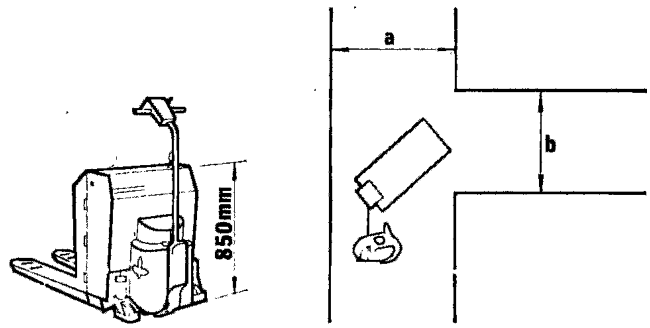
11 FIRE PRECAUTIONS

It is worth remembering that the goods stored within a building may be worth more than the building itself. Therefore, it may be worth considering the protection of the goods rather than the building – indeed, this may be a crucial part of the operator's business plan. Compartmentalisation and the judicious arrangement of sprinklers may need to be considered.

Table 12 of Approved Document B (Fire Safety), which came into effect April 2007, provides details about compartment sizes. If a building is fitted with sprinklers throughout, there is no need to compartmentalise; if a decision has been taken to dispense with sprinklers, then buildings must be compartmentalised. Each compartment must be no larger than 20 000 cubic metres and no higher than 18 m. In high bay buildings (up to 35 m), automatic sprinkler systems must be installed. Note: the more sophisticated and more sequential the sprinkler system, the less potential water damage.



15.23 *Manual pallet truck. For use inside the warehouse building up orders, loading vehicles on raised docks or with tail-lifts, general pallet handling. Increasingly used in retail premises for handling bulk goods. Capacity up to 1500 kg generally and for short-distance travel (operatives soon tire when pushing heavy loads any distance). Forklengths available 0.8–1.6 m, widths from 460 to 680 mm. Heights: lowered 83 mm, raised 203 mm. Pallet width should be 150 mm over fork (typical length is 1.06 m for a 1.2 m pallet). Where gangways are narrow and stability is important, a heavy truck should be used with maximum width between forks. This device will turn in its own length but needs additional clearance for overhangs. Normally, it requires level floors to operate satisfactorily, but large wheels in nylon or with solid rubber tyres plus articulating axles are available for use in older buildings; although instability may occur. Steel wheels are available but are less popular. Where loading ramps are used, pallet trucks with brakes should be used. Adaptors are available for use as a stillage truck*

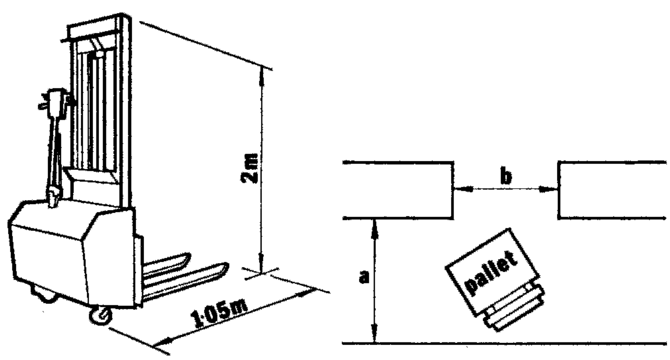


15.24 *Powered pallet truck. For internal transfer, loading vehicles on docks, order build-up, transporting roll pallets to load assembly position. For use with all types of pallet and cages. Capacity 1800–3000 kg, forklengths 0.75–1.8 m, speeds up to 3.6 km/h running light, widths up to 850 mm, usually 760 mm. Long forks available to carry three roll pallets at once. Special forks for drums and paper rolls. Will turn in its own length but needs additional clearance for overhangs. Some have 200° turn on the single power steering wheel. Aisle width depends on forklength:*

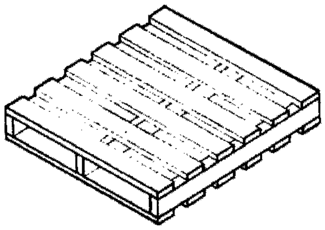
a *(90° stacking aisle) = 1840 mm (truck + 1 m pallet)*

b *(intersecting aisle) = 1570 mm*

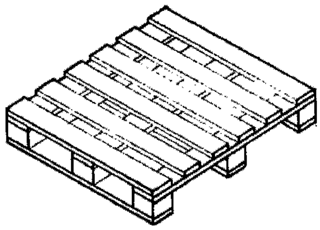
Turning circle 1.78 m radius with 960 mm long forks. This device requires level floors and a three-phase charging point. It can manage ramps up to 10%. Some larger-capacity units can also be ridden on, and can tow non-powered pallet trucks if long distances are involved



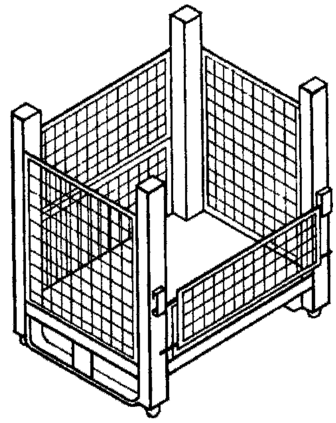
15.25 *Power travel and lift pedestrian-controlled stacker truck. When travelling the pallet rests on the stacker frame which has travel wheels. Power lifting is independent of the travel frame, and is directly into the rack. Only suitable for short travel distances. Lifting range up to 3.6 m. Can be supplied with attachments. Capacity up to 1500 kg at 600 mm centres, straddle width 0.86–1.3 m, travel speed up to 4.8 km/h laden. Will turn with full load on 2.1 m aisle*



a *Two-way entry pallet*

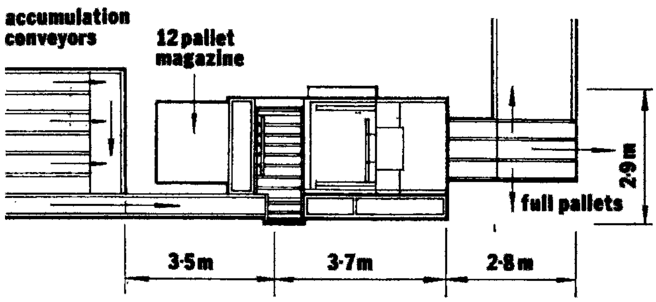


b *Four-way entry pallet*



c *Post pallet*

15.26 *Types of pallet*



15.27 *Plan of typical palletising machine. Top right is buffer track required for slower shrink wrapper*

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16 Agricultural buildings

John Weller, Rod Sheard, Frank Bradbeer and others

CI/SfB: 26, 565
UDC 728.94, 725:88
Uniclass: F5676

KEY POINTS:
- *Farming is an industry subject to continual change*
- *Animal welfare and concern about pollution is leading to legislative constraints, both domestic and European*

Contents

1 INTRODUCTION

1.01 The agricultural economy
Agriculture in the UK and also in the rest of Europe (particularly in the West) is becoming big business. Small farms and small farmers are becoming increasingly rare; marginal land is coming out of production. Owners of hitherto agricultural land are seeking other revenue-earning uses such as golf courses.

1.02 Planning
Buildings, irrespective of the enterprise, should be planned in terms of their functions for storage, processing or production. Food, like other industrial processes, should be designed for materials handling and flow-line production. Superimposing linear buildings within or over traditional courtyard forms is both a visual and a tactical problem.

Stock housing produces effluents. Farm waste management is an essential part of the building design and increasingly subject to statutory control. Wastes should normally be recycled, provided that this is done safely.

1.03 Building functions
Depending on managerial philosophy, building functions may be specialist, semi-specialist or flexible in their form. Farmers tend to equate flexibility with general-purpose layouts and with low capital investments; this can be a false equation. The loss of quality control, often difficult to evaluate, makes most 'cheap umbrellas' poor performers for specific end products.

The demand for flexibility reflects two factors – lack of confidence in stable markets, and the rapidity of technical change. UK food production is essentially controlled by EU policy (via CAP, the Common Agricultural Policy), which aims at market stability. Technical change is liable to continue, although expansion of power demand may become more selective.

1.04 Stock housing and storage requirements
In simple terms, most storage requirements are those of containers: cylinders, bins and bunkers. Wide-span portals are suitable for some layouts for cattle, bulk storage and general farm machinery. Compact and insulated 'boxes' of low profile are best for calves, pigs or poultry. They may include total or partial environmental control. In contrast, 'kennels' are cheaply framed, semi-open, mono-pitch structures suitable for some cattle and pig layouts.

1.05 Construction and procurement
Most buildings are partially or wholly prefabricated, or are purchased under package deals. Standard frames can be obtained 'off the shelf', and infilled by 'self-build'.

Performance specifications are rare. Overall costs are lower than for most buildings of similar type, partly due to lower standards being demanded (see BS 5502, Buildings and Structures for Agriculture, in its many parts).

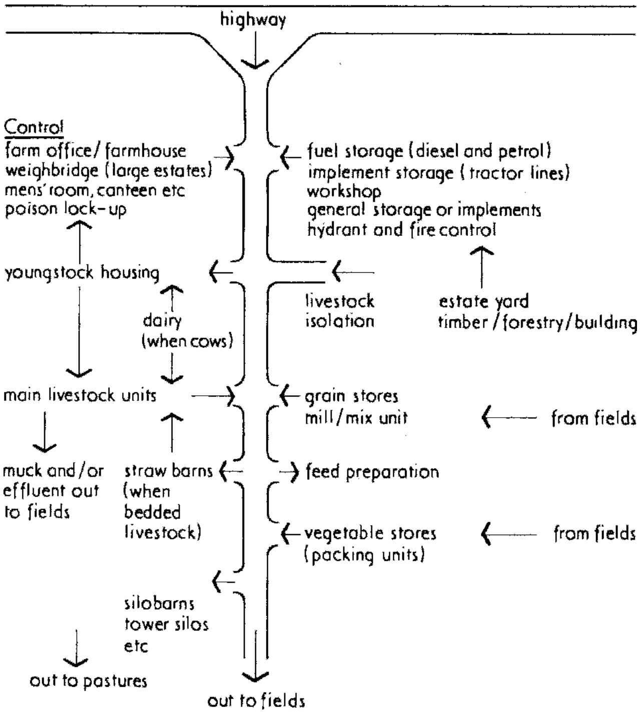
1.06 Lifespan of buildings
Most pre-1960 buildings are inefficient for modern production and many traditional buildings are redundant. A few are suitable for casual storage, administration, isolation units, or spare boxes. The issue of redundancy is not easy to resolve. Some historic barns have been dismantled and relocated. Tourism, recreation and craft work are all encouraged in rural areas. A tenth of all farms have some tourist income. In upland areas, it may be the principal source of income. Farm planning should allow for alternative uses for buildings and land.

The normal economic life for farm buildings is ten years, though some are depreciated over five. This is a major design constraint. Some estates may permit a longer term of 20–60 years, especially for 'umbrella' enclosures. Grants are available for all except plastic, cheap tents and for factory farms (i.e. without supporting land). EU grants are more generous but require carefully prepared development proposals.

The moving, alteration or demolition of historic farm buildings may be subject to listed building legislation. Some unlisted structures are also subject to listed building consent because they are curtilage structures to a listed farmhouse or manor house: the demolition of an unlisted but curtilage building usually requires listed building consent even if their alteration and repair does not.

1.07 Appearance
Farm building appearance, especially since many are exempt from control and since most are cheap compared to other building types, is a contentious issue. Simple forms, good colour, defined planes, and coordinated fittings such as vent pipes and flues, combined with careful siting and landscaping, make buildings acceptable. However, large roof surfaces are likely to conflict with vernacular buildings and can, near rising land, become dominant. Component design is often poor and unrelated to the basic structure. Surrounds to buildings, including yards, tanks, fences, etc. are often more unsightly than the buildings.

1.08 Criteria
Farm management in relation to resources of land area and terrain, climate, soil, capital, etc. is such that every farm building problem is different, despite prefabrication, package deals and BS 5502. In many enterprises, it is difficult to establish a good design brief. The basic layout, **16.1**, shows the relationships between the elements of the farm and the main service road. **16.2** shows a typical farm.



16.1 *Basic layout, mixed arable and stock farm. Although the arrangement shown has been stylised, in fact farms are usually linear to the main service road*

2 FARM ANIMALS

Average sizes and weights of animals are shown in **16.3**. Width of animal given is normal trough space allowed (i.e. about two-thirds of overall width). Length given is normal standing (not fully extended).

3 FARM MACHINERY

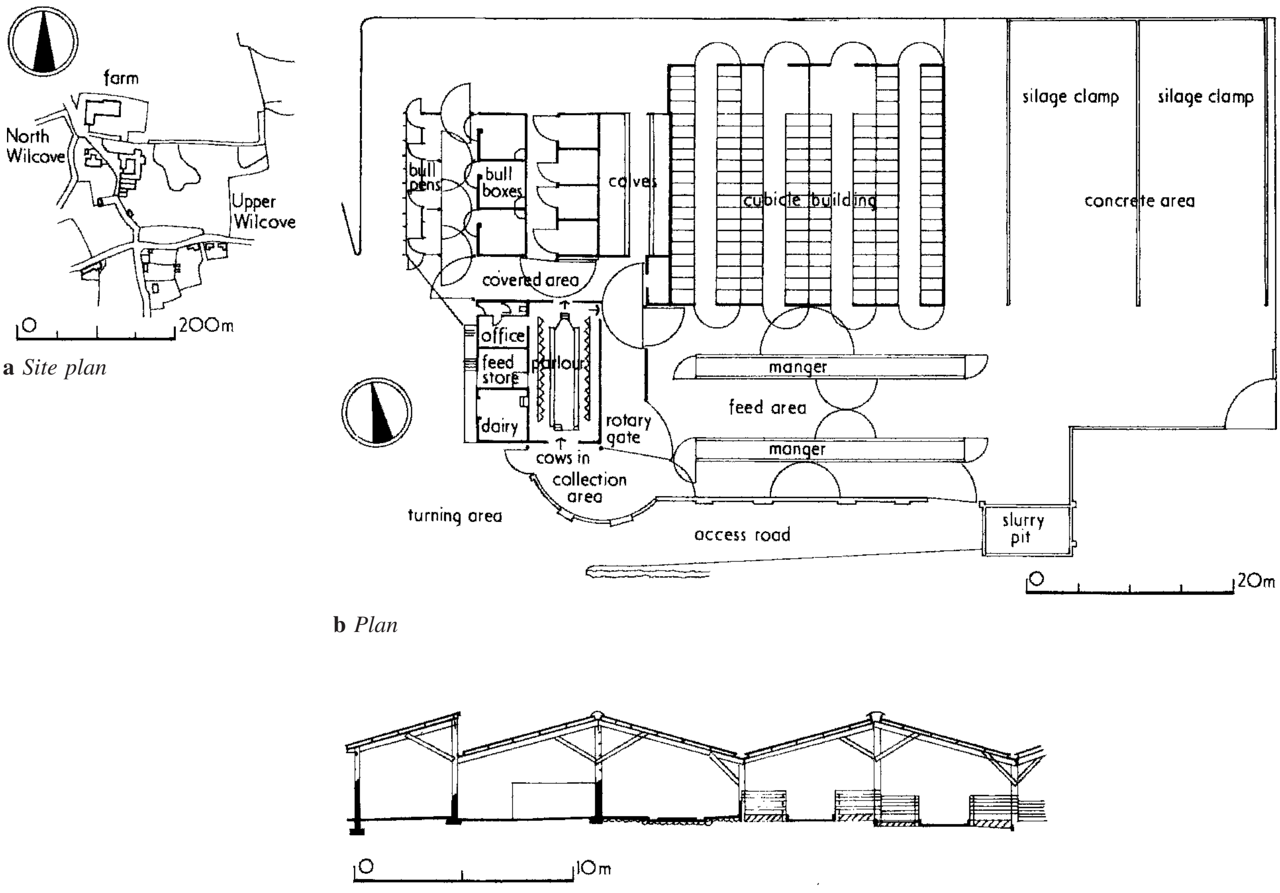
Average sizes and weights of tractors and other machinery are given in **16.4**.

4 DAIRY CATTLE HOUSING

Table I gives dimensions for cattle housing; examples suitable for a 120-cattle unit are shown in **16.5** and **16.6**. A typical cubicle house is 27 m wide × 55 m long plus 10 m turn area at one end plus a 4 m road. A 'kennel' has the same basic dimensions but the roof is lower and is held by the cubicle division and the passage is not completely roofed, as **16.7**. Various systems of milking parlour are shown in **16.8**. Rotary parlours are now considered obsolete, and the current favourite is the herringbone, **16.9**.

5 BEEF CATTLE AND CALF HOUSING

Straw-covered and slatted yards for beef cattle are shown in **16.10** and **16.11**. A calf house is illustrated in **16.12** and **16.13** is a 'general-purpose' straw-covered yard for cattle (700 mm/head for manger for adults, 500 mm for yearlings).

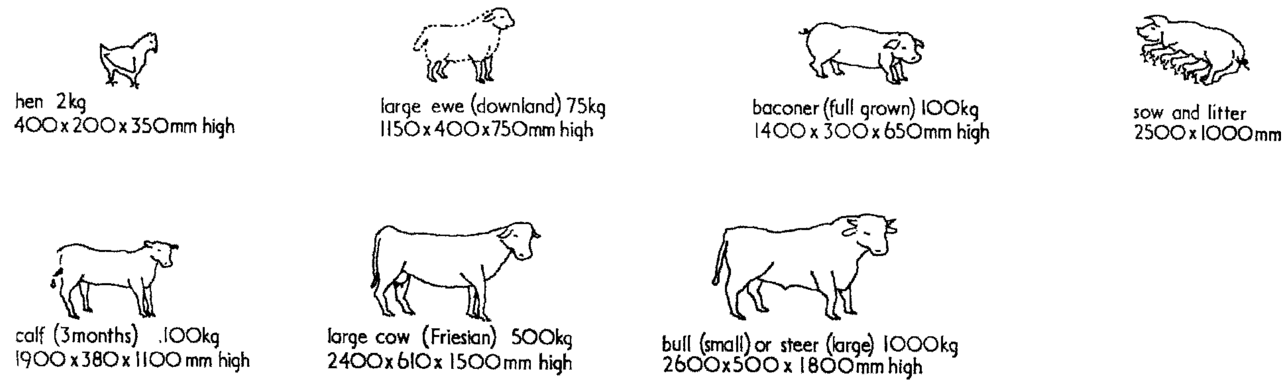


a *Site plan*

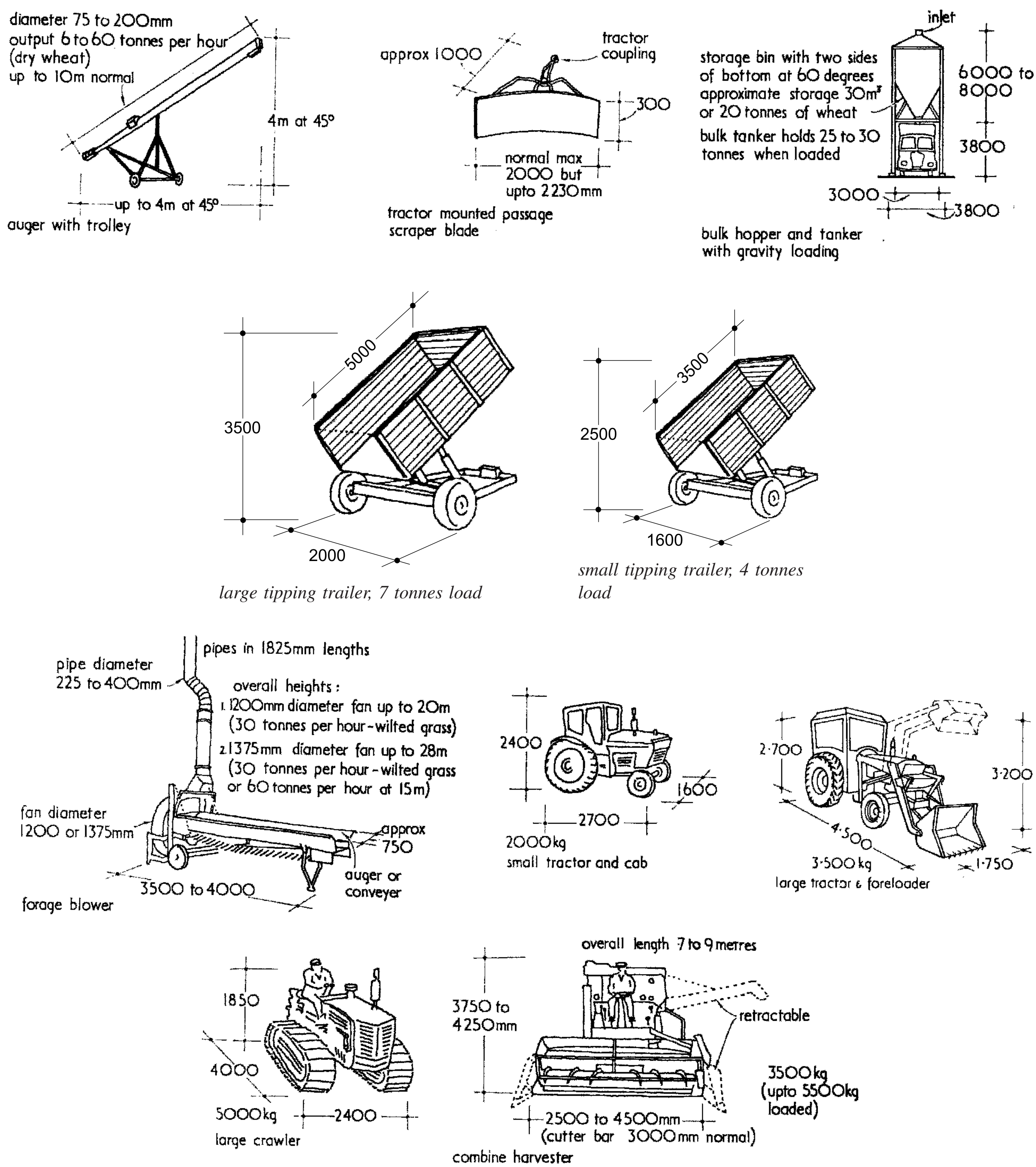
b *Plan*

c *Part cross-section*

16.2 *Typical farm: Wilcove*



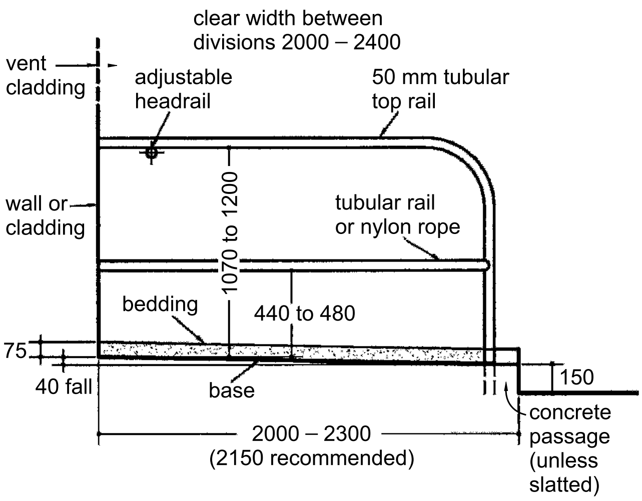
16.3 *Farm animals: average size and weights*



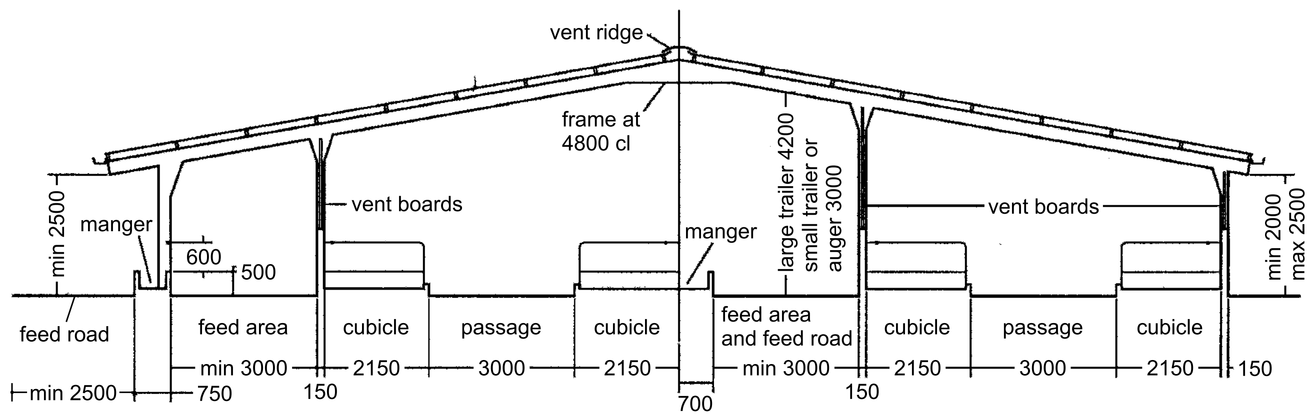
16.4 *Farm machinery: average weights and sizes*

Table I Dimensions of cattle housing

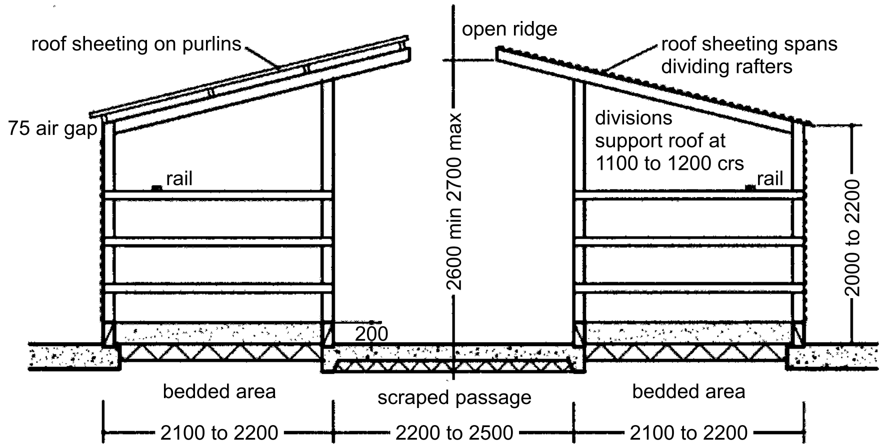
Mass of cow (kg)	Dimensions of cubicles (m)			Dimensions of cowsheds (m)					
	Length including kerb	Length behind trough	Minimum clear width between partitions	Length of standing without trough	Length of standing behind 0.75 to 0.9 wide trough	Clear width between stall divisions of a two-cow standing	Gangway width	Minimum width of feed passage (if any)	Longitudinal fall along gangway and dung channel
350–500	2.00	1.45	1.00	2.00	1.45	2.00	Single range: 2.0	0.9	1%
500–600	2.15	1.60	1.10	2.15	1.60	2.15			
600–650	2.30	1.80	1.15	2.30	1.80	2.40	Double range: 3.0		
650–700	2.30	1.80	1.15						
700–800	2.50	2.00	1.20						



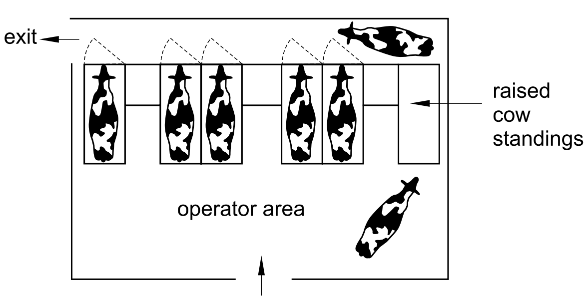
16.5 *Section showing cubicle division: dimensions for Friesian cows*



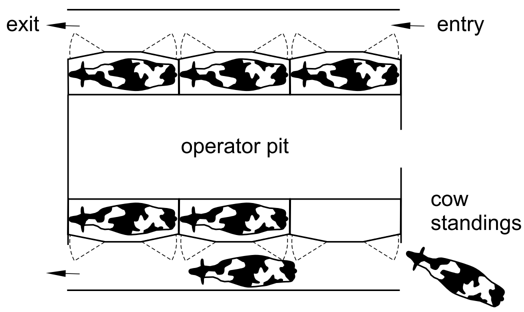
16.6 *Alternative sections of cubicle house showing perimeter feeding to left of centreline, centre feeding to right*



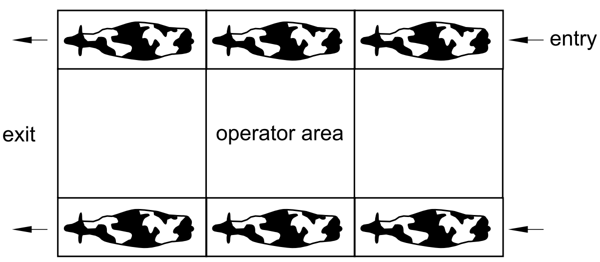
16.7 *Section through kennel for beef or dairy cattle*



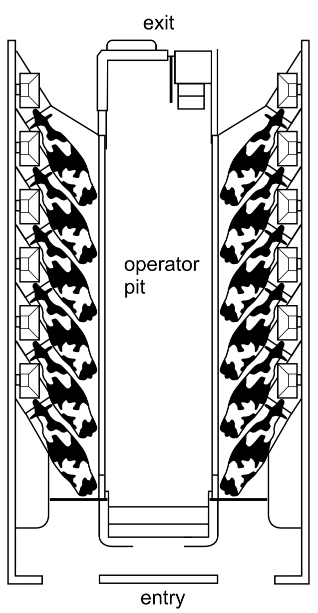
a *abreast*



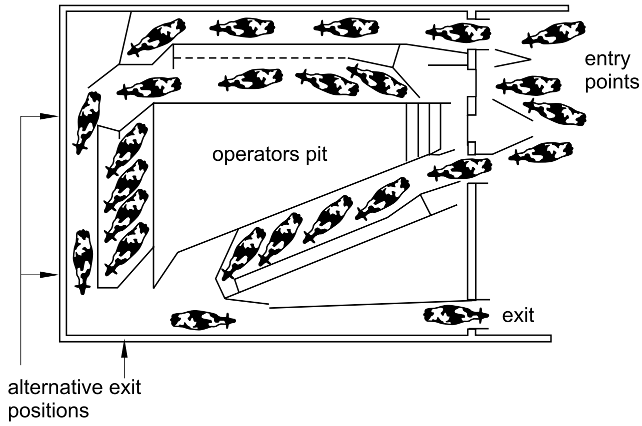
b *tandem*



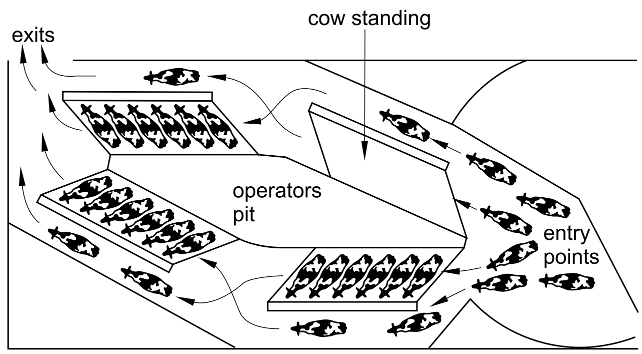
c *chute*



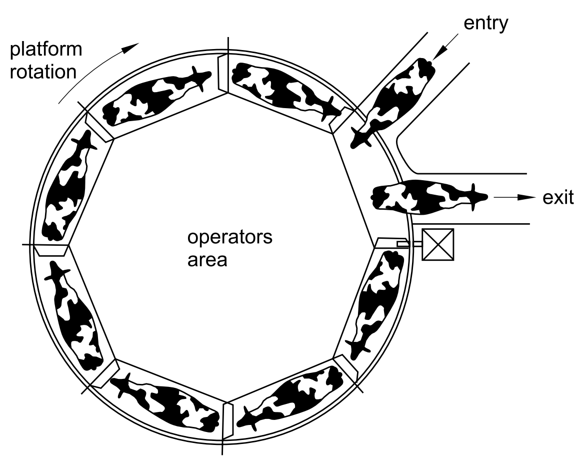
d *herringbone*



e *trigon*

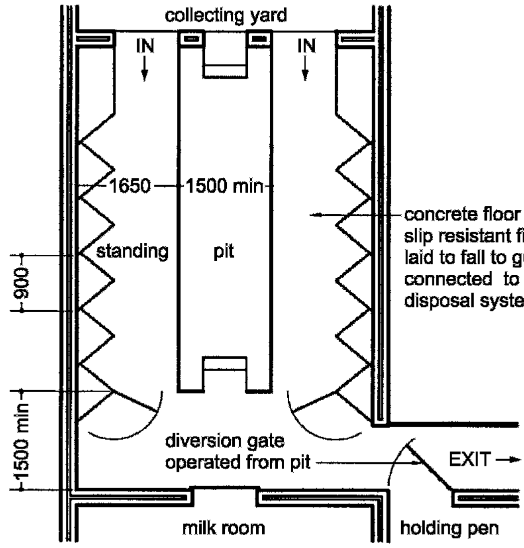


f *polygon*

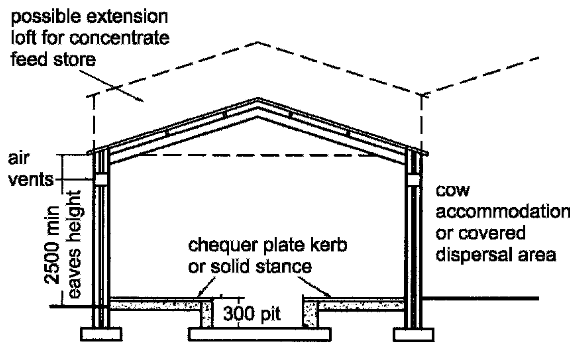


g *rotary*

16.8 *Milking parlour systems*

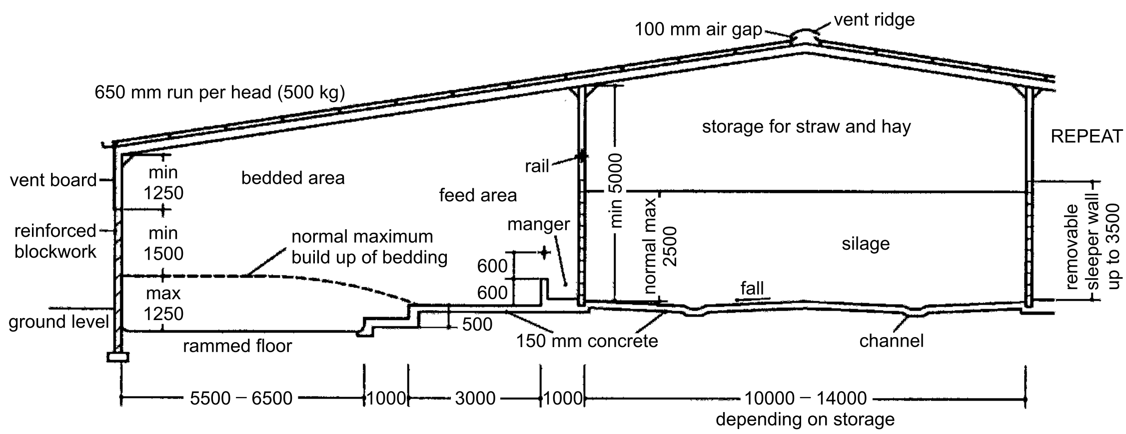


a *plan*

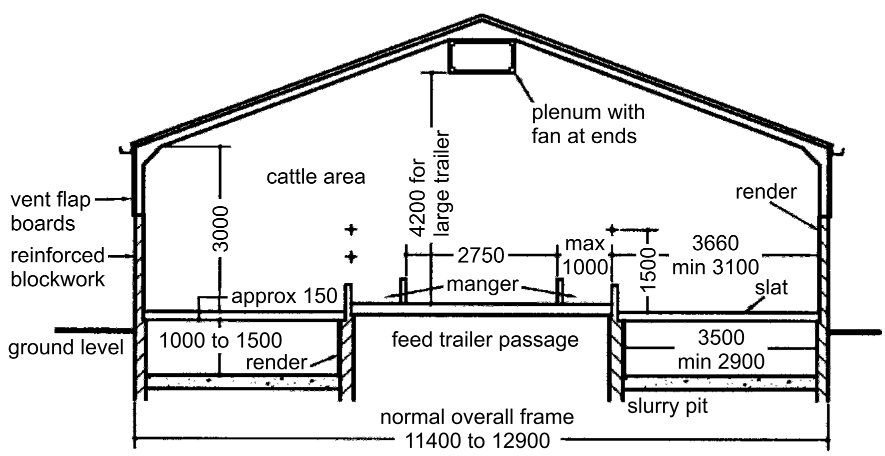


b *section*

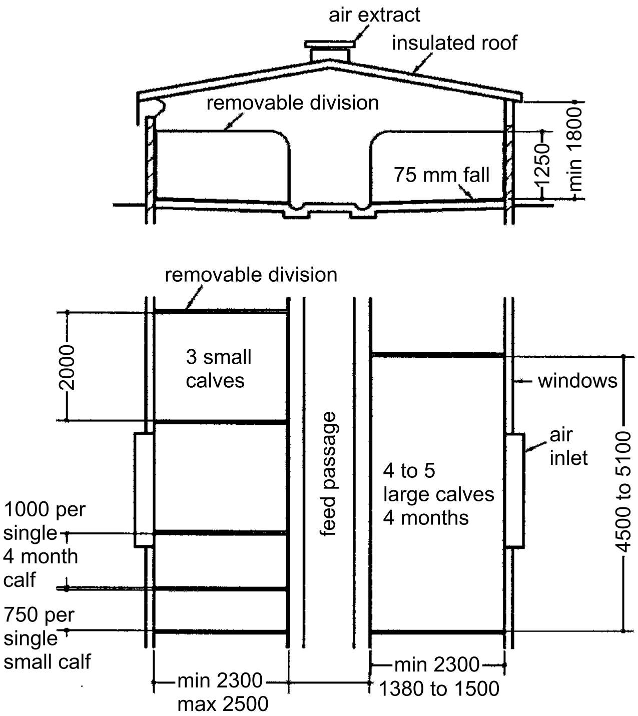
16.9 *Herringbone system milking parlour*



16.10 *Section through straw-covered yard for beef cattle with easy feeding*



16.11 *Section through slatted yard for beef using self-unloading trailers. Note: fully slatted yards are not approved by Brambell Committee*



16.12 *Plan and section of calf house*

6 SHEEP HOUSING

Required dimensions are given in Table II. A section through sheep housing is shown in **16.14**. A dipping tank suitable for large breeds is shown in **16.15**.

7 PIG HOUSING

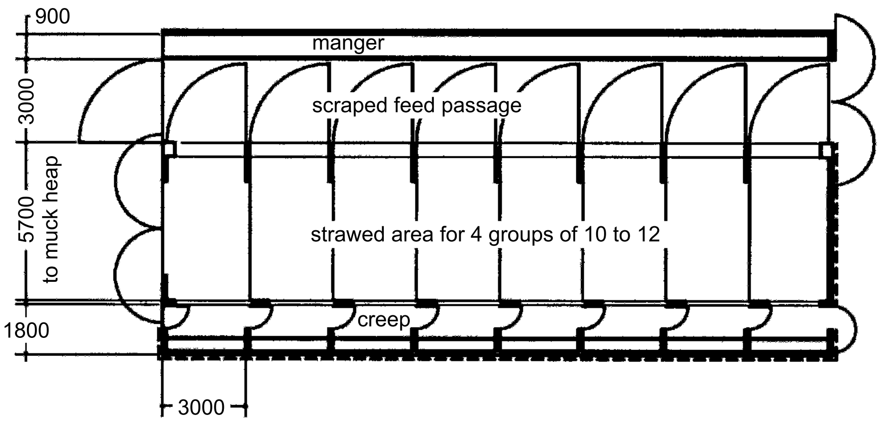
Table III covers the dimensional requirements. Three types of fattening house are shown in **16.16–16.18**, and two types of farrowing house in **16.19** and **16.20**.

8 POULTRY HOUSING

Dimensions are given in Table IV. Rearing, fattening and egg houses are shown in **16.21–16.25** and a pole barn for fattening turkeys in **16.26**.

9 CROP STORAGE AND EFFLUENT PRODUCED

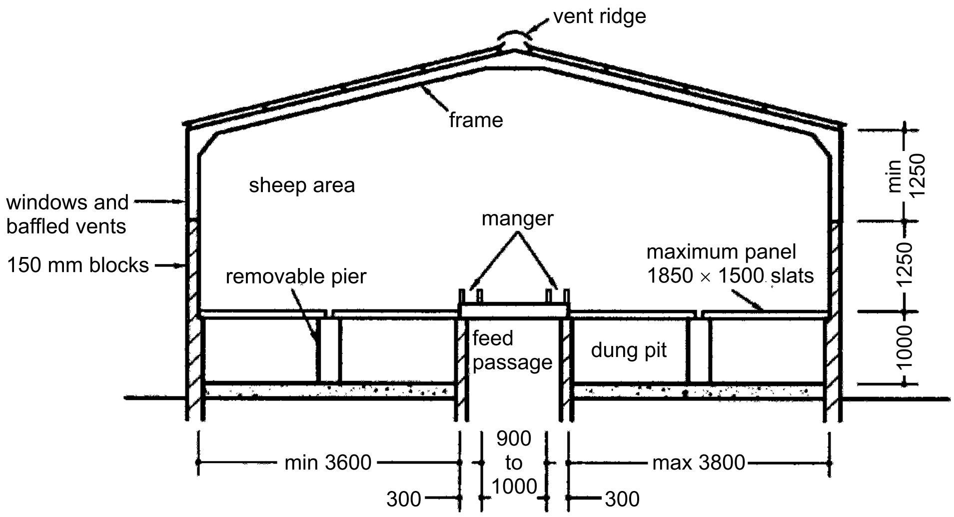
Some typical feed and produce stores are shown in **16.27–16.34**. Table V indicates the scope of manure likely to be produced.



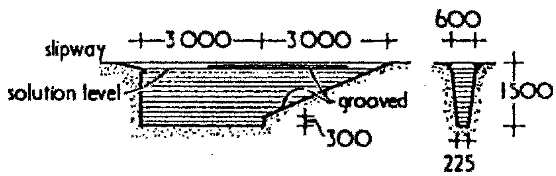
16.13 *Plan of general purpose straw-covered yard for cattle*

Table II Sheep housing

Type of sheep	Age or mass	Area per animal (m^2)		Length of trough (mm) depending on feeding system		
		Perforated floor	Solid floor with straw	Compounds/ concentrates	Ad lib hay/ silage	Big bale silage, self-feed
Pregnant ewes	45–60 kg	0.8	1.0	400	175	100
	60–75 kg	0.9	1.2	460	200	150
	75–90 kg	1.1	1.4	500	225	150
Ewes with lambs	Individually penned	–	2.2			
	Groups, 45 kg ewe	1.0	1.3	420	175	100
	Groups, 68 kg ewe	1.4	1.7	460	200	150
	Grouped, 90 kg ewe	1.7	1.8	500	225	150
Lambs	Individually penned	–	2.1			
	Group housed	–	1.5			
	Creep area at 2 weeks	–	0.15			
	Creep area at 4 weeks	–	0.4			
Hoggs	20–30 kg	0.5	0.7	300	125	100
	30–40 kg	0.6	0.8	350	150	100
	40–50 kg	0.8	0.9	400	175	100



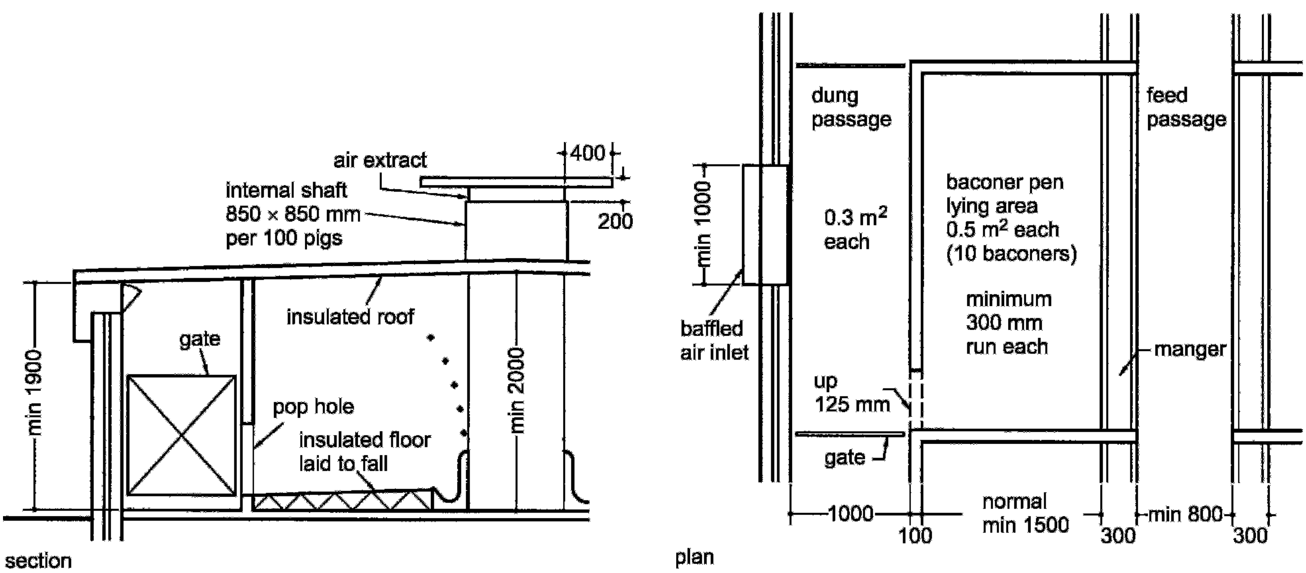
16.14 *Sheep housing, manger run per head:*
fattening lamb 300 mm
ewe and lamb 400 mm
yearling 500 mm



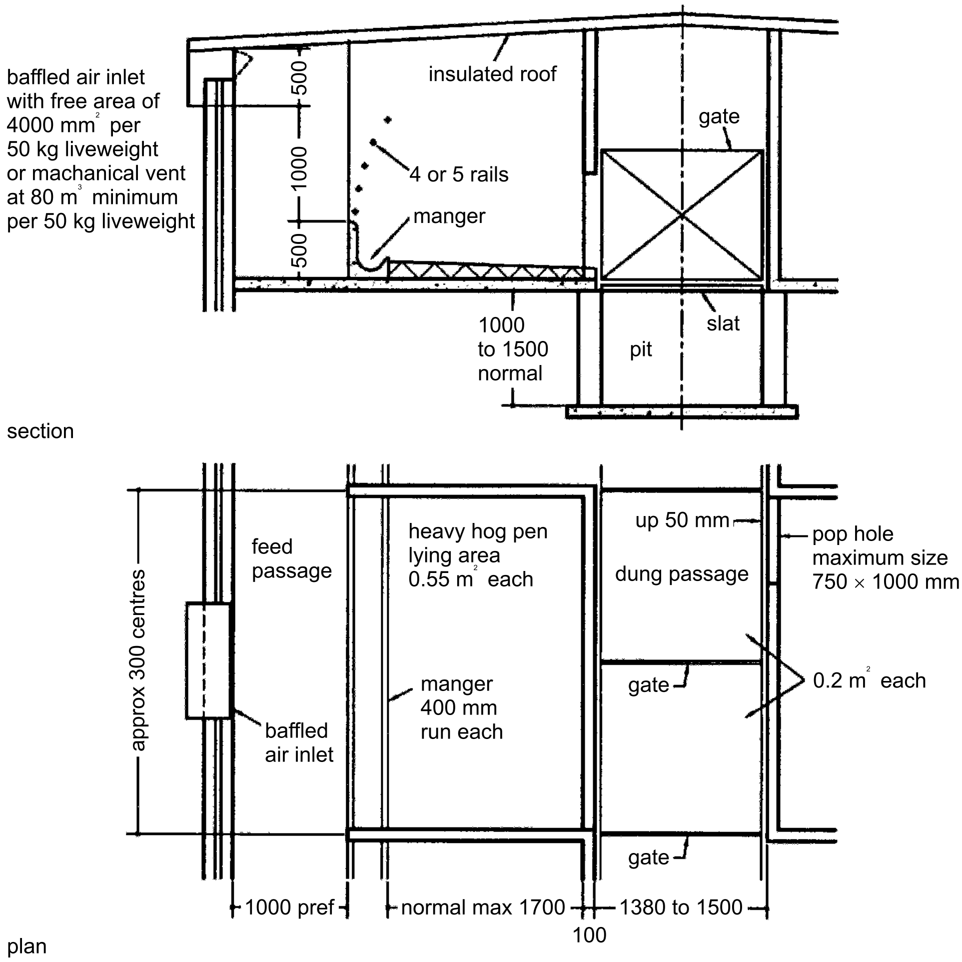
16.15 *Sections through dipping tank for large breed ewes. Allow 2.25 litres of solution per head*

Table III Pig housing: dimensions required for 10 animals

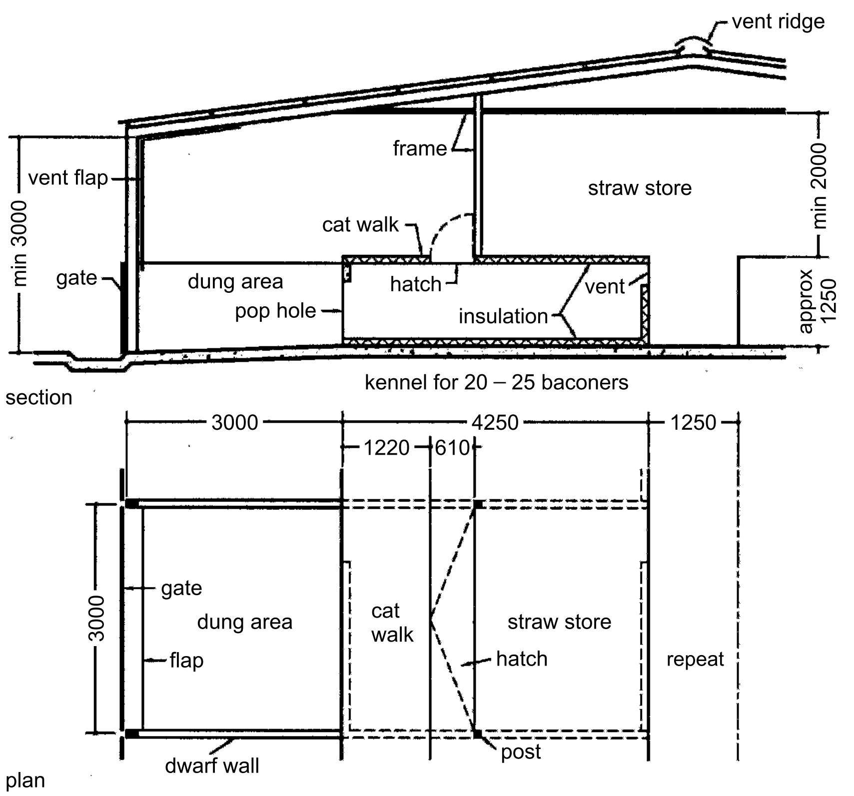
Typical age (days)	Mass (kg)	Type	Lying area (m²)	Min dung area (m²)	Total (m²)	Trough length (mm)	Lying pan depth (mm)
0	1.5	Piglets			1.3/litter	500	
20	5	Early weaners			1.75/litter	500	
35	9	Weaners	0.7	0.3	1.0	600	1170
65	20	Weaners	1.5	0.6	2.1	1750	860
115	50	Porkers	3.5	1.0	4.5	2250	1560
140	70	Cutters	4.6	1.6	6.2	2750	1280
160	85	Baconers	5.5	2.0	7.5	3000	1840
185	110	Heavy hogs	6.7	2.3	9.0	4000	1680
210	140	Overweight	8.5	3.0	11.5	5000	1700
–		Dry sows	15.0	5.0	20.0		3000
–	–	In-pig sows	15.0	5.0	20.0		3000
–	–	Boar		8.0/boar	500/boar		



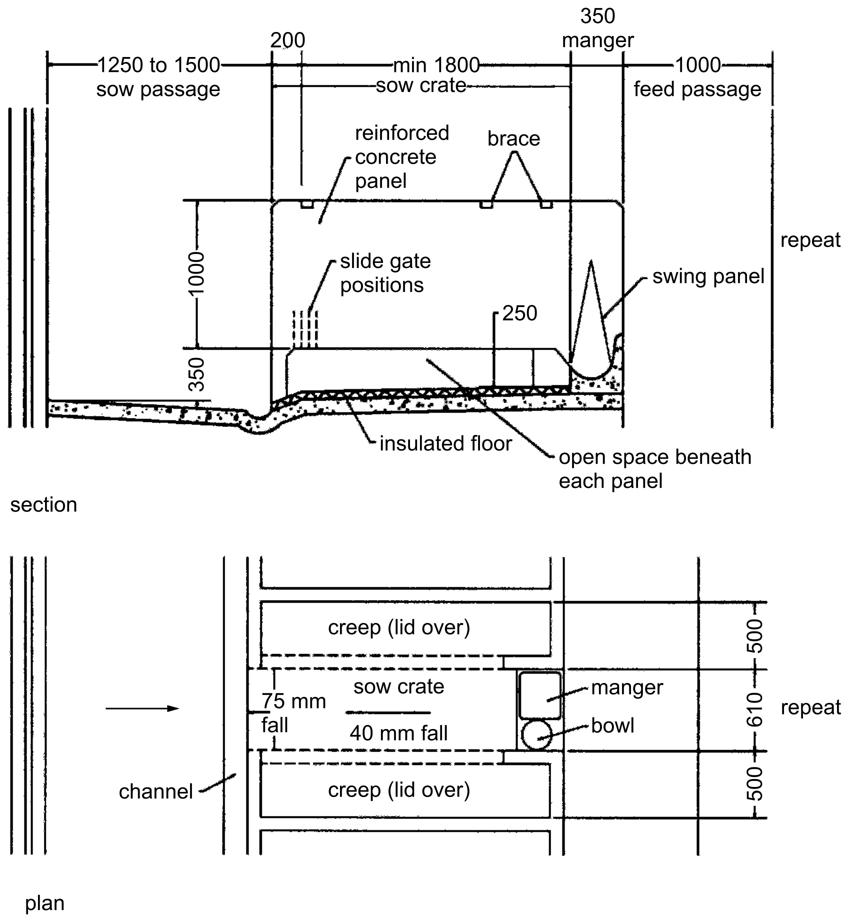
16.16 *Plan and section of fattening house with side dung passage*



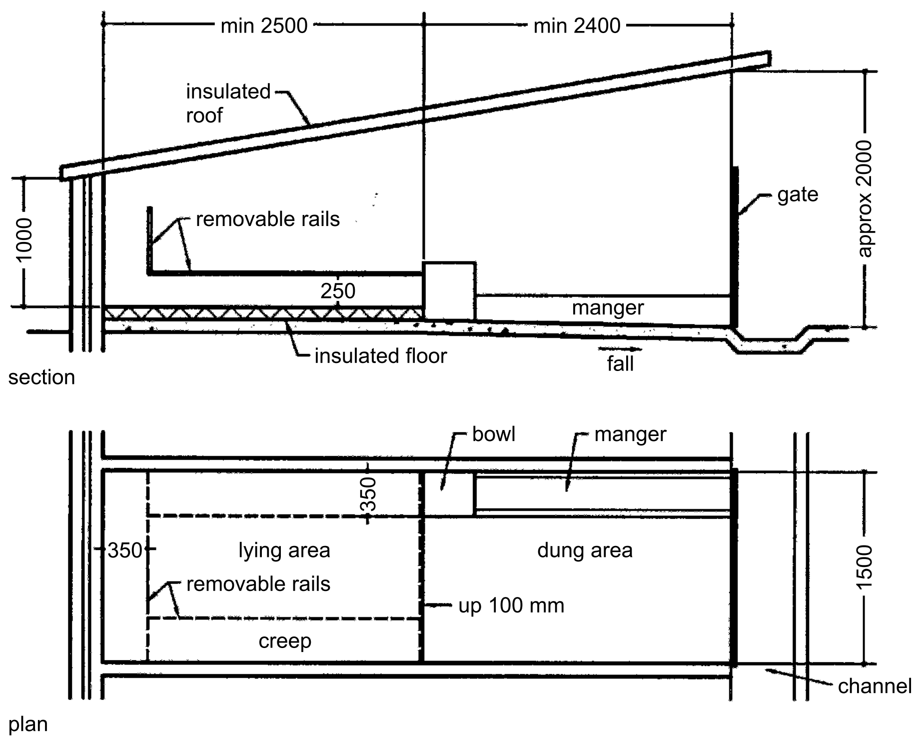
16.17 *Plan and section of fattening house with centre slatted dung passage*



16.18 *Plan and section of fattening house with straw-covered system and floor feeding*



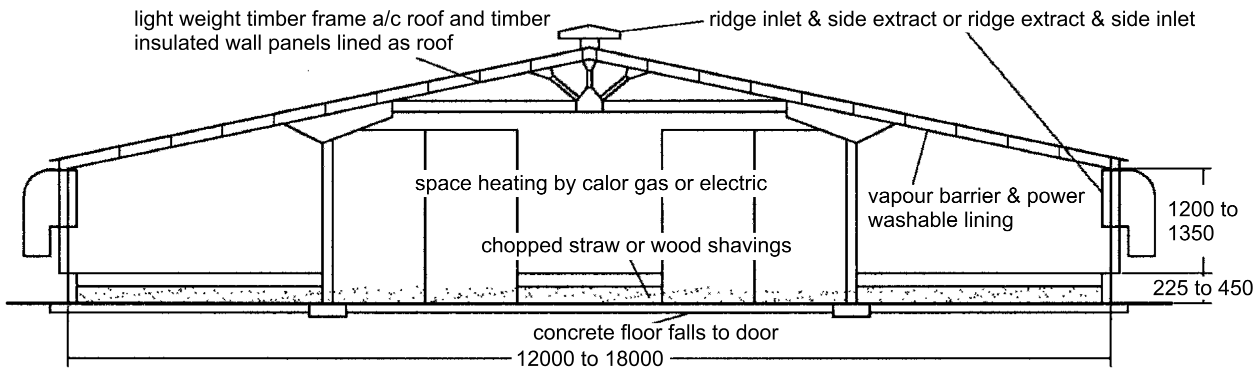
16.19 *Plan and section of permanent crate farrowing house*



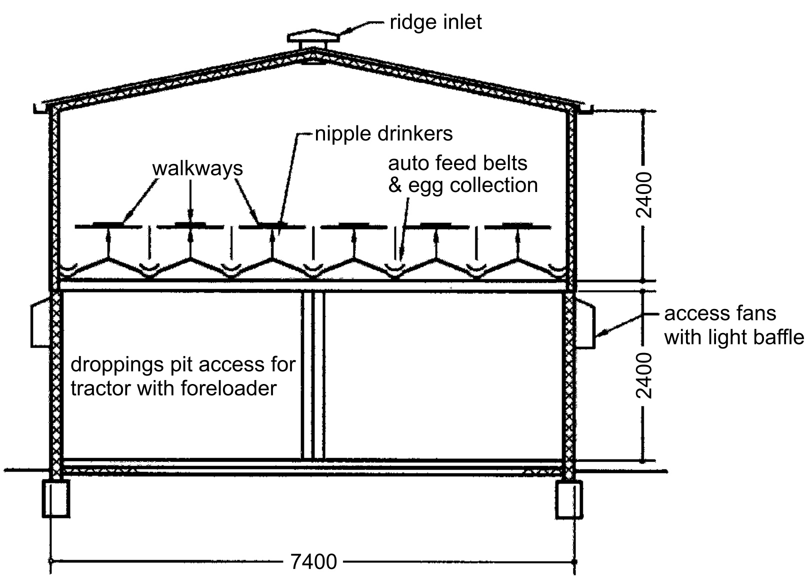
16.20 *Plan and section of Soleri open front farrowing house*

Table IV Poultry housing

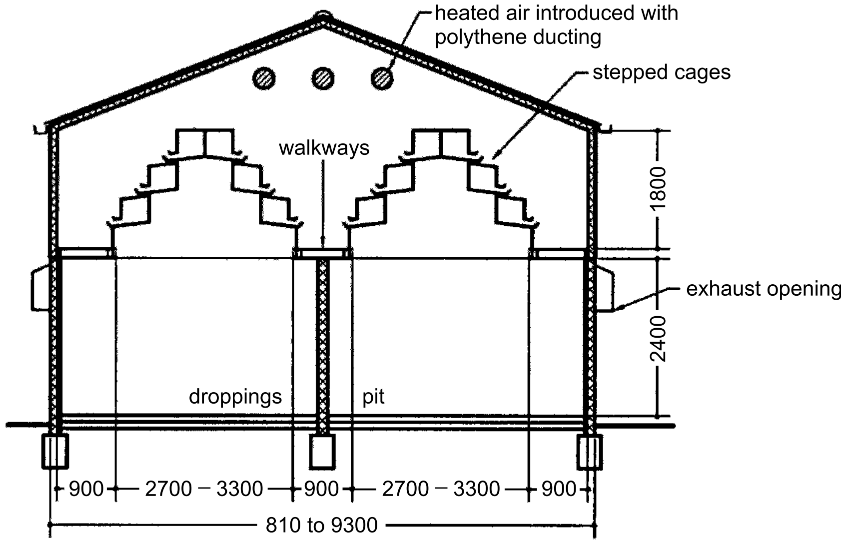
System	Species/cage numbers	0–4 weeks	4–8 weeks	9–16 weeks
Battery or tier brooder and cooling cage	One hen in cage	0.1	0.1	0.1–0.43
	Two hens in cage	0.075	0.09	0.1–0.43
	Three hens in cage	0.055	0.09	0.1–0.43
	Four hens in cage	0.043	0.09	0.1–0.43
Floor rearing on litter	Layers	0.025	0.09	0.18–0.28
	Broilers		0.09	
	Turkeys	0.09	0.14	0.37–0.46
	Ducks	0.09	Free range	
Part wire or slatted floor rearing	0.015	0.09	0.09–0.14	
Trough length (mm)	Birds in cages	100		
	Layers	30	40	60
	Broilers	30	50	75
	Turkeys	36	73	73
	Ducks	55	122	Free range



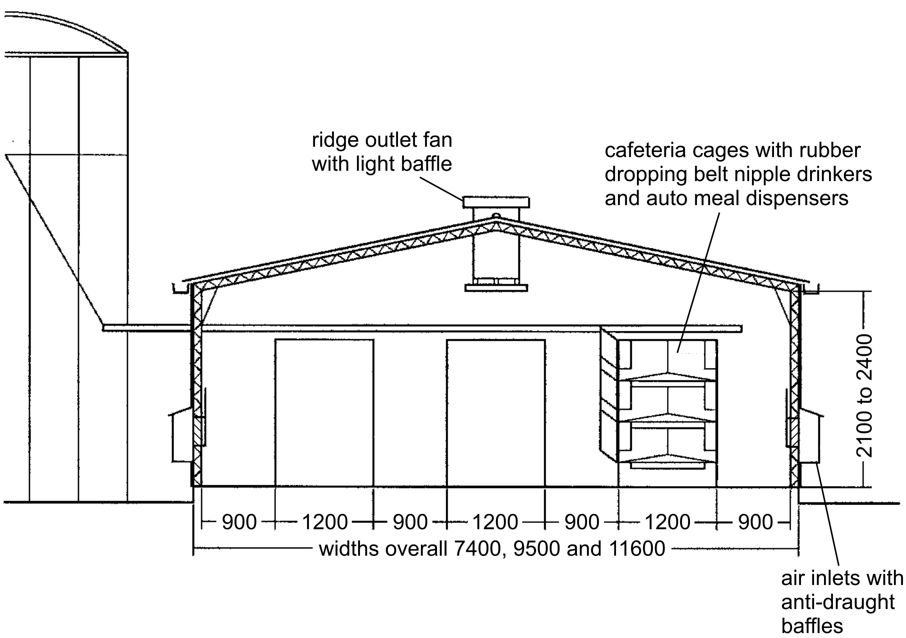
16.21 *Section through poultry broiler and rearing house. Roof insulated with minimum 25 mm rigid polyurethane or equivalent. Stocking density 10 birds/m^2, RH 60%, temperature 30°C*



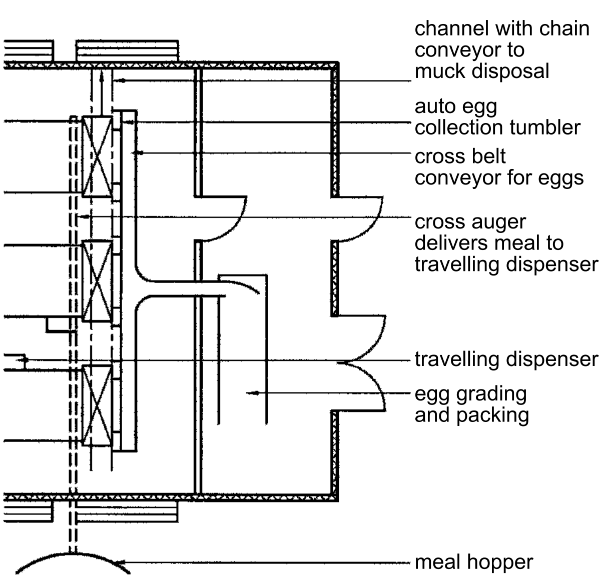
16.22 *Section through flat deck deep pit battery house. Roof insulated with minimum 25 mm rigid polyurethane or equivalent. Stocking at 100 mm trough per bird in multibird cages for light hybrids, 125 mm for heavier birds. RH 60%, temperature 20–25°C. If falls to 12° does not harm output but increases food conversion ratio*



16.23 *Section through California cage deep pit battery house. Roof insulated with minimum 25 mm rigid polyurethane or equivalent*



16.24 *Section through cafeteria cage battery house*



16.25 *Plan of end of cafeteria cage battery house showing gear*

10 EQUESTRIAN DESIGN

10.01 Horse riding today

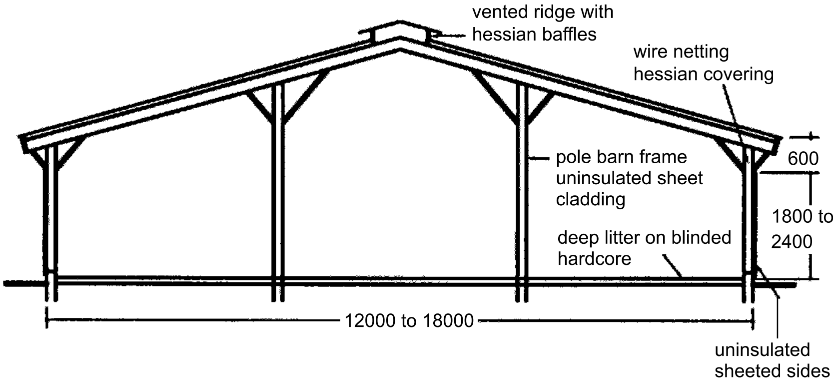
Facilities for keeping horses are mainly constructed for recreational riding, equestrian sport and breeding purposes. The use of horses for commercial haulage is unusual nowadays, and together with police or military facilities there is likely to be a specific brief.

10.02 Planning elements in private stables

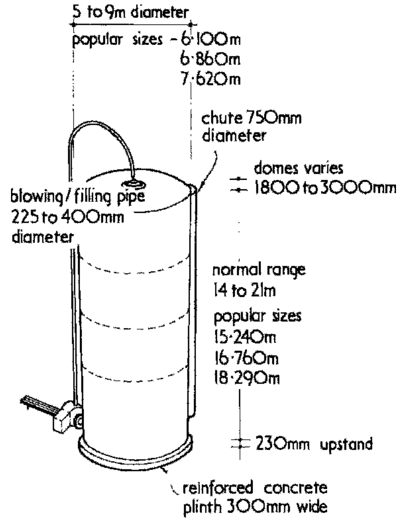
Private stables range from a stable for one horse to large complexes to accommodate a thousand horses or more, complete with full health and training facilities. The principal elements remain the same, **16.35**, and are based on the physical and psychological requirements of the horses.

1 Boxes

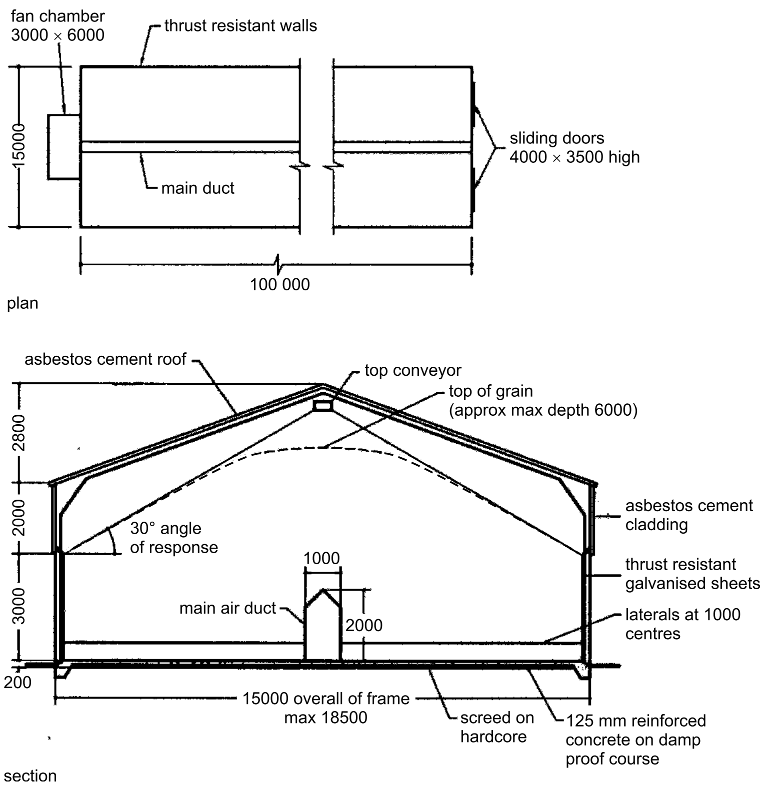
- Loose boxes
- *Sick box/boxes (50% larger)
- *Utility box/boxes



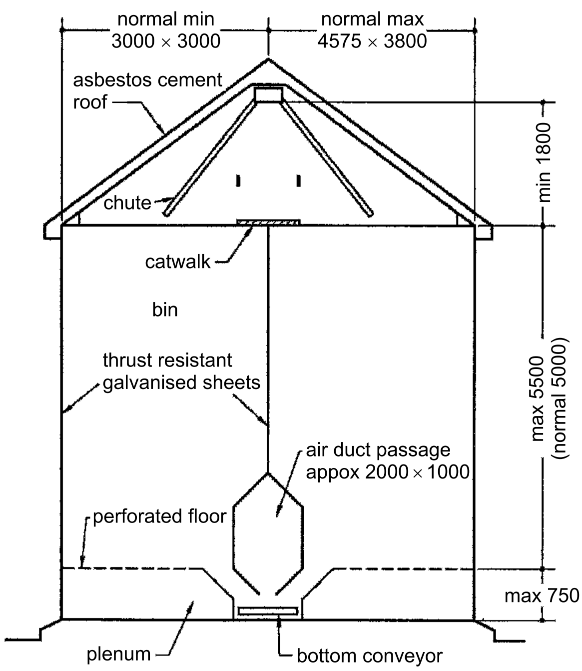
16.26 *Section through pole barn for fattening turkeys. Stocking density 30 kg/m²*



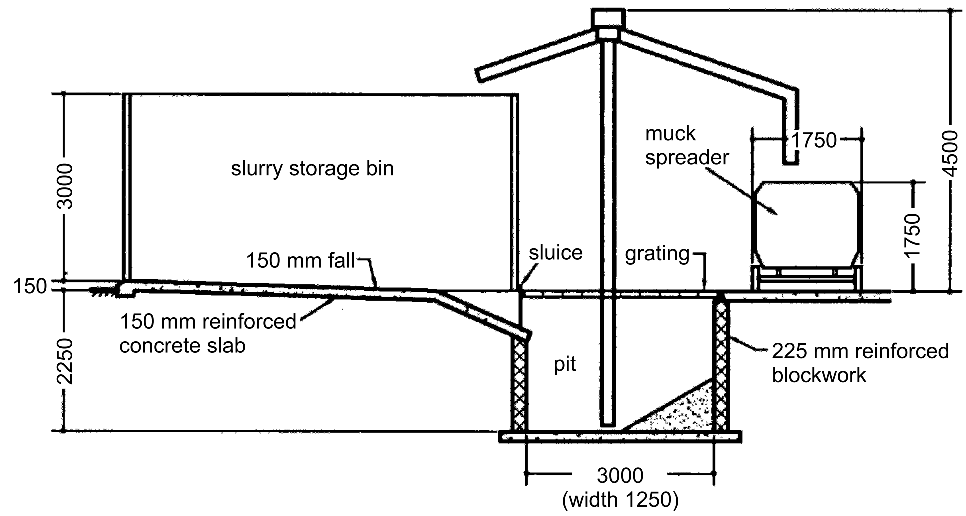
16.27 *Tower silo for wilted grass with 40–50% dry matter. Wet grass is stored in towers of 6 m diameter × under 12 m height*



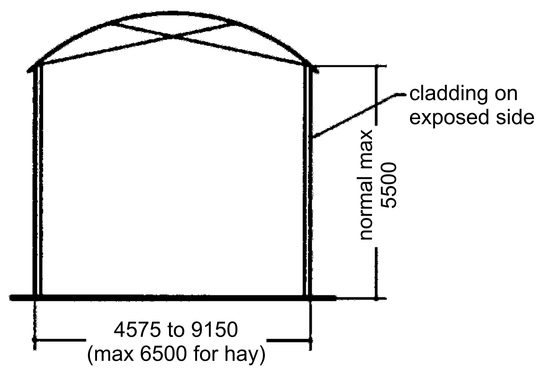
16.28 *Plan and section of storage for food grain, showing lateral system for 1200 tonnes storage*



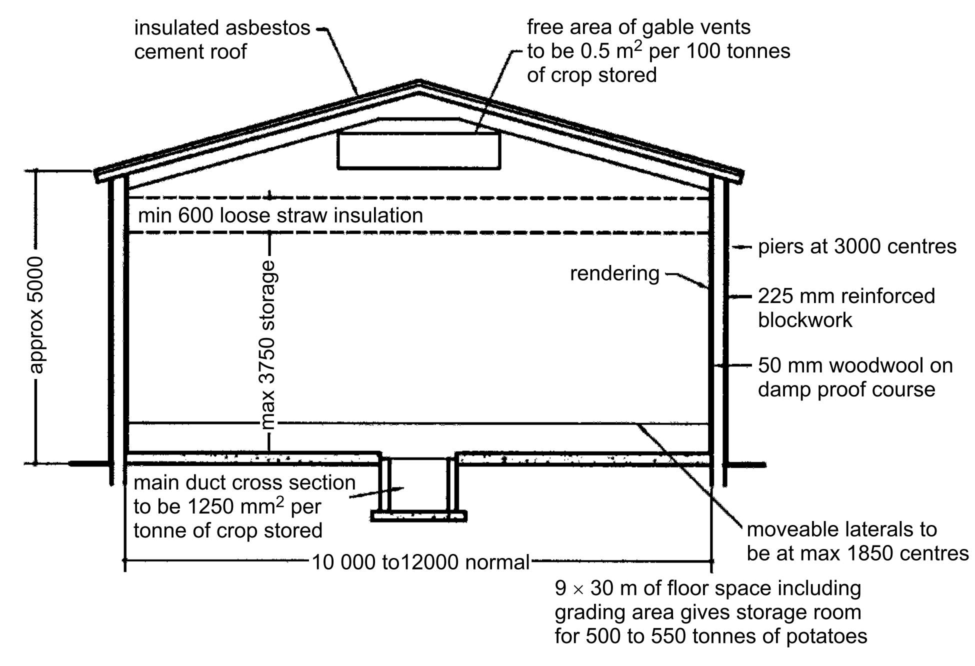
16.29 *Grain drying and storage: section through a nest of bins (square or rectangular) with roof. A bin 4.575 × 3.8 × 5 m holds 60 tonnes of wheat*



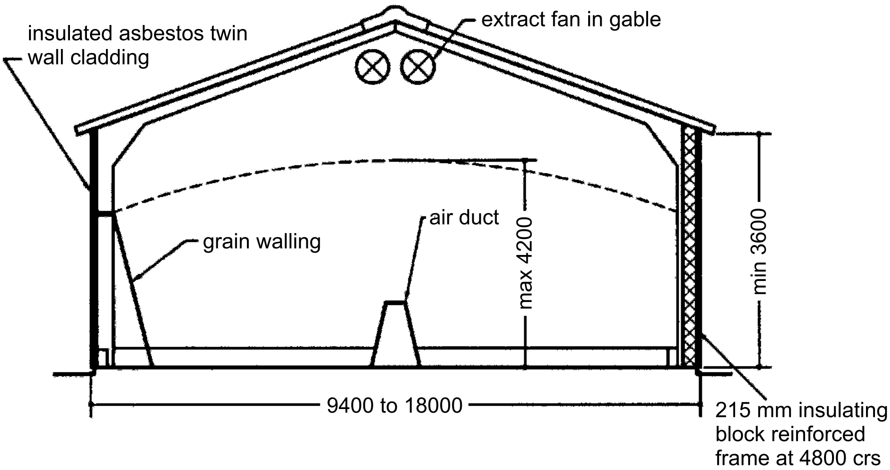
16.30 *Section through above-ground slurry storage*
Capacities: 4575 mm diameter – 50 m³
6100 mm diameter – 88 m²
6860 mm diameter – 110 m³



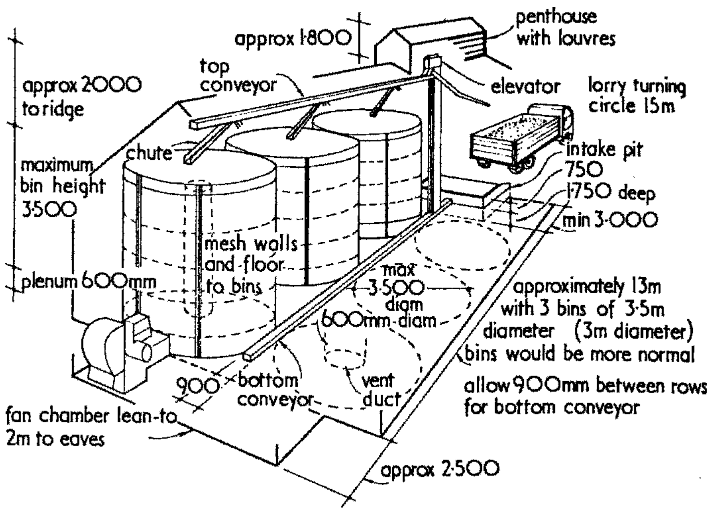
16.31 *Section through Dutch barn for bale storage. The capacities of a 4.575 m bay at 6.5 m span and 5.5 m high are:*
wheat straw – 12 tonnes
barely straw – 14 tonnes
hay – 27 tonnes



16.32 *Section through floor storage for potatoes. 9 × 30 m of floor space stores 500–550 tonnes. Movable laterals maximum 1.85 m centres. Free area of gable vents 0.5 m²/100 tonnes stored, main duct cross-section 1250 mm²/tonne*



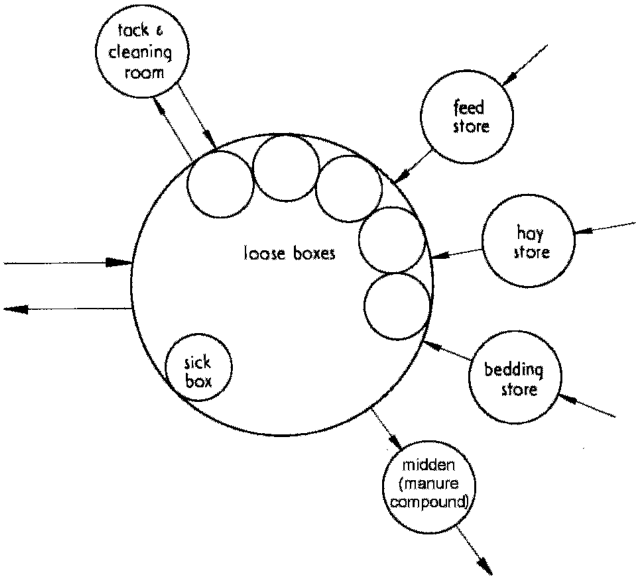
16.33 *Section through radial flow bins in a barn for grain drying and storage. The air duct delivers 400 m^3/h.t to dry and 100 m^3/h.t to store. Air temperature above 0°C, RH 75%*



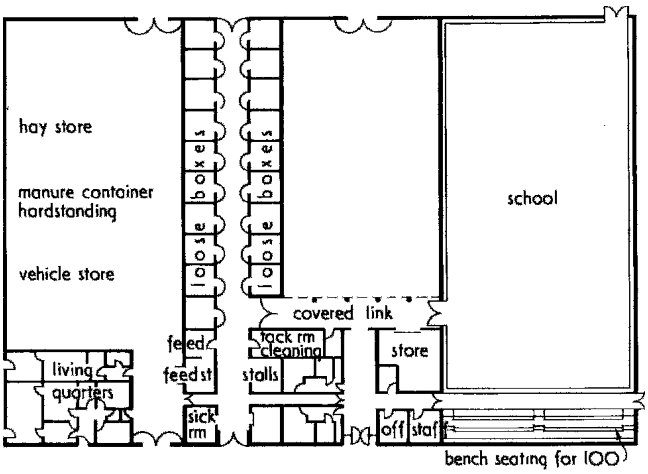
16.34 *Onion store*

Table V Average production of effluent

		Production per head per week					
		Mass (kg)	Output (l)	Volume (m^3)	Total solids (kg)	BOD (kg)	BOD population equivalent
Man	Adult	75	10	0.01	0.57	0.41	1.0
Cow	Dairy	450	250	0.25	21.20	4.20	10.2
Cow	Large dairy	550	380	0.38	32.22	6.13	14.8
Calf	3-month	100	200	0.20	19.05	2.54	6.2
Pig	Porker	50	38	0.04	3.00	1.20	2.0
Pig	Baconer	95	51	0.05	3.50	1.40	3.4
Pig	Wet-fed	95	100	0.10	3.50	1.40	3.4
Pig	Farrow sow	110	75	0.08	3.60	1.45	3.6
Poultry	Adult layer	2.25	3.75	0.005	1.27	0.09	0.13
Sheep	Adult ewe	75	35	0.04	3.81	0.70	1.7
Silage	30% dry matter	tonne	3.20	0.001	–	–	–
Silage	20% dry matter	tonne	37.00	0.04	–	–	–



16.35 *Relationships between elements of the plan*



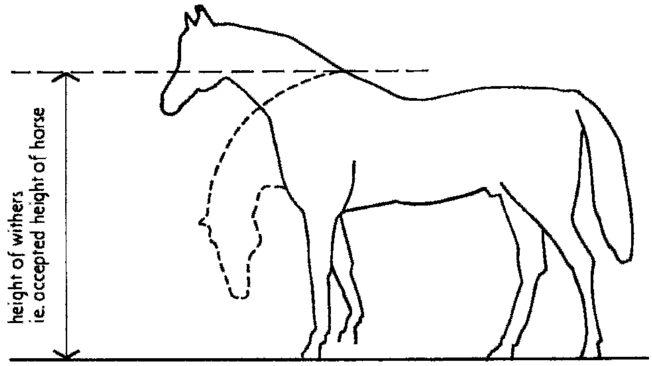
16.36 *Plan of Porter's Field Riding School, Leyton*

2 Stores
- Feed
- Hay
- Bedding
- Equipment (wheelbarrows, mowers, etc.)

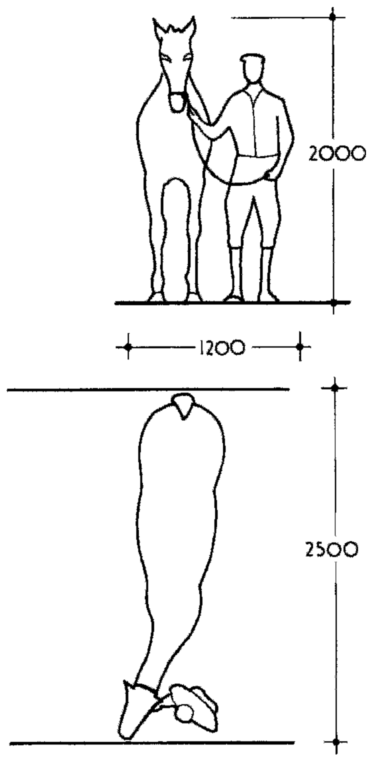
3 Housekeeping
- Tack room
- *Cleaning room
- *Drying room
- Staff lavatories/showers
- *Staff rest room
- *Office
- *Vet room

4 External facilities
- Midden
- *Washdown area
- Trailer parking
- Staff parking
- *Carriage store

5 Health/exercise
- Sand roll
- Lungeing yard



16.37 *Measurement of the height of a horse at the withers. Traditionally the height was measured in hands (4 inches), but a hand is equivalent to a decimeter (100 mm) within the limits of accuracy attainable. Table VI gives the heights of a number of breeds of horses and ponies*



16.38 *The led horse.* **a** *Front view.* **b** *Plan*

- Treadmill
- Weighing machine/weigh bridge
- Equine pool

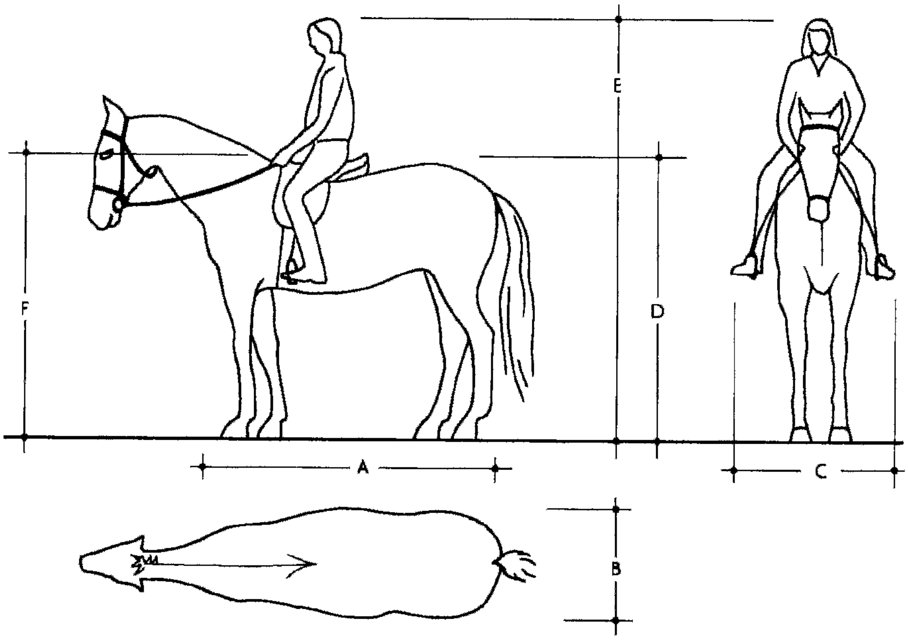
*In many cases, the accommodation will not require these items because of their small-scale activities.

A typical plan is shown in **16.36**.

10.03 Dimensional criteria

Dimensionally standardised criteria may be applied:

- The size of the horse, with and without rider, **16.37–16.39**, Tables VI and VII.
- Stabling and care of the horse, **16.40–16.43**.
- Tack rooms, **16.44**.
- Schooling, **16.45** and **16.46**
- The dressage arena, **16.47**
- Polo, **16.48**
- Transportation, **16.49–16.51**



16.39 *Dimensions of the horse and rider, see Table VII*

Table VI Common breeds of horses and ponies, with heights in hands and equivalent metric measure, 16.37 (*1 hand = 4 inches, 12.2 hands = 12 hands + 2 inches*)

Breed	Height in hands	Height in mm	Breed	Height in hands	Height in mm
Horses			**Ponies**		
Cleveland bay	16	1625	Connemara	14.2	1475
Clydesdale	16	1625	Dartmoor	12	1220
Morgan	14–15	1420–1525	Exmoor	12.2	1270
Percheron	16–16.3	1625–1700	Fell	13.1	1345
Shire	17	1725	Highland	12.2–14.2	1270–1475
Suffolk	16	1625	New Forest	14.2	1475
Tennessee Walker	15.2	1575	Shetland	39–42 inches*	990–1065
Thoroughbred	16	1625	Welsh	12	1220

*Shetland ponies are always described in inches.

Table VII Typical dimensions of horse or pony and rider, 16.39

Dimension	Thoroughbred	New Forest pony	Welsh pony
A	1600	1450	1200
B	550	500	415
C	900	815	675
D	1620	1470	1215
E*	2450	2225	1840
F	1625	1475	1220

*Assuming that the rider is in proportion to the horse or pony

10.4 Stabling and environmental conditions

The principal requirements can be identified as follows:

1 Dryness and warmth
2 Adequate ventilation without draughts
3 Adequate supply of water and good drainage
4 Good daylight and good artificial light.

Siting

- On well-drained ground.
- Avoid the tops of hills and hollows.
- Protected from severe prevailing winds.
- Avoid sites hemmed in without free circulation of air.

Temperature

The stable should moderate extremes of exterior conditions. Therefore a degree of air circulation is helpful and adequate ventilation essential. However, care should be taken to avoid draughts.

Size

Unless a particularly small breed is kept the standard dimensions should be adhered to.

Noise

Sudden noise may startle horses and disrupt sleep during the night, therefore relationship to public roads or urban developments requires careful consideration.

10.05 Detailed stabling design

Floor

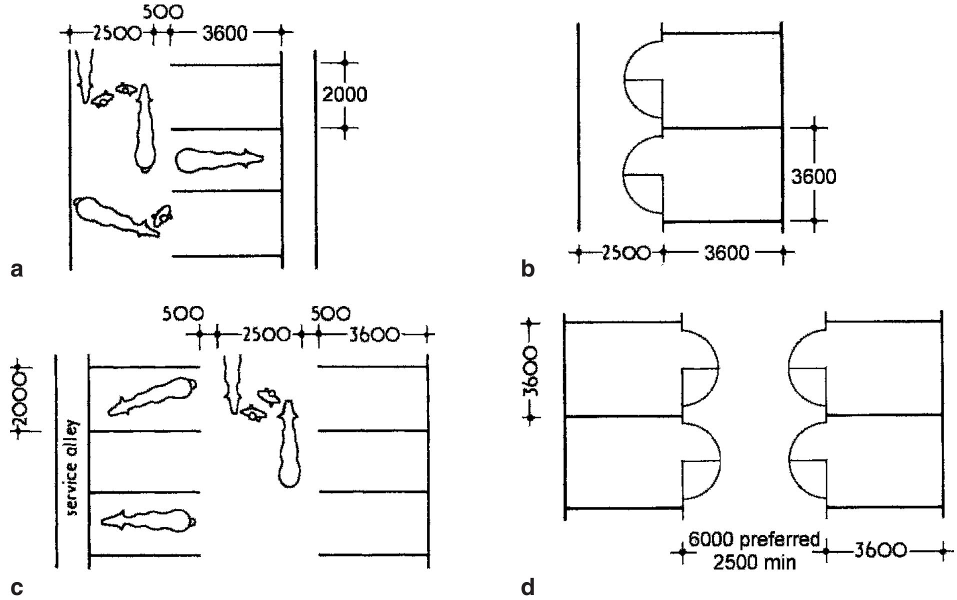
The floor should be impervious to moisture, hard wearing, nonslip, easily cleaned and protect the horse from any ground moisture. Selection of floor finish can vary from dense concrete, granolithic concrete or engineering brick-laid herringbone pattern to proprietary rubber mats and seamless rubber flooring.

Walls

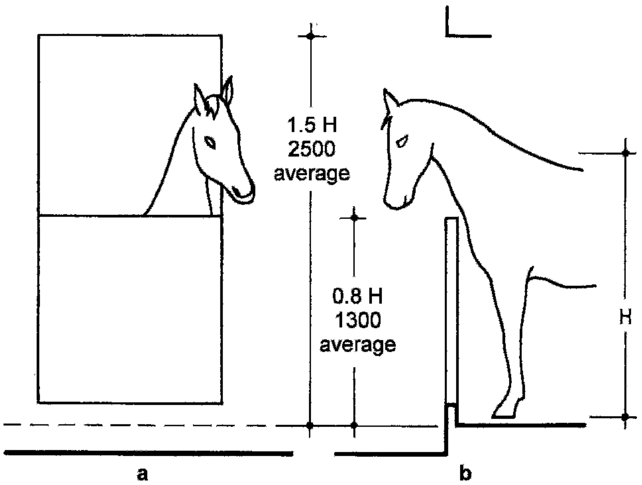
The walls should be smooth for cleanliness and, wherever possible, free from projections. It is preferable that masonry walls are protected up to at least 120 mm by stout timber or plywood panelling on battens. Masonry should be painted white or a light shade to encourage cleanliness. Horses are gregarious animals and therefore it is normal for the partitions to be solid up to 1200–1500 mm and have a metal grille up to 2100 mm above floor level.

Ceilings

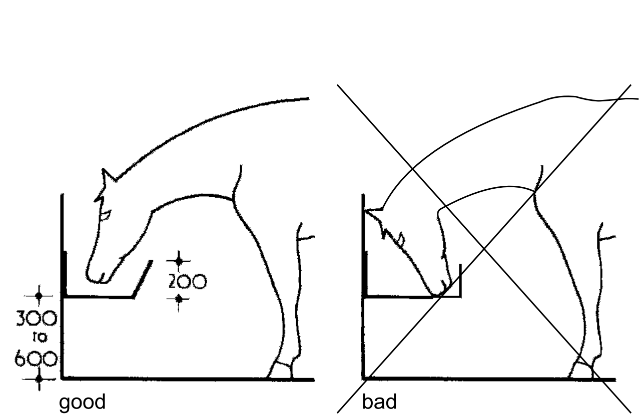
The ceiling should not be less than 3050 mm high and care should be exercised in the choice of materials to avoid the build-up of condensation.



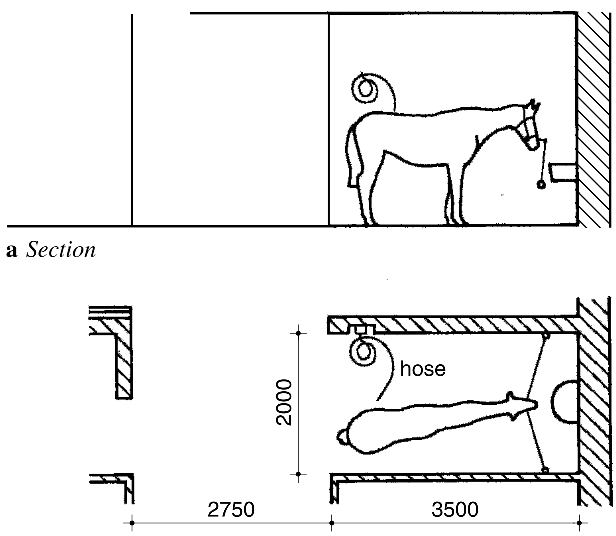
16.40 *Arrangements of stables.* **a** *Stalls on one side.* **b** *Loose boxes on one side.* **c** *Stalls on both sides.* **d** *Loose boxes on both sides: doors should not be directly opposite one another*



16.41 *The stable door. It is essential for the horse's mental well-being for it to see out – horses are inclined to be very inquisitive! H is the height at the withers (see* **16.37**). **a** *Front view.* **b** *Section*



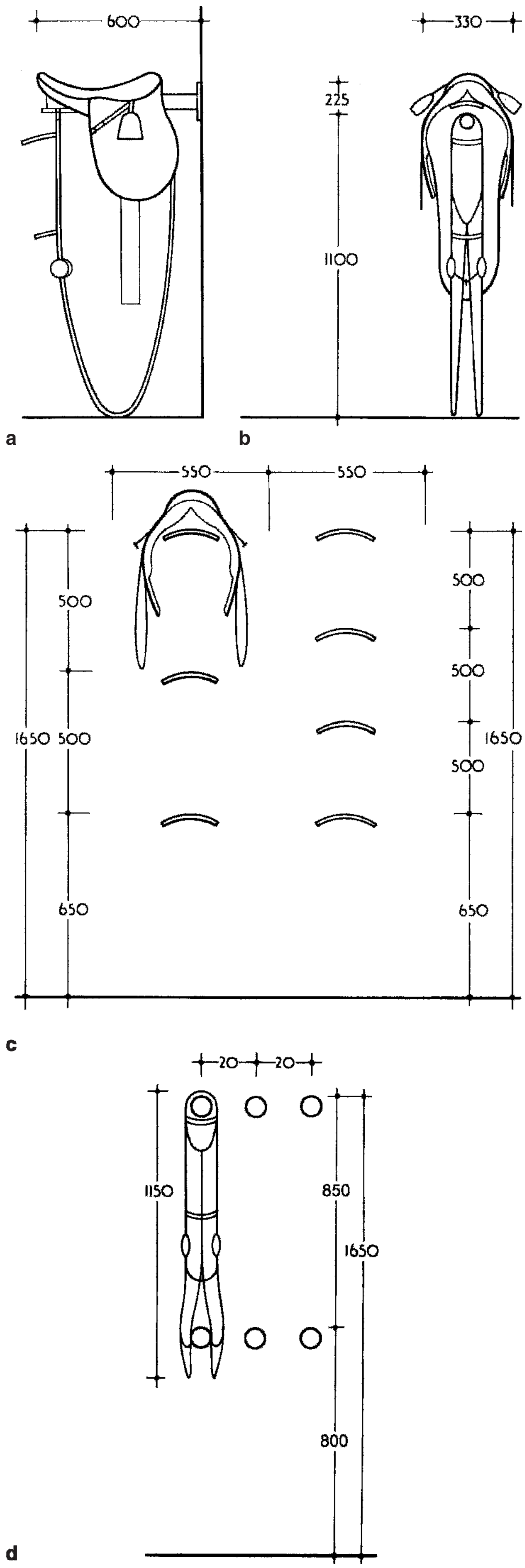
16.42 *Height of the manger*



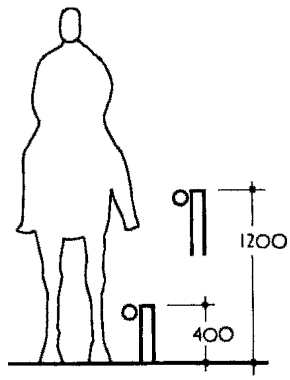
a *Section*

b *Plan*

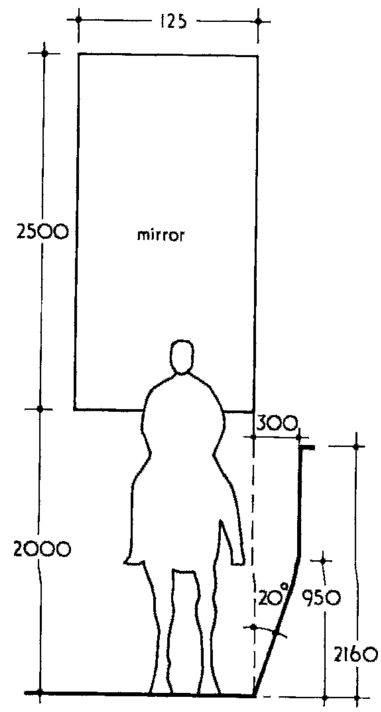
16.43 *Veterinary box 'Stallapotheke'*



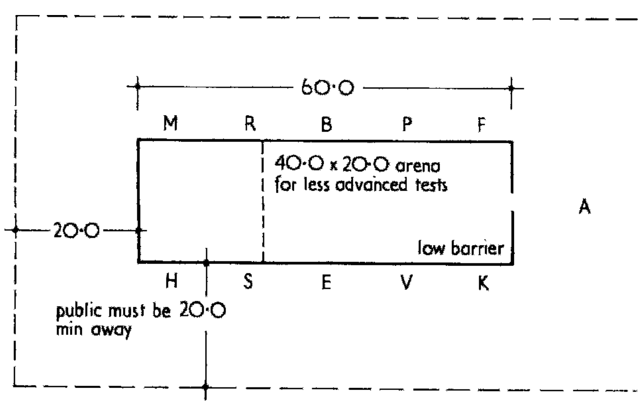
16.44 *Tack rooms.* **a** *Saddles and bridles together, side view.* **b** *Saddles and bridles, front view.* **c** *Saddles only.* **d** *Bridles only, when kept separate*



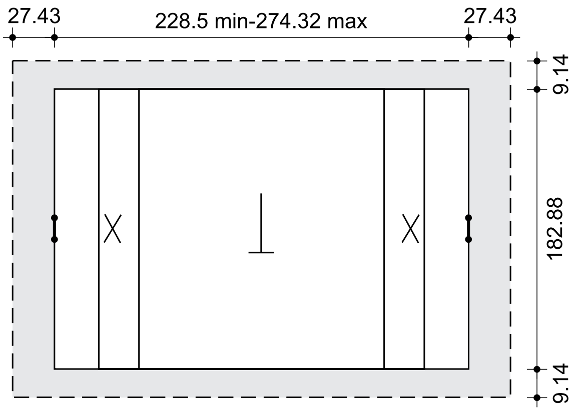
16.45 *Rails for the outside school*



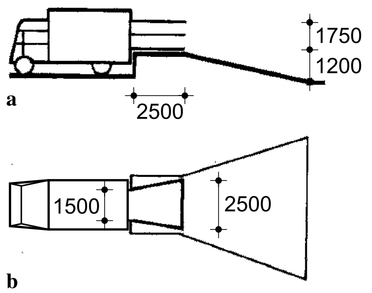
16.46 *Indoor school: batter to walls and arrangement of mirror tilted to give self-vision*



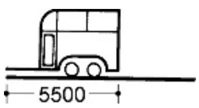
16.47 *Dressage arena*



16.48 *Polo*



16.49 *Ramp for loading horses into horse-boxes or trailers.* **a** *Section.* **b** *Plan*



16.50 *Large trailer*

16.51 *Small trailer*

Fire resistance

In large installations, the fire resistance of the structure and the location of fire separation barriers should be carefully considered bearing in mind the difficulty of evacuating frightened horses and the often rural location.

Doors and windows

Doors to loose boxes should be positioned to one side of the box to allow the horse to keep clear of the draught when the upper half is left open. Doors to two adjoining boxes should not be placed next to each other. The door should open back to 180° and any exposed edges be protected with a galvanised steel capping to avoid 'crib biting'. There should be no sharp arisses and a minimum clear width of 1200 mm. Windows should, where possible, be fitted at high level. Any low-level windows should have Georgian wired glass and a steel protective grille.

Fittings

Usually, these will consist of a manger, drinking water receptacle and two tie rings. The exact position of these items will depend to some extent on the management of the stables, and to whether automatic replenishment is incorporated. Tie rings are generally fixed between 1525 and 1800 mm in order to avoid a horse dropping a leg over the tie.

Services

An exterior quality plug socket will be required (one per six stalls maximum) for portable equipment. This should be sited outside the stall. Artificial lighting should provide illumination to both sides of the horse switched from outside the stalls.

Drainage

The floor should be laid to a fall of between 1:80 and 1:60 to a gulley outside the stall or loose box. Channels may be formed to enhance drainage. Good housekeeping is the key to drainage and all gullies should be equipped with a removable perforated bucket to collect bedding and feed that may wash down the gulley.

Midden

The midden must be arranged so that effluent does not run away into groundwater. There should be a gulley and an adjacent water supply to enable regular periodic cleaning. For hygiene reasons, it should be sited away from the stables.

11 BUILDING LEGISLATION

- *Town and Country Planning Act 1990*
  General Development Order 1988 amended and extended 1991.

Many farm buildings and developments are no longer classed as permitted development under planning law. Details of all schemes have to be sent to the local planning authority together with a fee. The authority will rule in each case whether further information needs to be submitted for formal planning approval before work can commence.

Particular developments normally requiring formal planning approval include:

- Buildings for non-agricultural purposes
- Dwelling houses
- Conversions of farm buildings to commercial or industrial or residential use
- Buildings not designed for agriculture, e.g. containers, lorry bodies, etc.
- Buildings exceeding 465 m^2 – in any 2-year period within 90 m – includes yards and slurry lagoons
- Buildings 12 m and over in height
- Buildings 3 m and over in height within 3 km of an airfield
- Buildings within 25 m from the metalled part of a classified road
- Livestock buildings within 400 m of a 'protected building'
- Caravan sites for which special rules apply
- Holiday cottages
- Recreational pursuits of a recurring nature, e.g. adventure games, canoeing, hang-gliding, windsurfing, water skiing, need consent if exceeding 28 days per year
- Farm shops: permission is needed for shops if produce is not derived from the farm involved and for new buildings to be used as shops. Particular care is required over access, parking and advertising signs.

The Building Regulations 2000

Many agricultural building are exempt from the Building Regulations 2000 – but not all. The following extract from the Regulations details the buildings that are exempt – all others are subject to Building Control and details must be submitted to the Local Authority before work commences.

Schedule 3 – Exempt Buildings and Works
Regulation 9 – Greenhouses and Agricultural Buildings

1. A building used as a greenhouse unless the main purpose is for retail packing or exhibiting.
2. a. A building used for agriculture which is:
    i. Sited at a distance not less than one and a half times its own height from any building containing sleeping accommodation, and
    ii. Provided with an exit which may be used in the case of fire which is not more than 30 m from any point within the building (unless the main purpose for which the building is used is for retailing, packing and exhibiting).

b. In this paragraph, 'agriculture' includes horticulture, fruit growing, seed growing, dairy farming, fish farming and the breeding and keeping of livestock (including any creature kept for the production of food, wool, skins or fur or for the purpose of farming the land).

Other relevant legislation

The Environmental Assessment Regulations, 1988
Health and Safety at Work Act, etc., 1974
Control of Substances Hazardous to Health Regulations, 1988 (COSHH)
Electricity at Work Regulation, 1989
The Noise at Work Regulations, 1989
The Food Safety Act, 1990
The Food Hygiene (HQ) Regulation, 1990
Code of Practice for the Control of Salmonella
The Environmental Protection Act, 1990
The Code of Good Agricultural Practice for the Protection of Air
Control of Pollution Act 1974 – Water Act 1989
The Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations, 1991
The Code of Good Agricultural Practice for the Protection of Water July, 1991
The Welfare of Livestock Regulations
The Building Standards (Scotland) Regulations, 1988

12 BIBLIOGRAPHY

BS 5502 Code of practice for the design of buildings and structures for agriculture.

Published in separate parts as follows:

Part 0: 1992 Introduction
Part 11: 2005 Guide to regulations and sources of information
Part 20: 1990 Code of practice for general design considerations
Part 21: 1990 Code of practice for the selection and use of construction materials
Part 22: 2003 Code of practice for design, construction and loading
Part 23: 2004 Code of practice for fire precautions
Part 25: 1991 Code of practice for design and installation of services and facilities
Part 30: 1992 Code of practice for control of infestation
Part 32: 1990 Guide to noise attenuation
Part 33: 1991 Guide to the control of odour pollution
Part 40: 2005 Code of practice for the design and construction of cattle buildings
Part 41: 1990 Code of practice for design and construction of sheep buildings and pens
Part 42: 1990 Code of practice for design and construction of pig buildings
Part 43: 1990 Code of practice for design and construction of poultry buildings
Part 49: 1990 Code of practice for design and construction of milking premises
Part 50: 1993 Code of practice for design, construction and use of storage tanks and reception pits for livestock slurry
Part 51: 1991 Code of practice for design and construction of slatted, perforated and mesh floors for livestock
Part 52: 1991 Code of practice for design of alarm systems and emergency ventilation for livestock housing
Part 60: 1992 Code of practice for design and construction of buildings for mushrooms
Part 65: 1992 Code of practice for design and construction of crop processing buildings
Part 66: 1992 Code of practice for design and construction of chitting houses
Part 70: 1991 Code of practice for design and construction of ventilated on floor stores for combinable crops
Part 71: 1992 Code of practice for design and construction of ventilated stores for potatoes and onions
Part 72: 1992 Code of practice for design and construction of controlled environment stores for vegetables, fruit and flowers
Part 74: 1991 Code of practice for design and construction of bins and silos for combinable crops
Part 75: 1993 Code of practice for the design and construction of forage stores
Part 80: 1990 Code of practice for design and construction of workshops, maintenance and inspection facilities
Part 81: 1989 Code of practice for design and construction of chemical stores
Part 82: 1997 Code of practice for design of amenity buildings

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17 Restaurants and foodservice facilities

Fred Lawson

Fred Lawson is a Visiting Professor at the University of Bournemouth, an international consultant on hotel and foodservice planning and the author of a number of Architectural Press books in this field

KEY POINTS:
- *Services must satisfy customer demands and operating criteria*
- *A highly competitive sector at all levels of expenditure*
- *Labour intensive requiring efficient planning*
- *New concepts continuously being introduced*
- *Design life cycles are often short*

Contents

1 INTRODUCTION

1.01 Profile
Restaurants and other facilities providing food and drink for consumption on the premises are labour intensive services which invariably operate in a highly competitive environment. These cover both *commercial businesses* aiming to attract the public and achieve profits from the investment and *semi-* or *non-commercial services* provided in institutions, places of employment and elsewhere. The latter need to meet specific requirements, including set cost limits, and are often operated by *catering contractors*. In all cases, the efficiency of every part of the operation needs to be maximised and this calls for careful planning and organisation.

1.02 Customer markets
Customer choice will vary with individual circumstances such as the location, time available, spending power, experience and particular requirements. The characteristics of potential market demands can be classified and quantified and this is used in market research to identify suitable locations and facilities.

1.03 Role of design
The role of design in foodservice premises is to:

- attract identified markets of customers and communicate a suitable image (merchandising);
- create an comprehensive style and quality of ambience appropriate to customer expectations;
- plan the layout, equipment, technical installations and operating systems as integral parts of the overall concept ensure that the facility can meet the objectives, costs and other criteria set by the operator.

1.04 Design concept
The design must reflect the basic concept, including range of menu and food preparation involved, style of service and staffing requirements, space allocation, desired atmosphere and other factors which influence customer choice.

1.05 Product development
Consumer requirements evolve with a desire for change, new styles of fashion and wider experiences of meals abroad. New concepts in food and beverage service operations are constantly being introduced and those which can be shown to be successful are invariably developed as specific product brands. Branding enables the same formula to be adapted to other sites as a chain of company owned, leased or franchised units with further advantages in marketing, customer confidence in quality and value, economies of scale and profitability.

The development of new products also reflects socio-economic changes in an area, trends and influences on consumers, e.g. promotion and health concerns – see Tables I and II.

Table I Trends in foodservices

Influences	Effects
Markets (socio-economic changes):	
Changes in habits	convenience
Social acceptance	informality
Multiple incomes	increase in demand
Single households	take away food
Demographic shifts	mature designs
Product supply (promotion, efficiency):	
Franchising	systemisation
Multiple outlets	standardisation
Promotion	branding
Consumer choice (education, experience):	
Healthy eating	lighter meals
Personal selection	self service
Variety, wider interest	ethnic foods

Table II Product development

	Trends in products reflecting market preferences
Self choice:	food displays, food halls multiple choice counters, buffets self-help starter & salad bars assisted service, carveries, trolleys
Variety:	displayed cooking, showmanship 'ethnic' options, featured designs pub meals, bistros, dining clubs themed experiences, memorabilia eat in, take away, home delivery
Reassurance:	attention to hygiene, cleanliness environmental responsibilities 'healthy' menu options, information value for money, inclusive prices confidence in standards, branding

1.06 Types of facility
Eating and drinking establishments fall into a number of broad categories:

- Commercial restaurants with self-service and waiter service operations, possibly licensed for sale of alcohol. Includes cafes and snack bars.
- Takeaways; fast-food outlets with or without customer seating space, supplying prepared food for consumption off the premises.

- Hotels and resorts: depending on standards, offering one or more restaurants, room service, banquets, bars, lounge services.
- Public houses, clubs: alcohol sales with or without foodservice.
- Semi- or non-commercial operations providing meals as a service in educational and institutional establishments and for employees in places of work.

Differences between these operations lie in:

- Variety of food offered
- Method of service
- Space and facilities available to the customer
- Amount of food processed on site
- Emphasis on the sale of alcoholic drinks
- Décor and degree of sophistication
- Price level.

Boundaries between these factors can be blurred and the whole field is constantly changing.

1.07 Location

Location will determine the success or failure of a facility. Commercial foodservice establishments must be located where people need to obtain meals and refreshments such as:

- City and town centres
- Resorts and visitor attractions
- At stopping places along main highways
- Airports and main railway stations
- Shopping centres

These are best served by different types of outlets appropriate for the main markets involved. For instance, chain fast-food outlets are sited in busy high streets within city and town centres to attract a large demand from passers-by ('footfall'). Upmarket restaurants are usually in less prominent locations, in or near good hotels, prime commercial districts and high-class residential areas. Foodservices are also provided to complement existing business as in pubs and places which attract visitors.

A balance has to be found between:

- The availability of customers
- Cost of location and investment
- Operational considerations such as space, customer parking, goods access.

1.08

Major locations such an airport, **17.1**, or motor service station usually provide a selection of outlets allowing customer choice in types of meals, prices and time available.

1.09

In city and town centres, there will usually be a range of different restaurants: fast-food, bistros, ethnic, themed, food-speciality and high-spend restaurants, as well as pubs, wine bars, cafes and snack bars.

1.10

Visibility is critical for casual trade and restaurants tend to be clustered in and around popular places, tourist attractions, squares and nearby side streets. Those sited in basements or on upper floors are at a disadvantage without specific promotion, attractive, easy access and designed facilities for transporting food deliveries and for the disabled.

1.11 Institutional foodservices

Foodservices provided in institutions and places of work generally fall into two categories:

- Centrally grouped: main cafeteria, refectories and/or restaurants sited convenient for most of the people involved. The location often provides a refreshing contrast to the workplace environment and is adjacent to the food preparation facilities.
- Dispersed: remote service of food to individual stations such as in hospitals, some institutions and remote work sites.

In most cases, these catering services are operated by contractors specialising in this field. This also applies in other main locations such as airports, motorway service stations and shopping centres.

1.12 External considerations

Separate vehicular access and parking is essential for delivery of food and other supplies together with suitable provision for hygienic storage and collection of waste. In large premises, a staff entrance may also be required.

1.13

Outside city centres well served by taxis and public transport, customer car parking is essential, particularly for evening dining and functions. Hotels need to make extra provision for this non-residential use. In restricted urban sites, nearby public car parking is an advantage.

1.14

External appearance is important for self-advertising and communicating information, with views of the interior, display of menus and prices and, for evening dining, flood-lighting. The customer entrance must be clearly defined, distinctive and easy to use including provisions for the disabled.

1.15

To attract passing customers, popular restaurants and cafes in large shopping centres, hotels and airports, **17.1**, may be seated within public concourses and atrium areas.

2 BASIC PLANNING

2.01 Foodservice operations

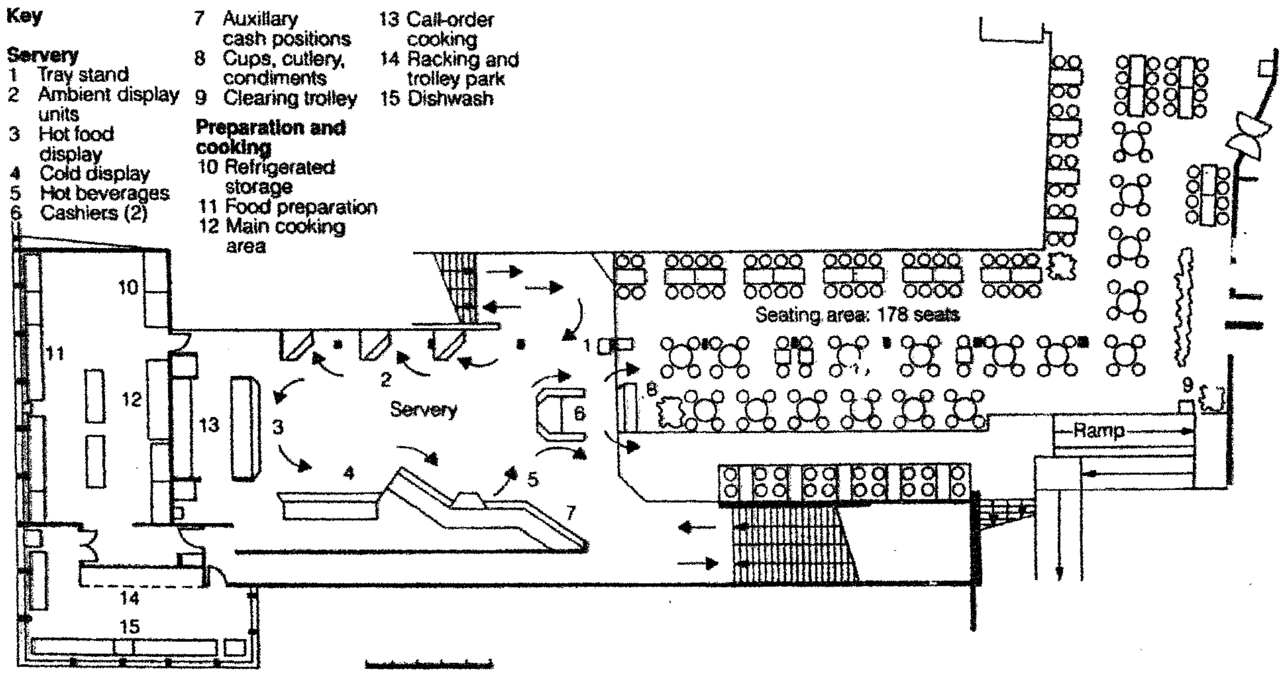
All foodservice operations involve three overlapping processes: production, service and customer areas, **17.2**. Each area will have specific requirements which will vary depending on the nature and the scale of operation.

Production:

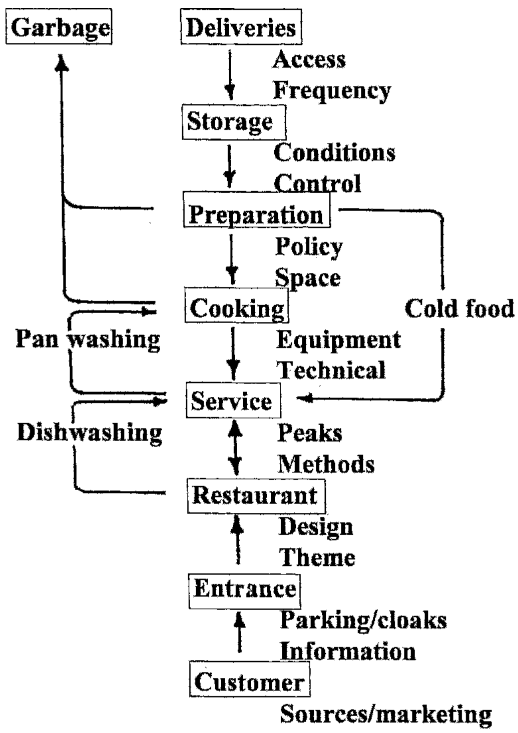
- Delivery and checking of food supplies, beverages and other items.
- Storage: separate for vegetables/fruit, dry goods, chilled and frozen foods.
- Preparation: using fresh ingredients, partially or fully prepared foods.
- Cooking: with large-scale centrally grouped or back-bar equipment.
- Assembly of meals to order, ready for service or refrigeration/freezing.
- Dishwashing of utensils and tableware and disposal of solid waste.

Service of meals: designed around self-service or table service

- Self-service using display counters accessible to the customers.
- Waiter/waitress service collected from a servery and taken to the tables.
- Collection of soiled dishes and return to the kitchen.
- Side tables and storage: for table items, condiments, equipment and furniture.



17.1 *Foodservice facilities at Prestwick Airport, UK. Located on a balcony above the concourse, the new self-service restaurant was designed to attract attention and provide an interesting range of local food specialities. Emphasis has been put on prominent signage and staircase design, as well as in menu graphics. Catering consultants: Tricon Foodservice Consultants Ltd. Client: British Airports Authority*



17.2 *Food service planning*

Customer facilities:

- Location: surroundings, character, site restrictions, parking.
- Entrance with cloakroom, toilets, reception services and bar if required.
- Seating areas: interior design to reflect concept and customer profiles.
- Billing and payment facilities.

2.02 Central food production

Large-scale foodservice operations usually involve two stages of production: bulk preparation and prime cooking followed by rapid chilling or freezing of the foods for later end-cooking (regeneration) when required near the place of service. *Cook-Freeze* systems provide rapid cooling down to −20°C for frozen storage (typical up to 1 month) whilst *cook-chill* equipment rapidly reduces food temperature to 1–3°C for refrigeration storage up to a maximum of 3–5 days. Chilling is commonly used in hotels and institutions for pre-preparation of meals on site to improve efficiency and hygiene.

2.03

Fast-food outlets use highly developed systems with specialised end-cooking equipment designed to provide rapid delivery of a limited menu of meals to order. Central cook-freeze systems are also used to supply prepared convenience foods to restaurants, airlines and other offsite catering arrangements. Cook-chill systems are more suitable for short-time holding of meals prepared in advance of use, as in banquets and functions, **17.3**.

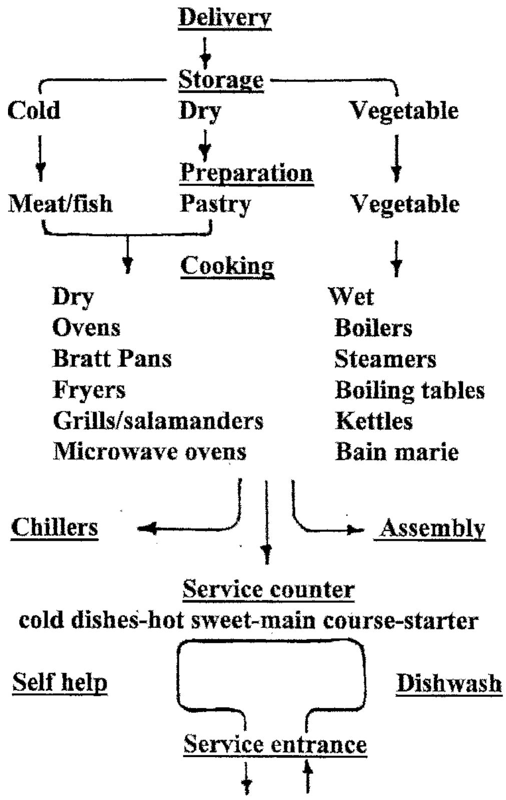
2.04 Legislation

Foodservice establishments are subject to Town and Country Planning and Building Regulations, disability discrimination, health and safety, food standards and hygiene requirements. Premises selling alcoholic drink must also be licensed. In the work areas, safeguards must be taken to reduce risks of accidents (e.g. burns, scalds, cuts, falls, exposed machinery, electric shock and fires). Instruction and first aid facilities must be provided. Hygiene requirements include training in food handling and the provision of suitable clothing and hand-washing facilities. Specific fire and smoke protection requirements apply.

3 PUBLIC AREAS

3.01 Concept

Restaurant design is developed around the concept of the operation. This will take account of the intended market, the clients' objectives and proposals, the location and type of premises,



17.3 *Large-scale production*

structural changes involved and cost targets. Brand led designs, including franchised and licensed outlets, are usually limited in scope but may be adapted to the type of building available.

3.02

The concept and operating strategies are invariably decided by the clients. Details of design may be set for brand consistency and customer assurance in chain operations. This applies particularly to middle and popular market requirements, including fast-food operations. However, entrepreneurs are also aware of social trends and changes in consumer requirements and new innovative design concepts are constantly being introduced.

3.03 Marketing criteria

Customer choice is influenced by price and expectations which vary depending on the occasion. Factors such as convenience, value and social atmosphere may be paramount. For others, the sophistication, menu choice and style of service may be important. Markets can be classified according to socio-economic categories which broadly indicate spending power and types of services required. Market studies also assess competition, changes in the area and optimum locations.

3.04 Design criteria

Interior design has to satisfy a number of requirements, both functional and aesthetic. It has to reassure confidence in standards, stimulate appropriate emotive responses, interest and visual appeal, and provide conditions which create the desired social atmosphere. Considerations include:

- *Function*: operation, efficiency, order, hygiene, durability, maintenance.
- *Ambience*: luxurious, sophisticated, exotic, homely, romantic, lively.
- *Characterisation*: operating style, theme, food specialisation, features.
- *Seating plans*: room proportions, horizons of interest, windows, perimeters.
- *Perception*: attention to detail, consistency, linkage of areas, personalisation.

3.05 Coverage

A comprehensive design scheme covers:

- interior finishes, fittings and equipment, decoration;
- theme design, furniture, furnishings and features;
- tableware, linen, table appointments and uniforms;
- display counters, service equipment, circulation plans;
- lighting, airconditioning and technical installations;
- motif, graphics, menu and drinks folders;
- desks, registers and monitoring equipment.

3.06

Shop-fitting frontage, entrance, cloakroom and ancillary bars are normally included. Kitchen equipment including their technical plant, services installation and utensils may be treated as a separate contract but must be planned as part of the whole project. Client requirements for accounting and management systems and equipment must also be incorporated.

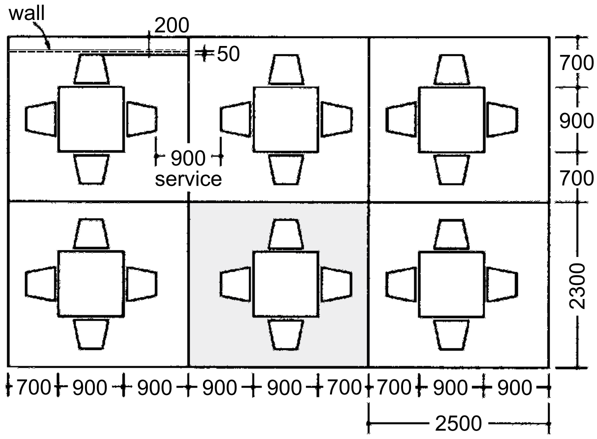
3.07 Seating plans

For meals consumed on the premises, maximum numbers of customers are dictated by numbers of seats (covers), mealtimes served and seat turnover. Customer densities (in m^2 per diner) depend on the room dimensions, method of service, table and chair sizes, seat groupings and layout within the room, **17.4**. Space allowances are given in Table III.

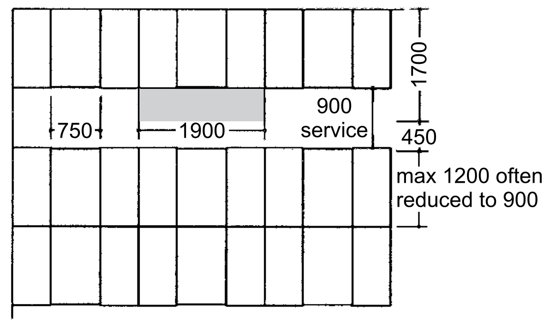
Table III Space allowances

Type of restaurant or service Example	Area per seat (m^2)	Service add (m^2)
Fine dining Traditional 80 seats	2.0–2.4	table service
Food speciality or ethnic High standard 80 seats	1.6–1.8	table service
Mid-market restaurant Limited menu 100 seats	1.5–1.7	counter 0.2
Cafeteria 140 seats Single line counter	1.4–1.5	servery 0.4
Popular chain restaurant Limited menu 100 seats	1.2–1.4	table service
Fast food/takeaway Set menu range 50 seats	0.8–1.0	counter 0.6
Pub bar (25% seating) Including counter	0.6–0.9	
Bar lounge (50% seating) Including counter	1.1–1.4	
Banquet hall dining area 200 seats	0.9–1.2	pantry 0.2
Employee cafeteria 200 seats	1.1–1.2	servery 0.2
Primary school Counter/family service	0.75–0.85	
Secondary school Including counter	0.9	
College refectory	1.1–1.2	servery 0.2

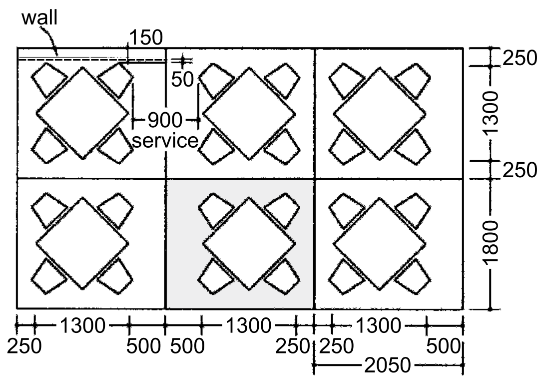
Note: Depends on rooms dimensions, circulations and type of furniture.



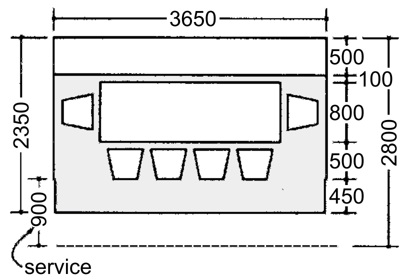
a *Square tables, square layout, local density 1.4 (in m² per diner)*



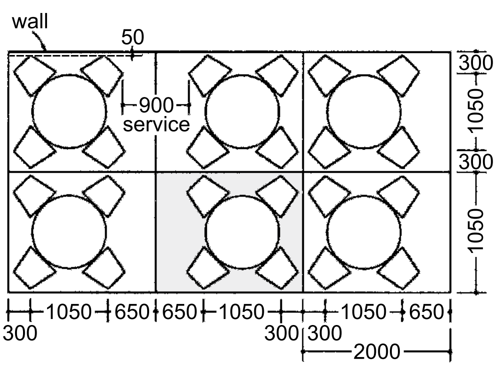
d *Banquette seating in booths, density 0.8*



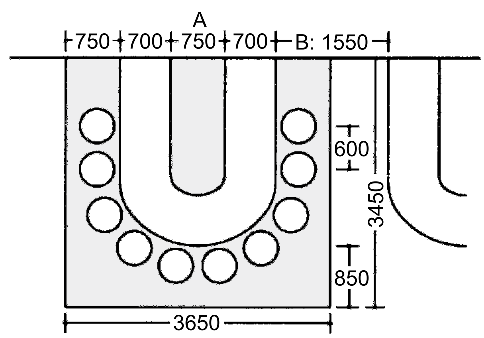
b *Square tables, diagonal layout, local density 0.92*



e *Large booth in recess, density 0.86 for 10 people, or 1.1 if only two people sit on bench seat*



c *Circular tables, diagonal layout, density 0.82*



f *Counter service, density 1.26. (Dimensions A and B are increased where more than one waiter is employed)*

17.4 *Layouts for restaurant tables*

3.08

Self-service requires wide aisles leading to and from the counter(s), orderly lines with increased space between tables, **17.5**. Waiter service layouts can be more flexible but service and customer circulations must not conflict, **17.6**.

3.09

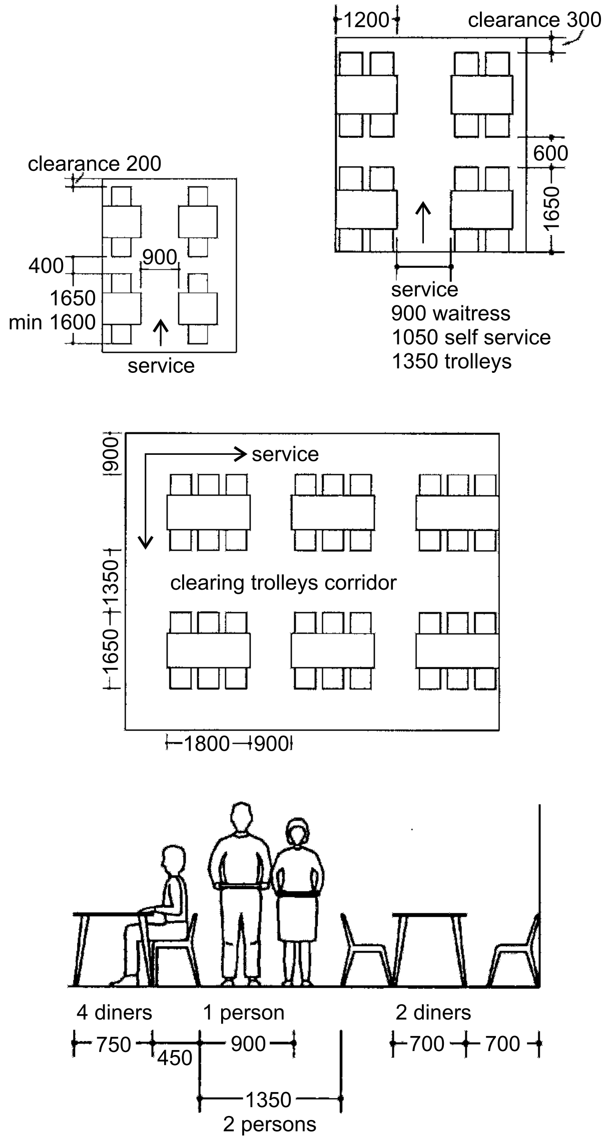
Table and chair sizes increase with sophistication and length of meal. Popular restaurants mostly provide tables for four which may be fixed or loose, square or round, in open- or booth-type layouts depending on style of operation. High-spend restaurants provide a higher ratio of tables for two, often allowing grouping together for parties of four, six or more as required. Employee and institutional arrangements use rows of tables to increase density which may also be removable for alternative use of the area.

3.10 Seating layouts

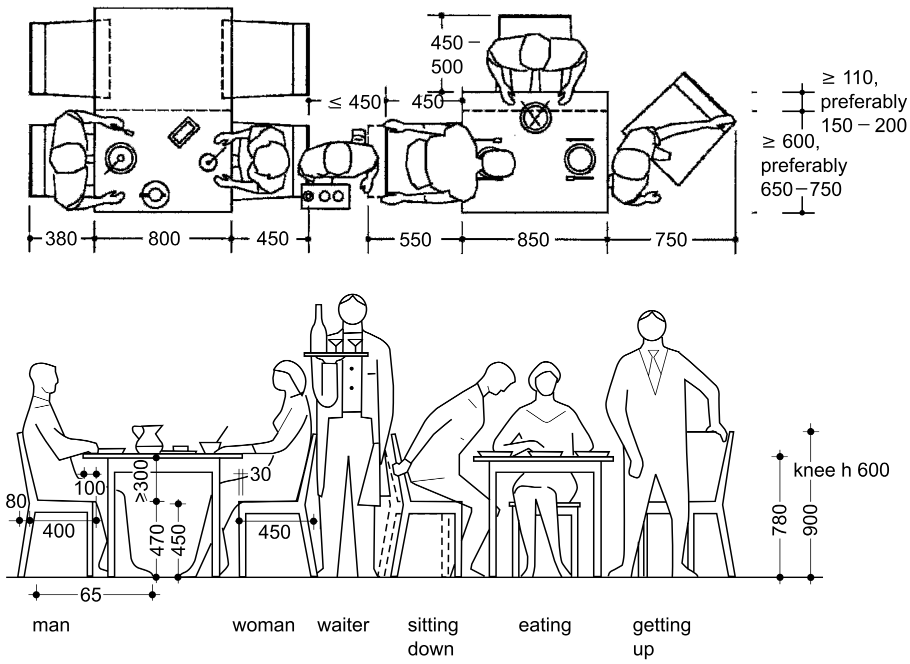
Layouts are influenced by windows and views. Individual seating areas may be separated by levels and partitions to extend choice (personalised areas, perimeter seating) and interest (features).

3.11

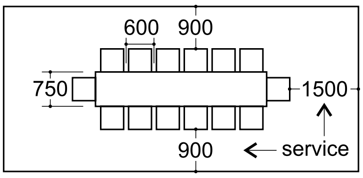
Functions, banquets and conference groups require adaptable stackable furniture, **17.7–17.10**.



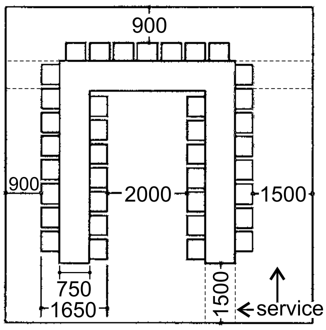
17.5 *Minimum space between tables to allow for seating, access and circulation*



17.6 *Restaurant critical dimensions*



17.7 *Small formal dinner arrangement*



17.8 *Banquet layout. The U arrangement can be extended in both directions to the limits of the banqueting room*

number of seats	table size: drinking mm	table size: eating mm
1	450 to 600	600 to 700
2	600 square	750 square
4	750 square	900 × 950
	–	1500 × 750
6	–	1400 × 950
	–	1700 × 750
8	–	1750 × 900
	–	2300 × 750

17.9 *Recommended rectangular table sizes relating to place numbers*

number of seats	table size: drinking mm	table size: eating mm
1	450 to 600	750
2	600	850
4	900	1050
6	1150	1200
8	1400	1500

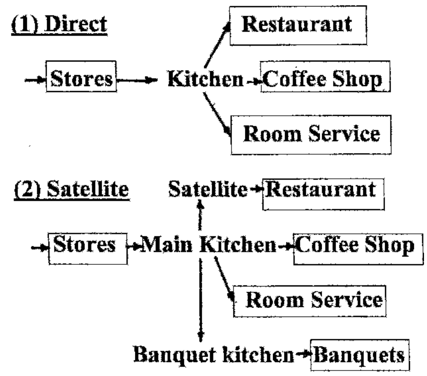
17.10 *Recommended circular table sizes for various place numbers*

3.12

Large hotels and resorts provide a choice of restaurants and facilities offering different menus, sophistication and prices, **17.11**.

Areas (net)	m^2/seat
Restaurant	2.0
Coffee shop	1.7
Banquet	1.0
Bar & loung	1.8 (1.2 crowded)
Kitchen & Stores	1.0 (0.5 satellite)

Arrangement



17.11 *Food and beverage services in large hotels*

3.13 Furniture and table top design

Restaurant furniture must be strong, durable and resistant to soiling. Depending on the type of operation, this includes:

- Fixed tables, usually pedestal or cantilevered for leg clearance, with loose chairs or fixed booth-type seating, **17.12**.
- Fitted counters and bars. Fixed bar/counter stools, **17.13**.
- Movable tables with loose chairs or fixed banquette seating.
- Stackable tables and chairs with carrier systems. Tables with extension brackets or alternative tops (square/round). With level access to storage area.
- Side tables and designed trolleys for food presentation and service at the table.
- Reception and cash desks with terminals, screens, cash registers and other equipment.

Table top design must be compatible with the overall concept and style of operation. It will range from high-class sophistication requiring quality linen, china, glassware and silverware to stylised easy-clean laminated surfaces with durable ware and stainless steel utensils.

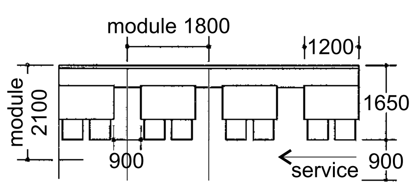
3.14 Steps in Interior Design

Brief, Terms of Reference:	Scope, aims, guidance, requirements, programme
Sketches, Proposals:	Design concept, visual ideas, preliminary estimates
Schematic drawings:	Perspectives, images, key features
Sample board:	Selected materials, finishes
Detailed drawings:	Scaled drawings for construction and installations
Specifications:	Requirements, quality, quantities
Suppliers:	Sources costs, discounts, replacements
Contracts:	Conditions, coverage of work, critical dates

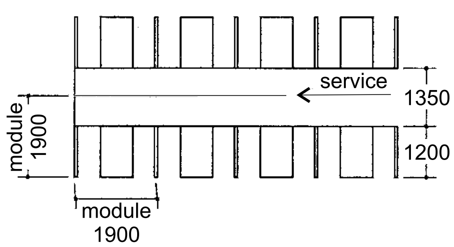
3.15 Maintenance and life cycle planning

Food and beverage service areas are subject to intensive use, breakage, spillage and damage requiring daily cleaning and frequent replacement or substitution. Carpets and finishes are selected to camouflage scratching or staining. Furniture and equipment must be durable and retain good appearance over the planned life-time of use.

Flexibility may be required to adapt to variable needs such as table groupings and rearrangements or changes in service style

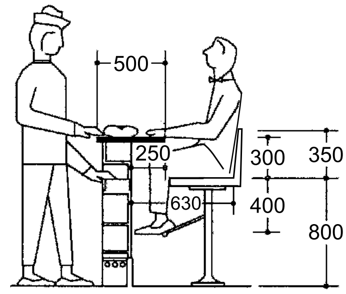


a *Banquette seating along a wall*

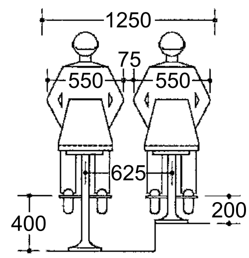


b *Booth seating with banquettes*

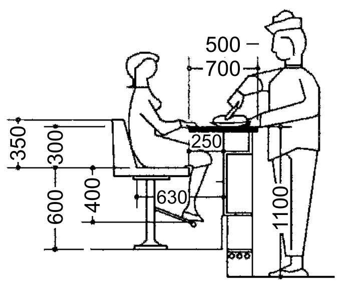
17.12 *Booths*



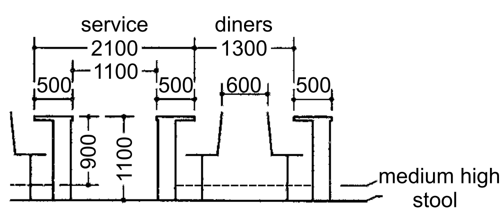
a *High bar stool*



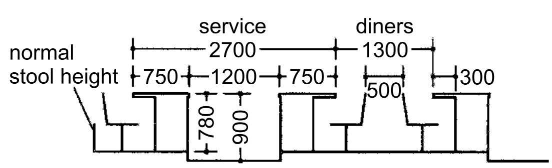
b *Bar stool spacing*



c *Medium-height bar stool*



d *High-density counter service*



e *Medium-density counter service*

17.13 *Counter-eating facilities*

from daytime to evening dining or for entertainment. This will call for furniture stacking and equipment storage facilities.

The life cycle of a restaurant will be affected by many factors such as changes in the surroundings, fashion and meal preferences; increasing competition; decline in standards and obsolescence. Kitchen equipment is usually planned for 7 years of usage but furniture and furnishings may need replacement in 5 years. In planning major refurbishments, it is opportune to revise the original concept and introduce changes in menu, design and style to meet new market opportunities.

4 FOOD PRODUCTION AREAS

4.01 Size and type

The size of the kitchen depends on the number of seats (covers) served at the peak period of demand – lunch or evening. It will also vary with the type of the menu and the extent to which food is prepared in advance. With a fixed menu, equipment and labour can be rationalised and ready-prepared food enables the kitchen to concentrate on finishing the meals to order. Conventional kitchens providing a varying (usually cyclical) range of menu choice are required in institutions and employee catering. They are also required in high-class restaurants and hotels. Convenience food is prepared in advance in bulk in central kitchens and chilled or frozen for distribution and storage prior to use (see **2.01**). This allows economies of scale, larger, purpose-designed equipment and factory-type processing. Finishing kitchens can be reduced in size and equipment.

Kitchen relative to size of dining area depending on:

- Conventional kitchen: 0.3 to 0.5:1 menu choice and seat turnover.
- Finishing kitchen: 0.1 to 0.3:1 storage and dishwashing.

Examples of kitchens areas are indicated in Table IV. Space requirements in large kitchens show the economies of scale by centralisation, **17.14**.

In large hotels, a central food production and dishwashing area may be located to serve a number of alternative restaurants directly or by circulation to more remote outlets such as in room service and banquet serveries.

4.02 Goods access

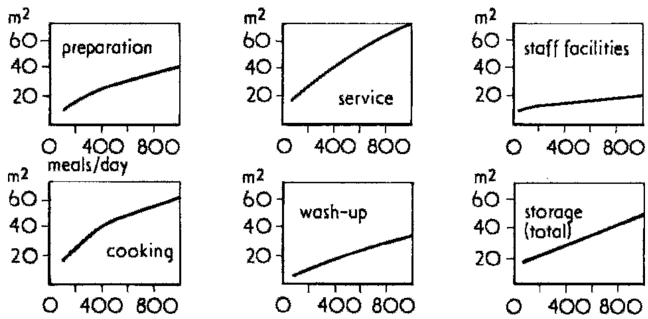
For sizes of vehicles, see Chapter 30 of this Handbook. Typical delivery arrangements are:

- Dry goods: weekly or fortnightly
- Frozen goods; weekly
- Vegetables and fresh fruit: twice weekly
- Perishable foods: daily
- Refuse and waste removal: depends on size and contract: weekly

Table IV Typical food production areas per restaurant seat

Type of restaurant Example	Kitchen area (m^2 per seat)	Type of food prepared
Fine dining 80 seats	0.9	choice menu, fresh food Cooked to order
Speciality food/ethnic 80 seats	0.7	a la carte menu, Cooked to order
Midmarket restaurant Themed 100 seats	0.6	limited menu part convenience food
Cafeteria 140 seats	0.4	cooked and cold choices part convenience food
Popular restaurant 100 seats	0.4	standard menu convenience food
Fast food/takeaway 50 seats	0.8–1.0	System production high volume sales

Note: Preparation, cooking and dishwashing take up about 50% of the total kitchen areas. Storage, service and staff facilities the remainder.



a *Preparation*
b *Service*
c *Staff facilities*
d *Cooking*
e *Washing up*
f *Storage (total)*

17.14 *Kitchen space requirements for various functions*

Large premises use bulk refuse containers (0.57–0.85 m^2) together with separate bottle, broken glass, metal compaction and packaging storage areas. Food waste must be sited in a refrigerated area (3–5°C) with suitable screening, vermin exclusion, washing facilities and drainage.

4.03 Storage areas

Storage depends on throughput and frequency of deliveries. Cold stores are grouped together and preferably entered through chilled holding areas to save energy. Floor slabs may need to be recessed to allow level wheeled entry to the store. Vegetable stores have direct access to their preparation area.

Purpose-designed moveable racks are used in food stores. Racks and shelves should allow about 50 mm between and above packages for easy access. The top shelf should not be higher than 1800 mm and the lowest should be at least 200 mm above floor. Shelves for heavy and frequently used items are best between 700 and 1500 mm high. Space may be required for containers awaiting return to suppliers, **17.15**.

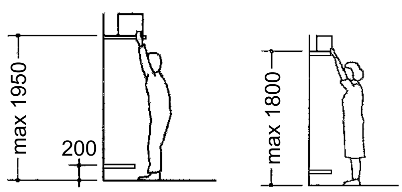
4.04 Preparation areas

Kitchen areas and layout are determined by:

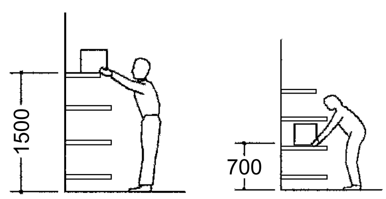
- The sizes of equipment and benches
- Space for working access and circulation

Some typical dimensions are:

- Work top and sink rim height: 870–900 mm
- Wall bench width: 600–750 mm

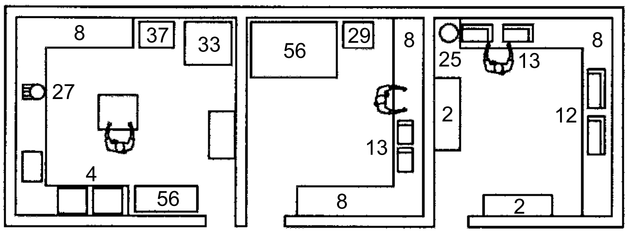


a *Limits for maximum reach for men and women*

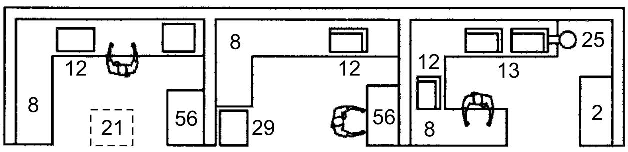


b *Convenient reach for heavy or frequently used items*

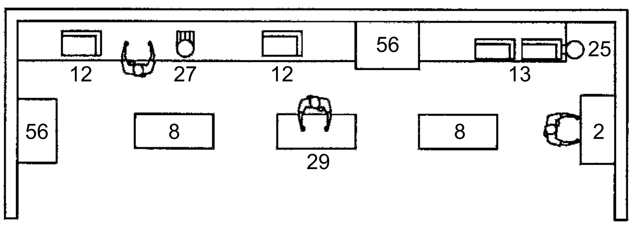
17.15 *Heights for storage shelving*



a *Separate rooms*



b *Bays*



c *Open plan kitchen*

17.16 *Alternative preparation area arrangements (see* **17.31** *for key to numbers)*

- Island bench or table width: 900–1050 mm
- Length of work area with convenient reach: 1200–1800 mm

Four main areas are required for conventional food preparation:

- Fresh vegetables, salads and fruit
- Meat and fish
- Pastry
- General including assembly of cold foods.

Specialised operations may require separate bakery and cake decoration areas. Preparation areas may be segregated in separate rooms, by low walls of 1200 mm height between the areas and main kitchen or the grouping of benches and fittings in specific areas around the sides, **17.16**.

Cross-contamination of food must be avoided and adequate work space with separate sinks provided in each area as well as for pan washing.

4.05 Cooking equipment

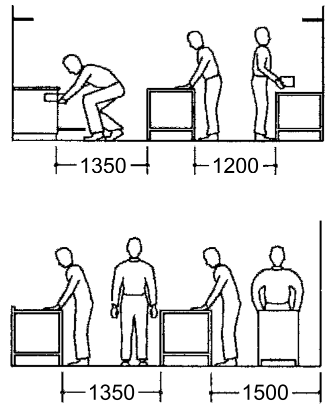
About 30% of the kitchen floor is occupied by equipment, 10–20% by benches and trolleys and 50% for circulation and access. Crowded space can lead to obstruction and accidents but excess space adds to circulation, cleaning, energy and maintenance costs, **17.17**.

Details of typical modern equipment are given in Table V. Size and duty is related to output and most ovens are designed to receive gastronorm sizes of dishes and trays. Some items are shown in **17.18**. Combination ovens incorporate both steam and hot-air convection modes. Other accelerated cooking includes microwave power with hot-air convection. Vitreoceramic induction hobs may be used instead of open burners.

4.06 Kitchen layout

A typical kitchen layout is shown in **17.19** with elevations in **17.20**.

Back-bar equipment fitted along a wall behind the serving counter is common in small kitchens and for finishing meals



17.17 *Minimum space between equipment for working and circulation*

enabling savings in engineering services, space and labour. Island grouping in the centre is better in larger units giving easier access from all areas, cleaning and maintenance. Engineering services, including fume extraction and floor drainage, are concentrated and perimeter sites can be used for refrigerators, storage, preparation areas and service counters. The minimum aisle width is 1050 mm but may need to be increased to 1500 mm to allow for cooker door swings or if trolleys are used.

4.07 Dishwashing

Dishwashing is expensive in terms of space, equipment, labour and energy costs. Disposables may be used in fast food and transport catering but give a poor image and problems in disposal.

Methods of collection for used dishes include self-removal with trays, trolleys or waiter removal. This must be decided at the initial planning stage. Trolleys will require straight aisles with minimum 1050 mm width and screened trolley parks.

Manual dishwashing in a double sink is inefficient and unhygienic for public foodservices. Spray machines may be intermittent or continuous throughflow and designed for corner (small kitchens) or in line position, **17.21**. Water softening is often used and modern machines incorporate energy- and water-saving devices. Space is required for depositing soiled dishes, scraping/spraying and loading as well as separate unloading sections. Trolley spaces should be allowed for return of clean dishes and utensils to the servery.

Typical sizes for tableware are given in Table VI and allowances for dishwashing spaces are show in Table VII.

4.08 Serveries

Arrangements for plating and serving food depend on the type and the scale of operation. In each case, circulation routes must be planned. Counters are designed to avoid risk of accidents, spillages and contamination, keep food hot, cool or chilled and retain an attractive hygienic presentation of the foods on offer.

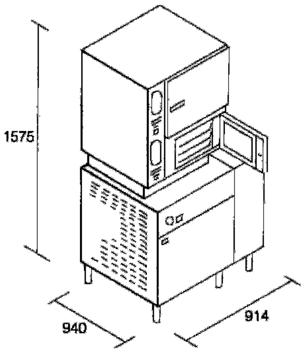
Waiter/waitress service

Service counter sited within the production area with hot, cold and refrigerated sections, shelves for plates and dishes and adjacent pantry area for supplementary serving items. Provided with a lobby which must be noise and glare screened from the dining area and have separate in–out doors, opening in direction of flow. May be supplemented by:

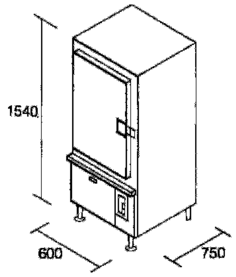
- Sideboard(s) within dining area
- Side table or trolley circulation, including flambé preparation/service at the table
- Featured display cooking section for special dishes
- Family service or self-selection from dishes brought to the table

Table V Kitchen equipment

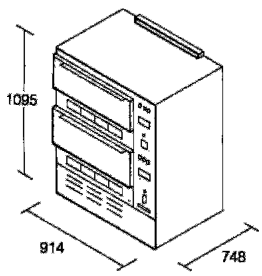
Type	Main features	Typical size and rating		
Ovens	Transfer heat to food within an enclosure. May use hot air (circulated by natural or fan-assisted convection), infrared or microwave emission	(s) – small units (m) – medium duty (h) – heavy duty		
General-purpose	Using hot air for baking, roasting or reheating. May be raised on stand or in tiers. Preloaded mobile racks used for speed and convenience. Working capacities: Trayed dishes 65–75 kg/m^3 (4–5 lb/ft^3) Poultry, meats 110–130 kg/m^3 (7–8 lb/ft^3)			
Oven range	Ovens combined with boiling hob top. Oven capacity based on shelf area 0.015 m^2 (24 in.^{2}) per meal	(s) (m) (h)	80 l. 160 1. 200 1.	11 kW 14 kW 16 kW
Forced convection oven	Hot air circulated at high velocities up to 4.5 m/s (900 ft/min) with directional flows to provide rapid heating, larger batch loadings, even temperatures. Normal cooking cycle: frozen food 25–35 min Combination (Combi) ovens incorporate both hot-air and steam convection modes. Accelerated cooking ovens include hot-air convection and microwave.	(s) (m) (m) (h)	50 1. 110 1. 200 1. 300 l.	2.6 kW 6 kW 9.3 kW 13.3 kW
Pastry oven	Tiered shallow ovens to give uniform heating for baking, pastry, pizza, etc. Capacity based on area: 0.004^2 (6 in.^{2}) per meal			
Roasting cabinet	Special cabinets for roasting meat, or mechanised spit roasting (poultry, joints, kebabs)			
Rotary or reel ovens	Specialised equipment for large-scale bakeries and continuous-cooking ovens			
Low-temperature ovens	For slow cooking of meat, etc. at 107°C (225°F) to reduce moisture loss. Specialist applications			
Microwave ovens	High-frequency (2450 MHz) alternating electromagnetic waves used to generate heat in dipolar molecules of food and water. Energy conversion factor high. Typical cooking cycle: 45–60 s (reducing with quantity)	(s) (m) (h)	20 1. 28 1. 28 1.	0.6 kW 1.3 kW 2 kW
Infrared ovens	Interspaced rows of heating elements in quartz tubes emitting mainly radiant heat in waveband 1.5–5.0 μm. Mainly used for reheating frozen food. Heating cycle 20–25 min			
Steam ovens	Free steam at or near atmospheric pressure: 3.5 kN/m^2 (1/2 lb/in.^{2}) Used for large-scale catering	(m)	200 1.	9 kW
Pressure steamers	Pressure steam up to 103 kN/m^2 (15 lb/in.^{2}) using jets for rapid heating of frozen food. May have option of free-vented steam	(m)		120 kW
Boiling and frying	May use loose pans and containers placed on or over external heat (gas burner, electric element, heated plate) Larger units incorporate heaters as part of design (with thermostatic control)			
Boiling tables	Usually provide four or six open burners or solid tops with tapered heat. Used as supplement or alternative to oven range	(s) (m)	2 ring Solid	3.6 kW 11 kW
Halogen elements	Alternative to gas burners and electric radiant rings. Used in hobs to provide instantly adjustable heat output			
Induction heaters	Electromagnetic alternating currents of 25 kHz directed through ceramic hob. Used to induce eddying currents in steel pans producing indirect heating for boiling or frying	(s) (m) (h)	1 ring 2 ring 4 ring	3.6 kW 7 kW 14 kW
Boiling pans and kettles	Containers heated directly or indirectly (preferred) Emptied by tap or by tilting over drain Output 45 l pan Root vegetables – 100–150 meals Soup – 150–200 meals	(m) (m) (h)	45 1. 90 1. 135 1.	7 kW 11.5 kW 14.5 kW
Bratt pans	Shallow tilting frying pans which are also used for stewing and braising. 150–350 mm (6–10 in.) deep. Mounted on trunnions for emptying	(m) (h)	0.28 m^2 0.44 m^2	6.4 kW 12 kW
Deep-fat fryers	Food immersed in heated oil. Frying temperatures typically 160–190°C (320–375°F) Fume extraction required Cooking cycles: typically 6–7 min	(s) (m) (m) (h)	5 1. 7 1. 16 1. 20 1.	3 kW 5.8 kW 10 kW 20 kW
Pressure fat fryers	Fryer fitted with sealed lid. Operated at 63 kN/m^2 (9 lb/in.^{2}), combining frying with pressure steaming of moisture Output: 80–90 portions/h			
Griddles	Shallow frying using surface contact with heated plate. Temperatures, 170–220°C (340–430°F)	(s) (m)	0.17 m^2 0.4 m^2	4 kW 7.5 kW
Grilling	Food exposed to elements emitting high-intensity radiation in wave band 0.7–2.2 μm	(s) (m) (h)	0.1 m^2 0.25 m^2 0.27 m^2	3 kW 5.7 kW 7.5 kW
Salamanders, broilers	Top heating over food on grating or branding plates			
Grills, chargrills, charbroilers	Bottom heating using red-hot tiles, plates or charcoal. Fume extraction required. May be featured in display cooking			
Water boilers, beverage-making equipment	Includes boilers operated by steam pressure or expansion of water May be installed in kitchen, in vending units, under service counter or as café sets. Capacity: Per litre 4–5 cups Per gallon 18–20 cups	(s) (m) (h)	28 1./h 48 1./h 68 1./h	2.8 kW 5.3 kW 7.5 kW
Holding units	Used to keep food hot or cold until served. Mainly incorporated into service counters			
Bains-marie	Heated well fitted with loose containers (standardised sizes). May be dry or water filled. Thermostatically controlled at about 74°C (165°F)	(s) (m)	2 units 4/6 units	0.5 kW 2 kW
Chilled shelves, wells and plates	For cold storage and display of salads, dairy products and prepared sweets. Usually incorporates under-counter refrigerator. Temperature about 3.5°C (37–41°F)			
Hot cupboards	Heated cabinets to keep plates and food warm prior to service. May be under-counter units, pass-through cabinets or mobile. Temperature kept at 76–88°C (170–190°F). Capacity: Standard 1,200 mm (4 ft) counter unit holds about 300 plates	(m) (m)	1.2 m wide 1.8 m wide	3 kW 4.5 kW



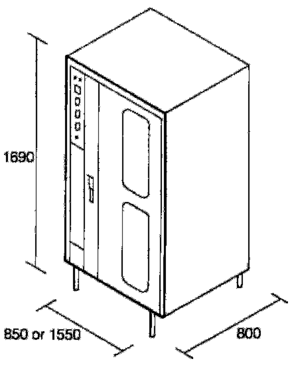
a *Convection steamer with two compartments*



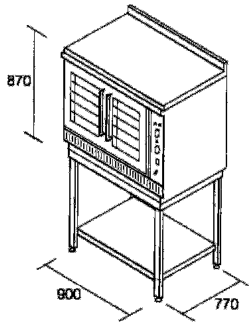
b *Atmospheric steaming oven with steam generator in base*



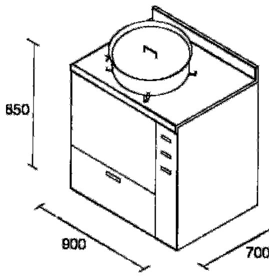
c *Tiered convection ovens, each 65 l rated 8.8 kW*



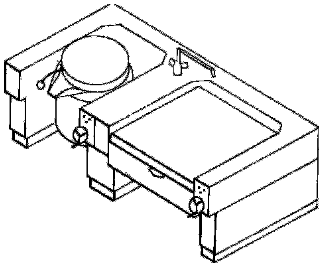
d *Autoreverse convection oven*



e *Forced convection oven on stand, 145 l, 9.2 kW*

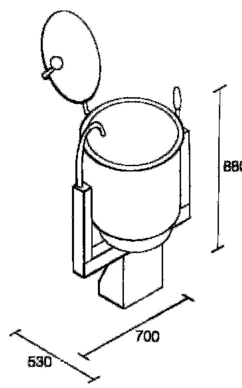


f *Dual-purpose boiling pan, 90 l Direct fired or steam jacketed*

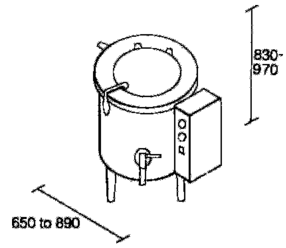


g *Tilting kettle and braising pan console:*

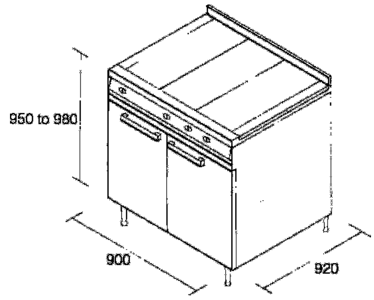
Unit width	*Kettle Capacity*	*Rating*	*Bratt pan Capacity*	*Rating*
1200 mm	*70 l*	*15 kW*	*68 l*	*9 kW*
1400 mm	*200 l*	*27 kW*	*89 l*	*12 kW*



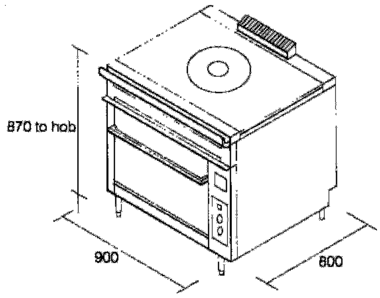
h *Tilting kettle with swivel cold water feed, 40 l capacity, electric or steam heated*



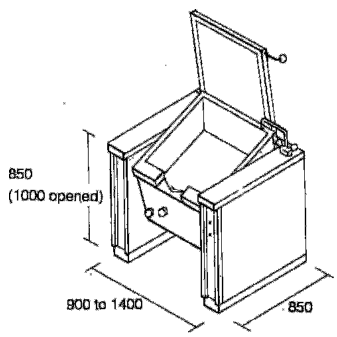
i *Vacuum boiling pan with electric or steam heated jacket, 20, 90 or 135 l*



j *Heavy-duty oven range, 200 l, 18 kW (electric), hob with three solid hotplates or griddle plate*



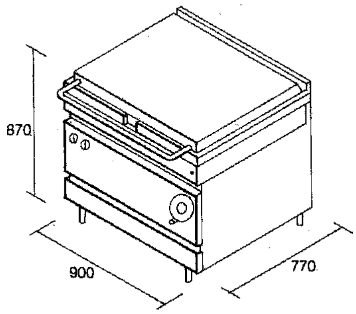
k *Heavy-duty oven range, 150 l, 16.5 kW, with drop-down door and solid hob top with tapered heat*



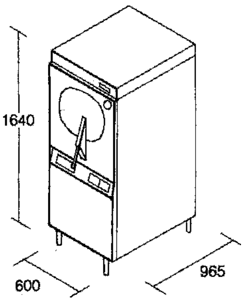
l *Bran or braising pan with pillar support:*

Capacity	*Width*	*Rating*
40 l	*900 mm*	*6.4 kW*
80	*1200*	*11.8*
100	*1400*	*14.8*

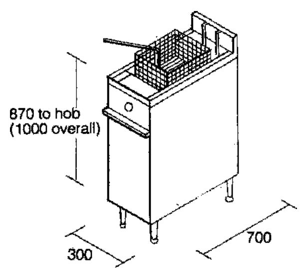
17.18 *Kitchen equipment (continued over)*



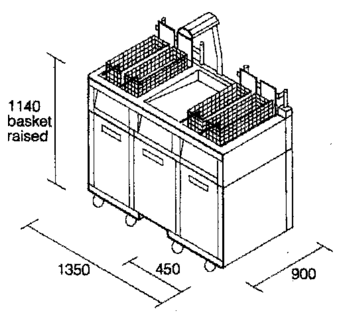
m *Tilting Bratt pan with operating wheel and trunion*



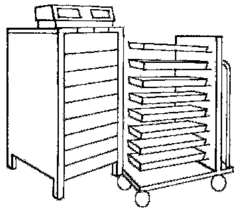
n *High-pressure steamer on stand, 12 kW rating*



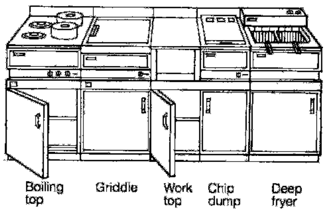
o *Deep fryer with one basket of 16 l oil capacity, 9 kW. Output 22.7 kg chips per hour*



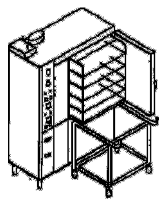
p *Combination of fast-food fryer with dual deep fryers and central chip dump. Each fryer 21.5 kW. Automatic basket lifting, integral oil filtration*



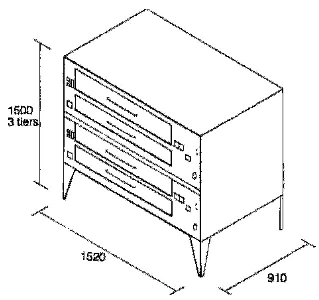
q *Infrared (regethermic) oven system, 4.7–5.0 kW*



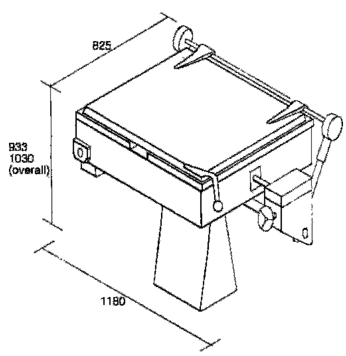
r *Example of combined units with under-counter cupboards*



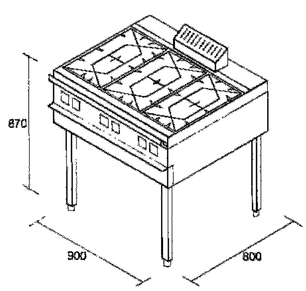
s *Bulk loading system with mobile transporter*



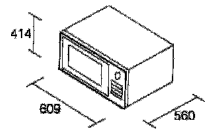
t *Tiered pastry or pizza oven*



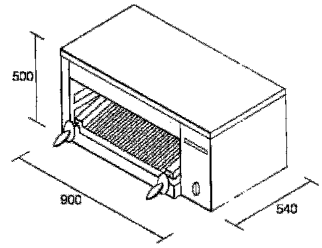
u *Tilting bratt pan*



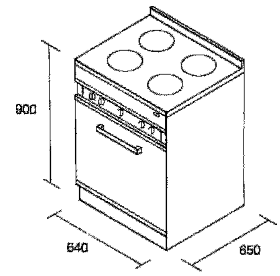
v *Heavy-duty boiling table with open gas burners*



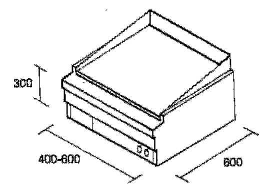
w *Microwave oven, 2.6 kW supply, 1300 W output rings, 8 kW rating*



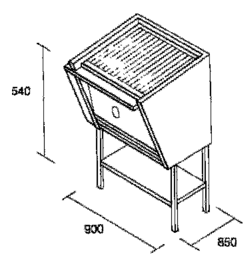
x *Salamander grill, wall or stand mounted, 7.5 kW rating*



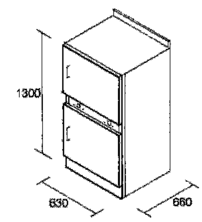
y *Medium-duty oven range, 84 l with four radiant rings, 8 kW rating*



z *Griddle, counter or stand mounted, 8 kW rating*

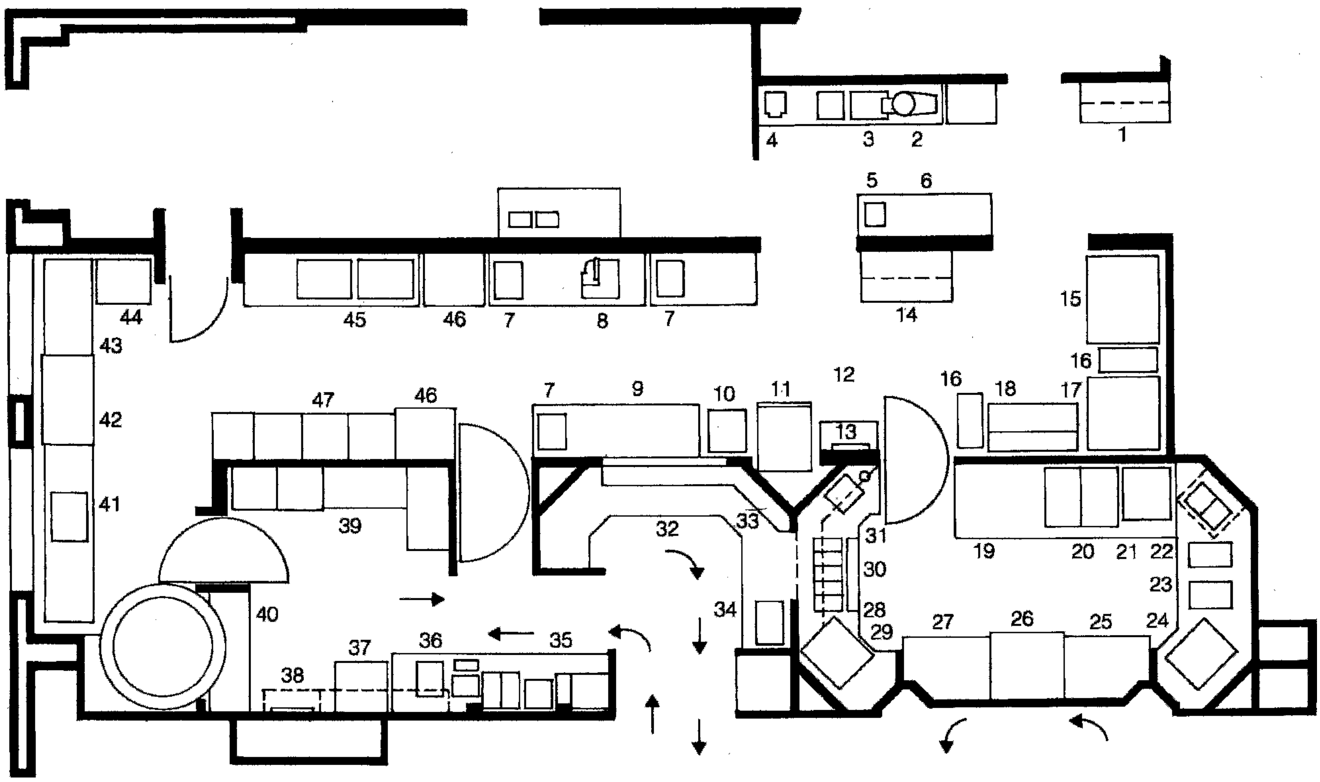


aa *Underfired grill, 37 kW*



ab *Two-tier general purpose oven each 80 l capacity*

17.18 *Continued*



Vegetable preparation area
1 *Trolley*
2 *Potato peeler*
3 *Double sink*
4 *Cutter/chipper with knife rack*
5 *Vegetable mill, with blade rack*
6 *Mobile table*

General preparation area
7 *Workbench with sink and wall shelving*
8 *Meat slicer*
9 *Marble pastry slab with flour bins under bench*
10 *Food mixer*
11 *Refrigerator*
12 *Ultraviolet insect control (on wall)*
13 *Wash-hand basin*

Main kitchen, primary cooking area
14 *Mobile heated trolley*
15 *Mobile two-tier convection oven*
16 *Boiling unit*
17 *Two induction heaters*
18 *Mobile workbench with shelves over*

Display kitchen – finishing area and servery
19 *Tiled bench with access to time clocks and refrigerator valves*
20 *Two induction heaters over bench with chilled drawers*
21 *Boiling top*
22 *Grill/salamander mounted over tiled worktop with inset heated pans*
23 *Two fryers with chilled drawers under bench*
24 *Microwave convection oven on corner shelving*
25 *Tiled heated worktop over deep-freeze cupboard*
26 *Gas broiler with shelving under*
27 *Tiled heated worktop*
28 *Tiled serving counter with shelf over*
29 *Microwave convection oven*
30 *Counter top with inset trays and cutting board*
31 *Inset sink and wastebin in corner recess*

Pantry and beverage area
32 *Fitted wall units*
33 *Two toasters*
34 *Large toaster over refrigerator*
35 *Beverage stand fitted with glass/cup racks and housing fruit juice dispenser, shake milk dispenser and two coffee machines*
36 *Water boiler stand with inset sink and drainer*
37 *Chest freezer*
38 *Wash-hand basin*
39 *Clean storage units*

Dishwashing area
40 *Carousel receiving unit with tray support shelf. Trolley bins under*
41 *Rack slide for soiled dishes with inset sink and basket shelves over*
42 *Conveyor dishwashing machine*
43 *Roller table for clean dishes*
44 *Mobile table*
45 *Double pot sink*
46 *Mobile pot racks*
47 *Mobile glass racks*

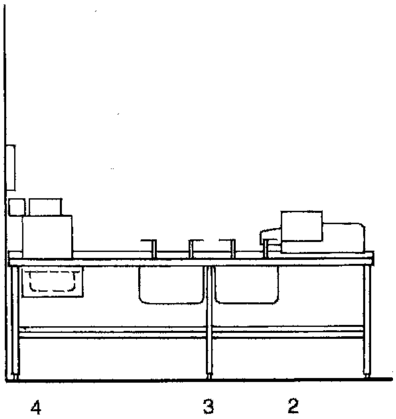
17.19 *Kitchens of Post House Hotel, Sevenoaks. Development: Trust House Forte Ltd. Plans prepared by Stangard Ltd*

Self-service
Serving counter arranged for self-selection of meal items with planned circulations for customers and food replacement. Display counters arranged in sequence of meal choice. Variations include:

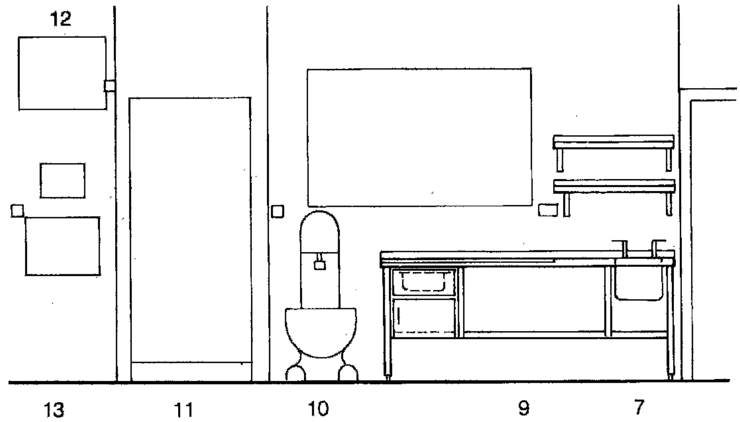
- Cafeteria style service for high throughput and sales promotion.
- Food hall and food court service with alternative counters and a common seating area.
- Temporary or installed buffet presentations, including assisted service at the counter.
- Snack and/or beverage vending machines with or without seating areas.

Central service
Distribution of centrally prepared dishes as hot, chilled or frozen foods to other locations for service. Central production calls for a fully integrated system, with standardised containers, equipment, transport and controls. Examples include:

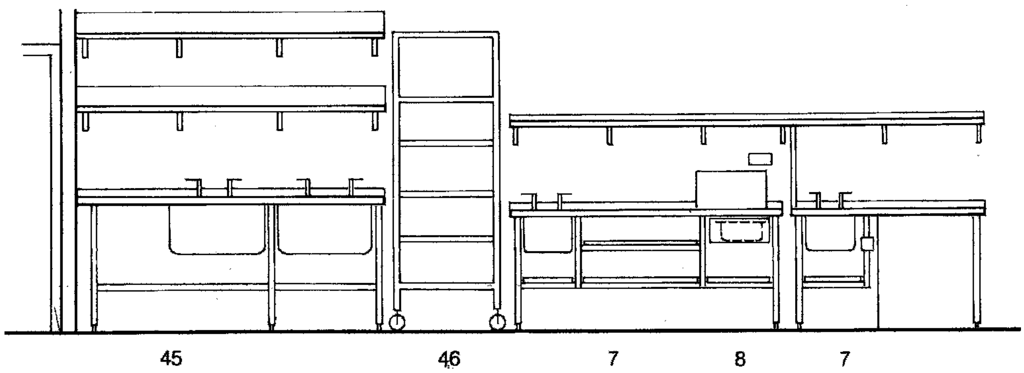
- Commissary systems to supply meals to finishing kitchens and in transit.
- Hospital systems to distribute meals to wards and individual patients.
- Banqueting systems to prepare meals in advance of functions.
- Central production of convenience foods for catering and restaurant outlets.



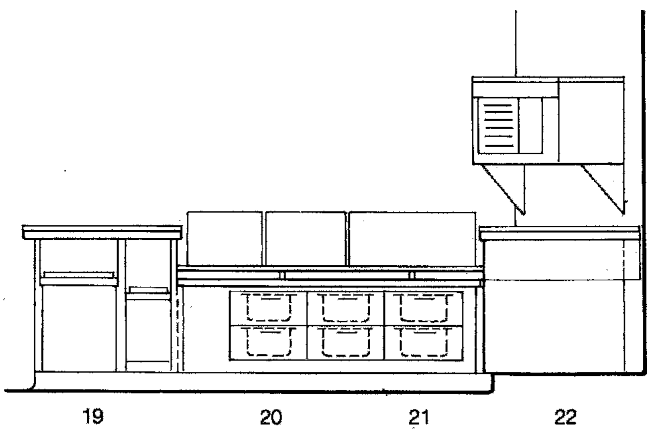
a *Vegetable preparation area*



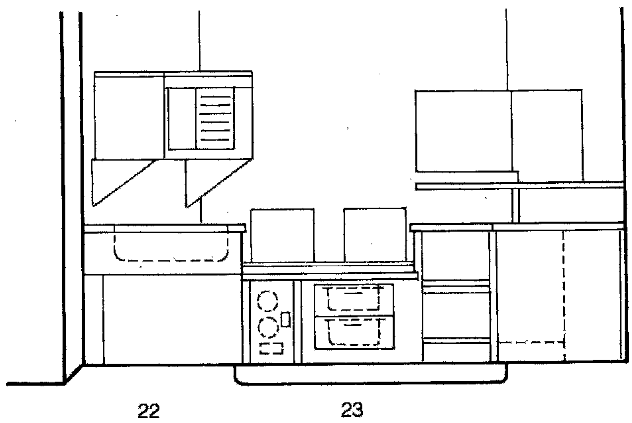
b *General preparation area*



c *Potwash and preparation area*



d *Display kitchen, finishing area and servery*



e *Display kitchen, finishing area and servery*

17.20 *Elevations of installed kitchen equipment (continued over)*

4.09 Facilities for staff

Employee ratios vary widely with the type of establishment and demand. The ratio of total employees to meals served over the peak period is about one employee to 8 meals served for full-menu, table service restaurants, 20 meals in limited menu table service and institutions and 33 or more in fast-food outlets. Changing rooms, lockers and sanitary facilities are required for total full- and part-time employees.

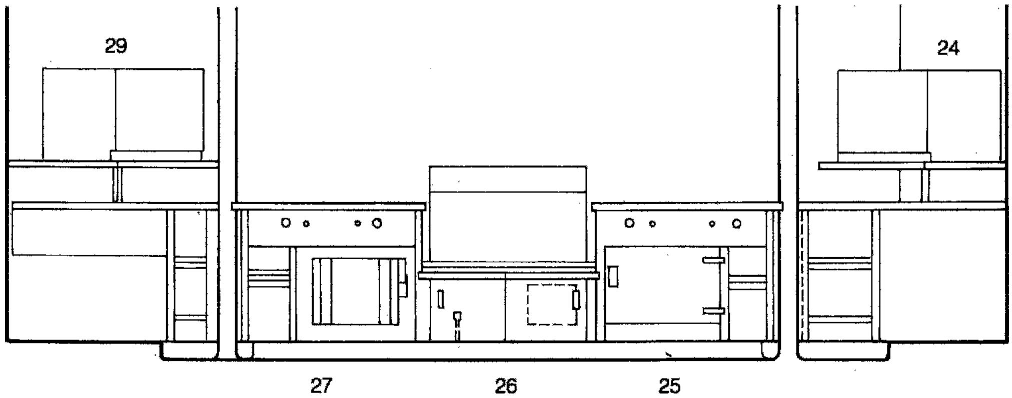
5 RESTAURANTS

5.01 Investment

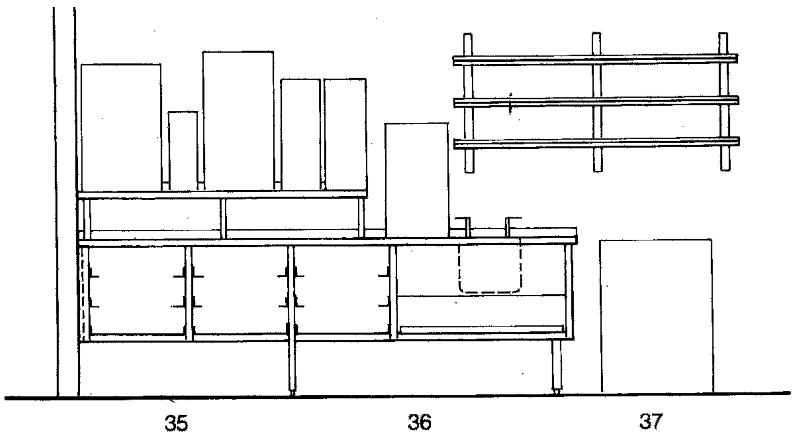
Commercial restaurants are affected by location, image, association and publicity. Location is critical in dictating the catchment area and potential market which may be based on local or transient customers. The image and association helps to create demand. However, sustained success depends on the customers' valuation of the meal experience.

Commercial restaurants are notoriously subject to fashion. They tend to have a short life, not often more than 8 years, and both the types of food served and facilities may need to be frequently changed. Investment has to be recovered within the planned life cycle period, requiring careful control of finance and operation.

Full-service high-class restaurants are only 5% of establishments. The mid-market range includes steak and seafood restaurants, grilles, brasseries and most ethnic restaurants. Commercial restaurants usually offer table service but self-service (see **6.01**) from attractive counter displays is common in departmental stores and some of the larger mid-market restaurants for convenience and sales promotion, **17.22**.

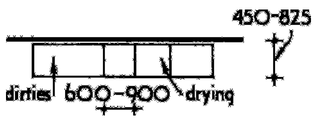


f *Display kitchen, finishing area*

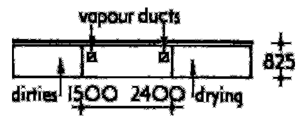


g *Beverage counter*

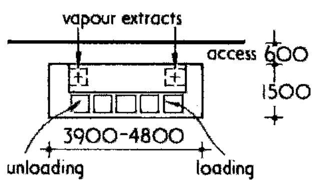
17.20 *Continued*



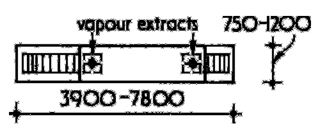
a *Small spray-type dishwasher*



b *Medium-size automatic conveyor dishwasher*



c *Rotary conveyor-type dishwasher*



d *Large 'fight'-type dishwashing machine with continuous escalator type conveyor*

17.21 *Alternative layouts for wash-up areas, with equipment dimensions*

5.02 Ethnic restaurants

In Britain, the increase of ethnic restaurants – particularly Chinese and Indian/Pakistani – has displaced many of the traditional establishments. Ethnic restaurants are the main choice for evening dining. Design is often symbolic rather than authentic and it is essential to research the types of foods, spices, traditional preparation and cooking methods represented. Specialist cooking equipment is often required to supplement the standard range normally used and in international hotels separate Western, Oriental and other types of finishing kitchens are required to serve the variety of restaurants provided, **17.23**.

Ethnic restaurants cover a wide range of quality and sophistication. The range of food choice is ever increasing with travel, holidays abroad and migration. Chinese food divides into four regions: Canton, Peking, Szechuan and Shanghai. The kitchens need to provide the extensive menus which can be up to 300 items. 'Indian' food is strongly spiced and much of it can be cooked by standard equipment although special ovens may also be used. Japanese food is subtle: preparation and service are seen as an art form and used as part of the presentation. Scandinavian food usually requires a counter display of smoked food, fish and cold meats. Greek restaurants are often designed as peasant–style

Table VI Range and sizes of tableware in general use

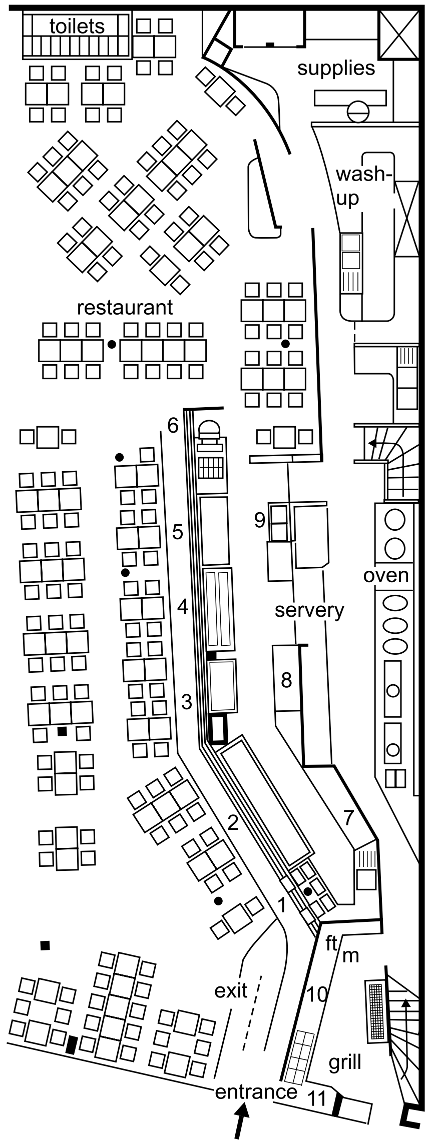
Type	Range	Size (rounded)
Pots (related to cups and pint sizes)	Tea	430, 570, 850, 1140 ml
Jugs	Coffee, hot milk/water	280, 570, 850, 1140 ml
	Cream	30, 40, 70 ml
	Milk	140, 280, 430 ml
Cups	Tea	170, 200, 230 ml
	Coffee (demitasse)	110 ml
Saucers	Size related to cups but should be interchangeable	
Plates	Side	165, 180 mm
	Dessert	190, 205 mm
	Fish/dessert	215, 230 mm
	Meat	240, 255 mm
	Oval meat	240, 255 mm*
Bowls	Cereal/fruit	155, 165 mm
	Sugar	90 mm
	Soup	215, 230 mm

* Usually maximum size for a dishwashing machine.

Table VII Allowances for dishwashing spaces (intermittent use)

Area/activity	Space (mm)	
Collection area for unsorted tableware prior to sorting and scraping	600 length per 10 meals* Minimum 900 Maximum 2400	
Stacking area for tableware sorted and stacked for manual washing	300 length per 10 meals† Minimum 900 Maximum 3600	
Loading onto racks for machine washing	Depends on rack/basket size Minimum 1000	
Draining and drying in racks or baskets after washing and sterilising	Minimum 1200 – Conveyor or spray-type machines up to 3600	
Unloading baskets and racks for clean crockery awaiting removal	100 length per 10 meals Minimum 600 Maximum 2400	
Spray-type machines with mechanised conveyor systems	Space occupied by machine conveyor system	
Rotary conveyor type (600–1000 meals/h)	Width 1500	Length 3900–4800
Flight-type escalator conveyor (over 1000 meals/h)	750–1200	3900–7900

* Based on self-clearance. Smaller areas suitable where part stacking is provided.
† Assumes some accumulation of dishes before washing up. The lengths relate to tabling 750 mm wide.



1 *Trays*
2 *Cold buffet*
3 *Beverages*
4 *Hot meals*
5 *Cheese and desserts*
6 *Cashier*
7 *Refrigerator*
8 *Beverages cupboard*
9 *Ice*
10 *Hot cupboard*
11 *Street sales counter*

17.22 *Self-service restaurant in Paris Architect: Prunier*

tavernas and this approach is common in Turkish, Mexican, Spanish, Thai and other popular ethnic restaurants. These traditionally use family service with a series of communal food dishes brought to the table. Italian food is more universal ranging from themed trattorie to specialised pizza chain outlets with purpose-designed ovens and preparation areas, **17.24**.

5.03 Cafes and coffee bars and snack bars

Typically, these have limited space and seating. The menu range of food offered is short and simply produced, normally operated with counter service and back-bar equipment. Beverages are an important product, particularly in the more specialised coffee bar chains. Cafes tend to emphasise a domestic character and are often located in shopping and visitor areas. Snack bars and sandwich bars have very restricted seating areas and primarily cater for local workers and others requiring snack meals or take-away food prepared to order. Compact table or booth areas and/or counter seating are used.

Chains of specialist coffee bars have expanded into almost every town using standard designs and equipment which offer a quick service of selected coffee beverages and pastries in comfortable surroundings.

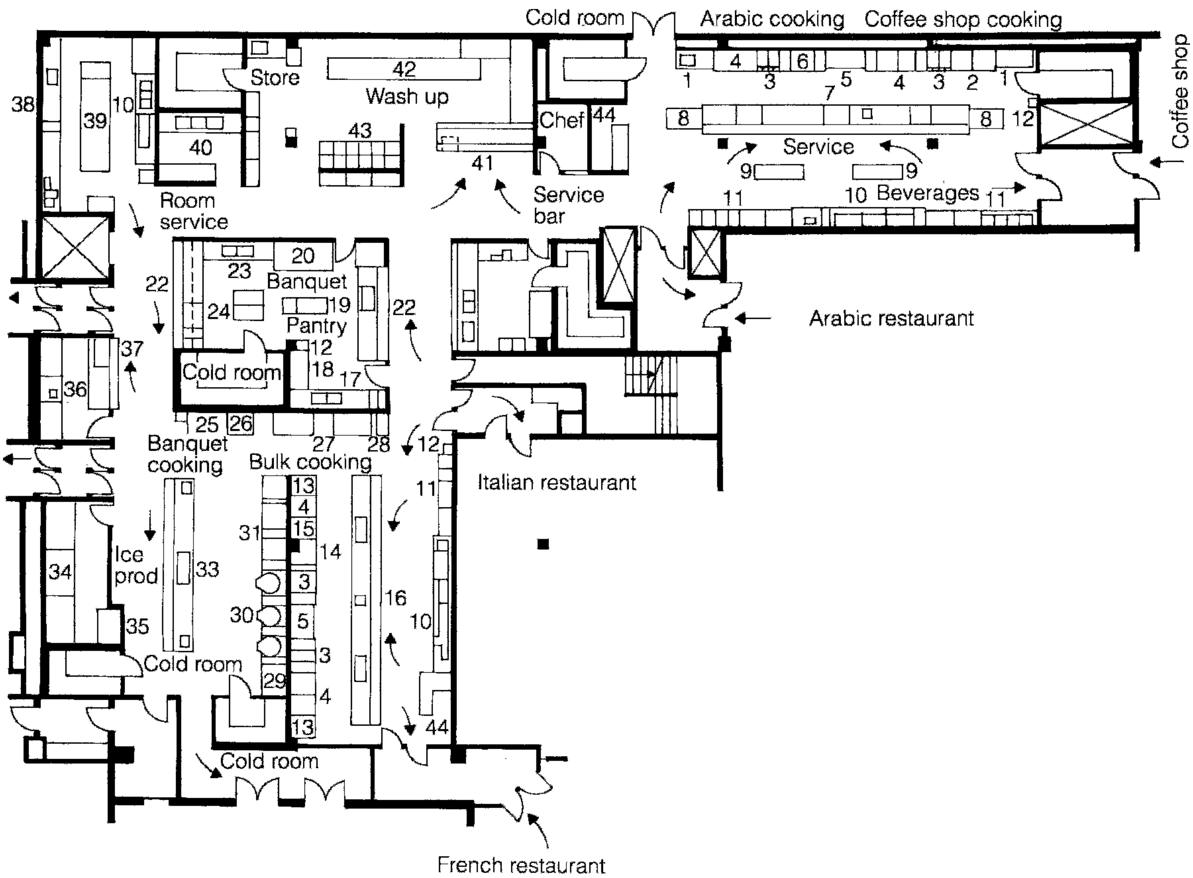
6 CAFETERIAS AND FOOD HALLS

6.01 Cafeterias

Self-service is mainly used in employee, educational and institutional catering, airports, motorway service stations and other locations which serve large numbers of people at peak meal times or in which time for meals are limited.

Characteristics:

- Scale of operation: usually large numbers of meals served allowing economies of scale in production.
- Concentrated demand: a short service period or limited time available for a meal demands a high rate of service with minimum delay. Above 600 meals per day, free-flow and

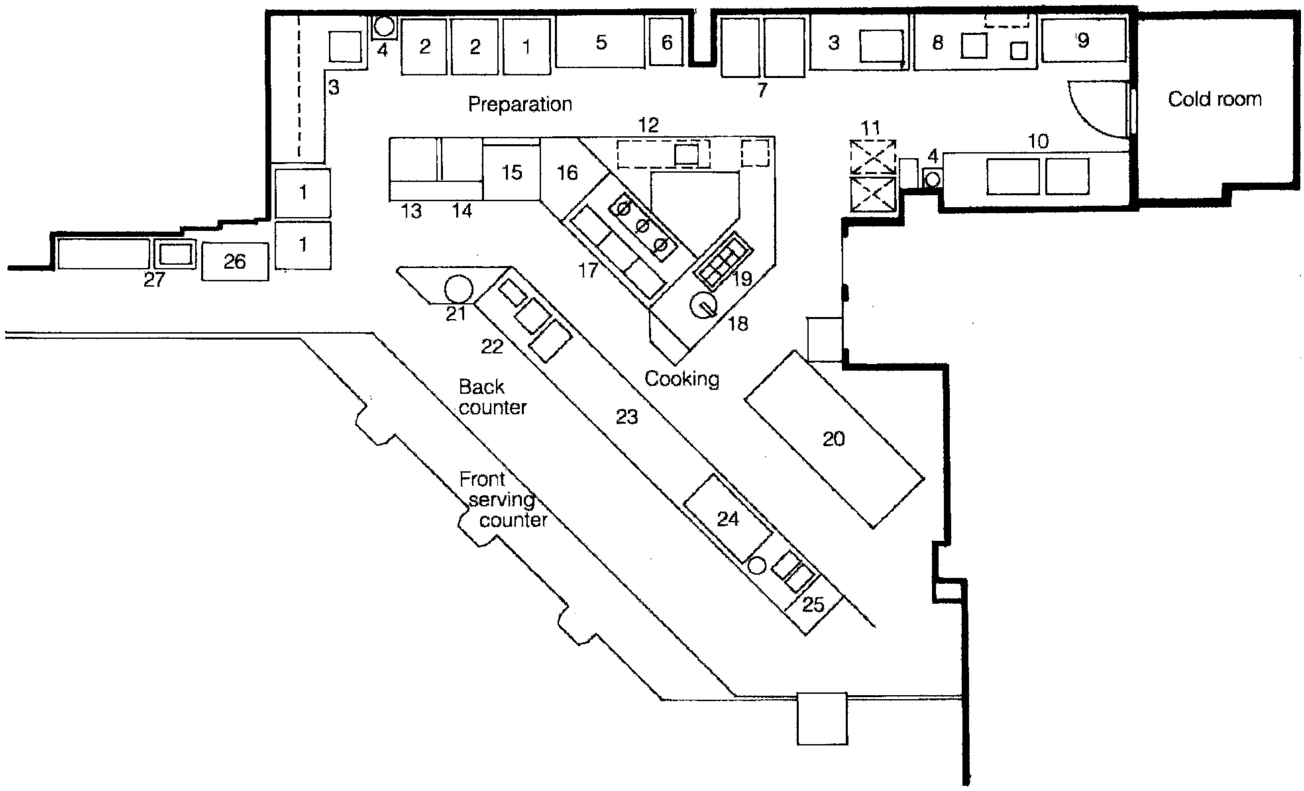


Key:
1 *Sink with wall shelf*
2 *Griddles*
3 *Fryers with adjacent worktop*
4 *Hot top ranges (two) with overshelves*
5 *Refrigerator*
6 *Beverage and breakfast counter with automatic boiler, conveyor toaster, fruit juice and chocolate dispensers, espresso and coffee machines*
7 *Wash-hand basin*
8 *Radiant broiler*
9 *Cold food counter with overshelf and tray slide*
10 *Service racks and basket racks*
11 *Range-mounted broiler*
12 *Charcoal broiler*
13 *Hot and cold distribution counter with overshelf and tray slide*
14 *Pass-through refrigerators*
15 *Hot cupboards*
16 *Pasta cooker*
17 *Griddle*
18 *Hot-food counter with overshelf and tray slide*
19 *Workbench with double sink and wall shelf. Conveyor toaster*
20 *Worktable with overshelf and trolley racks for gastronorm containers*
21 *Worktable with refrigerator cupboard and slicing machine*
22 *Combined mixer*
23 *Ice cream conservator*
24 *Workbench with double sink and wall shelf*
25 *Worktables*
26 *Roasting oven*
27 *Pressure/pressureless steamer*
28 *Convection oven*
29 *Pasta machine*
30 *Worktable with weighing scales*
31 *Tilting kettles*
32 *Brattpans*
33 *Hot-food counter*
34 *Ice-making machines*
35 *Iceflaker*
36 *Cabinet refrigerators with adjacent sink and workbench*
37 *Beverage service counter*
38 *Sink and workbench with egg boiler and toaster*
39 *Trolley park*
40 *Pot-wash area with triple sink and racking*
41 *Stripping shelves and rack slide with underbench waste containers*
42 *Flight dishwasher*
43 *Trolley park*
44 *Cashier desks*

17.23 *Sheraton Muscat Hotel. This is a recently built 350-room hotel in the Middle East, which illustrates the careful planning of foodservice facilities by the Sheraton Group. It offers a choice of Italian, French and Arabic restaurants in addition to banqueting for 250, a night club, various bars and room service. Food preparation is separated into specialised areas with common storage and dishwashing services. Development: Sheraton Corporation Foodservice consultants: David Humble Associates*

multi-counter service is practical and the counters are often grouped in a food hall separate from the seating areas.

- Space: counters add 0.2–0.3 m^2 to area per seat in the dining room.
- The average rate of customer flow through a single counter is 6–9 persons/min, dictated mainly by the speed of beverage service, cash payments and variety of menu choice.
- Bypass arrangements, duplication of the counter and cash point can increase the flow to 14–16 persons per minute. Beverage service may be in a separate area.
- Larger numbers require multi-counters choices, each serving particular types of meals and these may be arranged in a food hall separate from the seating areas.
- The layout must allow for direct access to the production area for easy food replacement.
- Menus: balanced to meet nutritional standards. The extent of choice will determine counter layout and length.
- Counter sections are heated or refrigerated and fitted out for food holding and display.



Preparation area
1 *Cabinet refrigerator*
2 *Workbench with sink and shelves*
3 *Wash-hand basin*
4 *Cabinet freezer*
5 *Mobile workbench*
6 *Mobile tray rack*
7 *Mobile proves*
8 *Workbench with sink*
9 *Workbench with cutter/slicer, can opener and cupboards*
10 *Five-tier mobile rack*
11 *Double sink*
12 *Trolley park*
13 *Pizza preparation bench with roller and tray racks*

Central cooking area
14 *Microwave convection oven*
15 *Steamer*
16 *Pasta cooker*
17 *Drainer*
18 *Heated bain-marie with infrared lamps over counter*
19 *Pizza-cutting machine*
20 *Chilled bain-marie with refrigerated cupboards under*
21 *Pizza oven*

Back counter to servery
22 *Post-mix, jet spray, ice well and drink dispenser cabinet*
23 *Heated pass-through chute*
24 *Beverage station with boiler, tea and coffee machines*
25 *Shake machine*
26 *Ice maker*
27 *Cleaner's sink*

17.24 *Seasons pizzeria, London*

- Critical features are the design of tray slides, easy access to the food items with protection from contamination.
- Cash-out desks are sited at or near the end of the service lines, duplicated where necessary and fitted with tray slide waiting areas. Stands for cutlery, condiment, etc. must be sited to avoid congestion.

6.02
Self-service arrangements require seating areas to be arranged in regular order with wide aisles, particularly in the circulation to and from the serving counters. Self-clearance or/and trolleys may be used. Furniture must be durable, easily cleaned and retain good appearance.

6.03
Table VIII indicates equipment requirements although these will depend on the type and range of menu. Counter arrangements are shown in **17.25** and **17.26** with design details in **17.27**. To minimise food handling, counters are designed to receive standard gastronorm containers, **17.28**.

6.04
An example of a mid-sized employee cafeteria is shown in **17.29** and a large free-flow arrangement in **17.30** with the standard key in **17.31**. A large-scale multi-choice layout is illustrated in **17.32**.

7 FAST-FOOD OUTLETS AND TAKEAWAYS

7.01 Fast-food systems

Fast food has been a rapidly growing sector accounting for about one-third of the market for meals outside the home. Outlets mainly concentrate on a limited range of popular products such as hamburgers, chicken, pizza. Food is highly standardised and operations are designed around systems which enable tight control over production and costs to ensure fixed competitive prices. Most outlets are chain operated.

Investment costs are high with sophisticated equipment designed for high-volume output with low-skill operatives. Locations are critical and prime high street sites having large pavement flows are preferred for major franchised units. The average size of large counter and table service outlets ranges from 320 to 460 m^2. Operations often extend over 15 h a day, 7 days a week to finance high investment and operating costs.

Table VIII Equipment requirements for a self-service cafeteria

Equipment for servery		Meals served per day – based on main meal period								
		50	100	200	400	600	800**		1000**	
							1	2 (1 – single line 2 – double line)	1	2
Trays										
Tray storage length	m	0.45	0.45	0.60	1.35	0.60	1.35	2 × 0.6	1.35	2 × 0.6
Bread, rolls, butter, etc.*										
Unheated counter with self-service display above: length	m	0.45	0.45	0.75	1.20	1.65	1.80	2 × 1.2	2.30	2 × 1.5
Cold meats, salads, etc.*										
Refrigerated counter with dole plate and glass display	m	0.45	0.75	0.90	1.20	1.80	2.30	2 × 1.2	2.60	2 × 1.5
above, refrigerator under of capacity	m^3	0.06	0.06	0.08	0.08	0.11	0.11	2 × 0.08	0.14	2 × 0.11
Hot foods										
Hot cupboard with sectioned bain-marie and heated service shelf: length	m	0.9	1.5	2.4	3.6	4.9	6.1	2 × 3.6	7.3	2 × 4.3
Beverages – hot drinks†										
Counter length	m	0.9	1.1	1.2	1.4	1.5	1.8	2 × 1.2	2.1	2 × 1.5
Comprising water boiler capacity	l/h	55	115	170	225	340	455	2 × 225	570	2 × 285
Tea/coffee urns										
No. × capacity	l	1 × 15	2 × 15	2 × 25	2 × 45	2 × 70	2 × 90	4 × 45	2 × 115	4 × 70
Storage racles under counter for cups/saucers:		50	100	150	200	250	350	2 × 200	450	2 × 250
counter: capacity	Capacity	–	–	50	200	350	450	2 × 200	550	2 × 250
Cold drink, etc.†										
Counter length	m	0.6	0.9	1.2	1.8	2.1	2.4	2 × 1.8	2.7	2 × 2.1
Comprising refrigerator capacity	m^3			0.06	0.08	0.08	0.11	2 × 0.08	0.11	2 × 0.08
Cold shelf length	m	0.45	0.6	0.6	0.9	1.2	1.2	2 × 0.9	1.5	2 × 1.2
Ice cream storage*	l			4.5	9.0	13.5	18.0	2 × 9.0	22.5	2 × 13.5
Squash dispenser		1	1	1	1	1	1	2	1	2
Iced water point				1	1	1	1	2	1	2
Cutlery†										
Counter length	m	0.30	0.30	0.45	0.60	0.60	0.90	2 × 0.6	0.90	2 × 0.6
Cutlery boxes fitted in top-capacity pieces		250	300	400	600	900	1000	2 × 500	1700	2 × 650
Reserve cutlery under			200	600	1400	2200	3000	2 × 1400	3800	2 × 1850
Cashier counter-cut away for cash desk length	m	1.2	1.2	1.2	1.2	1.2	1.2	2 × 1.2	1.2	2 × 1.2
Standard cash desks		1	1	1	1	1	1	2	1	2
Automatic change machine						1	1		1	1

* Depends on type of meals and customer preferences.
** Usually arranged as free-flow or with multi-choice counters.
† May be located away from service counter.
Based on equipment by Stotts of Oldham.

7.02 Operation

Most fast-food operators aim for a maximum door time (entering to leaving) of 3.5 min, 2.5-min queueing and 1-min serving. Counters are designed for rapid ordering and service with multiple stations. Production processes use automated equipment with control over cooking and holding time, portions and additions.

Food is delivered to outlets ready prepared, portioned and frozen or chilled. The entire procedure is tightly controlled and unsold hot food is kept only for a fixed period and then discarded. Employees have specific roles as till operators, backers and crew. Disposable containers are used for all food and beverage items and suitably designed waste receptacles and cleaning services must be provided in store and the vicinity.

7.03

Depending on the type of outlet, most fast-food stores also provide table and counter seating areas for meals on trays. These are grouped clear from the take-away routes and may be on upper or lower floors. Seating areas are designed for a high turnover, with self-service and self-clearance. Arrangements include fixed tables and seats, loose seats and wall counter seating. High standards of hygiene, cleaning and maintenance are important in system design.

7.04

Trends are towards health conscious eating with emphasis on lower fat, salt and sugar products and additional choice of salads, vegetarian, fresh fruit, yoghurt and real juices.

7.05 Food courts

Food courts are provided to offer a wider range of choice with a number of food outlets serving alternative products grouped around a common seating area. They may be provided in shopping centres, airports, universities and other places were the demand is high. Serving counters are backed by end-cooking, preparation and storage areas supplied from a service corridor, **17.33**.

7.06

Food and refreshment services are required by motorists, coaches and truck drivers. These are mainly grouped with filling stations, lodges and other services at convenient stopping places along main routes, near major junctions and within scenic tourist attractions, **17.34**.

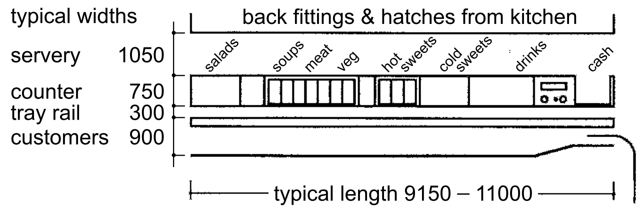
7.07 Other take-away facilities

Snack bars, most delicatessens and food shops offer food ready for consumption off the premises. This may range from products freshly prepared, baked or cooked to order, including fish and chips, pizza, pies and pastries to pre-packed sandwiches and vended beverages. Some include limited table and counter seating areas. Many popular and ethnic restaurants also offer a take-away facility, some with home delivery.

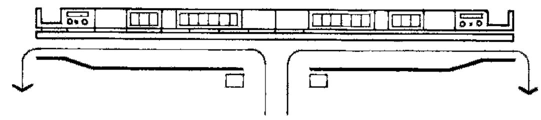
8 PUBLIC HOUSES

8.01 Licensing

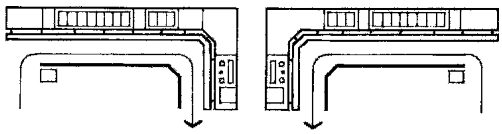
The requirements of public houses and wine bars are different from other food-service outlets in that alcohol sales are the dominant



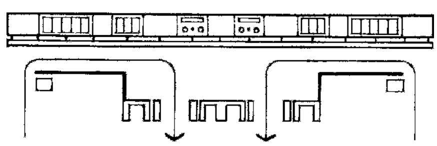
a *Single-line counter, 60–90 customers per min*



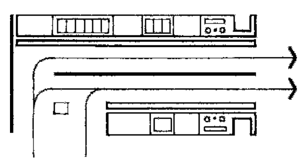
b *Divergent flow*



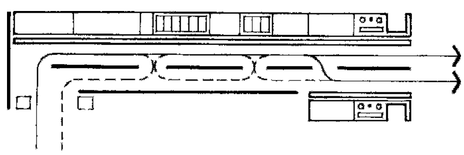
c *Convergent flow*



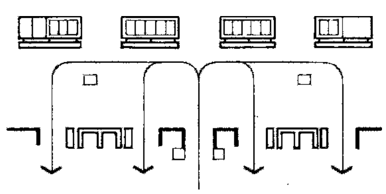
d *Multiple outlets*



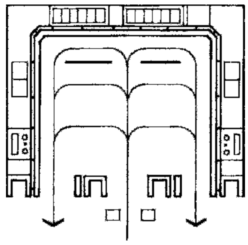
e *Parallel flow*



f *Bypassing*

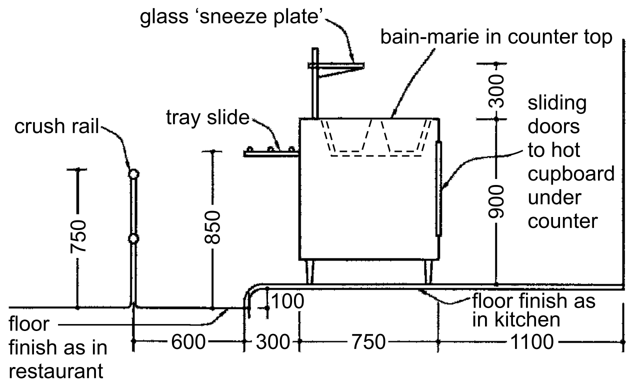


g *Free flow with counters in line*

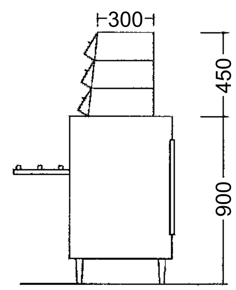


h *Free flow with counters in perimeter*

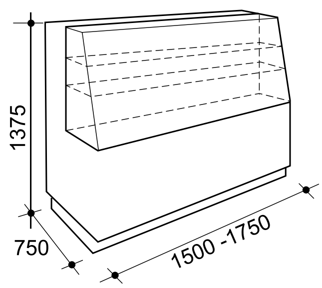
17.25 *Alternative arrangements for self-service counters*



a *Section through counter for hot food*



b *Section through cold-food counter*



c *Refrigerated showcase*

17.26 *Servery equipment*

rather than a subsidiary activity. Licenses to sell alcoholic liquor are granted only if the applicant and premises are suitable for the purpose. Safety means of escape, sanitary facilities and separation of bars from other areas must be approved before a license is granted as well as approval of any structural alterations before renewal.

Few new public houses are built. The majority of works are alterations to update the facilities and provide foodservices.

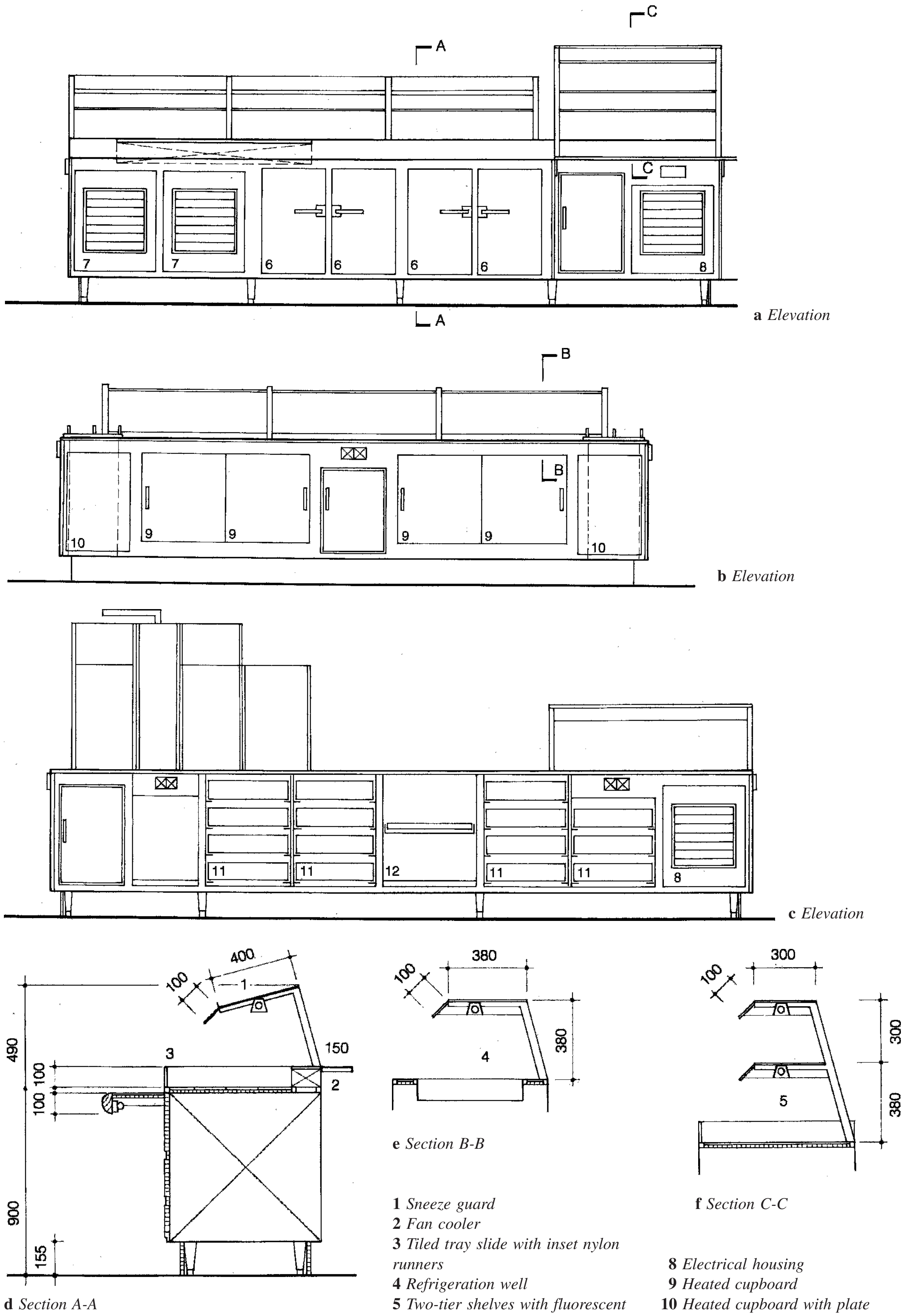
8.02 Separation

Pubs require two separate parts:

- Public areas: bars, lounges, dining areas, toilets and circulation used by customers;
- Private areas: serveries, storage (cellars), kitchen and accommodation used by staff.

Most pubs traditionally offer a choice of public bar and lounge areas. Drink storage areas must be easily accessible to each bar servery. Access to the kitchen is required for taking food orders from the counter and serving food directly to the dining area.

The main pub entrance and secondary entrances from car park are usually through lobbies to control temperature and airconditioning. Facilities must provide suitably located toilets of adequate



a *Elevation*

b *Elevation*

c *Elevation*

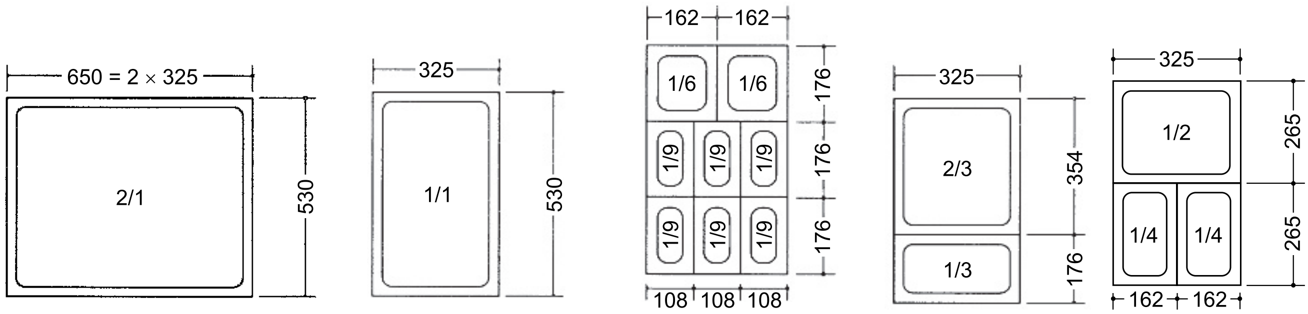
d *Section A-A*

e *Section B-B*

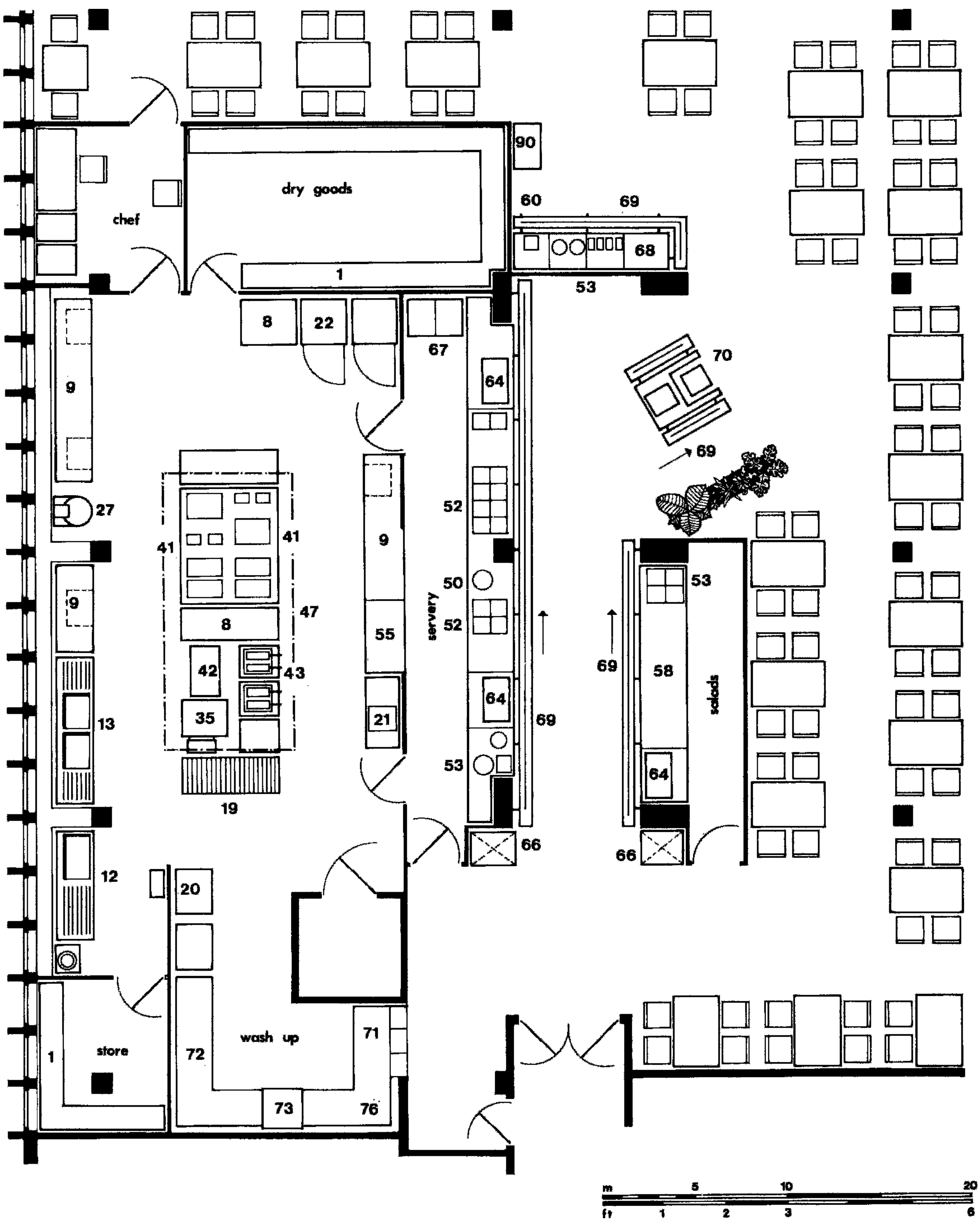
f *Section C-C*

1 *Sneeze guard*
2 *Fan cooler*
3 *Tiled tray slide with inset nylon runners*
4 *Refrigeration well*
5 *Two-tier shelves with fluorescent tube lighting*
6 *Refrigerated base*
7 *Refrigeration compressor*
8 *Electrical housing*
9 *Heated cupboard*
10 *Heated cupboard with plate lowerator*
11 *Open cupboard with cup basket*
12 *Open cupboard with shelves*

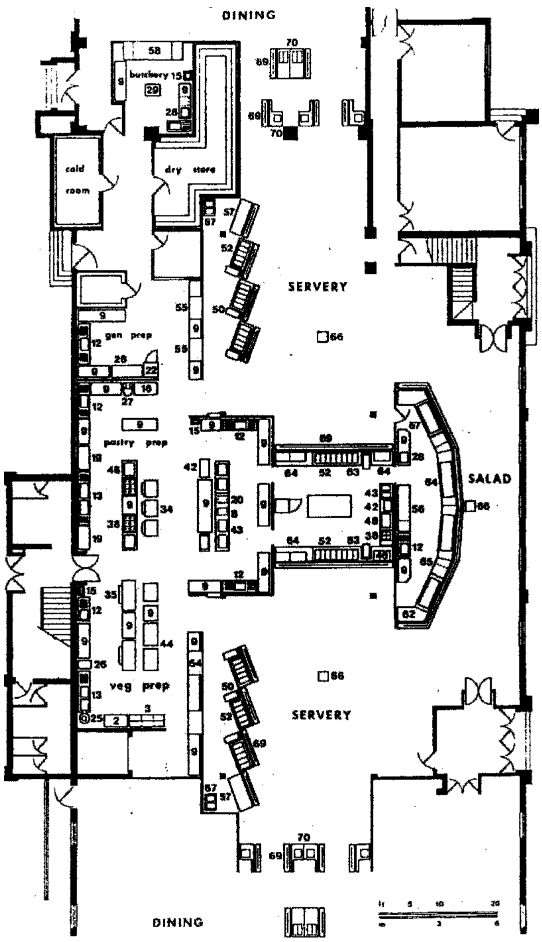
17.27 *Self-service counter*



17.28 *Module sizes for gastronorm containers*



17.29 *A self-service restaurant to serve 350 diners over a 1 hour 30 minutes period. The island salad bar is designed to divide the flow and increase the speed of service. Standard key,* **17.31**



17.30 *Large-scale staff catering facilities. Designed to provide up to 4000 meals within a period of 2.5 hours. Equipment by Oliver Toms Ltd, standard key,* **17.31**

Storage areas
1 *Shelving*
2 *Vegetable racks*
3 *Vegetable bins*
4 *Storage bins*

Preparation areas
8 *Worktable or bench*
9 *Workbench with cupboards/drawers*
12 *Single sink with drainer*
13 *Double sink unit*
14 *Mobile sink*
15 *Wash-hand basin (with dryer)*
16 *Marble-topped bench*
19 *Pot rack*
20 *Trolley*
21 *Mobile trays*
22 *Refrigerator*
25 *Potato peeler*
26 *Chipping machine*
27 *Mixing machine*
28 *Slicing machine/vegetable mill*
29 *Chopping block*

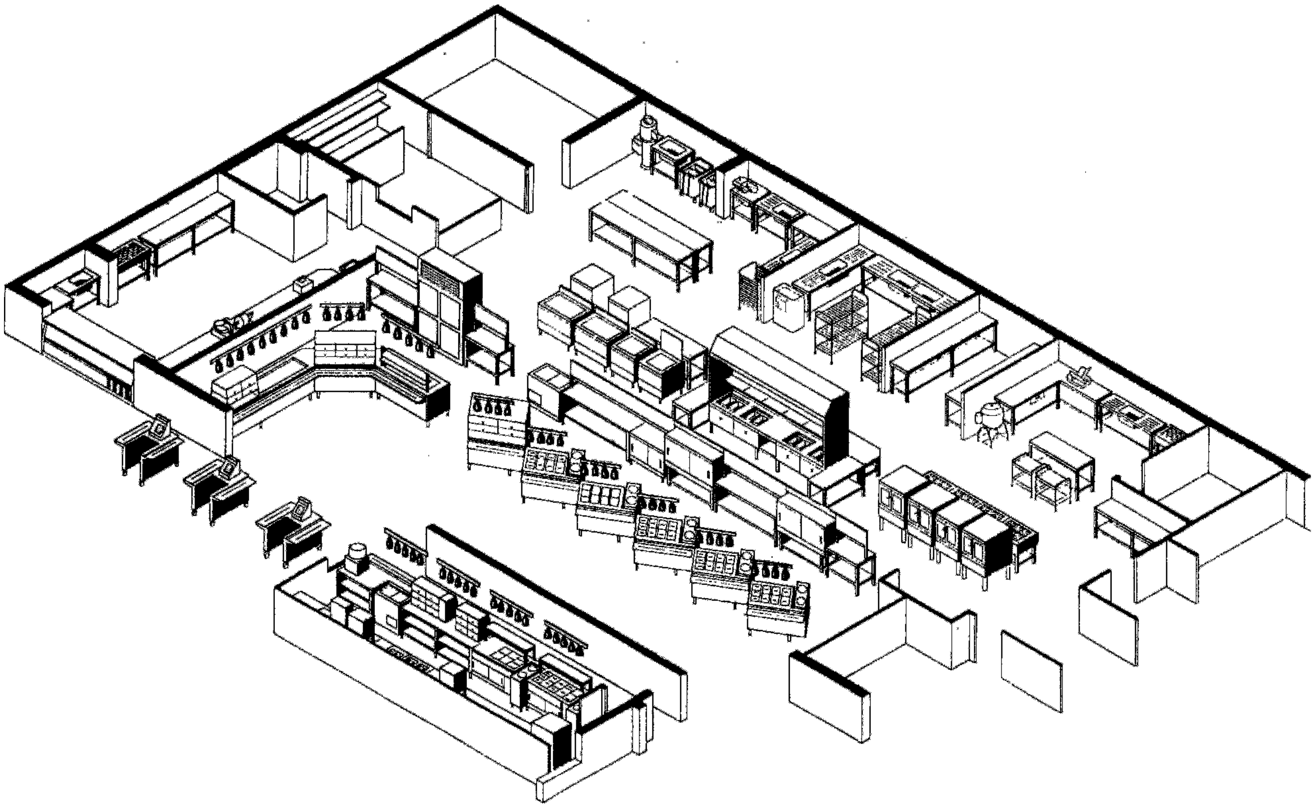
Cooking area
34 *Forced-air convection oven*
35 *Steaming oven/pressure steamer*
36 *Microwave oven*
38 *Boiling top with oven top*
39 *Boiling top with solid top*
41 *Oven range with boiling top*
42 *Griller or salamander*
43 *Deep fat fryer*
46 *Open-well bain-marie*
47 *Extraction hood over equipment*

Serving area
50 *Plate lowerator or dispenser*
52 *Hot cupboard with bain-marie top*
53 *Bench type bain-marie unit*
54 *Pass-through unit – heated*
55 *Pass-through unit – cold*
56 *Refrigerator under-cupboard/drawer*
57 *Refrigerated cupboard with doleplate*
58 *Refrigerated display cabinet*
59 *Milk dispenser*
62 *Counter unit – unheated*
63 *Counter unit with infrared lamps above*
64 *Counter display cabinet*
65 *Compressor or boiler under counter*
66 *Tray stand*
67 *Ice cream conservator*
68 *Cutlery stand*
69 *Tray rail*
70 *Cashier's desk*

Wash-up area
71 *Receiving table for soiled dishes*
72 *Stacking table for clean dishes*
73 *Dishwashing machine – semi-automatic*
76 *Waste-disposal unit or scraping point*

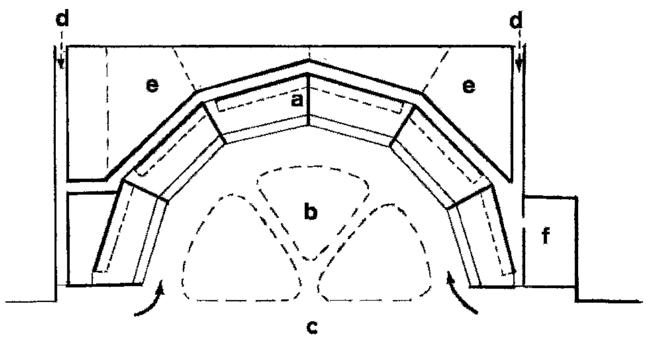
Dining areas
90 *Beverage vending unit*
91 *Food vending unit*
92 *Waiter/waitress serving station*

17.31 *Standard key for kitchen and restaurant layouts*

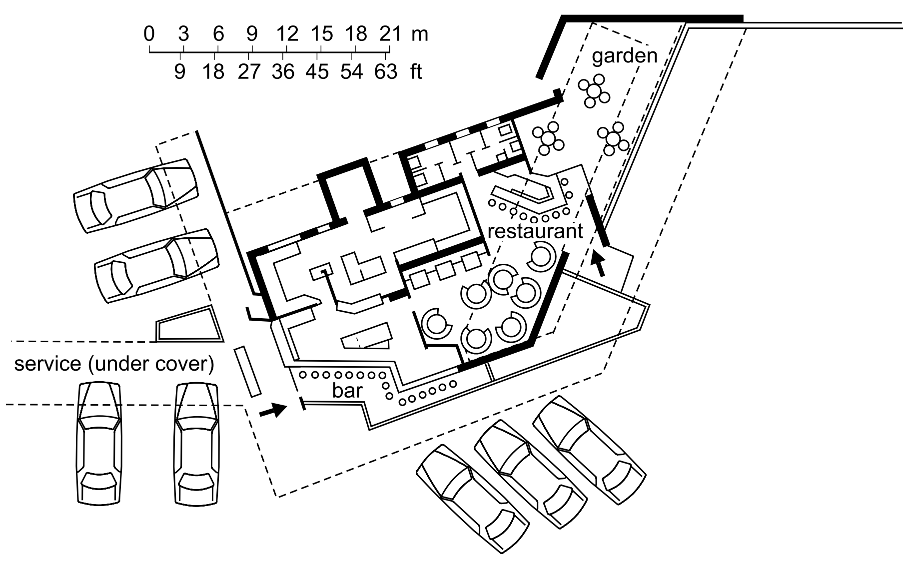


17.32 *Example of large-scale catering using multi-choice counters*

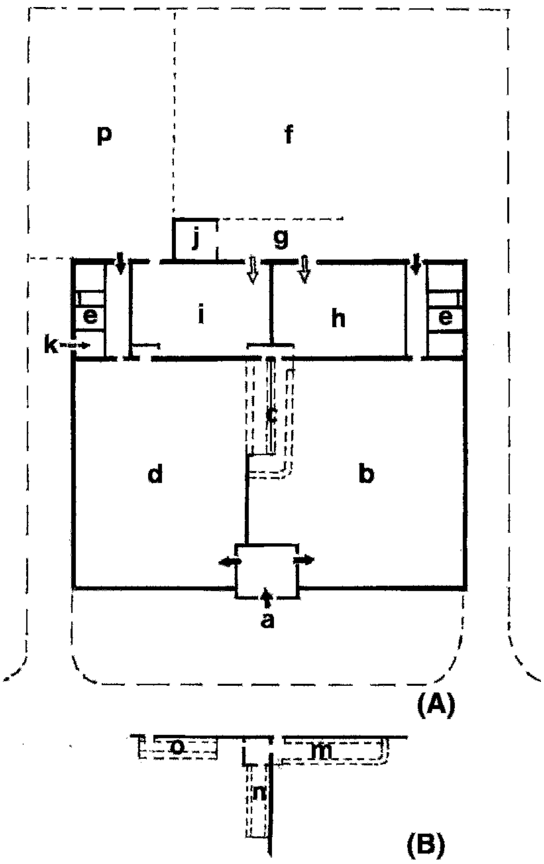
Key:
a *Food outlets with back-bar equipment*
b *Communal seating areas with utensil stands*
c *Concourse or main circulation area*
d *Service circulation from delivery bay*
e *Back-up storage and preparation areas*
f *Dishwash and trolley park*



17.33 *Typical food court with alternative choice food counters grouped around a communal seating area*



17.34 *Drive-in restaurant in California. Architect: Lauler*



A *Layout of public house with separate dining room. Extent of separation depends on nature of trade and space available*

a *Main front entrance with draught lobby and menu board*
b *Drinks bar with serving counter, large TV screen and possible separate games area*
c *Drink servery counter, arranged in parallel or as a continuous counter extending to both rooms*
d *Dining room with beverage service/snack counter*
e *Toilets, including disabled section. Separate for dining room and drinks bar*
f *Car park with secondary entrances for customers*
g *Goods delivery bay (screened) to cellar and kitchen*
h *Cooled cellar for drinks storage with secure areas for wines and spirits*
i *Kitchen stores, preparation, cooking and service*
j *Refuse and garbage storage (protected)*
k *Entrance to first floor flat for licensee and staff*

B *Alternative layouts for serving counters depending on marketing, business potential and need for flexibility*

m *Drinks counter to main bar*
n *Food display counter with refrigerated and heated sections for self-selection and self-service*
o *Beverages (and light refreshments)*
p *Parking or glasshouse extension for garden restaurant*

17.35

size, separated for men, women and disabled and entered through a screened, ventilated lobby. Relationships between areas are illustrated in **17.35** with alternative counter positions.

8.03 Pub meals

Most pubs offer meals to boost their sales by attracting a wider clientele and increased use of existing facilities and staff. Usually, a separate room or area of the lounge is used for foodservice with access (directly or via food hoist) to the kitchen. In country inns, glass-house extensions are common to extend the space into a garden environment. Most menus are standardised around popular choices with daily special additions to add variety – often with blackboard listings. Much of the food is bought in ready prepared. Kitchens are typically fitted with backbar equipment (e.g. microwave oven, grill, griddle, convection oven, boiling hob) together with preparation worktops, sinks, dishwasher, under-bench cupboards and refrigerators including chilled salad and food counters.

An example of a pub conversion is shown in **17.36**.

8.04 Drink storage

Traditional drink storage is in naturally cooled cellars with CO_2 pressure or pumps to transfer ale and other brewed drinks from metal kegs or barrels to ground-floor bars. Access to adjacent truck bays must be provided for deliveries, **17.37–17.40**. Temperature control is critical and cooling may be required for the 'cellar' (including secure wine stores) and may be installed in the pipeline to dispense cold beer and other beverages. Pipelines are contained in ducts, usually insulated and may supply more than one floor level, **17.41**. Hoists can be used to transport cases of drinks.

8.05 Bars and drink serveries

Drink serveries are usually centrally located to serve more than one room and provide a bar counter, and backbar fitting with work space between having access to the bar store. Counter lengths vary but the height and width are standard. A worktop with inset sink is provided below the counter top and dispense points. The backbar is designed as a decorative feature and includes a sideboard with cooled shelves, a display for spirits ('optics'), wine and glasses, cash register, cooler and glass-washing machine, **17.42** and **17.43**.

An alternative choice of bars is often provided and one may be adapted for foodservice. A high proportion of drinkers stand at the bar and stools may be fitted or loose.

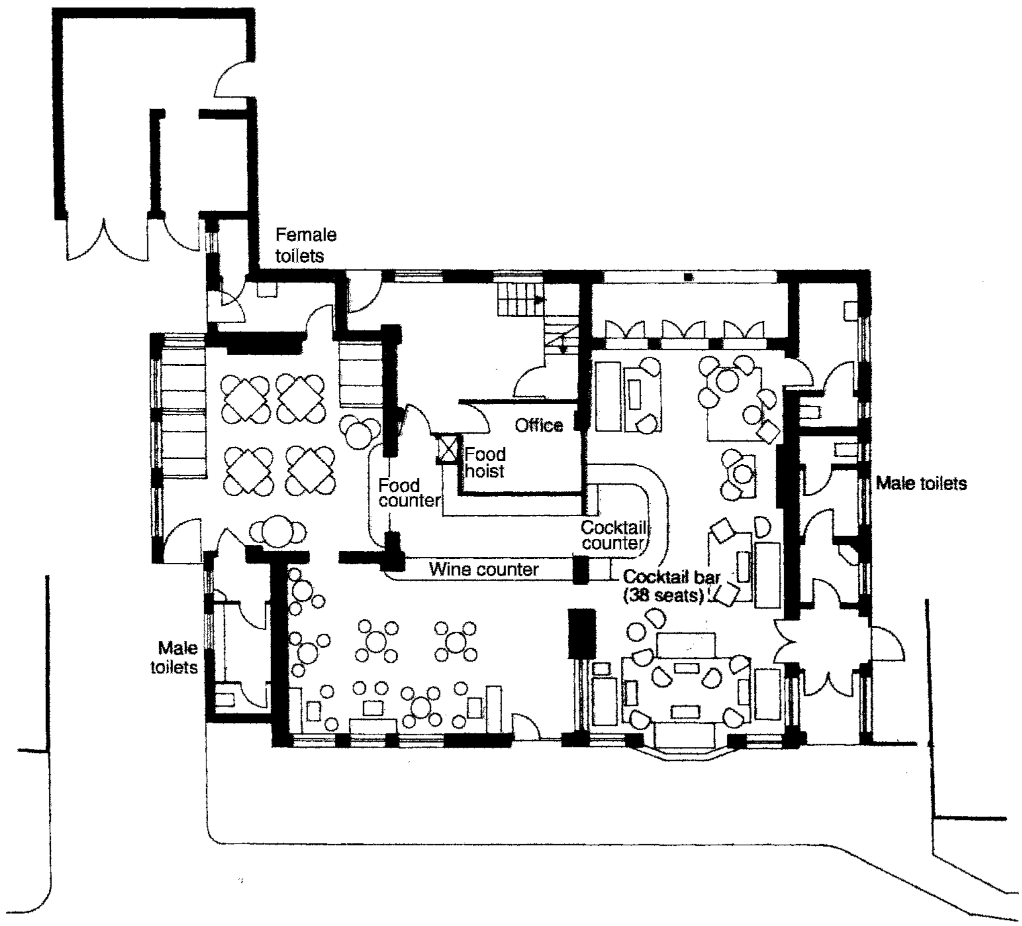
Traditional pub tables are heavy, with cast iron base or wood frame, and used with peninsular seating and stools, **17.44**. Depending on trade, drinking bars often provide a large screen television for sports interests and areas may be set aside for darts, pool, game machine(s) and a piano, **17.45** and **17.46**.

8.06 Wine bars

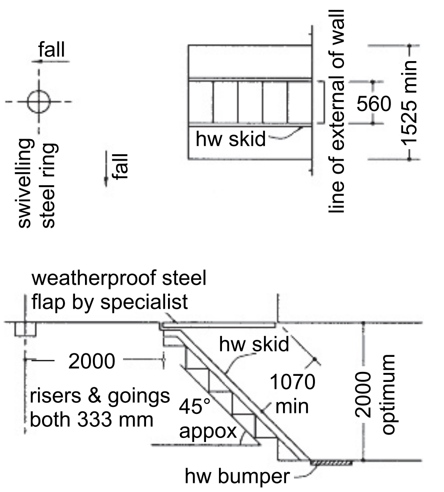
Located mainly in city commercial districts, wine bars are more upmarket and often offer a bistro-type food outlet. Cocktail bars are sophisticated in design and service style, usually associated with high-class dining facilities, hotels and clubs.

8.07 Clubs

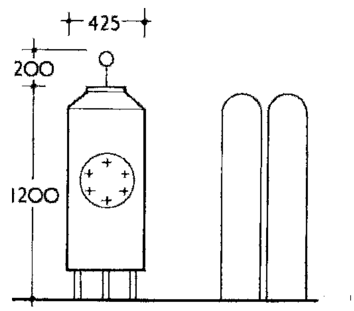
Clubs tend to specialised in late entertainment together with sales of beverages. Food may be served as in nightclubs. In each case, the design is specific to create the desired atmosphere and mode of operation. Entertainers require changing rooms with direct access to the stage. Sophisticated lighting, projection and sound systems with programmed control equipment is required as well as discotheque music centres. A traditional band stand is illustrated in **17.47**.



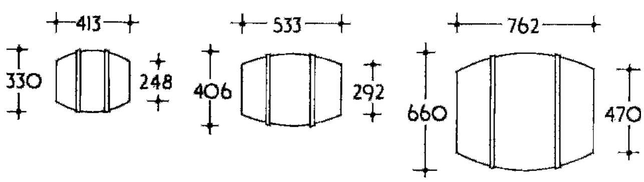
17.36 *Example of first-floor conversion of public house to provide an upmarket bistro-diner and cocktail bar. Lee Associates Ltd*



17.37 *Cellar flap and barrel chute for below ground storage of metal barrels or kegs*

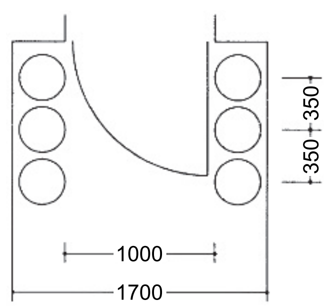


17.39 *Bulk storage in typical CO_2 canisters. Larger canisters also exist*

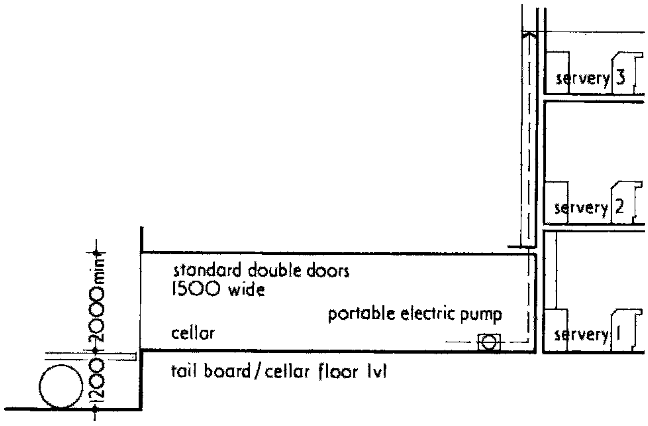


a *Pin, 4.5 gall/20.5 l*
b *Firkin, 9 gall/40.9 l*
c *Barrel, 36 gall/163.7 l*

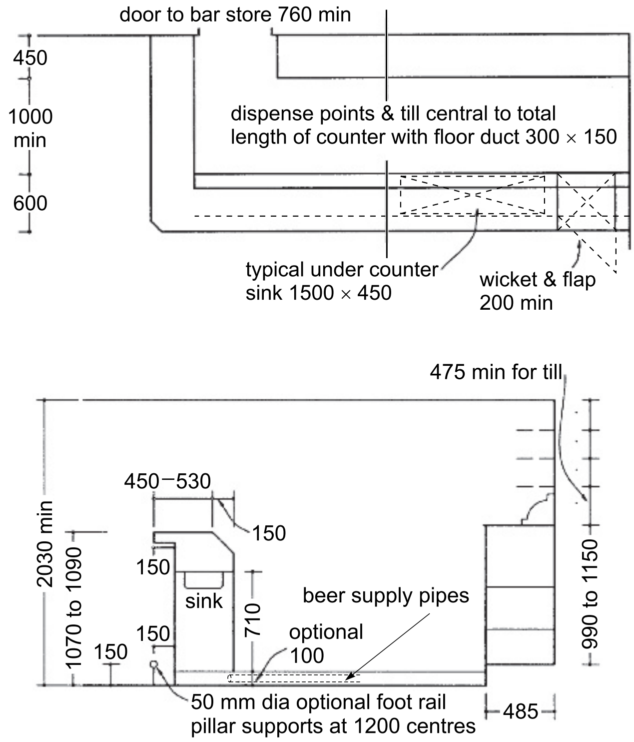
17.38 *Traditional sizes of metal barrels or kegs*



17.40 *Keg storage*



17.41 *Beer supplied through several storeys from ground-level cellar. A standard electric cellar pump will raise beer up to 9 m*



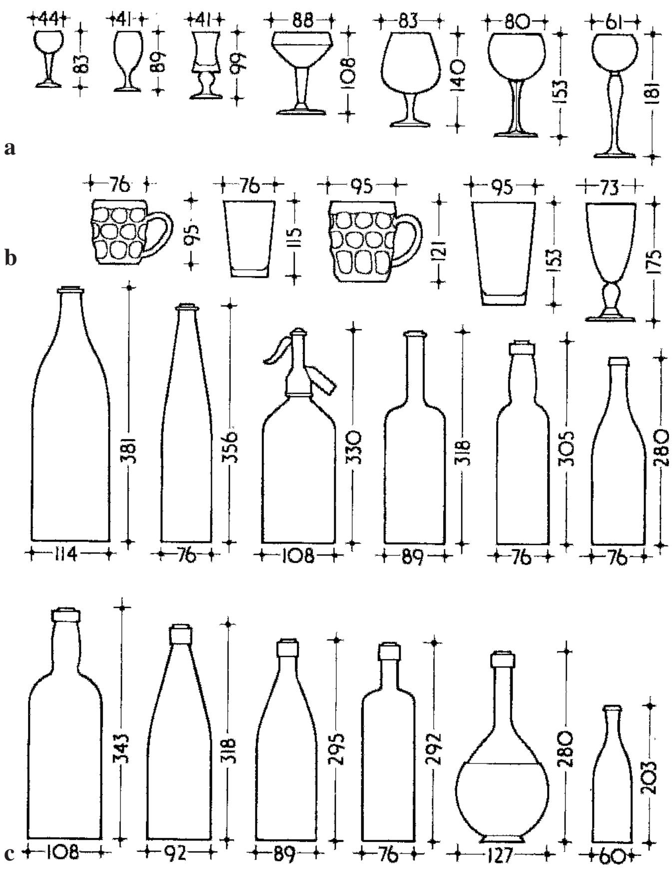
17.42 *Plan and section of a bar servery. Dispense points for various brands of drinks are usually sited at 225 mm centres along the counter top*

9 HOTELS AND RESORTS

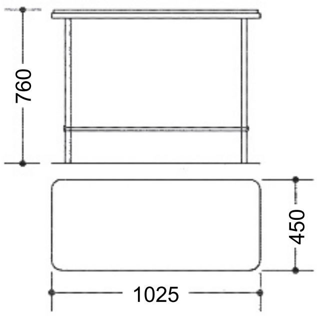
9.01 Hotels and cruise ships

Hotels are graded according to the quality of accommodation, price and range of services offering to guests. The extent of restaurant provision will also depend on the location and number of rooms. Typical space allowances are shown. Food production arrangements are rationalised to enable the main kitchen to supply several outlets directly or via satellite kitchens, **17.11**. An example of food production in a large international hotel is shown in **17.23**.

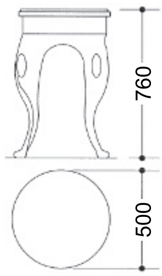
A high-grade city centre hotel with more than 200 rooms will usually provide at least two restaurants offering choice between fine dining and coffee shop style operation – this is also serving the peak breakfast demand, **17.48**. Resident demand for midday meals is often limited and a speciality restaurant may be featured to attract outside market interest. A hotel of this standard will also provide room service of meals, banquets for group meetings and events and meals for staff. Separate lobby, lounge and cocktail bars are typical.



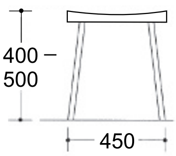
17.43 *Sizes of pub glassware:*
a *Wine and spirit glasses*
b *Beer and soft drink glasses*
c *Bottles*



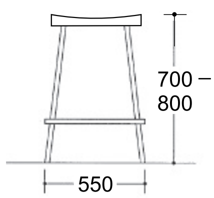
a *Rectangular cast iron base pub table*



b *Round 'Britannia' cast iron base table*

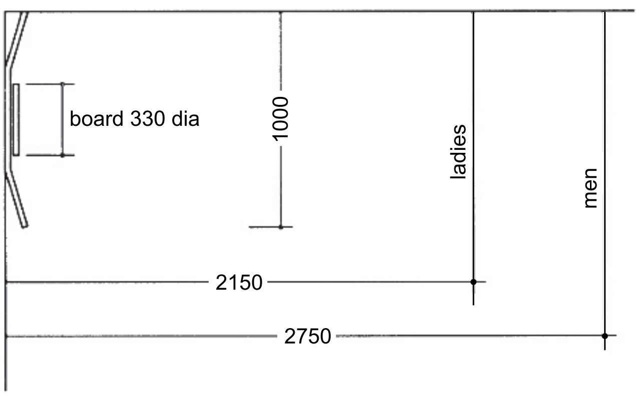


c *Low stool for use at a table*

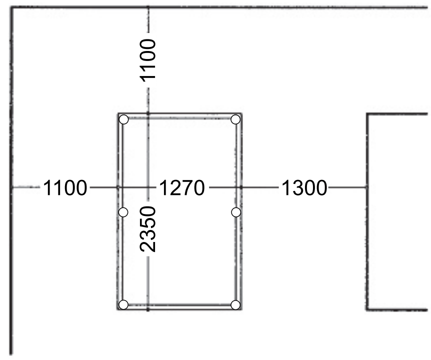


d *High stool for sitting at the bar*

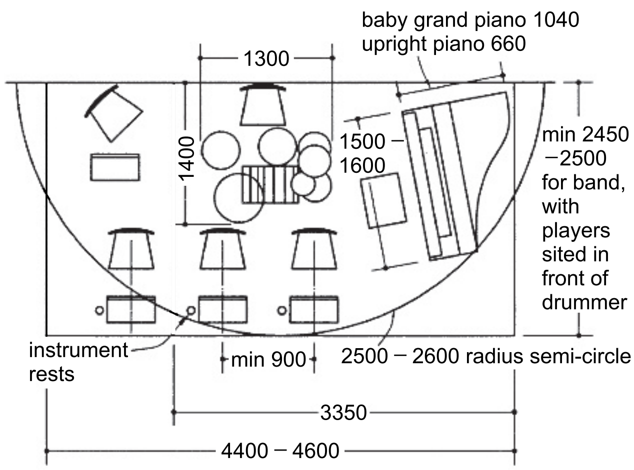
17.44 *Traditional pub bar furniture*



17.45 *Space required for darts*



17.46 *Smallest size of pool table with cue space (for short cues) now common*



17.47 *A band platform. Club entertainers use own equipment*

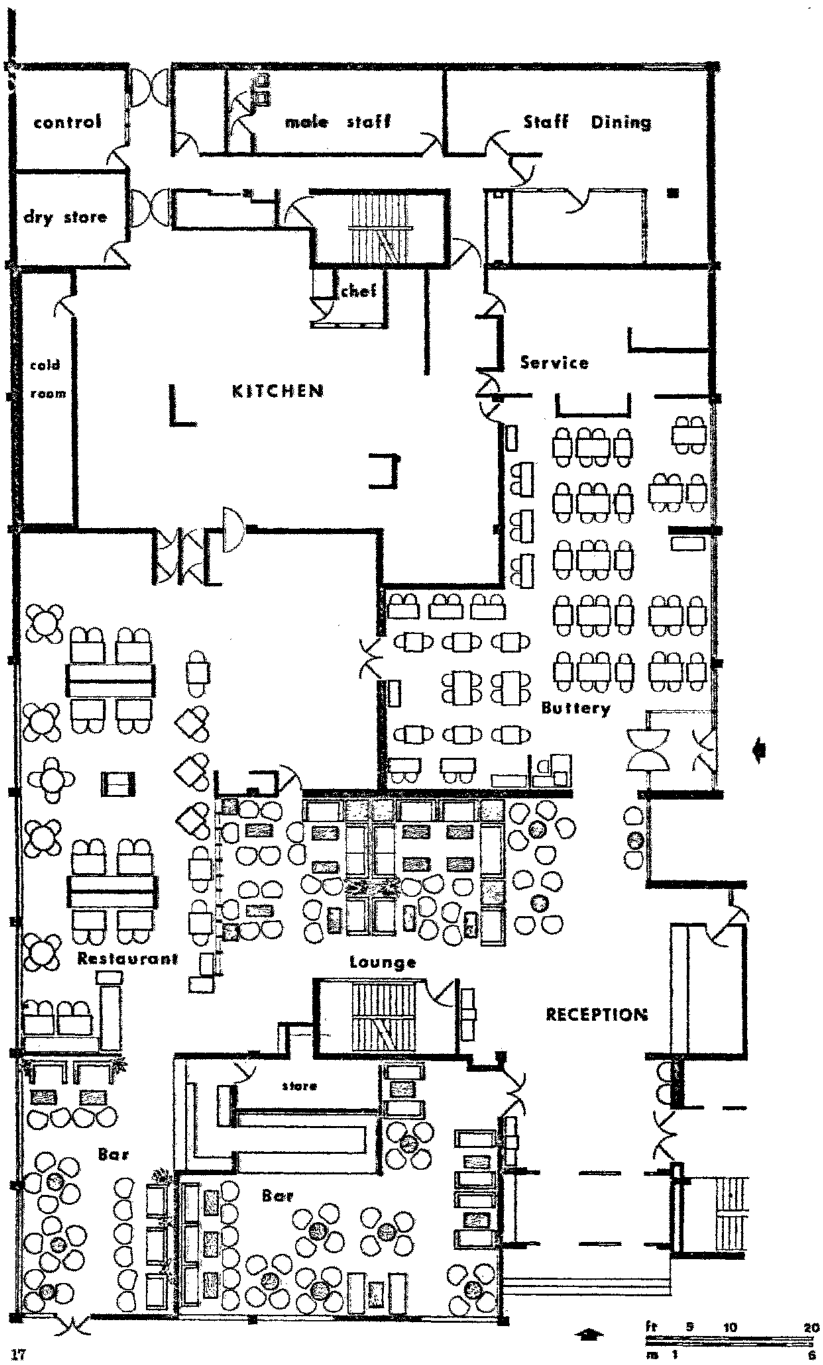
Resort hotels of high grade also offer guests and visitors a choice of restaurants and bars, including poolside bars. Bar and dining areas are commonly grouped together to serve evening entertainment. In mid-grade establishments, restaurant and bar provision are rationalised and budget accommodation may use external restaurants in the vicinity. Food production is generally centralised.

Cruise ships are broadly similar to high-grade hotels and need to provide a variety of foodservice outlets and bars to accommodate the number of passengers and crew involved. These services are often an important part of cruise attraction and are linked to entertainment and other facilities. Menu planning is complex to take account of dietary requirements, choice, variety of outlets, supply provisions and hygiene standards. Extensive storage and preparation facilities are involved with added fresh foods at pre-arranged supply ports.

9.02 Resorts and attractions

Self-contained holiday centres and villages offer foodservice options, ranging from all-inclusive to self-catering facilities. In a large complex, a variety of themed restaurants, cafés, bars and other outlets is provided, often operated independently under license.

Large visitor attractions usually need to provide cafes and restaurants as part of the facilities. These are invariably operated by catering contractors who supply the food partially or fully prepared to rationalise kitchen and staff requirements.



17.48 *Variety of food and beverage outlets in a hotel*

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18 Indoor sports facilities

Peter Ackroyd and Gerald Perrin

CI/SfB: 541, 562
UDC: 725.74, 725.85
Uniclass: F541, F562

KEY POINTS:

- *Because of the British climate, more and more indoor facilities for sport are needed*
- *Encouraging everyone to learn and enjoy swimming is a priority*
- *Provision divides into leisure and competitive facilities*

Contents

1 INTRODUCTION

Indoor sporting activity can be competitive, recreational or for training purposes. Most facilities are designed to cater for all three, and are either general-purpose spaces such as sports halls or special to one activity or range of activities, such as a swimming pool, squash court or ice rink. The different sports and activities will be found in alphabetical order in sections **3–6**: whichever is appropriate. Swimming is covered in sections **7–14**. Outdoor activities are covered in Chapter 20 of this Handbook.

In this chapter, the information given about each activity will generally be confined to the required overall sizes at the various recognised levels:

N – international and national competition
C – county and club competition and
R – recreational.

For further information, such as detailed dimensions, equipment, environmental installations, etc. refer to the *Handbook of Sports and Recreational Building Design.*

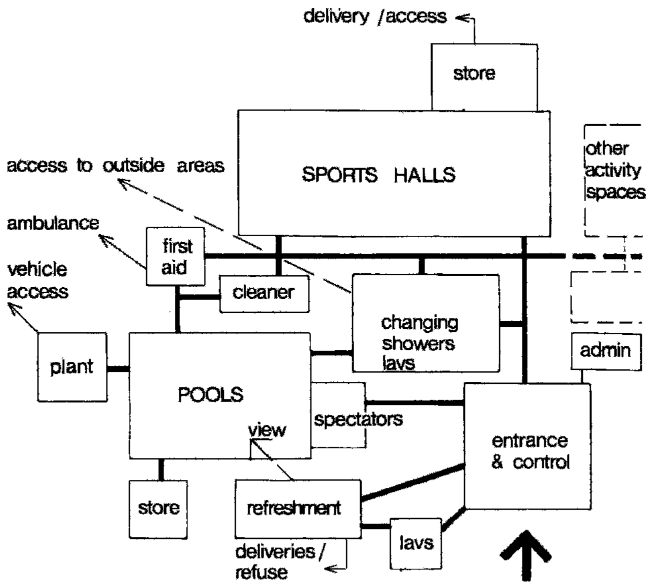
2 SPORTS CENTRES

Some sports centres are large complexes encompassing wet and dry sports. **18.1** shows the possible elements of such a complex, some of which are omitted in smaller centres. **18.2** is a plan of a large centre. The essential elements of a small dry sports centre are shown in **18.3**, and a plan of a centre in **18.4**.

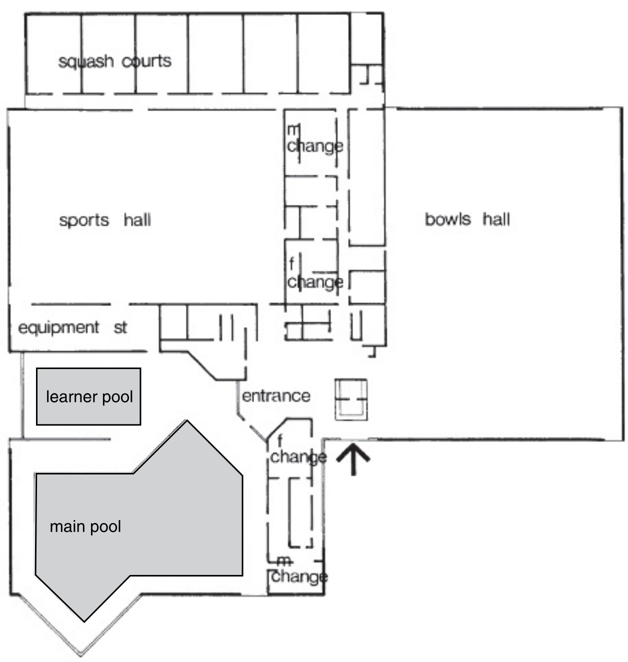
3 SPORTS HALLS

3.01 Use of facilities

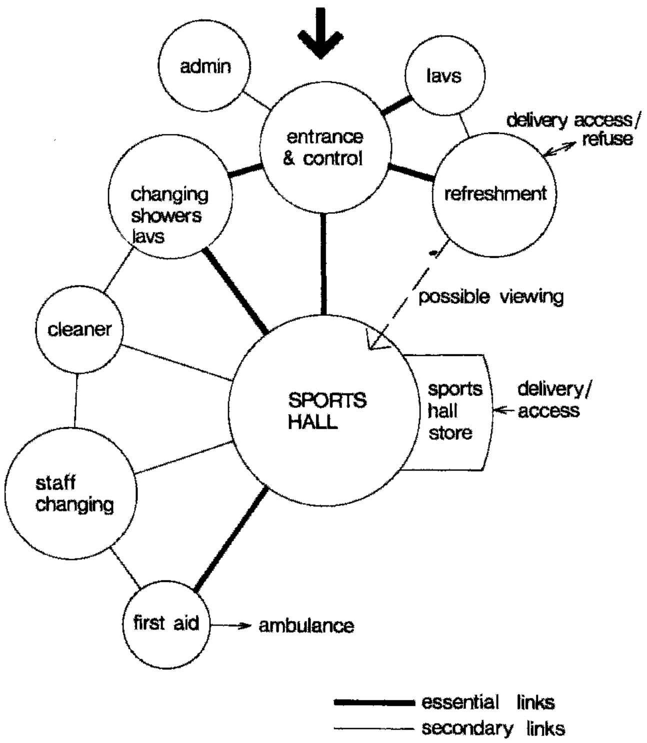
Sports halls are general-purpose spaces intended to cater for a great variety of activities. Some of these can take place simultaneously, but others need exclusive use for a time. In general, all the activities in sections **3–5** and even some of those in section **6** can take place in a suitable sports hall. However, the demand for time in sports halls is so great that those activities that can be carried on in less expensive accommodation tend to be confined to projectile halls and ancillary halls. In this section, information about the activities will be found under the most appropriate space.



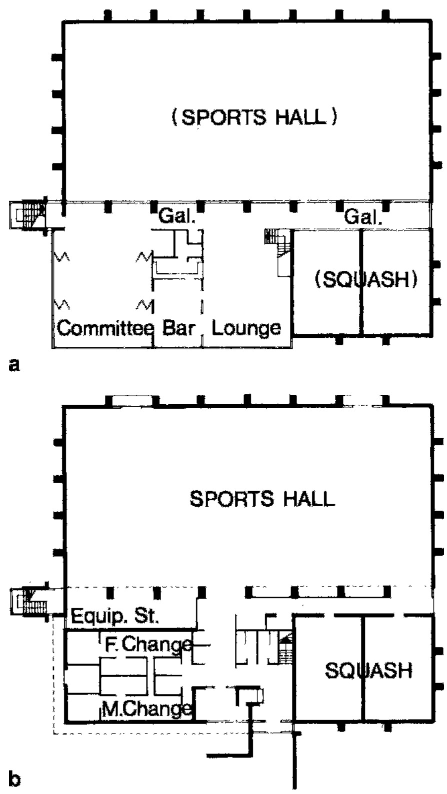
18.1 *Space and circulation diagram of a large wet and dry sports centre*



18.2 *Dunstable leisure centre: a leisure pool and dry facilities on a school site*



18.3 *Main elements of a dry sports centre*



18.4 *Harpenden, a small compactly designed centre. The social areas have been positioned to take advantage of the parkland site.* **a** *First floor.* **b** *Ground floor*

3.02 Sizes

Only the largest of halls will satisfy all required standards of play for all indoor sports, and therefore it will be necessary to decide on upon the range of sports and levels before determining the floor area. Table I shows what can be accommodated in the various standard sizes of hall.

The same floor area may provide for international standard in one or two sports and at the same time offer a wide variety of other activities at a lower standard. Typical arrangements are shown in **18.5–18.18**.

3.03 Height

The height of the underside of the roof structure, or the ceiling if there is one, above the floor is specified by each sport's governing body, and this is a critical design factor. Badminton, tennis and trampolining require an unrestricted height of 9.1 m for international competition, while 7.6 m is necessary at C level in all sports except those for which height is not critical. However, a height greater than justified by the intended use will increase running costs in heating, lighting and maintenance.

3.04 Construction

The construction and fabric of the hall should be such as to minimise damage, both accidental and from vandalism. Sports halls should only be naturally lit from above; any form of vertical glazing will produce some glare.

3.05 Activities

The sizes required for various activities in the sports hall are shown in **18.19–18.32** (scale 1:500).

4 ANCILLARY HALLS

To economise in the use of the large sports halls, larger centres have practice halls suitable for some smaller-scale activities. The two suggested sizes are:

- 15 × 12 × 3.5–4.5 m
- 21–24 × 12 × 4.5 m with a divider.

Sizes for various activities in this type of hall are given in **18.33–18.40** (scale 1:500). For yoga, each person will lie on the floor on a mat or blanket and will ideally need a clear area of 2.5 m diameter.

5 PROJECTILE HALLS

18.41–18.43 show plans and sections of a range of projectile rooms, and Table II shows which sports can be covered by them. The spaces required are given in **18.44–18.48** (scale 1:500).

Where the projectile room is to be used for firearms shooting, the construction must be to safety standards and robust enough to withstand the use. It may be found that this use will severely restrict the projectile hall's use for other activities.

6 SPECIAL SPACES

There are a number of activities that need spaces permanently and exclusively reserved for them. This may be due to the weight or size of the equipment, such as billiards/snooker, or because the playing area is closely defined, such as squash or real tennis. For some of these, semi-portable equipment is now being produced, but these are generally designed for special occasions such as national championships. The critical sizes for these special spaces are given in **18.49–18.59** (scale 1:500 except where shown otherwise).

Table I Definition of sizes: maximum number of courts related to standards of play

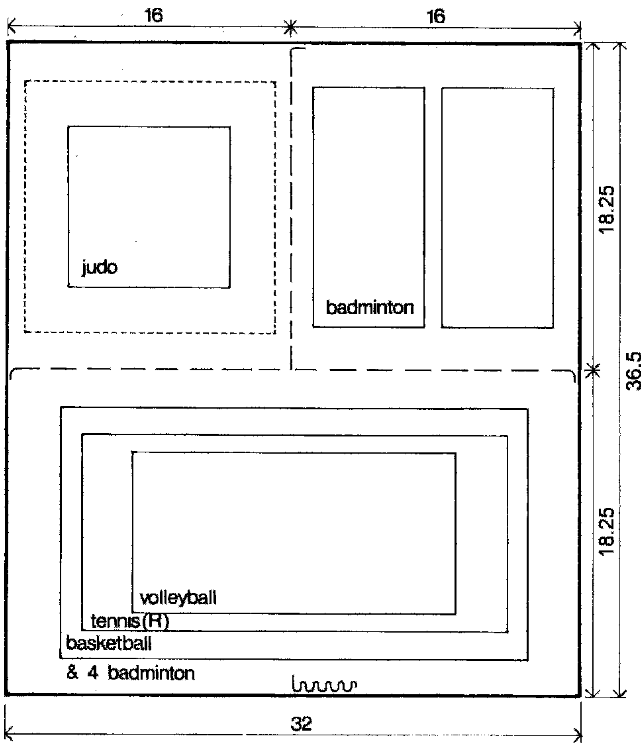
	Large hall[fr]		Medium halls[fr]						Small halls								Community halls			
	36.5 × 32 × 9.1 m 1168 m²		32 × 26 × 7.6–9.1 m 832 m²		29 × 26 × 7.6–9.1 m 754 m²		32 × 23 × 7.6–9.1 m 736 m²		32 × 17 × 6.7–7.6 m 544 m²		29.5 × 16.5 × 6.7–7.6 m 486.75 m²		26 × 16.5 × 6.7–7.6 m 429 m²		22.5 × 16.5 × 6.7–7.6 m 371.25 m²		17.0–20.0 × 15.6 × 6.7 m 265.2–321 m²		17.0–8.5 × 6.7 m 144.5 m²	
	No.	**Standard**	**No.**	**Standard**	**No.**	**Standard**	**No.**	**Standard**	**No.**	**Standard**	**No.**	**Standard**	**No.**	**Standard**	**No.**	**Standard**	**No.**	**Standard**	**No.**	**Standard**
Aikido	4 6	N C	4	N	4	N	2 +3(*)	C R	2 3(1*)	N R	2	N	2	N	1 2	N R	1	N	–	–
Archery (length of shoot)		*30 m 25 m 18 m 20 yd		*25 m 18 m 20 yd		18 m 20 yd	[s]25m	18 m 20 yd		[s]25m 18 m 20 yd		18 m 20 yd		18 m 15 yd		18 m 15 yd	–	–	–	–
Badminton	8	N	5 6(2*)	N° R	3/4 4	NC R*	4 6	N[1] R	4	C**	3 4	C** R*	3	C**	3	R	2	R[1]	1	R[1]
Basketball	2	N	1 2	N C*/R	1 2	N R*	1	N	1	C**	1	C**	1	C**	1 1	R* Mini BB	1	Mini BB	–	–
Bowls (portable non–competitive rinks)	7	R	5	R	5	R*	4	R	3	R	3	R*	–	–	–	–	–	–	–	–
Boxing (training rings)	9 12	N R	6 12	N R	4 9	N R	6 8	N R	3 6	C R	3 5	C R	2 5	C R	2 4	C R	2 4	C R	2 –	R –
Cricket six–a-side pitches ns	1 2	N C	1	C	–	–	1	C	1	R	–	–	–	–	–	–	–	–	–	–
Cricket nets	8	N	6	N	6	C	5	N	4	C	4	C	4	R	–	–	–	–	–	–
Fencing (pistes)	12 14	N C	8(3*) 9	N C	7 8	N C	6 8	N C	3/4 2/3	N/C R*	3/4* +2	N/C R*	3/4* +1	N/C R	3 4	N C*	3	C	2	R
Five-a-side football	1 2	N R*	1 2	C R*	1	R*	1	C	1	R*	1	R*	1	R*	1	R*	1	R*	–	–
Gymnastics (Olympic)	–	N	–	C	–	P	–	C	–	P	–	P	–	P	–	P	–	P	–	–
Handball	1	N*	1	C	1	R*	1	C	1	R	1	R*	–	–	–	–	–	–	–	–
Mini handball											1	C	1	C	1	C	1	R*	1	R*
Hockey	1	C*	1	R	1	R	1	R	1	R	1	R	1	R	1	R	–	–	–	–
Judo	4 6	N R	2 4	N C	1 4	N C	2 4	N R	2 3	N R	1 2	N C	1 2	N R	1 2	N R	1/2 –	R –	–	–
Karate	4 12	N R	2/4 6	N/C R	2 4/6	N* C/R	2 6	N R	2 6	N R*	2 3	N*/C R	1/2 3	N/C R	1 2	N R	1 2	N R	2 –	R* –
Keep fit; Movement and dance; Yoga, ns		✓		✓		✓		✓		✓		✓		✓		✓		✓		✓
Kendo	4 6	N R*	2 4	N C	2 4	N* C	2 4	N R	2	N	2 2	N* C	1 2	N C	1 2	N R*	1 –	R –	–	–

(Continued)

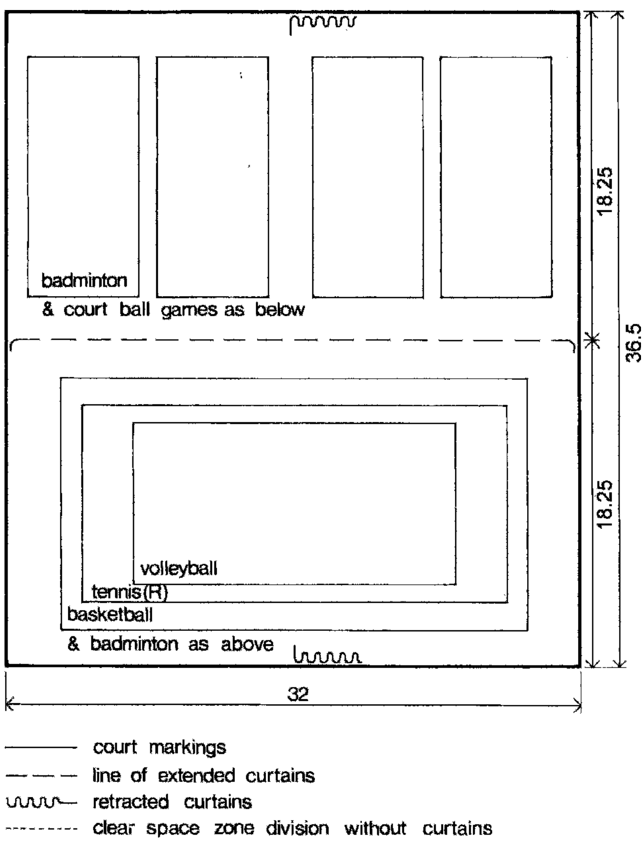
Table I (Continued)

	Large hall[fr]		Medium halls[fr]						Small halls								Community halls			
	36.5 × 32 × 9.1 m 1168 m^2		32 × 26 × 7.6–9.1 m 832 m^2		29 × 26 × 7.6–9.1 m 754 m^2		32 × 23 × 7.6–9.1 m 736 m^2		32 × 17 × 6.7–7.6 m 544 m^2		29.5 × 16.5 × 6.7–7.6 m 486.75 m^2		26 × 16.5 × 6.7–7.6 m 429 m^2		22.5 × 16.5 × 6.7–7.6 m 371.25 m^2		17.0–20.0 × 15.6 × 6.7 m 265.2–321 m^2		17.0–8.5 × 6.7 m 144.5 m^2	
	No.	**Standard**	**No.**	**Standard**	**No.**	**Standard**	**No.**	**Standard**	**No.**	**Standard**	**No.**	**Standard**	**No.**	**Standard**	**No.**	**Standard**	**No.**	**Standard**	**No.**	**Standard**
Lacrosse F	1	N	1	C*	1	R	1	C*	1	C*	1	R	–	P	–	P	–	–	–	–
Lawn tennis	1 2	N* R	1	R*	–	–	1	R*	1	R*	–	–	–	–	–	–	–	–	–	–
Micro korfball	1	C	1	C	1	C	1	C	1	R*	–	–	–	–	–	–	–	–	–	–
Netball	1 2	N C*/R	1	R	–	–	1	R	1	R	–	–	–	–	–	–	–	–	–	–
Table tennisc/c	10 15/21	N C/C	6 10/15	N C/C	6 10/12	N C/C	6 10/12	N C/C	7/9 14	C/C R	7 12	C/C R	6/7 10	C/C R	4 8	C/C R	3–6 6-8	C/C R	4	R*
Trampolining	12	N	8 12	N° R	8	N°	4 8	N° C/R	4 6	C** R	4	C**	4	C**	4	R	2	R	1	R
Tug of war	–	N	–	C	–	R	–	C	–	C	–	R	–	–	–	–	–	–	–	–
Volleyball	2 3	N° R	1 2 3	N° C R*	1 2	N° R	2* 2	N°/C R	1	C**	1	C**	1	C**	1	C**	1	R*	–	–
Weight lifting contests	–	N	–	N	–	N	–	N	C	–	C	–	C	–	C	–	C	–	–	–
Wrestling	4 12	N C	2 6	N C	6	C	2 6	N C	2 3	N* C	3 8	C R*	2 6	C R	2 6	C R	2 4	C R	2 –	R –

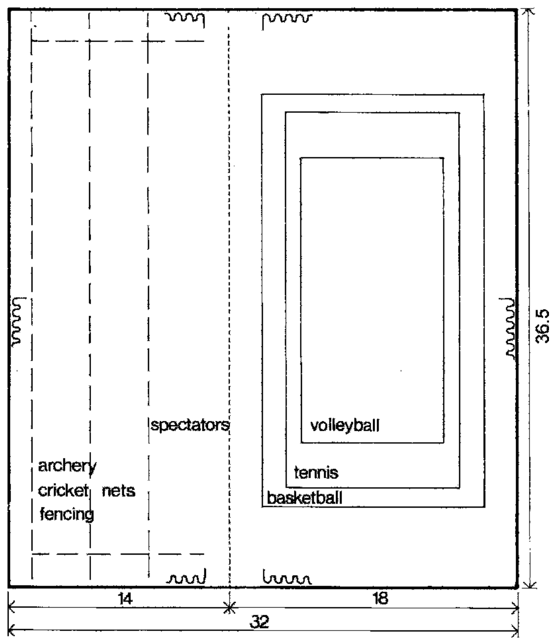
Key
N National/international standard
C County/club standard
R Recreational standard
P Practice area only
c/c For table tennis there are two grades of minimum space allowances for inter-county/inter-club standards of play
fr Fire regulations and maximum compartment volumes should be checked. Halls of 7000 m^3 or over need a DOE waiver, 'Volume' can include an unenclosed structural roof spaces ns No standards have yet been laid down
S Area behind shooting line is below safety standard recommended. Acceptable space can be provided with a slight lengthening of the hall; or existing spaces may be used for practice purposes
* Below minimum space standard recommended by the governing body concerned, but capable of providing purposeful and enjoyable activity
** Recreational standard where the hall is less than 7.6 m clear height for badminton and trampolining, or less than 7.0 m for basketball and volleyball 6.7 m height is suitable for mini basketball and mini volleyball
° County/club standard where the hall is less than 9.0 m clear height



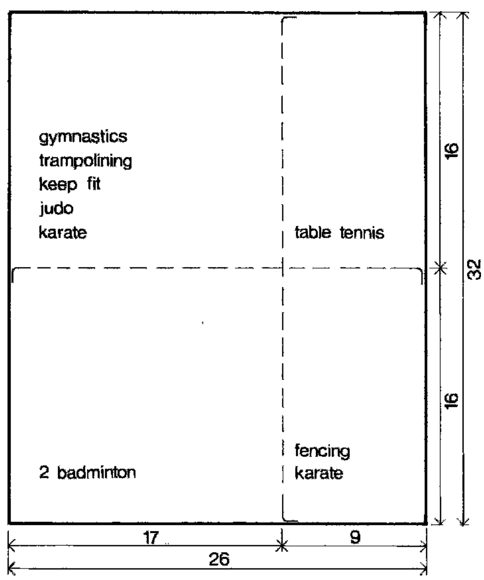
18.5 *Alternative arrangements for large sports halls*



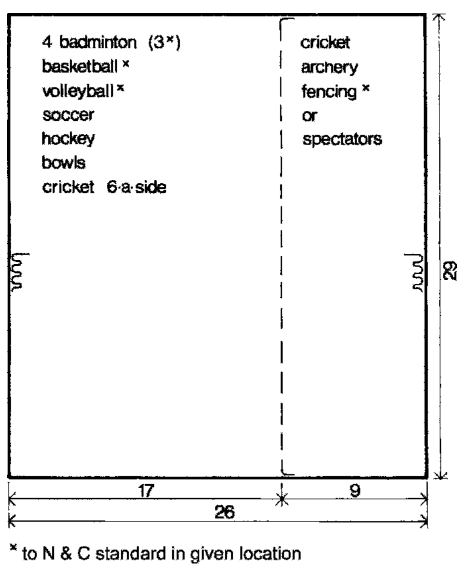
18.6 *Alternative arrangements for large sports halls*



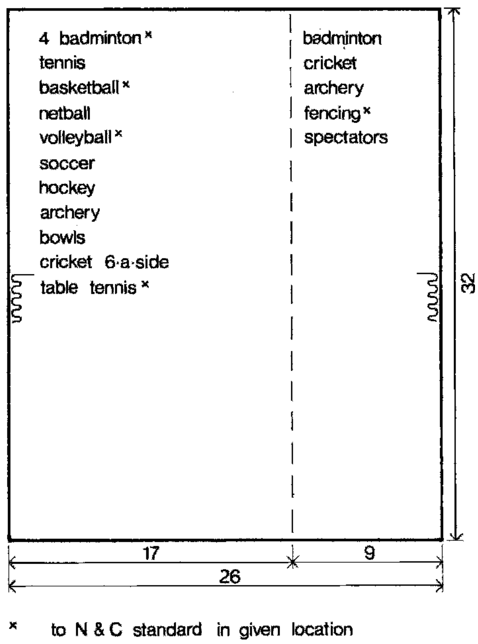
18.7 *Alternative arrangements for large sports halls*



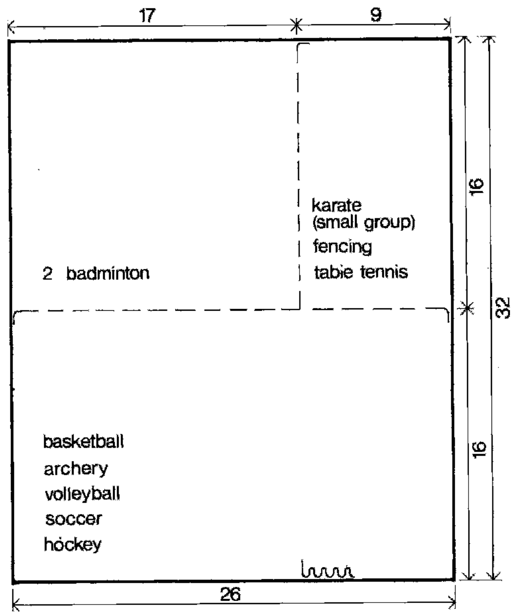
18.8 *Alternative arrangements for medium-size halls*



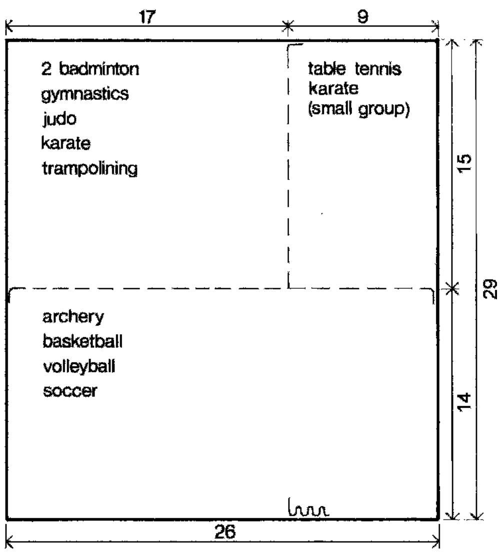
18.9 *Alternative arrangements for medium-size halls*



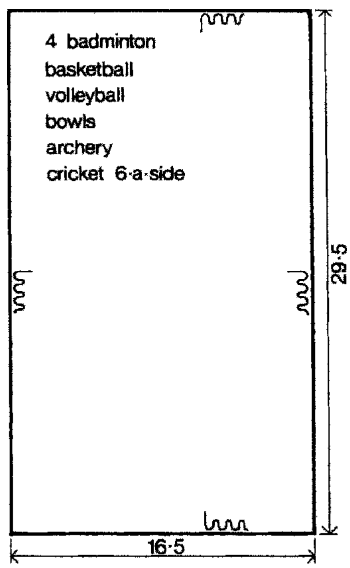
18.10 *Alternative arrangements for medium-size halls*



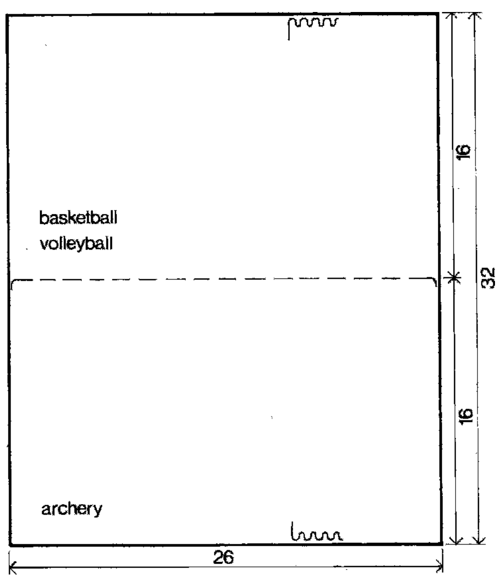
18.13 *Alternative arrangements for medium-size halls*



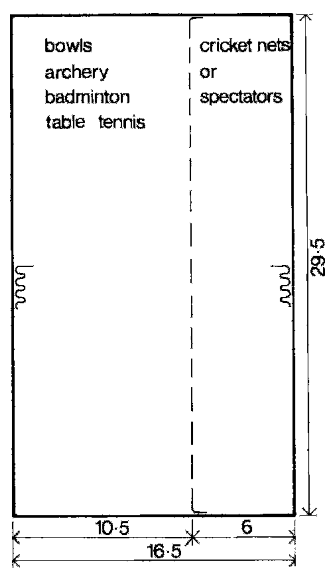
18.11 *Alternative arrangements for medium-size halls*



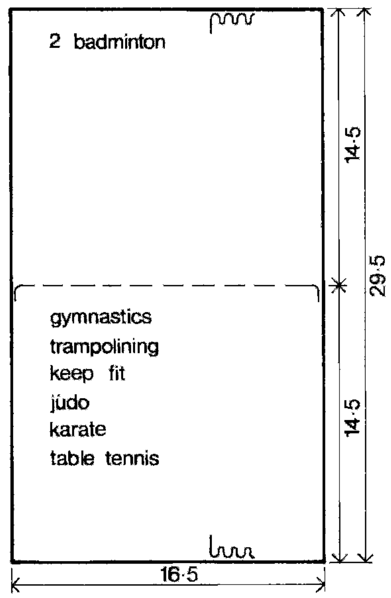
18.14 *For small halls*



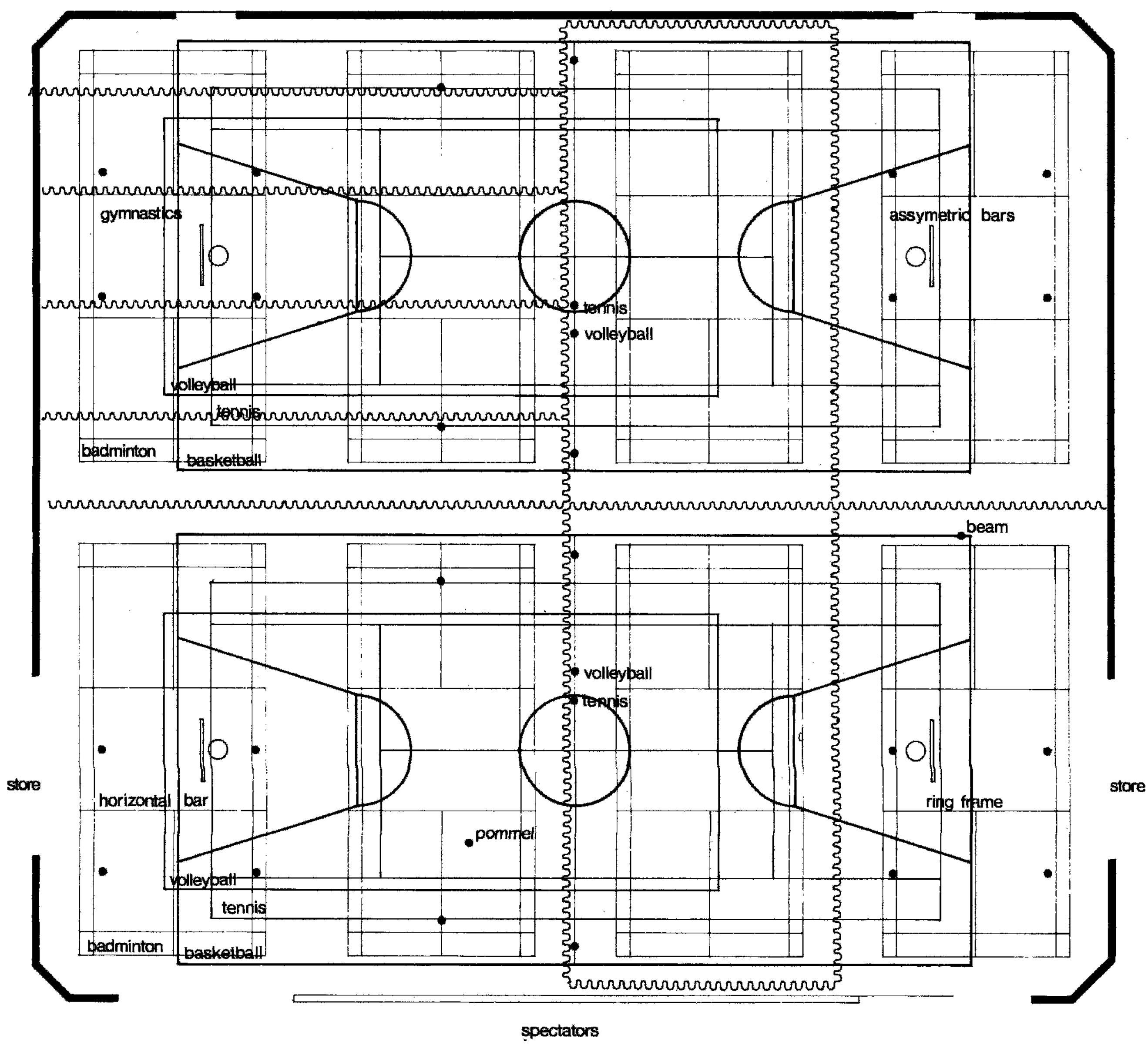
18.12 *Alternative arrangements for medium-size halls*



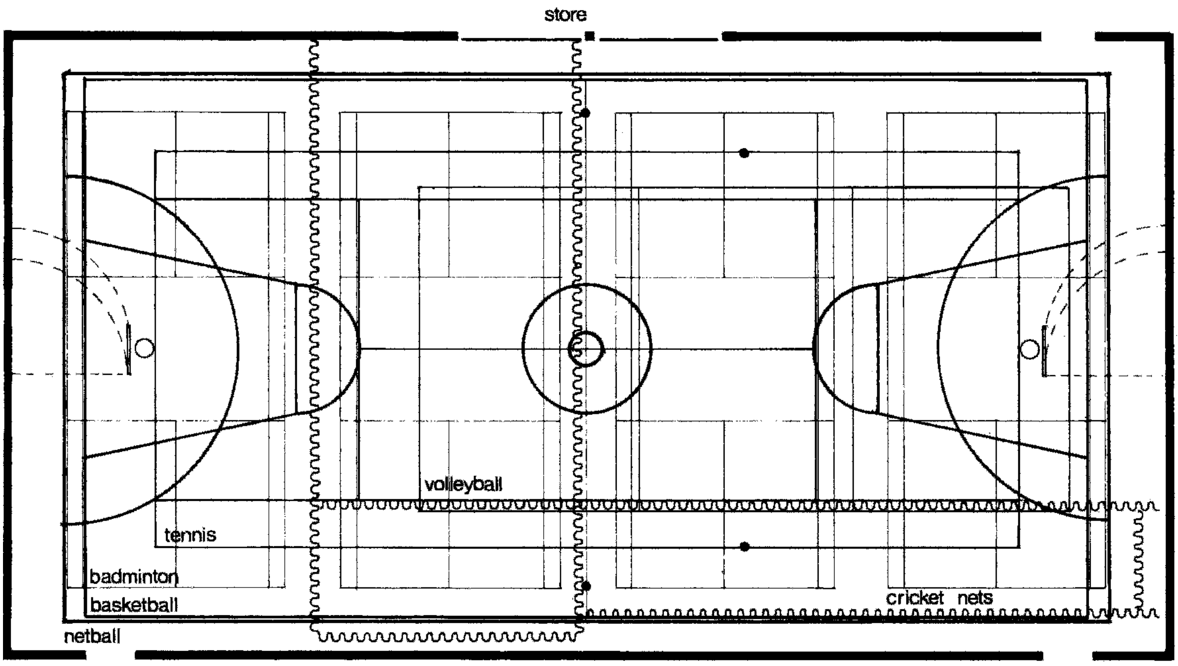
18.15 *For small halls*



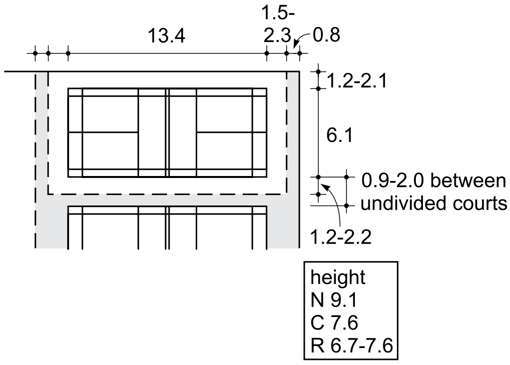
18.16 *For small halls*



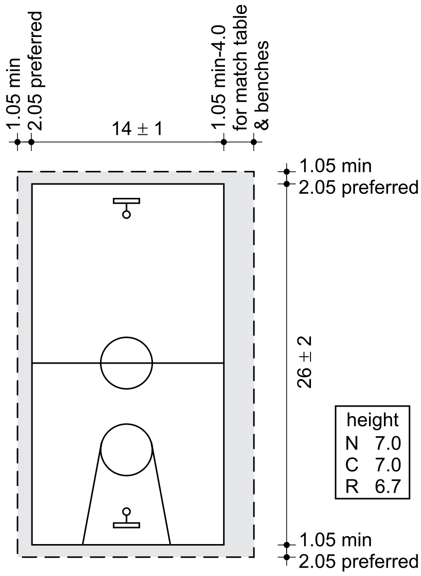
18.17 *Wycombe sports centre: plan of court markings and equipment fixings in sports hall*



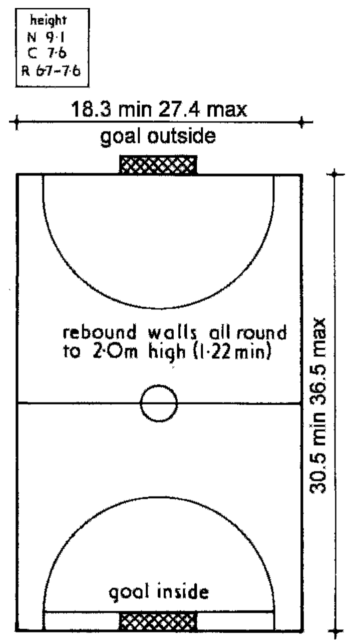
18.18 *Tamworth sports centre: plan of court markings and equipment fixings*



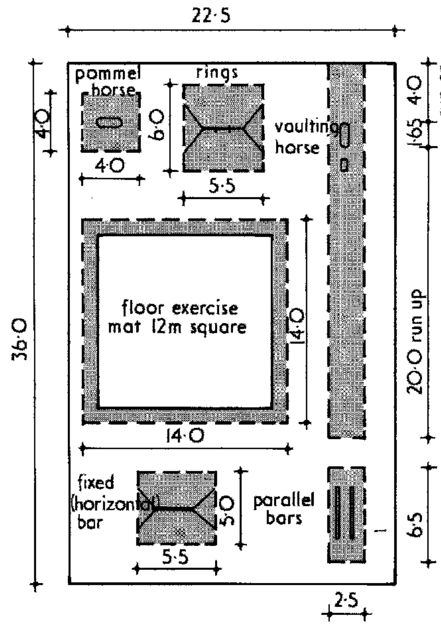
18.19 *Badminton, a doubles court for all standards of play. Where courts are placed side by side, tournaments are held with seating and play on alternate courts. Heights lower than 7.6 m are discouraged by the Badminton Association of England*



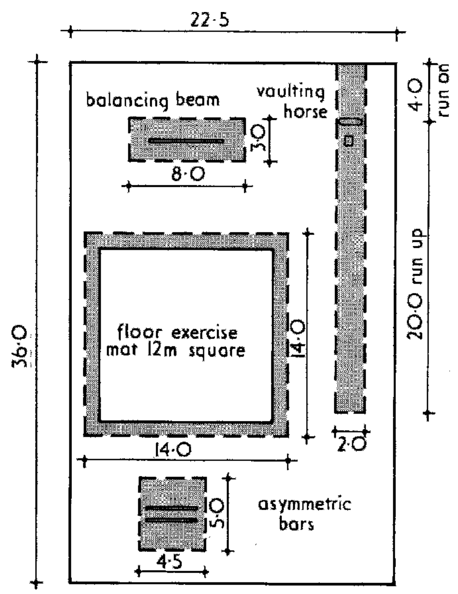
18.20 *Basketball. At a recreational level, this game can be played in a school gymnasium 21.3 × 12.2 m*



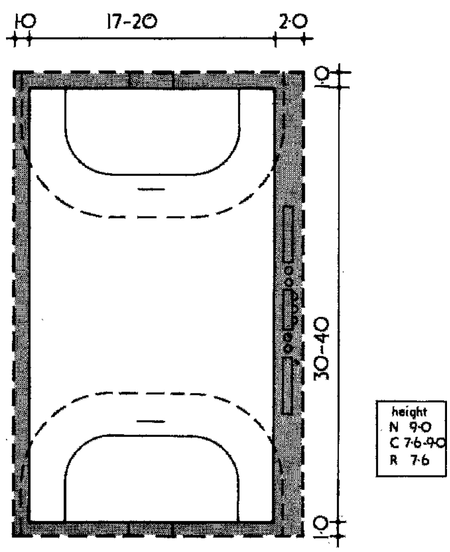
18.21 *Five-a-side football. This needs rebound walls all round to about a height of 2 m, but can be adapted to the available space. In a medium-size sports hall **18.10**, the playing area is the size of the hall. At a recreational level the game may be played in a small size hall, about 30 × 15 m being regarded as a reasonable minimum. Depending on age and sizes of players, their numbers on the pitch could be reduced as necessary for satisfaction. This game can also be played out of doors, but difficulties may be experienced in installing suitably robust rebound walls*



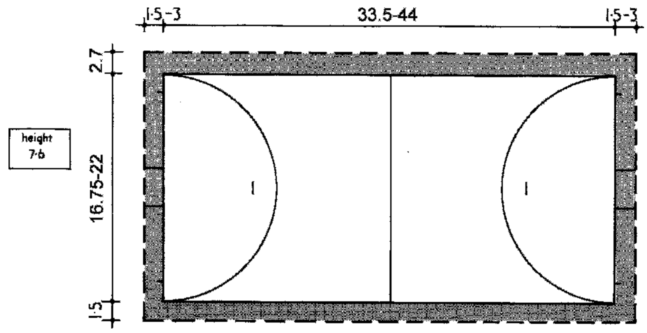
18.22 *Men's gymnastics. See* ***18.54*** *for special practice spaces*



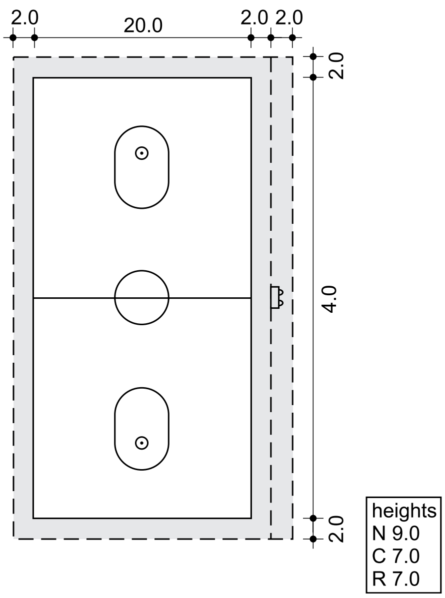
18.23 *Women's gymnastics. See* ***18.54***



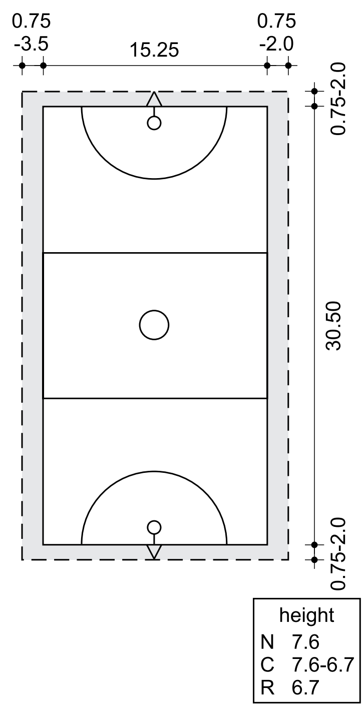
18.24 *Handball, seven-a-side*



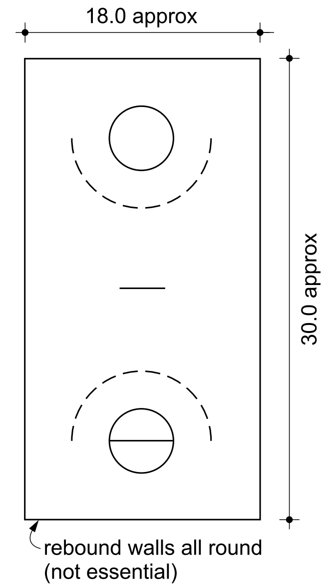
18.25 *Hockey. Team sizes are adjusted according to the size of the available pitch. Side boards should be provided 100 × 100 mm with a 20 mm inward tilt*



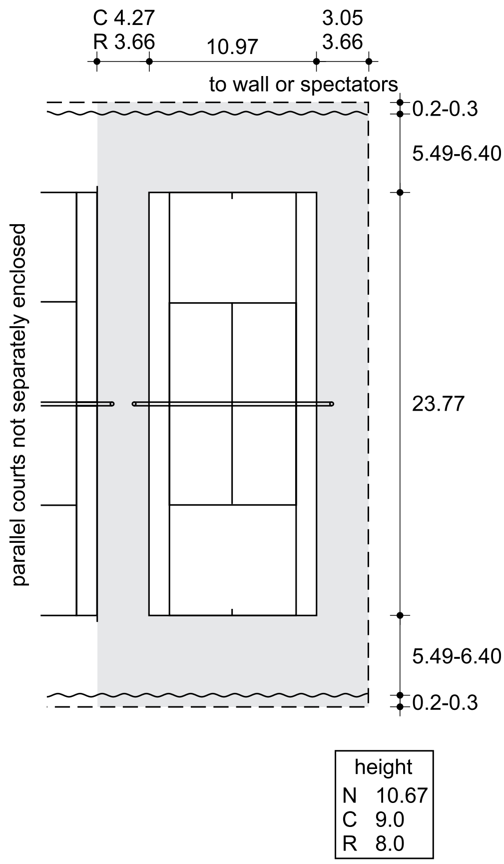
18.26 *Korfball. In halls of smaller dimensions, allow for full safety margins, keep pitch width about 18–20 m, and maximum possible length up to 40 m*



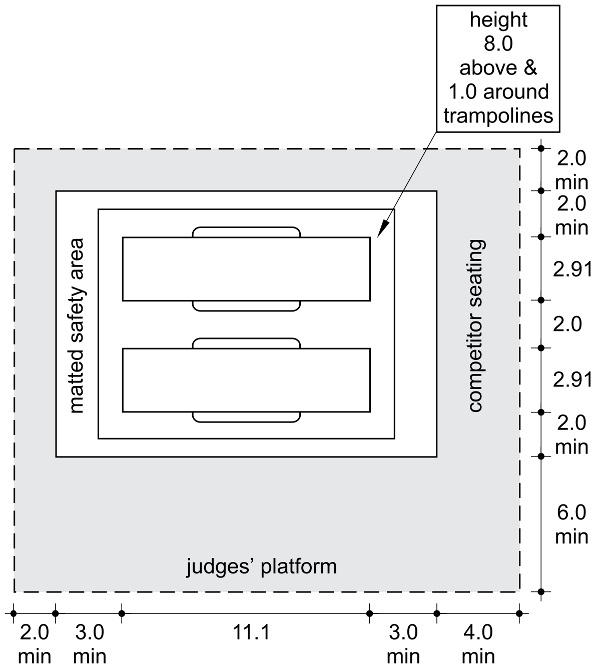
18.27 *Netball*



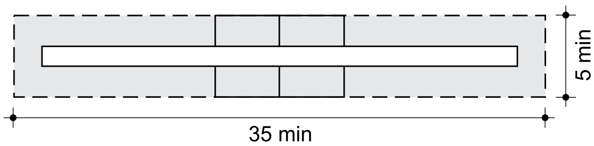
18.28 *Pop Lacrosse. This has superseded indoor women's lacrosse. It can also be played out of doors, when there is no boundary. The size approximates to four badminton courts, and could be played on a five-a-side football pitch. For further details, refer to the English Lacrosse Union, Ashton-under-Lyne, Lancs, or the All England Women's Lacrosse Association, Birmingham*



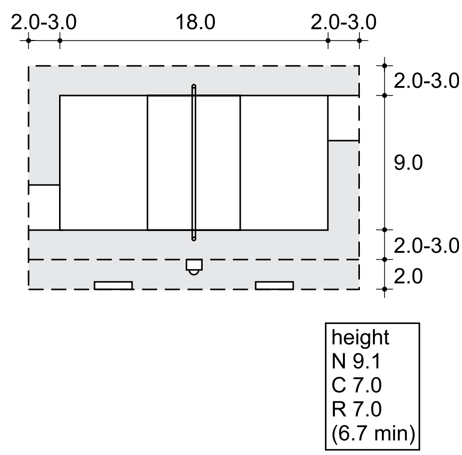
18.29 *Tennis*



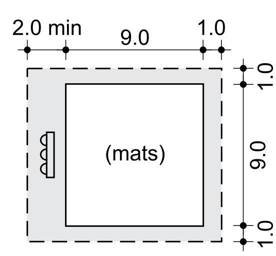
18.30 *Trampoline. The 'bed' is 0.95–1.05 m above the ground. Synchronised competitions must be parallel to each other and 2 m apart. Note etxended length of end frame units from that previously published*



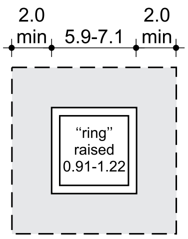
18.31 *Tug-of-war*



18.32 *Volleyball*

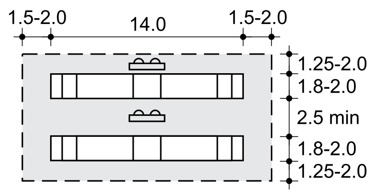


18.33 *Aikido*

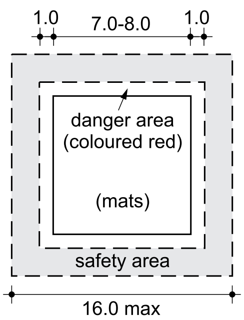


18.34 *Boxing. A ring for recreational purposes may be only 3.6 m square. For competitions, in addition to the ring and spectator accommodation the following are needed:*

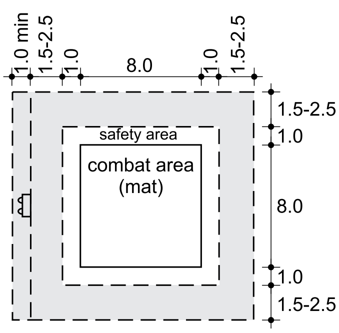
- *Medical examination room*
- *Weighing room*
- *Gloving-up room*
- *Administrative facilities*
- *Lighting above the ring*
- *Water supply to each 'corner'*



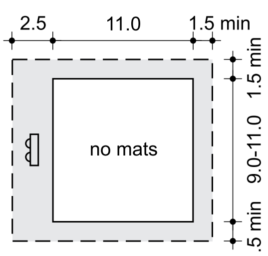
18.35 *Fencing pistes*



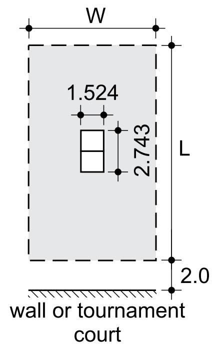
18.36 *Judo*



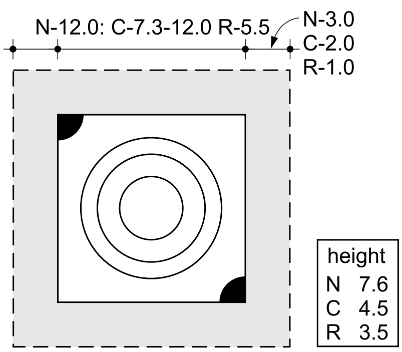
18.37 *Karate. Regional competitions require three international size combat areas*



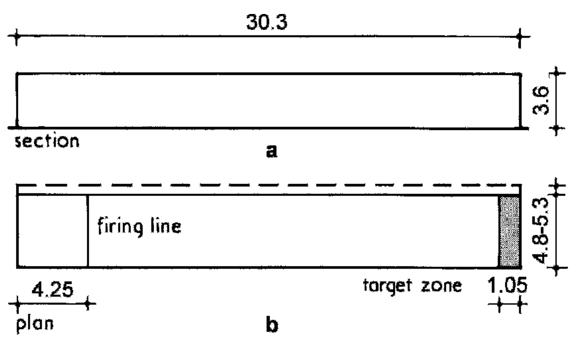
18.38 *Kendo*



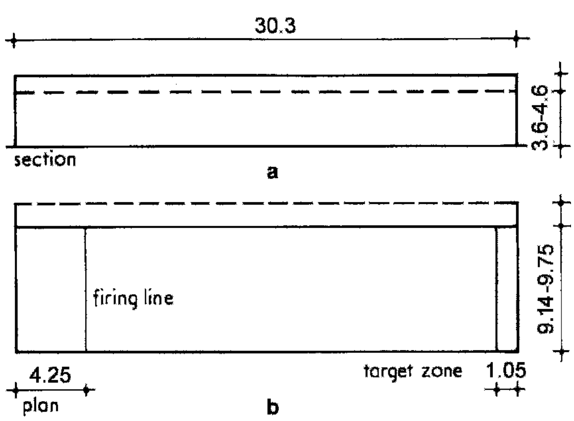
18.39 *Table tennis. See Table III for overall dimensions. The table is 0.76 m high, and normally requires a space 1.4 × 1.6 × 0.5 m for storage. When in use, each table requires individual lighting*



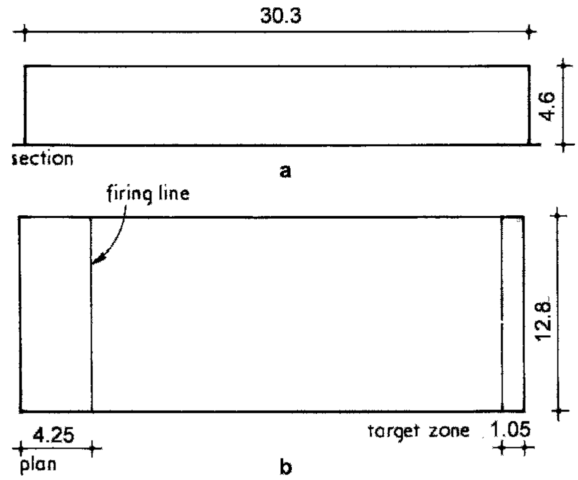
18.40 *Wrestling*



18.41 *Small projectile hall:* **a.** *Section.* **b.** *Plan*



18.42 *Medium-Projectile hall:* **a.** *Section.* **b.** *Plan*



18.43 *Large projectile hall:* **a**. *Section*. **b**. *Plan*

7 TYPES OF SWIMMING POOL: COMPETITION, LEARNER, TRAINING AND DIVING POOLS

7.01

There has been a general trend away from pools designed specifically for competition and diving towards shallow water, free-form 'fun' pools with many features including water rides. The introduction of compulsory competitive tendering (CCT) has further increased the emphasis on income-producing dryside provision, in the form of fitness rooms, health and beauty suites, sunbeds, saunas and steam rooms. This dryside space around the fun pool is often themed to represent 'tropical paradises' where dense planting provides the backcloth for steel bands, travel agencies, and poolside refreshments. Indoor/outdoor pools – often seen in European countries – are becoming popular.

Demand for serious swimming facilities in the meantime has reappeared in the form of 25 m pools with six or eight lanes, **18.60**. Many older 33.33 m pools have been converted into combined

Table II Projectile halls

	Large 30.3 × 12.8 × 4.6	**Medium** 30.3 × 9.75 × 3.6–4.6	**Small** 30.3 × 5.3 × 3.6
Air rifle	12 firing points	8 firing points	4 firing points
Archery	3 details × 6 archers 3 targets	3 details of 4 archers range 18 m	2 details of 4 archers
Bowls	2/4.5 × 27 m roll-up rinks (if no shooting)	1 roll-up rink (if no shooting)	1 rink
Cricket	3 nets 6-a-side cricket	2 nets	1 net
Fencing	1 piste 4 practice pistes	1 piste	1 piste
Golf practice	4 ranges	3 ranges	1 range
Pistol shooting	7 firing points 10 with side screens	5 firing points	3 firing points
Rifle shooting	12 firing points ranges 25 m, 25 yd, 15 yd	9 firing points	4 firing points
Table squash	15 tables	8 tables	4 tables
Table tennis	15 tables	8 tables	4 tables

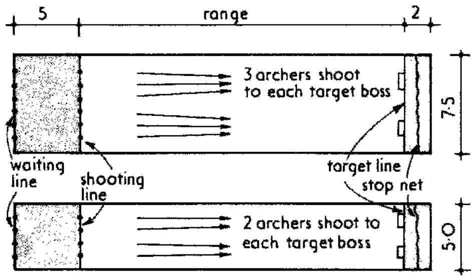
Table III Dimensions for table tennis playing space (m)

Standard of play	*L*	*W*	Ceiling height	Clear height below lights
International matches	14.0	7.0	4.20	4.05
Inter-league and inter-county matches	11.0–14.0 min	5.50–7.0 min	4.20	4.05
Practice and inter-club matches	10.0	5.0	4.20	4.05
Tournaments (more than one table)	8.0	5.0	4.20	4.05
Recreational play	7.6	4.6	–	2.7

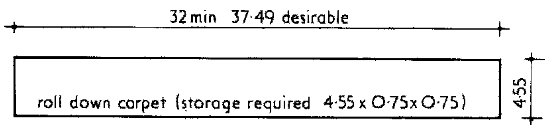
Table IV Dimensions for indoor athletics tracks (m)

Lap length	Length of straight (*s*)	Length of bend (*B*)*	Radius of bend (*R*)†	Overall length (L_1)		Overall width (*W*)		Space for sprint straight (L_2)
				6-track	4-track	6-track	4-track	
200	35‡	65	20.49	88	84	53	49	75.98
	50	50	15.716	93.44	89.44	43.44	39.44	81.44
	52.25	47.75	15.0	94.25	90.25	42	38	82.25
	65	35‡	10.94	98.88	94.88	33.88	29.88	86.88
160	35‡	45	14.124	75.25	71.25	40.25	36.25	63.25
	40	40	12.532	77.06	73.06	37.06	33.06	65.06
	45	35‡	10.941	78.88	74.88	33.88	29.88	66.88

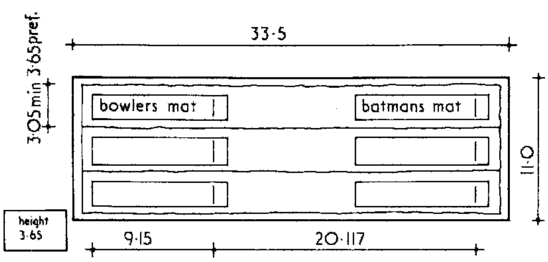
* Measured 200 mm from inside of outer white line around flat-edged track, or 300 mm inside a raised border or edge framework
† Nett radius allowing for 200 mm deduction. The smaller the radius, the greater the inclination of the banking, 10°–18° max
‡ A European Athletic Association regulation minimum dimension



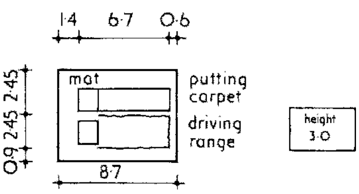
18.44 *Archery. International and national shoots require ranges of 30, 25 and 18 m, and of 20 yards (18.288 m). For club and recreational shoots 15 yards (13.716 m) will do, but 30 m is preferred for competition practice. Archers stand no closer together than 1.25 m when on the shooting line, with two or three to each target. The minimum ceiling height is 3 m. Where there is no public access the distance between the side wall and the first target should be at least 1.2 m. Where spectator accommodation is required, advice should be sought from the Grand National Archery Society. Storage is required for straw bosses and stands, preferably at the target end; and lockable storage for portable bow racks and tackle boxes*



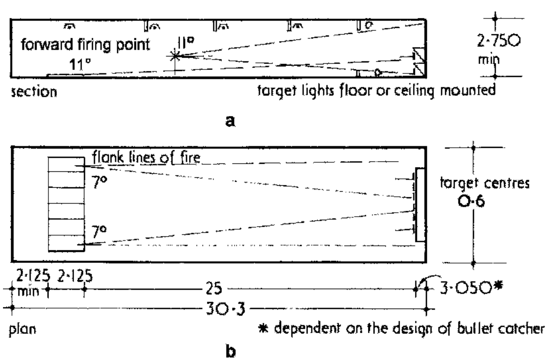
18.45 *Bowling. A single rink in a projectile hall. See also* ***18.52***



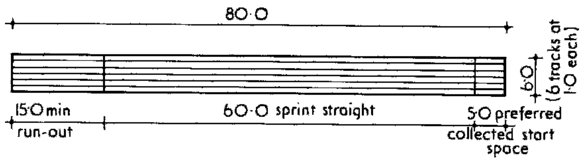
18.46 *Cricket practice nets. For the six-a-side game (not illustrated) the playing area is 30.4–36.5 × 18.9–30.4 × 6.1–7.6 m high*



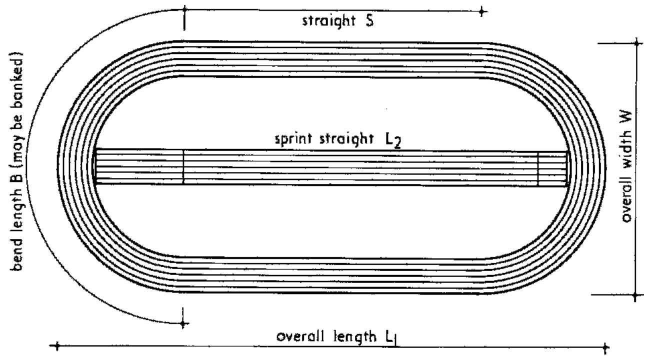
18.47 *Golf practice*



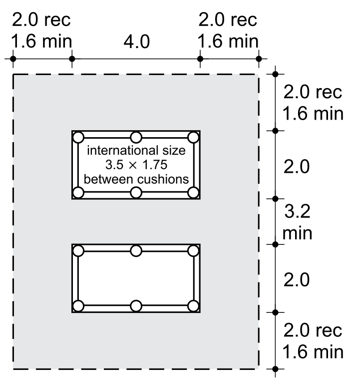
18.48 *Shooting range, small-bore target. For rifle shooting, ranges at 25 m, 25 yards and 15 yards are required at minimum 1.05 m centres. Pistols (where permitted) use 25 m and 25 yards at 1.8 m centres, or 1.15 m with side screens:* **a**. *Section.* **b**. *Plan*



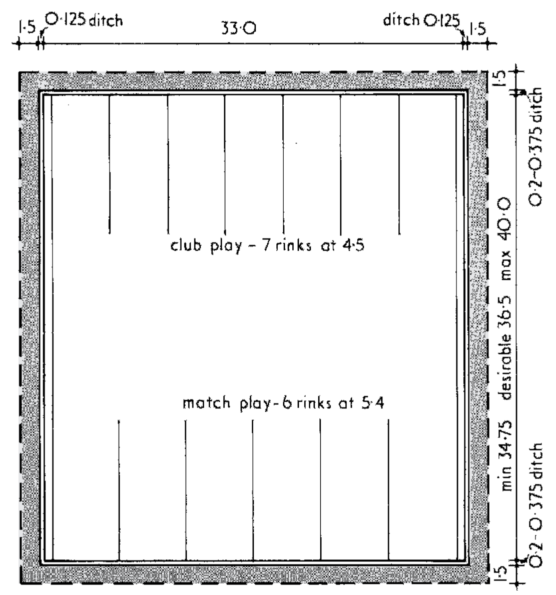
18.49 *Athletics: requirements for straight sprint*



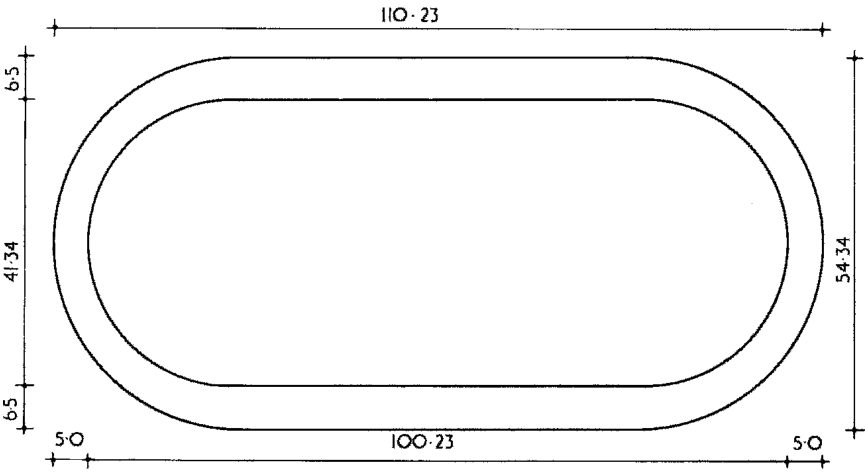
18.50 *Athletics: indoor tracks 200 and 160 m laps, with straight sprint in centre. See Table IV for dimensions. It is no longer considered satisfactory to fit a running track inside the cycle track in* ***18.53****. If spectator accommodation is needed around the track, a building of considerable clear span is necessary as supports in the central area are not acceptable*



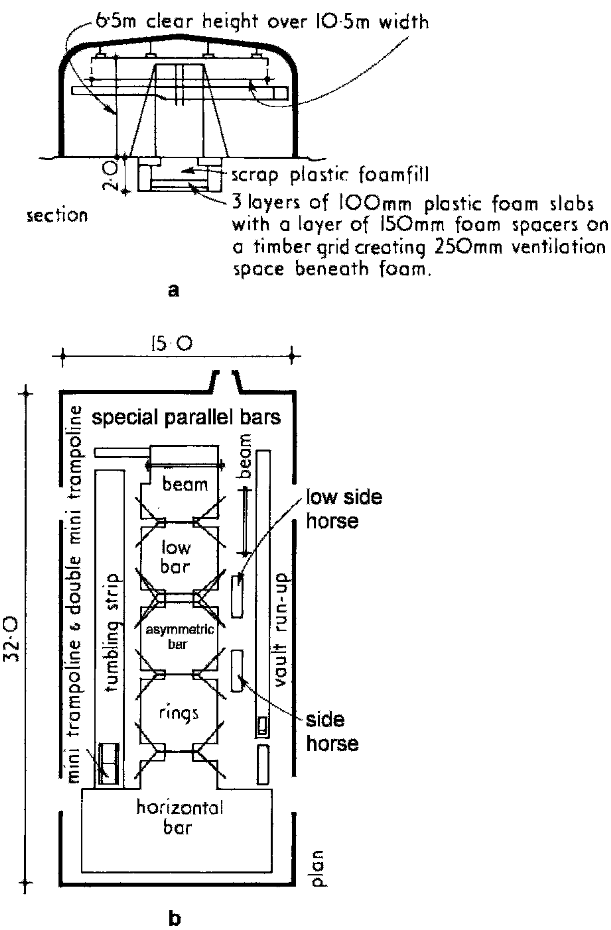
18.51 *Billiards and snooker. The agreed international size, due to become mandatory in 2025, of 3.5 × 1.75 m measured inside the cushions, has had little acceptance, even in major competitions*



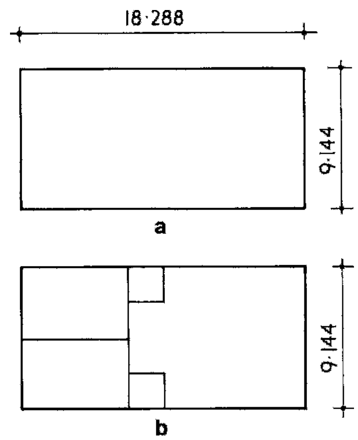
18.52 *Bowling. Four rinks are the minimum for recreation, six are required for tournaments*



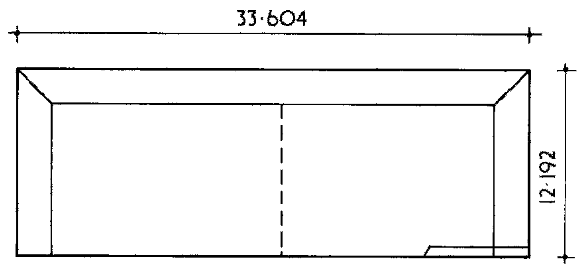
18.53 *Cycling, 250 m track. This is relatively steeply banked. The 333 1/3 m track [**24.48**] can be used internally*



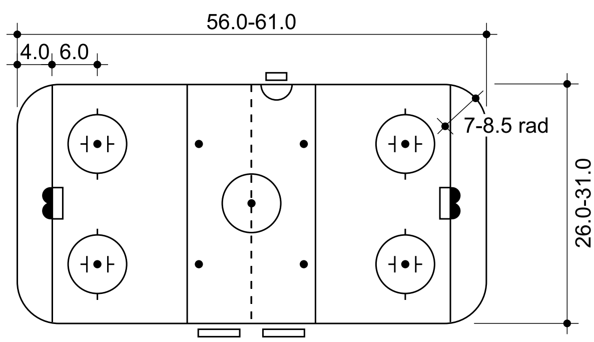
18.54 *Gymnastics practice: training hall at Lilleshall Hall NSC:* **a**. *Cross-section.* **b**. *Plan*



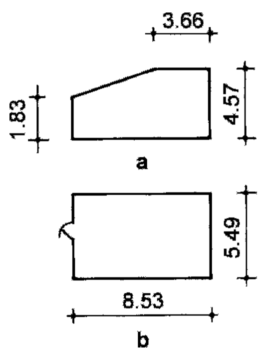
18.56 *Rackets, or racquets:* **a**. *Section.* **b**. *Plan*



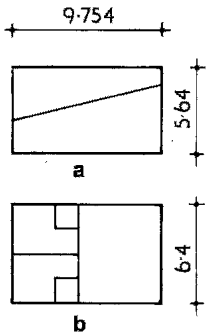
18.57 *Real (or royal) tennis. The dimensions are those at Hampton Court which is reputed to be the widest and among the longest*



18.55 *Ice hockey. Rinks are usually sized to accommodate the 'pad'; this should be surrounded by a 1.2 m high barrier*



18.58 *Rugby fives:* **a**. *Section.* **b**. *Plan*



18.59 *Squash. All dimensions are highly critical and are to internal finished surfaces, which are plastered to a special specification:* **a**. *Section.* **b**. *Plan*

competition and learner pools by means of causeways at the 25 m mark, **18.61**. Hybrid pools with 25 m training lanes down the centre and free-form sides are becoming increasingly common, **18.62**. Another leisure pool is shown in **18.63**.

The refurbishment of old Edwardian pools and buildings of similar vintage (corn exchanges, sawmills, etc.) has increased the present stock of good pools considerably, especially in the UK and Holland.

7.02 Dimensions for competition pools

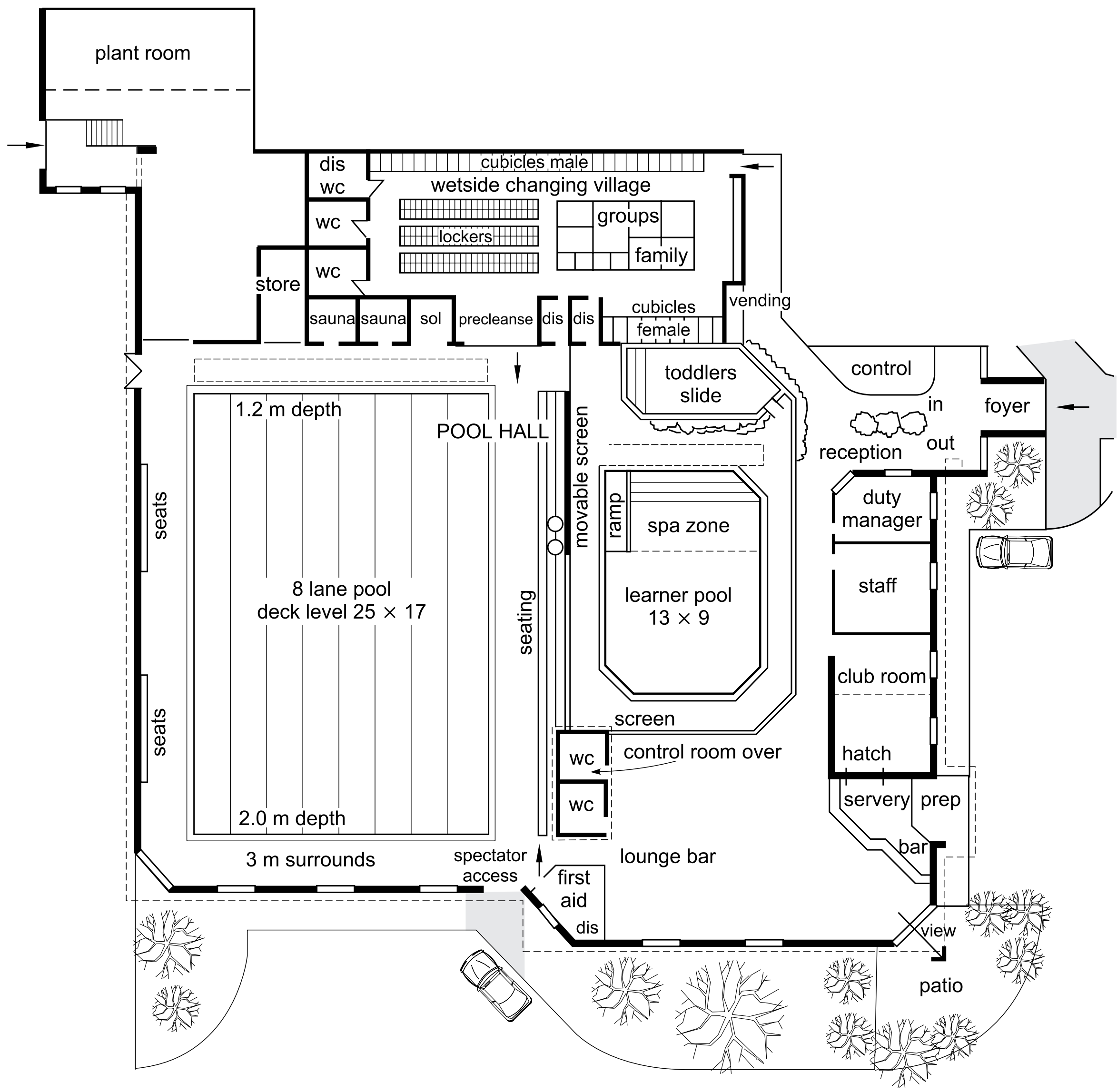
Dimensions of these pools, are strictly laid down by major governing bodies for swimming (FINA – international: ASA for UK). Changes are made from time to time and it is advisable to seek up-to-date information from the relevant authorities.

7.03 Competition pools

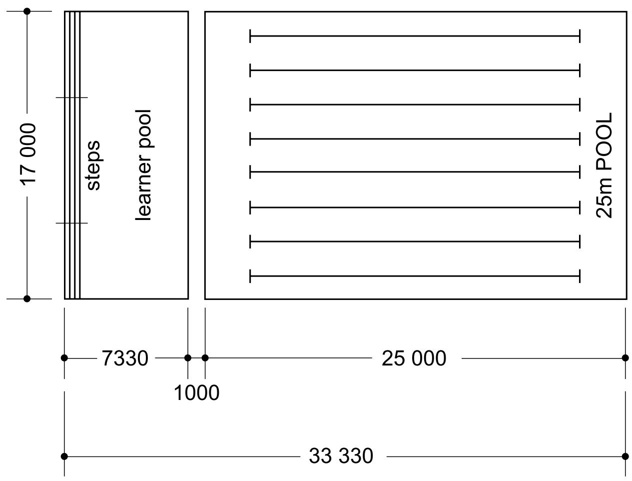
Competition pools are based upon long-course 50 m, **18.64**, or short-course 25 m, **18.65** requirements. Long-course pools have a minimum width of 21 m or 25 m for Olympic competition. The minimum depth of water may be 1 m, although 1.2 m is preferred in 21 m wide pools. Olympic standard pools require a minimum depth of 1.8 m.

7.04 Short-course pools

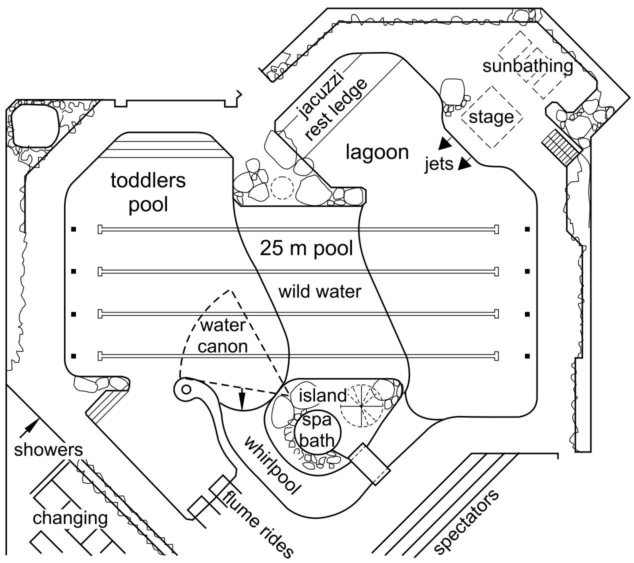
Short-course, 25 m, pools should have a width of 13 m for six-lane competition, or 17 m for eight-lane competition. Minimum water depth should be 0.9–1 m (preferably 1.2 m following recent court findings relating to accidents in shallow water pools). Maximum depth may be 1.8–2 m. These pools are suitable for ASA National, District and County standard competitions.



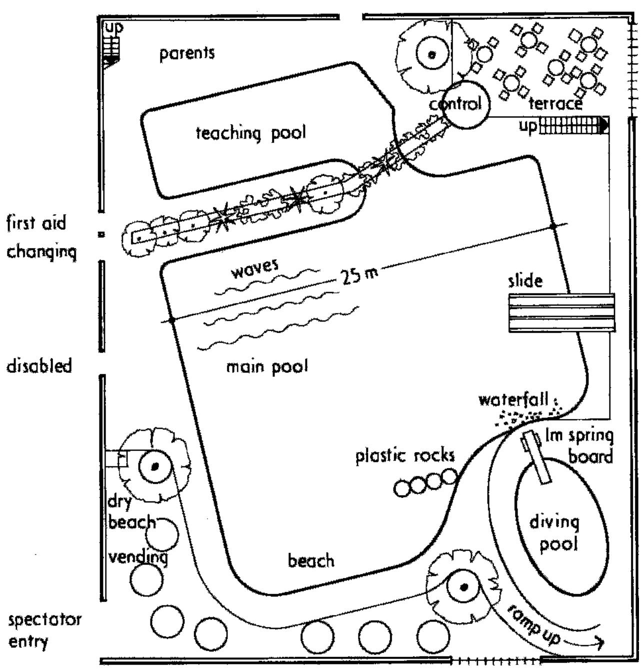
18.60 *25 m pool complex*



18.61 *Plan of 33 1/3+ metre pool, showing use as 25 metre pool plus learner pool*



18.62 *Hybrid pool*



18.63 *Plan of a leisure pool*

7.05 Training pools

Training pools of 25 m length may have four or five lanes (9 and 11 m wide). Depths should be as for short-course pools. In both cases, the last 6 m of the deep end should be level.

7.06 Learner pools

Learner pools for beginners and non-swimmers, **18.66**, should preferably be separated from the main pool far safety reasons and in order to maintain higher air and water temperatures. Steps along one side form part of the water-acclimatisation process especially for the young. Ramps are sometimes included for disabled non-ambulant users, although with level deck pools these have become largely unnecessary. Handrails should be provided where steps lead down into the water.

Dimensions are based upon class size down one long side (classes are of 30–35 pupils on average), with the width allowing beginners to take at least three or four strokes before reaching the side. Common dimensions are length 12–13 m, width 7–10 m and depth 0.7 m at the foot of steps to 0.9–1.2 m at the deep end.

7.07 Pools for the very young (two months old)

These are frequently provided separately, **18.67**, to acclimatise children to water accompanied by parents. Shallow water, seat/steps, and water features such as slides and play furniture make up the main characteristics of these pools. There are no fixed dimensions or shapes.

7.08 Hydrotherapy pools

These are commonly seen throughout Europe, particularly in Germany and Austria, for the elderly or infirm, **18.68**. The water is heavily salinated to assist swimming and healing. The increasing number of sports injuries clinics now appearing in the UK suggests a wider role for this type of pool.

7.09 Diving pools

Diving pools attached to main competition pools have been superseded by specialist diving facilities in separate self-contained spaces where diving can be carried on without interruption. The minimum distance to other pools should be 5 m. The minimum requirements for a diving pool are given in **18.69** and Table V.

Olympic or international standard competition diving requires more rigorous standards, **18.70**, and associated specialist facilities such as sprays to ripple the water surface and lifts to the higher diving boards. The FINA/ASA standards for these are shown in **18.71** and Table VI. An example of this type is shown in **18.72**. National training status requires length 30 m, width 25 m and depths as Table V.

All dimensions should be checked with the relevant authorities as they may be amended from time to time.

8 WATER ACTIVITIES

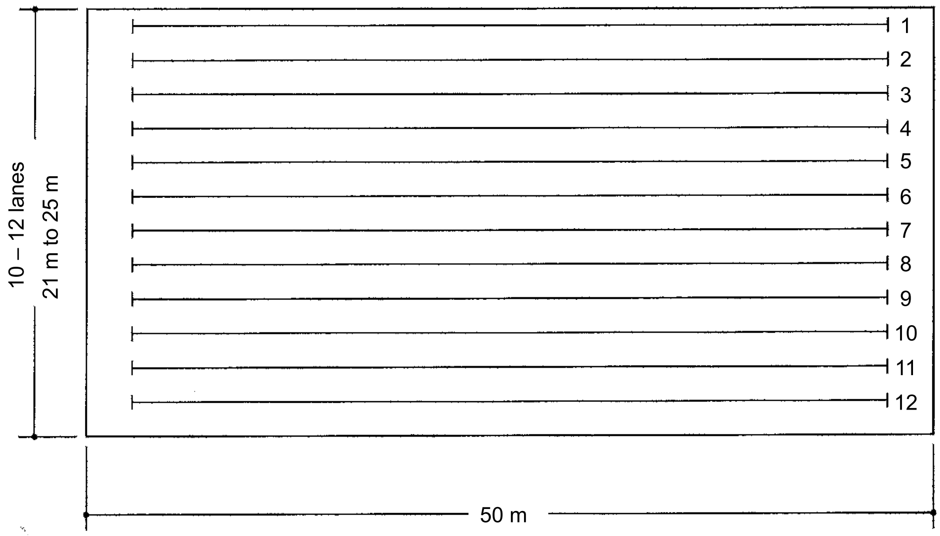
A number of activities are currently associated with deep water in hybrid or competition pools.

8.01 Water polo

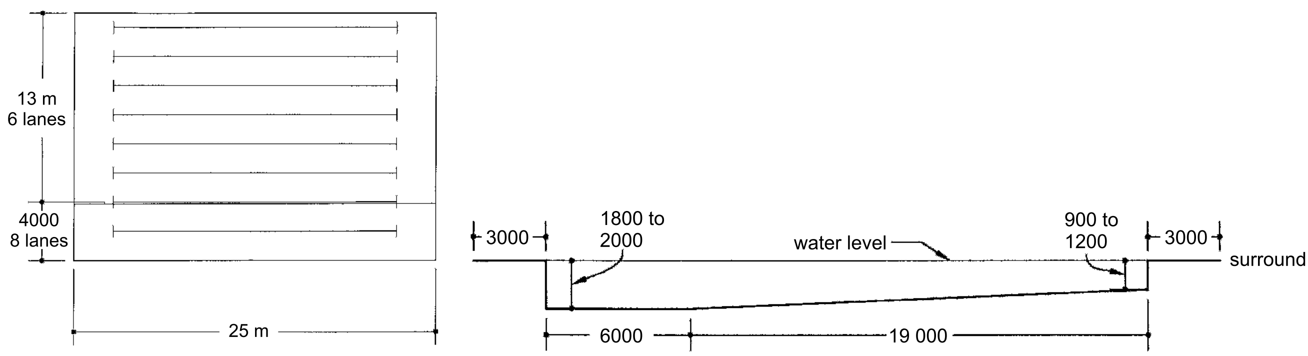
Water depth at Olympic standard should be not less than 1.8 m, and for lesser play, 1.2 m. The fields of play are:

- Olympic standard 30 × 20 m
- Club standard 25 × 10 m.

The standards are shown in **18.73**. However, the game can be played as a recreation in a standard pool, **18.74**. The field is marked above water level at the pool sides. Space should be accessible for the free movement of the referee and goal judges at goal lines.

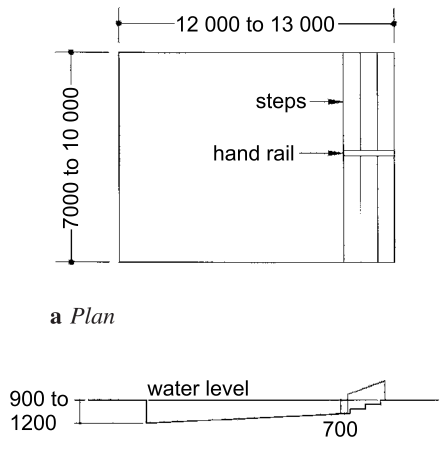


18.64 *Plan of 50 m pool*



a *Plan*   **b** *Longitudinal section*

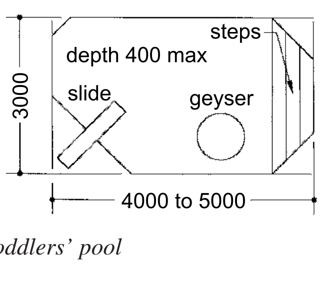
18.65 *25 m pool*



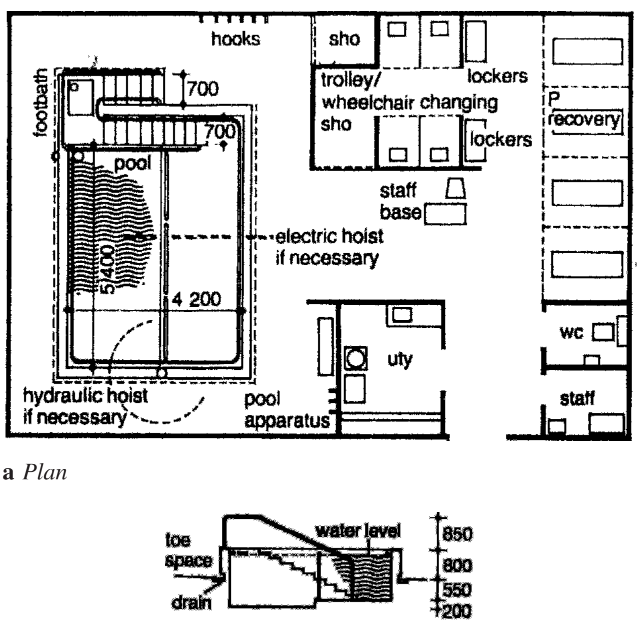
a *Plan*

b *Section*

18.66 *Learner pool*



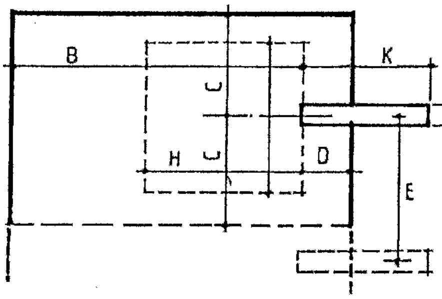
18.67 *Plan of toddlers' pool*



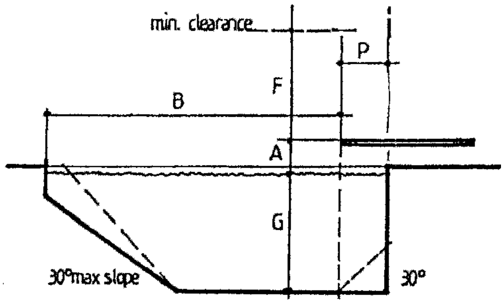
a *Plan*

b *Section through pool*

18.68 *Hydrotherapy pool complex*



a *Plan*



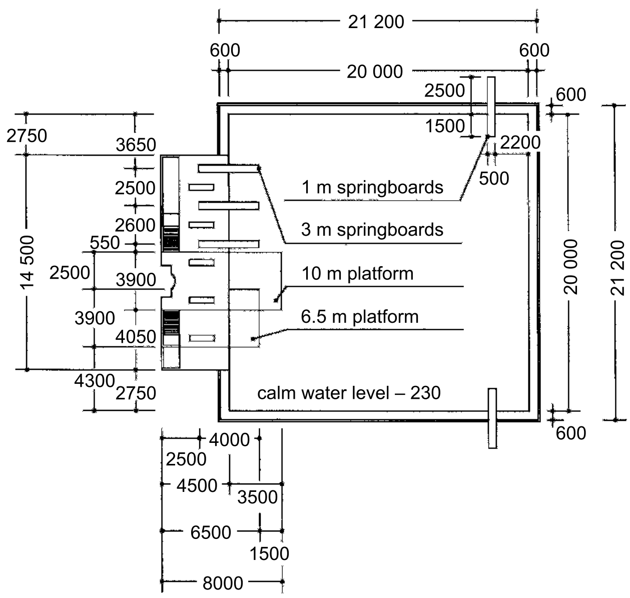
b *Section*

18.69 *Diving pool (see Table V for dimensions)*

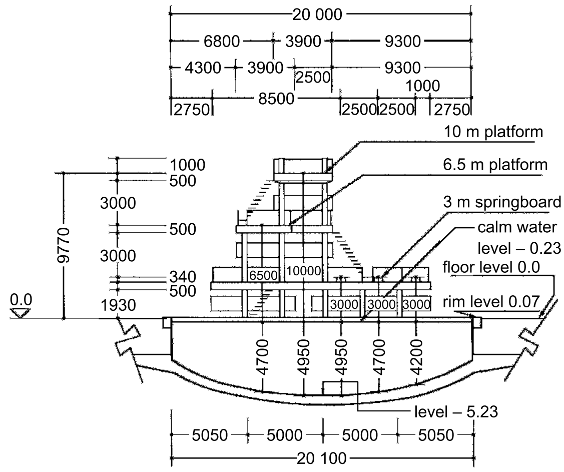
Table V Minimum dimensions in metres for diving boards

	Type of board	Spring	Spring	Fixed	Fixed*	Fixed
A	Board height*	1.0	3.0	5.0	7.5	10.0
B	Clearance forward	7.5	9.0	10.25	11.0	13.5
C	Clearance to sides	2.5	3.5	3.8	4.5	4.5
D	Clearance behind	1.5	1.5	1.25	1.5	1.5
E	Centre of adjoining board	2.5	2.5	2.5	2.5	2.5
F	Clearance overhead	4.6	4.6	3.0	3.2	3.4
G	Depth of water	3.0	3.5	3.8	4.1	4.5
H	Depth maintained forward	5.3	6.0	6.0	8.0	10.5
J	Depth maintained to sides	2.2	2.7	3.0	3.0	3.0
K	Board length	4.8	4.8	5.0	6.0	6.0
M	Board width	0.5	0.5	2.0	2.0	2.0
N	Clearance forwards overhead	5.0	5.0	5.0	5.0	6.0
P	Clearance sides and behind Overhead	2.75	2.75	2.75	2.75	2.75

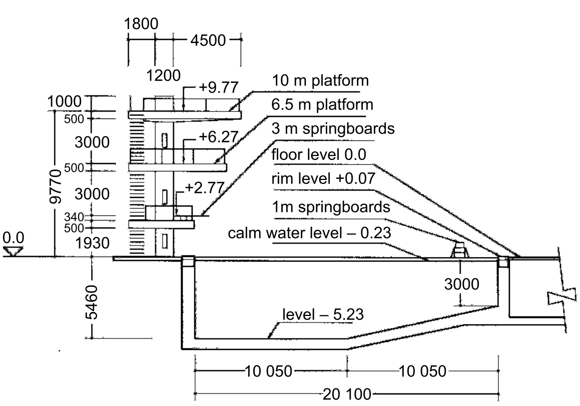
* The 7.5 m board is mainly used for training.
A tolerance of ±0.1 is permissible on board height, relate all dimensions to front edge centre of each board.



a *Plan*

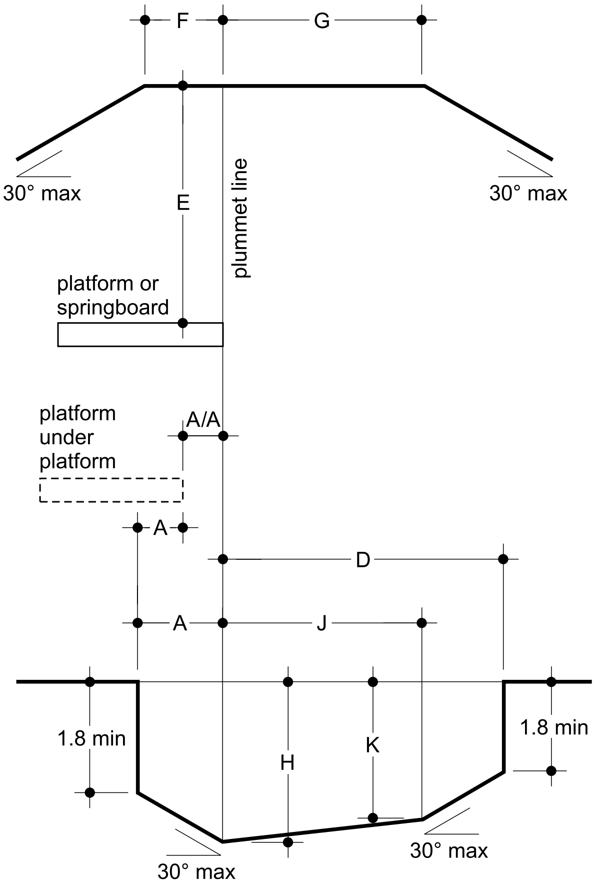


b *Elevation from pool*

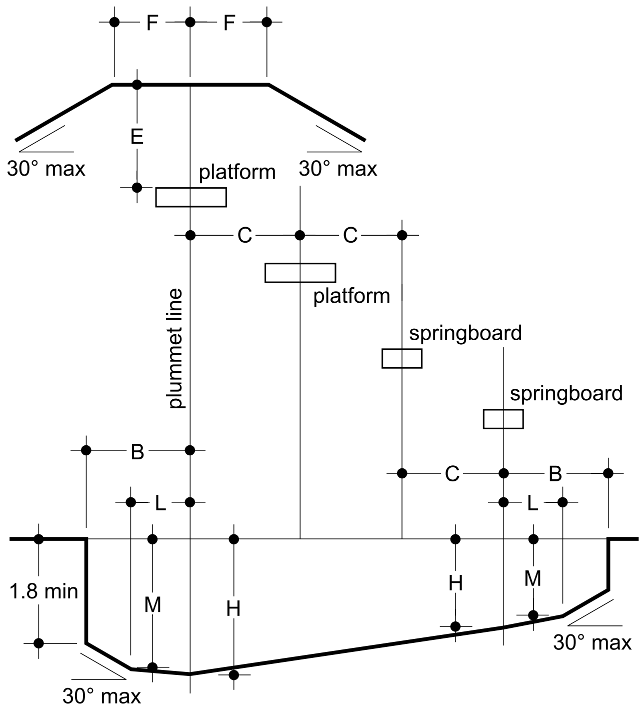


c *Side elevation and pool cross-section*

18.70 *Olympic regulations diving platform assembly and pool*



a *Side view*



b *Frontal view*

18.71 *FINA/ASA dimensions for diving facilities (see Table VI)*

8.02 Synchronised swimming

This has become progressively popular over recent years and is now performed up to Olympic standard. Water should be not less than 1.8–2 m. Provision should be made for underwater windows, lighting and sound for coaching purposes.

8.03 Sub-aqua diving

Water should be not less than 1.5–2 m in depth with a high degree of clarity. Other requirements are:

- Water depths up to 5.5 m for pressure valuation experience
- Compressor room of approximately 15 m^2
- Club room, **18.75**, for approximately 50 people
- Storage space for equipment of approximately 15 m, well drained
- Specialist rooms for advanced training including seminar rooms, club room, compressor store, equipment shop, separate changing rooms and an office
- Snorkelling pool ranging in depth from 1.5 to 5 m, with a diving pit 7 m deep and
- Access to the pool using suitable ladders, **18.76**.

Details from the British Sub-Aqua Club.

9 LEISURE POOLS AND WATER FEATURES

9.01 Fun pools

Fun pools, **18.77**, with irregularly shaped sides and a considerable amount of shallow water space approximately 350–400 m^2 in area, may have combinations of the following features:

- Wave-making machinery, **18.78**
- Water cannons
- Underwater massage jets
- Waterfall
- Rapids/wild water, jungle river, lazy river/indoor–outdoor rides
- Whirlpool
- Jacuzzi spa bath
- Plume/water rides
- Slides
- Lagoons with Jacuzzi rest ledges
- Underwater lighting and sound.

9.02 Dryside facilities

Dryside facilities usually associated with the above may include:

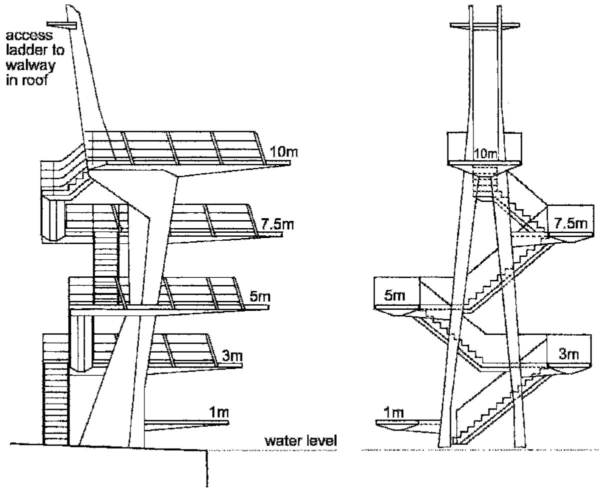
- Health and fitness suites plus separate changing, toilets and showers
- Beauty salon – massage, aromatherapy, manicure, hair treatment
- Rapid-tan sunbeds
- Sauna, steam cabins
- Platform for concerts, receptions, fashion shows, steel bands
- Lighting to match
- Themed baths (Turkish, Roman, Japanese, Scandinavian)
- Creche, meetings room
- First-aid room
- Equipment store
- Landscape features normally themed to represent a tropical setting
- Food and drinks points
- Administration/supervision/control points
- Travel agency/displays.

9.03 Hybrid pools

These, **18.62**, are similar to leisure pools, but have a central area 25 m in length marked out with four or six training lanes for serious

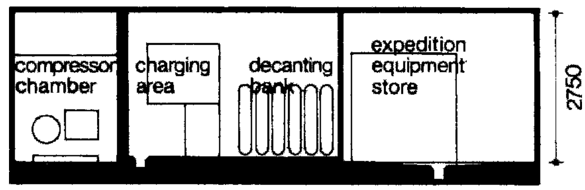
Table VI FIN A/ASA dimensions for diving facilities (see 22.71)

			Springboard				Platform									
			1 metre		3 metre		1 metre		3 metre		5 metre		7.5 metre		10 metre	
		Length	**4.80**		**4.80**		**5.00**		**5.00**		**6.00**		**6.00**		**6.00**	
		Width	**0.50**		**0.50**		**0.60**		**0.60 min 1.50 pref.**		**1.50**		**1.50**		**2.00**	
		Height	**1.00**		**3.00**		**0.60–1.00**		**2.60–3.00**		**5.00**		**7.50**		**10.00**	
			Horiz.	**Vert.**	**Horiz.**	**Vert.**	**Horiz.**	**Vert.**	**Horiz.**	**Vert.**	**Horiz.**	**Vert.**	**Horiz.**	**Vert.**	**Horiz.**	**Vert.**
A	From plummet back to pool wall	Designation	A–1		A–3		A–1 pl		A–3 pl		A–5		A–7.5		A–10	
		minimum	1.50		1.50		0.75		1.25		1.25		1.50		1.50	
		preferred	1.80		1.80		0.75		1.25		1.25		1.50		1.50	
A/A	From plummet back to platform plummet directly below	Designation									A/AS/1		A/A/.5/3.1		a/A10/5, 3, 1	
		minimum									0.75		0.75		0.75	
		preferred									1.25		1.25		1.25	
B	From plummet to pool wall at side	Designation	B–1		B–3		B–1 pl		B–3 pl		B–5		B–7.5		B–10	
		minimum	2.50		3.50		2.30		2.80		3.25		4.25		5.25	
		preferred	2.50		3.50		2.30		2.90		3.75		4.50		5.25	
C	From plummet to adjacent plummet	Designation	C1–1		C3–3, 3-1		C 1–1 pl		C 3–3 pl, 1 pl		C 5–3, 5-1		C 7.5–5, 3, 1		C 10–7.5, 5, 3, 1	
		minimum	2.00		2.20		1.65		2.00		2.25		2.50		2.75	
		preferred	2.40		2.60		1.95		2.10		2.50		2.50		2.75	
D	From plummet to pool wall ahead	Designation	D–1		D–3		D–1 pl		D–3 pl		D–5		D–7.5		D–10	
		minimum	9.00		10.25		8.00		9.50		10.25		11.00		13.50	
		preferred	9.00		10.25		8.00		9.50		10.25		11.00		12.50	
E	From plummet to board to ceiling	Designation	E–1		E–3		E–1 pl		E–3 pl		E–5		E–7.5		E–10	
		minimum	5.00		5.00		3.25		3.25		3.25		3.25		4.00	
		preferred	5.00		5.00		3.50		3.50		3.50		3.50		5.00	
F	Clear overhead behind and each side of plummet	Designation	F–1	E–1	F–3	E–3	F–1 pl	E–1 pl	F–3 pl	E–3 pl	F–5	E–5	F–7.5	E–7.5	F–10	E–10
		minimum	2.50	5.00	2.50	5.00	2.75	3.25	2.75	3.25	2.75	3.25	2.75	3.25	2.75	4.00
		preferred	2.50	5.00	2.50	5.00	2.75	3.50	2.75	3.50	2.75	3.50	2.75	3.50	2.75	5.00
G	Clear overhead ahead of plummet	Designation	G–1	E–1	G–3	E–3	G–1 pl	E–1 pl	G–3 pl	E–3 pl	G–5	E–5	G–7.5	E–7.5	G–10	E–10
		minimum	5.00	5.00	5.00	5.00	5.00	3.25	5.00	3.25	5.00	3.25	5.00	3.25	6.00	4.00
		preferred	5.00	5.00	5.00	5.00	5.00	3.50	5.00	3.50	5.00	3.50	5.00	3.50	6.00	5.00
H	Depth of water at plummet	Designation		H–1		H–3		H–1 pl		H–3 pl		H–5		H–7.5		H–10
		minimum		3.40		3.70		3.20		3.50		3.70		4.10		4.50
		preferred		3.50		3.50		3.30		3.60		3.80		4.50		5.00
J K	Distance and depth ahead of plummet	Designation	J–1	K–1	J–3	K–3	J–1 pl	K–1 pl	J–3 pl	K–3 pl	J–5	K–5	J–75	K–75	J–10	K–10
		minimum	5.00	3.30	6.00	3.60	4.50	3.10	5.50	3.40	6.00	3.60	8.00	4.00	11.00	4.25
		preferred	5.00	3.40	6.00	3.70	4.50	3.20	5.50	3.50	6.00	3.70	8.00	4.00	11.00	4.75
L M	Distance and depth each side of plummet	Designation	L–1	M–1	L–3	M–3	L–1 pl	M–1 pl	L–3 pl	M–3 pl	L–5	M–5	L–7.5	M–7.5	L–10	M–10
		minimum	1.50	3.30	2.00	3.60	1.40	3.10	1.80	3.40	3.00	3.60	3.75	4.00	4.50	4.25
		preferred	2.00	3.40	2.50	3.70	1.90	3.20	2.30	3.50	3.50	3.70	4.50	4.40	5.25	4.75
N	Maximum slope to reduce dimensions beyond full requirements	Pool depth Ceiling ht	30 degrees 30 degrees		Note: Dimension C (plummet to adjacent plummet) apply to platforms with widths as detailed. If platform widths are increased then C is to be increased by half the additional width(s)											

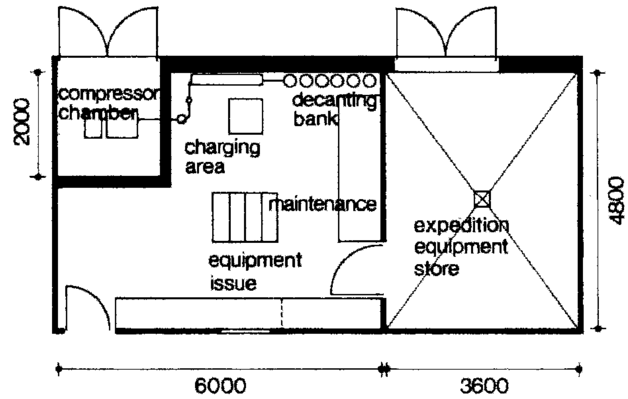


a *Side view* **b** *Frontal view*

18.72 *Ponds Forge, Sheffield: diving stages*

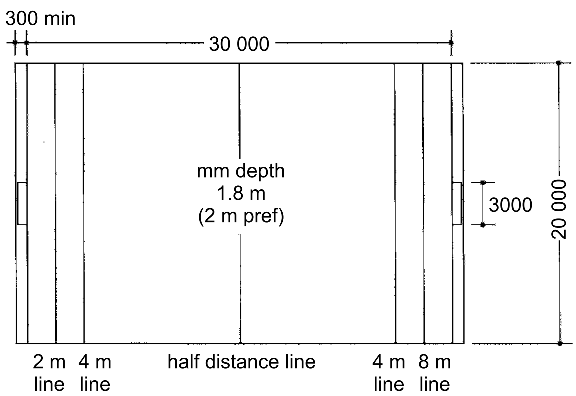


a *Elevation*

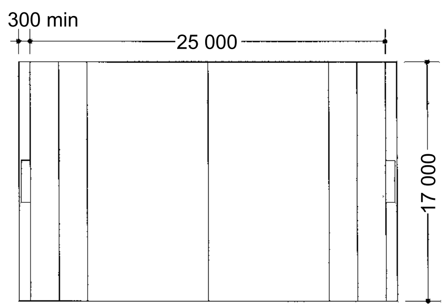


b *Plan*

18.75 *Sub-aqua equipment store and compressor room*

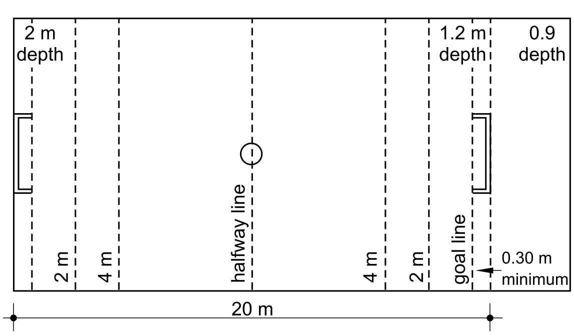


a *For men*

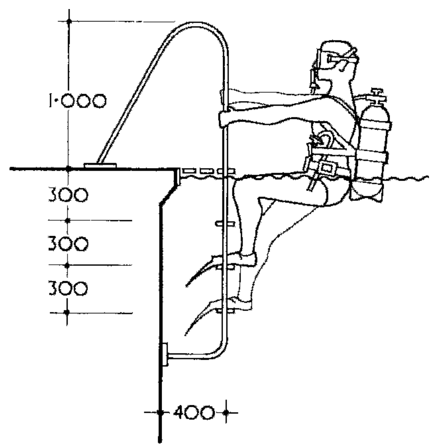


b *For women*

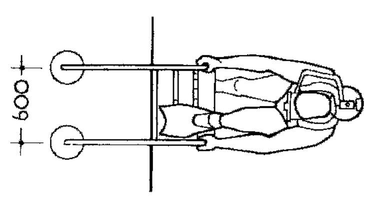
18.73 *Water polo layouts*



18.74 *Water polo layout for a 25 m × 12.5 m pool*

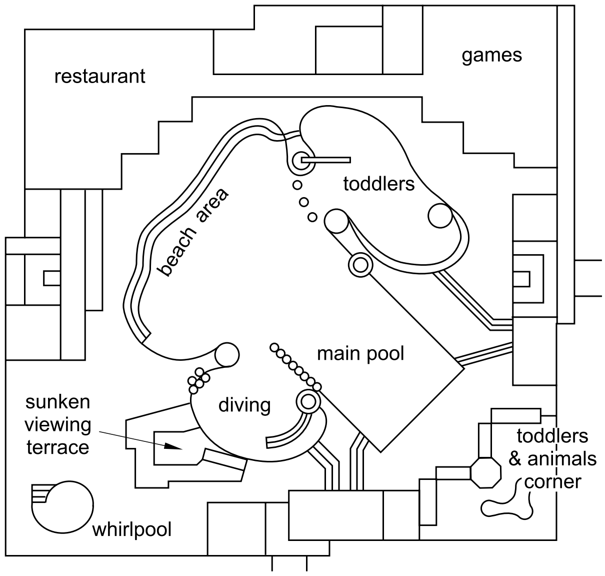


a *Elevation*

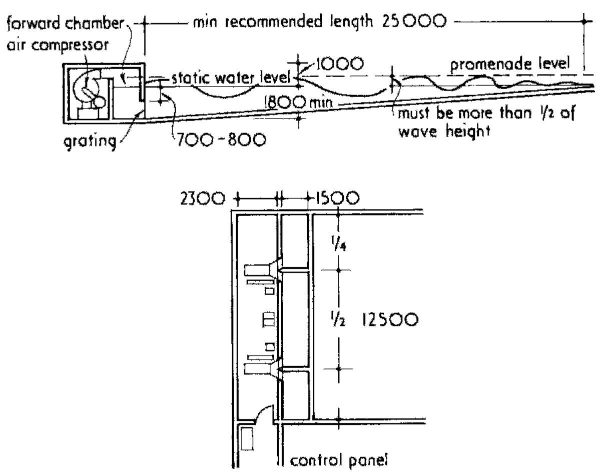


b *Plan*

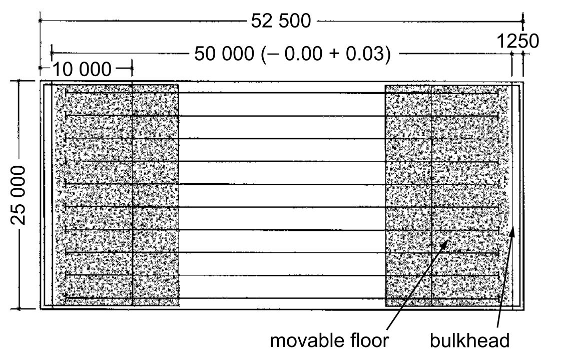
18.76 *Access to the pool for sub-aqua diving. Specially designed removable steps assist a heavily laden diver*



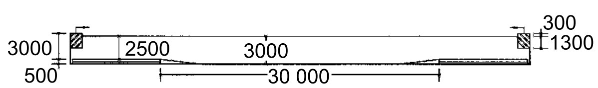
18.77 *Layout of leisure pool De Mirandabad, Amsterdam. Architects: Architektenburo Baanders, Frenken*



18.78 **a** *Section through a leisure pool showing wave making machine room and 'beaching' of pool* **b** *Sectional plan of wave-making machine room*

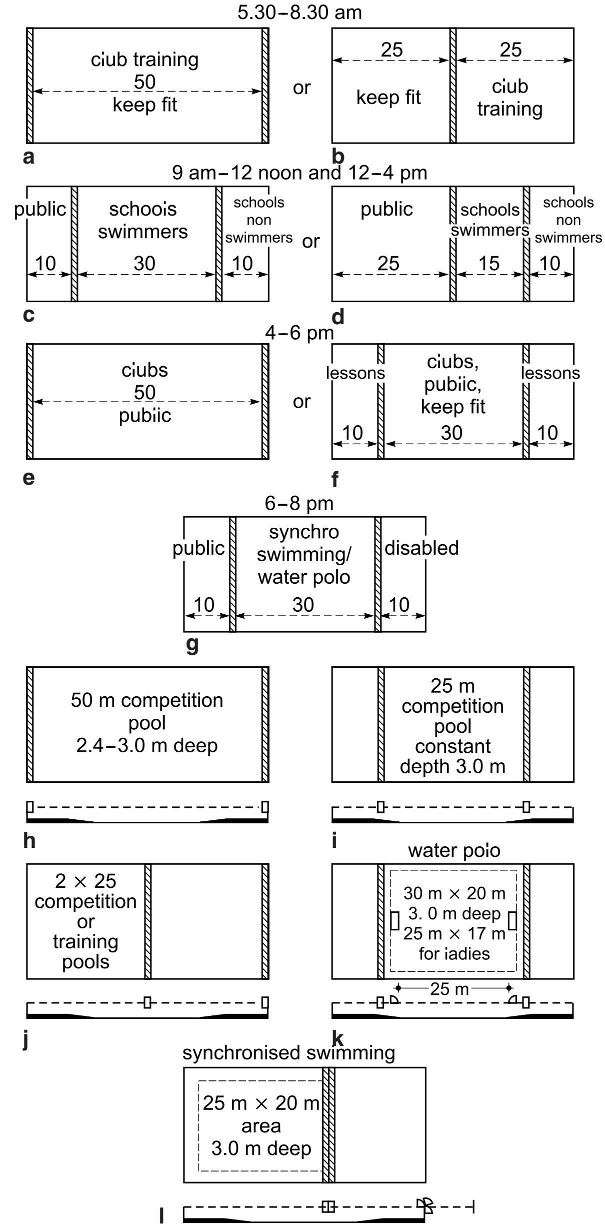


a *Plan*



b *Cross-section*

18.79 *A 50 m pool with ultimate flexibility. This has two movable floors and two laterally moving bulkheads*



18.80 *Various arrangements of the pool above:* **a** *5:30–8:30 am, club training and keep fit.* **b** *5:30–8:30 am, alternative for club training and keep fit.* **c** *9 am to noon, public, school swimmers and school non-swimmers.* **d** *A 9 am to noon, alternative for public, school swimmers and school non-swimmers,* **e** *4–6 pm, clubs and public,* **f** *4–6 pm, alternative for clubs, public, keep fit and lessons,* **g** *6–8 pm, synchro swimming or water polo, public and disabled people.* **h** *50 m competition pool 2.4–3 m deep,* **i** *25 m competition pool constant 3 m depth,* **j** *Twin 25 m competition or training pools,* **k** *Water polo: 30 m × 20 m, or 25 m × 17 m for women, 3 m deep.* **l** *Synchronised swimming: 25 m × 20 m by 3 m deep*

swimming. Depths at either end of this area must be the same as for normal 25 m competition pools. Because the sides may be free-form in shape and other features intrude (e.g. whirlpool, flume rides), competitions cannot be judged properly.

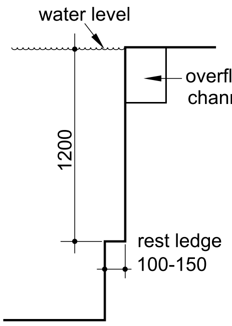
10 MOVABLE FLOOR POOLS

18.79 shows a pool with movable floors; while **18.80** shows the flexibility offered to 50 and 25 m pools by movable floors. Flexibility is further increased by the inclusion of two movable floors and two laterally moving bulkheads.

11 POOL DETAILS AND LANE MARKINGS

11.01 Rest ledges

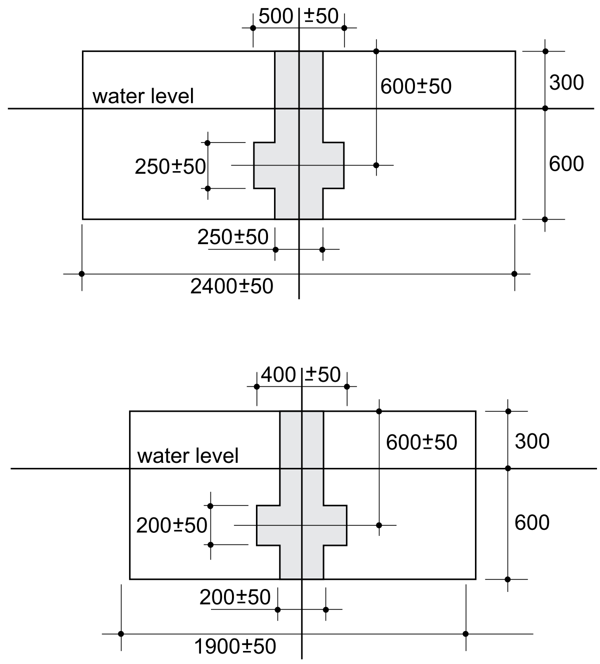
These are required around pool sides where the water depth exceeds 1.2 m, **18.81**.



18.81 *Rest ledge*

11.02 Raised ends and touch pads

Where pools are to be predominately used for competitions and serious training, raised ends should be provided, **18.82**, equipped with touchpads, **18.83**.



18.83 **a** *Touch pad to conform to FINA regulations,* **b** *Touch pad for ASA Championship requirements in 25 m pools*

11.03 Edge channels

The present preference for deck level pools requires edge channels designed for overflow purposes, finger grip and demarcation between water edge and pool surround, **18.84**.

11.04 Lane rope anchorage

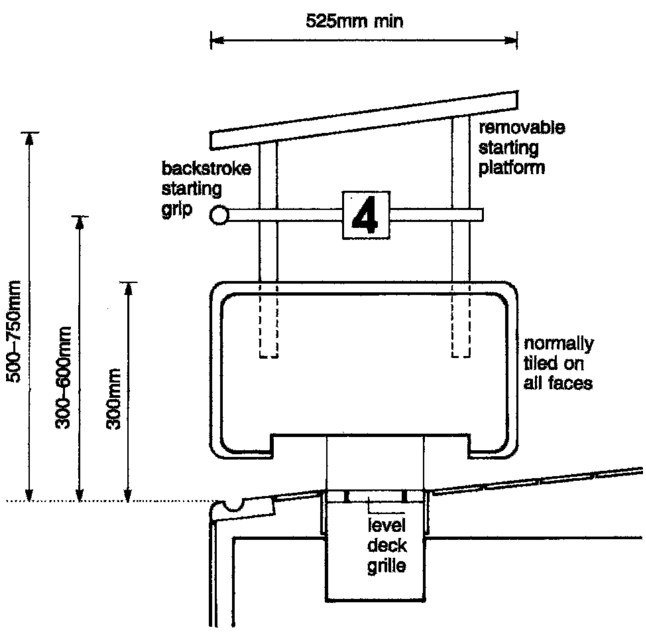
This is for fixing lane booms on level deck pools and is usually behind edge channels on pool surrounds.

11.05 Start-recall

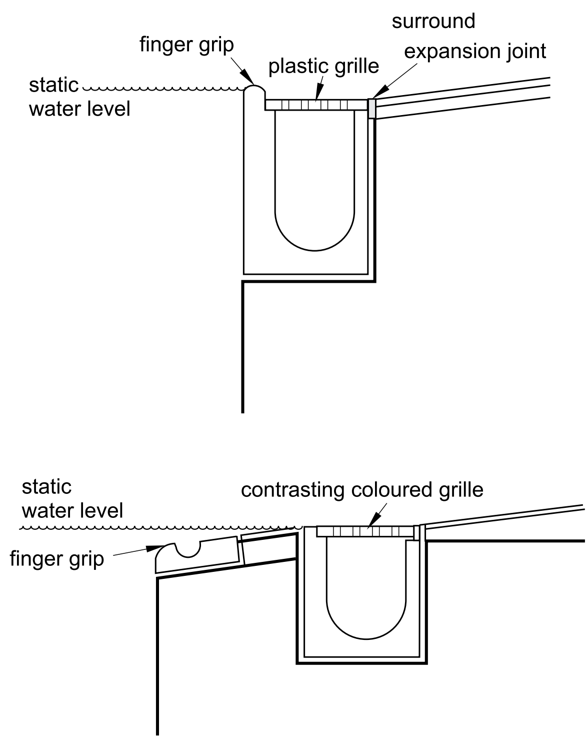
A recall rope and flags are required 15 m in front of the start for competition use.

11.06 Lane markings in competition pools

These should be laid in accordance with FINA/ASA recommendations, **18.85** and Table VII.



18.82 *Removable starting platform*



18.84 *Edge details for deck level pools*

11.07 Backstroke turn indicators

These are required 5 m from end walls, **18.85**.

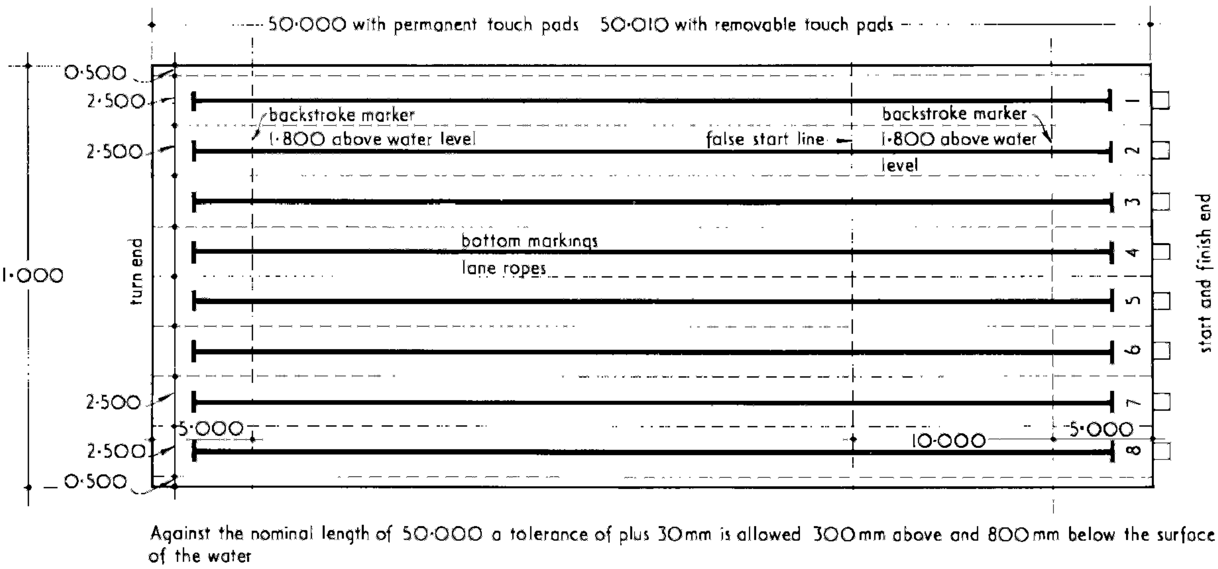
11.08 Underwater windows

These may be considered for coaching and video. Underwater lights may be required for environmental purposes.

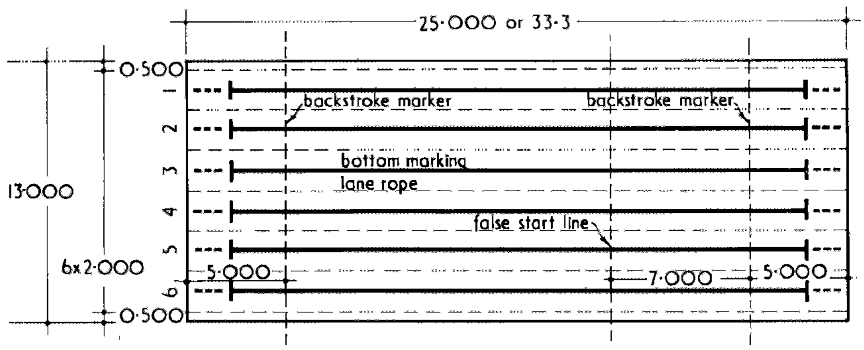
12 CHANGING PROVISION

12.01 Facilities

Segregated changing facilities, **18.86**, have been largely replaced by the changing 'village' arrangement, **18.87**, which is based upon



a *50 m pool to Olympic standard*



b *25 metre and 33⅓ m pools*

18.85 *Lane and other marking required for competitive swimming*

Table VII Dimensions of lane markings in metres

		FINA/ASA 50 m pools	ASA 25 m pools
A	Width of lane markings, end lines, targets	0.25 ± 0.05	0.2 ± 0.05
B	Length of end wall targets	0.5 ± 0.05	0.5 ± 0.05
C	Depth to centre of end wall targets	0.3 ± 0.05	0.3 ± 0.05
D	Length of lane marker cross line	1.0 ± 0.05	0.8 ± 0.05
E	Width of racing lanes	2.5	2.0
F	Distance from cross line to end wall	2.0 ± 0.05	2.0 ± 0.05
G	Touch pad	2.4 ± 0.05	1.9 ± 0.05

separation of dry and wet footpaths to and from changing cubicles. Minimum cubicles are shown in **18.88**, but it is important to provide a proportion of larger cubicles for the use of families and disabled people.

12.02 Other arrangements

Toilets should be positioned between lockers and poolside. Precleanse footbaths are no longer mandatory although foot sprays are still desirable. Showers are largely for after-swim shampooing. Hairdrying facilities are desirable close to changing room exits.

12.03 Sauna and steam rooms

These may also form part of the 'village', **18.87**.

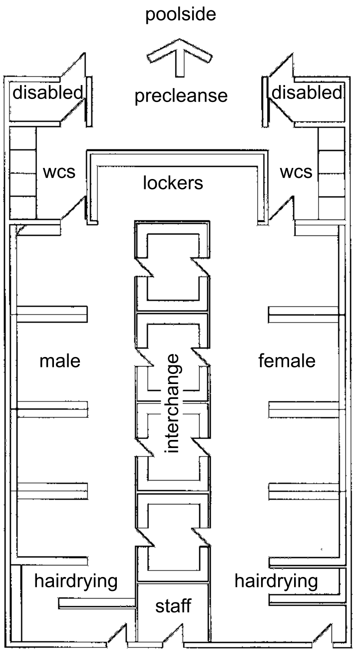
13 PROVISION FOR DISABLED PEOPLE

13.01 Disabled people

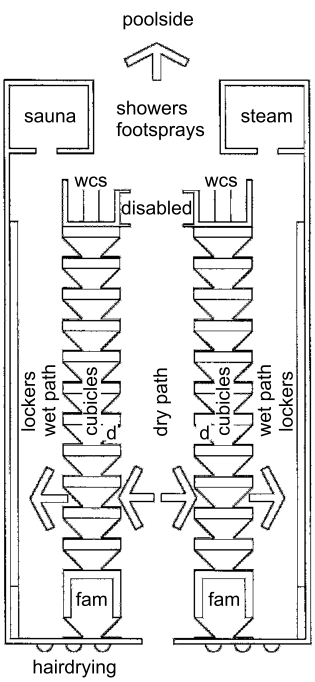
Consideration for disabled people is mandatory. As well as wheelchair users this includes people with impaired vision and those with learning difficulties. Wheelchair users may be provided for either in the changing village or alternatively in rooms around the pool, **18.89** and **18.90**. The disappearance of the footbath has eased wheelchair access to the poolside.

13.02 Deck level pools

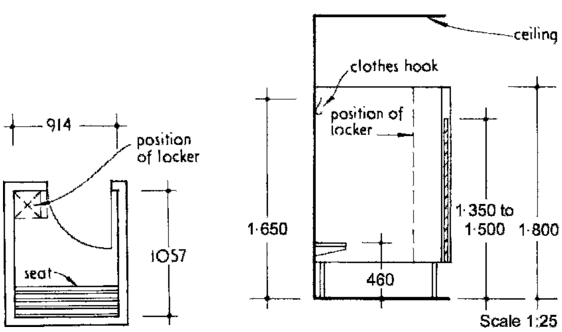
These also improve access into and out of the water for disabled people. Chair hoists are still sometimes provided for this purpose although they are often disliked by users for the attention they cause.



18.86 *Traditional layout of changing rooms*

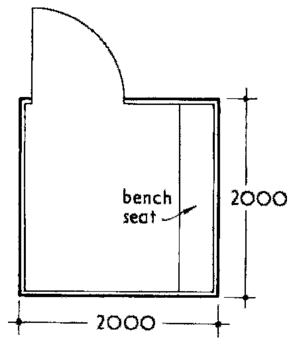


18.87 *Changing village. No segregation. Average cubicle occupancy 4 minutes*

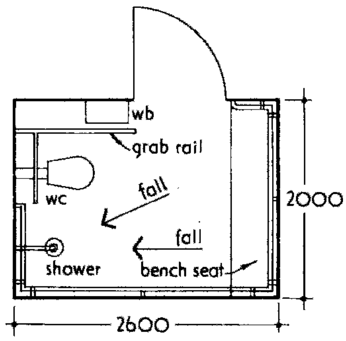


a *Plan* **b** *Section*

18.88 *Changing cubicle*



18.89 *Minimum changing provision for disabled people*



18.90 *Better provision for disabled people*

13.03 Other arrangements

Shallow water spa (bubble) areas are much liked by those with learning difficulties.

Large, clearly marked signs, colour-coded footpaths and rails are required for visually impaired people.

14 POOL CAPACITY ANALYSIS

As a rule of thumb, pool capacities may be determined by dividing the water surface area by 2. Thus a 25×13 m pool can accommodate to reasonable comfort standards $325 \div 2 = 162$ bathers.

Changing cubicles, lockers and car parking provision can be based upon the same analysis plus the following allowances:

- Locker allowance based upon pool capacity, with a further 162 changing = 324 lockers, usually in two- to three-tier compartments
- Changing cubicle provision may be based upon a time factor of 5–10-min occupation per bather. Thus in any one hour 162 bathers in the pool plus a further 162 changing ready to enter the pool = 324 bathers ÷ 10 min = 32 cubicles
- Car parking provision may be calculated thus: 324 bathers, 3 persons per car average = 101 spaces + a further allowance for staff, disabled, etc. say 125–150 spaces.

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Information published by the ruling bodies for each particular sport

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19 Outdoor sports and stadia

Peter Ackroyd, Geraint John and John Rawson

Peter Ackroyd was until his retirement an architect in the Sports Council Technical Unit, where Geraint John was Chief Architect. John Rawson is an architect

CI/SfB: 546, 564
UDC: 796, 725.82, 725.87
Uniclass: F561, F5678

KEY POINT:
- *Standards are constantly changing, so check with sports' governing bodies*

Contents

1 INTRODUCTION

A few sports (mainly those based in the USA) still quote critical dimensions in imperial units. These dimensions are shown here in metric equivalents to the second or third decimal point, which should not be rounded off.

Sports are in alphabetical order under the appropriate classification. Boundary lines are shown by a solid line, safety and other marginal areas by tone, bounded by a broken line, the dimensions of which can vary and should be checked with governing bodies of sport. Court markings are usually indicated by fine lines.

2 SPORTS GROUNDS AND STADIA

2.01 Facilities

For higher levels of competition in most sports, purpose-built facilities are usually provided. These incorporate special qualities of turf and its sub-grade, together with appropriate facilities for the players and for spectators.

While many sports events can be enjoyed by spectators situated on the sidelines or the boundary of the playing or competing area, there are a number of progressively more elaborate forms:

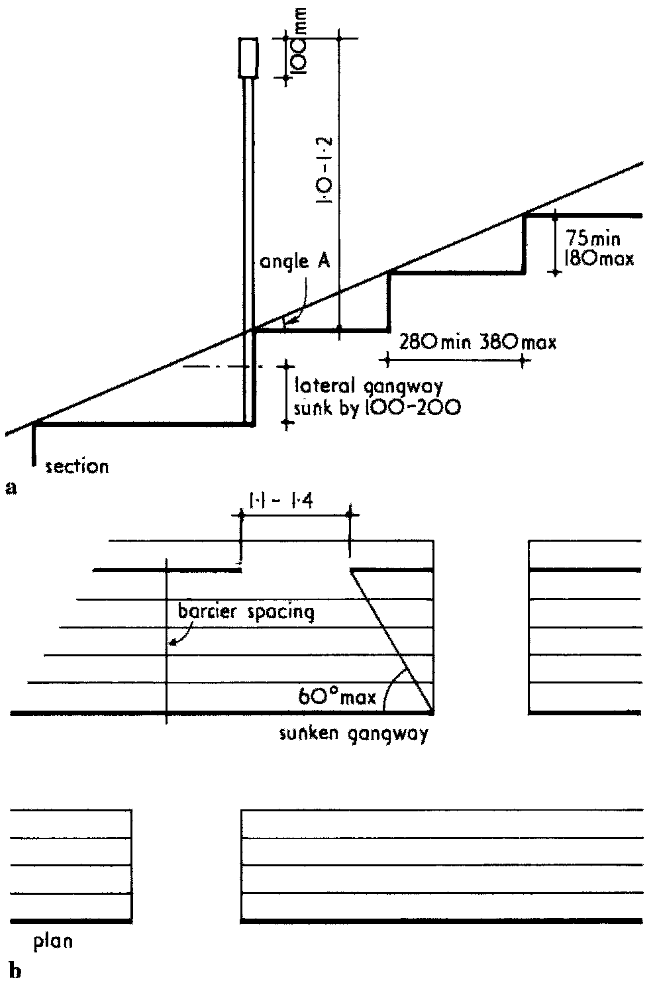
- Viewing slopes;
- Open terraces;
- Viewing stands (which despite their name incorporate seating) overlooking part of a playing area; and
- Stadia which are generally playing and competing areas completely or substantially surrounded by seating, some even provided with permanent or removable roofing.

2.02 Viewing slopes

These are not suitable for large numbers, and should not be steeper than 17% or 1:6.

2.03 Terraces

Details of a terrace are shown in **19.1**. Barriers are provided at intervals as a protection against crowd surge; the spacings are given in Table I. Gaps are provided in the barriers, but these should



19.1 *Details of terraces for standing spectators*

Table I Spacing of barriers on sports grounds (from *Guide to Safety at Sports Grounds*, Home Office, 1973)

Angle of terrace			Peak areas of ground*		Other areas of ground	
			A	B	A	B
5°	8.8%	1:11.4	5.0	3.3	8.4	5.6
10°	17.5%	1:5.7	4.3	2.9	6.7	4.5
15°	27%	1:3.7	3.8	2.6	5.6	3.7
20°	37%	1:2.7	3.4	2.3	4.8	3.2
25°	47.6%	1:2.1	3.1	2.1	4.2	2.8
30°	58.8%	1:1.7	2.9	1.9	3.8	2.5

* **Peak areas of ground are those where the crowd collects thickest, such as behind the goals in association football.**
Type A barriers are tested for 6 kN/m loading, or designed for 5 kN/m.
Type B barriers are tested for 4.3 kN/m, or designed for 3.4 kN/m.
Barrier foundations are designed for a factor of safety against overturning of 2.

be staggered as shown on the plan. Gangways should be sunk 100–200 mm below the adjacent terrace to discourage standing in them and radial gangways should be 'dog-legged' for the same reason. No point on a terrace should be more than 6 m from a gangway; the normal capacity is between 27 and 54 persons per 10 m^2. The front of the terrace should be no nearer the touchline than:

$(1.75 \pm H)$ cot A or 3 m, whichever is the greater

where 1.75 m is the height of an average male person
*H*m is the difference in level between the pitch and the bottom of the terrace, and
A is the angle the terrace makes to the horizontal.

2.04 Stands

The design of seating in stands and stadia is similar to that in auditoria (see Chapter 20). The minimum area occupied by a seat is 460 mm wide × 610 mm deep, the preferred 550 × 760. There should be a minimum clearance of 305 mm between front and back of empty seats, although this is included in the above areas. The maximum run of seats with a gangway at each end is 28, half that if only at one end. No seat in a stand should be further than 30 m from an exit.

2.05 Sight-lines and rake of spectator tiers

The rake of spectator tiers is determined either mathematically or graphically in section, where the principal factors are:

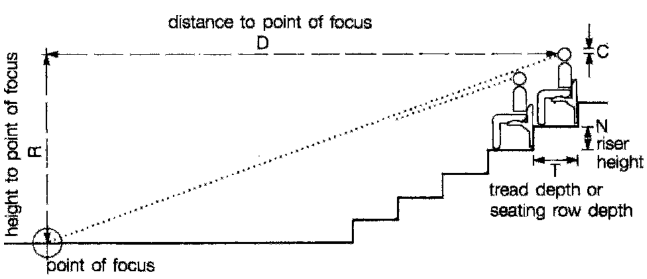
- The assumed constant of 'the crown', i.e. the distance from the eye to the top of the head which is known as the *C* value
- The tread depth or seating row depth
- The point of focus (the middle of the innermost athletics track or the near touchline in football or rugby)
- The height of the spectator's eye in the first row, **19.2**.

In determining the rake, the lines of sight from the eyes of spectators in each row to the focus should be clear of, or at worst tangential to, the top of the head of the spectators in the row in front. This will give a profile which is parabolic, with the rake increasing with the viewing distance. In some countries, this is considered to be uneconomic to construct and unsafe for crowd movement – the stairs in gangways become unequal and therefore unacceptable. Nevertheless, the parabolic approach is acceptable in some countries and was used at the Munich Olympic Stadium.

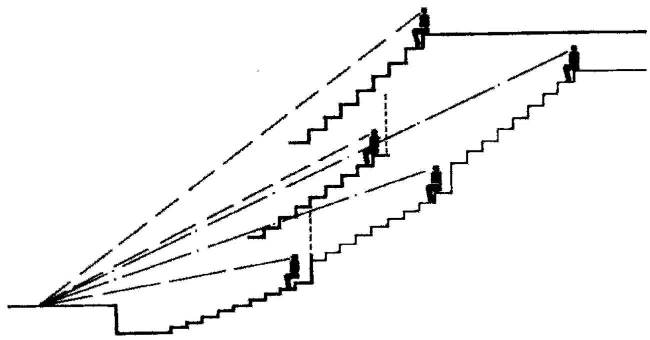
A straight rake with the necessary elevation between steps will be satisfactory. However, a series of straight rakes tangential to the theoretical parabolic curve is practical and widely used, **19.3**. The effect of lowering the eye level of the front spectator is quite significant.

The following guidelines are suggested for *C* values:

- 150 mm is an ideal standard capable of giving excellent viewing conditions
- 120 mm is the optimum standard for most spectators, giving very good viewing
- 90 mm should be regarded as the minimum viewing standard



19.2 *Terms for calculating the suitable rake*



19.3 *Three straight tiers approximately tangential to the theoretical curve in a single tier is economical in cost but not in space. Separating and overlapping the tiers reduces the plan area. The rake angle must not exceed 35° to the horizontal*

- 60 mm is a figure which means that good viewing can only be achieved between the heads of spectators in the row in front. In very large stadia, there may be some positions where this is the best standard which can be achieved from some seats, but these should be kept to a minimum.

Riser heights: Viewing standards will be affected by the riser height of each seating row. The following calculation is used to determine the riser height:

$$N = \frac{(R + C) \times (D + T)}{D} - R$$

where N = riser height
R = height between eye and point of focus
C = viewing standard (C value)
D = distance from eye to point of focus (typically the near touchline)
T = tread depth, ie depth of seating row.

2.06 Seating

In the move towards all-seated major stadia, it is important to give some consideration to the seat where spectators will spend some time. The time for sitting in the seat will vary with the stadium type. The following are some examples:

Cricket	all day, perhaps even more than one day
Football	1.5–2 h
Rugby	1.5–2 h; for seven-a-side tournaments perhaps all day
Pop concerts	3 h or more
Athletics	sometimes all day, e.g. Olympics
American football	3–4 h

The need for comfort will vary and multipurpose stadia should be flexible.

Outdoor stadia seats should be weather-resistant and robust as well as comfortable. Suitable materials include aluminium, some timbers and the most common material for modern stadia, some form of plastic. This has the greatest potential for moulding and shaping for comfort.

Fire retardance also needs to be taken into account. With plastic, additives can be introduced but they often limit colour choice and sometimes will add only delay to fire resistance. The design of the seat is as critical as the material itself in regard to fire resistance. Double-skin forms avoiding edge details which can ignite easily are best.

Colour is important. Some stadia use colour blocks to aid management, but most now use patterns incorporating club insignia which are can be seen when the stadium is not full. Some colours are better at resisting fading under ultraviolet rays than others.

The seat must be designed to drain and not hold water, and be easy to clean itself, around and underneath. This is important to avoid damage, as dirty seats encourage vandalism.

The fixings must be as few as consistent with strength (to assist cleaning), corrosion-resistant and robust. Spectators will occasionally stand on seats, or rest their feet on them from behind, exerting considerable force.

In existing stadia, particularly the older ones, the floor construction will limit the fixing choices available. This can be an important factor in reequipping an existing stadium with seats, because of the large number of fixing points required.

The life of a seat used to be considered as about twenty years, but it is doubtful whether current models will need to be as long-lasting.

Forms of seating: The quality of the seating will vary depending on the use, but also to produce a range of seats available in the stadium. Standards of comfort demanded by users tend to be rising.

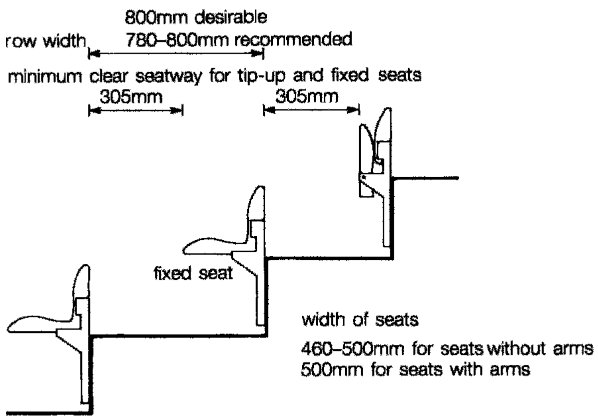
The better quality will be on an individual seat basis with a back, **19.4**. The seat may fold back when not in use. This increases the seat gangway, providing greater convenience and safety. VIP seating in selected areas will require even higher standards. Cheaper seating can be provided by the use of benches or seats with no backs, **19.5**. This produces a more economical spacing of rows.

Comfort and event usage: Upholstered versions of standard seats are widely available, while some clubs may wish to upgrade their existing standard seating with the addition of back pads and cushions or full covers. Armrests cannot usually be added to existing standard seats.

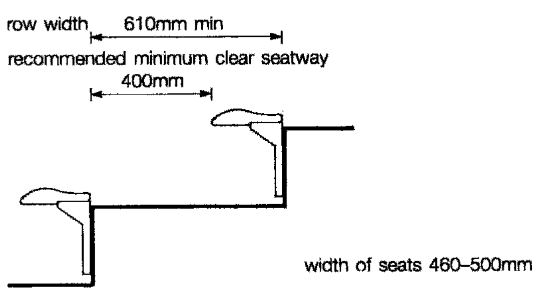
If the stadium is to be used for events other than football – for example, pop concerts, American football, public gatherings – it may be worth considering higher-grade seats in sections where customers will sit for a longer period than 90 min, perhaps at higher admission prices.

Press box seating: Seats in the press box should be provided with integrated writing shelves or tablets, **19.6**. However, consult with regular press box users to determine how much space they need for computers, monitors, telephones, fax machines or other equipment.

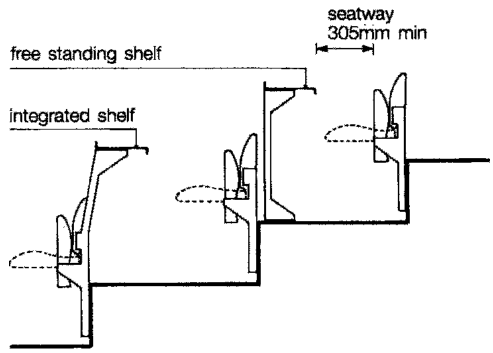
Note that the requirement for a minimum seatway of 305 mm applies in this case to the distance between the rearmost projection on the shelf and the front of the seat.



19.4 *Spacing between seating with backs, fixed and fold-up*



19.5 *Spacing between benches without backs. These allow closer spacing but are less comfortable and are increasingly unacceptable*



19.6 *Two options for press box seating: integrated or free-standing writing shelf*

2.06 Exits from sports grounds

Large numbers of spectators in sports grounds are a source of danger to themselves, particularly from:

- Tripping, slipping and falling
- Crowd pressure on terraces and exits
- Fire and hooliganism.

All spectators should be able to leave a sports ground within 8 min. If there are combustible stands (such as constructed of timber) spectators must be able to be cleared from them within 2.5 min.

The flow through an exit is about 40 persons per minute per unit of width of 550 mm. Where there are narrowings in the exit route there should be 'reservoir' areas to accommodate those that are waiting to pass. These should not be less than 15 m from an incombustible building, nor 45 m from one that is combustible, and should be designed to hold 54 persons per 10 m^2. Nowhere should an exit or escape route be less than 1.1 m wide, minimum headroom 2.4 m. Steps should be a minimum of 280 mm going (305 mm preferred). No flight should have less than three or more than 16 risers and two flights with more than 12 risers should have a turn between. Ramps should not be steeper than 10% (1:10).

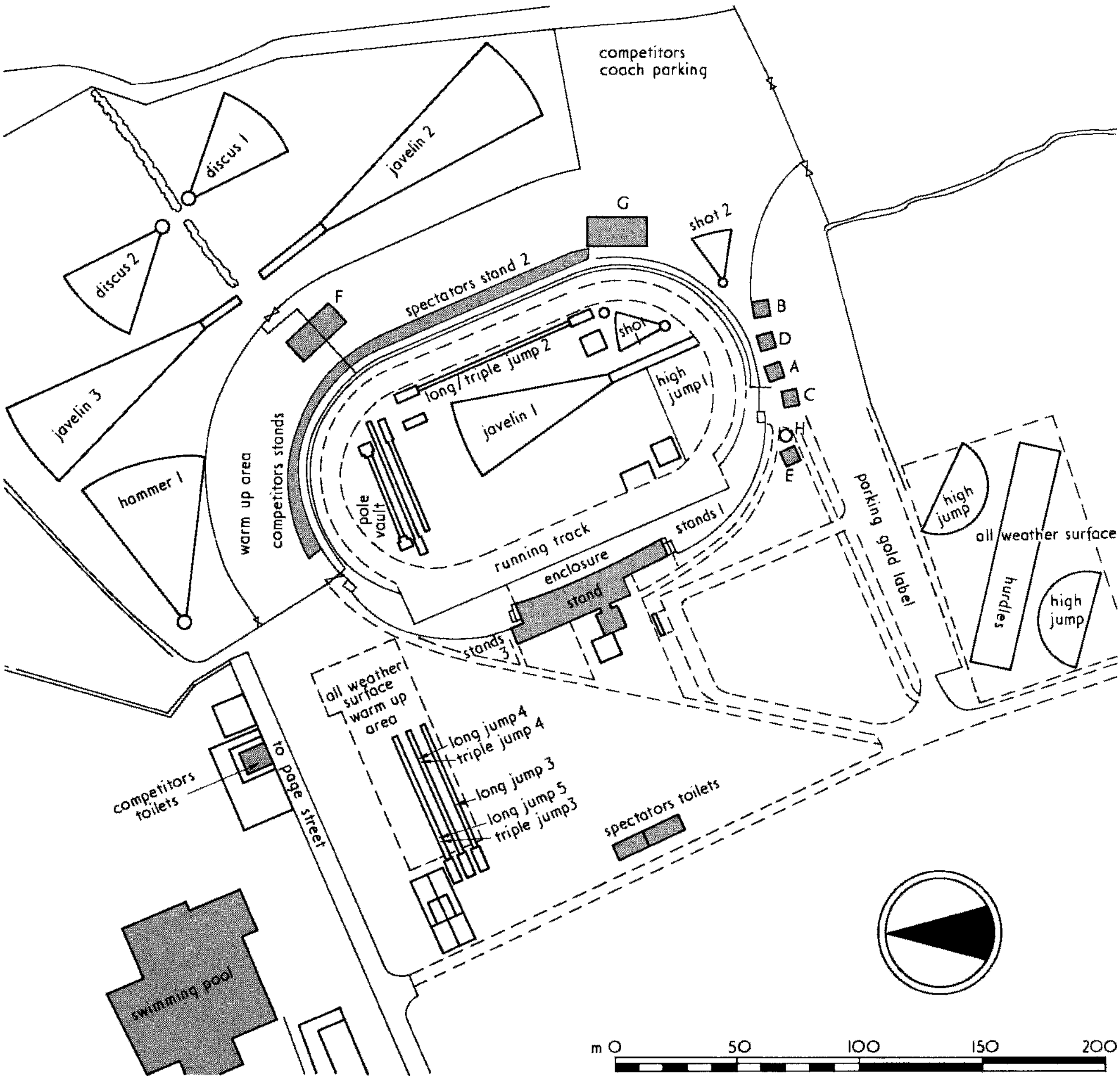
3 ATHLETICS

3.01 Athletics stadia

Facilities at a stadium capable of staging national and international meetings should include:

- A 400 m, eight-lane floodlit track with one ten-lane straight of sufficient length to permit a 110 m hurdles to be run with space for the athletes to pull up after passing the tape
- A steeplechase water jump
- Full provision for all field events
- A separate warming-up area (desirable)
- Changing and washing facilities for 200 athletes in the proportion two-thirds male to one-third female
- Additional separate changing accommodation for boys and girls is desirable
- A covered stand to seat least 2000 spectators
- Appropriate toilet and car parking facilities
- An announcer's box and provision for the press, broadcasting and television
- Officials' room
- Equipment rooms and store
- The perimeter of the track not covered by the stand should, if possible, be terraced to provide further spectator accommodation.

Wherever possible, regional athletic stadia should be associated with other sports provision. An indoor sports centre or sports hall alongside the stadium is a distinct advantage. Consult the AAA and NPFA regarding regional and local track gradings with specifications for minimum facilities.



19.7 *Plan of Copthall Sports Centre, courtesy of the London Borough of Barnet. This is an example of a good district athletics centre. KEY: A Transport office, B Public telephones, C Police kiosk, D Billeting enquiries and lost property, E box office, F Souvenir sales, G Refreshments, H First aid*

A typical district athletics centre is shown in **19.7**. Athletics centres for national and international level competitions vary with the money available. Famous examples of less affluent centres are shown in the *Handbook of Sport and Recreational Building Design.*

3.02 All-weather surfacing

- Where surface is all-weather, six lanes are acceptable on circuit.
- Runways for long and triple jumps and pole vault should be all-weather, and the width may be reduced to 0.9 m. For the high jump, an all-weather take-off strip 5 m wide is acceptable.

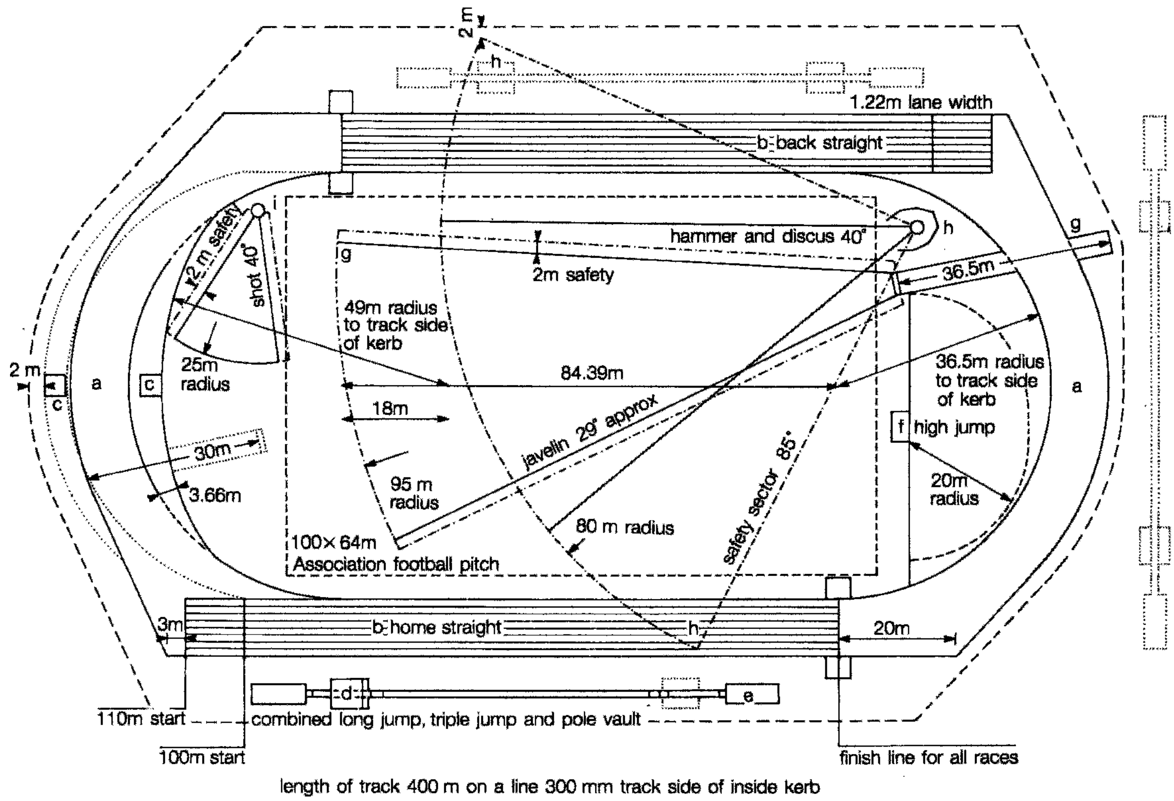
3.03 Layout

- The layout for the field events may be varied to suit local requirements
- Where space allows, additional throwing facilities may be sited outside the track, provided there is proper control and safety
- On cinder tracks, the straight sprint and hurdle are run on the six outer lanes, thus avoiding the inner lane which is subject to heavy use during long-distance events
- If the central area is not required for winter games, the distances from the shot circle to the inner edge of the track and the javelin runway should be increased to 10 m
- The safety radius for the throws should be adjusted according to the standards expected to be attained by the competitors
- The triple jump landing area should be increased to 3.35 m where space and funds permit.

A recommended layout guide is shown in **19.8**.

3.04 Orientation

Siting for pole vault and all jump approaches should be such that the jumpers do not run towards the sun. The arc to be avoided for these events is approximately south–west to north–west (225°–315°) in the UK. This also applies to grandstand siting.



19.8 *Layout guide for 400-m running tracks and field events. This layout with alternative sitings for field events, is based on NPFA diagram 13b. Different arrangements are possible to suit particular circumstances. For high-level competition, however, alternatives for the throwing circles are limited if maximum distances are to be thrown safely*

3.05 Safety precautions

Detailed specifications and safety for field events are set out in the *National Handbook*. Extension wings should be provided to the safety throwing cage for the protection of the jumps and inner running lanes.

3.06 Discus and hammer circles

Hammer throwers prefer a smoother finish to the concrete than discus throwers. For this reason, also to allow simultaneous training in each event, separate cage-protected circles are often provided.

3.07 Javelin runway

In order not to restrict the use of the running track, the runway should wherever possible be laid down clear of the track by extending it further into the arena. This necessitates the reinstatement of the winter games pitch.

3.08 Tracks without a raised border

Where a track is marked out on grass or on a hard porous area without a raised or flagged border, the track length must be measured along a line 20 cm instead of 30 cm from the track side of the inner edge. This has the effect in the example shown of increasing the radius to the inner edge from 36.50 to 36.60 m and of reducing the width of the first lane to 1.12 m.

3.09 Formula for other track proportions

Where a track of wider or narrower proportions or of different length is required, the appropriate dimension can be calculated from the following formula:

$$L = 2P + 2(\pi r + 300\,\text{mm})$$

where L = length of track in metres
P = length of parallels or distances apart of centres of curves in metres
R = radius to track side of inner kerb in metres
$\pi = 3.1416$ (not 22/7)

The radius of the semicircles should not normally be less than 32 m or more than 42 m for a 400-m circuit.

3.10 Alternative surfacing for areas

If preferred the spaces at each end of the winter games pitch can be hard surfaced to the same specification as the track with the following advantages:

- Maintenance is simplified
- Runways do not have to be separately constructed and edged and their position can be varied as required
- Portable landing areas for high jump practice and coaching can be placed where most convenient.

3.11 Running tracks

Layouts for running tracks scale 1:1000 are given in **19.9–19.11**.

3.12 Field events

The important dimensions for the main field events are shown in **19.12–19.19** (scale 1:1000).

4 PLAYING FIELD SPORTS

4.01 Playing fields

Games and recreations that take place on ordinary playing fields are shown in alphabetical order in **19.20–19.42** (scale 1:2000 except where shown otherwise).

5 SPORTS REQUIRING SPECIAL CONDITIONS OR CONSTRUCTION

A selection of special constructions are given in **19.43–19.50** (scale 1:2000 except where shown otherwise).

6 BOATING

6.01

There is great pressure on the available areas of enclosed and semi-enclosed water. The various uses, which continually increase, are not all compatible (see Table II).

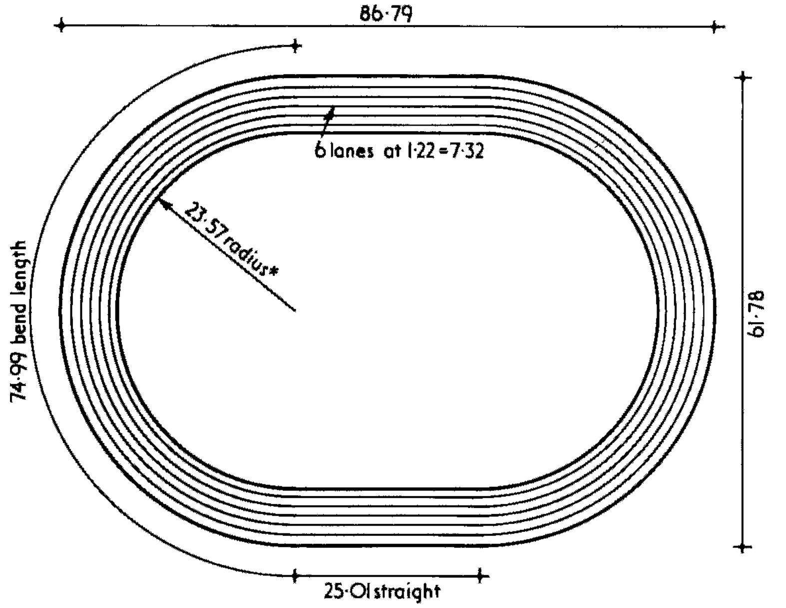
6.02 Suitability

There are a number of types of waterbodies the suitabilities of which are given in Table III.

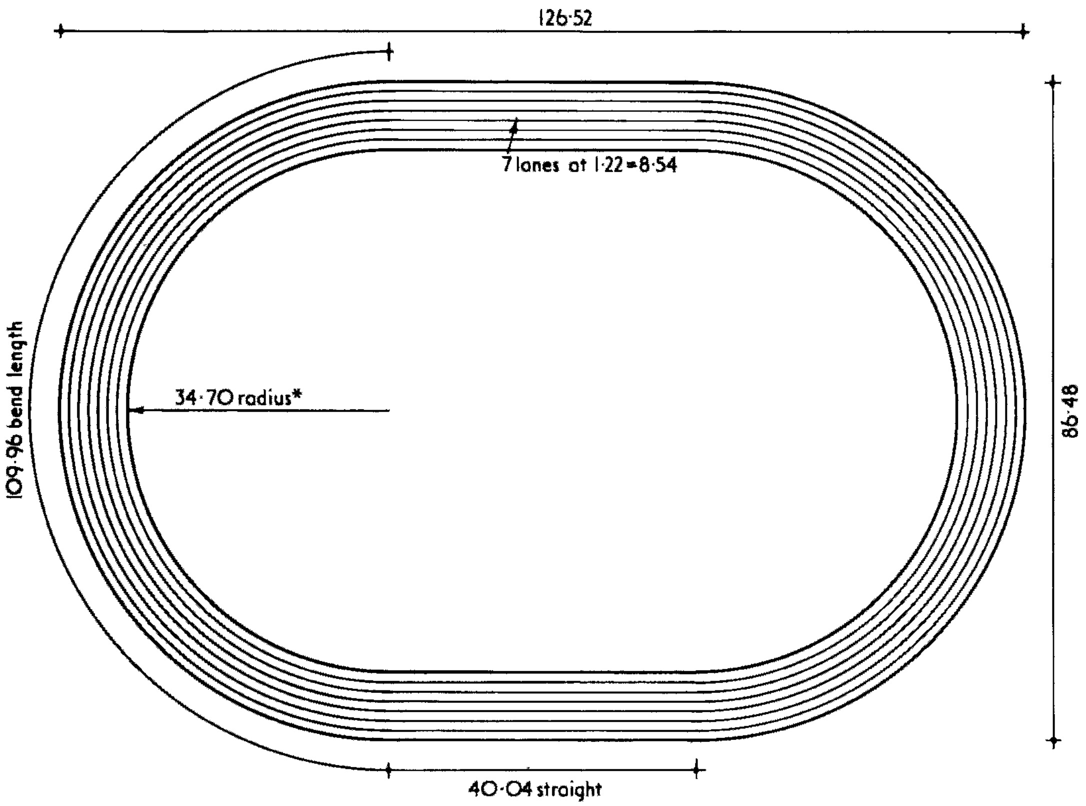
6.03 Launching facilities and slipways

Most foreshores and some lakes are private. For light recreational use virtually no built facilities are necessary. The smallest boats, canoes and sailboards, which can be carried, can be launched from any bank or beach. Larger boats need facilities. Launching places need to have good road access for vehicles towing trailers, with adequate parking nearby. Backing cars with trailers attached needs space and experience. Charging for parking greatly decreases use.

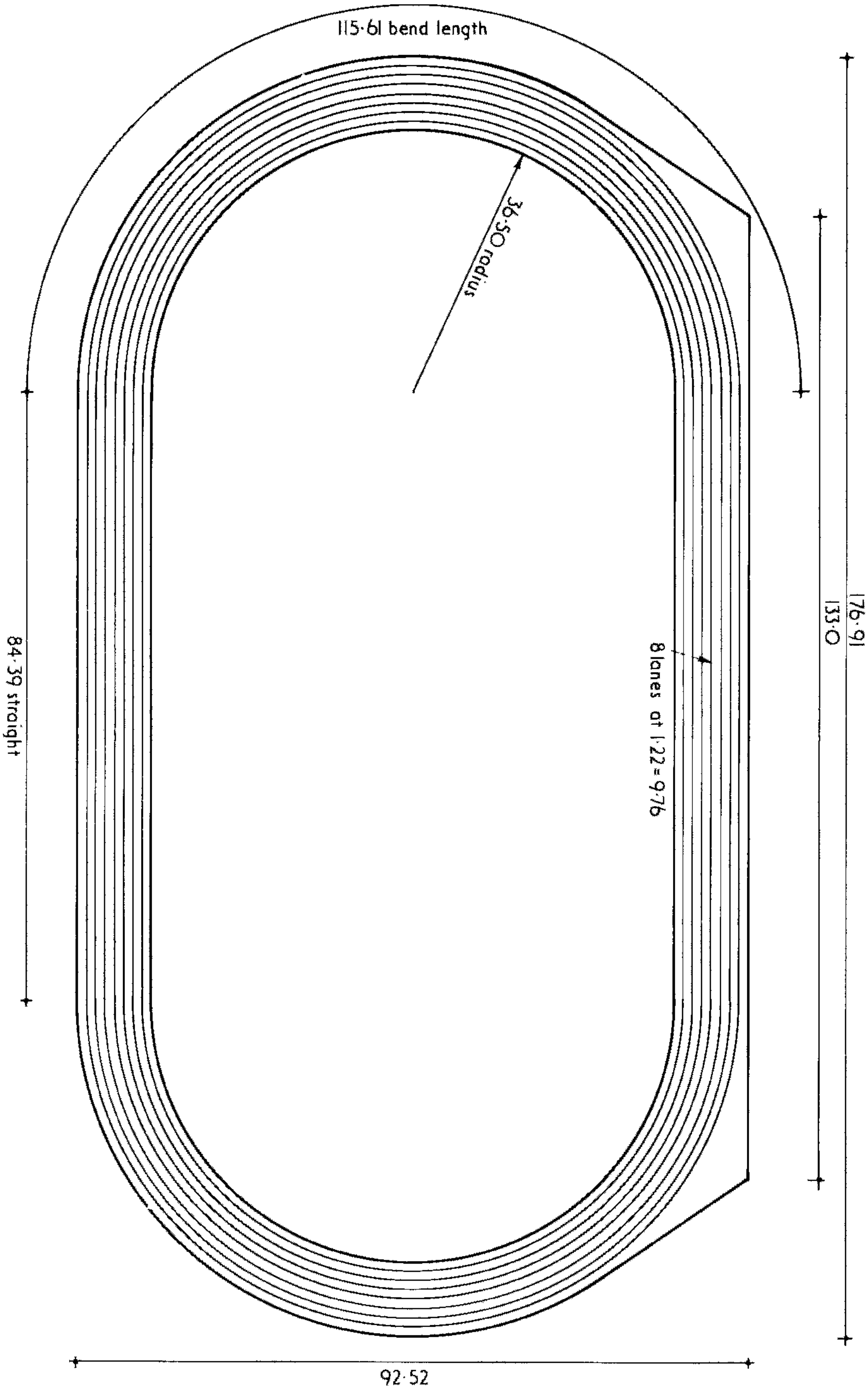
At the seaside, beaches and slipways may not be usable at all states of the tide. The speed of tidal currents may be faster than the top speed of small boats. Craft which do not sail well upwind can



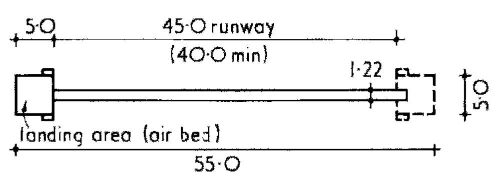
19.9 *200-m running track. *Radius is measured to the track side of raised or flagged edge. If only a chalk line the radius is 23.67 m*



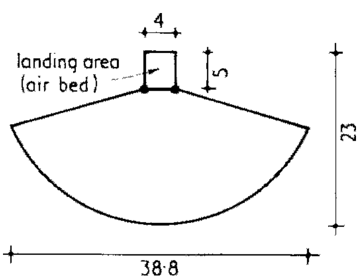
19.10 *300-m running track. *Radius is measured to the track side of raised or flagged edge. If only a chalk line the radius is 34.8 m*



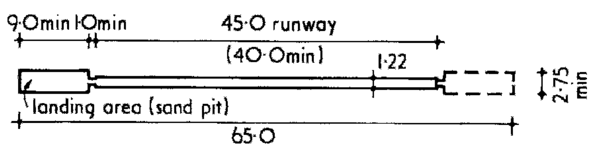
19.11 *400-m running track: the standard 7-lane club track. For 6-lane all-weather surfaces, reduce overall dimensions by 2.44 m. For major competition tracks and regional facilities, 8 all-weather lanes with a 10-lane sprint straight is required: increase overall dimensions by 2.44 m, and sprint straight as shown*



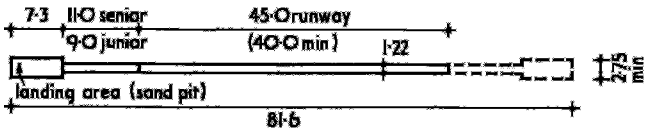
19.13 *Pole vault*



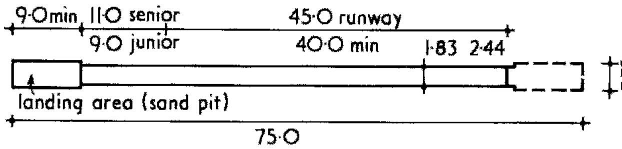
19.12 *High jump*



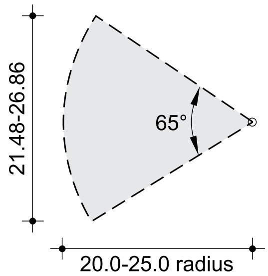
19.14 *Long jump: to avoid adverse wind conditions, landing areas are at both ends*



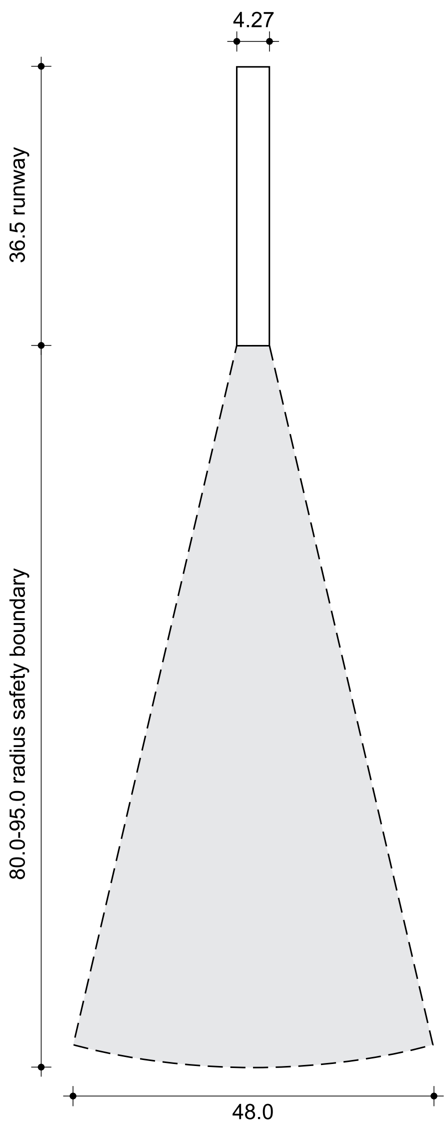
19.15 *Triple jump*



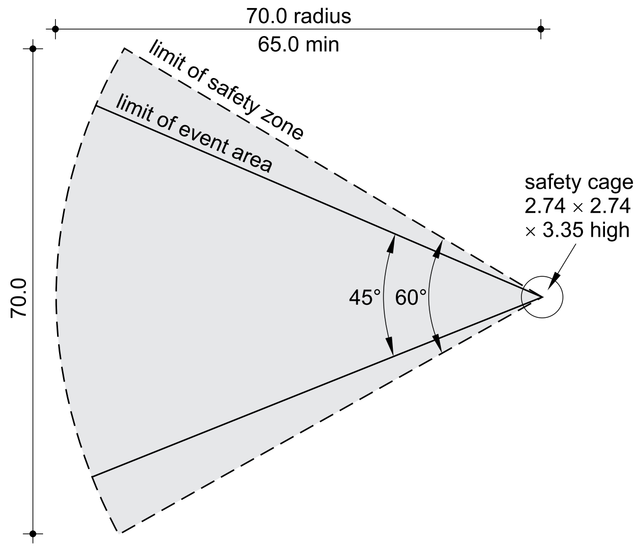
19.16 *Combined triple and long jump*



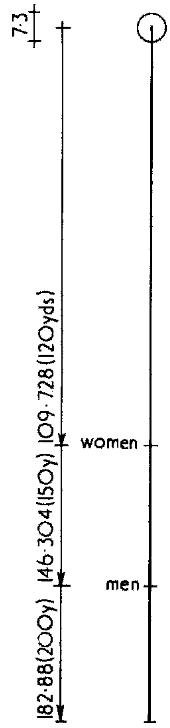
19.17 *Shot*



19.18 *Javelin*



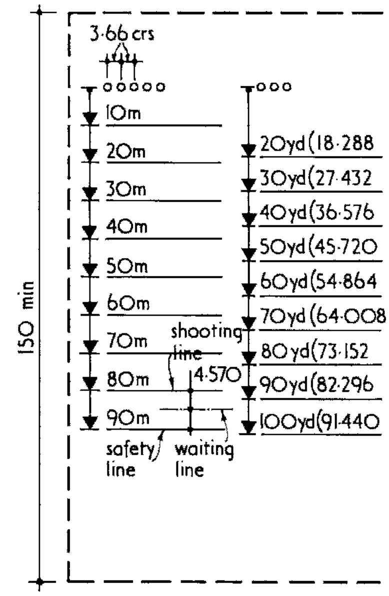
19.19 *Discus and hammer: discus base is 2.5 m diametre, hammer base 2.135 m diametre*



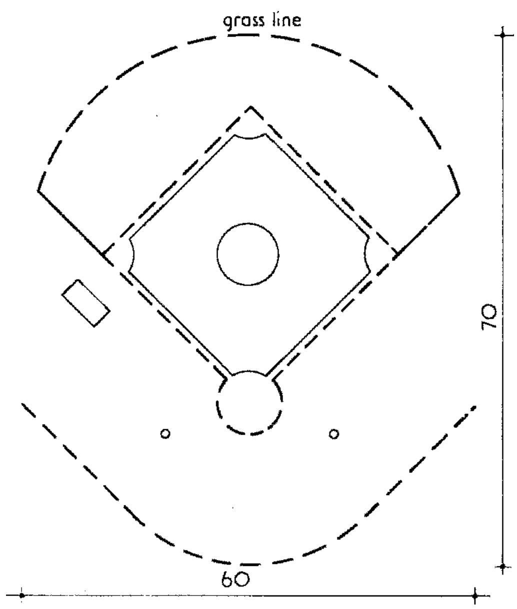
19.20 *Archery, clout. The arrows are shot high into the air to fall into circles marked on the ground, or a circular cloth pegged down, the centre of each being marked by a flag. The various shooting distances are clearly defined on the grass by white lines, tapes or spots and are always measured in yards. Archers move up and back to the distance position, and the waiting line moves accordingly. The overall distance for clout archery is about 230 m*

be swept out to sea in off-shore winds, unless they carry auxiliary motors.

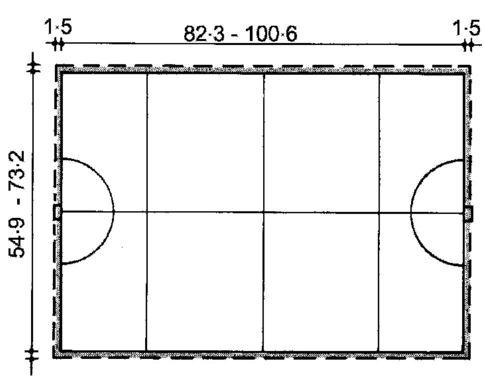
There is a severe shortage of direct access from roads to water. Launching, and particularly recovery, takes time and many people may wish to do it at once. For this reason, very wide slipways are required. Also, they need parking areas adjacent where cars with trailers attached can be left when boats are launched. There should be space for cars towing trailers to turn in circles where possible, as it is much quicker than backing with them. However large slipways are, speed of throughput is important in busy periods.



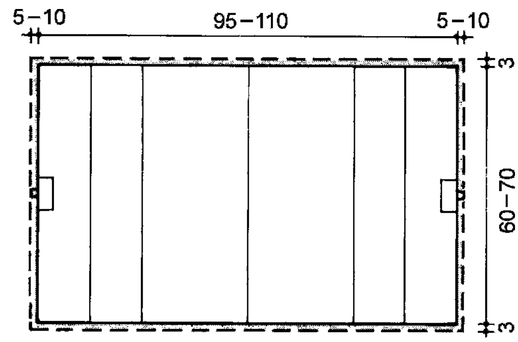
19.21 *Archery, target: club archery 100 m, championships over 150 m depending on the number of targets. Some competitions are shot over metric distances and some will always be shot over imperial lengths. Metric and imperial competitions take place during the same meeting. The waiting and safety lines are moved to positions behind the correct shooting line for each competition. In this example, shooting is over a distance of 50 m*



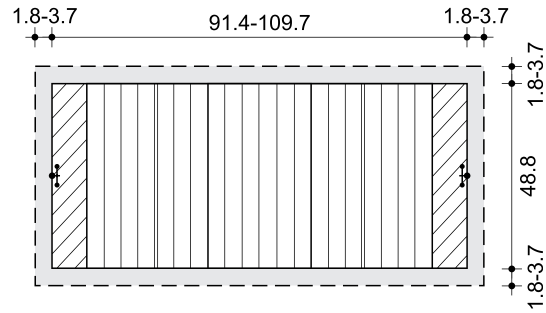
19.22 *Baseball: full-size diamond. Little league, for young players, is two thirds the size*



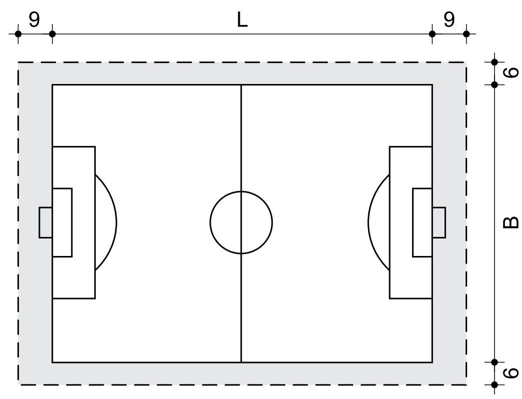
19.23 *Bicycle polo*



19.24 *Camogie*



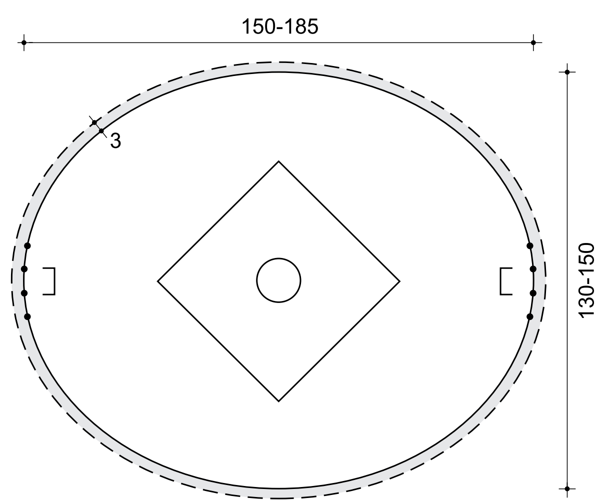
19.25 *Football, American*



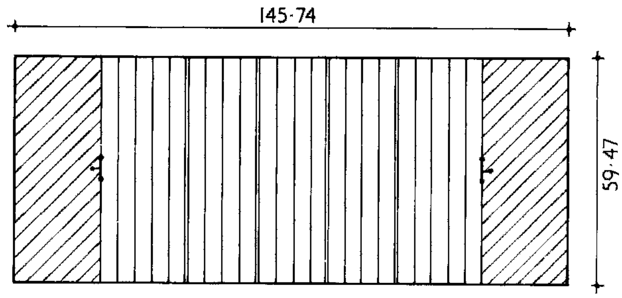
19.26 *Football, Association (Soccer). The NPFA gives the following recommended sizes:*

	L	*B*
International:	*100–110 m*	*64–75 m*
Senior:	*96–100 m*	*60–64 m*
Junior:	*90 m*	*45–55 m*

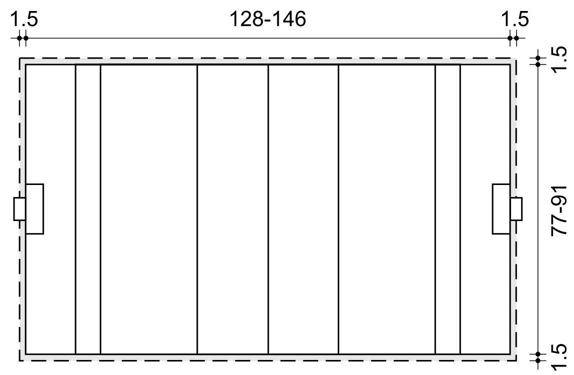
For five-a-side Association Football, see Chapter 18



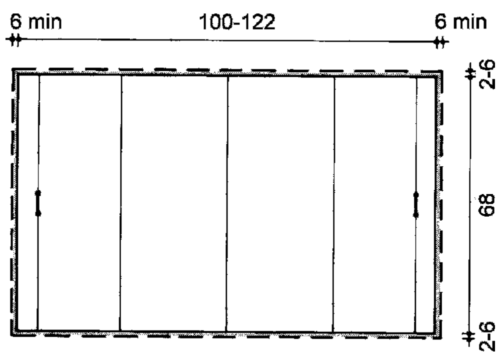
19.27 *Football, Australian*



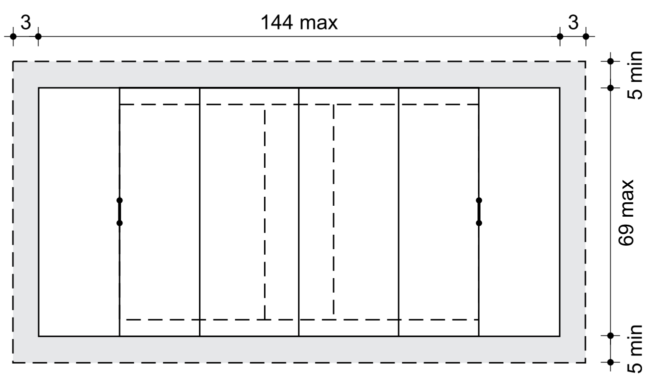
19.28 *Football, Canadian*



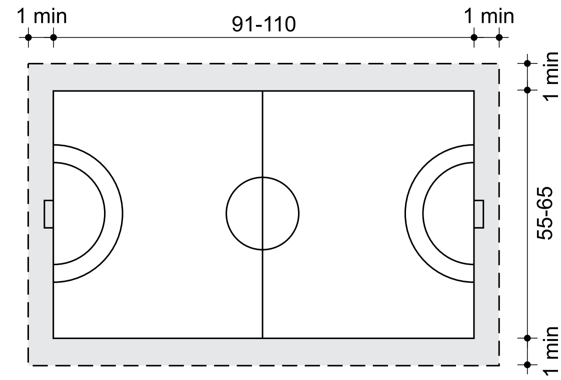
19.29 *Football, Gaelic*



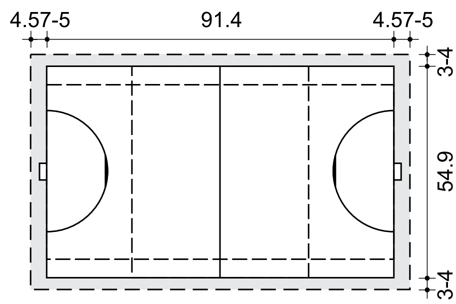
19.30 *Football, Rugby League*



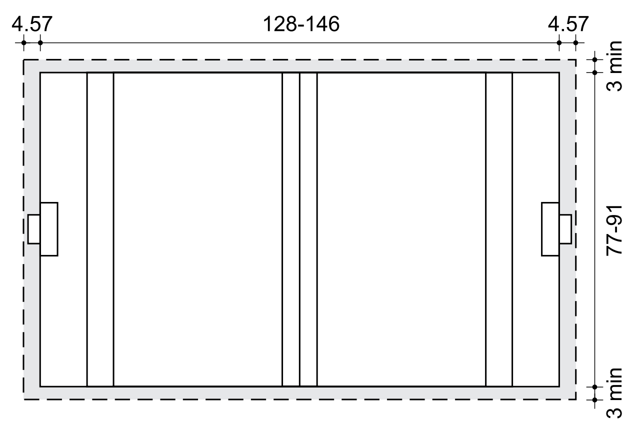
19.31 *Football, Rugby Union*



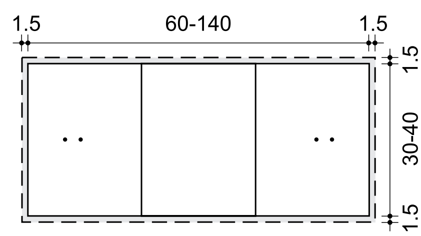
19.32 *Handball*



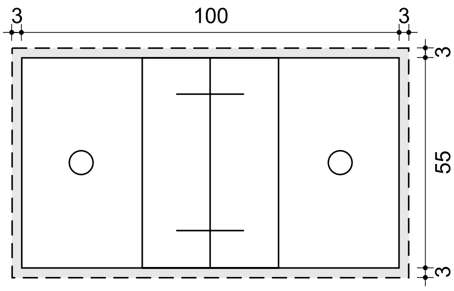
19.33 *Hockey. For county and club matches the NPFA gives a pitch size of 90 × 55 m in an overall space of 95 × 60.4 m, allowing for circulation about the pitch*



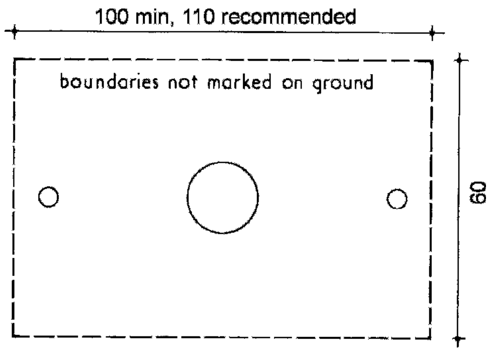
19.34 *Hurling (a similar pitch to that of Gaelic Football)*



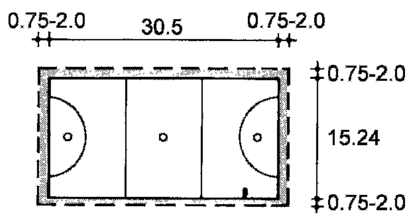
19.35 *Korfball*



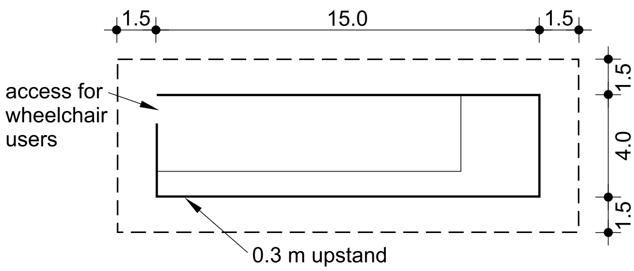
19.36 *Lacrosse, men's*



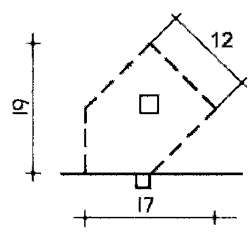
19.37 *Lacrosse, women's. The ground has no measured or marked-out boundaries. The women's indoor seven-a-side game has been superseded by Pop-Lacrosse*



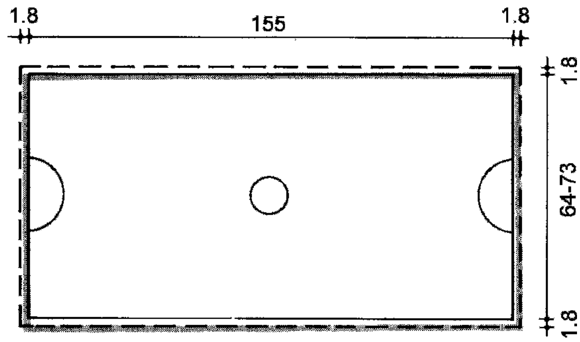
19.38 *Netball*



19.39 *Petanque. Additional space is needed for competition officials and players' sitting out*

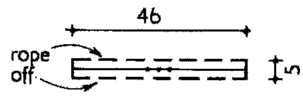


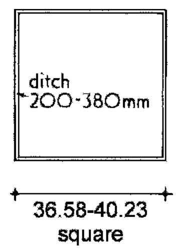
19.40 *Rounders. An outfield boundary consisting of a circle about 50 m diametre is used*



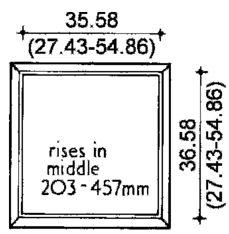
19.41 *Shinty*

19.42 *Tug-of-war*

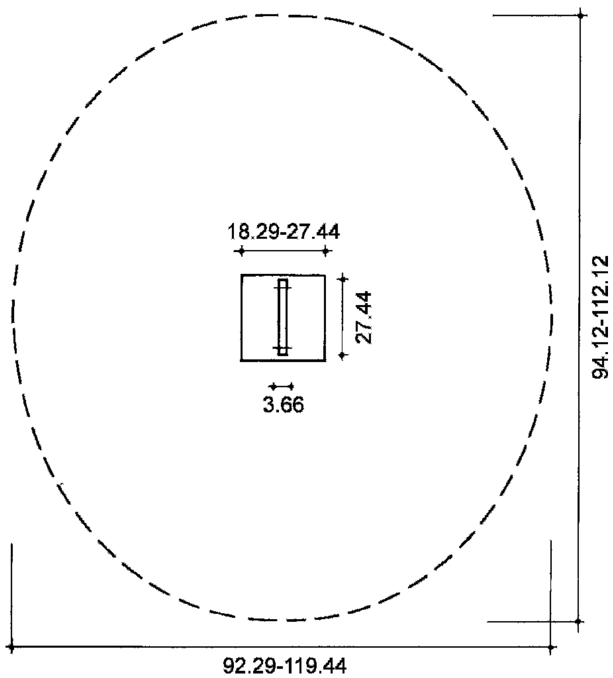




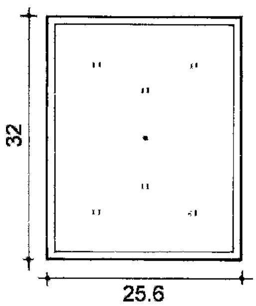
19.43 *Bowls. Greens should not be shorter than 30.2 m in the play direction. For domestic play the rink should be a minimum of 4.3 m wide. The square above is suitable for six rinks*



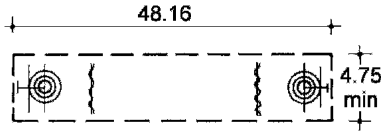
19.44 *Crown bowls: played mainly in northern England and Wales and in the Isle of Man. The 'crown', which need not be central, is between 0.25 and 0.46 higher than the edges*



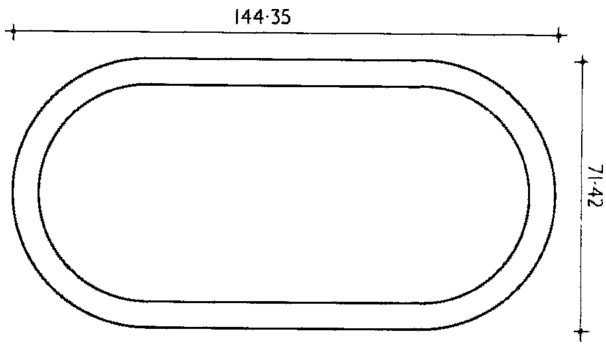
19.45 *Cricket. The central square of about 22 m side is able to take the wickets in either direction. This would be special turf and grass species, and is kept roped off when not in use. The outfield, however, can be used for other games when not required for cricket*



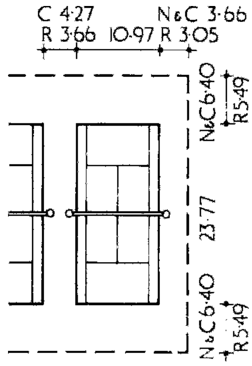
19.46 *Croquet. This can be played on an ordinary field, but the good game demands turf similar to a bowls green*



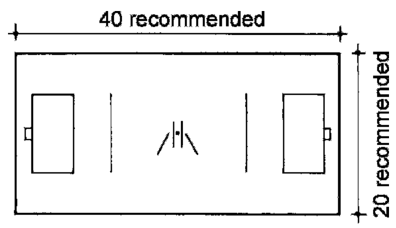
19.47 *Curling. This Scottish game is played on ice*



19.48 *Cycle racing 333 1/3 m track*



19.49 *Lawn tennis. The surface may be grass, suitable asphalt or a modern composition. The surrounds are of wire netting 3–4 m high*



19.50 *Roller hockey. This demands a surface suitable for roller skating: strip wood, terrazzo, smooth concrete or a suitable asphalt*

Table II Compatibility of watersports

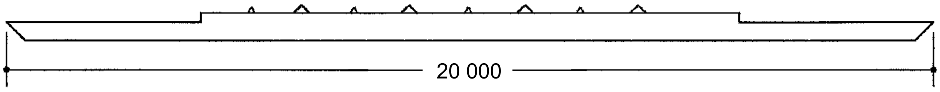
	Fishing	Swimming	Sub-aqua	Wildfowl	Canoeing	Rowing	Sailing	Water skiing	Hydroplaning	Power boats	Cruising
Fishing		X	X		PZ	PZ	PZ	X	X	X	PZ
Swimming	X		Z			Z	Z	Z	Z		Z
Sub-aqua	X					PZ	PZ	PZ	PZ	PZ	Z
Wildfowl		Z						X	X	X	
Canoeing	PZ					PZ	PZ	PZ	PZ	PZ	
Rowing	PZ	Z	PZ		PZ		PZ	P	P	P	PZ
Sailing	PZ	Z	PZ		PZ	PZ		PZ	PZ	PZ	Z
Water skiing	X	Z	PZ	X	PZ	P	PZ		PZ	PZ	N/A
Hydroplaning	X	Z	PZ	X	PZ	P	PZ	PZ			N/A
Power boats	X		PZ	X	PZ	P	PZ	PZ	PZ		N/A
Cruising	PZ	Z	Z			PZ	Z	N/A	N/A	N/A	

X incompatible; P programming; Z zoning; N/A not applicable

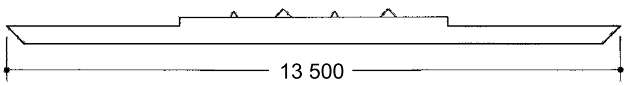
Table III Areas suitable for watersports

	Lakes	Canal feeders and compensation reservoirs	Water supply reservoirs	Rivers	Canals	Sea
Fishing	X	X	X	X	X	X
Swimming	X			X		X
Surfing	X					X
Sub-aqua	X			X		X
Diving	X	X	X	X	X	
Wildfowl	X	X	X	X		X
Canoeing	X	X	X	X	X	X
Sailing	X	X	X	X		X
Water skiing	X	X				X
Hydroplaning	X	X				
Power boats	X	X				X
Cruising	X	X		X	X	X

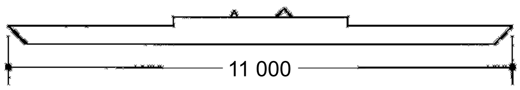
X incompatible; P programming; Z zoning; N/A not applicable



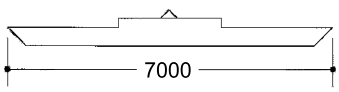
a *8-oar skiff, 20.0 × 0.62 wide*



b *4-oar skiff, 13.5 × 0.57 wide*



c *2-oar skiff, 11.0 × 0.95 wide*



d *Single-oar skiff, 7.0 × 0.45 wide*

19.51 *Various boats*

Slipway gradients are critical, and about 1:8 is good. Too steep, and vehicles may fail to tow laden trailers up the slope. Too shallow, and it may not be possible to immerse a trailer deep enough to float a boat off it, while it is still attached to a vehicle.

Slipways need to be long, if there is a tide. They need to provide a hard surface to at least 2 m below low water level, or below the lowest draw-down level of a reservoir, as some boats have a quite deep draught. Marine growths at the bottom of a slipway can make launching difficult, or impossible, at low tide.

Dinghy sailing is very popular as it is suitable for all ages and degrees of athleticism, can be recreational or racing, suitable for large or small lakes, or even the sea, and the boats can always be trailed behind a car.

A large open uninterrupted waterbody is required, well related to the prevailing wind, with as few indentations as possible. Ideally, it should be of a shape to allow for a triangular racing course, with one side of the triangle parallel to the prevailing wind. The surrounding landform and buildings should not cause windshadows.

6.04 Boats and waterbody needs

Boats are found in great variety, but there are two broad types: powered and unpowered. These have different needs.

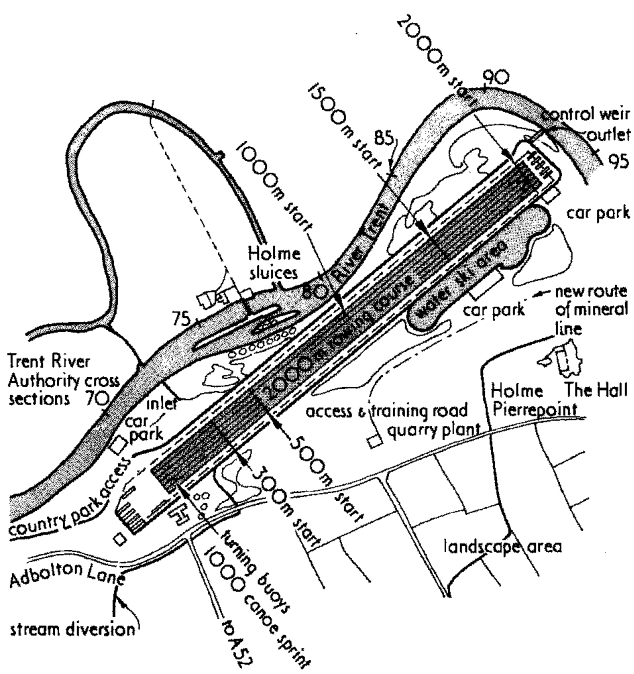
Unpowered: This covers rowing boats, punts, canoes, sailing dinghies and sailing cruisers. The first three are human-powered, the others wind-driven. There are various types of rowing boats, **19.51**. Regulations laid down by FISA (the International Rowing Federation) for international standard events require six rowing lanes for racing, at 13.5 m in width with circulation outside the lanes on each side of the course. The optimum depth to reduce bias in certain lanes should be in excess of 3.8 m, but for economic reasons 3.5 m is considered acceptable to all classes. For domestic events 1000 m at three lanes wide is a basic minimum. **19.52** shows a typical layout.

Coaching can be done in an indoor tank facility, **19.53** or in pairoared skiffs with the coach as passenger and handling facilities for the skiff may be needed. The modern trend is to start beginners in stable sculling boats and to use indoor rowing machines for basic body movement coaching and fitness. In the past, the coach of an eight used to cycle along the bank adjacent to the boat. However, it is now also possible to use a fast motor boat. Facilities are required for mooring and storing it.

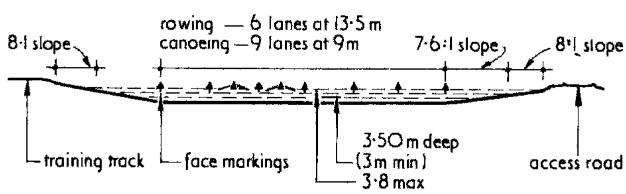
Boats often have to be transported to races in other locations. Many eights are now built with a joint in the middle to reduce the length for transport. Access is required for trucks and/or trailers for boats.

Kayaks, **19.54**, are the usual form of canoe used. Users are recommended to travel in groups of a minimum of three for safety reasons. Wild-water slalom is a popular form of racing. Kayaks can be transported on car tops or on special trailers that carry up to eight boats. Storage may be required for kayaks on cantilever shelves, and for the special trailers.

Sailing boats vary greatly in size from small dinghies, **19.55** and **19.56**, catamarans, **19.57**, to twin-masted schooners, **19.58**. The larger boats nowadays all include some form of auxiliary power, and have requirements much as power boats.

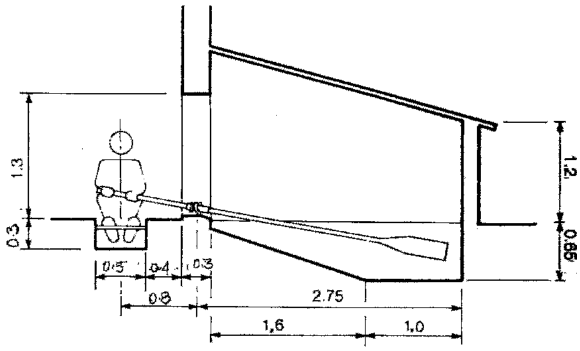


a *Plan*

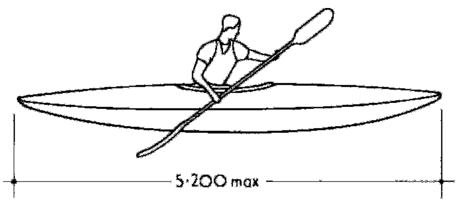


b *Section through the 2000 m rowing course*

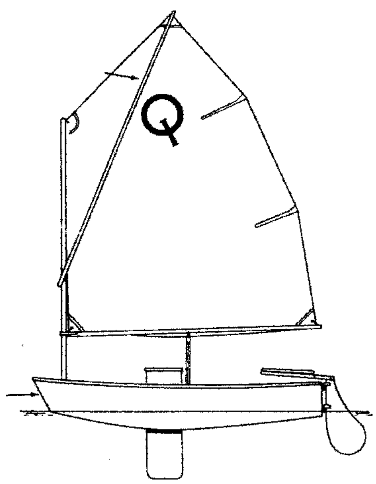
19.52 *The National Water Sports Centre at Holmes Pierrepoint*



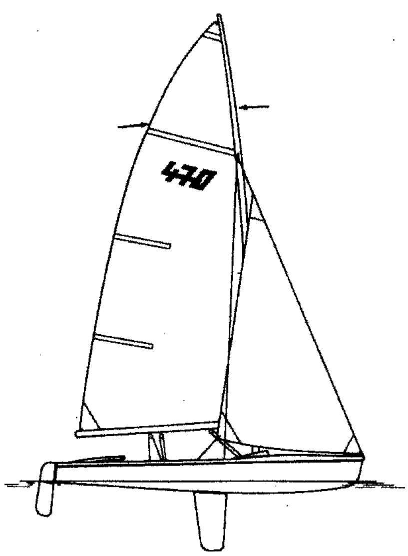
19.53 *Rowing tank*



19.54 *Canoe size*

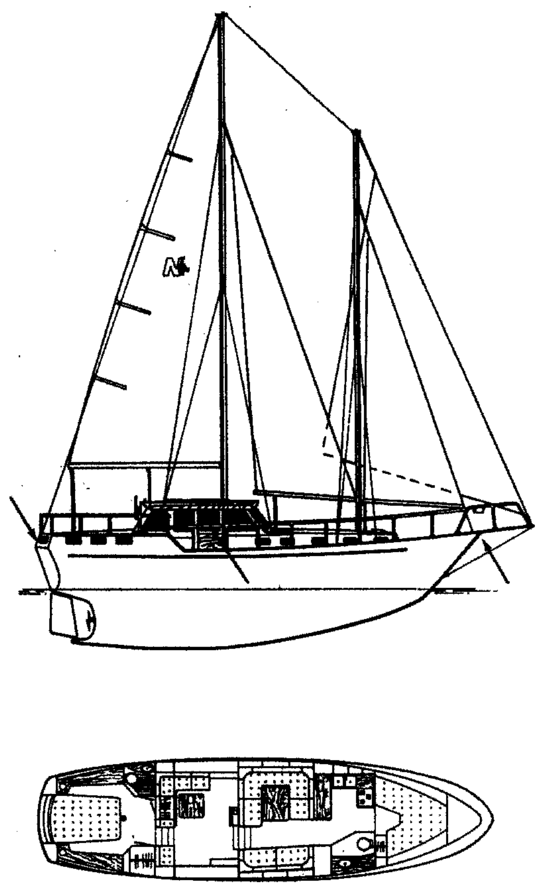


19.55 *Optimist: together with the Mirror dinghy, the most widely used boat for junior training. Length 2.36 m, beam 1.12 m, draught 0.84 m, mass or displacement 35 kg, sail area 3.25 m^2. For other boats below L/b/d/m/s = 2.36/1.12/0.84/35/3.25*



19.56 *470: an Olympic boat. L/b/d/m/s = 4.7/1.68/0.97/120 min/ 9 main, 3.7 jib, 13 spinnaker*

19.57 *Gougeon 32: a big, fast and stable catamaran; sailable single-handed or with two; sleeps two adults and two adults and two children. L/b/d/m/s = 9.75/2.54/1.3 (boards down)/500/17.4 main, 10.1 jib*



19.58 *Nautical 44: a big motor sailer with a schooner rig. L/b/d/m/s = 13.28 o/a 11.79 w/1/3.68/1.83/18, 000/28.4 main, 11 staysail, 27.5 jib, 8.9 forestaysail*

The depth of the water should not be less than 1.5 m, though 1.0 m is acceptable for sailboards. Shallow water can encourage reed growth.

The area of water required is:

- Small boats and training: 1.5 ha
- Club sailing: 6 ha+
- Open competition: 20 ha+

or alternatively

- Dinghies: 0.8 ha per boat
- Small boats such as Optimists: 0.2 ha per boat.

An open beach, ideally on a lee shore, is required for instruction and for the launching of sailing boats. Most minerals that are quarried such as sand, gravel and clay make a suitable lake bottom. Excessively alkaline water will cause corrosion of alloy equipment. Algae can be a disadvantage.

One problem can be the occurrence of Weil's disease, associated with rats, that can cause serious illness through the infection of cuts by contaminated water, but it is quite rare.

Power boats: This covers small motor boats, fast ski boats, jet-skis, inflatables, speedboats and motor cruisers. They require access to fuel supplies.

Power boats produce noise and wash. This may cause legal or planning restrictions on their use, or prevent the use of lakes nearer than 500 m from noise-sensitive areas for power boating. The wash can damage banks, which should not be vertical; sloping shingle beaches are preferable to prevent backwash. Marginal reedbeds can also absorb backwash.

The area required should be enough to lay out a triangular racing course with 400 m legs, or an oblong space of 800 m × 400 m. A minimum depth of 2.0 m is required.

6.05 Recreational rowing facilities

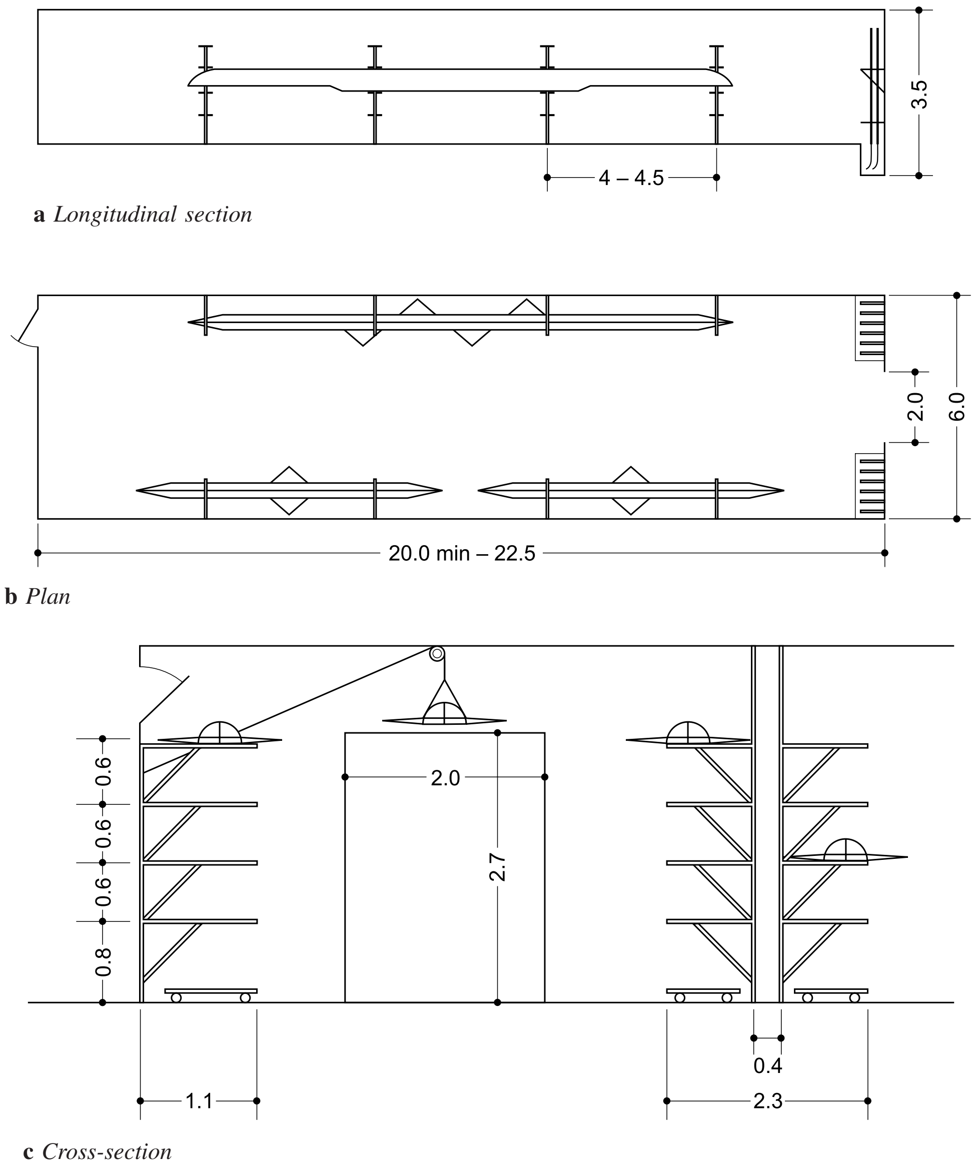
Commercial boat hire: A stretch of beach or a floating pontoon is all that is needed, but a yard or shed adjacent is required, for gear storage, and an office. Changing facilities may also be appropriate.

Private: Private wet boathouses are sized to accommodate the boats required. Space around moored boats in boathouses has to be generous as they can move in bad weather.

All boats need to be taken out of the water in the winter (even GRP absorbs water). Winter boat storage should be under cover is possible, but good tarpaulins may be enough. Sheds may be required adjacent to the shore for the storage of lifejackets, oars, canoes and sailboards.

6.06 Racing (rowing) facilities

The boathouse: The racing eight, 20 m long, determines the layout of boathouses, **19.59**. The standard storage bay accommodates

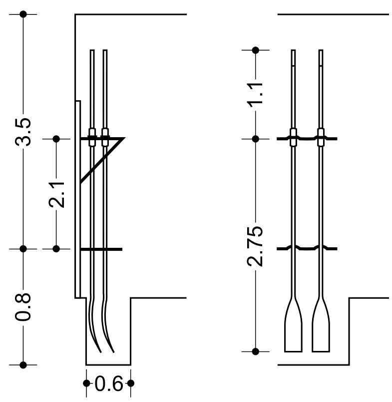


19.59 *Boathouse for a racing club*

eight boats on special sliding racks. Several of these bays are usually placed side by side in a suitable building. This needs to be over 20 m from the water so that boats can be turned round. Boats can be launched from a pontoon parallel to the shore by the whole crew moving to one side of the boat. The height of the edge of the pontoon above the water is critical as the riggers and oars of the boat project over it. About 150 mm is acceptable.

Smaller boats – fours, pairs, sculls – can be accommodated on special shelves within a building that is suitable for eights, provided the shelves are spaced correctly. Changing facilities and parking should be adjacent.

Oars can be stored in special racks with the oar handles in a small pit, **19.60**. This saves space and encourages crews to carry oars vertically which is safer than horizontally.



19.60 *Storage of oars*

6.07 Sailing dinghy facilities

Dinghies are too heavy to carry, but on a trailer the smallest can be launched by one or two people. They are normally kept on a simple launching trailer that can be pushed into the water by hand. These trailers cannot be towed.

Road-legal trailers cannot be immersed, hence the double piggy-back trailer for boats that have to be driven to a launch site. Clubhouses and dinghy parks adjacent to launching sites are popular, as towing is obviated, masts can be left erect, and changing facilities are available. Dinghy-sailing, particularly racing, is a wet activity. Only the largest dinghies will lie safely at moorings.

A number of sailing clubs are now buying special trimarans for the use of people with spinal injuries. These require parking adjacent to the boat-launching site, and a hard surface such as concrete (not gravel) right into the water, for wheelchairs.

6.08 Yachts and powerboats

This covers all sail and power boats over about 18 ft long, i.e. larger than dinghies. The smaller ones can be trailed. Larger ones generally move under their own power, racing or cruising from a fixed base.

Sailing cruisers are designed for various degrees of seaworthiness, from inland-only to ocean-going. They have high masts, which conflict with bridges when afloat, and which have to be removed for trailing on land. Many have auxiliary power for use in emergency or in constricted spaces.

6.09 Yacht club buildings

The design of yacht club buildings is not covered here. They have not emerged as a distinctive building type. The facilities required vary considerably in both quantity and quality. Few new ones have been built and most use converted facilities (one uses an old ship). Most need social facilities of some kind, often with a bar. Clubhouses for dinghy sailors need extensive changing facilities, where many crews can change for races. If the location is suitable accommodation for a race officer can be useful.

6.10 Boat storage

It is important to note that boats are used for only a very small percentage of their lives. So storage and access to water is the limiting factor in most places. They can be stored wet at:

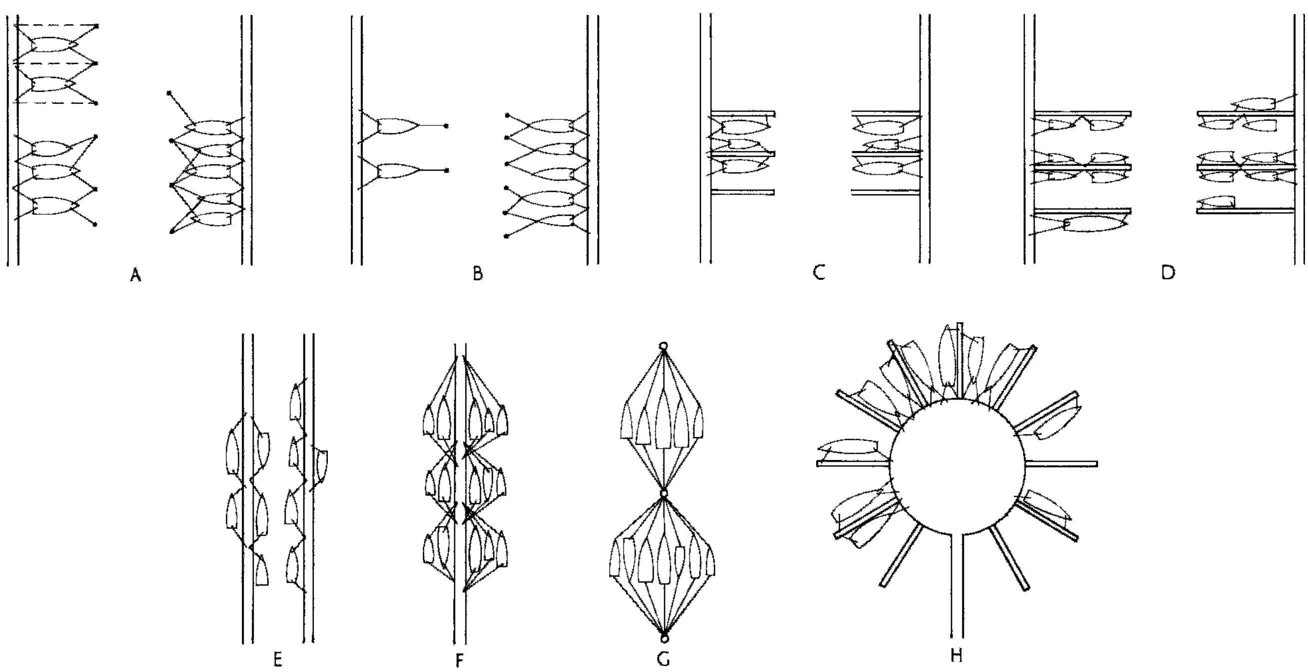
- Swinging moorings
- Marina berths

or they can be stored dry in:

- Boat parks
- Dry-berthing systems.

6.11 Moorings

The term 'mooring' generally means tying a boat to a fixed point, such a buoy or post, which has no land access, **19.61** (also see Table IV).



19.61 *Types of mooring (see* Table IV*)*

Table IV Moorings

References (Figure 19.61)	Type of mooring	Examples	Advantages	Disadvantages	Remarks
A	Stern to quay, jetty or pontoon, bows to piles	Chichester La Grande Motte Rotterdam Kristiansund	Jetty economy	Not as convenient for embarking as alongside jetties or pontoons	
B	Ditto but bows moored to anchors or buoys	Deauville and the majority of Mediterranean marinas	Jetty economy	Not suitable with large tide range as excessive space required for head warps; danger of propellers being entangled in head warps	Particularly suitable for large yachts in basins with little tide range where gangways can be attached to sterns
C	Alongside finger piers on catwalks one yacht on each side of each finger	Cherbourg, Larnaca (Cyprus) and many American marinas	Convenient for embarking and disembarking		
D	Ditto but more than one yacht on each side of each finger	Port Hamble Swanwick Lymington	Ditto, also allows flexibility in accommodating yachts of different lengths	Finger piers must be spaced wider apart than in C though this may be compensated for by the larger number of craft between jetties	Fingers may be long enough for two or three vessels, if more than three then provision should be made for turning at the foot of the berths
E	Alongside quays, jetties or pontoons single banked	Granville	Ditto		
F	Alongside quays jetties or pontoons up to 3 or 4 abreast	St Malo Ouistreham St Rochelle	Economical in space and pontoons	Crew from outer yachts have to climb over inner berthed yachts	This is one of the most economical and therefore most frequently adopted types
G	Between piles	Yarmouth Hamble River Cowes	Cheapest system as no walkways, also high density	No dry access to land; difficulty in leaving mooring if outer yachts are not manned	Not recommended except for special situations such as exist in the examples quoted
H	Star finger berths	San Francisco			

Traditionally, most yachts have been kept at swinging moorings, which consist of single buoys fixed to ground tackle, in natural harbours, lakes and rivers. These are scarce, relatively cheap, space consuming and not very convenient. Owners will need to row out to the mooring in a dinghy, which they will want to keep nearby.

Boats can be moored bow and stern, between pairs of buoys, for closer packing. Adding further boats alongside the moored one ('rafting-up') can be done only temporarily, and is unpopular with owners.

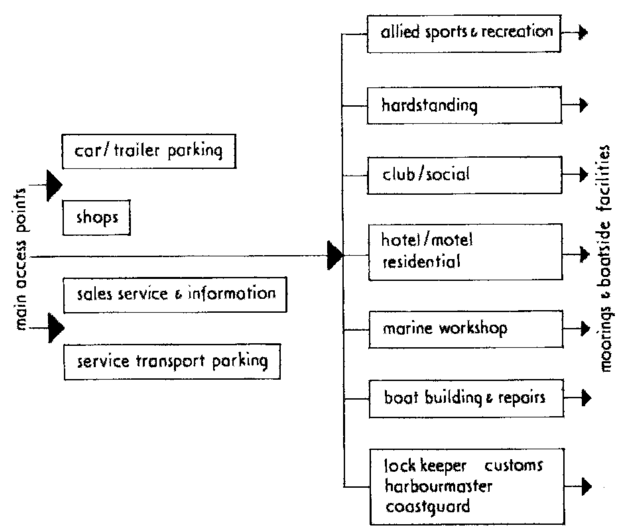
6.12 Marinas

Marinas have been built in suitable seaside cruising locations. To be successful, they must have convenient access from both land and water.

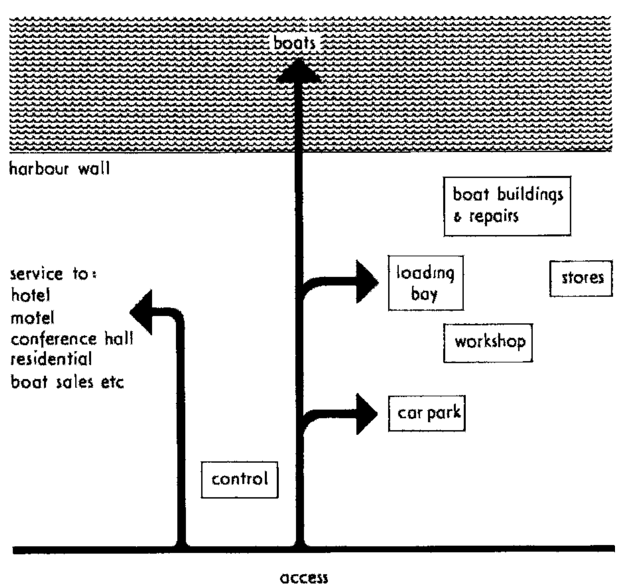
The interrelation between the amenities provided, **19.62**, and the main activities, **19.63**, will control the basic layout. A marina may be off-shore, landlocked or anything in between, **19.64**.

There are many possible layouts, but generally, equal amounts of space are allocated to land and water, **19.65** and **19.66**. A detailed breakdown of spaces and ratios is given in Table V, and a checklist of accommodation and services in Table VI.

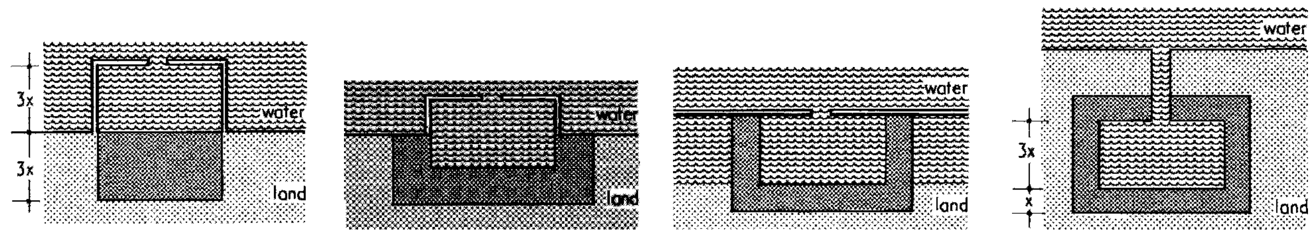
Marina pontoons are now standard items, **19.67**. They are arranged to rise and fall with changes in water level. Boats are usually moored stern to the pontoon, which often has access fingers between alternate boats, **19.68**. Services such as electricity and water are supplied to each berth. Boats vary in size and layouts have to accommodate this. Because of the necessity for locks to



19.62 *Relationship diagram for a marina for development into a basin layout*



19.63 *Activities in a marina*



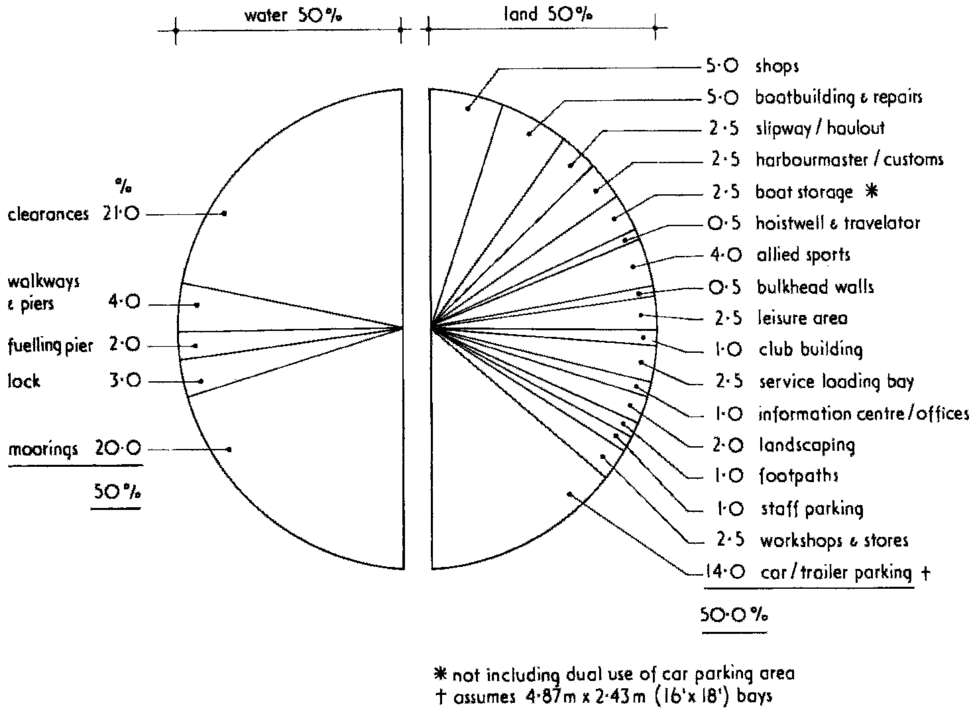
a OFFSHORE
Advantages
minimum quay wall, minimum land take, minimum dredging
Disadvantages
expensive in deep water, vulnerable to weather and currents, navigation hazards, minimum enclosure, silting by litoral drift

b SEMI-RECESSED
Advantage
good for cut and fill economics
Disadvantage
navigation hazard

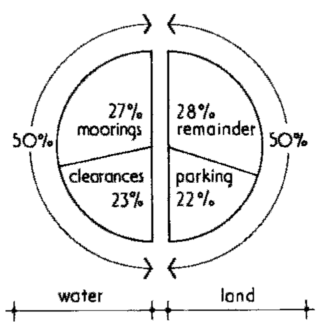
c BUILT-IN
Advantages
uninterrupted shoreline, large land/water interface, considerable enclosure
Disadvantages
large land take, length of quay wall, amount of dredging

d LAND-LOCKED
Advantages
maximum enclosure, minimum interruption of shoreline
Disadvantages
maximum quay wall, distance from open water

19.64 *Types of land-to-water relationships, all with equal areas of land and water*



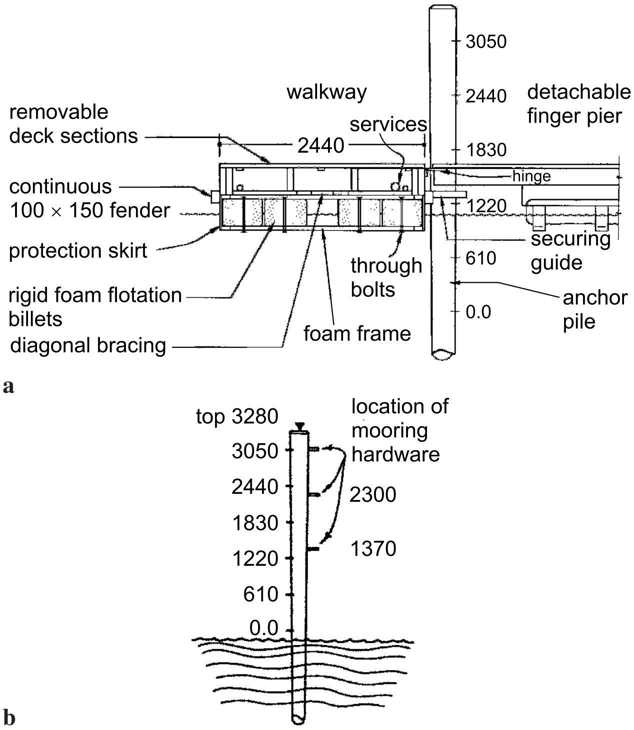
19.65 *One allocation of on- and off-shore space assuming a 50:50 land/water split. This is appropriate to European standards*



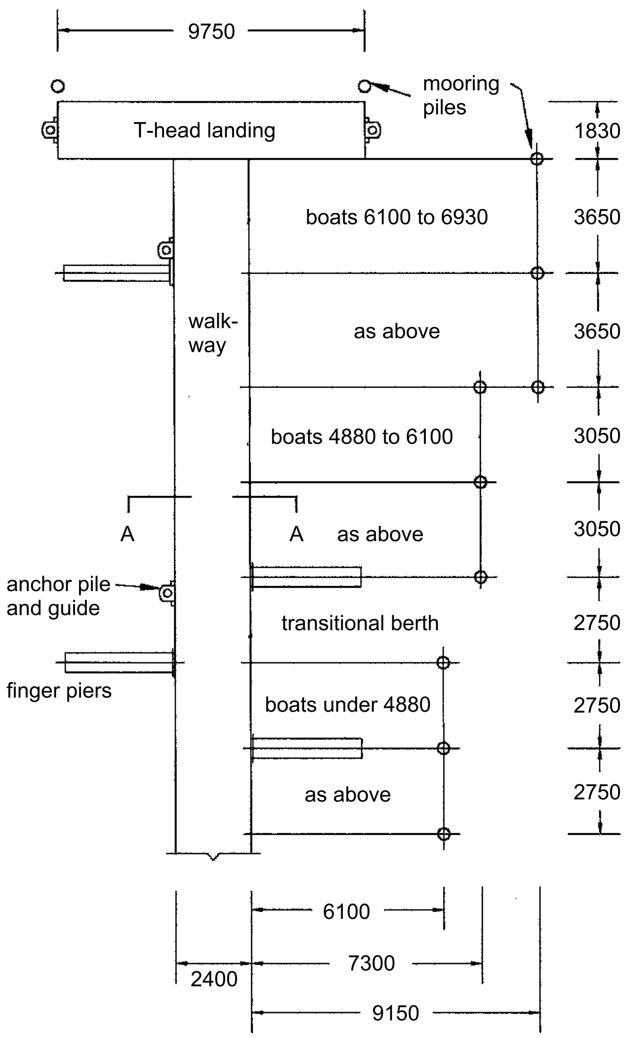
19.66 *Principal space allocations based on the average of 10 American marinas. The difference between these figures and those in* **19.65** *are mainly due to the use of a 2.7 × 5.8 m parking bay*

Table V Spatial requirements and likely size ranges

	Min.	Max.
Land-to-water ratio	1:1	2:1
Density of boats/hectare (wet moorings)	62	162
Density of boats/hectare on hardstanding	25	75
Car-to-boat ratio	1:1	1:5:1
Density of cars/hectare (2.4 × 5.0 bays)	350	520
Ranges of boat length (m)	4.8–13.7	4.3–21.3
Ranges of boat beam (m)	1.8–4.3	1.5–6.0
Ranges of boat draught: Inboard (m)	0.64–1.27	0.48–1.65
Outboard (m)	0.30–0.56	0.20–0.64
Sailing boats (m)	1.14–1.77	1.00–2.16
Average boat length (m)	5.5	9
Percentage total parking area to total water area	20	50
People-to-boats ratio	1.5:1	3:1
People-to-cars ratio	1:1	4.5:1
Cars-to-boats ratio	1:2	2:1



19.67 **a** *Construction detail of floating pier, section A–A* **b** *Detail of anchor pile*



19.68 *Layout of floating pier*

Table VI Checklist of marina accommodation and services

Social activities
Clubhouse, boat-owners' lounge, public house, bar, snack bar, restaurant, offices, committee rooms, starters' post, lookout, viewing terraces, sunbathing, reading room, navigational library, weather forecast board, chart room, television, children's play space, crèche, paddling pool

Shops
Food and general stores, tobacco, stationery, etc.
Bookshop
Chandlery, clothes
Hairdresser, beauty salon
Barber's shop
Sauna
Masseur
Chemist
Laundry, launderette

Services and information
Marina office, information centre, caretaker's maintenance workshop, storage and staffroom
Banking
Post office, Giro
Visitors' information service (e.g. doctors, restaurants, entertainment)
Flagpole, windsock,
Weather and tides information
Kennels

Allied activities
Customs house
Harbourmaster's office
Coastguard, weather station and information
Radar, communications mast
Sea Scouts
Lock-keeper's accommodation
Police, security station

Boatside facilities
Storage lockers
Lavatories (public and private)
Showers, baths
Drying rooms, cabinets
Bottled gas service
Electricity, lighting and power
Plug-in telephone service
Dockside laundry service
Tannoy system
Litter bins
Mail service

General services
Gas, main, bottled or in bulk storage
Electricity, lighting and power to piers and grounds (see Safety equipment)
Sewage and refuse disposal
Water supply
Telephones
Centrally controlled security system

Boat services
Boat building, repair, maintenance yard, material store
New and second-hand boat and engine sales and hire
Launching and hauling equipment (fixed and mobile)
Hardstanding
Launching ramps and slips
Dry storage of boats
Covered moorings (wet and dry)
Information board of local services
Brokerage, insurance, marine surveyors
Divers' service
Fuelling station or tender

Allied sporting activities: provision and instruction
Rowing
Scuba, skin-diving equipment and instruction
Water skiing, skikiting
Swimming
Fishing tackle (hire and sale of bait)
Sail training
Tennis, badminton and squash courts

Allied accommodation
Hotel, motel, holiday flats, public house, holiday inn

Transportation areas and services
Car parking and service (fuel, repairs and hire)
Trailer bays and hire
Bus bay
Transport to and from local centres
Carts for stores and baggage
Motor cycle/bicycle sheds (open and covered)
Boat trips and coach tours
Marina staff electric runabout
Marina workshops and transport areas

(*Continued*)

Table VI (Continued)

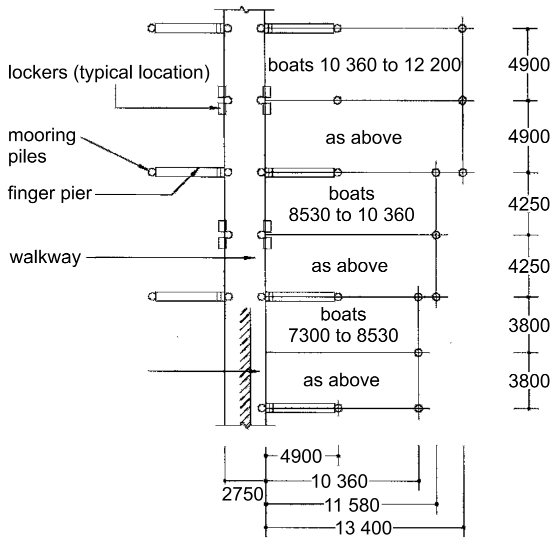
Safety equipment
First-aid post and observation platform
Fire-fighting equipment, fireboat
Life-saving equipment and instruction
Warning or flood lights to breakwaters, lock and harbour entrance
General security system, fences and lighting
De-icing or aeration equipment
Weather and tides information

Miscellaneous
Casual recreation area (e.g. picnic and kick-about areas)
Swimming pool
Vending machines, ice dispenser
Paved and grassed areas
Landscaping
Gardeners' stores and sheds, etc.

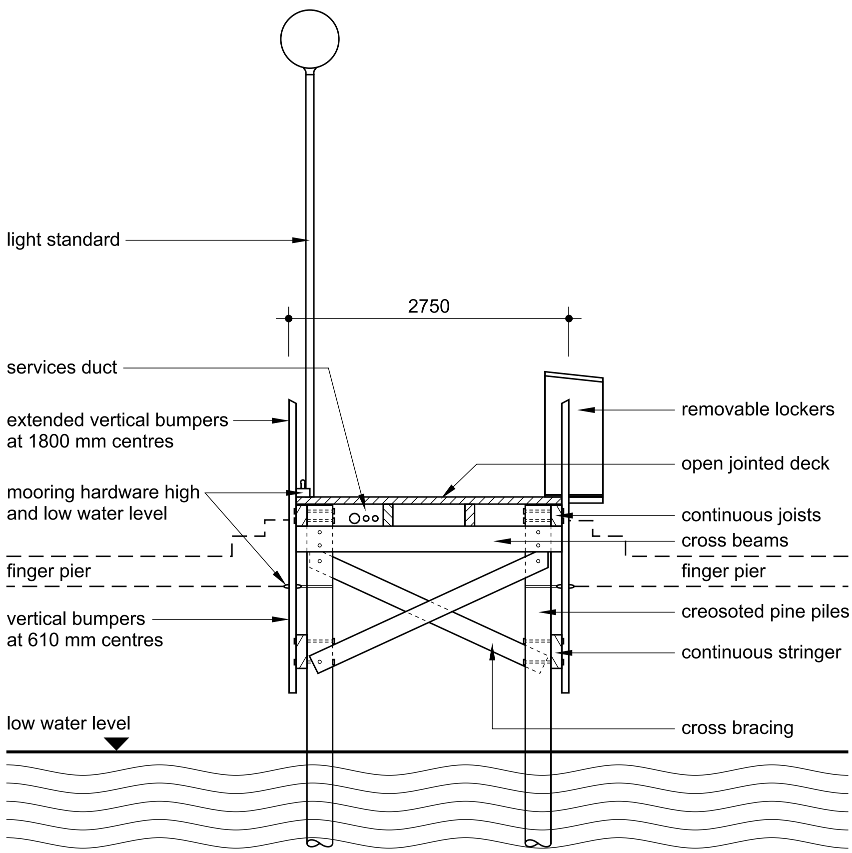
connect a non-tidal marina to the tidal sea, access may be slow. See the checklist of requirements in Table VI. Marinas in non-tidal situations, such as on canals, have fixed piers, **19.69**.

British marinas are expensive; several thousand pounds a year for storage only. Owners are beginning to resist the charges by organising into berth-holder groups, or by berthing abroad. **19.70** shows a large facility.

A development of the marina is the marina village. Essentially, this is a housing estate with water frontage to every property. Each boat is moored stern-to in front of a house with the bow tied to a buoy. Houses are often in terraces, with varied shapes and sizes. Car parking is adjacent to the house on the land side. Each house includes a gear store for boat equipment. In spite of the expense of this type of development because of civil engineering costs, these

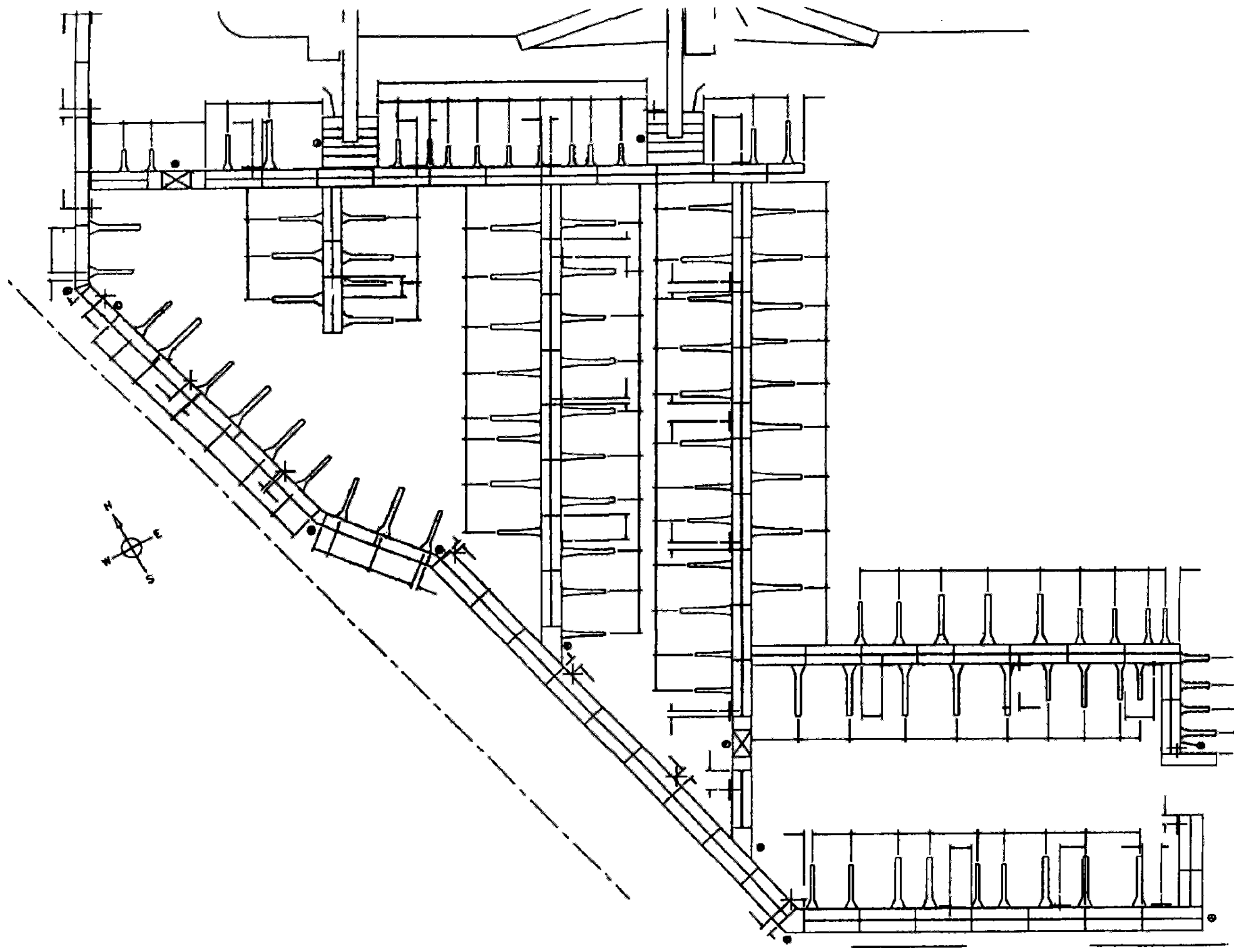


a *Layout*



b *Construction detail*

19.69 *Fixed finger pier*



19.70 *Southampton International Boat Show 1992*

places are even becoming popular with non-sailors who like the marine environment. Adding housing to a marina can have a considerable effect on its financial viability, but brings with it environmental and pollution problems.

New anti-pollution legislation may soon be introduced to force cruising boats to have sewage holding tanks. Marinas will need to provide pumping-out facilities.

6.13 Boat parks

Many yacht clubs and boat builders run some sort of boat park. This consists of an enclosed area of hard-standing adjacent to the water. Dinghies are parked on their launching trailers with erect masts.

Cruisers, both sail and power, are stored on cradles; or are shored up depending on what handling facilities are available. A modern straddle-carrier can carry a boat to a fixed cradle. A tractor can tow a boat on a mobile cradle onto a slipway at low tide ready for it to float off as the tide rises. Cruisers stored in this way are launched in the spring, moored during the season and recovered in the autumn.

DIY maintenance is commonly done in boat parks. Electricity for power tools, and water supplies are required. A mast crane may be needed. Some sort of catering facility nearby is very popular.

6.14 Dry-berthing

Keeping a boat in the water is not desirable, but it is able to afford instant availability. Storage on land is cheaper and is a sensible alternative provided convenient fast launching facilities can be provided.

Dry-berthing for power boats launching is carried out by a forklift which stacks boats on multilevel racks, rather like a pigeon-hole car park. The operator launches the boats when owners arrive to use them. The current maximum size of boat stored this way in England is 33 ft long/4 tons weight.

Dry-sailing is becoming popular with the owners of racing keel-boats up to 30 ft long. The yard owner has launching equipment and puts all the boats in the water every weekend, taking them out during the week.

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20 Community centres

Jim Tanner

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CI/SfB 532
Uniclass F532
UDC 725.835

KEY POINTS:
- *There is a need for a community facility in most areas*
- *Existing centres are often inadequate*

Contents

1 INTRODUCTION

1.01 Briefing

By their nature community buildings must serve a variety of functions among which are:

- Meetings
- Child care (creche, day nursery, pre-school playgroup)
- Childrens' activities (scouts, guides)
- Concerts and plays
- Dances
- Parties and receptions
- Exhibitions
- Sporting and leisure activities, and
- Adult education.

The client, such as a church or a local authority, may have its own specific requirements; but the financial viability of community facilities usually depends on letting them out to other organisations. At the briefing and planning stage it is wise to consider activities which could or should be accommodated.

1.02 Space requirement and arrangement

The following points should be borne in mind:

- Meetings can range from committee meetings of half a dozen people to public meetings with an audience of a couple of hundred. If this range is anticipated then accommodation should include one or two smaller meeting rooms as well as the main hall.
- Child care and childrens' activities invariably require storage for furniture and equipment. If scouts use the facilities on a regular basis, for example, they are likely to need permanent storage for camping equipment, such as tents and poles, and cooking as well as games equipment.
- Some indoor sporting activities such as badminton, require generous space provision. See Chapter 18. These are likely to dictate the dimensions of the hall.

2 PLANNING AND DESIGN

2.01 Relationships

The principal plan elements and their relationship to each other are illustrated in **20.1**, **20.2** and **20.3** are typical examples of the type.

2.02 Space requirements

Table I gives recommended floor areas for various functions and activities.

2.03 Design

Community centres are multi-purpose buildings. Needs and priorities will often conflict; the skill of the designer in consultation with the client, statutory authorities and specialists must be exercised so that a balance is struck. All the following factors should be considered.

2.04 Structure and construction

Most new-build self-contained community centres are domestic in scale. The most economic forms of construction are those used in domestic building: solid ground floors, masonry load-bearing walls and lightweight flat roofs or framed pitched roofs. Alternative forms of construction are only occasionally justified: for a difficult site or when only a short-life building is required. In the latter case, it is worth considering proprietary off-the-peg buildings. The appearance of such a building is not always aesthetically pleasing, but there are exceptions. Where the community facilities are to be accommodated in a larger building also used for other purposes, structure and construction will be determined by the wider considerations.

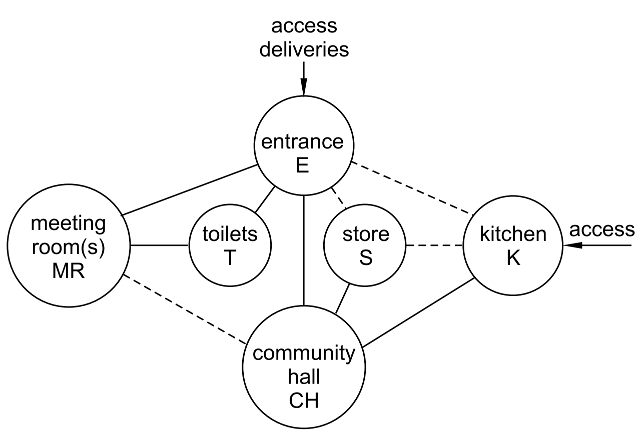
2.05 Materials and finishes

For self-contained community centres it is worth while designing for minimum maintenance, as upkeep funds are always limited. Choice of finishes should be influenced by the following considerations:

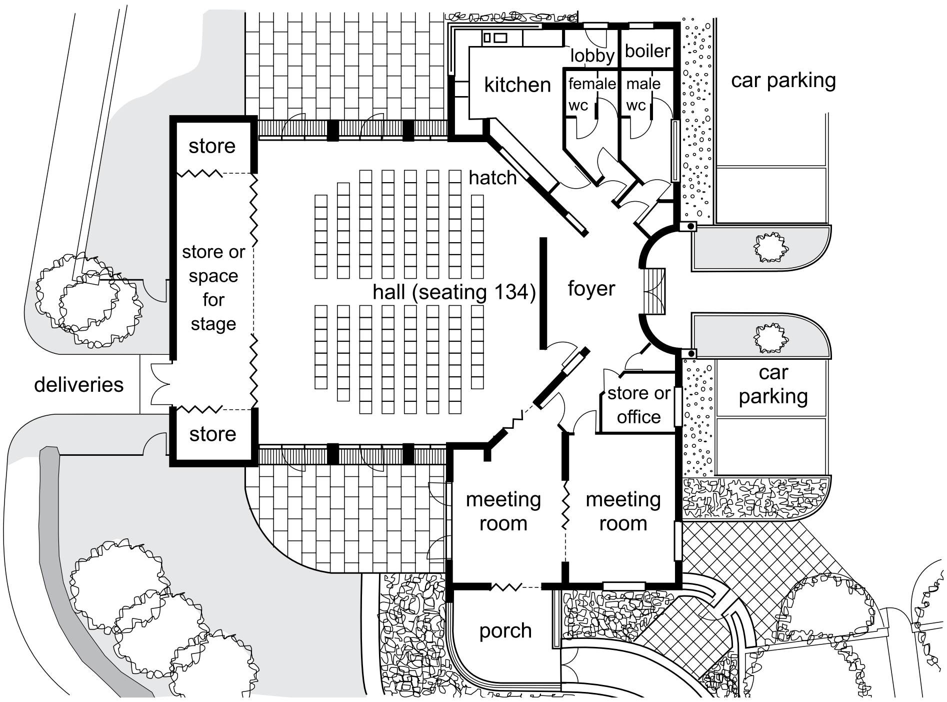
Nature of use may dictate forms of construction and finish which are non-standard. For example, when regular provision for dancing (particularly classical ballet) or indoor sport such as badminton or gymnastics is required, the floor should provide some resilience and specialist advice should be sought.

Durability: Some uses, particularly sporting activities, can be exceptionally hard on surface finishes. The main hall may need to be equipped with retractable bleacher seating as used in sports centres and educational buildings. Pulling out and stacking back such seating creates localised loading and wear. Resilient floors are particularly vulnerable. The manufacturers of the seating and of the floor finishes should be consulted at an early stage.

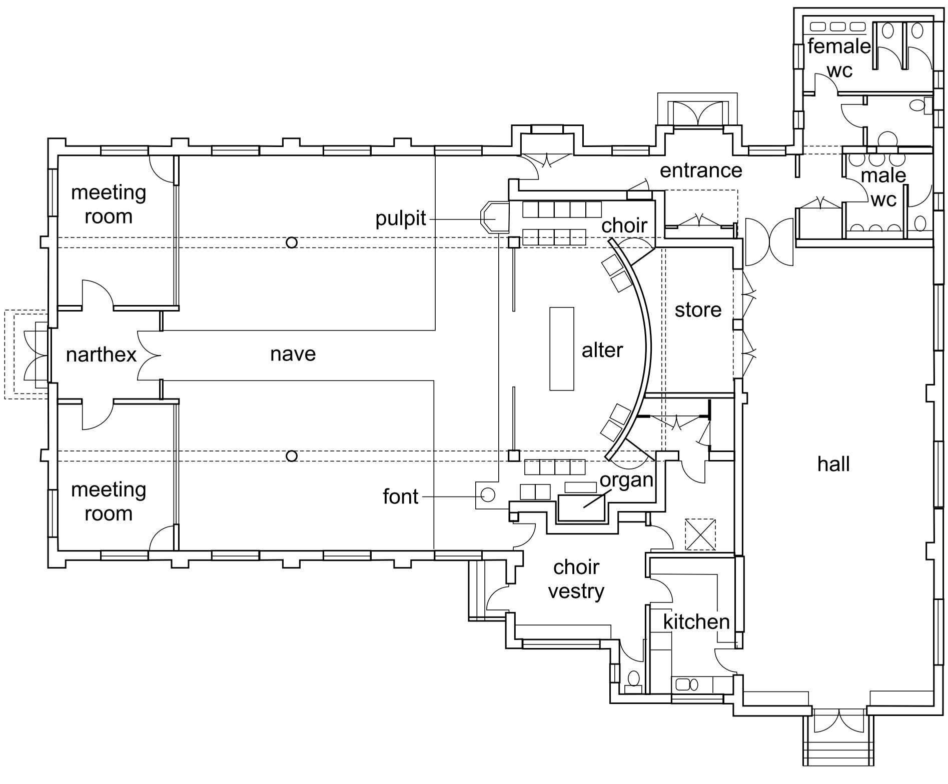
Safety: Users of a community centre range from small children to elderly and disabled people. Finishes should be chosen with a



20.1 *Elements of the plan of a community centre*



20.2 *Church centre for St James's Church, Finchampstead. Architects: Nye, Saunders & Partners*



20.3 *Community centre for St Francis Church, Westborough: an example of an addition to an existing building. Architects: Nye, Saunders & Partners*

view to safety, all floors, ramps and steps should be non-slip. Projections, sharp corners and angles should be avoided.

Cleaning: Community facilities get heavy use and limited operating budgets. The building should be easy to clean.

2.06 Means of escape

Care in planning and signposting the means of escape in case of fire is especially important because:

- The users, such as audiences at occasional concerts and meetings will not be familiar with the building layout.
- Small children are likely to be present in a creche or day care centre.
- Elderly and disabled people may use the centre.
- Facilities for leisure or educational purposes may be used by people with learning difficulties.

Early consultation with the local fire authority is essential.

Table I Minimum floor areas for various activities

Function	Area per person (m^2)
Main hall:	
Closely seated audience	0.46 (based on movable seats, usually armless, 450 mm centre to centre; with fixed seating 500 mm centre to centre will increase to 0.6 m^2)
Dances	0.55 to 0.9
Dining	0.9 to 1.1
Creche, day nursery or pre-school playgroup	0–2 years 3.75 2–3 3 3–5 2.5
Children 5–8 years (out of school and holiday schemes, open access projects)	2.5
Meeting rooms	2.25 up to 4 people 2 6 people 1.55 8–12 people 1.25 20 people

Table II Requirements for child care

Item	Comment
Child care: (creche, day nursery, playgroup)	
Regulation	Child care for children in their early years (generally defined as under-8) usually comes within the Children Act 1989 (see Section 3) and local authorities are responsible for approving and registering facilities. Many of these authorities provide published requirements and guidance on standards
Staffing ratios	0–2 year olds 1:3 2–3 year olds 1:4 3–5 year olds 1:8 (minimum staff 2)
Outdoor play	A safe area with easy access from the building is a usual requirement
Catering	The Pre-school Playgroups Association recommends that children and adults should sit together during meals and consequently separate dining accommodation for staff is not required

2.07 Licensing
A licence will be required for certain uses and these invariably have conditions attached.

2.08 Noise
A community centre is more likely to generate than to suffer from high noise levels. They are commonly used at night and at the weekend, and are often situated within residential communities. They must therefore be designed to avoid nuisance. Where uses take place simultaneously, sound separation will be necessary between a noisy activity such as a dance and one requiring relative quiet such as a lecture.

The basic principles of acoustic design should be applied:

- Orientation, e.g. location of entrances, exits and windows relative to adjoining buildings
- Layout
- Shape of rooms
- Double glazing, only viable in association with mechanical ventilation
- Sound-absorbent finishes, balanced with requirements of durability and cleanability, and
- Landscaping, including trees, to contain external noise.

Unless unavoidable, noise-producing spaces should not be located alongside quiet spaces. Absorbent surfaces may have to be concentrated at ceiling level or provided by means of drapes and wall hangings. Management can also play a significant part in controlling noise and this should be discussed with the client at an early stage.

2.09 Security
Community centres are more than usually vulnerable to break-ins and vandalism as they do not have resident caretakers or 24-hour surveillance, are not continuously occupied, are visited by a large number of people, contain expensive equipment and are isolated from other buildings. Requirements for security can conflict with those of means of escape, so it is important to consult with experts and local authorities.

2.10 Child care
Table II is a checklist of design considerations where creches, day nurseries or playgroups use the facility.

2.11 Disabled people
There are statutory regulations relating to access for disabled people. These apply not only those using wheelchairs but also include people with visual and auditory impairments and those using other types of walking aids. All these have difficulties with steps and changes of direction, and the design of entrances, circulation spaces and toilets should take this into account.

2.12 Legislation
This is constantly changing. Table III gives some current examples but is not exhaustive. The local authority will advise on the latest requirements. It is particularly important to ensure full conformity if the public are going to be charged for admission.

Table III Legislation

Legislation	Comment
Licensing Act 2003	Legislation requires that a licence is obtained for premises which are to be used, regularly or occasionally for the following purposes: • Public music or public music and dancing • Public performance of plays • Cinematograph exhibitions to which the public are admitted on payment • Cinematograph exhibitions for children who are members of a cinema club • Indoor sports entertainment Statutory requirements must be satisfied in terms of means of escape in case of fire and other safety considerations. Administered by the local authority
The Children Act 1989	Covers requirements for premises used by children in, for instance, day nurseries, playgroups, creches, out-of-school clubs, holiday play schemes, adventure playgrounds and open-access projects. Administered by the local authority

3 ELEMENTS OF THE PLAN

3.01 Entrance
This should be large enough to accommodate an influx of people, such as prior to a meeting or concert. Signposting should be clear as many will be unfamiliar with the building. Unless there is a separate goods entrance, it should allow for bulk delivery of food and drink, display material and equipment. Consider the arrangement of the doors, the durability of surfaces and easy accesses to both the kitchen and the hall.

3.02 Hall
For sports purposes refer to Chapter 18. A rectangular shape is likely to be suitable for a wider range of uses than a square or any other shape. If black-out is required, pay special attention to size and location of windows; mechanical ventilation may be needed.

3.03 Meeting rooms
If more than one, make them different sizes. Aternatively, have one space that can be divided using sliding folding doors; although some of these do not provide adequate sound insulation. At least one meeting room should have direct access to the hall.

3.04 Toilets
Separate toilets will be needed for men, women and disabled people. There may also be a need for smaller toilets for little children. Unisex baby-changing facilities should be provided. If considerable sports usage is expected, showers will be necessary for each sex.

3.05 Kitchen
There should be little need for more than a domestic kitchen. If catered functions are expected, provide space for setting out and final preparations.

3.06 Storage
A separate store should be provided for each main use:

- Kitchen
- Sports
- Seating and other furniture
- Creche/kindergarden
- Scouts.

The kitchen store should be directly accessible from the kitchen, the others from the hall. Storage space should be as generous as space and budget will allow.

3.07 Furniture
Refer to trade catalogues, and seek specialist advice.

4 BIBLIOGRAPHY
PPA Guidelines, published by the Pre-School Playgroups Association

21 Schools

Andy Thompson, based on previous material by Guy Hawkins, with material on Furniture and Equipment by Alison Wadsworth

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KEY POINTS:

- *School building replacement subject to major programmes over 15–20 year period: Building Schools for the Future in secondary and Primary Capital Programme.*
- *Range of approaches to educational provision – all age schools, campuses of primary, secondary and special schools; schools as centres for the community providing a range of services including childcare, training and family support; learning beyond the school: school grounds, other centres of learning, at home.*
- *Design Quality is considered an important contribution to raising educational achievement.*

Contents

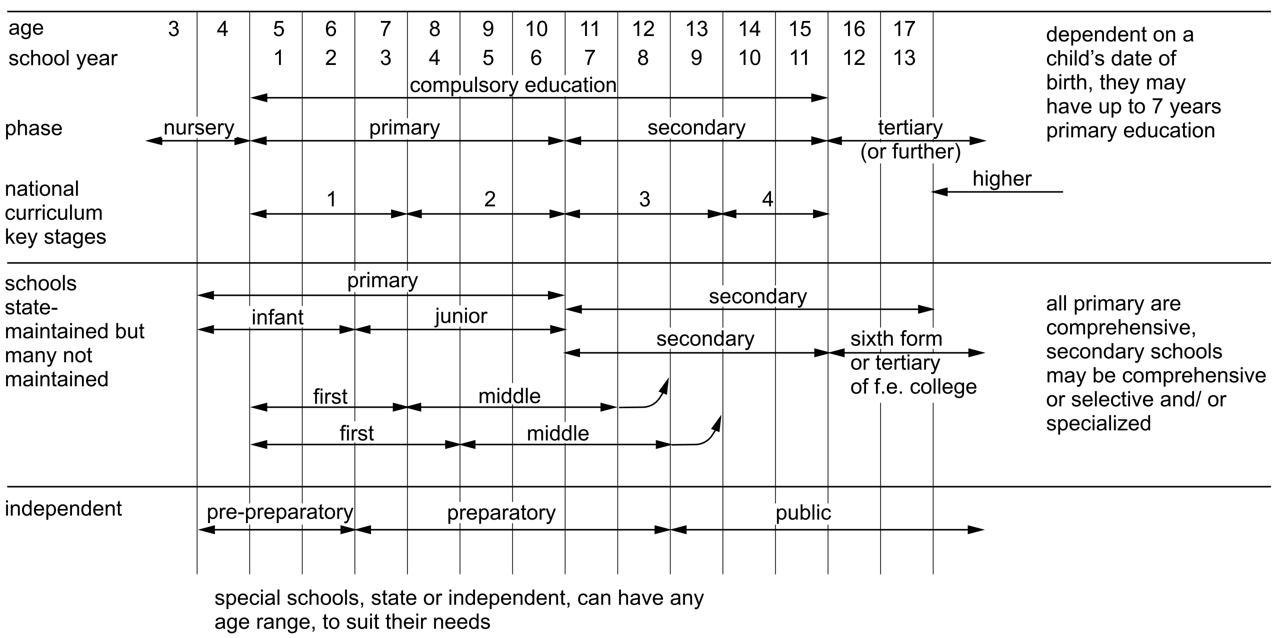
1 INTRODUCTION

1.01

This chapter relates specifically to the education system in England and Wales at the time of writing. In other parts of the United Kingdom and elsewhere it varies. Also, education is in a constant state of change, so that what is said will need continual updating. Although many of the general principles remain, there is change and experiment encouraged to achieve higher standards and a range of settings including all age schools or co-location of schools that break the mould of the traditional organization. The reader is recommended to refer to the following web site to determine the latest state of development in all aspects of school design: www.teachernet.gov.uk/management/resourcesfinanceandbuilding/schoolbuildings.

1.02 Types of school

Full-time education is compulsory between the ages of 5 and 16 years. Schools are either independent ('private' and 'public'), run by their owners or by charitable foundations, or maintained ('state' schools). Maintained schools are funded at public expense via the Department for Children, Schools and Families (DCSF), Local Authorities (LAs), Diocesan Boards of Education or special Foundations. Schools are largely defined by their form of government and the ages and sex of the pupils they admit. Currently, there are three main categories of school: Community, Foundation and Voluntary (either Controlled or Aided). Most maintained schools are comprehensive – open to all and providing courses for all abilities, but some secondary schools select all or a proportion of their pupils by general or specific ability or interest. Special schools cater for pupils with special needs in education which cannot be met in ordinary schools. Types of school are summarised according to their age range in **21.1**. Within a geographical area there is a common age of transfer from one type of school to another.



21.1 *Types of school, age range and National Curriculum stages*

1.03 The national curriculum

Maintained schools must teach, as a minimum, the National Curriculum, organised in four ‘Key Stages’ up to the age of 16 as well as the ‘Foundation Stage’ covering education for children before they reach five. The curriculum for those over 16 is made up from a range of optional courses leading to specific academic or vocational qualifications. At each of the ‘Key Stages’, there are specific programmes of study set out as a requirement for all pupils in Maintained schools which are periodically reviewed to ensure that it continues to meet the changing needs of pupils and society.

1.04 The school as a community

Schools have a duty to look after their pupils’ welfare (referred to as ‘pastoral care’). This is done by formal and informal counselling, and also by the fostering of a school community through assemblies, sport, charitable projects, expeditions and other shared activities. Each pupil belongs to a basic class or group, and may be part of a larger ‘house’ or year group. The extent to which this has a direct effect on the provision of space varies, but schools should be designed for a community with a wide range of social needs, activities and groupings.

2 THE BUILDING OF SCHOOLS

2.01 Funding and promotion of building projects

LAs, Diocesan Boards, or individual Foundations for Academies, City Technology Colleges (CTCs), Trust Schools or Foundation Schools (formerly Grant Maintained (GM)) promote new schools via annual capital programmes, and set design briefs with the aid of specialist advisers. In the case of extensions or improvements at existing schools, the head teacher and governors have an important role, both as users and as carrying financial responsibility for running cost and maintenance under the local ‘Fair Funding plan’ which contains a formula by which the available ‘Individual Schools Budget’ is shared. They may also promote their own locally funded projects.

2.02 Statutory control, design guidance and briefing

All new and remodelled buildings must comply with the Education (School Premises) Regulations 1999, and related DCSF standards and procedures conveyed through Circulars and Administrative Memoranda. School building projects must comply with Building Regulations and from 2001 are subject to the normal procedures for obtaining approvals.

2.03 Consents

LAs which are both Education Authorities and Planning Authorities may grant themselves planning consent for educational developments. Independent schools must obtain Planning Consent through normal procedures. Local advice should be sought over arrangements for other types of schools within the maintained sector.

2.04 Regulations

Most general regulations apply to schools – Health and Safety at Work, Food Hygiene, Electricity, Water, Gas, Public Entertainment Licensing. Any substantial piece of construction work at a school will be required to follow the Construction (Design and Management) Regulations 2006 (CDM).

2.05

The DCSF publishes a series of Building Bulletins (BBs) on aspects of school design. As the 1999 Regulations are less prescriptive than previous versions, and schools enjoy more autonomy and self-government, the role of non-statutory advice from the DCSF has increased. Most important are the area standards now contained in the Briefing Framework for Secondary School Projects BB98 and that for Primary School Projects BB99. Area guidance for Special schools is covered by BB77 which at the time of publication is being revised but the latest guidance and area schedules are available at: www.teachernet.gov.uk/schoolbuildings/designguidance.

2.06

LAs have standard procedures for commissioning and managing building projects, and many have standard briefs and design guidance for the most common types of school or specialised facility. Advice for those interested in setting up an Academy should, in the first instance, contact the Academies Division at DCSF.

2.07 Sites for new schools

Completely new schools are only likely to be required in association with large housing developments, for which a full Planning and Highways framework will have been established. This may include provision of sites for schools at no cost, via Section 106 of the Town and Country Planning Act 1990. **21.2** and **21.3** set out a range of overall land requirements for schools, but each case requires a full site feasibility study.

Schools may require additional space for parking and turning of buses, for parents’ cars, or for community use. Local Planning Authorities will set or agree standards in their area. LAs and their schools are now required to have a Green Travel Plan. Space should also be allowed for the retention and enhancement of existing landscape features.

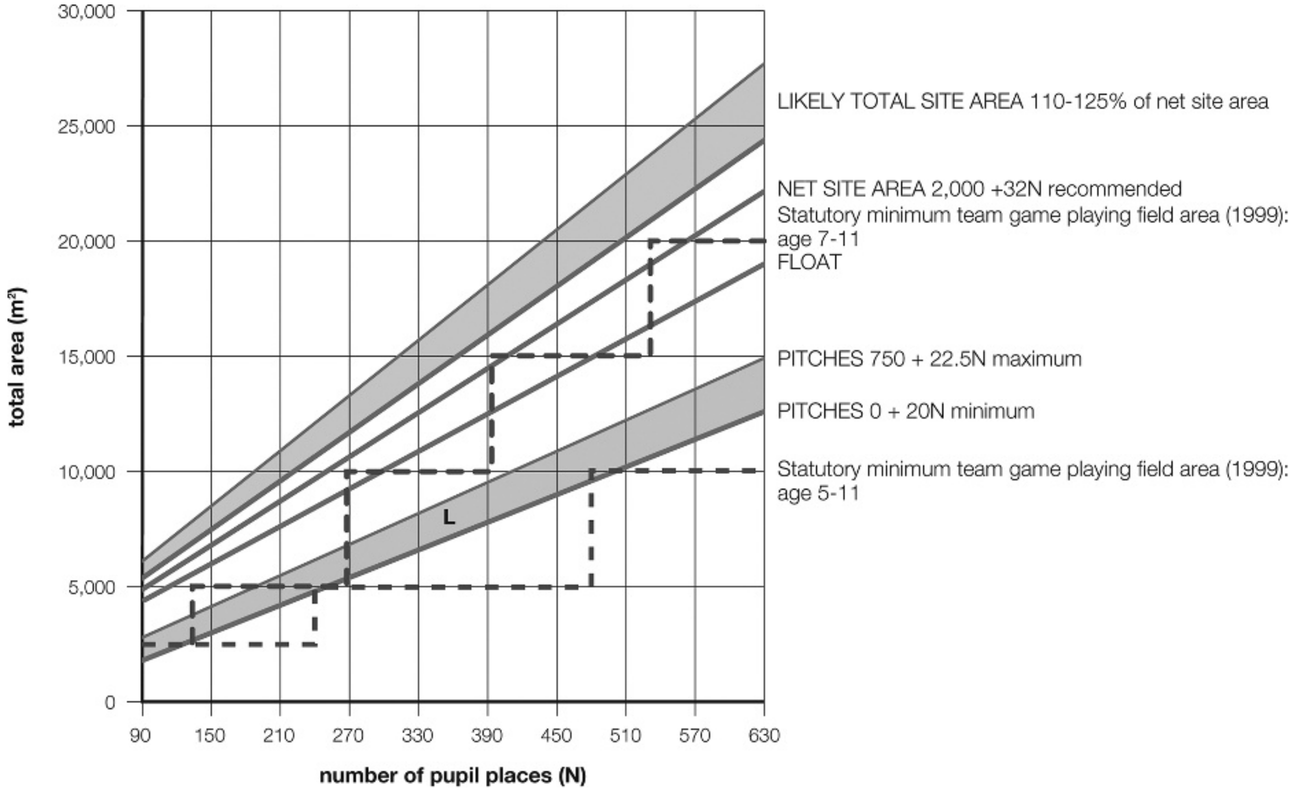
2.08 Community use/extended schools

Most schools are used outside school hours and increasingly so now are specifically planned and funded as community schools or joint-use centres. To meet the ‘Every Child Matters Vision’ schools are designed beyond simple community use to a full range of ‘extended services’. The aim of government is for all schools to provide access to a core offer of extended services by 2010, including: High-quality, year round childcare; a range of study support activities; parenting support, including family learning; access to a wide range of specialist support services and wider community access to learning and recreational facilities for adults.

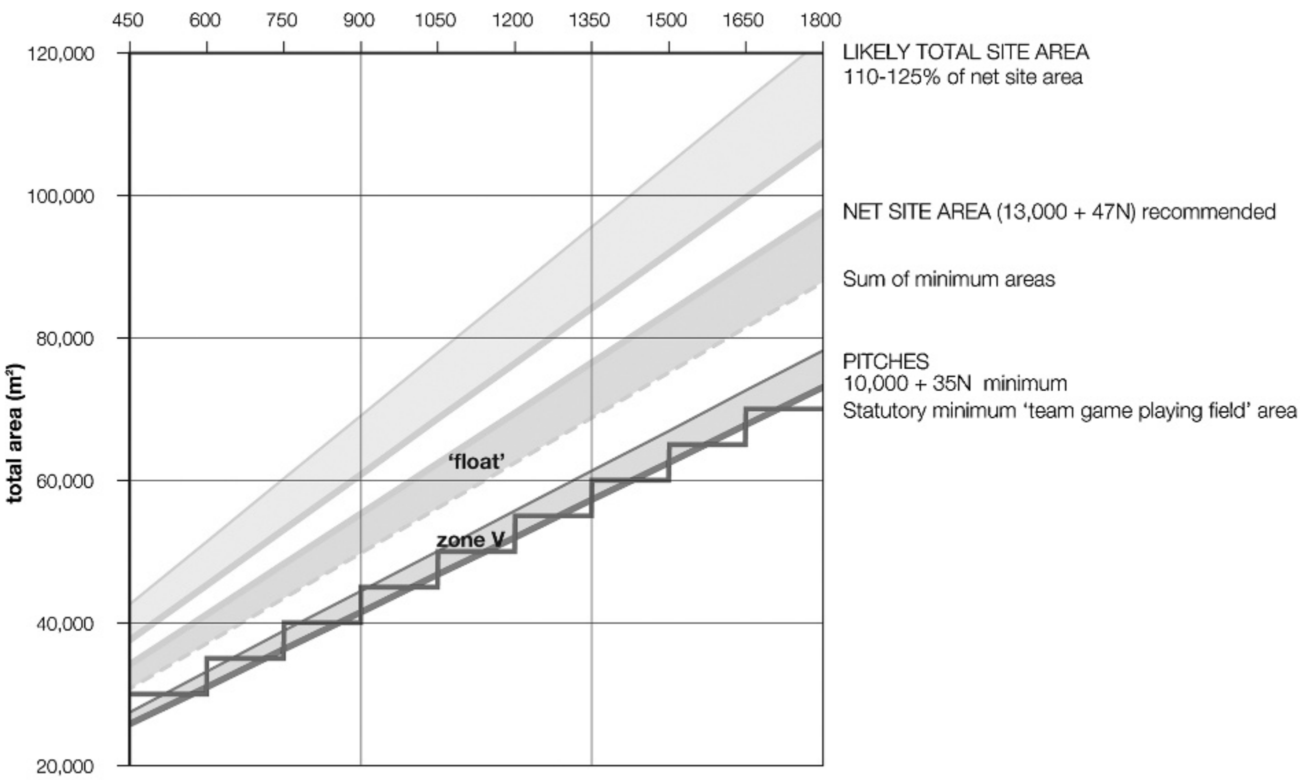
All such joint use schemes require careful design for premises management – heating and lighting must be zoned, and possibly separately metered, and the conflicting demands of security and fire escape resolved. Halls need to be licensed for public entertainment. Outdoor areas must be secure and well lit, parking adequate and easy to control, and signposting and routes clear. Large joint-funded schemes require good financial and management planning to be successful. Where there is no outside source of finance, all income from lettings of premises goes to the school governors, who must be able to cover their costs.

2.09 Growth and change, flexibility and adaptability

Schools are vulnerable to changes in population and popularity, curriculum and teaching methods. The potential for growth, change and possible contraction and change of use must be considered seriously at all stages and levels of design. Short-term flexibility of use can be maximised by good standards of space and services provision, and appropriate furniture. Adaptability in the medium term is assisted by good site development strategy, buildings with regular planning grids and simple shapes, and the positioning of fixed elements such as staircases and lavatory blocks to give maximum freedom in relocating partitions. In the longer term, change of use of part or all of the buildings for non-education purposes requires fresh planning consent and may have major implications for road access and on-site parking provision.



21.2 *Recommended standards for total and net site area and for sports pitches, for various sizes of 5–11 primary schools. BB99 Briefing Framework for Primary Schools*



21.3 *Recommended standards for total and net site area and for sports pitches for any secondary school, and the statutory minimum 'team game playing field' area required by the Education (School Premises) Regulations. BB98 Briefing Framework for Secondary Schools*

3 DETAIL DESIGN CONSIDERATIONS

3.01 School furniture and ergonomics

It is important that appropriately sized furniture is used in schools. Inappropriate sized furniture can affect the concentration of pupils and lead to neck and back pain in later life. Furniture sizes (one of the issues which sits under the heading of 'ergonomics') is a complex issue – detailed information is most clearly set out on the furniture size website www.cfg.gov.uk/schoolfurniture.

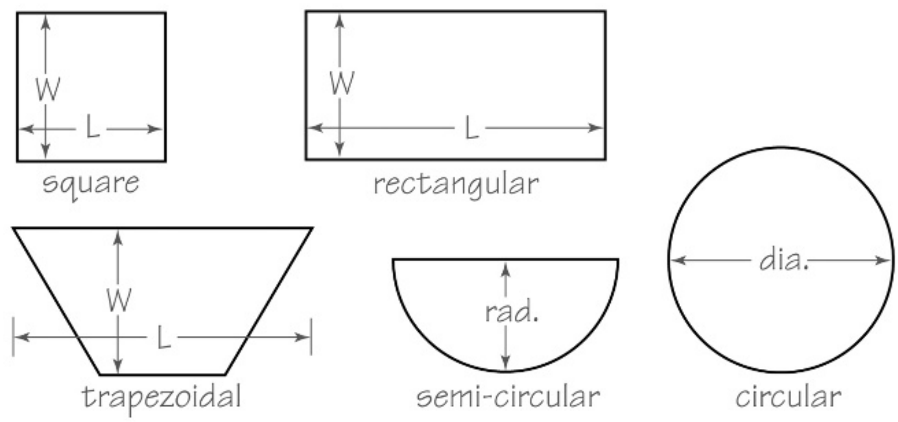
Heights

It is very important that children are provided with heights of furniture appropriate for the activities being carried out, some of which have health and safety implications – for example, science experiments using a Bunsen burner. *www.cfg.gov.uk/schoolfurniture* gives height dimensions for work surfaces and shelving for different age groups, although, as the website explains, compromises may need to be made when using age group-related data as the size of pupils can vary.

Chair and table fit
Chairs and tables will usually correspond to the size marks set out in British Standard 5873 or the more recent European standard, CEN1729 which contains six size marks for pupils aged 3–18. It is important that the same sizemark chairs and table are used to avoid mis-match. www.cfg.gov.uk/schoolfurniture discusses the use of size marks and the need for more than one size mark in classrooms.

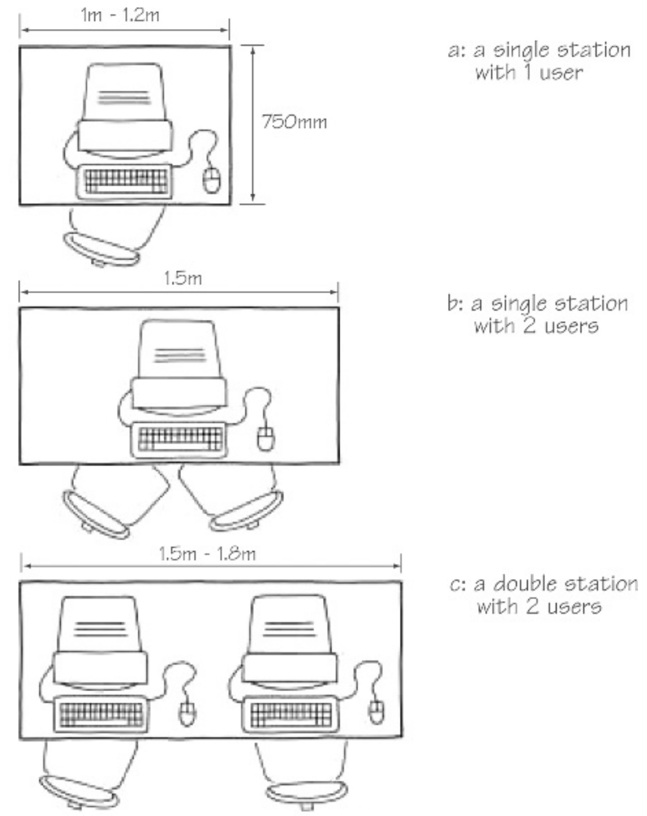
Adjustable furniture
One solution to the range of pupil sizes is to use adjustable height furniture. Furniture and Equipment in Schools: A Purchasing Guide (Managing School Facilities 7) looks at this issue in detail.

Furniture plan sizes
MSF 7 identifies two main categories of furniture – fixed and loose. Loose furniture can be further identified as general tables, specialist tables, storage and seating. **21.4** shows the sizes of loose tables used in



		PRIMARY		SECONDARY	
Usage	**Pupils**	**W**	**L**	**W**	**L**
Square					
Classroom	1	550	550	600	600
Classroom	4	900	900		
Classroom/informal area	4	1200	1200		
Rectangular					
Classroom	2	550	1100	550	1100
Classroom	2	600	1200	600	1200
Specialist (eg IT)	2	750	1200		
Specialist (eg IT)	1			750	1200
Specialist (eg IT)	1 to 2			750	1500
Specialist (eg electronics)	2			750	1800
Specialist, small groups	2 to 3			900	1800
Specialist, group gatherings	10 to 12			1200	2400
Circular					
General table, informal use	1	600dia			
General classroom table	2	900dia			
General table, informal use	2			900dia	
General classroom table	4	1200dia			
General table, informal use	3 to 4			l200dia	
Semi-circular					
General classroom table	2	550rad			
General classroom table	2	600rad			
General table, informal use	2			600rad	
Trapezoidal					
Classroom	2	550	1100		
Classroom	2	600	1200		
Classroom/informal area	1 to 2			600	1200

21.4 *Sizes of loose tables used in schools*



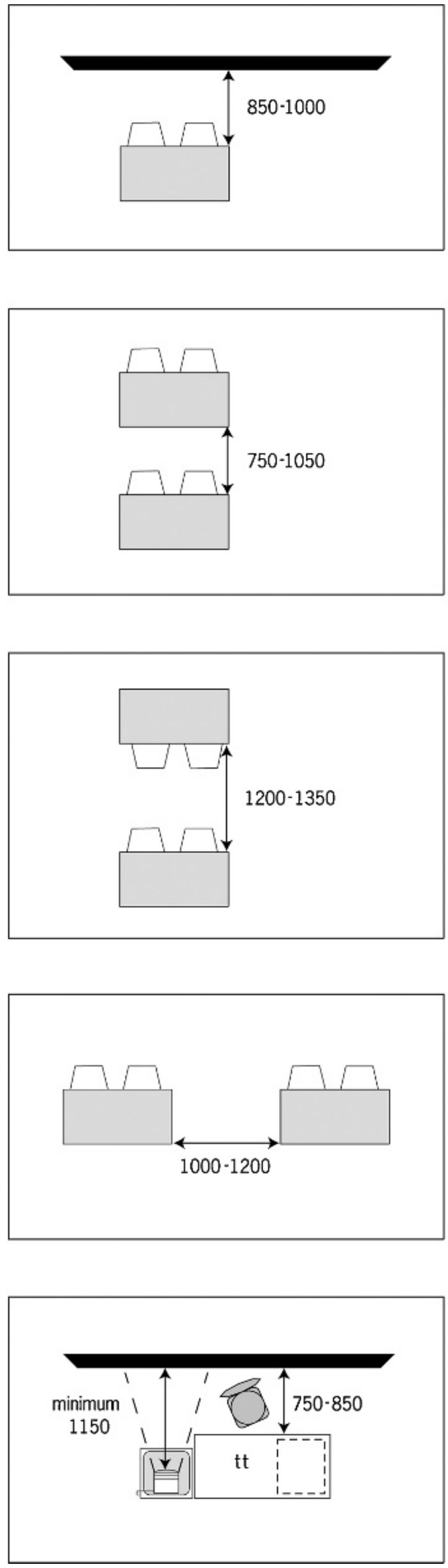
21.5 *Recommended sizes of tables for ICT use*

schools. A larger table plan size of 1400×700 could also be used in Secondary school general teaching spaces, however this will require classrooms to be on the upper end of the general classroom area graph as set out in BB98. The use of specialist ICT furniture may reduce as technology advances and computers are used in a more *ad hoc* way. The use of wireless technology reduces the need for complicated wire management accessories and makes tables simpler and, in some cases, smaller. It is important however to ensure that there is sufficient depth to prevent pupils sitting too close to a screen and also for sufficient leg clearance under the table, 750–800 mm depths are therefore recommended where possible. **21.5** shows the widths recommended for ICT use. Although ICT furniture may not be rectangular in plan (some systems offer triangulated work surfaces) a similar area should be provided. Storage should be modular; the use of trays is particularly useful to allow resources to be carried and stored in a number of different units. Units are generally around 1100×475 mm with the height of the unit controlling the number of trays stored.

Fixed furniture includes wall benching and shelving. A minimum depth for benching is 600 mm, with an optimum depth of 800 for serviced equipment. *www.cfg.gov.uk/schoolfurniture* gives a list of recommended heights for shelving, although the use of adjustable shelving gives flexibility. AV equipment includes the increasing use of interactive whiteboards. It is usual for a projector to be fitted to the ceiling with a screen on the main teaching wall. The height of the whiteboard must be carefully considered to allow all teachers to reach most of the board. A screen or board with a reflective surface may be difficult to view it if reflects a light source. A view of a bright window beyond a screen or whiteboard can cause discomfort as well as reducing visibility.

3.02 Layout issues

It is important that sufficient space is allowed around each workspace in order to create a safe and calm environment where pupils can carry out their activities safely and effectively. **21.6** sets out some of the main dimensions to be considered as part of the classroom planning process – specific BBs gives more detailed information however.



21.6 *Space requirements between tables. BB92 Modern Foreign Languages Accommodation*

3.03 Provision for people with disabilities

One of the most recent developments has been Part 4 of the Disability Discrimination Act 1995 (DDA), where planning duties require LAs and schools to develop accessibility strategies and plans, respectively, to improve access to school education for pupils with disabilities. There is a requirement now for all schools to have a Disability Equality Scheme (DES). People with disabilities should be consulted and involved in a DES. Access should include for staff and visitors with disabilities. See *www.teachernet.gov.uk/sen*. Further design parameters for this will be found elsewhere in this handbook.

Arrangements for safe escape in case of fire are the most difficult part of the exercise. These require combinations of design provision together with management procedures involving assistance by able bodied persons. The means of escape for people with disabilities in some existing buildings may be extremely difficult and expensive to organise. Current thinking is that a small risk is acceptable when otherwise a disabled person would be totally denied access.

When referring to the needs of people with disabilities the tendency is to concentrate on requirements for wheelchair users. The needs of people on crutches, with visual or aural impairments or with other disabilities should not be ignored. In particular, adequate guidance for blind pupils, staff and visitors should be provided. Blind people may also have assistance from guide dogs.

3.04 Construction and environment

School building has pioneered much technical innovation, originally in the interest of low capital cost and rapid production, there is a constant drive for energy conservation; but design solutions should not result in problems of maintenance, and environmental discomfort. The ‘deep plan’ remains an important means of creating appropriate planning relationships, and attention is currently focused on use of appropriate sections, control of ventilation, and use of passive solar energy. Room acoustics remain a crucial element in the success of any school building.

Compliance with COSHH regulations may require upgrading of those areas where fumes and dust are created, including replacement of convectors by radiators, and the provision of fume and dust extraction to individual appliances.

3.05 Services

In the provision of services, the widespread use of computers gives rise to the need for glare-free lighting as well as increased power outlet and network cabling provision.

3.06 Security

Security is a major issue in schools, and many have installed sophisticated external lighting, intruder alarm and TV surveillance systems. However, the most elaborate technological systems are of no value if not backed up by appropriate management procedures.

The hazards emanate from several directions

- Externally from burglary, particularly of computer equipment
- Also externally, attacks on staff and pupils
- Internally from vandalism and pilfering.

The design of the school can make a substantial contribution in all these areas. Doors and windows must be sufficiently secure. Flat roofs making external access to upper floors easier should be avoided. Despite some design trends which deprecate them, straight corridors without local widening are easier to keep under observation, and prevent places where people can lurk unseen.

There should be a minimum of entrances to the school, and all should be able to kept under observation at all times. In any case, only one entrance should be usable by the general public, parents, etc. and this should lead directly to a reception area covered by the school office. It should not be possible to penetrate from here into the main school without permission. Any service entrance for kitchen supplies, etc. should be similarly organised so that the main school is not easily accessible from here.

3.07 Fire

In some schools, particularly secondary, problems are caused by letting off fire alarms, and interference with fire point installations. As a result, these are no longer situated in corridors. They are placed within classrooms and offices so that they can be kept under observation.

4 EARLY-YEARS

4.01 Age range and settings

Early Years covers children from 0 to 5 years and effectively overlaps with the first year of compulsory school. It includes the more traditional nursery school and nursery class but now covers a whole range of different settings such as Sure Start and Children’s Centres. The Foundation Stage of the National Curriculum applies to children from the age of three to the end of the reception year (usually at age 5). Provision here should not be confused with play groups or day nurseries, although both sectors are subject to OfSTED inspections. **21.7** illustrates how a new early-years centre is linked to an existing two-form entry primary school via a reception class.

4.02 Accommodation

Internal space

The area depends upon the age and use but internal space guidelines are for children 0–2 years – 3.5 m^2 per child, 2–3 years – 2.5 m^2 and 3–5 years – 2.3 m^2. One of the key factors in creating a successful learning environment for pupils of this age range is allowing the children and staff to vary their surroundings. Providing for this flexibility can involve:

- Minimising fixed furniture and equipment, and locating services to allow activities to take place in different areas;
- Avoiding floor finishes that limit activities to particular areas;
- Keeping surface colours fairly neutral to avoid determining zones of activity;
- Providing sufficient storage space for furniture, materials and equipment so that activities and environments can be varied.

Outdoor play area

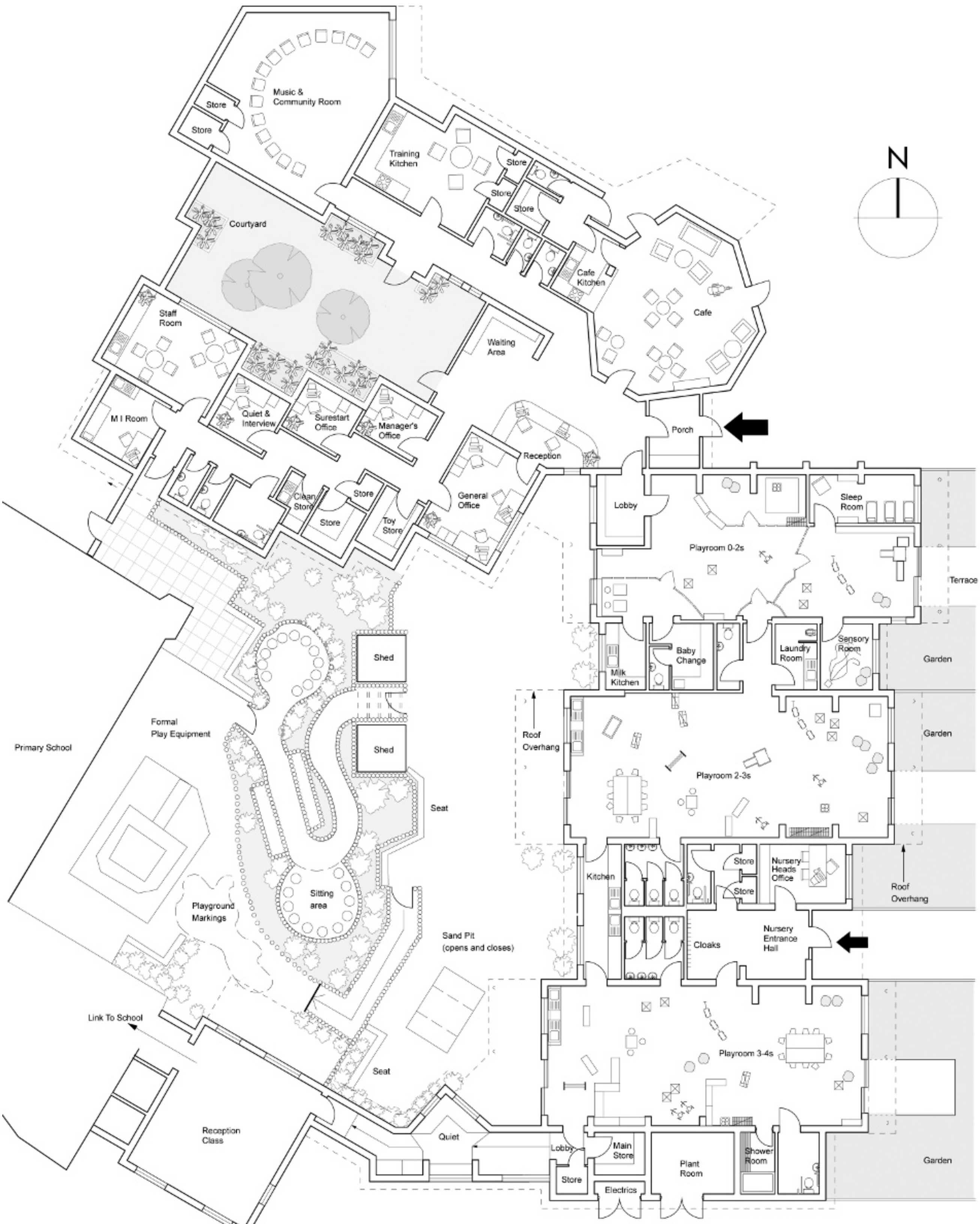
As a guide around 9 m^2 can be allowed per child. Outside spaces should be diverse, interesting and fun, affording children the widest possible range of stimulating experiences and opportunities. Spaces should be securely fenced with controlled access, orientated towards the sun but with some means of providing effective shade in hot weather and shelter from wind and rain. Access from the main playrooms is very desirable and children should be able to access a lavatory from outdoors and they should have access to drinking water without having to enter the building.

Toilets and coat hanging

One WC and washbasin per 10 children, usually unisex. All cubicles should be big enough to allow adults to give assistance and at least one cubicle should be big enough for children with physical disabilities. Appropriate provision should be made for washing down children after ‘accidents’ in a way that protects their privacy and dignity. Coat areas should be accessed from the outside via a draught lobby provided with a rack for Wellingtons.

Staffroom/quiet room/parents room

Space should be allowed for these depending upon the nature of the setting, but all will require accommodation for staff to rest, have refreshments, prepare their work and hold meetings. Staff must have a flexible attitude towards their office accommodation as rooms may have to be designated for multifunctional use.



21.7 *A new early-years centre linked to an existing two-form entry school via a reception class*

4.03 Security

Attention should be focused on the need to ensure both that children cannot wander out of the setting enclosure and that they are protected inside the enclosure from those that might wish to harm them.

5 PRIMARY SCHOOLS

This term includes Infant, Junior and First schools.

5.01 Age range and typical sizes

The Statutory age range is from 5 to 11 (Years 1–6). However, many Primary schools have Nursery classes as part of the school, sometimes as part of an associated Early Years facility. The so-called Foundation Stage of the National Curriculum applies to children from the age of three to the end of the 'reception year' (usually at age 5) which used to be known for taking 'Rising Fives'. Because of this Nursery and Reception classes are much more closely integrated in many Primary schools. Because the first year is still called 'reception' the full primary school age range is actually 7 years. Primary schools typically range from 90 to 420 pupils. Separate infants' (Years Reception, 1–2), and Junior schools (Years 3–6) are often provided to avoid having schools which are too large. Infants schools range from 120 to 240 pupils, Juniors from 180 to 360. First schools, age range 5–8 or 5–9, are provided in areas which have Middle schools.

5.02 Curriculum and organisation

The National Curriculum at Key Stages 1 and 2 forms the basis of primary school work. Pupils spend most of their time in a group of around 30, with one class teacher; but pairs or groups of class spaces are often clustered together to allow sharing of specialist teacher skills or resources, and variation of group sizes for different activities. It is increasingly common for other teaching support staff to be present all the time, offering increased flexibility to break down into smaller groups.

Most activities are class based but some activities take place in specialist spaces such as PE in the hall, music in a studio. At any time small groups could be working in a library or resource area accessible to the whole school. Now most of the children will probably stay to lunch, either bringing sandwiches or having a hot school meal.

5.03 Site planning – access and road safety

Most children arrive on foot accompanied by parents. Schools organize access into school in a range of different ways, some enter their class directly from the playground others have the children all enter from the front. However, security considerations now tend to restrict the number of entrances so that they can be closely monitored.

In some areas, many children are brought to school by car; setting down and picking up can cause congestion and contribute to road safety problems. It may be necessary to provide turning and waiting areas in order to obtain planning consent for a new or enlarged school.

In many cases, children are brought from outlying districts by school bus. It is not altogether desirable for these to set down or pick up on the road outside the school, and space within the school grounds may have to be provided. Space may also have to be provided for the parking of staff cars. There is now a requirement for all schools and LAs to have a school access policy which should address all of these issues including a 'green routes' statement.

5.04 Community use and extended school

Joint use of primary schools has in the past generally been confined to the hall, any large room not used as a class base, and possibly the outdoor play areas and changing rooms. The design needs to ensure that these can be used as self-contained areas without risking disturbance to materials and displays left out in class bases, and can be heated and serviced in such a way that the running cost can be controlled and correctly apportioned. These principles are perfectly valid but in a much expanded market of extended schools. Facilities for things like 'after schools clubs', family support and sharing with public libraries on site are increasingly being seen.

If meetings of adults are to take place frequently in the spaces that might be jointly shared with the school, normal size chairs will have to be available. Storage for these will be necessary.

5.05 Recreation areas, playing fields and landscape

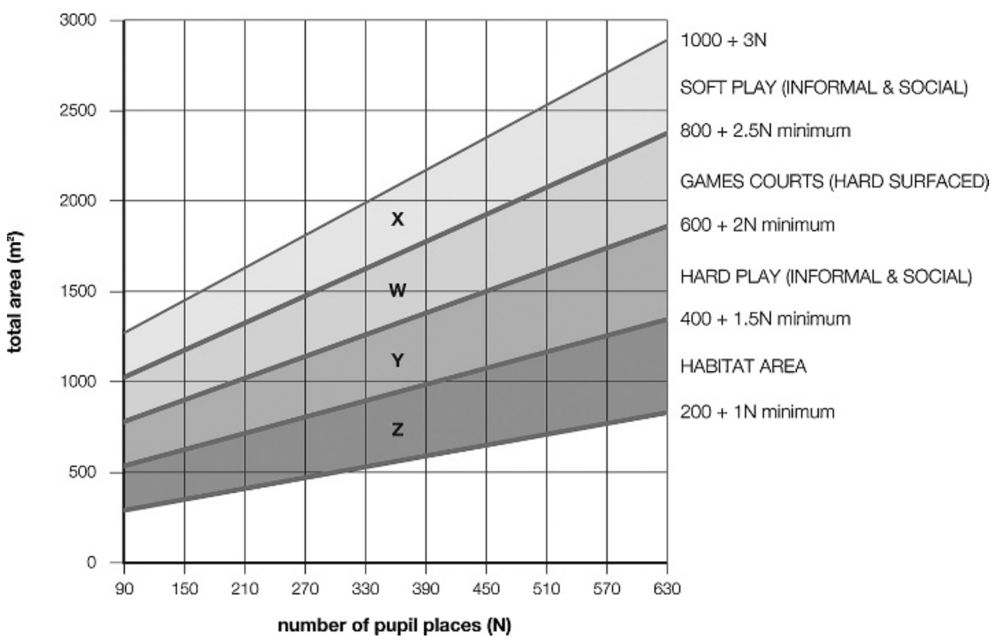
Both hard and soft recreation areas are needed with a good visual link and easily accessible from the building. For infant schools, the hard area need not be laid out for formal games. **21.2** shows the total area for pitches and playing fields and **21.8** shows the additional informal recreation area needed, of which half should be hard surfaced. The remainder is usually soft and can be developed to provide a variety of activities, including wild area, pond or animal enclosures.

Playing fields are required at schools having pupils over 8 years of age. A junior football pitch size is around 75 m × 45 m, but training grids and running tracks are probably more useful than a second pitch at the larger junior schools. The fullest use of outdoor areas depends on comfort and protection from wind, and the role of landscaping in providing this is as important as its visual or educational function.

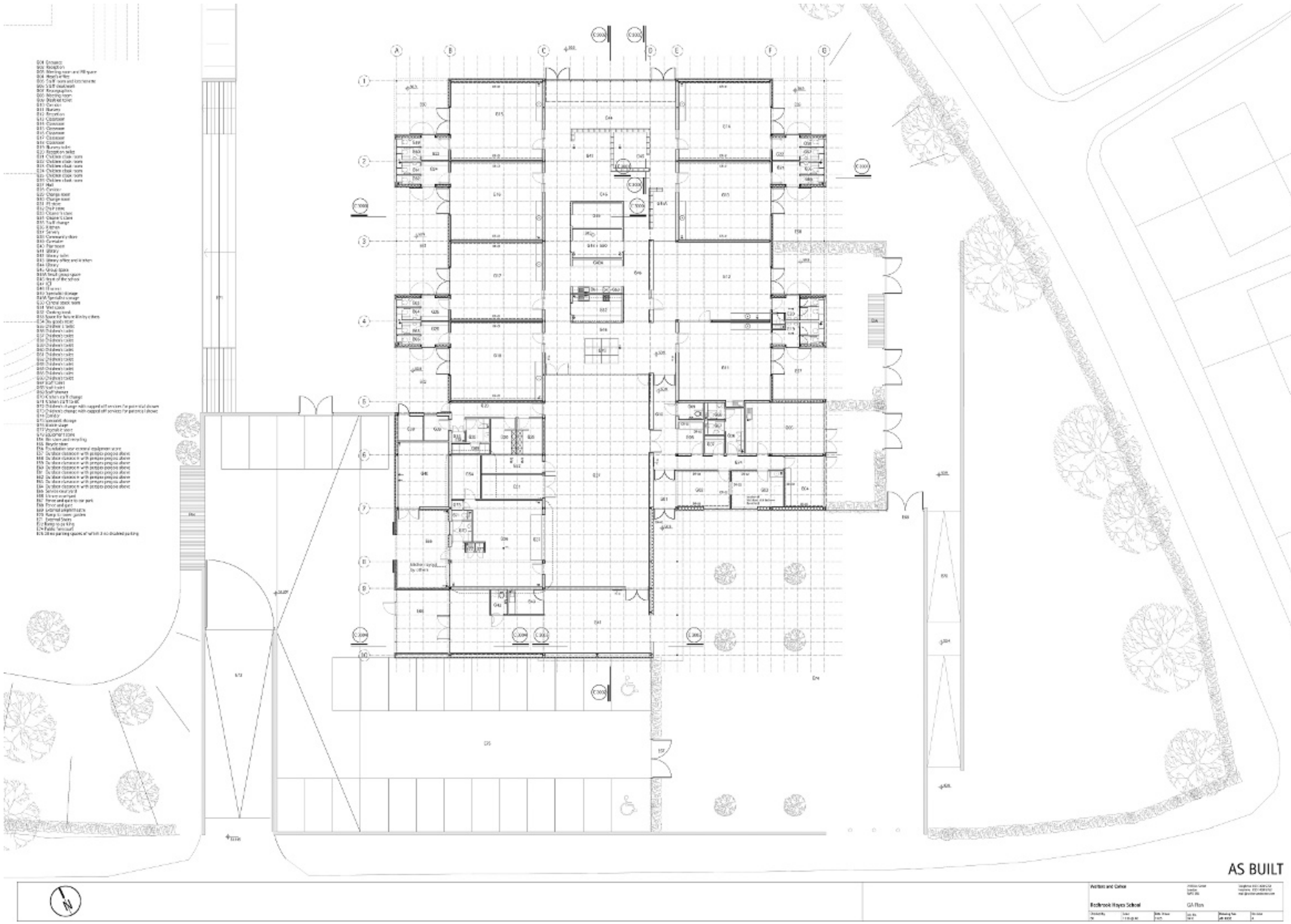
5.06 Design strategy for new schools

Primary school buildings are usually single storey, to allow flexibility in organisation, easy access to common resources and outdoor areas, and easy movement of people with disabilities and trolleys carrying teaching equipment. Changes of floor level appropriate to steep sites require ramps to provide for these. The main elements, the class bases, are grouped to allow the sharing of resources and quiet rooms; with easy access to the library and other common areas such as the hall. The visitors' entrance and the the kitchen should be closely associated with the hall.

21.9 shows one design. Similar organisational structures underlie many other schemes, including those in other forms. Approaches to



21.8 *Minimum recommended additional resource areas for games courts, informal and social (hard and soft play) and habitat for Primary Schools*



21.9 *Redbrook Hayes School, Staffordshire. Architects: Walters & Cohen. An approach to a 1FE Primary School with nursery and branch library incorporated within the site. The new branch library is physically connected to the new school and can be entered from the school hall or from the shared forecourt. The school and library can operate independently and have different opening hours, but can also work together so that pupils will be able to access the library from their school and, if desired, the community will be able to use the school hall after school hours without opening the remainder of the school. As a result, toilets and change facilities have been located off the hall to encourage community use. The nursery has been located close to the public forecourt to give parents easy access. The main school has a central space, or 'heart' which can accommodate a range of activities and give the school an opportunity to create its own identity. The classrooms are arranged in rows on either side of the 'heart' opening onto this space for circulation so that moving around the school becomes part of the learning experience*

Primary school design can vary, some work with all activities in one space, others have shared practical spaces.

5.07 Extending and remodelling existing schools
Primary schools tend to have strong design characteristics according to their date of construction, and the adaptability of their form varies widely. In consequence, many extension projects include an element of remodelling, to remedy the revealed problems of the original plan and to ensure the coherence of the overall scheme.

5.08 Schedules of accommodation
BB 99, *Briefing Framework for Primary School Project*s offers guidance for teaching and total floor areas for all types of primary schools. **21.10** shows the possible range of these areas according to the number of pupils on roll, and individual promoters have to decide an appropriate balance between space and cost.

5.09 Design requirements

Class bases
Each class should have a definable 'home base' but this can be achieved with a variety of forms from fully open plan to enclosed rooms, and all variations continue to be built. Commonly, two or more class areas are closely associated, with some sharing or intercommunication. **21.9** shows one design approach.

The floor area needs to accommodate a range of activities including sitting at tables or on the floor, practical activities including science and technology, with a sink with hot and cold water, standing-height worktop, and direct access to an outside paved area for summer use. However, to use such a door for general access all year round, though tempting, can easily negate all other energy-saving strategies, to say nothing of possible security problems. Table I shows the range of activities that may have to be accommodated in the classroom or class-base.

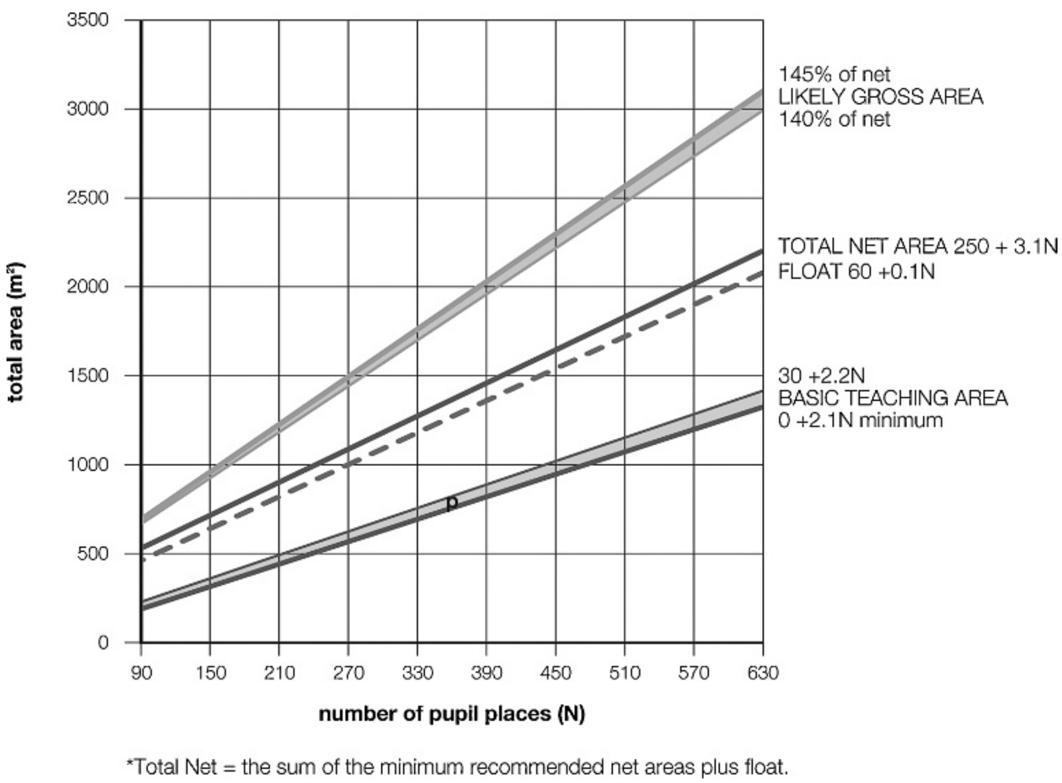
A number of different furniture layouts should be provided for with the use of mobile items where possible to enable quick classroom set-ups. Storage of resources should be arranged for ease of pupil access. Teachers may want some storage for their own use in the classroom, this could be provided at a higher level than pupils' storage. A teaching materials' store is needed for each class base, either 'walk-in' with a door or open shelving. Two classes might share a double size store.

Hall
Used for assembly, physical education, music, drama and for parents' meetings and social events. It is also usually used for dining and with the recent concerns over the quality of food eaten at school there is new guidance on design for both kitchens and dining areas from the DCSF. The hall should be easily accessible from the visitors' entrance. The hall should not used for general circulation and should be acoustically isolated from teaching areas. Height 4.8 m over most of the area to permit climbing frames pivoted to one wall. A sprung floor is desirable, if seldom affordable. It may be licensed for public entertainment. Stores for PE equipment and dining furniture should have full-width access directly from the hall and preferably full-size chairs.

Other teaching areas
- A group room may be provided in larger schools, often referred to as the second large space. This is an enclosed, acoustically isolated area, used for drama, music or TV. It will have a carpeted floor and dimmable lighting.
- One or two small enclosed quiet rooms should also be provided around the school.
- The library may be planned as a central area or as part of a widened corridor, accessible to the whole school.
- Resource areas for science, technology, cooking or clay work in larger schools, possibly in the form of bays of around 8 m^2 accessible to the whole school.

However, it may be useful to be able to close off library and resource areas.

Toilets, changing rooms, coat storage
A minimum of 1 WC and washbasin per 20 pupils, but often two per class are provided. Easily supervisable from the class bases and



21.10 *Recommended areas for total gross, net and basic teaching*

Table I Activities to be accommodated in the classroom or classbase
All those activities marked as required can be accommodated in the minimum recommended size of small classroom (the bottom of zone B). Activities marked as preferred or optional will generally need a standard classroom (zone C), while four computers or further tables for wet and messy work will require a large classroom (zone D).

Activities	Facilities[1]	Foundation	Y1 and 2	Y3 and 4	Y5 and 6
Group discussion, whole class teaching	whiteboard, interactive screen or similar	required			
Literacy, numeracy, other subjects	adequate table space, generally arranged in groups (half table per pupil assumed)	for 1/3 to 2/3 of class	required for whole class		
Group discussion, literacy and generally not required numeracy, whole class activities, storytelling	free floor space, usually on a carpeted area, for gathering the whole class together sitting on the floor	required	one area used for both	one area used for both	generally not required
Large scale construction kits, practical 3D work, some ICT work using robots etc.	[smaller] free floor space for space-consuming work on the floor, including large-scale construction	required			required
Individual or group reading/research	a book corner or quiet area with room to browse, and cushions (with the option to overlap with the free floor area if small class-base in zone B)	required	preferred	optional	not required
For creative play and role play	space for creative play and role play	required	preferred	not required	not required
individual, group or whole class ICT based work	desktop computer workstations or laptops	1 to 2	2 to 4 depending on other ICT available		
Individual AV music or language work	audio-[visual] resources (overlapping with book corner)	preferred	preferred (if available)	optional	not required
Group or whole class music activities	music resources, on trolleys or out on permanent display	optional	optional	available elsewhere	available elsewhere
Drawing, sketching and working with 'compliant' materials such as fabric and cardboard etc.	resources for 'dry' practical activities, using the tables available, such as making and testing	required			
2D and 3D science, art and design technology work using paint, glue, sand, water etc.	sink, washable floor area and resources for simple 'wet' practical activities	required	required (may be in shared teaching area)		
2D and 3D design and technology work using resistant materials such as wood and some plastics	further tables or fixed side benching and sink and resources for wet and messy work, some 'heavy duty' tables for hand tool work	required	optional (may be in shared teaching area)		
All activities as identified above	space for wheelchair user, specialist appliances or equipment and possible assistant	required			

1. For information on furniture and equipment specifications please see 'Furniture and Equipment in schools: A Purchasing Guide' or download it at **www.teachernet.gov.uk/schoolfurniture**

accessible from out of doors via a draught lobby without entering the class areas. Separate toilets for each sex are required where children are over 8 years old. Coat areas may be conveniently combined with an entrance lobby shared by a pair of bases, possibly incorporating the toilets. Provision of Toilets at school has been a major area of concern for some time and the DCSF has produced design guidance 'Toilets in Schools' that gives standard specifications, layouts and dimensions on how to provide better toilet facilities. Shelves or racks should be provided for lunch boxes and sports bags. Changing rooms are no longer a statutory requirement for those aged under 11, but may be considered appropriate, and may be combined with one set of toilets.

Non-teaching areas

- Visitors' waiting area with space for displays of school work
- School office, including a reception counter overlooking the entrance. The computer with all management, finance and pupil records will be housed here, and some privacy is necessary for this. A curtained corner with a chair or bed for sick children

to rest under supervision is often thought more convenient than using the medical room for this purpose
- Stock room
- Head teacher's room, near school office, but not too isolated from teaching areas. In small schools, this room may also have to serve for medical inspection (MI) and should be fitted with a washbasin
- A deputy head's room may be required in larger schools and this usually serves for MI
- A MI room must be provided and may be used for visiting therapists or other support for pupils with SEN and disabilities, if there is a separate 'sick bay' (see above – school office and options for headteacher's or deputy head's room)
- Staff room for relaxing and some preparation of teaching material
- Staff lavatories are more flexible if unisex, each with a washbasin
- A lavatory for disabled use can be provided for use by children and adults in a small school; in a larger school two may be justified
- Caretaker's store and separate office

6 MIDDLE SCHOOLS

6.01 Age range and typical sizes

May take pupils aged 8–12, whereupon treated as a primary school by the DCSF. Sizes range from 240 to 360 pupils. Alternatively, takes pupils aged 9–13, and is treated as a secondary school by the DCSF. Their sizes range from 360 to 600 pupils.

6.02 Curriculum, organisation and accommodation

Years 8–12 middle schools are generally similar to primary schools, but have the challenge of covering the start of Key Stage 3 of the national curriculum; 9–13 schools do have more specialised spaces, but still have similar challenges of straddling two Key Stages. The range of teaching and total floor areas and the schedule of individual areas for middle schools can be calculated by the methods given in BBs 98 and 99, and the design features determined from an appropriate combination of elements of primary and secondary practice. A number of the challenges faced by separate middle schools can be addressed through the increase in all age campuses.

7 SECONDARY SCHOOLS

7.01 Age range and typical sizes

Contains pupils 11 years of age and over. Sizes range from 450 to 1200 pupils in years 7–11. Secondary schools are usually described as having so many 'forms of entry' (FE). For example, a four FE school has four forms up to or around 30 pupils in each of its 5 year groups = 600 pupils under 16 years.

Those who wish to continue full-time education beyond the age of 16 can do so at the same school, or at a tertiary college, sixth form college or college of further education. It is difficult in a school sixth form of under 100 students to ensure variety of choice and viable teaching group sizes, so schools of less than four FE are often 11–16 only. This is often addressed by partnering between schools and between schools and colleges of Further Education, or by shared satellites which offer different ways of accommodating a range of courses post-14.

7.02 Curriculum and organisation

Secondary schools must cover the national curriculum at Key Stages 3 and 4. The curriculum for those over 16 years old is largely determined by national examination requirements: 'A' levels and vocational qualifications.

Pupils are based in a form or tutor group for pastoral care purposes, but move to specialist rooms and teachers for most subjects. The sixth form may have their own social base with a common room.

Schools can be organised in a range of different ways some may be by subject departments or faculties of related subjects, some of them have home bases, whatever the approach this is reflected in the layout of the buildings. Larger schools may also be divided into lower and upper schools, usually after year 9.

7.03 Site planning – access, roads and parking

Secondary schools are substantial land users and traffic generators. A new school may require extensive off-site road works, on-site turning facilities for buses and large car parks; particularly if community use during the day is involved. Vehicular access will be required to the rear of the buildings for service deliveries, playing field maintenance and fire-fighting. Adequate provision should be made for cyclists and storage of bikes and attention must be given to pedestrian access and the need for separation and safety. LAs are required to have clear policies on these matters, agreed with the school.

7.04 Recreation areas, playing fields and landscape

This is described in BB 98 as the 'Net Site Area: Playing fields' and is the total of the following five categories of space, **21.3** and **21.11**:

- Sports pitches
- Games courts (hard surfaced)
- Soft informal and social
- Hard informal and social
- Habitat areas

Plus any supplementary net site area needed for non-school or support functions.

In confined sites, the sports pitches area may be provided on a nearby site and/or through a single all-weather pitch. Where there are no other outdoor PE facilities on the site, a multiuse games area (MUGA) should be provided on the site, to allow easy access for outdoor team games.

The informal and social areas and habitat can also be a rich resource for teaching work related to vocational courses such as horticulture, gardening, landscape design, art and design and land management.

The total area of sports pitches must include playing field area laid out to suit team games. All-weather pitches, including synthetic turf pitches or polymeric surfaces, allow more intensive use than grass and, particularly with floodlighting, can also offer a popular community resource. The area of all-weather pitches can be counted twice for the purposes of both these guidelines and regulations, as they can be used for significantly more than the 7 h a week required of team game playing fields.

7.05 Design and development strategy for new schools

The major components of a secondary school plan are the subject departments with different needs in regards to size, shape, location and environment. Frequently, there is a requirement to develop in phases. As each successive phase of new building is added, some remodelling of existing areas is needed to preserve departmental suitabilities.

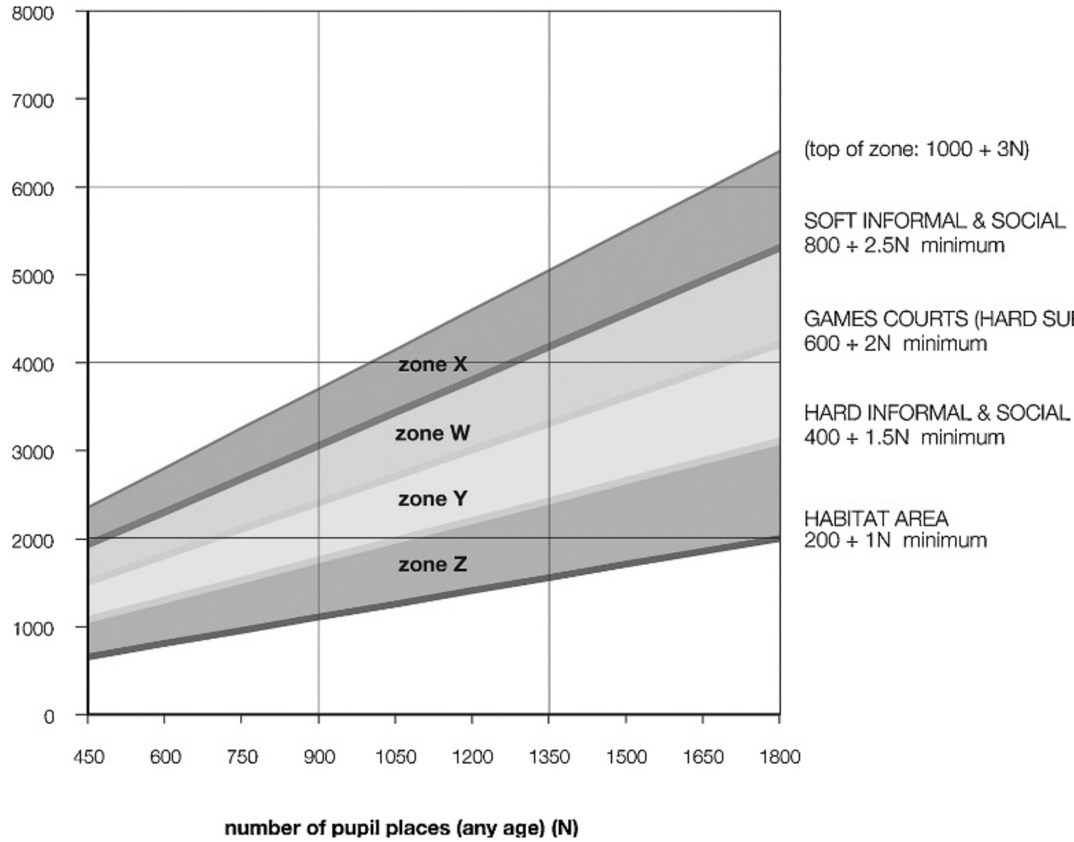
One approach to addressing these factors may be a campus of linked buildings, often incorporating a central mall or pedestrian street. This allows new buildings to be attached to an extendible circulation core. The basic planning unit may consist of several departments, each with a cluster of specialised and general teaching spaces around a common resource centre, an illustration of this approach is shown in **21.12–21.14**.

7.06 Community use and Extended School

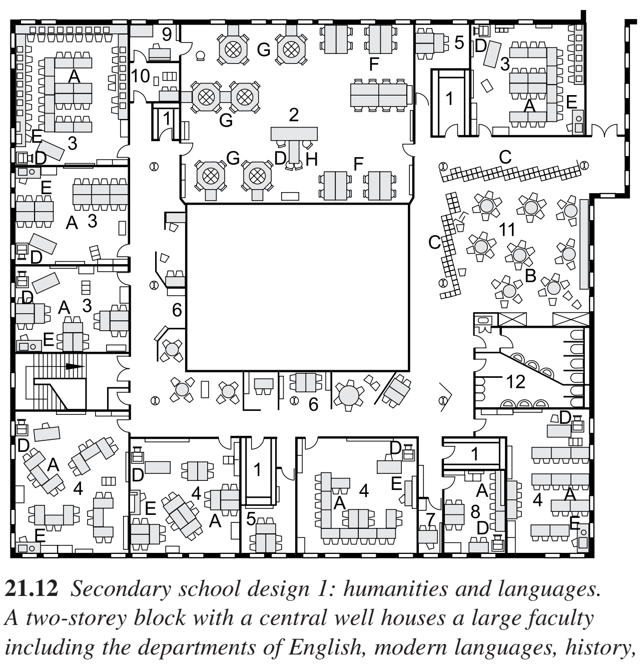
Many secondary school facilities are suitable for joint use, particularly those for sport and the performing arts. Other areas are suitable for evening classes and for youth and community organisation lettings.

Many schemes are designed now for a wide range of extended services appropriate to the local community. Any large joint-use scheme will be jointly funded, from a range of sources and promoters will expect to see these areas prominent on the most visible part of the site, designed to attract the general public. It is important, however, that the design is coherent and proportionate and all the stakeholders co-operate and arrive at a community consensus.

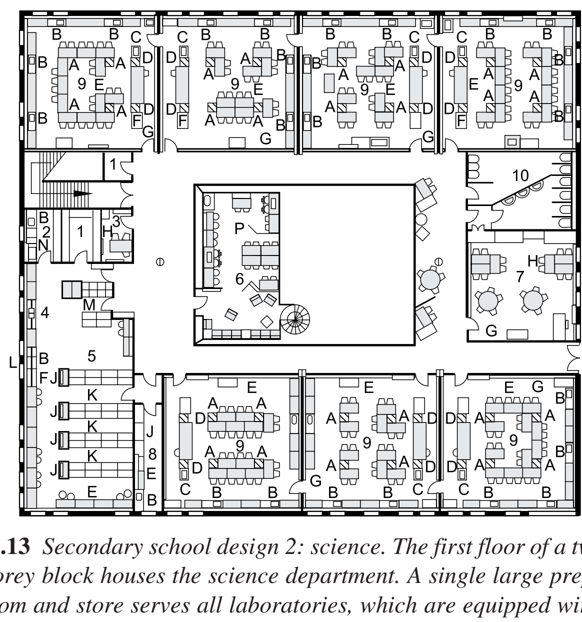
Security is an important issue, to prevent crime against persons and property, and to ensure that the users feel safe, especially at night. This is a matter of basic design as much as sophisticated electronic systems or hostile-looking railings. **21.15** shows the ground plan of a large secondary school with extensive community and extended services use.



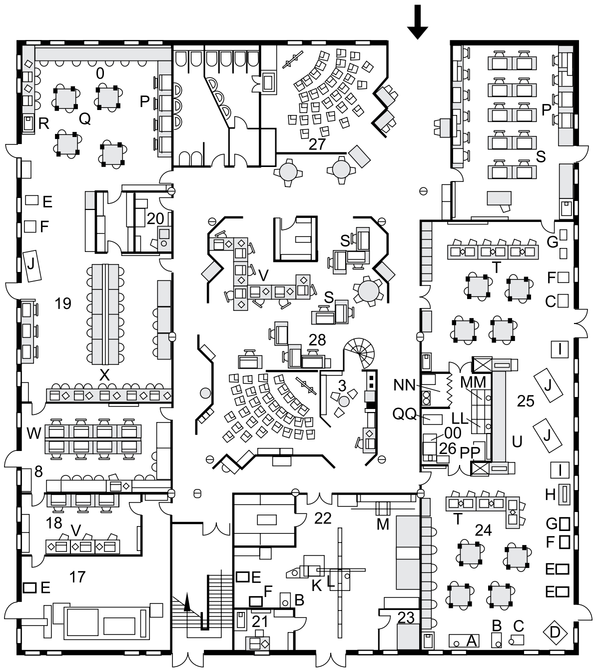
21.11 *Minimum recommended additional resource areas for games courts, informal and social (hard and soft play) and habitat for Secondary Schools*



21.12 *Secondary school design 1: humanities and languages. A two-storey block with a central well houses a large faculty including the departments of English, modern languages, history, geography, and religious studies. The first floor shown includes a large 'open-learning' language centre, teaching rooms of various sizes, staff offices, storage, and shared study or social areas surrounding the central glazed well*



21.13 *Secondary school design 2: science. The first floor of a two-storey block houses the science department. A single large prep room and store serves all laboratories, which are equipped with service bollards and loose worktables to allow a variety of arrangements. The central mezzanine study and work area is accessible from a similar central area on the floor below, which houses technology*



21.14 *Secondary school design 3: design and technology. The ground floor of a two-storey block, with central resource/work/display area, large materials prep room and store, and paired technology areas for work with a range of materials and components*

7.07 Extending and remodelling existing schools

Most existing secondary schools have reached their present form over many years, via reorganisation and multiphased extension. Pressures of cost and time favoured the addition of detached ‘blocks’, usually resulting in departments being split between several buildings, a good deal of external circulation, and generally haphazard organisation and appearance.

Projects for rationalising existing buildings to improve departmental suitability and to upgrade individual facilities involve a complex mix of remodelling, linking and small-scale extension. The design process involves extensive consultation with the users and managers, who will have strong views on historic features which do not work, and may be prepared to cooperate in facilitating complex on-site working arrangements in order to get the right end result. The age of the buildings may mean that substantial maintenance and energy conservation work, including rezoning of heating systems may also be required, involving synchronisation of capital and revenue budgets. **21.16** shows such a project.

7.08 Schedules of accommodation

The schedule of individual teaching spaces is derived from the analysis of proposed curriculum and pupil numbers, plus communal or untimetabled areas such as the library, study areas, and halls. DCSF BB 98 explains the calculation process fully. **21.17** shows the possible range of gross floor and teaching areas.

7.09 Design requirements

English, maths, humanities, languages

All require a mix of general classrooms, seminar and tutorial rooms, for groups of 15–30 pupils, sitting formally at tables, for ‘chalk and talk’ or less formally around grouped tables for discussion. Some larger rooms will also be required for teaching which includes practical work in a classroom context, with larger tables and extra work surfaces, for example, using large maps, recording equipment, or a small number of computers. Rooms for teaching can be grouped round a common resource and study area, as in **21.12**.

Information communication technology and business studies

Use of information communication technology (ICT) will be possible throughout the school, but teaching of basic techniques will require one or two dedicated rooms possibly associated with business studies. These range from word processing to management and ‘mini enterprise’ activity, and require seminar and group work space with furniture and ICT facilities which can be easily rearranged, as in real business and industrial environments. A business studies suite may have extended functions: careers advice, industry liaison or a conference centre, perhaps jointly financed and used by local enterprises. This could comprise a display area, library and reference area, and one or two small interview rooms.

Science

Laboratories are seldom devoted to one science, and need to be internally flexible (see Chapter 23). Approaches include Service bollard systems and overhead boom systems with movable standing-height tables. A single central preparation and storage area is more practical and economical in use of support staff than the traditional small prep rooms shared by two labs and is conveniently associated with the faculty staff room. A separate external store is needed for flammable materials in bulk. The provision of outdoor areas – ponds, greenhouses, growing plots or animal farms – is a matter of local tradition rather than curriculum requirement, but is very strong in some areas not all of which are rural. **21.13** shows a typical new science department with single preparation and storage area, central pupils’ reference and computing area, and laboratories with service bollards and movable workbenches. DCSF Faraday Project designs for science gives the latest advice.

Design and technology

Pupils will be involved in design and construction in metals, wood, plastics and fabrics. Design takes place in close proximity to making and testing. Washbasins and warm-air hand driers are essential whether designing on paper or with computer-aided design (CAD) systems. Heat treatment and other processes produce fumes and dust, which must be extracted at the point of origin.

A central resource area is one approach for display and reference, supervisable from the work areas, as shown in **21.14**. In remodelling of existing premises, the existing ‘industrial workshop’ image may be a problem. The creation of such a central area, perhaps by infilling between blocks, can be the key to the visual transformation of the suite, as well as providing an extra facility.

Secure storage is required for pupils’ work in progress, and this might be associated with the faculty room used by teaching staff and technicians. A central storage and preparation area for bulk materials is required, but small electronic components and the like are best kept in a separate clean store.

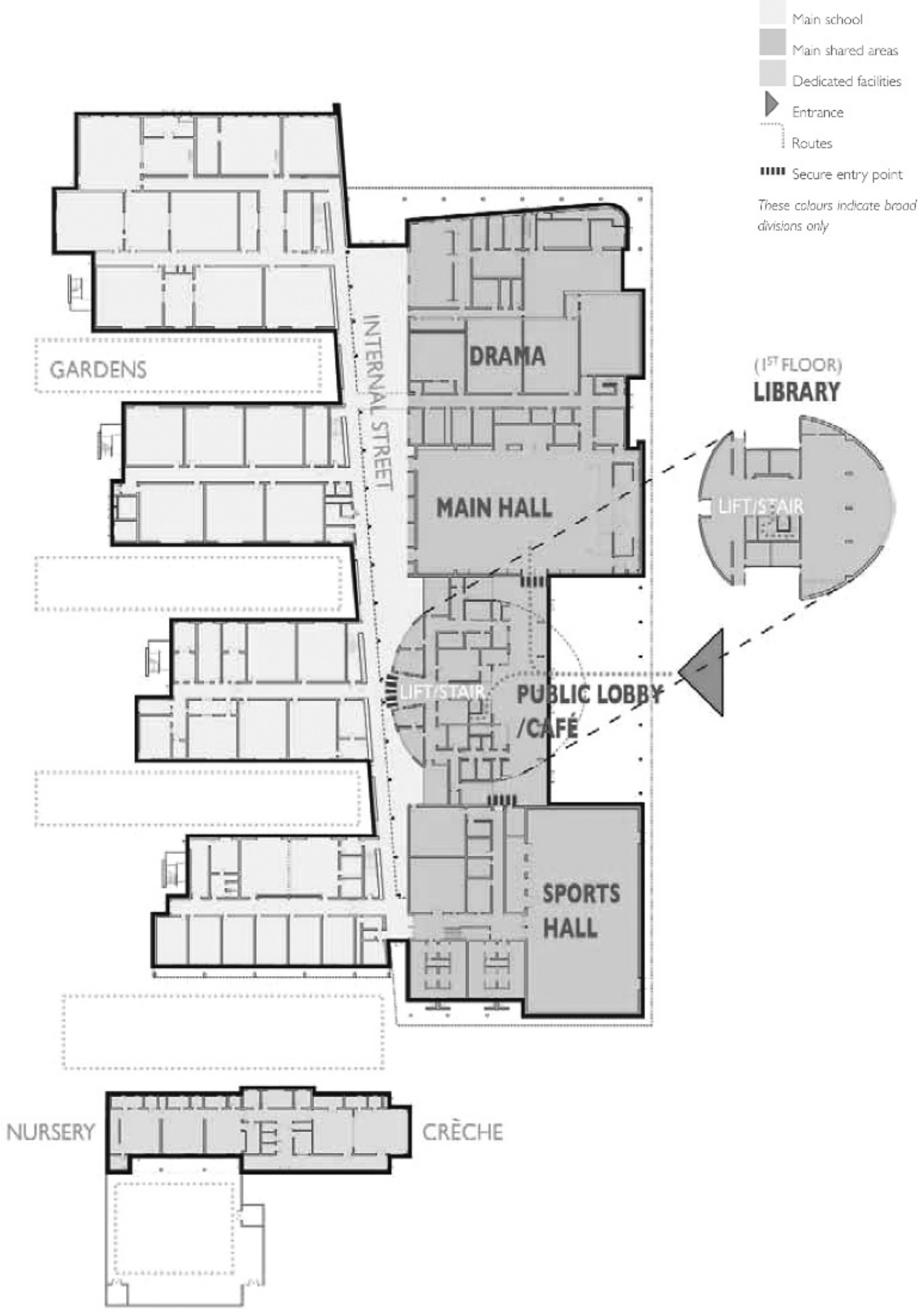
Food technology may be part of general technology and this will include experimental work and testing as well as cookery.

Art and design

Planning can be similar to that for technology suites, possibly with more flexible open plans, and with similar careful separation of more messy activities – sculpture and ceramics – from cleaner areas. Work with fabrics will take place here as well as in technology. Daylight remains a valued commodity in these areas.

Physical education

Most schools will require two spaces. These have traditionally been a sports hall and a gymnasium, but rising standards in sports halls – sprung floors, heating and lighting as found in public and joint-use sports centres – make it possible to perform most activities in the same space; see Chapter 18. Separate dance studios and multigyms are then often provided instead of a gym.



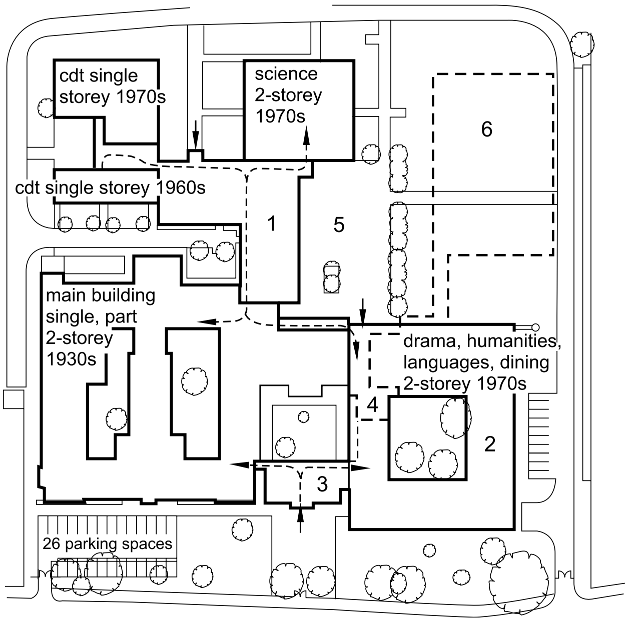
21.15 *Jo Richardson Community School, Barking and Dagenham. Ground Floor Plan. Architects: architectureplb*

Community use is an essential element of most school sports and PE provision, and may have a radical influence on the amount and type of space and facilities provided. Typically, additional joint funding would allow a larger sports hall, a multigym, separate exercise studio and improved quality changing rooms to conform to adult expectations and to withstand constant use.

Swimming are unlikely to be provided except by joint funding for community use. The most common and workable scenario is for the school to provide the site in exchange for agreed hours of use. The major financing and management will lie with the Local Authority recreation department, or with a commercial enterprise. Where a swimming pool is readily available to pupils, the regulation playing field requirement may be abated.

Music and drama

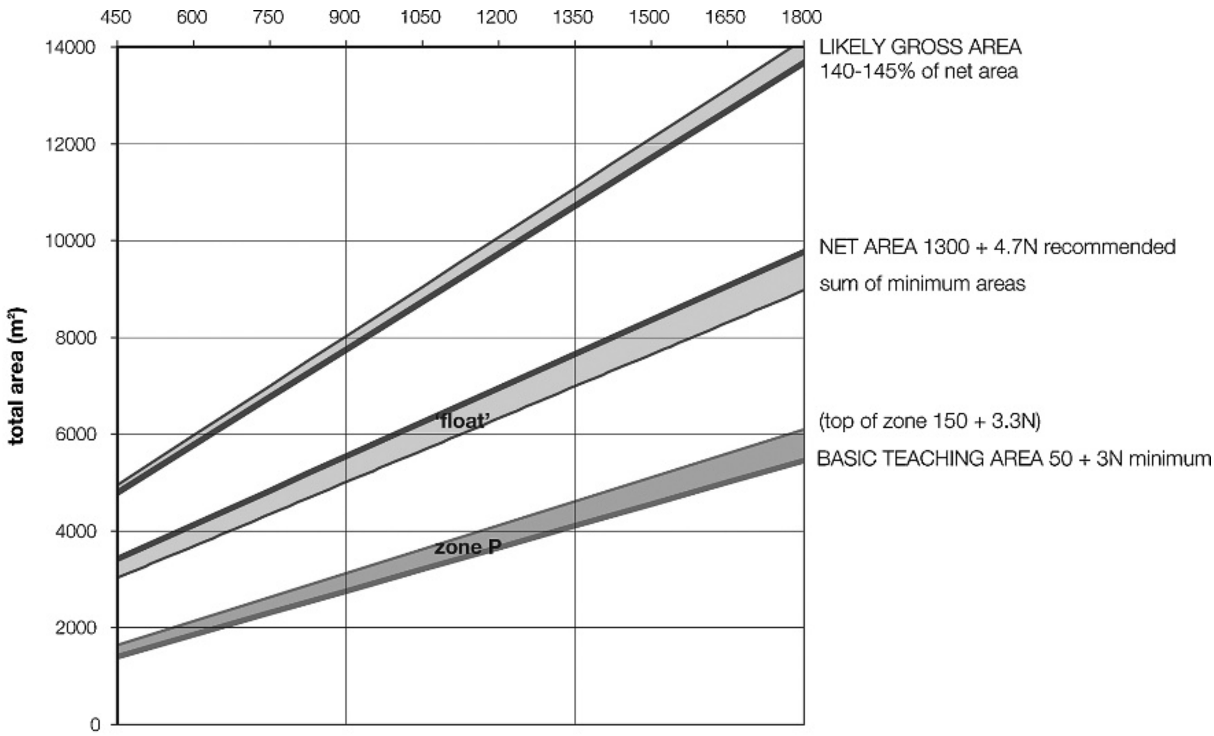
These subjects may well share a suite. Dance activity also overlaps with physical education. In music, a good deal of emphasis is placed on individual and small-group work, often involving advanced electronic instruments. Consequently, security and extensive provision of electrical power is important, as well as acoustic isolation from the remainder of the school. Drama studios



21.16 *Shoeburyness High School, rationalisation plan*

1 *New art/link block unites departments and reduces energy losses*
2 *Former art rooms converted to general teaching space*
3 *New link classrooms and pupils' entrance*
4 *Open area at ground level filled in to form link and extra classroom*
5 *Landscaped courtyard*
6 *Site for future expansion*

This school consisted of separate single- and two-storey blocks built between the 1920s and the 1970s. The most recent phase, to replace a number of demountable classrooms, knits the disparate parts together by means of a new art block and a further linking classroom block, together with some infilling of open areas at ground floor level, and internal remodelling. Besides relating departments more closely and providing fully internal circulation, energy use and security are improved, and more attractive outdoor areas created. The joint-use sports centre is separate from the main buildings



21.17 *Recommended areas for total net, gross and teaching*

need not be elaborate, and may take the form of a large classroom or a multipurpose hall, with blackout and simple lighting system. Secure storage is necessary for all areas.

Library, resource and study areas
Developments in ICT reinforce the library's importance as information centre rather than rendering it unnecessary; books and printed material remain important alongside use of the Internet, CD-ROM and programs networked from central file servers. However, both resources and study areas may also be dispersed around the school in faculty centres. If the school is appropriately located and planned, the school's library may be combined with a public library jointly financed (see Chapter 28).

Halls
Full assemblies of large schools are seldom practicable, and all main large spaces will be used for assemblies of year or house groups, and for other functions – dining, drama, music, parents' meetings. This gives rise to the usual design problems of multipurpose halls – floors, seating, stages, acoustics.

Social areas
Areas where sixth formers can socilaise and study are usually provided, and sometimes for other groups. Casual social areas may be situated about the school by widening corridors, providing seating and a drinks vending machine.

7.10 Non-teaching areas

Toilets and changing rooms

These follow normal adult practice – see Chapter 5. Changing rooms should be designed to reflect the different demands of indoor and outdoor activities. If possible, provide access from outside via a boot-cleaning area to a single set of changing rooms which is also directly accessible from inside should be provided. Provision of Toilets at school has been a major area of concern for some time and the DCSF has produced design guidance 'Toilets in Schools' that gives standard specifications, layouts and dimensions on how to provide better toilet facilities.

Coat hanging and lockers

Lockers or coat and bag storage for all pupils to store their personal belongings during the day, might be provided at the equivalent of at least 2 m^2 per class group. There are many solutions that depend on design, management and organization but lockers and coat and bag racks may be located in classrooms, centrally (perhaps in a theatre style cloakroom, manned at certain times of the day), or in corridors or social areas: ideally in circulation areas of at least 2.7 m wide, but not dead ends.

Dining rooms and kitchens

Dining rooms may be dedicated or dual purpose – see Chapter 17. The proportion of pupils who take a cooked meal varies very widely, but staggered lunches with up to four starting times are universal.

Dual-purpose rooms require adjacent storage for the dining tables and chairs, and they cannot be fully timetabled because of the time required to set out and clear away furniture. School catering arrangements have constantly gone through change with the move towards 'Fast food' and the consequent reduction in size of large old kitchens with the surplus space being used for other purposes. Recent concerns about poor food and the impact of poor diet on concentration and performance has led to new guidelines on 'Healthy Eating' at school and DCSF has produced guidance on kitchens and dining.

Staff rooms

Where staff preparation and resource facilities are provided in faculty areas, the central staff room is largely social in character. It should be adaptable for meetings, staff conferences and in-service training events. A separate room for smokers may be requested.

Staff offices

Individual rooms will be required for the head teacher, possibly a bursar, and for deputy heads, year heads and any staff who need to interview pupils, staff, and parents, and to keep confidential records. Heads of faculty or department may have their own rooms or may use the faculty staff room.

Administrative and service staff offices

A reception and waiting area with display facilities is required for visitors adjoining the main office. The computers for the management information system should be in a separate room, as confidential information is often on-screen. The office for the caretaker, school keeper or site manager (whatever his or her title), should also be in this area and not adjoining the boiler house.

8 PROVISION FOR SPECIAL NEEDS IN EDUCATION

8.01

Some children have special needs in education: physical or mental difficulties which mean they cannot cope with the normal curriculum or school activities. Wherever possible, these pupils are provided with extra assistance or facilities within ordinary schools, or in support units attached to them.

There remains a requirement for special schools for some pupils, with a very high level of specialist teaching and care staff, curricula geared to their individual needs, and purpose-built space and facilities. In addition to the education authority, the local health authority provides some services including speech and physiotherapy, and may contribute capital for hydrotherapy pools or other facilities. Social services departments also have an overall duty towards children with disabilities, and may be involved in briefing and provision of capital.

8.02 Provision in mainstream schools

Some children, mostly those with moderate learning difficulties (MLD), mobility problems, vision or hearing impairment, or speech and language disorders, can attend normal schools given staff support, some minor building adaptations, and the use of special facilities for part of the time. BB 94 gives very full design guidance.

In the case of wheelchair users, it is often difficult to make entire secondary schools accessible and with adequate means of escape. However, the practice of designating one school in an area fully accessible and concentrating provision there is seldom applied and BB 91, a Management and Design Guide, offers a range of practical solutions to accommodating both wheelchair users and other people with disabilities following an Accessibility Audit.

8.03 Special schools in general

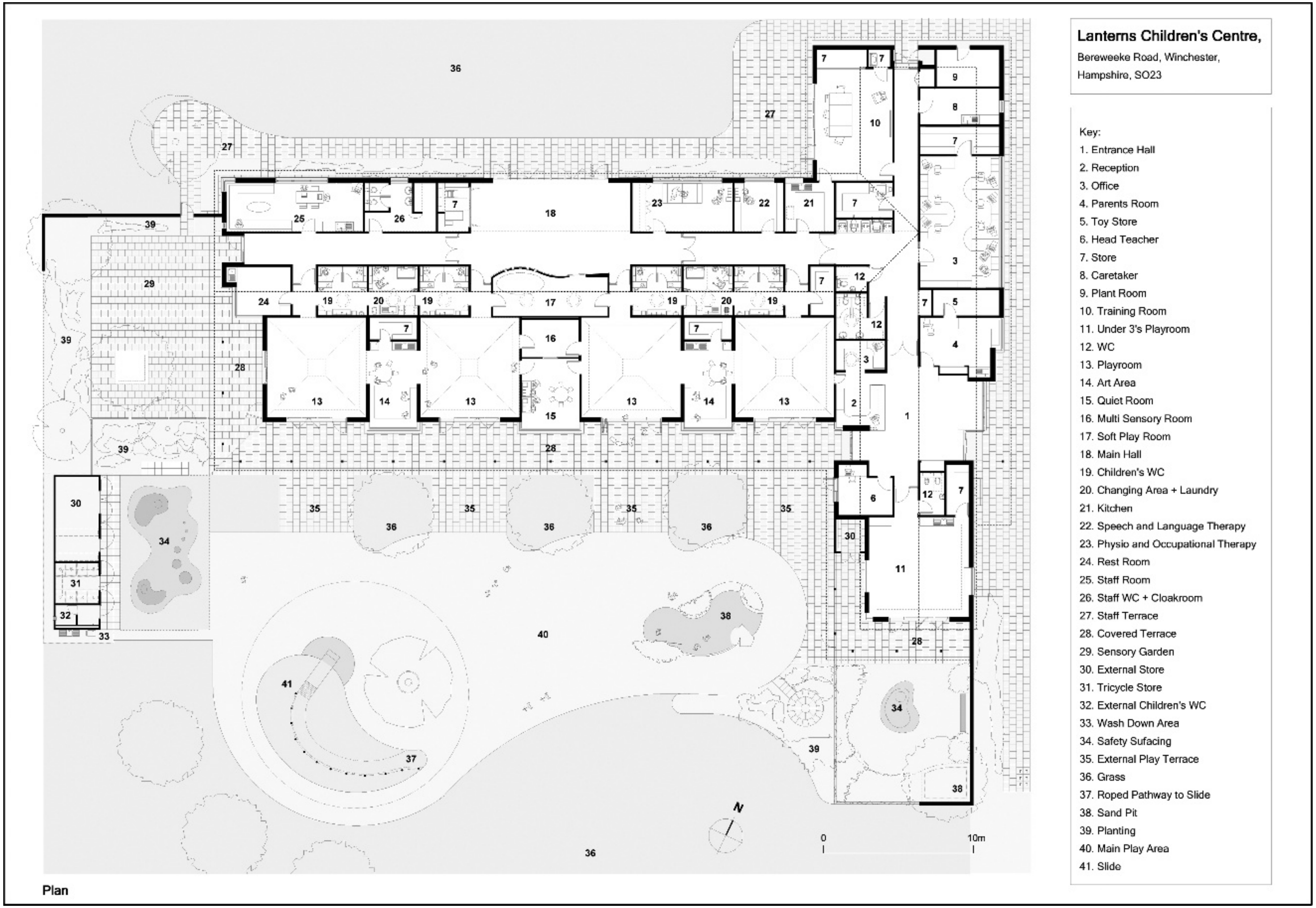
The types of special school which are widely found are detailed below. Although described as having a specific role, each special school is different and tends to follow the needs which emerge in a particular locality. **21.18** shows an inclusive 55-place pre-school setting for 0–5 year olds, with additional integrated therapy and parental support services for families, particularly those caring for a young child with special educational needs. BB 77 (revised) gives full design guidance. Very specialised schools for the visually and aurally impaired, or for accident victims are very small in number and generally run by charitable foundations.

8.04 Provision for pupils with MLD

Most pupils with Specific Learning Difficulties (SpLD) or MLD attend mainstream school and are included in general classes and tutor groups. For some subjects, however, they may be in smaller teaching groups or appropriate sets.

However, there are a number of children, typically these are at secondary age range who cannot keep up in mainstream school work and there are a few independent special schools for children with SpLD and some community special schools accommodate children with MLD. School size is from 60 to 120 pupils, using a modified mainstream curriculum with class sizes of around 12 pupils. To provide adequate specialised facilities in a school of this size is difficult and these schools benefit from being near mainstream schools for mutual support, exchange of expertise and a variety of schemes for part-time integration.

Some children have multiple disabilities and may have mobility problems in addition to mental or behavioural difficulties. Where no such need exists, detailed design requirements are similar to those for mainstream schools. The fact that a school for pupils with moderate learning or behavioural difficulties has provision for wheelchair users should not be a reason for sending pupils there who have only physical disabilities.



21.18 *Lanterns Children's Centre, Winchester. Hampshire County Council Architecture and Design Services*

8.05 Schools for pupils with severe learning difficulties (SLD)

These are all-age schools for children with permanent severe brain damage which affects physical functions as well as learning. The range of ability is wide, the curriculum is developmental. It focuses on independence, self-care, and social living together with National Curriculum work at a level appropriate to the pupils' abilities. Schools are typically of 50–80 pupils divided into primary and secondary sections, and probably with a separate unit for 16–19-year-olds.

Class sizes are around eight pupils. Detailed design requirements can be very specific: non-teaching areas are extensive, requiring special toilet and hygiene facilities, storage for special supports and equipment, therapy and treatment rooms, and facilities for a large number of teaching and ancillary staff. Many pupils come in taxis or special buses, and there may be a need for on-site turning and unloading with a canopy for wet weather. Outdoor areas for some relatively inactive children need to be very sheltered and large internal courtyards have many advantages.

8.06 Schools for pupils with physical and neural impairment

These are all-age schools, for those who cannot cope physically with a normal school environment: some of those in wheelchairs, some with brittle bones or weak hearts, or who cannot perform basic physical tasks such as writing. The range of ability can be very wide up to mainstream curriculum standards; but requiring extra support or equipment such as personal computer interface devices. Typically all-age schools are of 50–80 pupils, with class groups of around eight. Extensive non-teaching areas are required similar to SLD schools.

8.07 Schools for pupils with emotional and behavioural difficulties

Separate primary and secondary schools for children who are aggressive, withdrawn or insecure. A mainstream curriculum may be followed, but the main function of the school is to modify behaviour by social means as much outside the classroom as within it. Class groups are of around eight pupils. These schools are often weekly boarding schools.

9 REFERENCES

General

The Education School Premises Regulations 1999, The Stationery Office
DCSF Circular 'The School Premises Regulations' www.teachernet.gov.uk/sbregulatoryinformation. Available free from DCSF publications
Fire Safety – Managing School Facilities Guide 6. DCSF Fire Safety Guidance for Schools – new draft guidance is now out for public consultation
DCSF requirements for fire safety were absorbed in the 2000 edition of Approved Document B (*Fire and the design of educational buildings* (6th edn), Building Bulletin 7; The Stationery Office – Since the Building Regulations are not retrospective, it may continue to provide useful advice on how to apply Regulation 17 of the School Premises Regulations to existing buildings.)
BB67 – *Crime prevention in schools: practical guidance*, 1987
BB69 – *Crime prevention in schools: specification, installation and maintenance of intruder alarm systems*, 1989
BB71 – *The Outdoor Classroom* Second Edition 1999 DCSF
BB75 – *Closed circuit TV surveillance systems in educational buildings*, 1991
BB78 – *Security lighting*, 1993
BB79 – *Passive solar schools: a design guide*, 1995
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BB85 – *School Grounds: A Guide to Good Practice* 1997 DCSF
BB87 – *Guidelines for Environmental Design in School*. Revised 2003 DCSF
BB91 – *Access for disabled People to School Buildings: Management and Design Guide* 1999
BB93 – *Acoustic Design of Schools* 2003
BB94 – *Inclusive School Design* 2001 DCSF
BB95 – *Schools for the Future Design Guide* – 2002
BB100 – *Designing Against The Risk Of Fire In Schools* 2007
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BB80 – Science *Accommodation in Secondary Schools: A Design Guide* – Published 1999. Revised 2004
BB81 – *Design and Technology Accommodation in Schools: A Design Guide* – 1996. Revised 2004
BB89 – *Art Accommodation in Secondary Schools*, 1998
BB86 – *Music Accommodation in Secondary Schools*, 1997
BB92 – *Modern Foreign Languages Accommodation: A Design Guide*, 2000
BB98 – *Briefing Guide for Secondary School Projects* DCSF, 2004
Assessing the Net Capacity of Schools (DCSF/0739/2001REV) www.DCSF.gov.uk/netcapacity – 2002

Transforming Schools: an inspirational guide to remodelling secondary schools – 2004 – DCSF
Design of sustainable schools: case studies – 2006 – DCSF

Special needs in education
BB94 – *Inclusive School Design* – 2001
BB77 – *Designing for pupils with special educational needs: special schools*. This has been superseded by draft BB77: Designing for Pupils with Special Educational Needs and Disabilities. Downloadable from http://www.teachernet.gov.uk/management/resourcesfinanceandbuilding/schoolbuildings/designguidance/SENandDisabilities/

Boarding schools
BB84 – *School boarding accommodation: a design guide*, 1997

General notes
The Schools Capital Assets Design Team of the Department for Children, Schools and Families is the main source of design information in this area. Its list of publications is obtainable free from DCSF or at http://www.teachernet.gov.uk/docbank/index.cfm?id=10674. Further design guidance is in preparation, and those on the following subjects are expected to be published during 2007
Faraday Project – Case Studies in science
Kitchens and dining guide

22 Higher education

CI/SfB: 72
UDC: 727.3
Uniclass: F72

KEY POINTS:
- *New institutions becoming Universities are upgrading their facilities*
- *Training facilities for in-service education are increasingly demanded*

Contents

1 INTRODUCTION

Higher education is taken to mean all post-secondary education. Table I gives the main types of institution covered in this section, although the Open University will not be specifically detailed. No particular institution is without its peculiarities of one sort or another: siting; constituents or functions. What follows, therefore, is a series of generalisations which may or may not apply in another time or place.

Many of the building types found in higher education have their counterparts elsewhere. Factors controlling their design will therefore be found in other sections of this Handbook, and will not be repeated here.

Table I Categories of higher educational institutions

UK designation	Features	Designations elsewhere for institutions with similar features
University	Full-time courses to first and succeeding degrees Research	University University College Polytechnic Technical University Specialist academy
College of further education	Full- and part-time courses to diploma level for vocational and recreational subjects	Technical college Technical high school Sixth form college Vocational training college Non-advanced further education centre Adult education centre
College of Education	Full-time course for non-graduates for Bachelor of Education or equivalent Full-time course for graduates for Certificate of Education	Teacher training college
Open University	Courses by correspondence, also using radio and television Summer schools and evening tutorials at other educational establishments borrowed for the purpose Staff accommodation as for universities No student accommodation	Correspondence colleges

2 UNIVERSITIES

2.01

Since 1993 all former polytechnics and a number of other colleges have become universities. They have undertaken a process of upgrading their buildings: originally they were subject to lower standards than university buildings.

2.02

All over the world new universities are being established, and existing ones enlarged. The criteria developed and published by the UK, USA and other Western government agencies for the design and management of their institutions of higher education can be used as a basis for other parts of the world. However, local considerations may necessitate modifications:

- Climatic
- Socio-religious, e.g. segregation of the sexes in Moslem countries
- Standard of living.

Caution is therefore needed in transposing Western source data to projects elsewhere. It is recommended that where doubt exists to re-synthesise space planning data from detailed net workstation areas, in consultation with the, future users or other experienced local equivalents.

2.03 Types of university

There are three basic types of university, illustrated in UK practice as:

- *Oxbridge*, consisting of a number of semi-autonomous colleges providing residential and catering facilities for students and staff together with some small-scale teaching space; with an amount of central shared facilities jointly administered. This type is unique to Oxford and Cambridge.
- *London*, consisting of a number of more or less independent colleges, many of a specialist nature, each virtually self-contained universities. There are some central services, nearly all duplicating college facilities. This type is unique to London.
- *Provincial*, consisting of a number of subject departments or faculties, and various central facilities including usually an element of residential accommodation. This is the archetype, and most of what follows applies to this type of university.

2.04

A provincial type of university can be built in one of two ways, or a combination of them:

- Integrated and dispersed, where separate buildings and facilities are found among the local community, as and where sites become available. Often facilities are fitted into converted existing buildings, when space standards as described later may have to be modified. Otherwise, the design principles are not different from:
- Campus, where the buildings, or most of them, are arranged on one large site.

2.05 Types of campus

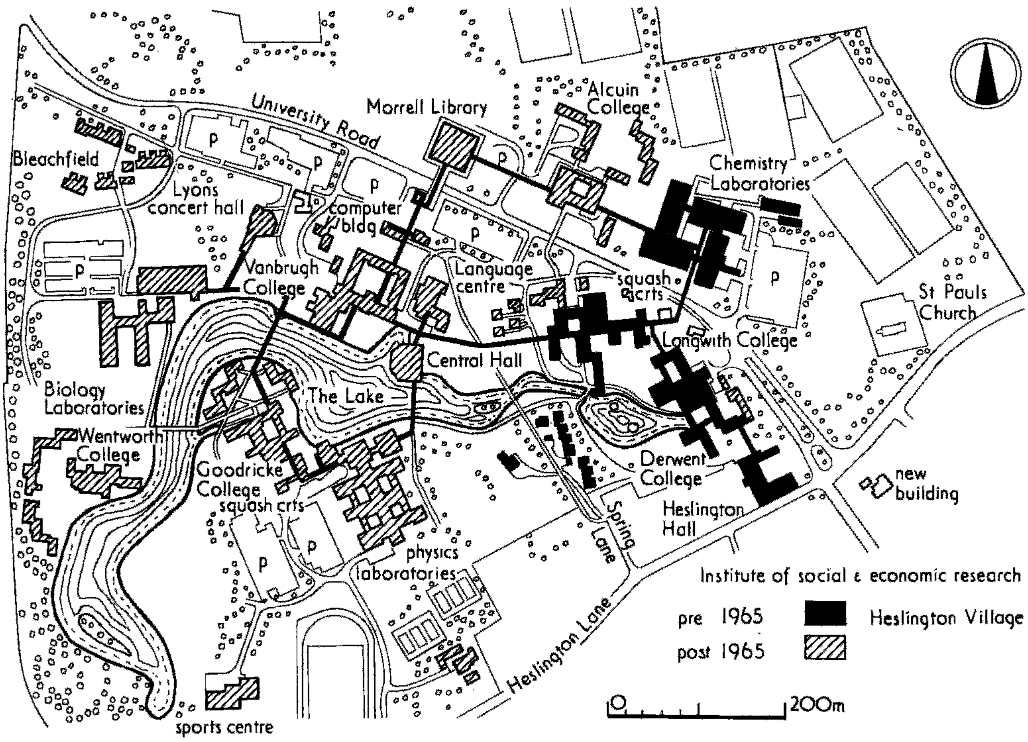
When a new university or college is to be built, a development (or master) plan is drawn up, showing how it is intended for the institution to cope with the expected expansion over the years to come. Expansion usually occurs by increasing the sizes of existing departments, rather than by the establishment of many new ones (although some new departments may be set up). There are three ways in which a department can expand:

- Extension to its existing buildings externally, for which space must be available
- Displacement of adjoining departments, for which the buildings must have been designed with flexibility in mind and
- Fragmentation over a series of separated buildings, which is normally deplored.

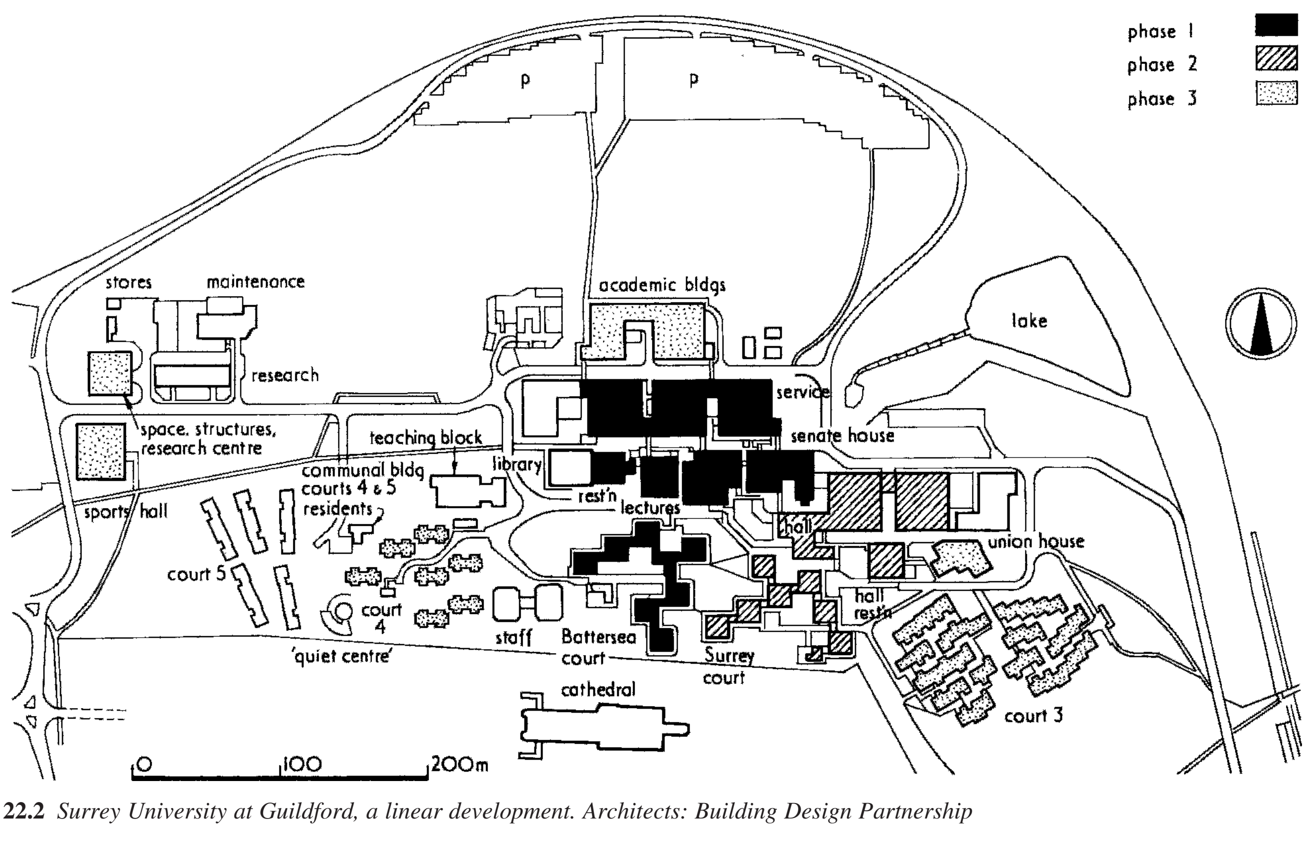
2.07 Forms of development

The form of the initial development of the campus will reflect the decision on methods of expansion. The common forms are:

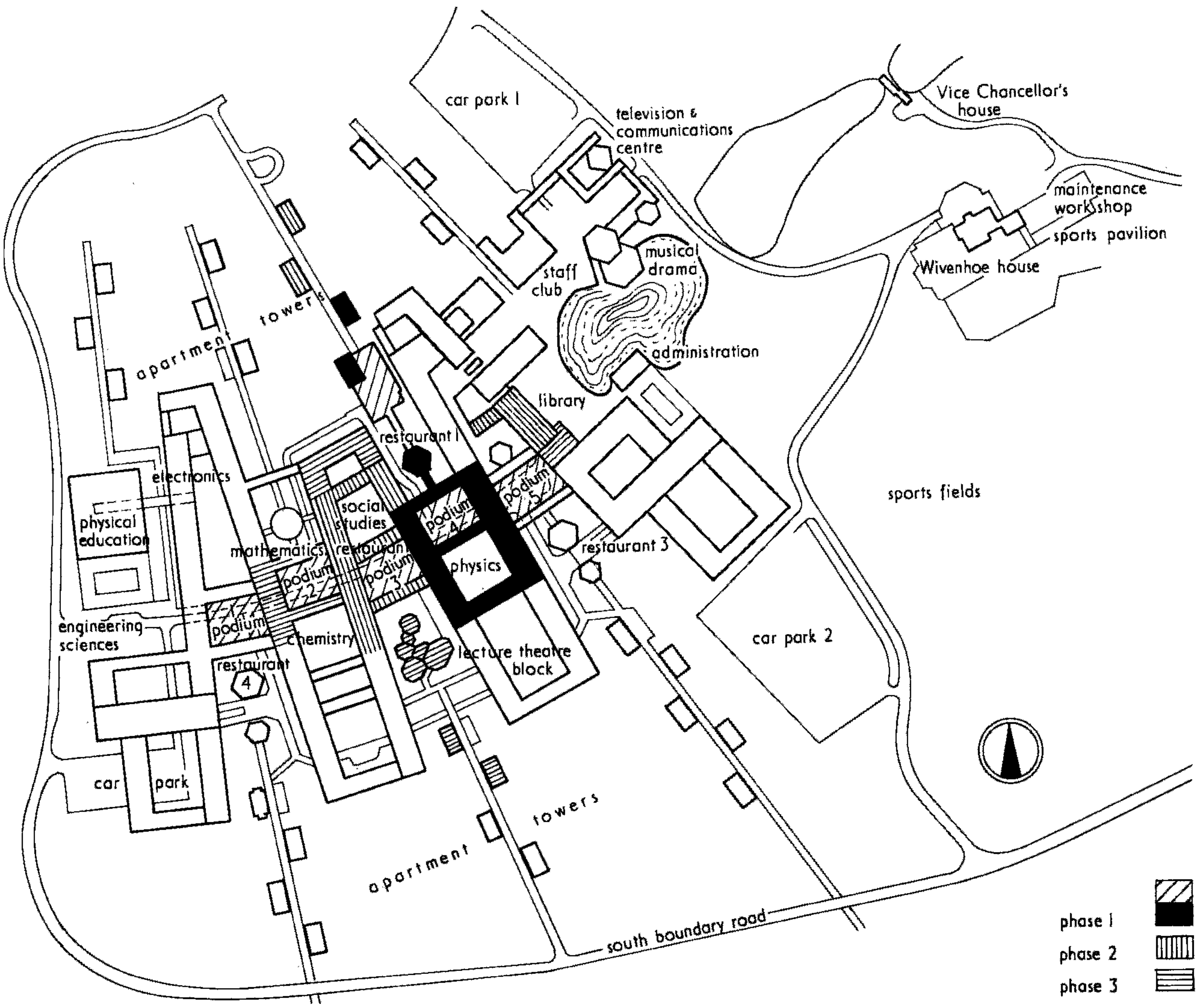
- Molecular, as at York, **22.1**, where departments and facilities are in widely separated buildings, leaving ample space for expansion. The disadvantage of this scheme is that there are long distances to be covered between facilities, and some minor functions such as parking, lavatories and refreshments have to be repeated at each 'nucleus',



22.1 *York University, a molecular type of development plan. Architects: Robert Matthew, Johnson-Marshall and Partners*



22.2 *Surrey University at Guildford, a linear development. Architects: Building Design Partnership*



22.3 *Essex University at Colchester, radial development. Architects: Architects' Co-Partnership*

- Linear, as at Surrey, **22.2**, which is designed with three strips containing residential, general and academic accommodation respectively. These strips can be extended at either end, and the academic accommodation is designed for easy conversion, enabling displacement to be facilitated
- Radial, such as Essex, **22.3**, where expansion takes place all round.

2.08 Building types

The main types of buildings are shown in **22.4**, which also indicates where information can be found elsewhere in the Handbook. The form of the campus will also be determined by a number of important policy decisions regarding these buildings.

2.09 Non-specialist teaching building policy

Most departments will have their own seminar and tutorial rooms, and may even use academic staff offices for such functions. A policy on whether departments should have their own lecture theatres, classrooms or even libraries must be established. In most new universities such facilities are usually shared between some or all departments for more economy of usage.

2.10 Residential accommodation policy

Students may live:

- In accommodation provided by the university on-campus
- In accommodation provided by the university off-campus
- In lodgings, with or without meals
- In privately rented accommodation, usually shared between a number
- At home (in their parents' house).

Before constructing students' accommodation it is usual to conduct a survey of lodgings and rentable accommodation in the locality. When doing this it is important to estimate other demands on such resources: other higher educational establishments, specialist industrial enterprises, etc. From such surveys, it can be determined what number of students will need to have accommodation provided directly or indirectly by the university. Of this number, some may be situated on-campus, although there are arguments for and against such accommodation:

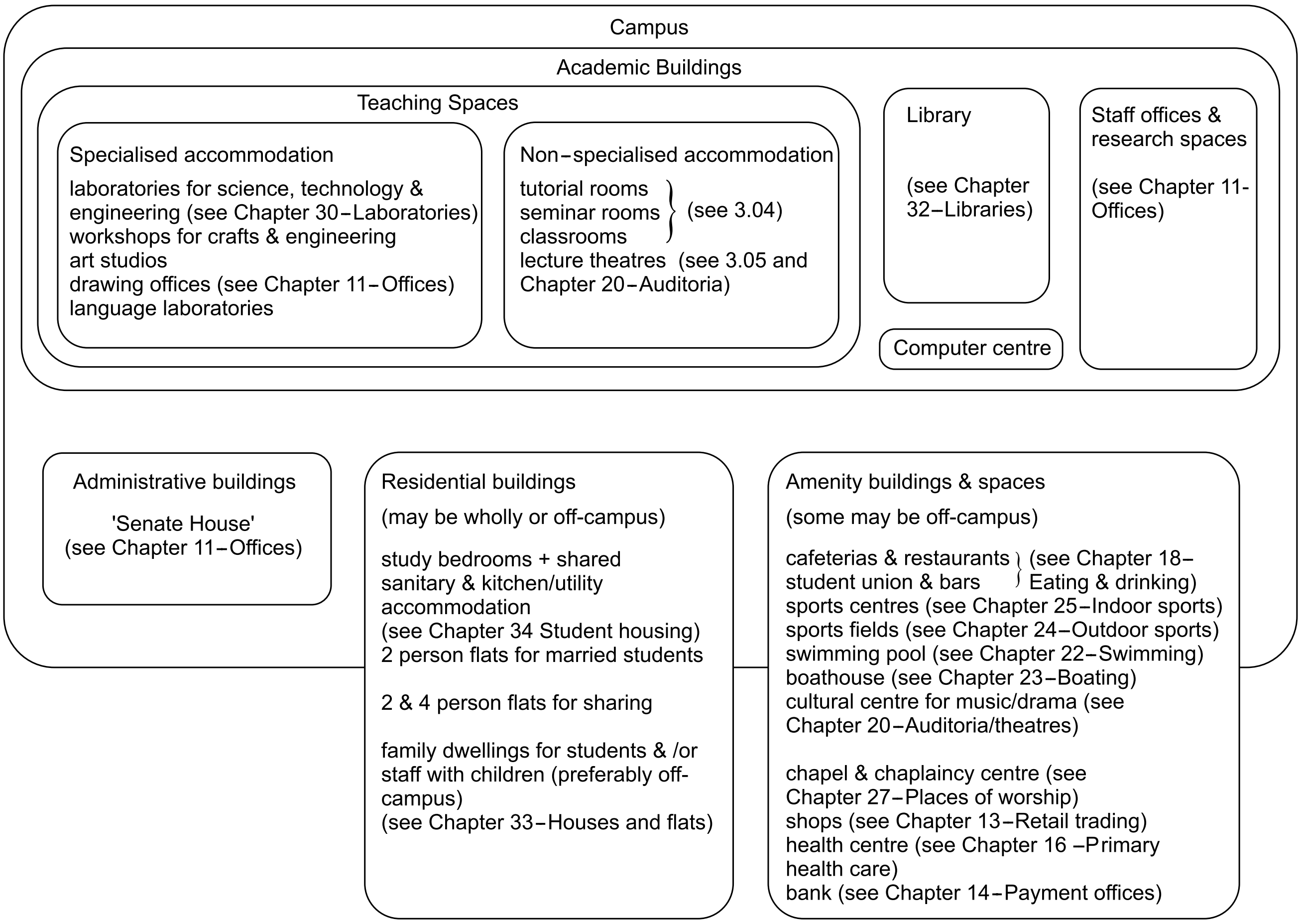
Advantages

- Savings of time and money in travel
- Ability to prepare all meals oneself
- Reduction in private study facilities in other university buildings
- Propinquity to library, etc. over weekends.

Disadvantages

- Mutual disturbance by noise, etc.
- Lack of contact with locality
- Need for parking facilities for students' vehicles on campus.

The types of accommodation that might be provided are given in **22.4**. Further information on this can be found in Chapter 34.



22.4 *Schematic diagram of a university campus*

2.12 Catering policy
The third policy decision affecting campus shape is concerned with the communal catering service. This can be:

- Completely centralised preparation and consumption (one large kitchen and dining room)
- Centralised preparation, dispersed consumption (one large kitchen, separated dining accommodation)
- Dispersed preparation and consumption (separate dining rooms, often specialising in different kinds of food and catering, each with its own kitchen).

Dispersed facilities can be centred on residential buildings to resemble Oxbridge colleges, as at York; or can be distributed at random as at Surrey. Design details for catering can be found in Chapter 17 of this Handbook.

2.13 Existing buildings
Much work needs to be done on refurbishing, converting and extending existing buildings for university and other educational use. **22.5** shows one such scheme.

2.14 Training centres
There is an increasing requirement for facilities for in-service training of staff in industrial, commercial and governmental organisations. The buildings for the BT Training Centre are shown in **22.6**.

2.13 Space standards
Allocations of space for different functions cannot be made to rigid rules, as each circumstance will be specific. However, the figures in Table II can be used as an initial design guide.

2.14 Part-time students
Not all students, even in universities, will be full time. Various forms of higher education are intended to keep the student from becoming completely divorced from the real world of industry and commerce to which he or she will return at the end of his course. Table III gives the forms of part-time involvement common in the UK, and the equivalent full-time student (FTE) factor to be taken in connection with the space standards in Tables II, VI and VII.

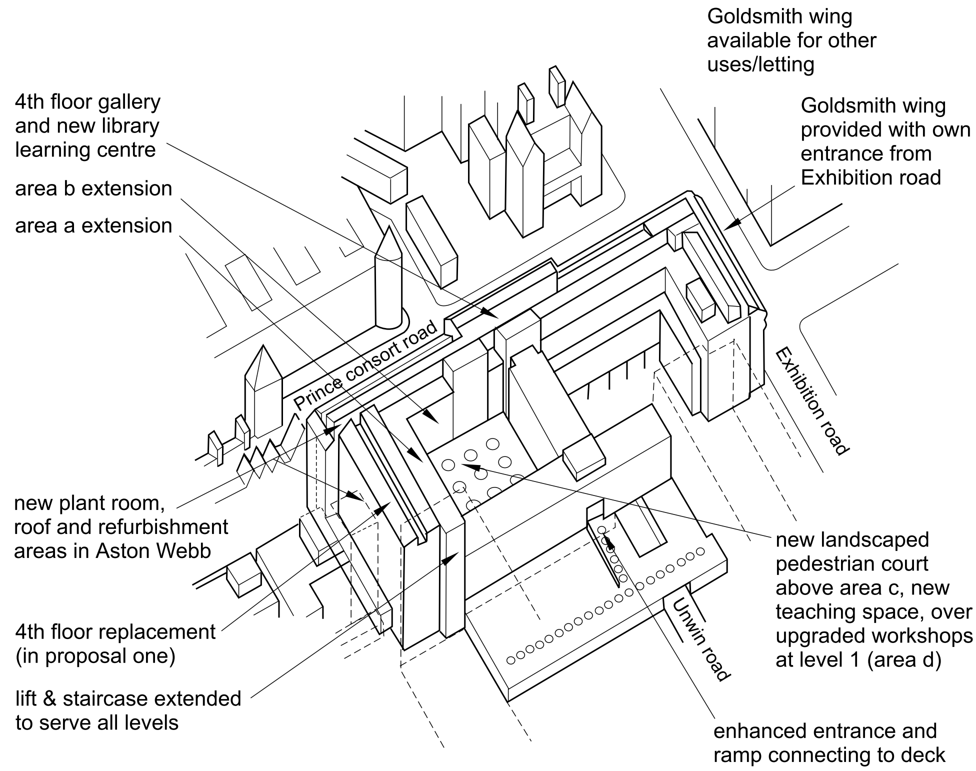
2.11 Balance area
The areas given in Table II are mainly net usable areas. To these have to be added balance areas, given as a percentage of the net usable area:

$$\text{Net usable area} + \text{balance area} = \text{gross area}$$

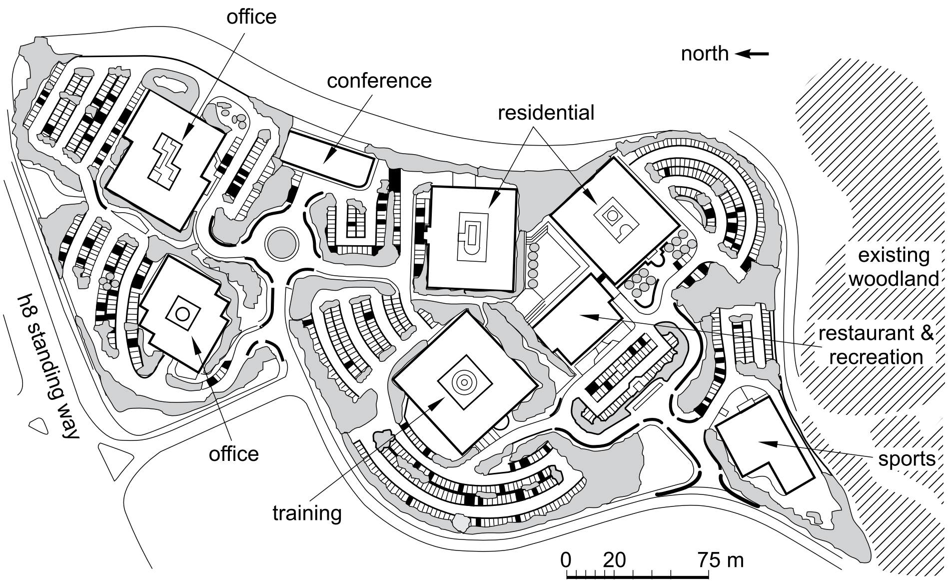
Balance area includes allowance for corridors and stairs, entrance foyer, enquiry counter, cloakrooms, locker spaces, lavatories, cleaners' stores, maintenance workshops, gardeners' stores, boiler rooms, electricity sub-stations and meter rooms, delivery bays, porters' rooms, plant rooms, service ducts. The percentage allowances for balance area are given in the appropriate places in Table II.

3 TEACHING SPACES

3.01 Density of academic development
The numbers of students that can be accommodated on a campus are given in Table IV.



22.5 *Royal School of Mines, Imperial College, London. A feasibility study. Architects: RMJM*



22.6 *British Telecom Training Centre, Milton Keynes. Architects: RMJM*

3.02 Teaching places

The numbers of teaching places that will be required for any type of institution can be calculated from the following formula:

$$N_t = N_s \times H_s / H_w \times 100/F$$

where N_t = number of teaching places required
N_s = number of students
H_s = hours per week per student in the accommodation
H_w = total number of available hours a week for the accommodation
F = net utilisation factor

Example:

200 students require an average of 10 hours a week of lectures in a working week of 40 hours and assuming a net utilisation factor of 80 per cent. What number of teaching spaces should be provided?

$$N_s = 200,\ H_s = 10,\ H_w = 40 \quad \text{and} \quad F = 80$$

hence $N_t = 200 \times 10/40 \times 100/80 = 63$ spaces.

3.03 Areas of teaching spaces

The areas required for various forms of teaching accommodation, related to teaching spaces rather than to total student population, are given in Table V.

Table II Space standards for universities

	Staff offices and research spaces	**Administrative, technical and secretaries**	**Classrooms, seminar rooms, etc.**
TEACHING AREAS			
1 Arts, social sciences, mathematics, architecture	1.55 m^2/student	0.5 m^2/student	0.65 m^2/course student
2 Science, engineering science, electronics	4.35	0.45	0.35
3 Engineering	4.50	0.45	2.4
4 Preclinical medicine	3.80	0.45	0.35
5 Clinical medicine	6.15	1.0	0.35
6 Clinical dentistry	5.05	1.0	0.35
Additional areas for specialised accommodation:			
1 Languages and social psychology		0.8 m^2/course student	0.8 m^2/research student
Mathematics		1.1	1.1
Education, traditional geography, archaeology		2.7	2.7
Scientific geography		5.5	5.5
Experimental psychology		6.9	6.9
Architecture		6.55	6.55
Music (departments of 50 students only)		7.5	7.5
2 Laboratories and ancillary accommodation for:			
Biology		5.0 m^2/course student	15.2 m^2/research student
Physics, engineering science, electronics		4.9	13.8
Chemistry		5.0	14.25
3 Engineering laboratories, workshops, preparation, storage		3.95 m^2/course student	14.3 m^2/research student
4 Preclinical medicine teaching laboratories: multi-disciplinary		7.50 m^2/course student	
anatomy		1.88 m^2/course student	
5 Clinical medicine reasearch space including ancillaries			16.0 m^2/research student
6 Clinical dentistry: teaching laboratories including ancillaries		5.0 m^2/course student	
research and writing-up space including ancillaries			11.0 m^2/research student
Additional space in association with lecture theatres for audio-visual facilities: allow for TV studio accommodation ancillaries (see Chapter 19)	for between 3000 and 6000 students and over 6000 students (provides second studio)		450 m^2 40 m^2
Balance areas	for general teaching areas excluding workshops		40%
	for workshops		25%
	for academic staff workrooms		50%
	for non-academic staff workrooms		40%
LIBRARIES			
Basic provision:	1 reader space for 6 students		0.40 m^2/student
	books: 3.8 m run of shelving/student		0.62 m^2/student
	administrative and support facilities		<u>0.2 m^2/student</u>
		Total (say)	1.25 m^2/student
Additional area in law schools to provide	1 reader space for 2 students		0.80 m^2/student
	Additional area for book stacks to accommodate excess of accessions over withdrawals for ten years		0.20 m^2/student
	Additional area for special collections of books, manuscripts or pamphlets		as required
	Addition for reserve store, separate from main library		50 m^2 plus 3.5 m^2/1000 volumes
	Balance area		25%
ADMINISTRATION			
For central administration, including Senate House, conference room, committee rooms	up to 3000 students		450 m^2
	additional students		0.35 m^2/student
For maintenance depot, including central stores and workshops, but excluding furniture stores	up to 3000 students		0.25 m^2/student
	additional students		0.15″
	Balance area		50%
AMENITY BUILDINGS			
Restaurants and cafeterias	Dining areas (based on 60% usage)		0.2 m^2/student
	Kitchens, etc.		0.17 m^2/student
	or can be calculated:		
	Kitchen area:		
	for 3 main meals including breakfast		0.45 m^2/meal/sitting
	1 meal per day		0.4 m^2/meal
	cooked snacks		0.3 m^2/snack
	coffee and sandwiches		0.1 m^2/snack
	balance area for catering spaces		25%
Communal and social areas	students		0.7 m^2/student
	academic, senior administrative and research staff (excluding medical schools)		0.19 m^2/student
	ditto in medical schools		(0.30)
	non-academic staff		<u>0.16</u>
		Total	1.05 m^2/student
		Total in medical schools	1.16 m^2/student
	large hall or space for use in conjunction with social space between 3000 and 6000 students		450 m^2
	balance area for communal spaces		30%
Students' Union offices and administration	up to 3000 students		0.15 m^2/student
	additional students		0.02 m^2/student
Sports facilities			
Indoor sports (see section 27)	up to 3000 students		0.47 m^2/student
	additional students up to 6000		0.13 m^2/student
	additional students		0.02 m^2/student

Table II (Continued)

	Staff offices and research spaces	Administrative, technical and secretaries	Classrooms, seminar rooms, etc.
Outdoor sports (see section 28)			
Grass pitches, playing fields	up to 3000 students additional students		28 m^2/student 14.5 m^2/student
Pavilion and groundsman's store	up to 3000 students additional students		0.18 m^2/student 0.10 m^2/student
Health services (see Chapter 16) Simple consultancy suite for doctor and nurse treatment based on NHS provision for a group practice to service an equivalent number of patients	up to 3000 students additional students		0.03 m^2/student 0.015 m^2/student
Dental services are only provided if unavailable locally			
A central sickbay may be provided unless located within residential accommodation			2 beds/1000 students
Complete health service, including dentistry	up to 3000 students additional students		0.10 m^2/student 0.03 m^2/student
RESIDENTIAL ACCOMMODATION where provided (for students)			
Medium-rise buildings with no lifts			420 students/hectare
High-rise buildings			600 students/hectare
Allocations of space	study bedrooms ablutions storage amenities utilities communal space balance area for circulation additional area for self-catering dining and kitchens		8.4–13 m^2/place 1.21 m^2/place 0.54 m^2/place 1.0 m^2/place 0.5 m^2/place 0.65 m^2/place 25% 1.2–1.7 m^2/place
Where a warden is in residence, allow for warden's residence			107–120 m^2/place
offices for	warden domestic bursar secretary porter records		9.3 m^2 9.3 m^2 7.0 m^2 6.5 m^2 5.6 m^2
In independent housing with self-catering	study bedroom ancillary amenity balance		9.3 m^2 1.5 m^2 2.2 m^2 3.0 m^2
		Total	16.0 m^2

Table III Part-time students

Type of student/description	Full-time equivalent (FTE) for planning purposes
Full-time student Has no other occupation. Probably attends minimum 20 hours a week. May live in	1
Thick sandwich student Attends full-time for three academic years in rota but works in industry for at least a year during the period	1
Thin sandwich student Attends full-time for six months, works in industry the other six months including the long vacation. Repeats as long as necessary	1
Block release student While being trained in industry (e.g. an apprentice) attends full-time for a block of three or four months	1/3
Part-time day student Attends one day a week plus two or more evenings	2/9
Evening student Only attends in evening	No allowance

Table IV Density of facilities for academic areas

Plot ratio	Number of students per hectare	
	Art based	Science and technology
0.5:1.0	395	200
1.0:1.0	790	400
1.5:1.0	1185	600
2.0:1.0	1580	800
2.5:1.0	1975	1000

Table V Usable area per working space for teaching accommodation (for balance areas see Table VII under 'Teaching Space')

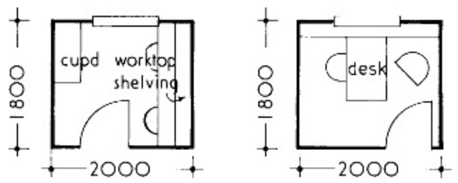
Non-specialised	
Tutorial rooms	
Rooms with informal seating	1.85 m^2/space
Rooms with tables or desks	2.30 m^2/space
Rooms with demonstration area	2.50 m^2/space
Lecture theatres	
Rooms with close seating	1.00 m^2/space
Drawing offices: Al and smaller	3.70 m^2/space
A0 and bigger	4.60 m^2/space
Laboratories	
Advanced science and engineering	5.60 m^2/space
Non-advanced science and engineering	4.60 m^2/space
Management and Business Studies	
Work study	4.60 m^2/space
Typewriting	3.20 m^2/space
Accounting	2.80 m^2/space
Workshops	
Crafts involving large-scale machines and equipment, e.g. welding, motor vehicles, machine tools	8.40 m^2/space
Crafts requiring workbenches and smaller scale machines and equipment, e.g. carpentry, plumbing, electrical	5.60 m^2/space
Craft rooms, e.g. dressmaking, cookery	5.60 m^2/space

3.04 Tutorial and seminar rooms

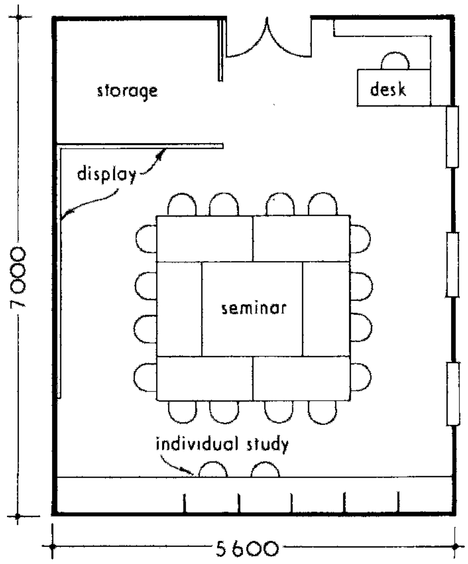
Tutorials often take place in academic staff offices. Some prefer special rooms for the purpose, **22.7**. Seminar rooms are shown in **22.8**.

3.05 Lecture theatres

These are expensive facilities which are often under-used. They range in size from large classrooms accommodating 50 students to large theatres for 500. However, investigation has shown that the



22.7 *Two types of tutorial rooms*



22.8 *A seminar room*

common lecture group is between 30 and 60, so the larger sizes are appropriate only when conference facilities are needed, or where use as an assembly hall or cinema is also envisaged. Further details of lecture facilities will be found in Chapter 32.

4 COLLEGES OF FURTHER EDUCATION

These have a higher proportion of part-time and evening students. Areas for teaching spaces must therefore be calculated by the method in para **3.02**. Areas for other facilities will be found in Table VI.

Table VI Space standards for colleges of further education

Teaching spaces see para 3		
Libraries		
	colleges with 30% advanced work	colleges with less than 30% advanced work
first 500 FTE students	390 m^2	300 m^2
additional FTE students	0.44 m^2/student	0.38 m^2/student
balance area	25%	

Non-teaching areas for the following:	
principal's and vice-principal's rooms	
registrar's and departmental heads' rooms	
main offices	
rooms for principal's and departmental heads' secretaries	
offices for welfare and advisory services	
building maintenance officer's room	
interview room	
enquiry kiosk	
porter's room	
bookshop	
medical room	
storage for the above at 15%	
*up to 500 FTE students	255 m^2
500 to 2500 FTE students	0.128 m^2/student
additional students	0.05 m^2/student
academic staff rooms (other than departmental heads)	0.36 m^2/student
non-academic staff allocated to departments	0.20 m^2/student
Balance areas: administrative	50%
academic staff workroom	50%
non-academic staff workroom	40%
communal	30%

Table VI (Continued)

Communal accommodation for the following:	
physical recreation including changing rooms	
student and staff common rooms	
students' union/staff association	
music/indoor sports	
storage for the above	
*up to 500 FTE students	590 m^2
500 to 2000 FTE students	0.42 m^2/student
additional FTE students	0.14 m^2/student
additional area for full-time and sandwich course students who make full use of the facilities	0.5 m^2/full-time/ sandwich student
dining rooms, allow for quarter to half of student body	1.12 m^2/space
cooking and service areas, see universities	
Student common rooms	0.75 m^2/student
Staff common rooms	1.85 m^2/member
Lockers, baths, showers, laundry/drying space for day/lodging students	0.9 m^2/student
(A single-sex changing room is about 74 m^2)	
Balance areas: communal	30%
catering	25%
Residential accommodation see Table II	

* approximation to complex formula

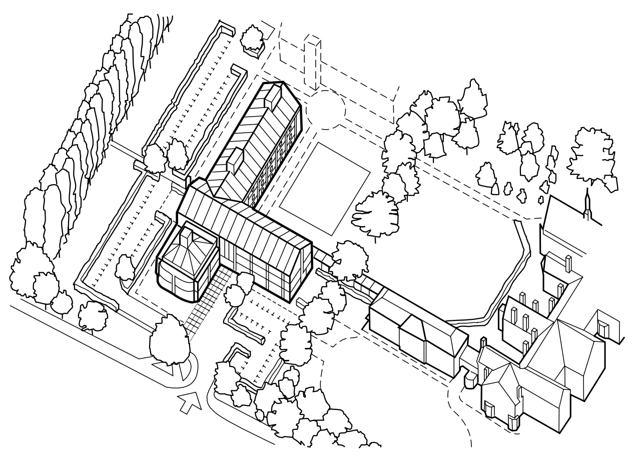
5 COLLEGES OF EDUCATION

Space standards for institutions training teachers are given in Table VII. One such is shown in **22.9**.

Table VII Space standards for colleges of education

Teaching space	
Total space provided	4.65 m^2/student
tutorial/seminar rooms	13.5 m^2/staff member excluding principal and vice-principal
lecture rooms: first 100 places	1.1 m^2/student
additional spaces	0.9 m^2/student
general teaching rooms	1.85 m^2/student
additional area for storage	10%
balance areas: general teaching spaces	40%
academic staff workrooms	50%
non-academic staff workrooms	40%
Libraries	
including private study areas	
*first 200 students	1.1 m^2/student
additional students	0.95 m^2/student
balance area	25%
Non-teaching areas see colleges of further education	
Communal areas / **students' residences** }	see universities and polytechnics

* approximation to complex formula



22.9 *Homerton College, Cambridge, Teacher Training Facility. Architects: RMJM*

23 Laboratories

Catherine Nikolaou and Neville Surti

CI/SfB: 732
UDC: 727.3
Uniclass: F739

Catherine Nikolaou and Neville Surti are both associates at Sheppard Robson Architects specialising in the design of laboratory facilities

KEY POINTS:

- *The planning and design of modern laboratory facilities should be based on a combination of current best practice and predictions together with recognition of the future needs for flexibility*

Contents

1 INTRODUCTION

1.01 Definition

A laboratory is a facility which provides controlled conditions in which scientific methods including research, experiments and measurement may be performed and/or taught.

1.02 Scope

There is great diversity amongst laboratories; however, many commonalities are found in their architecture and engineering. This section of the handbook provides an indication of the basic requirements specific to a broadly representative range of laboratory facilities (the scope is too extensive to cover in any detail in this document). The information provided relates primarily to bench-scale laboratories, focusing mainly on the commonalities and provides guidance for their planning and design. The figures presented are based on average requirements. Specific needs, ascertained through detailed briefing with the stakeholders, may vary these figures.

Whilst this section provides information on the design of new facilities, the broad principles can also be applied to renovation/refurbishment projects. In these instances, compromises may need to be made due to space restraints and operational procedures may have to be put in place to compensate.

1.03 Laboratory types

In this handbook, laboratories are grouped into three main types, all of which incorporate various scientific disciplines and work processes. They are:

- Wet
- Dry
- Microbiological/clinical

Teaching laboratories are grouped separately. They may be wet, dry or microbiological/clinical laboratories but they differ in that they *teach* scientific method.

Wet laboratories utilise, test and analyse chemicals, drugs or other material/biological matter. They typically require piped services (including water, specialised utilities) and ventilation, e.g. chemical science laboratories.

Dry laboratories contain dry-stored materials, electronics and/or large instruments with few piped services. They typically require accurate temperature and humidity control, dust control and clean power, e.g. analytical, engineering laboratories.

Microbiological/clinical laboratories often involve work with infectious agents. They typically require higher levels of environmental containment including specialised ventilation and air treatment systems and utilise controlled access zones, airlocks or separate buildings or modules to isolate the laboratory, e.g. biomedical laboratories.

Teaching laboratories include primary, secondary schools and higher education. They require space for teaching equipment, storage space for student belongings and typically less instrumentation. They are typically found in the academic sector.

Laboratories can be found in either academic, government or private/corporate sectors.

Academic laboratory facilities include both teaching laboratories and laboratories that engage in public interest or profit-generating research.

Government laboratory facilities focus on research, testing and innovation specifically in the public's interest. They are in many respects similar to those of the private/corporate sector.

Private/corporate laboratory facilities focus on research and innovation but are usually driven by the need to enhance the operation's profit potential.

In addition to the laboratories, facilities may include:

- Reception/Lobby
- Office/Write-up
- Auditorium/Conference/Meeting/Interaction
- Seminar/Classroom
- General storage
- Library
- Foodservice
- Child care
- Clinic/Health unit
- Physical fitness (Exercise room)
- Joint use retail
- Light industrial
- Loading dock
- Parking

The sectors differ principally in their focus and in the various space types their facilities offer. For example, private/corporate sector facilities are often more expensive and larger than academic or government facilities because competitive markets require more discoveries each year and may have more 'incentives' in the form of support spaces to retain and attract talented employees.

1.04 Defining environmental conditions

A detailed assessment should be made with stakeholders and regulatory authorities to define the environmental conditions and operational practices required for the facility before the design starts, as this will impact on the specification of the laboratory's physical and servicing requirements and its operational costs.

In some laboratories, conditions are no more dangerous than in any other room. In many, however, hazards may be present that need to be contained and/or controlled including (but not limited to):

- Biological/infectious agents
- Poisons/chemicals
- Flammable substances
- Explosives
- Radioactive material
- Magnetic interference

- Moving machinery
- Extreme temperatures
- High voltage

These hazards must be identified and countermeasures or mitigation strategies specific for each facility determined/implemented in accordance with the relevant industry standards and regulations. Refer to the attached Bibliography for further references specific to some of the various hazards which may be present in any of the laboratory types described.

For facilities such as microbiological/clinical laboratories and for teaching laboratories handling biological or potentially infectious agents, specific reference should be made to BS EN 12128 which specifies minimum physical containment levels (PCL) to be provided for handling microorganisms of different hazard groups (HG). These HG are defined by the Advisory Committee on Dangerous Pathogens (ACDP) and the Advisory Committee on Genetic Modification (ACGM) as categories of risk to health ranging from Cat 1 (lowest) to Cat 4 (highest). The HG rating of the biological agents in use determines which PCL is required for each specific laboratory ranging from PCL 1 (lowest) to PCL 4 (highest). Refer to Table I for a summary of the minimum physical containment requirements for each level.

A laboratory may be designed as a cleanroom facility. A cleanroom is defined as a room in which the concentration of airborne particles is controlled; which is constructed and used in a manner to minimise the introduction, generation and retention of particles inside the room; and in which other relevant parameters such as temperature, humidity and pressure are controlled as necessary. Cleanroom conditions are typically required, for example, in micro- and nano-electronic research.

The grades of cleanroom are defined by the global ISO classification system, EN ISO 14644-1 which classifies ranges from Class 8 (least clean) to Class 3 (cleanest). Table II shows how it compares to other systems used in the past. Refer to EN ISO 14644-4 for guidance on the design, construction and start-up of cleanrooms.

Laboratories may be designed as both cleanroom and containment facilities. For example, some products require a containment level Category 2–4 to protect the operator and a cleanroom environment of ISO Class 5–8 to protect the product. Refer to Bibliography for further reference on the design, construction and start-up of combined cleanroom and containment facilities.

Finally, the final form of the facility will also be dictated by the individual site constraints and opportunities for each project and the varied preferences and detailed needs of the stakeholders.

Table I Summary of ACDP minimum physical containment requirements from PCL 1 (lowest) to PCL 4 (highest). These requirements are for laboratory facilities handling microorganisms of different hazard groups. PCL 4 facilities are relatively rare. This level of containment represents an isolated unit functionally and when necessary, structurally independent from other areas

Requirements	Physical Containment Level			
	1	2	3	4
Laboratory rooms separated from other activities in the same building by doors	○	•	•	•
Laboratory physically separated from areas open to unrestricted traffic flow				•
Restricted access to laboratory	•	•	•	•
Entry to laboratory via an airlock			•	•
Door locked when room is unoccupied			•	
Controlled card access or combination lockset				•
Self-closing doors	○	•	•	•
Observation window/visibility into laboratory		•	•	•
In-use warning light to outer door of airlock				•
Containment level labelled and hazard zones labelled with biohazard sign (where necessary)	•	•	•	•
Means of communication between laboratory/outside (e.g. fax, computer, telephone)			○	•
Adequate space for each worker, storage and equipment	•	•	•	•
Route for personnel, materials to avoid cross-over/contamination	•	•	•	•
Finishes/furniture easy to clean	•	•	•	•
Bench tops impervious to water, resistant to acids, alkalis, organic solvents, mild heat, disinfectants (where used)	•	•	•	•
Minimise horizontal surface to prevent dust contamination			•	•
Safe storage of biological agents		•	•	•
Microbiological Safety Cabinet (MSC) Class I/equivalent containment device for infectious aerosols		•	•	
Microbiological Safety Cabinet (MSC) Class II/equivalent containment device for infectious aerosols		•	•	
Microbiological Safety Cabinet (MSC) Class III/equivalent containment device for infectious aerosols			•	•
Laboratory to contain its own equipment where practicable			•	•
Uninterruptible Power Supply (UPS) for critical equipment			○	•
Personal protective equipment storage (clean and dirty) to be provided in suite and to be suitably maintained	○	•	•	
Changing and showering area with storage for laboratory PPE				•
Hand wash sink near exit to laboratory/suite	•	•	•	•
Eyewash/safety shower near exit to laboratory/suite		•	•	•
Knee/elbow/sensor operated taps to wash sink facilities	○	•	•	•
Exposed horizontal utility pipe, ductwork and open storage cabinets to a minimum				•
Non-recirculating mechanical ventilation	○	○	•	•
Air pressure negative to atmosphere (where mechanical ventilation is provided/required and work is in progress)	○	•	•	•
Interlocked supply and extract airflows to prevent positive pressurisation of room in event of extract fan failure			•	•
Alarm system fitted to detect unacceptable air pressure changes			•	•
Directional airflow from clean areas to contaminated areas				•
HEPA filtered extracted air			•	
Double HEPA filtered extracted air				•
Dedicated exhaust air ventilation system for the module				•
HEPA filtered supply air				•
Specified disinfection procedures (laboratory sealed to permit disinfection/fumigation where required)		•	•	•
Laboratory design to permit vector, e.g. insect and rodent control		○	•	•
Access to autoclave for sterilisation in building/suite		•		
Access to autoclave for sterilisation within laboratory/suite			•	
Access to double ended autoclave with interlocking doors in laboratory/lobby			○	•
Means for safe collection, storage, disposal and labelling of waste		•	•	•
Secure access to incinerator (local or distant)		•	•	•

• Required
○ Optional (should be decided on a case by case basis subject to risk assessment)

Table II Comparison of the global ISO cleanroom classification system, EN ISO 14644-1, with other systems

Classification system	Classifications					
EN ISO 14644-1 (1999)	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8
US Federal Standard 209E (1992)	1	10	100	1000	10 000	100 000
EU cGMP (1998)	–	–	A/B	–	C	D

Table III Factors defining the width of a typical laboratory module

	Width (mm)
2 × half wall thickness between module	150
2 × clear bench depths (600 or 900 mm)	1200–1800
2 × service spines above bench	300
minimum space between benches	1500*
Total module width	**3150–3750****

* This is the recommended minimum distance which will accommodate the required distance between a bench and a fume cupboard and also requirements for DDA compliance
** The minimum and maximum figures are largely dependent on equipment requirements. A 3300 mm module width is recommended for most generic laboratory facilities to ensure that a bench and a fume cupboard (nominal 900 mm) can be accommodated on either wall

2 LABORATORY LAYOUT GUIDANCE

2.01 Key points

The planning and design of modern laboratory facilities should be based on a combination of current best practice and predictions together with recognition of the future needs for flexibility.

Safe and secure environments: Safety must always be the first concern in laboratory design. Securing a facility from unauthorised access is also of critical importance to prevent theft, misuse or, for facilities handling infectious agents, the release of pathogens. Laboratory designers must work within the dense and stringent regulatory environment in order to create safe, secure and productive laboratory spaces.

Statistically reproducible data: One of the most fundamental requirements of successful scientific research is to provide statistically reproducible data. The ability to achieve this relies not only on the availability of high-quality reproducible material but also on the quality and appropriateness of the controlled physical environment.

Responsive to change: Laboratories should be designed to accommodate change irrespective of the scale of work or the scientific discipline involved. The need for change will result from the continuing and rapid developments in technology/equipment, evolving working methods and procedures and increasingly stringent regulations. It should, therefore, be a fundamental principle that the basic design of a building allows sufficient flexibility for future changes to be accommodated without the need for major and often costly alterations and with minimum disruption to operations.

Interaction and collaboration: Scientific interaction and collaboration often leads to new inventions, new cures and faster progress. As a result, equipping laboratory facilities with spaces that encourage interaction will enhance the scientist's ability to succeed.

Recruit and retain staff: Because of increasing competition in the scientific field, more effort and money is often invested in creating high-quality facilities to attract and retain staff including state of the art laboratories, gracious public areas, extensive amenities and the latest in computer technology. These facilities serve to support employees and enhance efficiencies and productivity.

Sustainability: Sustainable design is a basic responsibility and should serve as a research, teaching and policy-changing tool.

2.02 Laboratory planning modules

A starting point for the planning and design of many laboratory facilities is the planning module which accommodates basic planning requirements. It should provide adequate space for partitions, benches, floor standing equipment and extract devices and aisles which minimise circulation conflicts/safety hazards. The laboratory module should also be fully coordinated with the architectural and building engineering systems.

Basic laboratory module: The width of a typical laboratory planning module is defined in Table III.

The length of the module will depend on the unit size of the chosen laboratory furniture, requirements for freestanding equipment and the number of persons that will occupy the space, **23.1**.

Two-directional laboratory module: Further flexibility can be achieved by designing a laboratory module that works in both directions, **23.2**. This allows laboratory benches and equipment to be organised in either direction. This concept is more flexible than the basic laboratory module concept but may require a larger building.

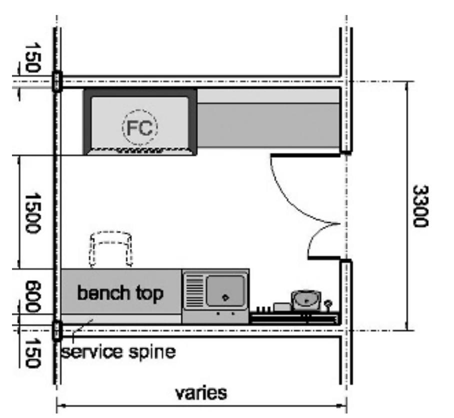
Three-dimensional laboratory module: To create a three-dimensional laboratory module a basic or two-directional module must be defined, all vertical risers including fire stairs, lifts, restrooms and utilities shafts must be fully coordinated (e.g., vertically stacked) and the mechanical, electrical and plumbing systems must be coordinated in the ceiling to work with the corridor/circulation arrangements, **23.3**. This concept provides the greatest flexibility.

Combining modules: In addition to accommodating the basic and functional spatial requirements, modularity maximises efficiency and the potential for flexibility/adaptability. As modifications are required because of changes in laboratory use, instrumentation or departmental organisation, partitions can be relocated and laboratory units expanded or contracted into larger or smaller units without requiring significant reconstruction of structural or mechanical building elements, **23.4**.

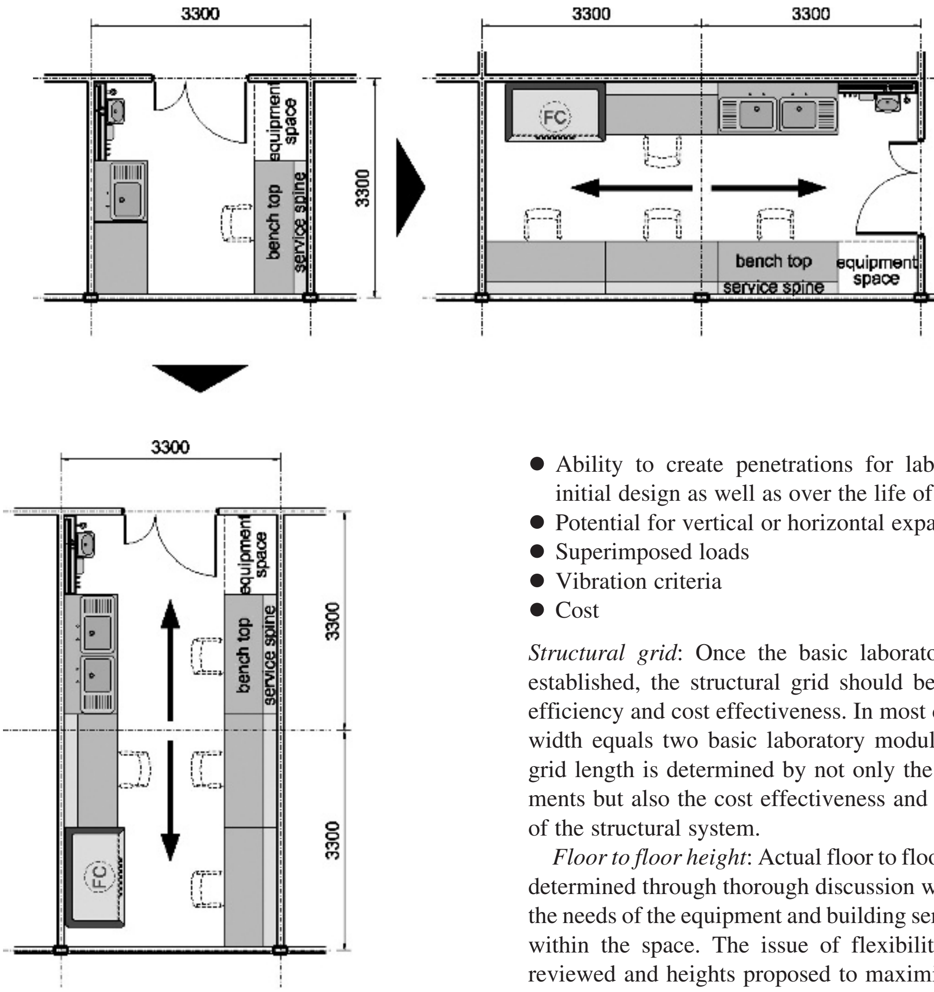
2.03 Structure

Key design issues to consider in evaluating a structural system include:

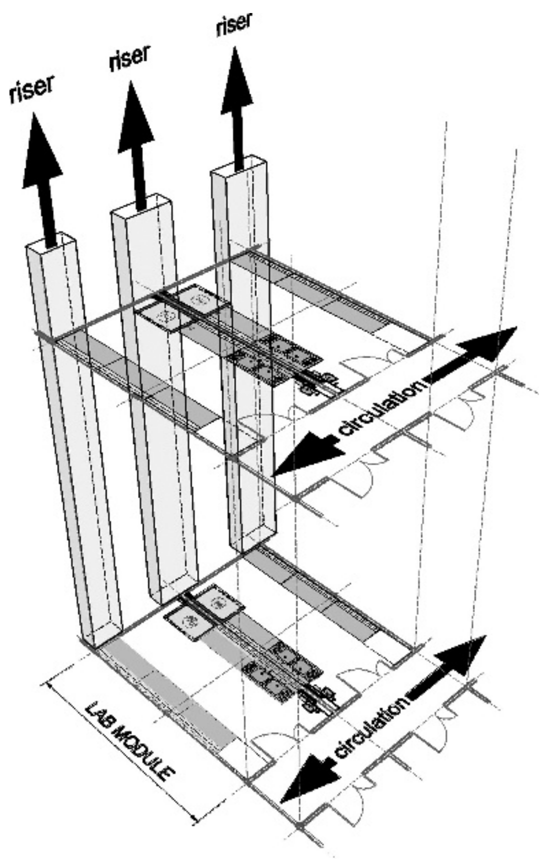
- Ability to coordinate the structure with the laboratory planning modules
- Slab thickness and effective floor to floor height



23.1 *The basic planning module needs to accommodate basic planning requirements for partitions, laboratory benches, equipment, extract devices and circulation in addition to laboratory personnel*



23.2 *Two-directional laboratory planning module*



23.3 *Three-dimensional laboratory planning module (section)*

- Ability to create penetrations for laboratory services in the initial design as well as over the life of the building
- Potential for vertical or horizontal expansion
- Superimposed loads
- Vibration criteria
- Cost

Structural grid: Once the basic laboratory planning module is established, the structural grid should be determined to provide efficiency and cost effectiveness. In most cases, the structural grid width equals two basic laboratory modules, **23.5**. The structural grid length is determined by not only the basic planning requirements but also the cost effectiveness and functional requirements of the structural system.

Floor to floor height: Actual floor to floor heights will need to be determined through thorough discussion with the stakeholders and the needs of the equipment and building services to be incorporated within the space. The issue of flexibility will also need to be reviewed and heights proposed to maximise the future use of the space, Table IV, **23.6**.

Flexibility: Fixed elements of structure, for example, floor slabs, columns, braced bays, shear walls, service shafts, lift shafts and staircases, should be planned to minimise constraints on the extension and reconfiguration of the layout, **23.7**.

Superimposed loads: Structures must be designed to withstand the loadings set out in BS 6339. They must also be designed in accordance with the appropriate British Standards which will depend on the structural material adopted for the structure. For generic/bench-scale laboratories including equipment and corridors subject to loads greater than from crowds, such as wheeled vehicles, trolleys and similar, design for:

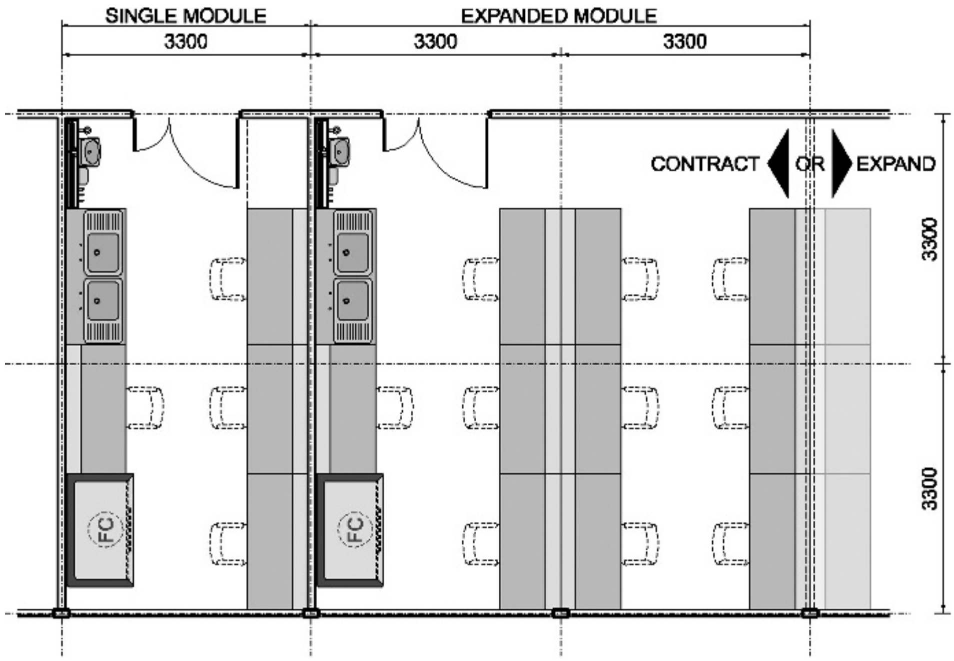
$$5.0\text{kN/m}^2 + 1\text{kN/m}^2 \text{ for lightweight partitions}$$

Heavy-engineering equipment and rigs such as cyclotron, nuclear magnetic resonance (NMR), electron microscopes, etc. are most economically located on ground floors and require individual and separate consideration.

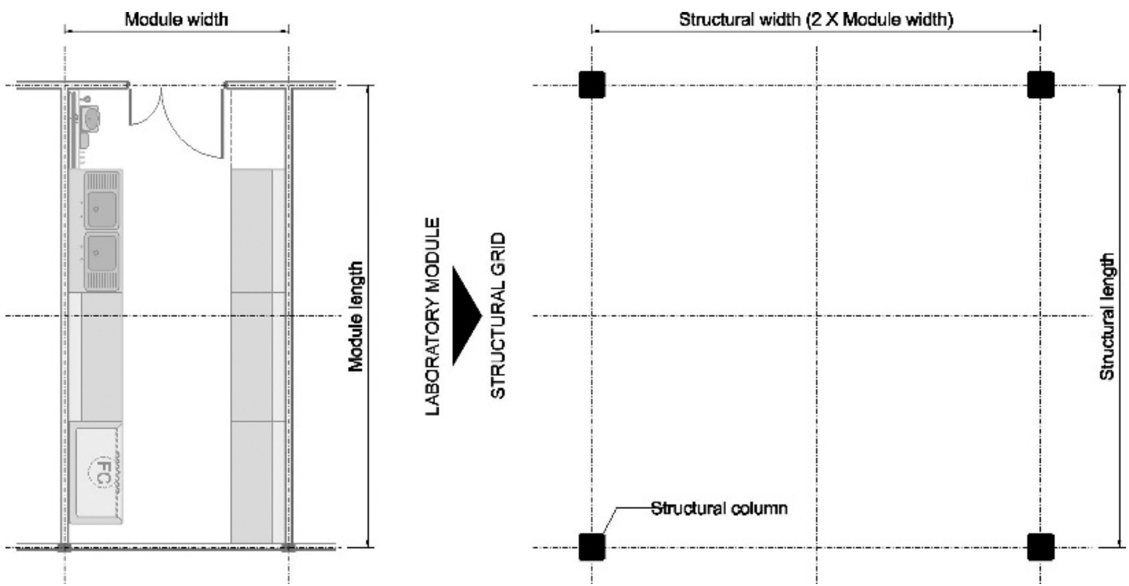
Vibration: The structural frame system and selection of furniture base should take into account vibration throughout the laboratory areas where sensitive equipment balances and microscopes are being utilised. The main vibration sources include external and internal sources. Common sources (and their indicative frequencies) are:

- Tall building sway (0.1–5 Hz)
- Ground and upper floor resonance (5–50 Hz)
- Street/vehicular traffic (5–100 Hz)
- Machinery (10–200 Hz)
- Motorised equipment and instruments (20 + Hz)
- Acoustic vibrations (10–500 Hz)

The accurate selection of vibration criteria and prediction of vibration levels is important in laboratory design because construction costs increases as designed floor vibration levels decrease.



23.4 *Utilising the concept of modularity in laboratory planning to create efficient, flexible and adaptable spaces that can be expanded and contracted to meet changing requirements*



23.5 *The building's structural grid derived from the laboratory planning module, the cost effectiveness and the functional requirements of the structural system*

Table IV Effective floor to floor height, minimum and maximum recommended figures

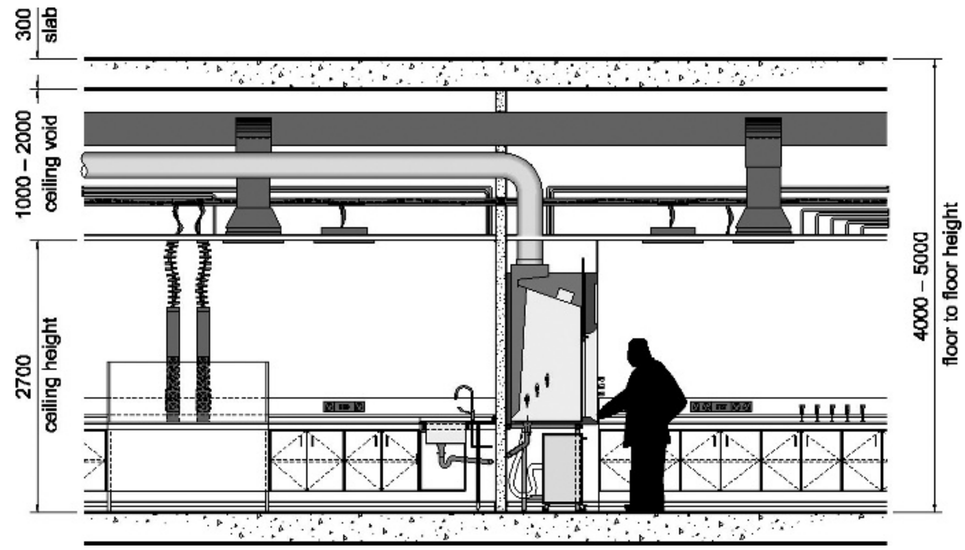
	Height (m)
Minimum ceiling height in laboratories	2.7*
Minimum ceiling void	1.0**
Preferred ceiling void	1.5–2.0**
Slab thickness (nominal allowance)	0.3
Floor to floor height	**4.0–5.0**

* To allow clearance height for extract cabinets
** To allow adequate depth for the installation of building services. Consider exposed mechanical, electrical and piped systems for easy maintenance access from the laboratory

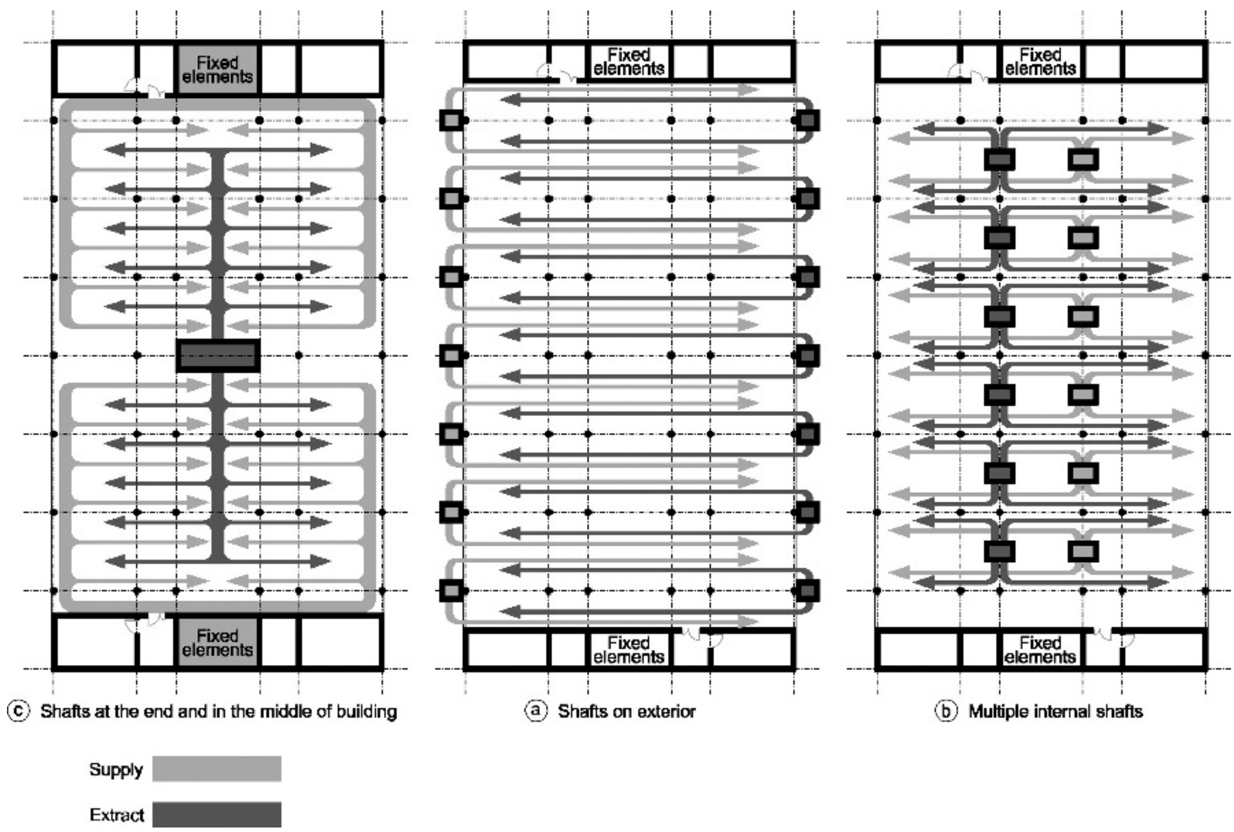
Vibration criteria can be determined based on published vibration limits, manufacturer-provided criteria, and subjective tests of vibration-sensitive equipment. Vibration criteria for areas intended to accommodate sensitive equipment are based on RMS velocity level as measured in one-third octave bands of frequency over the frequency range of 8–100 Hz. Generic vibration criterion (VC) curves have been developed for different types of equipment, shown in Table V. Criterion curves VC-A to VC-E are applicable to laboratory facilities. International Standards Organisation (ISO) criteria for human exposure to vibration are also shown.

The structural floor system should be designed to meet the required VC criteria in accordance with the applicable guidelines (refer Bibliography).

Whilst it is a requirement to provide a high level of flexibility, it is normally accepted that to design all parts of the building such that extremely sensitive research equipment can be placed anywhere without further local isolation is not practical. Therefore, a vibration design criterion and design strategy must be adopted that will satisfy the majority of needs, whilst accepting that local isolation devices will be used where a particular item of equipment has more stringent requirements. Table VI lists basic techniques that should be utilised where possible to control vibration.



23.6 *Effective floor to floor height (minimum and maximum recommendations)*



23.7 *Maximising flexibility through the rational placement of fixed structural elements*

2.04 Building services

Typically, more than 35–50% of the construction cost of a laboratory building can be attributed to the building services systems (mechanical, electrical and process). Close coordination of these systems is necessary to ensure a flexible, economic and successfully operating facility.

Three common strategies for servicing laboratories are as follows though needs may dictate a combination of any of them:

- Embedded service risers
- Sidestitial service zone
- Interstitial floor service zone

Embedded service risers: Vertical service risers are located within the building floor plate as required, **23.8**. Whilst this option offers the most economical solution, it is also the least flexible with respect to floor planning, Table VII.

Sidestitial service zone: A vertical continuous service zone is located within the length of the laboratory area, **23.9**. This option offers good flexibility and maintenance access and is potentially best suited to sites with unsuitable/undesirable views to one side – Table VIII.

Interstitial floor service zone: A complete service floor zone is located either above or between laboratory floors,

Table V Design criteria for sensitive instrumentation and equipment not otherwise vibration-isolated

Criterion curve	V_{RMS} (μm/s)	Velocity level (dB) Ref: 0.025 μm/s	*Detail size (μm)	Description of use
Workshop (ISO)	800	90	N/A	Distinctly feelable vibration. Appropriate to workshops and non-sensitive areas.
Office (ISO)	400	84	N/A	Feelable vibration. Appropriate to offices and non-sensitive areas.
Residential Day (ISO)	200	78	75	Barely feelable vibration. Appropriate to sleep areas in most instances. Probably adequate for computer equipment, probe test equipment and low-power to 20 × microscopes.
OP. Theatre (ISO)	100	72	25	Vibration not feelable. Suitable for sensitive sleep areas. Suitable in most instances for microscopes to 100 × and for other equipment of low sensitivity.
VC-A	50	66	8	Adequate in most instances for optical microscopes to 400 ×, microbalances, optical balances, proximity and projection aligners, etc.
VC-B	25	60	3	An appropriate standard for optical microscopes to 1000 ×, inspection and lithography equipment (including steppers) to 3 μm line widths.
VC-C	12.5	54	1	A good standard for most lithography and inspection equipment to 1 μm detail size.
VC-D	6	48	0.3	Suitable in most instances for the most demanding equipment including electron microscopes (TEMs and SEMs) and E-Beam systems, operating to the limits of their capability.
VC-E	3	42	0.1	A difficult criterion to achieve in most instances. Assumed to be adequate for the most demanding of sensitive systems including long path, laser-based, small target systems and other systems requiring extraordinary dynamic stability.

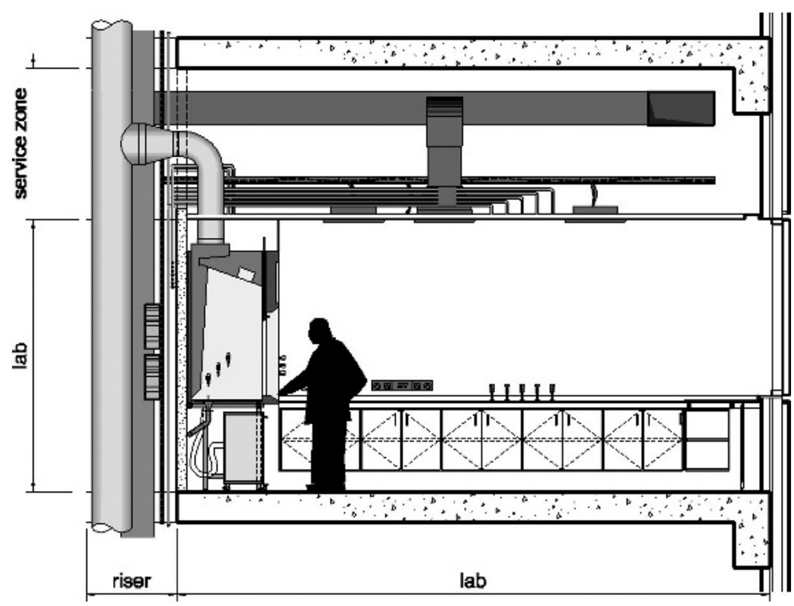
* The detail size refers to the line widths for microelectronics fabrication, the particle (cell) size for medical and pharmaceutical research, etc. The values given take into account the observation that the vibration requirements of many items depend upon the detail size of the process

Table VI Basic vibration control techniques

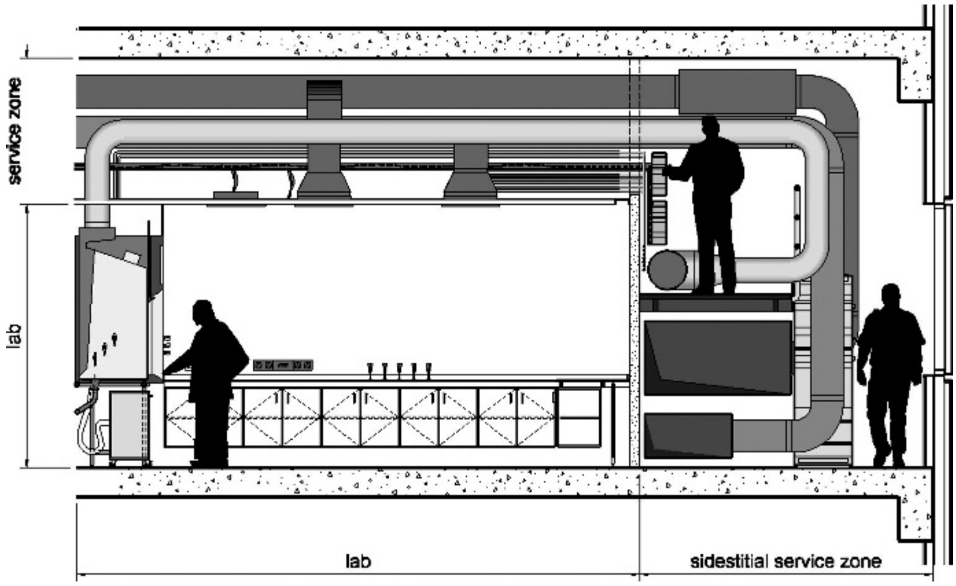
Vibration control	Technique
Building location	Away from traffic, vibration sources
Room location and floor features	Slab-on-grade/stiff floor/isolated floor
Equipment location	Away from centre of bay, motorised equipment
High rigidity and low-weight tables/ benches	Top honeycomb structures
Direct isolation of equipment	Rubber mounts/air springs/isolators
Active vibration isolation	Piezoelectric/electrodynamic actuators

Table VII Pros and cons of embedded service risers within the building floor plate

Pros	Cons
Potentially unrestricted views out	Restricted flexibility
Short horizontal service runs within ceiling void	Changes could disrupt adjacent spaces
Least space required out of floor plate	Maintenance access within ‘clean’ environment
Low-cost impact	



23.8 *Embedded service risers within the building floor plate*



23.9 *Sidestitial service zone*

Table VIII Pros and cons of a sidestitial service zone

Pros	Cons
Good flexibility especially if services are modular	Restricted views on one side
Short horizontal service runs within ceiling void	Medium cost impact
Maintenance access outside 'clean' environment	Dedicated zone required out of floor plate

Table IX Interstitial floor service zone

Pros	Cons
No restrictions to views out	High-cost impact
Total flexibility for laboratories above or below	Increased building height
Maintenance access outside 'clean' environment	
Limited horizontal service runs within ceiling void	

23.10. This is potentially the most expensive of the options however it offers the greatest flexibility and excellent access for maintenance with minimum disruption to the laboratory functions – Table IX.

2.05 Space organisation

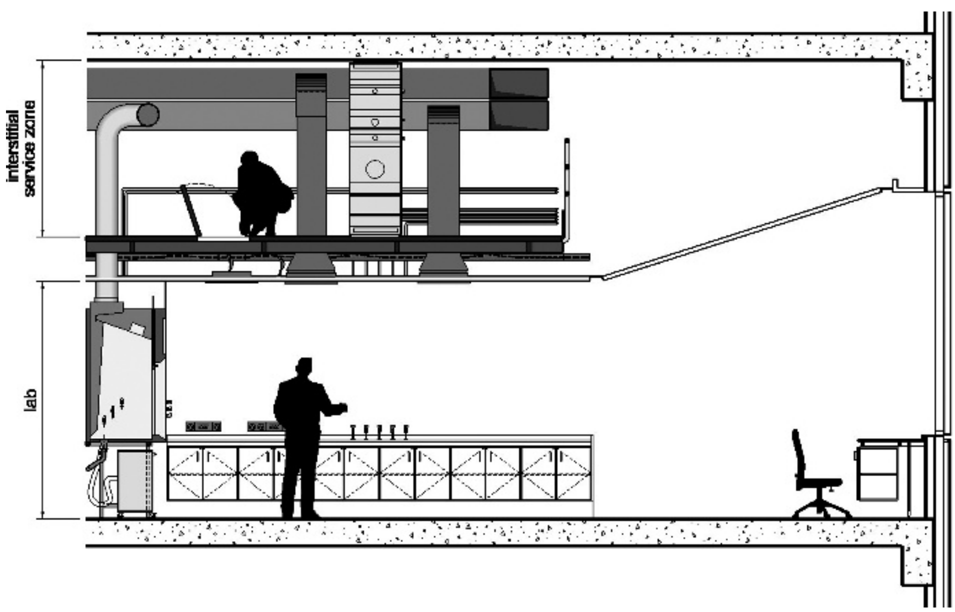
The following definitions apply for the purpose of measurement:

- *Laboratory worker*: A user who is allocated a bench space within the primary laboratory space.
- *Researcher*: A user who is directly involved in scientific work, including staff that may not have an allocated bench space within the primary laboratory space (e.g. staff working predominantly on computer applications or senior staff who may work principally from an office space).

2.06 Space designation

For the purpose of organisation, the different spaces in a laboratory facility are designated as primary, secondary, tertiary and balance spaces.

Primary space: Primary space is the area in which researchers perform their tasks. It is divided into primary laboratory space and primary office/write-up space, each with different accommodation and service requirements.



23.10 *Interstitial floor service zone*

Primary laboratory space will normally include:

- Designated bench space for laboratory workers, including those who also have the use of an office/write-up space equipped with appropriate services and local storage.
- Additional workstations associated with a piece of equipment or an experimental procedure, which are not the principal work location of a particular person, but may be used by one or more persons from time to time including PC and other IT terminals, fume cupboards, extract cabinets and laminar flow cabinets.
- Shared storage for laboratory equipment and materials.
- Shared general facilities including display and notice boards, telecoms, dispensers.
- Facilities for waste disposal.
- Services as applicable to the laboratory type.

Primary office/write-up space will normally include:

- Write-up areas for laboratory workers
- Offices of senior laboratory workers
- Offices for members of the team who do not use a laboratory workstation
- Workstations for secretaries
- Services as applicable to the space type (similar to a standard office environment)

Secondary space: Secondary spaces (sometimes referred to as ‘ancillary areas’ or ‘slave spaces’) include all areas which accommodate functions directly related to the operations carried out in the primary space.

Secondary space will normally include:

- Facilities such as equipment rooms, instrument rooms and preparation rooms, which may not have special accommodation or service requirements, but which are better separated from the primary laboratories to increase utilisation through shared use.
- Highly specialised laboratory facilities such as containment suites, fermentation suites and decontamination suites whose accommodation needs are very different from primary laboratory spaces.
- A full range of mechanical, electrical, data/telecom and piped services as applicable to the space type.

Tertiary space: Tertiary spaces are those whose functions, in addition to the primary and secondary spaces, support the goals and aspirations of the facility. They include other space types such as conference/meeting rooms, interaction spaces, general storage, etc.

Balance space: Balance space will normally include:

- Reception
- Cleaner’s rooms
- Corridors/lifts/stairs
- Lavatories
- Service risers
- Circulation/support areas which are not defined as primary, secondary or tertiary space

2.07 Area calculation

The Net Useable Area (NUA) is the sum of primary, secondary and tertiary space. In laboratories and large open plan spaces (e.g. multi-occupancy offices or grouped write-up spaces), the measurement of secondary circulation spaces as contributing to NUA or to Balance Area may depend upon the configuration of the spaces and the extent to which circulation space may be considered to contribute to the use of the space, other than exclusively for access and circulation. Schedules and drawings will clearly need to identify which areas have been measured as part of the Balance Area.

$$\text{NUA} = \text{Primary space} + \text{Secondary space} + \text{Tertiary space}$$

The Gross Internal Area (GIA) is the sum of NUA and Balance space. The GIA does not include plant areas. The area required for plant rooms is particularly difficult to define at the early stages of design as, depending on requirements, this could be anything between 25 and 100% of the laboratory floor area. Therefore, comparative data is more useful if plant rooms are excluded from Balance Area and GIA.

$$\text{GIA} = \text{NUA} + \text{Balance space}$$

2.08 Assembly

Primary, secondary and tertiary space functional adjacencies: Zoning the building between laboratory and non-laboratory spaces will reduce costs. For example, the ventilation of laboratories may require 100% outside air while non-laboratory spaces can be designed with recirculated air or naturally ventilated, similar to an office building.

Primary laboratory space is typically designed as modules to suit the laboratory team sizes and their requirements with secondary laboratory spaces in close proximity to the primary space.

As the secondary spaces will be shared by the laboratory teams, a separation zone or corridor should be included between the two to ensure no interference to the on-going research in the primary areas.

The primary office/write-up functions should be physically separated from the laboratory functions in accordance with Workplace Health and Safety guidelines. This ensures that laboratory activities are contained to areas where appropriate finishes, containment and air handling can be provided. Considerations for adjacencies between the write-up and laboratory space include:

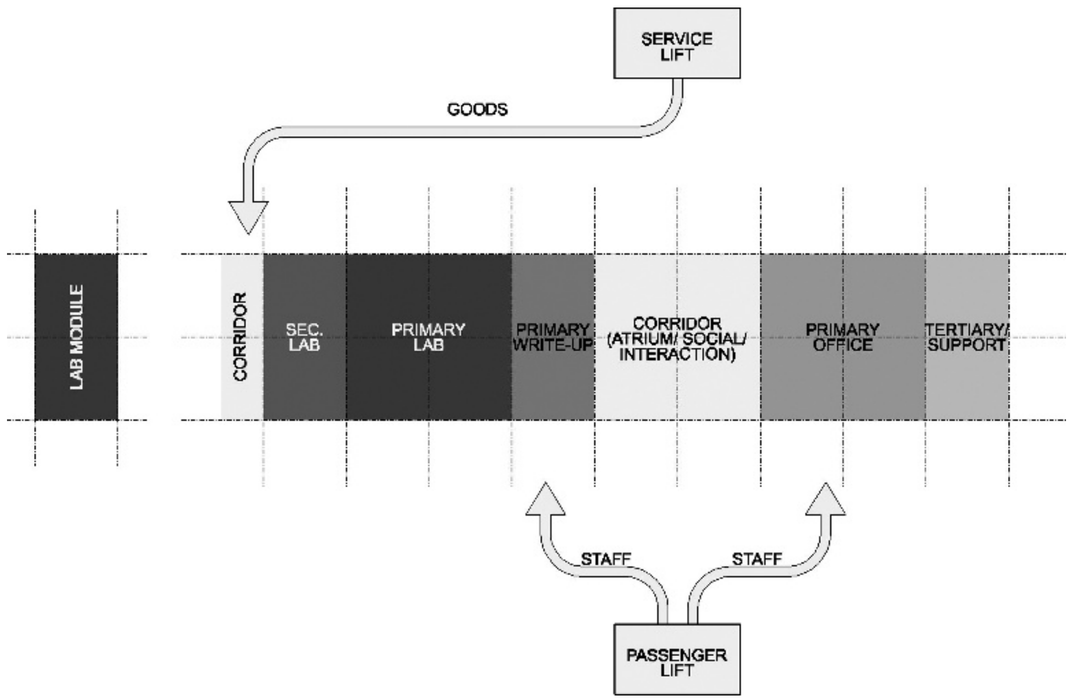
- *Visibility/safety*: If processes are occurring in the laboratory that require viewing from a write-up space or the laboratories are small so fewer people may be in the laboratory at any one time, then laboratories and write-up should be directly adjacent to each other with glass vision walls between.
- *Convenience*: If the user is writing up an experiment and conducting an experiment simultaneously then direct adjacency is desirable.
- *User preference*: If neither of the above applies, then this is a matter of user preference.

Tertiary spaces do not always need to be close to the primary and secondary areas. Their location is a matter of preference and is determined through discussion with the stakeholders.

23.11 illustrates one of many ways of assembling primary, secondary and tertiary space in a facility. The example shown would be suitable for a biomedical facility. Refer Table X for a ration of the areas relative to the gross floor plate.

Layout considerations

- *Views/wall space*: Do the stakeholders want a view from their laboratories to the exterior or will the laboratories be located on the interior with wall space used for laboratory benches and equipment?
- *Light sensitivity*: Some scientific methods do not require or cannot be exposed to natural light. Special instruments and equipment such as NMR apparatus, electron microscopes and lasers cannot function properly in natural light. These are typically located in the interior of the building.
- *Shape of space*: Regular and rectangular shapes are generally the most efficient for laboratories. Irregularities on the perimeter of a space will reduce the overall effective area.
- *Open/cellular laboratories*: The open plan laboratory concept is significantly different from that of the cellular laboratory of the past which was based on accommodating the individual principle investigator. In open plan laboratories, researchers share not only the space itself but also the equipment, bench space and support staff. This format facilitates communication between scientists and makes the laboratory more easily adaptable for future needs.



23.11 *Plan layout illustrating an example of a typical relationship between primary, secondary, tertiary and balance laboratory spaces in a biomedical facility*

Table X Table of relative areas for primary, secondary and tertiary spaces in a laboratory facility. Relative Areas

Laboratory space type	% of gross
Primary laboratory space	18–23
Primary office/write-up spaces	14–18
Total primary space	32–36
Secondary space	16–23
Total primary plus secondary space	50–59*
Tertiary space	9–18
Total net useable space	**65–70**
Gross internal area (excluding plant rooms)	**100**

* The ratio of secondary to primary space is in the range 40–70%. It will depend, among other things, on the disposition of equipment between laboratory space and special instrument rooms.

2.09 Areas/workspace

Academic (teaching): In primary schools, science is regarded as one of the specialist practical activities in the curriculum and generally utilises a space that could also be used to teach design and technology (including food) and art. This space can either be a stand-alone discrete room or an open bay within a standard classroom, **23.12a**. The base requirements for these spaces are a sink, washable floor and furniture for 'wet' practical activities. Area requirements are indicated in Table XI.

In secondary schools, laboratories are generally located as suites. In addition to the laboratories (the number which can be estimated from Table XII), non-teaching support spaces are required such as preparation and storage areas. These areas would also provide a departmental staff base with space for the secure storage of pupil's records and other paperwork. Other associated teaching spaces for post-16-year-old students could include spaces such as a small science project room, green house or microbiology room, **23.12b** and **23.12c**.

In higher education, the traditional distinction between teaching and working laboratories has become less important and an increasing number of institutions are integrating these areas. There are several reasons for creating 'homogenous' laboratory facilities:

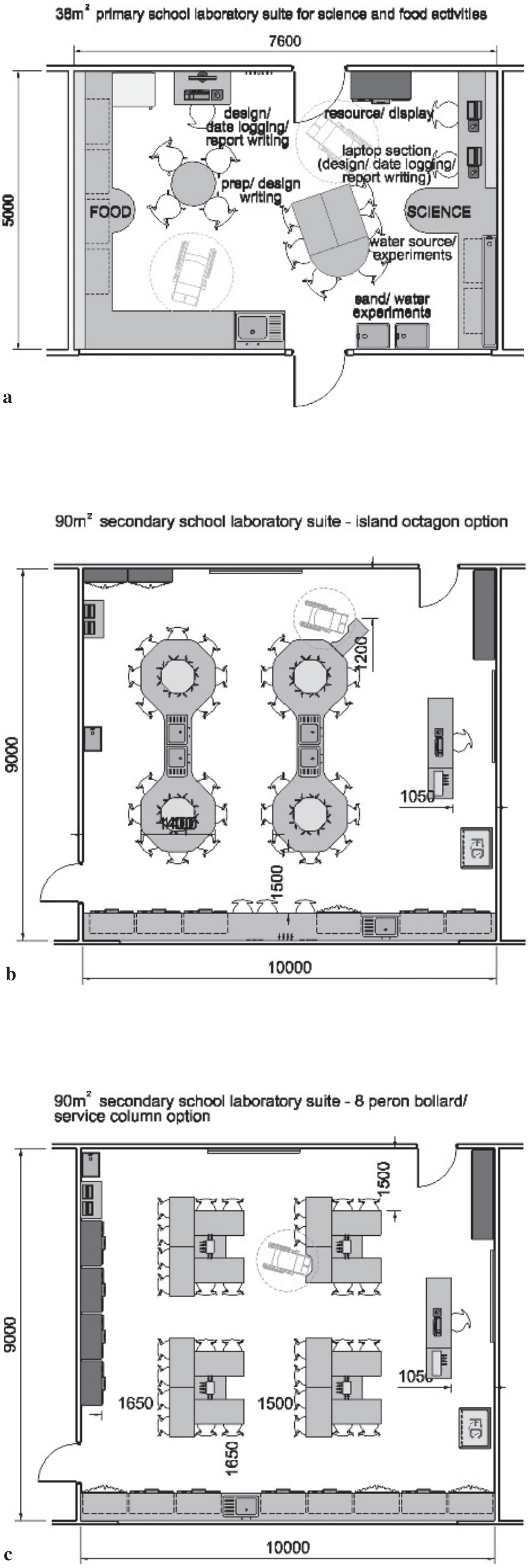
- Students at all levels are introduced to current techniques.
- Interaction is encouraged between faculty, graduate students and undergraduates.
- A standard serviced laboratory module accommodates change readily.
- Common and specialised equipment may be shared reducing project costs.
- Common facilities can share support spaces and specialty rooms.
- Greater utilisation of space and equipment enhances project cost justification.
- Teaching laboratories can be used for faculty research during semester breaks.

For these reasons, the standards applicable to academic research laboratories are also applicable to higher education Table XIII.

Academic (research), government, private/corporate: Laboratory allocation may be driven by space per researcher (e.g. biology and chemistry laboratories) or by equipment needs (e.g. analytical and engineering laboratories) leading to greater variances between facilities. In this handbook, the areas provided are based on space per researcher. Equipment driven laboratories require individual consideration with the stakeholders on a project basis. Table XIII provides recommended average areas for laboratory workers/researchers in the academic (research) and government sectors.

Note that, for example, a biologist needs far less fume cupboard space than say a chemist, however, there is a significantly greater need for ancillary equipment such as refrigerators, incubators, centrifuges and environmental rooms. The overall space requirements balance and, for the purpose of flexibility, should be generic.

Private/Corporate sectors often have their own standards for space organisation. They typically use benchmarking to estimate the amount of space and benching to be provided to each researcher. Benchmarking can be an unreliable process in part because it is difficult to acquire solid, relevant data. There is a very wide range between the minimum and maximum for commercial data which reflects the complexity of uses in laboratory environments (e.g. US laboratories can range from 22.7 to 41.1 m^2/person, net primary plus secondary space/researcher). The areas provided in Table XIV are the guidelines adopted by a large UK private pharmaceutical company.



23.12 *Typical layouts for academic (teaching) facilities* (**a**) *primary school;* (**b** *and* **c**) *secondary school laboratory suite*

Table XI Space standards for primary education laboratories
Primary School (combined food/science/design and technology room) Space standards based on Building Bulletin 99: Briefing Framework for Primary School Projects, DFES (BB 99, refer Bibliography)

Number of places	Group size (maximum number)	Average room size (m^2)	Number of rooms (minimum)
Less than 120	8	24	1
121-419	8	38	1
420 and above	15	38	2

Table XII Space standards for secondary education laboratories
Secondary School 11–16 years old with no curricula emphasis
Space standards based on Building Bulletin 98: Briefing Framework for Secondary School Projects, DFES (BB 98, refer Bibliography)

Number of places	Group size (maximum number)	Average room size (m^2)	Number of rooms (minimum)
577–642	30	90	5
850–945	30	90	7
1125–1251	30	90	9
1399–1555	30	90	11

Secondary School 11–16 years old with science, design and technology curricula emphasis
Space standards based on BB 98

Number of places	Group size (maximum number)	Average room size (m^2)	Number of rooms (minimum)
834–927	30	90	5

In addition to the above, a total preparation and storage area of approximately 0.4 m^2 per workplace is required.

Secondary Post-16 years old (with no curricula emphasis)
Space standards based on BB 98

Number of places	Group size (maximum number)	Average room size (m^2)	Number of rooms (minimum)
100	30	90	1
250	30	90	2

Secondary Post-16 years old (with science, design and technology curricula emphasis)
Space standards based on BB 98

Number of places	Group size (maximum number)	Average room size (m^2)	Number of rooms (minimum)
137–361	30	90	3

In addition to the above, a total preparation and storage area of approximately 0.5 m^2 per workplace is required

Table XIII Table of average areas per person (academic, government sectors)

	Area/person (m^2)
Net primary laboratory area/laboratory worker	6–10*
Net total primary space/researcher	10–16
Net primary plus secondary space/researcher	15–25
Gross internal area (excluding plant rooms)/person	20–30

* Add 2–3 m^2 when a writing place is included in the laboratory area

Table XIV Table of average areas per person (example of guidelines adopted by a large UK private pharmaceutical company)

	(m^2)
Net primary laboratory area/laboratory worker	10–11
Net total primary space/researcher	14–17
Net primary plus secondary space/researcher	18–24
Gross internal area (excluding plant rooms)/person	23–34

2.10 Circulation

- Corridors, stairs, lifts, ramps, holding and other balance areas must allow ease of movement of people, materials, waste and equipment in respect of access routes dimensions, configuration and doors.
- Circulation should provide safe pedestrian egress from each individual laboratory and laboratory support space through an uncomplicated path of egress to the building exterior at grade.
- Separation of workspace and circulation reduces the likelihood of accidents and eases the problem of escape from hazards.
- The circulation system should accommodate the preferred adjacencies identified for the relationships between primary, secondary and tertiary laboratory spaces.

Adjacencies with corridors can be organised with a single, two corridor (racetrack) or a three corridor scheme. There are a number of variations to organise each type, **23.13–23.15**.

Distance between aisles: Recommended clear distances between aisles in laboratories is indicated in Table XV and illustrated in **23.16**.

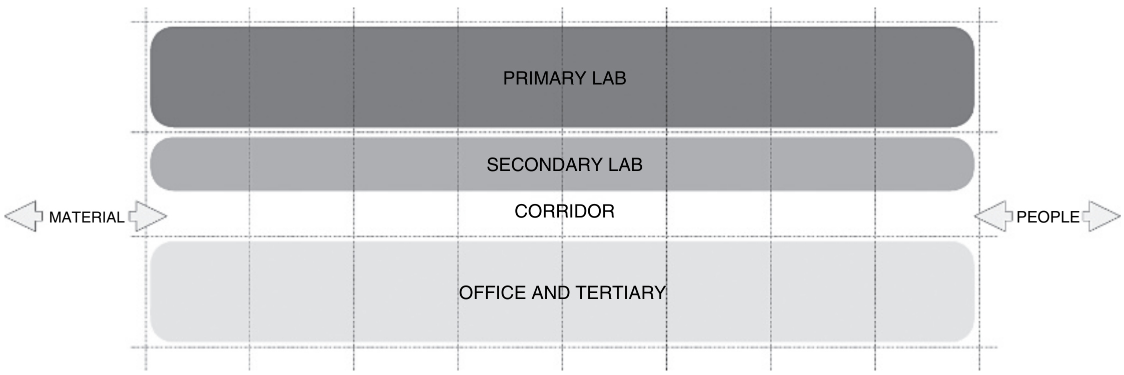
Aisles and corridor widths: Recommended clear distances between aisles and corridors in laboratories is indicated in Table XVI and illustrated in **23.17**.

Doors: Table XVII indicates the minimum width dimension (clear opening) recommended for at least one door into laboratories and equipment rooms to accommodate the periodic movement of equipment. This can be accomplished using an opening with a 900 mm active leaf (with a clear opening of 800 mm for DDA requirements) and a 300 mm inactive leaf. Future equipment should be anticipated and equipment lists reviewed to verify that individual pieces of equipment can be transported and manoeuvred between spaces.

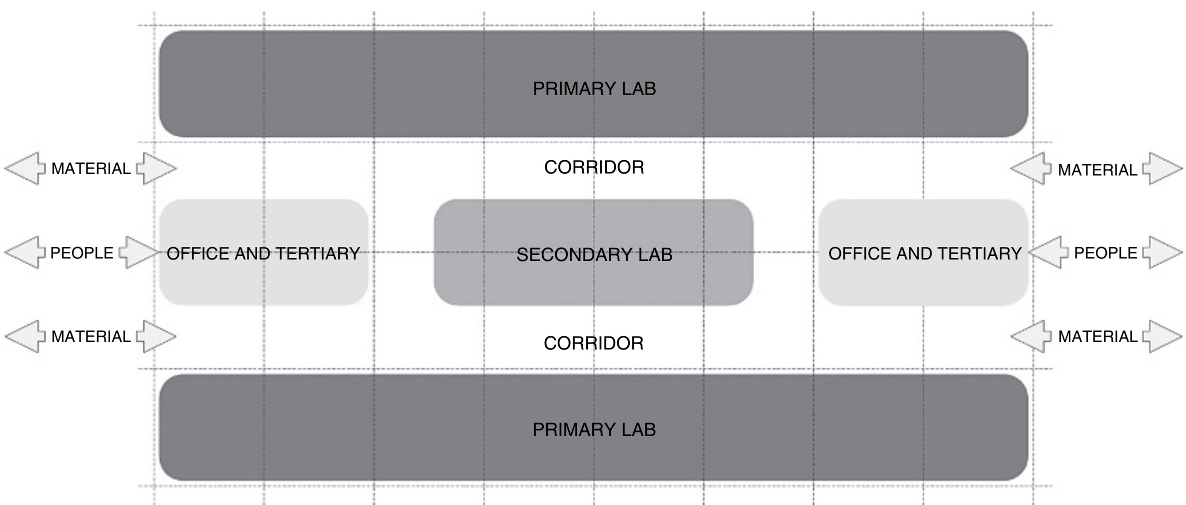
Escape: Under the Building Regulations 2000 Approved Document B Volume 2, laboratories are considered under the same purpose group as an office whereby the maximum travel distance where travel is possible in more than one direction is 45 m while if in one direction only it is 18 m. In the past, the Building Regulations stipulated a variation to this of 18 m travel distances where travel is possible in more than one direction while 9 m if in one direction only for laboratories with open heat sources (e.g. bunsen burners) defining them as 'Places of Special Fire Hazard'. This is no longer included in the latest amendment as all fire safety in work places is covered by Regulatory Reform (Fire Safety) Order 2005 where the onus now is for a 'responsible person' to arrange for a risk assessment for fire safety to be undertaken, **23.18**.

Where a piece of equipment in a laboratory, which could be the source of a health hazard (such as a fume cupboard exploding), is located within an escape route it is recommended that an alternative route be allowed for in the design. In addition to this, if gas cylinders are required within a laboratory they should be securely fixed in a position away from any escape route or final exit, **23.19**.

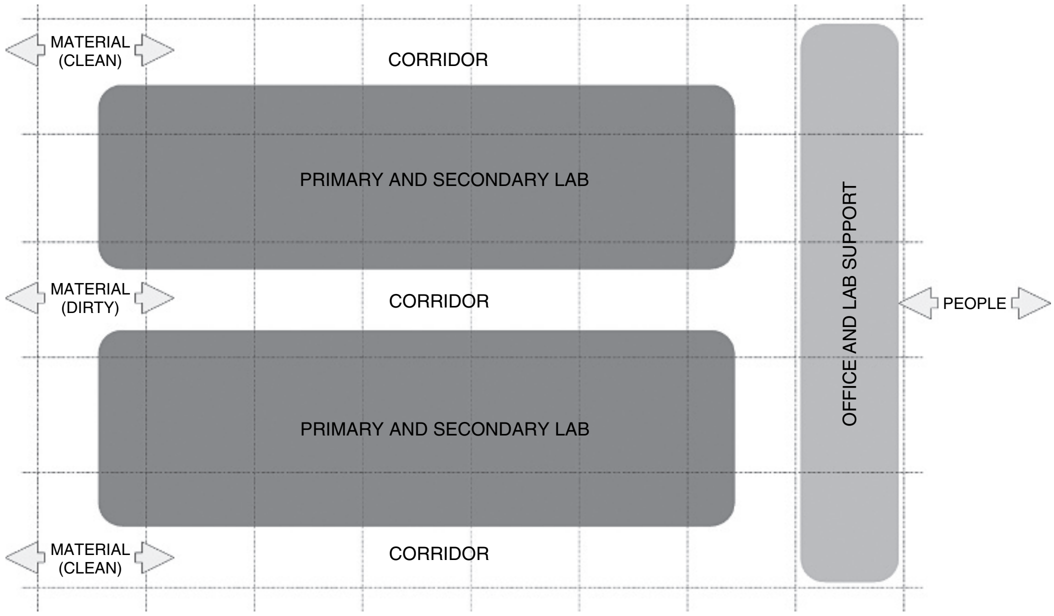
Lifts: The service lift also often doubles up as access to the plant room for items of plant. Engineers will typically ask for a lift with



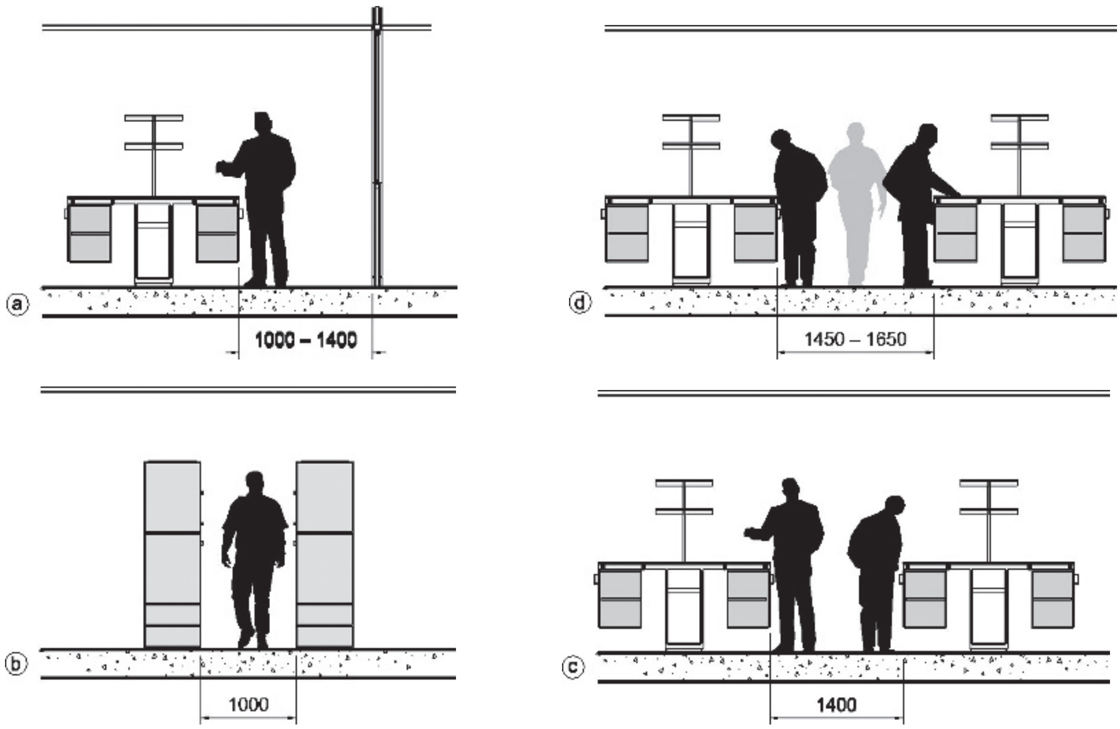
23.13 *Plan layout illustrating a single corridor arrangement. This layout is efficient however the single circulation route may result in material/people flow cross-over and conflict*



23.14 *Plan layout illustrating two corridor (racetrack) arrangement. This layout effectively separates people and material circulation within the facility*



23.15 *Plan layout illustrating three-corridor arrangement. This layout provides the greatest opportunity for optimising circulation within the facility however it is also potentially the most inefficient with respect to area*



23.16 *Aisle distances* **(a)** *bench and wall/equipment, single throughway;* **(b)** *bench and/or equipment, no workstations, single throughway;* **(c)** *two workers back to back, single throughway;* **(d)** *two workers back to back, multiple throughways*

Table XV Recommended aisle distances in laboratories

Minimum Distance	Width (mm)
Between front of bench or work station and a facing wall, other furniture or equipment or pedestrian route (with one person at bench)	1000*–1400*
Between benches, furniture or equipment without work spaces either side allowing passage of one person at a time	1000*
Between two people back to back but no need for a third person to pass between front of facing benches, work stations or equipment where people work allowing one of the people to pass behind the other	1400*
Between two people back to back where space is required for a third person to pass between front of facing benches, work stations or equipment where people work allowing a third person to pass behind the others	1450*–1650 (1800 exceptionally)

* 1200 mm is required for DDA compliance and 1500 mm when opposite a fume cupboard or microbiological safety cabinet

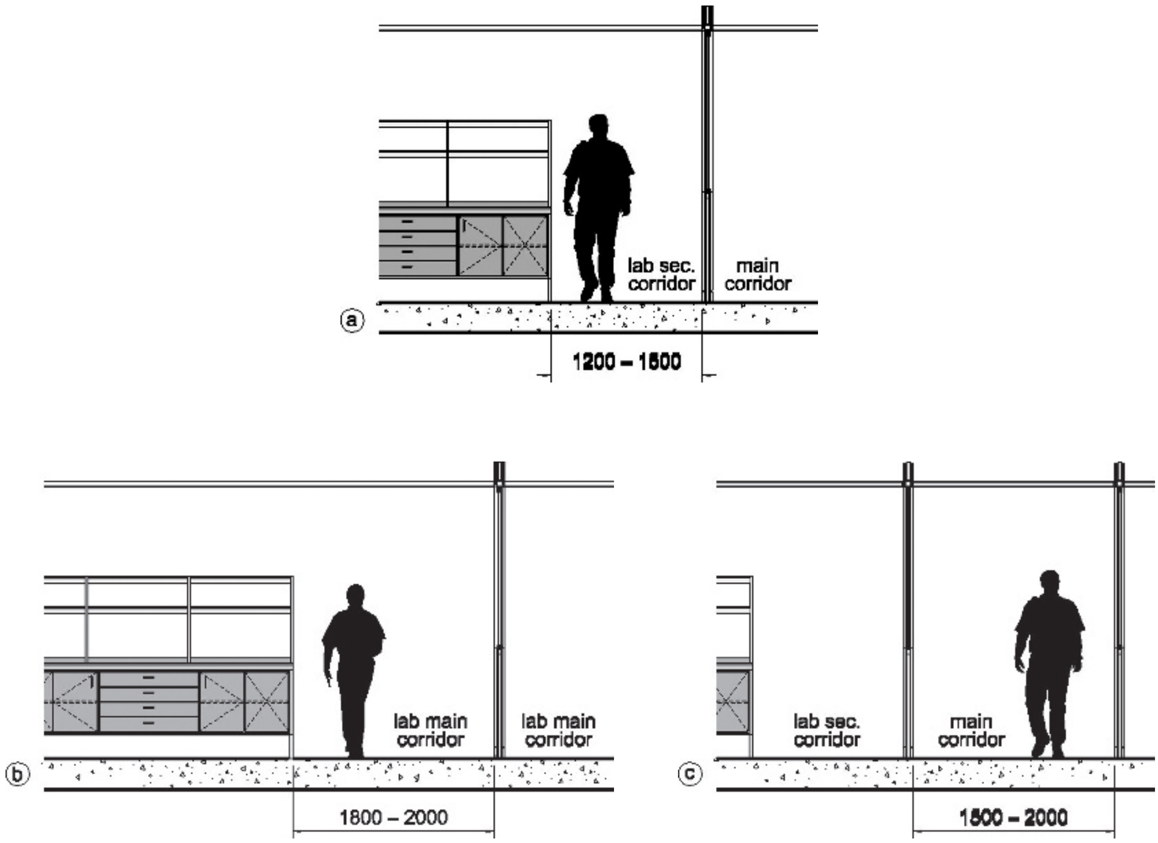
Table XVI Aisle and corridor widths

	Width (mm)
Aisles running along the ends of benches providing circulation within a laboratory	1200–1500*
Similar aisles, where there is no separate corridor for general circulation outside the laboratory	1800–2000*
General circulation corridors	1500–2000**

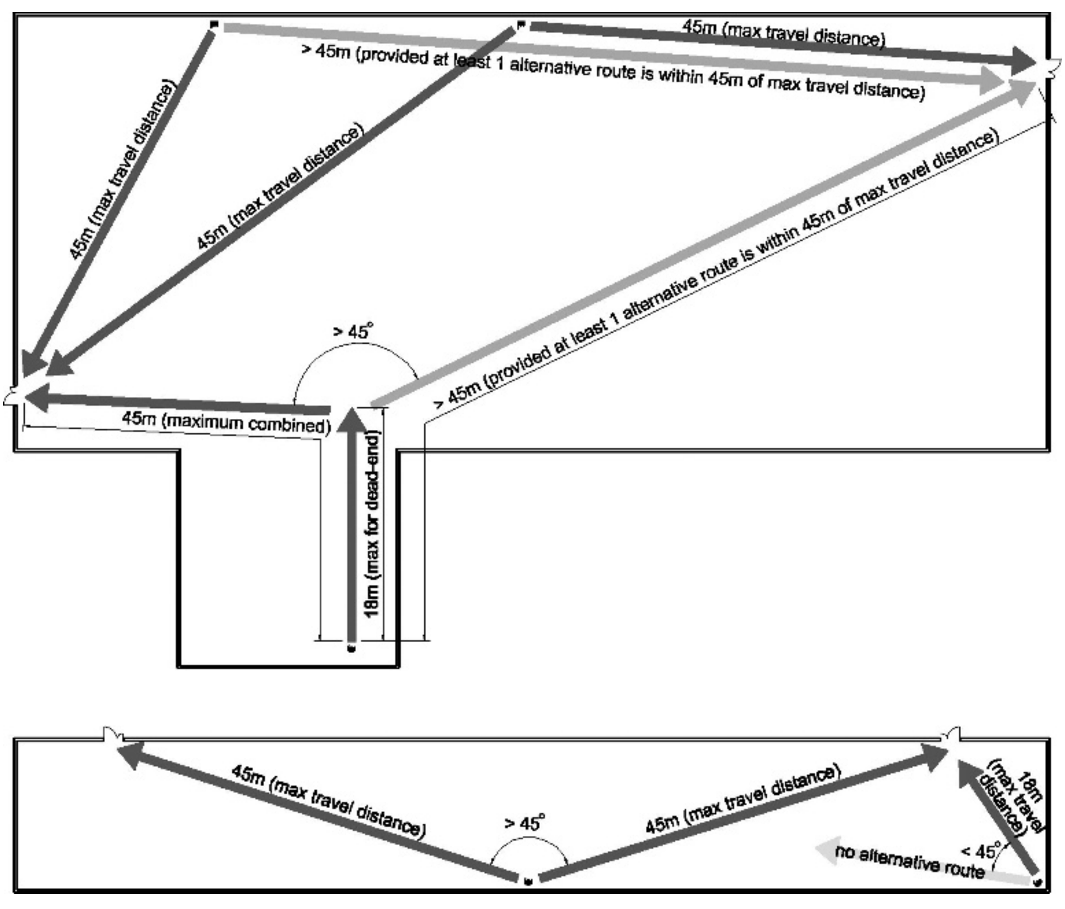
* Allowance must be made when the aisle may be partially obstructed, for example by staff using bench-end sinks, by doors opening into the aisle, by equipment and by fume cupboards and microbiological safety cabinets

Table XVII Door width requirements (minimum)

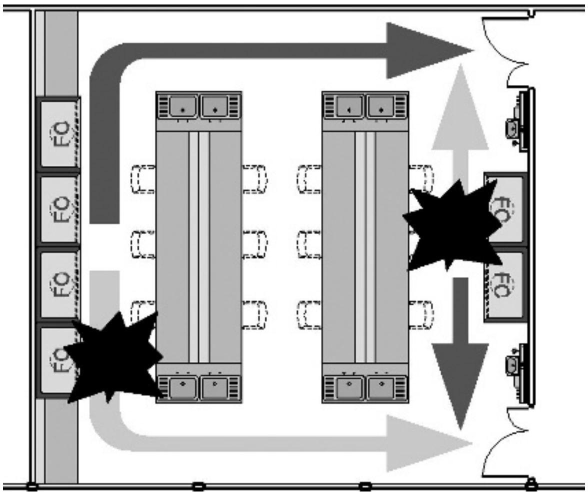
	Leafs	Leaf width (mm)
At least one doors into laboratories and equipment rooms	1.5 leafs	1200



23.17 *Aisle and corridor widths* **(a)** *at the ends of benches, additional means of circulation within the laboratory;* **(b)** *at the ends of corridors, single means of circulation within the laboratory;* **(c)** *general circulation*



23.18 *Means of escape in a laboratory*



23.19 *Alternative means of escape where potential sources of hazards exist*

the capacity to take a 2 m cube (minimum) to allow items of air handling equipment to be dismantled and taken down in the lift and this would generally be a suitable size to accommodate most large equipment in a laboratory, for example, a $-80^{o}C$ freezer or an item of furniture. Specific requirements should be confirmed with the stakeholder.

2.11 Furniture

Laboratories should be designed to allow relocation of furniture within the limits of the modular configuration. Particular reference is made to:

- Selection of laboratory benching and storage systems
- Distribution of services systems

Ideally, benches should be movable and in modular lengths (typically in increments of 1000 mm for the UK furniture manufacturers and 600, 900 or 1200 mm for other European manufacturers), depths and heights to allow space to be reconfigured and adapted with ease.

Provide height adjustable furniture where possible to accommodate various equipment and DDA requirements. Provide at least one DDA compliant workstation/write-up area for each laboratory unit and in accordance with stakeholder requirements.

Bench length, depth and height – primary schools: As science is undertaken in a multi functioning area around clusters of tables, perimeter benching or a combination of the two and limited to groups of eight children the only critical dimension in planning such a space is to ensure wheelchair access to key facilities within it, Table XVIII, **23.20**.

Bench length, depth and height – secondary schools: See Table XIX, **23.21**.

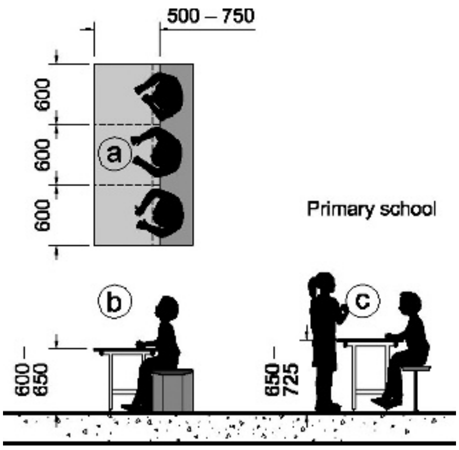
Bench length, depth and height – higher education/research: A height adjustable bench and laboratory chair is recommended where possible (subject to budget and requirements for vibration control and cleanliness). Flexibility can be further increased by providing removable bench tops which allow floor standing equipment to be accommodated as required – Table XX, **23.22**.

2.12 Storage

- Centrally located storage rather than local is preferred (for ease of maintenance, avoiding duplication, diversity and more intense use of equipment).
- Storage depth and height dimensions should be based on convenient reach.
- Modular (based on industry standard sizes where possible).
- Movable/adjustable.

Table XVIII Recommended student laboratory benching dimensions for primary schools

	Dimension (mm)
Length of bench per student	600
Clear bench depth for normal requirements	500–750
Bench height: Seated	600–650
Standing/seated on laboratory stool	650–725

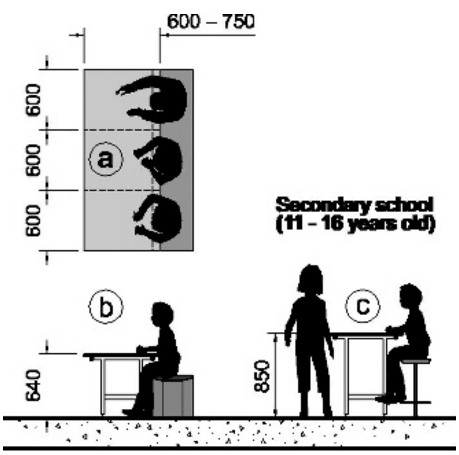


23.20 *Recommended student laboratory benching dimensions for primary schools* **(a)** *plan of bench;* **(b)** *seated;* **(c)** *standing/seated on laboratory stool*

Table XIX Recommended student laboratory benching dimensions for secondary schools

	Dimension (mm)		
	Secondary (11–16 years)	Secondary (post-16 years)	DDA
Length of bench per student	600	600–1200	1200
Clear bench depth for normal requirements	600–750	600–750	600–750
Bench height:			
Seated	640	720	850
Standing/seated on laboratory stool	850	900	
Height adjustable	700–1050*	700–1050*	700–1050*

* Height adjustable recommended where possible

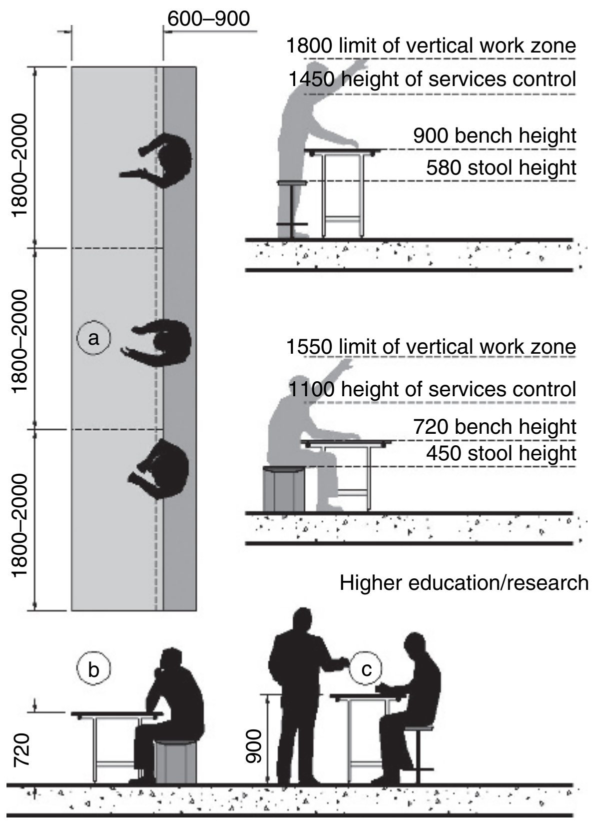


23.21 *Recommended student laboratory benching dimensions for secondary schools* **(a)** *plan of bench;* **(b)** *seated;* **(c)** *standing/seated on laboratory stool*

Table XX Recommended laboratory benching dimensions for higher education/research

	Dimension (mm)
Length of bench per researcher	1800–2000 (2400 exceptionally)*
Clear bench depth for normal requirements	600–900**
Bench height:	
Seated	720***
Standing/seated on laboratory stool	900****
Height adjustable	700–1050*****
Height of services control (sitting/standing)	1100/1450
Limit of vertical work zone (sitting/standing)	1550/1800

* Suitable length will depend upon the amount of bench-mounted equipment. 2000 mm is a good starting point. Exceptional cases include benchmark allowances made in private/corporate sectors
** Certain operations and pieces of equipment may require a greater bench depth. These need to be identified early in the briefing process and are generally accommodated on double depth peninsular benches. 750 mm is a good median figure
*** Increases to 850 mm for DDA compliance
**** Care should be taken to co-ordinate the bench height with under bench equipment such as refrigerators and freezers as these vary in height
***** Accommodates DDA requirements and is recommended where possible (subject to budget and requirements for vibration control and cleanliness)



23.22 *Recommended laboratory benching dimensions (length, depth and height) for higher education/research.* **(a)** *plan of bench;* **(b)** *seated;* **(c)** *standing/seated on laboratory stool*

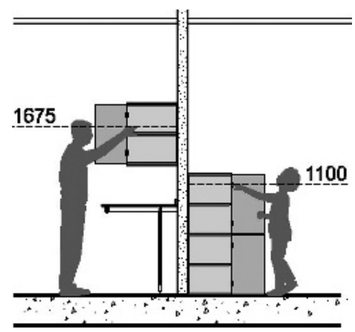
Convenient reach: Comfortable reach into a 300–500 mm deep cupboard above floor level is as follows – Table XXI, **23.23**.

Cupboard depth and height: The depth of storage cupboards should be between 300 and 500 mm for ease of access and fit with bench top and rail, **23.24**. The maximum height and lowest level of storage which is frequently used should be based on convenient reach. Extreme high and low zones tend to be used for dead storage – Table XXII, **23.25**.

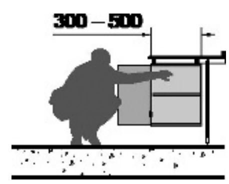
Underbench storage: Underbench storage ideally should not exceed 50% of the underbench space and should be removable.

Table XXI Convenient reach dimensions for ages 7–18+ and DDA compliance

Age	Convenient Reach (mm)
7 years	1100
9 years	1170
10 years	1260
11 years	1300
12 years	1375
17 years	1640
18 years +	1675
DDA reach height	1160



23.23 *Convenient reach dimensions for ages 7–18+ and DDA requirements*



23.24 *Storage depths based on convenient reach*

Table XXII Recommended storage heights based on convenient reach

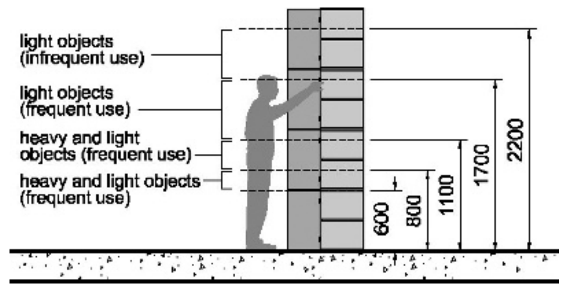
	Dimension (mm)
Light objects infrequently used	1700–2200
Light objects frequently used	1100 –1700
Heavy & light objects frequently used	800–1100
Heavy objects infrequently used	600–800
DDA control height	1200 max–380 min

Options include suspended (movable), on castors or glides (movable) and plinth mounted. Movable units are recommended for ease of maintenance and relocation, **23.26**.

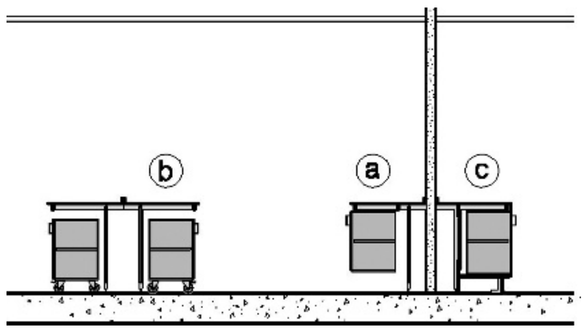
Shelves: Shelves and trays within storage units should be height adjustable and removable. Pull out drawers with shelves are recommended.

Gas cylinder storage: The mechanical engineering consultant will be primarily responsible for defining gas cylinder storage requirements, however, the following should be considered:

- The types of gas required and whether they are to be temporarily stored for later transportation or permanently stored for piping to their locations.
- Gas store proximities, cylinder separation for different gas types, explosion proofing/venting/fire rating, accessibility for delivery lorry to refill Dewar/s.



23.25 *Recommended storage heights based on convenient reach*



23.26 *Underbench storage options* **(a)** *suspended;* **(b)** *on castors or glides;* **(c)** *plinth mounted*

- Pipework distribution routes, venting, proximity to electrical services.
- Leak detection and alert systems including links to fire alarm/ building management system (BMS)/shut off at manifold and laboratory.
- Electrical equipment in store and laboratory.
- Ventilation equipment in laboratory.
- Gas supplier to the facility.
- Facility representative responsible for the above.

Liquid nitrogen storage

- If the fill point is located internally, continuous ventilation and an oxygen level detection system will be required.
- Ideally, store externally, located against a fire rated external wall. This requires no specialist venting. The only requirement for an external fill point would be a lightweight lean-to-roof arrangement, to protect it from the elements.

2.13 Equipment

General/standard floor standing equipment may include items noted below (note that confirmation with manufacturers is necessary as individual sizes vary considerably pending capacity and make. Sizes indicated are nominal):

- Fridge/freezer
- Underbench (600d × 600w × 650h)
- Tall/floor standing (600–750d × 600–750w × 1800h)
- Centrifuge (900–1200d × 900w × 950h)
- Oven (1000d × 1000w × 800h)

(Note: large storage freezers, typically −80°C, requiring approximately 1 m^2 minimum footprint should be located within designated freezer rooms which will provide sufficient noise attenuation and local cooling.)

Space allocation is dependant on individual requirements which are subject to change. Utilise removable or relocatable equipment in preference to purpose built fixed facilities where possible. Ideally, laboratory benching should be removable to allow floor standing equipment to be incorporated as required during the life of the laboratory.

Special equipment: Special equipment may include:

- NMR
- Microscopy
- X-ray and other imaging equipment
- IT equipment
- Balances and other measuring equipment
- Mass spectrometers
- Autoclaves

Room dimensions, structural loading, rigidity and resonance, environmental conditions, wave and particle shielding and services connections for special equipment require individual consideration and therefore should be dealt with on a case by case basis and must take full account of manufacturer's and health and safety requirements.

Fume cupboards (FCs): All FC setting out should comply with BS 7258 and give optimum protection to the user working with chemicals/aerosols. Single person fume cupboards are generally 1500–1800 mm long.

They should be positioned to avoid disturbances to the cupboard and its operator, **23.27** and **23.28**. Disturbances include people walking parallel to it, open windows, air supply registers or laboratory equipment that creates air movement such as, for example, vacuum pumps and centrifuges. They should be located away from high traffic areas, doors and air supply/exhaust grilles that may interrupt airflow patterns. There should be an alternative means of escape in the event of an explosion/fire.

The use of recirculating fume cupboards (non-ducted) can greatly reduce energy consumption although the cupboard usage may be limited. Relocatable FCs with flexible ducting and variable extract are recommended for maximising flexibility and minimising energy consumption.

The number of fume cupboards required should be confirmed with stakeholders.

Microbiological safety cabinets (MSCs): All MSC setting out should comply with BS5726 and EN12469 to give optimum protection to the user working with biological agents up to Hazard Group 4. Single person safety cabinets are generally 1500–1800 mm long.

They should be positioned to avoid disturbances to the cupboard and its operator, **23.29** and **23.30**. Disturbances include people walking parallel to it, open windows, air supply registers or laboratory equipment that creates air movement such as, for example, vacuum pumps and centrifuges. They should be located away from high traffic areas, doors and air supply/exhaust grilles that may interrupt airflow patterns. In general, we would recommend that all have ducted exhausts (not recycling air within the laboratory). Note, moving a cabinet can cause damage to the high efficiency particulate air (HEPA) filters and its seals.

The number of cabinets required should be confirmed with stakeholders.

2.14 Fittings

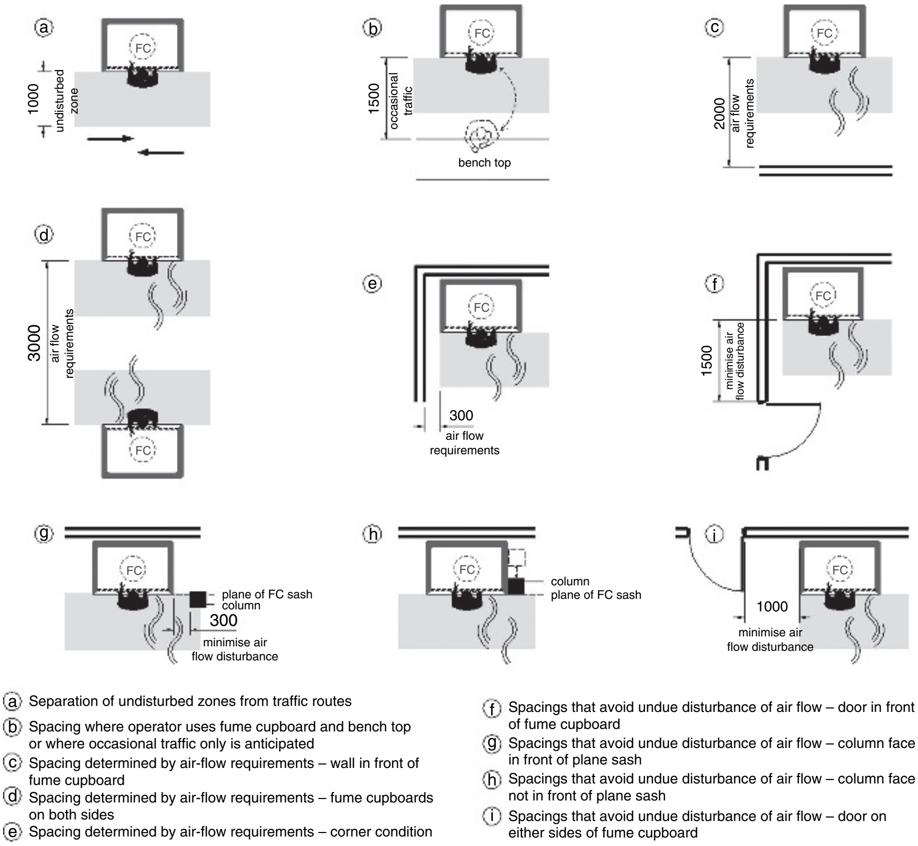
Handwashing sinks: Handwashing sinks where required, should be located near the point of exit from the laboratory or in the anteroom.

Emergency eyewash and safety shower facilities (EE/SS): EE/SS where required, should be provided in accordance with Workplace Health and Safety Requirements. They should be placed in the corridor, close to and highly visible from the laboratory exits.

2.15 Services requirements

Systems must deliver laboratory services suitable for the accurate and reliable conduct of research procedures, conforming to relevant standards and codes of practice and satisfying specific criteria, in respect of parameters, including:

- Composition
- Purity



23.27 *Fume cupboard minimum distances for avoiding disturbances to the fume cupboard and its operator*

- Stability and reliability (e.g. temperature, pressure, uninterruptible power supply (UPS), flow rate)
- Control of delivery

A well-controlled system will provide flexibility and minimise the operational cost of the building. Considerations should include:

- Expansion space allowed in the utility corridors, ceilings and vertical chases for future heating, ventilation and air conditioning (HVAC), plumbing and electric needs.
- Easy connects/disconnects at walls and ceilings to allow for fast and affordable hook up of equipment.
- Modular distribution.

Power: Three types of power are generally used for most laboratory projects. Requirements should be confirmed with stakeholders during the briefing phase.

- *Normal power*: Circuits are connected to the utility supply only, without any backup system. Loads that are typically on normal power include some HVAC equipment, general lighting and most laboratory equipment.
- *Standby power*: Depending on the size or height of the building, standby power, which is created with generators, may be required for life safety systems (e.g. smoke control systems, sprinkler pumps, fireman's lift, car park extract, etc.). Standby power may also be necessary from a business continuity/loss of product point of view in the event of a normal power cut-off (e.g. power to plant servicing critical temperature rooms, maintaining pressure to containment or clean room applications, power to sump and sewage pumps, extract systems for radioactive areas, etc.).
- *Uninterruptible power supply (UPS)*: UPS is required to condition and maintain uninterrupted power to critical loads for data recording, certain computers and microprocessor controlled equipment and selected bench outlets where long running experiments may be connected. The UPS can be either a central unit or a portable system pending extent of requirement, cost and space constraints. UPS systems are very expensive and therefore careful consideration is necessary when defining their rating.

Load: Connected electrical loads are anticipated loads estimated during the briefing phase. The loads provided in Table XXIII are indicative to assist with preliminary sizing of a generic bench scale laboratory building.

Services distribution: The method of distributing services to furniture and equipment has a major influence on the flexibility of layout possible during the laboratory's total life.

Where services are integral to the furniture, equipment and partitions, any major change in layout will involve adaptation or extension of the service runs. If, however, the distribution of services within the laboratory can be separated and flexible connections made to loose services units, layouts can be adjusted directly by stakeholders to meet new requirements.

There are three main methods of distributing services (power, data, gas, water) to laboratory benching and equipment:

- Overhead
- Perimeter
- Floor

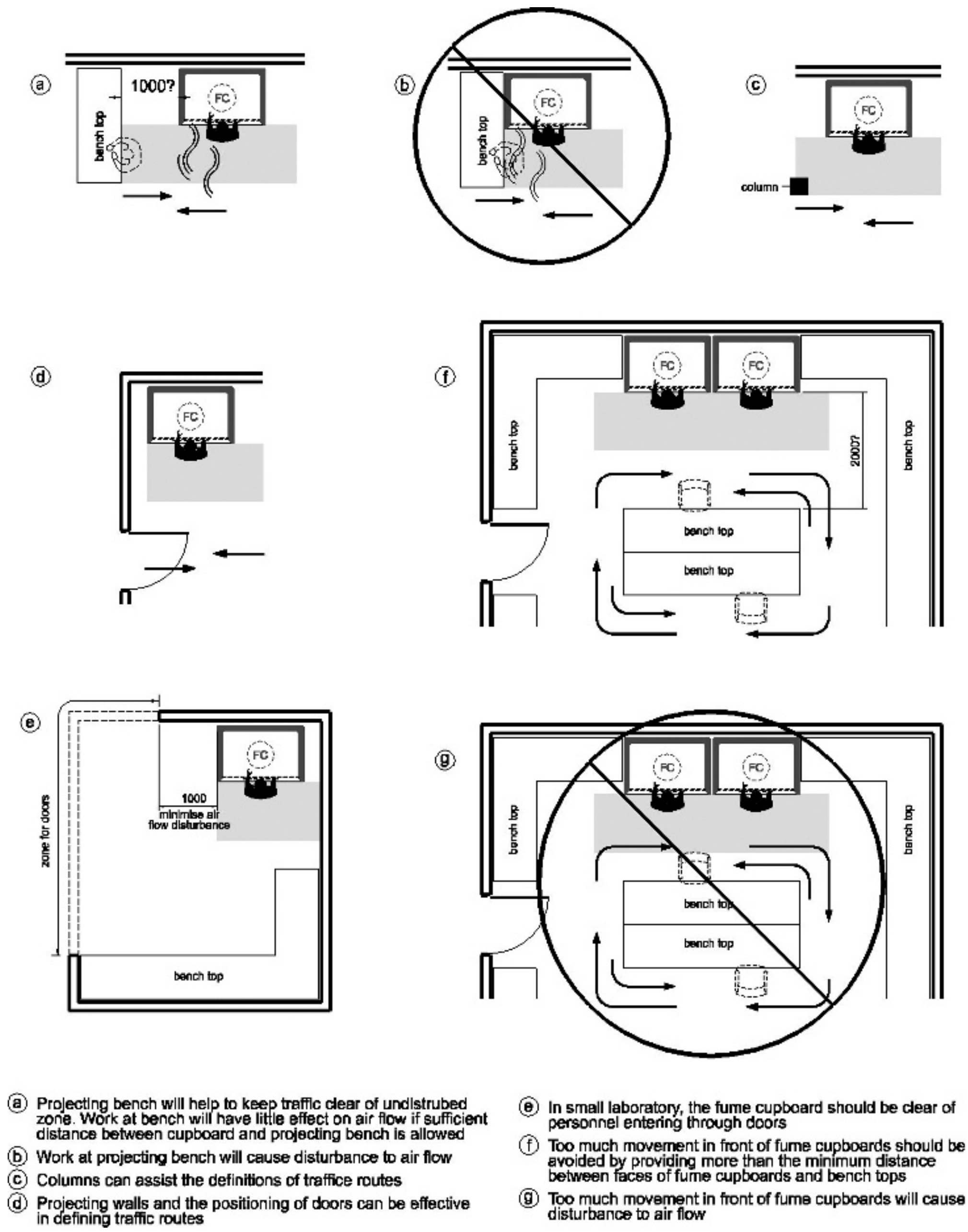
This allows furniture to be arranged in peninsular/perimeter and/or island configurations, **23.31–23.33**.

Power and data services outlets: Utilise accessible trunking that can readily accommodate the future addition and subtraction of outlets as required. Extension leads should be avoided for health and safety reasons.

Socket outlets should not be placed immediately adjacent to sinks where splashing could present a risk (refer BS7 671).

The number of outlets required should be confirmed with stakeholders and the services engineers. An indicative guide (typically maximum) for generically designed laboratories is as follows:

- Double power at 450 mm centres/bench and equipment run
- Double data at 900 mm centres/bench and equipment run



23.28 *Fume cupboard planning arrangements for avoiding disturbances to the fume cupboard and its operator and from other personnel*

Cleaner's sockets should be provided and clearly identified to avoid cleaner's equipment interfering with active experiments/ laboratory equipment.

Piped services: Laboratory piped services should be delivered to each laboratory on a modular basis (even though all services may not be initially required in all of the laboratories) for flexibility and to minimise remodel and retrofit costs as laboratory use changes. Each laboratory unit should have separate shut-off valves located in a consistent, accessible manner for repairs or emergency shut-off without affecting other laboratories. Except for waste and vent systems, distribution systems are recommended to be looped.

Initially, the frequency and quality requirements should be assessed. Where demand is intermittent or a particular quality is required, localised sources may be provided.
Basic requirements include:

- Potable water, hot and cold (HW, CW)
- Industrial water, hot and cold (IHW, ICW)

Optional (as required):

- Deionised water (DI)
- Purified water (PW)
- Laboratory air (Air)
- Natural Gas (NG)
- Vacuum (VAC)
- Compressed air (CA)
- Steam

Specialty gases (as required):

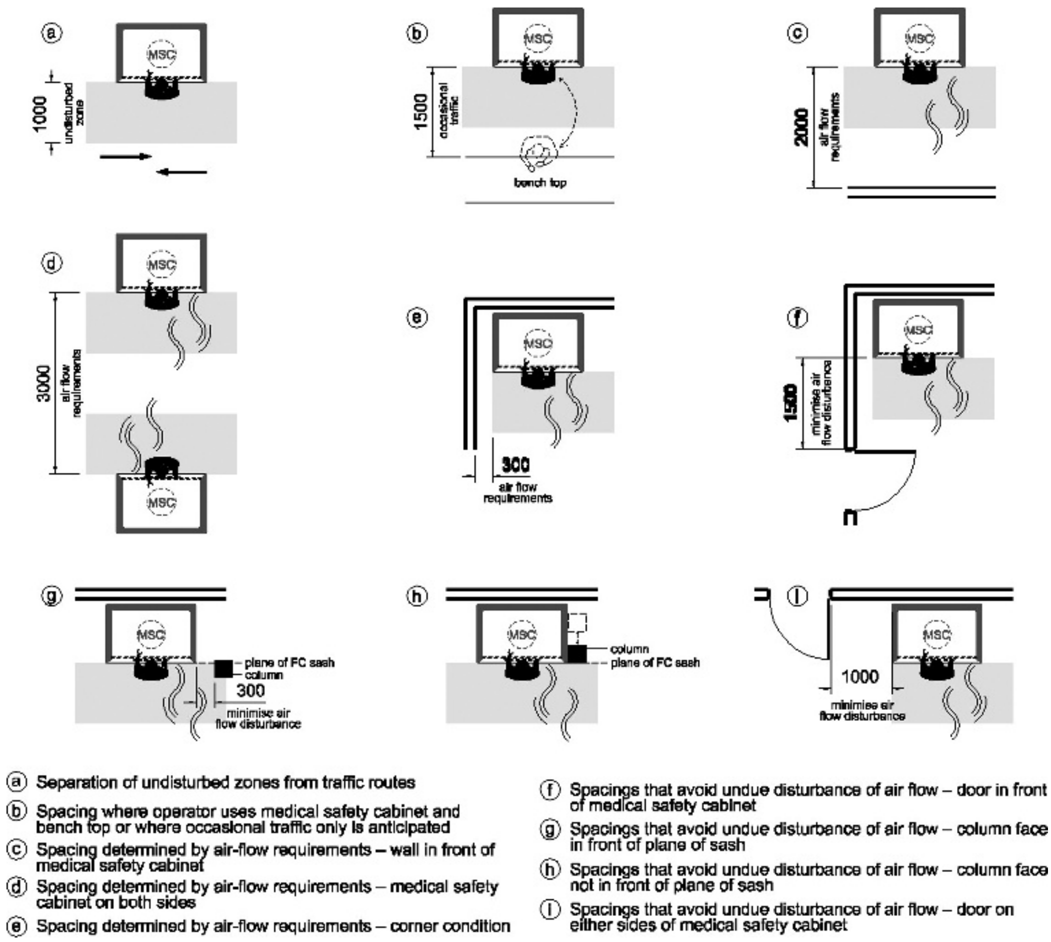
- Should be provided by local cylinders

Table XXIV provides guidance for basic requirements (to be determined with the engineer and stakeholders).

3 ENVIRONMENT

3.01 General

The typical laboratory uses far more energy and water per square metre than the typical office building due to intensive ventilation requirements and other health and safety concerns. Therefore, designers should strive to create sustainable, high performance, and low-energy laboratories that will minimise overall environmental impacts and optimise whole building efficiency on a life-cycle basis.



23.29 *Microbiological safety cabinet minimum distances for avoiding disturbances to the cabinet and its operator*

Systems must however maintain background environments suitable for the accurate and reliable conduct of research procedures satisfying criteria for each accommodation type, in respect of:

- Temperature
- Relative humidity
- Ventilation rates (air change rate, heat loads, equipment extract)
- Room pressurisation
- Control and variation of environmental parameters

3.02 Design criteria

Temperature: The recommended temperature values listed in Table XXV for laboratory and laboratory support spaces are generally acceptable, however, individual requirements should be confirmed with stakeholders. Higher or lower values can be specified depending on type of activity, equipment and personnel wearing.

Relative humidity (RH): Requirements should be confirmed with stakeholders. Humidity lower than 30% can cause electrostatic effects and relative humidity above 50% can augment oxidation and corrosion. Relative humidity is more difficult to regulate than temperature. Reducing the relative humidity as low as 40% is possible with standard cooling methods. Dehumidification below this level requires expensive desiccating equipment. Fluctuation ranges below ± 2% are difficult to achieve and maintain and are very expensive.

Ventilation rates

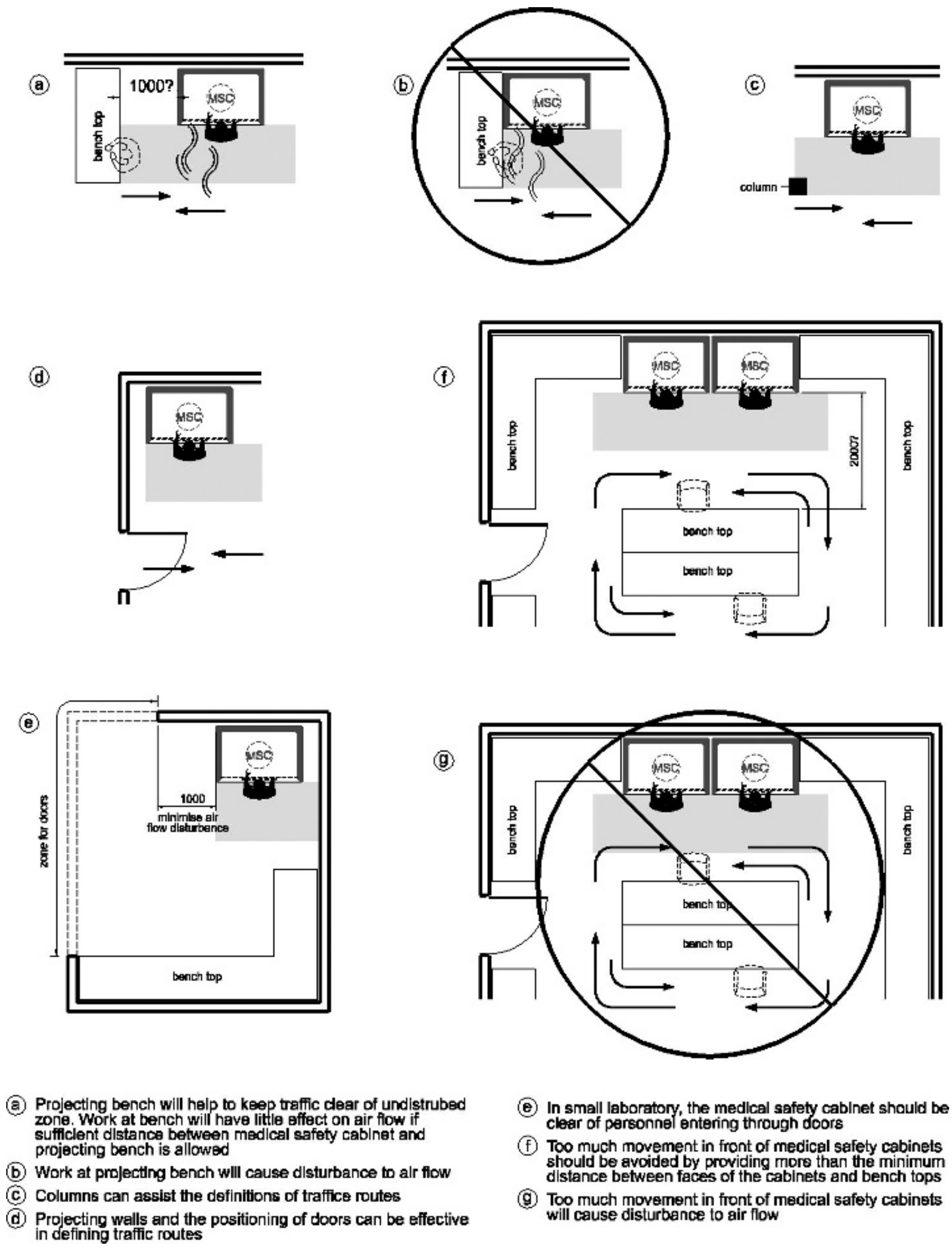
- *Air change rate*: Typical air changes per hour (ac/h) for laboratory and laboratory support spaces are 6–10 ac/h depending on the use and individual requirements.
- *Heat loads*: Heat loads from laboratory equipment for each space is calculated during the design stage for each project. The following specific laboratory heat loads in Table XXVI are based on anticipated loads for generic research scale laboratories and are provided to assist with the preliminary sizing of the building systems.
- *Equipment extract rates*: Schedules should be developed for each space during briefing for each project. The extract schedule in Table XXVII is provided to assist with the preliminary sizing of the building systems.

Room pressurisation: For environments requiring containment, relative pressure to surroundings is typically negative, principally for the containment of hazards and smells.

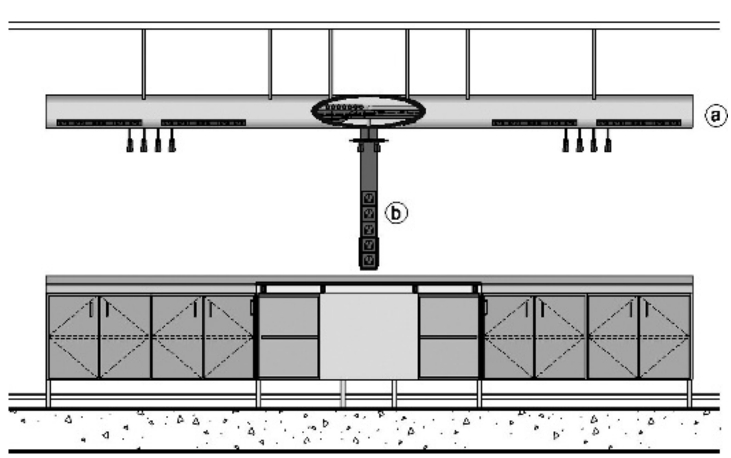
Lighting design: Lighting levels should not be less than CIBSE recommendations. The illumination levels recommended for general laboratories (performance of visual tasks of medium contrast or small size) are 350 lux generally, 500 lux on the working plane. Consider local task lighting to reduce overall illumination levels. Good to high colour rendering should be considered in laboratory areas. Emergency lighting needs to comply with BS6651.

Acoustics: The recommendation for background noise levels in general laboratories is NR 45. Noise control methods include the use of acoustically lined enclosures and reduced sound level operating equipment. Silencers may be used in air distribution systems within the materials and constraints available. Duct liners should be avoided.

Control and variation of environmental parameters: Where economically viable and without compromising the functionality of the research environment, stakeholders should be allowed limited control over their immediate environment including temperature and lighting. Consider natural ventilation to the offices and any atria/light-wells.



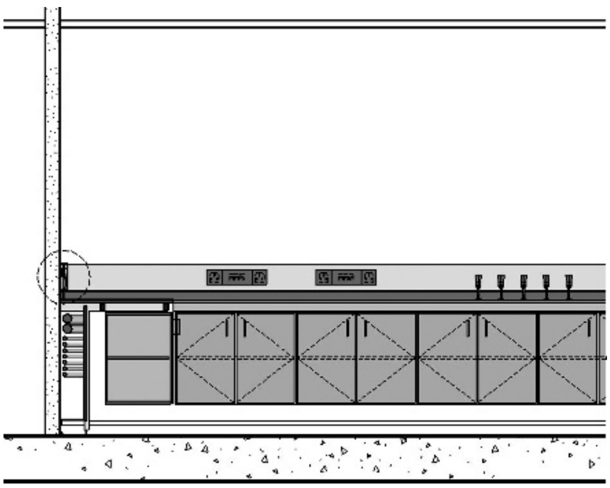
23.30 *Microbiological safety cabinet planning arrangements for avoiding disturbances to the cabinet and its operator and from other personnel*



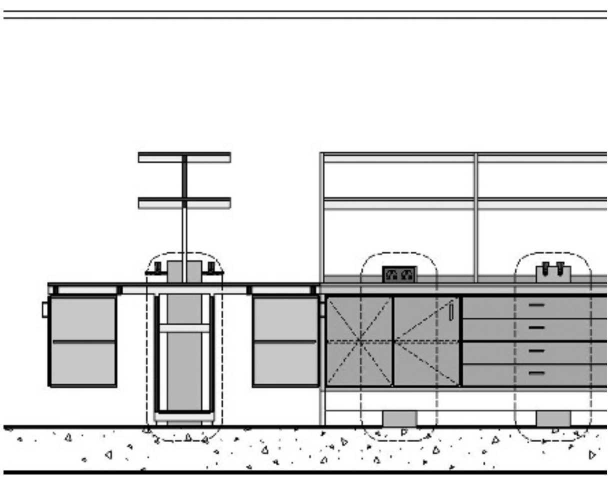
23.31 *Overhead services distribution (***a***) service wing;* **(b)** *service column*

Table XXIII Connected electrical loads (indicative)

	Load (W/m^2)
Laboratories	325
Equipment and instrument rooms	650
Shared support rooms	430
Glassware washing/autoclave rooms	540



23.32 *Perimeter services distribution through walls and trunking*



23.33 *Distribution of services through floor mounted bollards*

Table XXIV Basic laboratory piped services requirements (indicative – subject to confirmation with stakeholders)

Service	Outlets/module
CW (for emergency eyewash and safety shower facilities)	1
IHW	1
ICW	2

Table XXV Indoor design conditions (temperature) for laboratory and laboratory support spaces

Space	Typical summer room temperature (°C)	Typical winter room temperature (°C)
Laboratory	24 max (22±2°C)	20 min (22±2°C)
Laboratory Support	24 max (22±2°C)	20 min (22±2°C)
Specialist areas	(to user specification requirements)	

Table XXVI Preliminary heat gain from laboratory equipment (indicative loads)

Space	Load (W/m^2)
Research laboratory (wet, microbiological/clinical)	75
Research laboratory (dry)	65
Laboratory support (equipment rooms)	175
Laboratory support (instrument rooms)	100

Table XXVII Preliminary extract requirements from equipment (indicative)

Extract type	Extract air flow (m^3/sec)
Fume cupboard	0.30
MSC	0.15
Equipment vent	0.02–0.04
Snorkel	0.07–0.1

4 BIBLIOGRAPHY

4.01 Legislation and standards

Any design shall be formulated acknowledging as relevant all design and codes, regulations, standards and statutory requirements. The examples listed below should not be regarded either as prescriptive or inclusive. These generally state minimum requirements though there is nothing to prevent a designer from exceeding the applicable requirement especially once a risk assessment has been undertaken by the stakeholder on the space's operational requirements.

TITLE	AUTHOR/PUBLISHER	BRIEF SUMMARY
BENCH AND EQUIPMENT		
BS EN 285:1997 Sterilization. Steam sterilizers. Large sterilizers	British Standards Institution (BSI)	Provides guidance on specification requirements and the relevant tests for large steam sterilizers
BS 2646-2:1990 Autoclaves for sterilization in laboratories	British Standards Institution (BSI)	Provides guidance on basic setting and associated services for autoclaves
BS 3202-2:1991 Laboratory furniture and fittings. Specification for performance	British Standards Institution (BSI)	Provides guidance on specification and testing procedures for different grades of laboratory furniture
BS 3202-3:1991 Laboratory furniture and fittings. Recommendation for design	British Standards Institution (BSI)	Provides guidance on space and dimensional information for different types of laboratory furniture
BS 3970-1:1990 Sterilizing and disinfecting equipment for medical products	British Standards Institution (BSI)	Provides guidance on specification requirements and the relevant tests for sterilizers and steam sterilizers
BS 5726:2005 Microbiological safety cabinets	British Standards Institution (BSI)	Provides guidance on siting and use of cabinets
BS 7258-2:1994 Laboratory fume cupboards	British Standards Institution (BSI)	Provides guidance on siting and use of cabinets
BS EN 12347:1998 Biotechnology. Performance criteria for steam sterilizers and autoclaves	British Standards Institution (BSI)	Provides guidance on specification requirements and the relevant tests for sterilizers and autoclaves
BS EN 12469:2000 Biotechnology. Performance criteria for microbiological safety cabinets	British Standards Institution (BSI)	Provides the minimum performance criteria for safety cabinets, test procedures for microbiological safety cabinets

TITLE	AUTHOR/PUBLISHER	BRIEF SUMMARY
BS EN 13150:2001 Work benches for laboratories	British Standards Institution (BSI)	Specifies safety requirements, test methods and recommendations on sizes
BS EN 14056:2003 Laboratory furniture – Recommendations for design and installation	British Standards Institution (BSI)	Provides basic information on furniture types and services provision
BS EN 14175-1:2003 Fume cupboards. Vocabulary	British Standards Institution (BSI)	Provides basic information on terminology and testing with respect to fume cupboards
BS EN 14175-2:2003 Fume cupboards. Safety and performance requirements	British Standards Institution (BSI)	Provides basic information on terminology and components with respect to fume cupboards
BS EN ISO 15883-3:2006 Washer disinfectors Washer-disinfectors. Requirements and tests for washer-disinfectors employing thermal disinfection for human waste containers	British Standards Institution (BSI)	Provides guidance on basic setting and associated services for washer disinfectors
SERVICES: ELECTRICAL		
BS EN 61010-1 2001 safety requirements for electrical equipment for measurement, control and laboratory use	British Standards Institution (BSI)	Provides guidance on electrical equipment in laboratories
Energy efficiency in buildings. 2nd edition. (Including corrigenda 2004)	The Chartered Institution of Building Services Engineers (CIBSE)	Provides information on both the energy requirements committed by the design and the energy costs in use
Electricity at work regulations 1989. Statutory Instrument SI 1989/635	Legislation UK	Provides legal requirements for electrical works and their isolation
BS 7671:2001, Requirements for electrical installations. IEE Wiring Regulations. Sixteenth edition	The Institution of Electrical Engineers	All electrical wiring works must the Wiring Regulations to ensure a safe and efficient electrical installation
SERVICES: GAS		
Safety in the installation and use of gas systems and appliances: Gas safety (installation and use) regulations 1998. 2nd edition	Health & Safety Executive (HSE)	Provides guidance on the safe installation, maintenance and use of gas
IGEM Technical Publications	Institute of Gas Engineers & Managers (IGEM)	Provides a variety of technical advice information
Industrial gas cylinder manifolds and distribution pipework/ pipelines (excluding acetylene) Code of Practice CP4: Revision3: 2005	British Compressed Gases Association (BCGA)	Provides guidance on the minimum safety standards for the design, installation, operation, and maintenance of industrial gas supply manifolds and associated narrow pipework
Code of Practice for the Storage of Medical, Pathology and Industrial Gas Cylinders.	Department of Health (DH)	Provides advice on design, installation and testing of gas systems
Safety of pressure systems. Pressure systems safety regulations 2000. ACOP (SI 2000 No 128)	Health & Safety Executive (HSE)	Provides guidance on pressure systems including gas cylinders
Guidance Notes for Siting Gas Manifolds	BOC Gases	Provides general guidance on the siting of gas manifolds and storage of cylinders
Guidance Note GN2: Guidance For The Storage Of Transportable Gas Cylinders For Industrial Use	British Compressed Gases Association (BCGA)	Provides basic design information on storage compounds and proximity of different types of cylinders
Guidance Note GN2: The Safe Use of Individual Portable or Mobile Cylinder Gas Supply Equipment	British Compressed Gases Association (BCGA)	Provides guidance on the safe use of individual cylinder gas supplies provided from a single cylinder regulator
Guidance Note GN11: The management of risks associated with reduced oxygen atmosphere	British Compressed Gases Association (BCGA)	Provides information on the risks of utilising gases which when accumulated can become hazardous
HSG71 Chemical warehousing – The storage of packaged dangerous substances	Health & Safety Executive (HSE)	Provides guidance on the hazards associated with the storage of packaged dangerous substances includes safety; fire, emergency aspects
The safe use of gas cylinders	Health & Safety Executive (HSE)	Provides simple advice on eliminating or reducing risks
SERVICES: WATER		
Water supply (water quality) regulations 2001 SI 3911	Legislation UK	Provides legal standards for water to be used within a building
Plumbing engineering services design guide. 2002 edition Part 2 – Hot and cold water supplies	Institute of Plumbing	Provides information and guidance on current technologies and practices
The Water Supply (Water Fittings) Regulations 1999	Office of Government Commerce (OGC)	These Regulations replace the Water Bylaws in England and Wales only
L8 Legionnaires' disease: The control of legionella bacteria in water systems. Approved Code of Practice and guidance.	Department of Health (DH) Health & Safety Executive (HSE)	Provides the approved code of practice for preventing or controlling the risk from exposure to legionella bacteria
TM13 Minimising the risk of Legionnaire's disease	The Chartered Institution of Building Services Engineers (CIBSE)	Provides advice on the design necessary to minimise the risk of infection from Legionella bacteria
SERVICES: ENVIRONMENT/VENTILATION/ENERGY		
BS 5720:1979 Code of practice for mechanical ventilation and air conditioning in buildings	British Standards Institution (BSI)	This standard has been withdrawn as the code of practice as it is now out of date, but still referred in the Building Regulations
Guide A Environmental Design	The Chartered Institution of Building Services Engineers (CIBSE)	Provides information on the design of low energy sustainable buildings
TM32 Guidance on the use of the carbon emissions calculation method	The Chartered Institution of Building Services Engineers (CIBSE)	Provides the basis of a procedure for applying the carbon emissions calculation method (CECM).
The Enhanced Capital Allowance Scheme	Carbon Trust	Provides guidance and forms for making an ECA claim depends on the purchase energy-saving equipment
Conservation of fuel and power in new buildings other than dwellings (2006 edition) Building Regulations 2000: Approved Documents L2A or L2B	Office of the Deputy Prime Minister (OPDM)	Provides building control advice for England and Wales on environmental and energy issues
HEALTH AND SAFETY		
The United Kingdom Good Laboratory Practice Monitoring Authority. Guide to UK GLP Regulations 1999	Legislation UK	Sets out the organisational processes and conditions under which certain laboratory studies are undertaken
Various Guidance & advice notes	Health & Safety Executive (HSE)	HSE provide numerous useful guidance sheets which are relevant to different type of laboratories such as in sections on Biotechnology, Dangerous Pathogens, Health and Safety Regulations, Nanotechnology
The Workplace [Health Safety and Welfare] Regulations 1992	Legislation UK	Sets out legislation with respect to most workplaces
The Health and Safety at Work Act 1974	Legislation UK	Sets out legislation with respect to occupational health and safety at work
The Control of substances Hazardous to Health (COSHH) Regulations 2002	Legislation UK	Sets out legislation with respect to the requirement on employers to control exposure to hazardous substances to prevent ill health

(Continued)

TITLE	AUTHOR/PUBLISHER	BRIEF SUMMARY
MICROBIOLOGICAL PROTECTION		
BS EN 12128:1998 Biotechnology. Laboratories for research, development and analysis. Containment levels of microbiology laboratories, areas of risk, localities and physical safety requirements	British Standards Institution (BSI)	Specifies minimum physical requirements for the four levels of containment for biological safety in laboratories
BS EN 12738:1999 Biotechnology. Laboratories for research, development and analysis. Guidance for containment of animals inoculated with micro organisms in experiments	British Standards Institution (BSI)	Specifies minimum physical requirements for the four levels of containment for biological safety in laboratories
BS EN 12740:1999 Biotechnology. Laboratories for research, development and analysis. Guidance for handling, inactivating and testing of waste	British Standards Institution (BSI)	Provides information on different types of waste produced by different containment level laboratories and methods for their disposal
BS EN 12741:1999 Biotechnology. Laboratories for research, development and analysis	British Standards Institution (BSI)	Provides information on basic protocols within different hazard level laboratories
BS EN 13441:2002 Biotechnology. Laboratories for research, development and analysis. Guidance on containment of genetically modified plants	British Standards Institution (BSI)	
Advisory Committee on Dangerous Pathogens (ADCP) The management, design and operation of microbiological containment laboratories 2001	Health & Safety Executive (HSE)	Provides guidance on the management and operation of Containment Level 2 and 3 microbiological labs
The Genetically Modified Organisms (Contained Use) (Amendment) Regulations 2005	Legislation UK	Specifies minimum physical requirements for the four levels of containment for GM work in laboratories
CR 12739:1998 – Biotechnology. Laboratories for research, development and analysis. Guidance on the selection of equipment needed for biotechnology laboratories according to the degree of hazard	British Standards Institution (BSI)	
NHS Estates Health Building Note 15, Accommodation for Pathology Services	Department of Health (DH)	Provides guidance on facilities for pathology services provided within acute general hospitals
RADIOLOGICAL PROTECTION		
HBN 6 Vol. 3 2002 Accommodation for magnetic resonance imaging	Department of Health (DH)	Provides design and specification information for MRI areas.
BS 4094-1:1966 Recommendation for data on shielding from ionizing radiation. Shielding from gamma radiation	British Standards Institution (BSI)	Provides information on legislation, regulations, guidance and other standards.
HBN 6 Vol. 1 2002 Facilities for Diagnostic Imaging and Interventional Radiology, HBN 6 2002	Department of Health (DH)	Provides design and specification information for imaging and associated areas
FIRE PROTECTION		
Conservation of fuel and power in new buildings other than dwellings (2007 edition) Building Regulations 2000: Approved Documents B Vol. 2	Communities & Local Government	Provides building control advice for England and Wales on fire issues
BS 5588-0:1996 Fire precautions in the design, construction and use of buildings. Guide to fire safety codes of practice for particular premises/applications	British Standards Institution (BSI)	Provides information on types of premises and relevant codes of practice
BS 5588-5:2004 Fire precautions in the design, construction and use of buildings. Access and facilities for fire-fighting	British Standards Institution (BSI)	Provides information on access and facilities for fire-fighting and covers vehicle access, water supply, control systems, heat and smoke control and electrical services
BS 5588-8:1999 Fire precautions in the design, construction and use of buildings. Code of practice for means of escape for disabled people	British Standards Institution (BSI)	Provides information on measures that enable disabled people to be assisted to safety in the event of a fire
BS 5588-9:1999 Fire precautions in the design, construction and use of buildings. Code of practice for ventilation and air conditioning ductwork	British Standards Institution (BSI)	Provides information on fire protection of services
BS 5588-12:2004 Fire precautions in the design, construction and use of buildings. Managing fire safety	British Standards Institution (BSI)	Provides information on fire safety systems
CLEANROOMS		
BS EN 14644-1:1999 Cleanrooms and associated controlled environments. Classification of air cleanliness	British Standards Institution (BSI)	Provides guidance on definitions and classifications of clean rooms
BS EN 14644-4:1999 Cleanrooms and associated controlled environments. Classification of air cleanliness	British Standards Institution (BSI)	Provides guidance on design and servicing of clean rooms
SCHOOLS		
Building Bulletin 80: Science accommodation in Secondary School-	Department for Education & Skills (DFES)	Provides design information on laboratories in secondary schools
Building Bulletin 88: Fume cupboards in Schools	Department for Education & Employment	Provides design information on fume cupboards in secondary schools
Building Bulletin 98: Briefing Framework for Secondary School Projects	Department for Education & Skills (DFES)	Provides general spatial for secondary schools
Building Bulletin 99: Briefing Framework for Primary School Projects	Department for Education & Skills (DFES)	Provides general spatial for primary schools
Designing & Planning Laboratories L14-	CLEAPPS School Science Service	Provides design and planning information on laboratories in secondary schools
OTHER		
The BRE Green Guide to Specification	British Research Establishment	Provides guidance on the relative environmental impacts of elemental specifications
BCO Guide 2005 – Best Practice in the Specification of Offices	British Council for Offices (BCO)	Provides advice on future design and construction of office buildings, including sustainability, business performance and cost and value

4.02 Web sites

SITE ADDRESS	ORGANISATION	BRIEF SUMMARY
www.hse.gov.uk	Health & Safety Executive (HSE)	Provide numerous useful guidance sheets which are relevant to laboratory working environmental and safety requirements for the UK
www.cibse.org	The Chartered Institution of Building Services Engineers (CIBSE)	Provides numerous publications relevant to various service disciplines and environmental requirements for the UK
www.dh.gov.uk	Department of Health (DH)	Provides statistical reports, surveys, press releases, circulars and legislation with respect to health care facilities in the UK
www.wbdg.org	Whole Building Design Guide (WBDG)	Provide information on various laboratory types based mainly on US projects
www.dfes.gov.uk	Department for Education & Skills (DFES)	Provides information of school planning and spatial requirements in the UK
www.cleapss.org.uk	CLEAPPS School Science Service	Provides an advisory service for subscribers, supporting practical science and technology in schools in the UK
www.phac-aspc.gc.ca	Health Canada	Provides considerable data on microbiological labs produced by Government of Canada
www.bco.org.uk	British Council for Offices (BCO)	Provides research data on best practice in all aspects of the office sector in the UK
www.carbontrust.co.uk	Carbon Trust	Provides information on grants and technologies funded by the UK Government to help promote low carbon technologies
www.bcga.co.uk	British Compressed Gases Association BCGA)	Provides information on gases supplied to manufacturing industry, laboratories, and the medical sector for the UK
www.igem.org.uk	Institute of Gas Engineers & Managers (IGEM)	Provides a variety of technical advice information
www.bsistandards.co.uk	British Standards Institution (BSI)	Provides opportunity to purchase UK and European standards

4.03 Acknowledgements

Particular thanks are due to the late Gordon Kirtley for his architectural input on the documenting of laboratory space standards and working dimensions as set out in the Wellcome Trust's 'Guidance on space standards, layout and specification for biomedical buildings' 1999.

Sincere thanks are also due to Andrew Bowles, Partner at Sheppard Robson Architects, for his helpful assistance and to Patrick Ng, Architectural Assistant, for producing the graphics.

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24 Primary health care

Ann Noble

CI/Sfb: 423
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Ann Noble, after many years with the Medical Architecture Research Unit (MARU), is now an architect and health planner in the all-important field of health facilities

KEY POINTS:

- *We are in a period of major change, with more being provided at primary level and community level rather than in hospitals*
- *The NHS is supporting the development of large primary and community care centres where a wide range of services will take place*

Contents

1 INTRODUCTION

1.01 Health sector overview

From the 1990s onwards, there has been a very substantial investment in buildings in the UK health care sector. While these buildings are a result of Central Government policies, the design and management of each project is in the hands of a local client project team, most of whose members have little experience of briefing for, or procuring health buildings and have demanding jobs within the health service. Their task is not helped by frequent policy changed from the Government, introducing new and different initiatives, nor by the continuing uncertainly of how the health service will be delivered in the future.

The intention that services will move from being hospital based to community based, that hospitals will reduce in size, that elective procedures will be separated from acute procedures and that a limited number of specialist (tertiary) hospitals will exist, have been voiced for many years. In addition, decisions to increase the number of health buildings for specific groups of patients have created hospices, mental health units, day centres and specialised care centres such as those for cancer patients.

With these developments, the traditional classification of health buildings such as hospitals or primary care has become less relevant as differentiating between health buildings has become inconsistent and unclear. The terminology of different types of buildings no longer provides a clear definition of the services that will be delivered from them. Each General Hospital, District Hospital, Health Centre, Medical Centre, Community Centre, Community Care and Treatment Centre, Women and Childrens' Centre, Walk In Centre, Cancer Centre, Diagnostic Centre, Rehabilitation Centre and Mental Health Unit will offer different services and require different facilities. This situation emphasises the importance and the need for client project teams and design teams to clarify the scope and scale of the services to be provided and the operational policies before developing and finalising the brief for a new building. It is generally acknowledged that, currently, insufficient time, wisdom and experience is allocated to this critical stage for a project. Initial programmes and resources may need to be modified to ensure that this is achieved. It is also generally acknowledged that many problems are due to inexperienced health client teams, inadequate importance and time given to site selection, site appraisals and feasibility studies.

The NHS publishes a wide range of valuable guidance. This includes:

- Health Technical Memoranda (HTMs) – 73 in number, which cover most aspects of technical engineering systems.
- Health Building Notes (HBNs) – 38 in number, mostly based on the departments of a District General Hospital.
- Building Component Series – 16 in number.
- Electrical Model Engineering Specifications – 24 in number.
- Mechanical Engineering Specifications – 23 in number.
- Health Facility Notes (HFNs) – There are 41 covering a wide range of topics. These notes contain interesting and useful information but HFNs have not been through the rigorous reviews and processes as HBNs and do not have the same status.

The scope and scale of the Guidance Documents is vast. It is not possible for them to be continually reviewed and updated to take account of changes in practice, policies, external circumstances (such as climate or procurements routes), of relevant new legislation, new developments and improvements in available equipment, materials, finishes and systems.

There are discrepancies within the guidance and there are requirements which are generic and cover a wide range of activities resulting in an over-specification for some activities, for example, requiring the same environmental requirements for modest surgery as for very major interventional surgical procedures.

Design Guidance was developed to provide guidance for those who found it useful, not to be prescriptive nor to prevent innovation, not to be inflexible in responding to project circumstances and needs. Currently, the guidance is being used by clients to be taken as standard requirements which must be met, often to the detriment of the project. Private sector providers of public sector buildings also use compliance with the guidance as a means of risk reduction for them. Most of the guidance is not freely available to people not employed by the NHS.

In common with many sectors, NHS buildings are mostly procured by the Government approved routes: Public Finance Initiative, Procure 21 – a regionally based Public Private framework agreement, and Local Initiative Finance Trusts – a public private partnership between the NHS Primary Care Trusts (PCTs) and Private Sector Providers. Sometimes Local Authorities are also included in the Partnership. The Private Sector is also constructing and owning health buildings from which they are providing services to the NHS.

1.02

Until recently, primary health care has been delivered from one of four building types:

- Health centres.
- General medical practicioners' (GPs') premises.
- Clinics.
- Dental practitioner premises.

located conveniently for the population served.

Now the distinctions between acute and primary health care services and between GP and health authority community services are becoming increasingly blurred; as are the distinctions between the different types of primary health care buildings.

1.03 Health centres

A health centre was a building provided, equipped, maintained and staffed (with the exception of family doctors and dentists who were licensed tenants) by the local health authority. The purpose of the health centre was to draw together a combination of traditionally separate health services. Many health centres have been successful, some have been unpopular, some have become overcrowded as the activities and numbers of staff have expanded beyond the intended use, some have suffered from poor management and some from a lack of investment in building maintenance.

When in 1974, the responsibility for health centres was transferred from local to health authorities, it was anticipated that 80% of GPs would be working from within them by 1980. The concept of primary health care teams gained acceptance but, as a result of changes in national policy, health authorities were subsequently discouraged from building more health centres, and by 1984, only 28% of GPs were practising from them.

Family doctors and dentists have been licensed tenants in health centres; but after 1995 the NHS Trust owners were looking to change the lease arrangements.

1.04 General practice premises

GP premises have been provided by the practitioners for their own use as a surgery, and they are reimbursed by the NHS for providing these facilities for NHS patients.

As an alternative to NHS investment in health centres, GPs were encouraged to raise the capital to develop their own premises, and given financial incentives to do so by means of a ‘cost rent reimbursement’ scheme. The standards set for cost rent schemes represented substantial improvements over many existing premises: they required minimum space standards, facilities for a practice nurse, access for disabled patients and the possibility of offices for attached community nurses and health visitors. However, the range of services they could accommodate was generally fewer than for a health centre but there have been exceptions. For practices who did not wish to invest in buildings, third parties have developed premises for the practices to lease.

1.05 Clinics

Clinics offer community health services such as antenatal and baby clinics or chiropody and speech therapy where there is not a local health centre offering these. Many clinic buildings have of poor quality and under-used.

1.06 New directions

In some ways, the primary health care needs of a local population have not changed significantly over the years: Finsbury Health Centre was built in 1932 and continues in use in 2007. However, recent trends are affecting the ways in which services are organised and financed and, consequently, the buildings from which they are provided.

- There is an increasing emphasis on a wide range of primary and community-based health care and associated social service professionals working as teams and being based in one building, which benefit both staff and patients.
- Changes in GP practice have led to many GPs offering an increased range of services, such as immunisation, child development, antenatal care, family planning and minor surgery: activities which have been traditionally carried out in health centres and clinics, and for which many GP premises are not suitable. Some GPs work closely with other health care professionals such as acupuncturists and osteopaths, not normally associated with NHS primary health care, as well as with chiropodists, physiotherapists and dentists. These trends have been developing for many years, usually with the GP practice providing the accommodation.
- There is an increasing pressure to move consultant out-patient clinics, diagnostic and therapeutic activities out of acute hospitals into less costly, community settings.
- As with other health buildings, increasing emphasis is being placed on obtaining maximum and efficient use of all facilities, on the sharing of resources and on reducing running costs.
- Information technology, theoretically, if not yet operationally, makes information instantly available between primary, community, and acute health care locations, meaning that physical proximity to sources of information (such as test results, X-ray pictures, specialist opinion or medical records) is no longer a determinant of accessibility to the information.
- More education at all levels of most health care professionals is taking place in primary and community settings. In some cases, educational centres are integrated into health buildings.
- In common with other buildings in the public sector, and the NHS in particular, there is the stated intention that development should be of high quality, appropriate to their location, provide easy access for the elderly, and people with disabilities, and be attractive and pleasant for users.
- From 2002 onwards, the public sector has been taking a more proactive role in the procurement of primary and community health care facilities by forming partnerships with the private sector to provide new and upgrade existing premises to meet the local service needs of their population. This reduces the need for investment in property by GPs and facilitates the provision of buildings which can house a wider group of services.
- Implementation of the local investments finance trust (LIFT) programme for procuring primary and community premises was introduced as a means of creating much needed healthcare buildings across the country.
- The LIFT programme enables selected PCTs to invite several consortia to submit designs, facilities management proposals and costs for several (sample) buildings which meet the PCT’s briefs. On the basis of this, one consortium is selected to be the Private Sector Partner with the Public Sector to create a LIFT Company which builds the sample schemes and all future buildings commissioned by the PCTs and, where relevant, Local Authorities. The Public Sector takes a head lease(s) and sublets, as appropriate, to GP practices, other service providers or other users of the building. Commercial activities such as chemists usually have a direct lease with the LIFTCo. The health sector rent is paid to the LIFTCo by The Trust for both Trust areas and GP areas. Rent for any Local Authority services located in a building is paid by the Local Authority. The LIFTCo is responsible for designing, fitting out and maintaining the building for an agreed number of years, at the end of which the building passes to the public sector. The tenants pay maintenance costs for the building and the facilities management services provided by the LIFTCo. This comes directly or indirectly from the public sector. The LIFT process enables partnering and team relationships to develop between the public and private sector participants and should enable the company to benefit from the lessons learnt from each project and continually improve every aspect of their performance including the design of the buildings.

2 NEW BUILDING TYPES

2.01

The strategic health authorities produce service development plans for their area. New and refurbished projects have to be compatible with the strategic plans to obtain the support of the local PCT. It is also essential to confirm that there are available financial resources within the PCT to cover rental or improvement grant costs.

2.02
As a result of new directions, wider ranges of services, activities and staff are being grouped together in different and larger configurations, often in buildings undertaken as joint ventures by different providers, with funding which reflects this. In addition to health centres and GP premises, terms such as *primary health care centres, medical centres, resource centres* and *polyclinics* are coming into use. There is no standard definition of services, staff, management, ownership or funding for any of these but the term *resource centre* implies some specialised facilities which are available for use by various practitioners and the term *polyclinic* implies a grouping of specialist consultant facilities with some diagnostic and treatment support.

2.03
Any of these building types could include general medical practitioners (GPs), dental, ophthalmic and pharmaceutical practitioners, community nursing services, specialist out-patient services, community services, such as chiropody, physiotherapy and speech therapy, non-acute beds, resource centres, educational facilities, out-of-hours services for GPs, 'walk-in treatment' and minor surgery facilities, social services and voluntary bodies.

3 GP PREMISES

3.01
Notwithstanding the new building types, GP premises continue to comprise the largest number of primary health care buildings. GPs themselves may have limited experience and understanding of their current and future needs and may need guidance to achieve high standards of space and design. Without experienced financial advice, they may limit themselves unnecessarily.

3.02
GPs are reimbursed for the use of their premises by the NHS PCTs. This enables them either to raise capital to invest in premises themselves or to pay rent. It is imperative that the PCT is involved in any development proposal, as its support is crucial. Some PCTs offer better advice than others but the following points should be borne in mind:

- The space required for both the delivery of health care and for administrative support is frequently under-estimated by GPs.
- There is no limit to the size of premises for which a PCT can reimburse GPs a current market rent (actual or as assessed by the District Valuer); provided the PCT agrees that the space is both needed and used.
- The 'cost-rent scheme' was introduced in the 1960s as a basis for paying GP practices an enhanced reimbursement to encourage new purpose-built developments. The area on which the enhanced reimbursement was made reflected the pattern of GP practice at that time and so did not include any allowance for additional services. The virtual withdrawal of the 'cost rent reimbursements' raised serious problems for the financial affordability of premises developments for GPs.

4 THE BRIEF

4.01
Decisions about which services are to be delivered from a particular building have to be made within the overall strategy for primary care provision for each locality, enabling the various facilities within the area to support and complement each other. For this reason, establishing a precise brief can be complicated, particularly when the building is seen as a means of enabling changes and developments in the delivery of services to take place.

4.02
The brief should be expressed in the following terms:

1 A list of services to be delivered (the functional content).
2 The scope and scale of the specific activities and the number of staff required for each of the services (e.g. the requirement for physiotherapy could range from a staff team and a fully equipped gymnasium to one physiotherapist using one treatment table for two sessions a week).
3 The number of staff to be based in the building.
4 The number of staff working in the building on a sessional basis.
5 The number of patients per session.
6 Operational policies that affect the organisation and management of the whole building or individual services (e.g. having one shared or several separate reception points, or requiring to close some areas while others remain open).

4.03
This information enables schedules of accommodation to be developed and decisions about sharing or multiuse spaces to be made.

5 FUNCTIONAL CONTENT

5.01
Content will vary considerably including combinations of the following.

5.02 General practices
- General medical practice (varies between one and 30 GPs), in one or more practice partnerships.
- General dental practice.
- General pharmaceutical practice.
- General ophthalmic practice.
- Others such as osteopath, acupuncturist.

5.03 Community and school health and dental services
- Maternity and child welfare
- Ophthalmic services
- Child guidance
- Speech therapy
- Physiotherapy
- Community nursing services
- Community health visiting services
- Chiropody
- Health education
- Social services

5.04 Services traditionally hospital-based
- Hospital out-patient services.
- Hospital diagnostic services.
- X-ray services and other imaging.
- Minor surgical procedures.
- Drop in centre (drug addiction centre), walk-in centre.
- Walk-in treatment facilities.
- Beds – intermediate and day care beds.

5.05 Education
- Post-graduate education centres.
- Teaching facilities for medical students. or any of the allied professions
- GP Registrar training.

5.06 Types of spaces

The activities generated by the range of services listed above do not all need different types of spaces. Their activities will require one or more of the following types of space:

- Entrance/waiting/reception/patient amenity
- Record storage/administration
- Consulting/examination rooms/interview rooms
- Treatment rooms (general and specialised)
- Diagnostic rooms (general and specialised)
- Large spaces with associated storage for group activities (baby clinics, health education, relaxation classes)
- Staff office bases
- Seminar rooms/meeting rooms/library
- Staff facilities
- Support facilities (clean and dirty utility rooms, storage, disposal, cleaners' rooms)
- Non-acute in-patient wards with support
- Plant rooms
- Car parking/drop off points

5.07

To facilitate the multiuse of spaces, the provision of adequate and secure equipment storage is needed; and size rooms need to be sized so that their function can be flexible. Where rooms are tailored too tightly to a specific function, it limits their flexibility.

6 DESIGN PRINCIPLES

6.01 Location

The location of the building in relation to the people, it serves, is crucial. If it serves a wider public than can walk to the building, it should be adequately served by public transport and have appropriate facilities for those using private transport.

6.02 Circulation

The entrance to the building and the circulation within it should be designed with due consideration for wheelchair users, parents with small children, people with visual, audio or ambulatory disabilities, and the physically frail who constitute a large proportion of the users of primary care.

Everyone should be able to arrive at, move around and leave the building without unnecessary effort, anxiety or embarrassment. The pattern of circulation should be obvious to the visitor and should not rely on complicated signs. Staff also need to work efficiently, moving easily from one place and activity to another. The translation of these broad requirements into details is imperative for example, doors should not be too heavy for frail, elderly to open, door ironmongery and taps should be suitable for people with limited manual dexterity.

6.03 Zoning

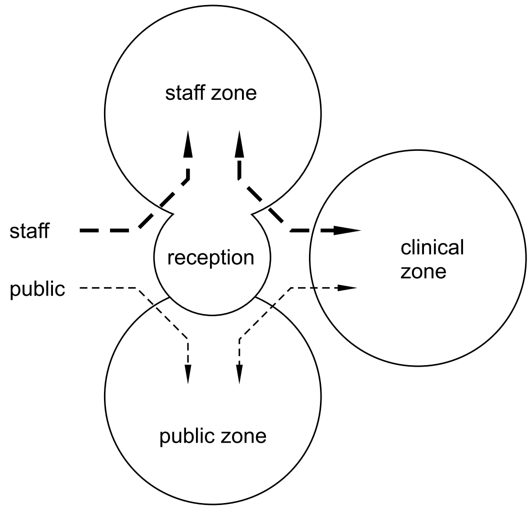
To facilitate the translation of planning principles into the design, group activities within the building into the following three zones:

- Public zone: where callers are received and wait
- Clinical zone: where patients meet clinical staff
- Staff zone: where staff meet each other and work in private

Grouping spaces into these zones controls contact between staff and clients, ensures privacy, minimises unnecessary movement and increases security, **24.1**.

6.04 Privacy

Privacy and confidentiality are important aspects of the relationship between a patient and staff members. Two places where these aspects suffer from poor design are:



24.1 *Relationship and zoning diagram for a health centre*

- The reception desk, where one side of a telephone call can be overheard by people waiting, seating close to, or facing reception desks should be avoided and
- Clinical rooms during consultations and treatments, where personal topics must be discussed freely and in confidence without fear of being seen or overheard. There should be no waiting outside patient rooms.

6.05 Security and supervision

Movement of the public about the premises should be supervised by reception staff without disrupting their work. Supervision also promotes security within the building. Sub-waiting areas should be avoided unless they will be managed and supervised by staff.

Staff need security against personal assault; the equipment and facilities need security against theft and vandalism. The degree and types of security needed depends on the location and on the nature of the services being provided.

6.06 Environment

The building should be comfortable, welcoming, with good natural lighting and ventilation; and it should be easy to maintain and keep clean. It should also include sound absorbent finishes.

A combination of increased external temperatures, revised building regulation thermal requirements, the inappropriate selection of windows, concerns for security and fire requirements, is too often resulting in unsatisfactory environmental conditions for staff and patients in many new primary care buildings. Design of a total system is essential and diligence may be required to ensure that the elements are not eliminated when there is a pressure to reduce capital costs.

6.07 Infection Control

A serious number of hospital associated infections (HAIs) has raised concern leading to more stringent requirements across the whole health sector. There is no history of HAIs in primary care buildings but there is a policy to reduce risks in all health buildings. The most important design factor is to facilitate good, hygienic practice by staff. Buildings should avoid creating any potential reservoirs of infections and promote easy cleaning. Finishes, fabrics and materials which have anti-microbiological properties are now on the market. All NHS Trusts now have Infection Control Officers who have a strong role in accepting or rejecting design elements of a project. Their knowledge of buildings, environmental systems, materials and detailing is generally limited in the primary care sector so there is a tendency for them to focus on standard solutions rather than on performance specifications.

6.08 Running costs

Staff salaries are the largest component of the running costs so the design should facilitate efficient staffing. Energy-efficient, long-life and low-maintenance approaches should be adopted for the building.

6.09 Flexibility and growth

Designs should provide for the flexible use of some spaces from day to day; and for the inevitable changes in the demand for services and the pattern of delivery during the life of the building. Provision for extending it should be considered, as should the installation of hard standings and temporary building services connections for special, mobile diagnostic units.

7 SPACES

7.01 Car parking

Car parking needs to be provided for staff and patients. The number of places required will depend upon the functional content of the building and on local circumstances. For traditional primary health care buildings, an approximate guide would be four parking spaces per consulting room (1.5 for staff, 2.5 for patients). Provision for disabled parking must be made adjacent to all buildings, and for patient transport by ambulance for some buildings.

7.02 Main entrance

The main entrance should be clearly visible, identifiable and easily accessible, preferably with a covered setting-down point from cars.

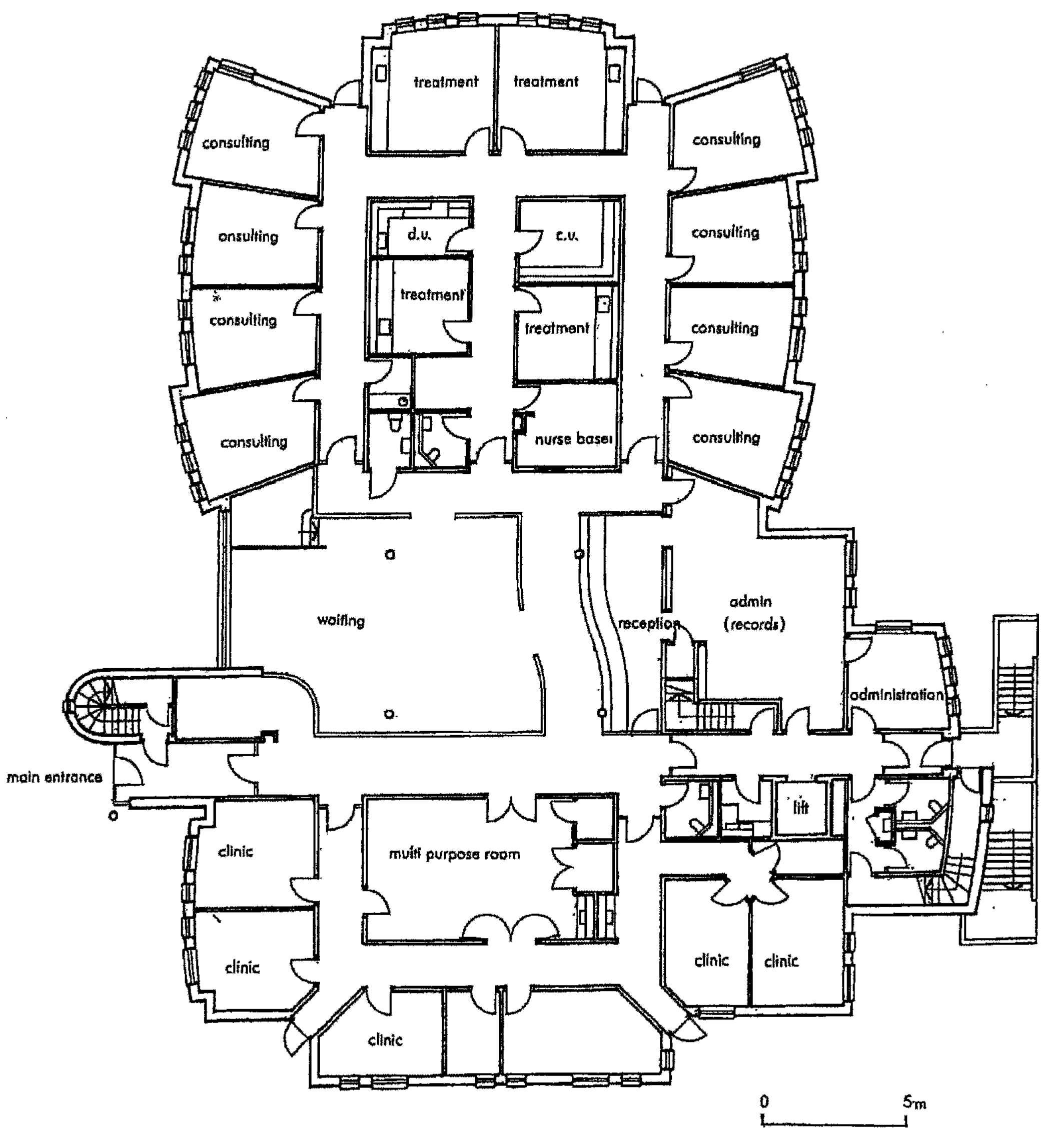
7.03 Reception

The reception area should be visible from the main entrance. Receptionists need to oversee the waiting area and the main circulation routes **24.2**. Allow 1.5 m counter length for each receptionist, and space in front of the counter for patients to stand without encroaching on circulation routes or waiting space. Counter design should be open but should provide some protection for staff. Provision for people with disabilities should be incorporated, for example, a lower section for wheelchair users and incorporating aids to hearing.

7.04 Record storage

Record storage needs to be close to the reception area, but ideally not part of it. Records should be out of sight of patients and secure.

The use of electronic records and information systems is increasing within GP practices and some of the other services. GP practices need to keep the paper records for reference but in many practices, they no longer need to be near the reception counter and are archived elsewhere in the building. Where there are paper records, the space required needs to be calculated for the selected storage system.



24.2 *Primary Care Centre with all patient activities on the ground floor. Note that the receptions have visual control of movements. Also note the confidentiality zone in front of the reception counter*

7.05 Administration and office bases

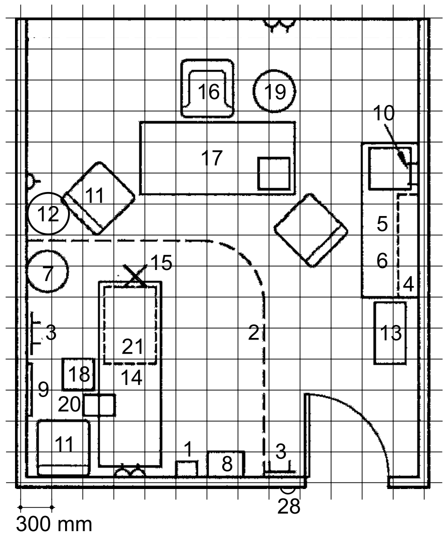
Offices are required for administrative functions.

Some staff require offices for full-time use. Others, such as health visitors, district nurses and midwives, need to return to an office base once or twice a day. Consideration should be given to flexible arrangements which meet this requirement. This can be done by providing work stations for use by anyone, with mobile personal storage units, rather than personal desks.

7.06 Waiting areas

Waiting areas should be visible from reception but sufficiently separated to provide some privacy and confidentiality for patients at the reception desk. Pram storage and WCs need to be near the reception and waiting area. Part of the waiting area can be designed and furnished for children. Some seating suitable for the elders should be provided. Assessment of the number of seats required is important as this is often provided, either too large or too small.

Patients should not wait in corridors nor outside consulting or treatment room doors. Sub-waiting areas should usually be avoided.



24.4 *Consulting/examination room used for teaching, 18 m²*

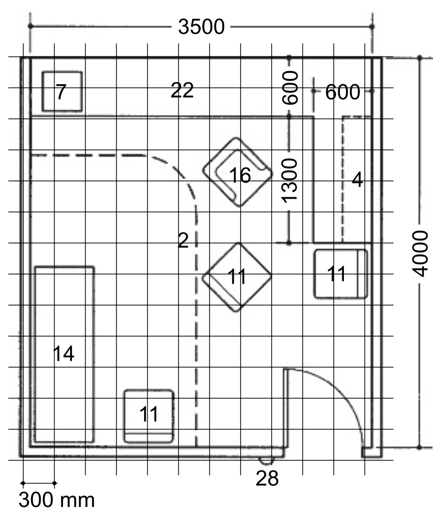
7.07 Consulting/examination rooms

Consulting rooms are usually provided for each practitioner on a personal basis. Where this results in under-use, they can be scheduled for the use by other staff or for other purposes. Combined consulting/examination rooms are more economical of space than having separate examination rooms but patterns of practice vary and separate rooms may be required.

If the desk is a built-in work surface and access is provided to the foot and one side of the couch only, allow 14–15 m^2, **24.3**. If the desk is free-standing and access is provided to both sides of the couch, allow 17 m^2 as a general rule, **24.4**. When the rooms are used for teaching medical students, the area increases to 18 m^2.

7.08 Treatment rooms

The increase in practice nurses, in addition to district and school nurses, has resulted in enhanced requirements for treatment facilities. Some GPs also use treatment rooms for some clinical procedures, for example, fitting contraceptive coils. In addition, GPs now undertake minor surgery. As a result, the conventional provision of a treatment room of 17 m^2 for use by one nurse, **24.5**, is being replaced by treatment suites comprising several treatment rooms, with separate clean and dirty utility rooms, a specimen WC (sometimes with a hatch to the dirty utility room) and a nurse base, **24.6**. A mix of treatment chairs and couches may be provided. Couches in treatment areas must be accessible from both sides and one end, **24.7**. Leg ulcer clinics can now be fitted out with fixed seating, *in situ* running water and drainage relieving nurses of the need to fill and empty buckets in sluices.



24.3 *Standard consulting/examination room, 14 m². 15 m² is better for wheelchairs and provides a more flexible space. The clinical wash hand basin can be inset in work surface if properly detailed. Some infection control advisors prefer it to be located inside the cubicle.*

7.09 Minor surgery

Treatment spaces used for surgical procedures need to be equipped and finished to standards appropriate for the proposed procedures. There may be requirements for general anaesthetic (not for GPs), additional ventilation and a recovery space. Minor surgery facilities can be provided as separate suites with their own clean and dirty utility areas or as part of a larger treatment suite, sharing support spaces.

7.10 Chiropody treatment rooms

Allow 11 m^2 for a one-chair room plus changing facilities. Many chiropody patients will be in wheelchairs, **24.8** and **24.9**.

7.11 Speech therapy rooms

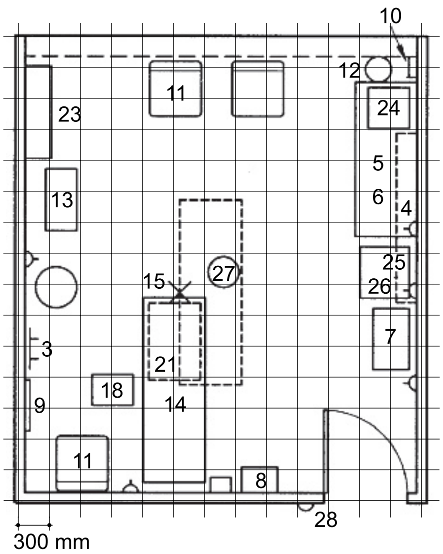
Requirements can range from rooms where individuals can be assessed and treated to larger spaces for groups of adults and children sometimes with viewing facilities. Noise levels need to be low, 40 dBA is recommended and must not exceed 45 dBA.

7.12 Dental suites

Most dental room layouts are developed with specialist suppliers of dental equipment and units, and all dimensions should be checked with them. Allow 16.5 m^2 for each surgery, **24.10**, and 28 m^2 for a laboratory if required. If the throughput of patients warrants it, separate waiting, reception and record storage may be required; but dental staff should not be isolated from other staff. Community dentists in particular need provision for wheelchair patients. An arrangement is now available which enables dental treatments to take place without a client leaving their wheelchair.

7.13 Multipurpose rooms

Large rooms will be required for health education, baby clinics, relaxation classes, physiotherapy and other group activities. Associated storage is essential for chairs, relaxation mats, baby scales, etc. Hand-washing facilities are needed for some of the activities. Tea-making facilities are desirable. Ideally, this room should be accessible when the rest of the building is closed for evening activities. Allow 40 m^2 for eight relaxation mats. Sufficient storage for equipment is essential if the room is going to be available for a wide range of activities.



24.5 *Treatment room*

Key to 24.3, 24.4, 24.5 and 16.11

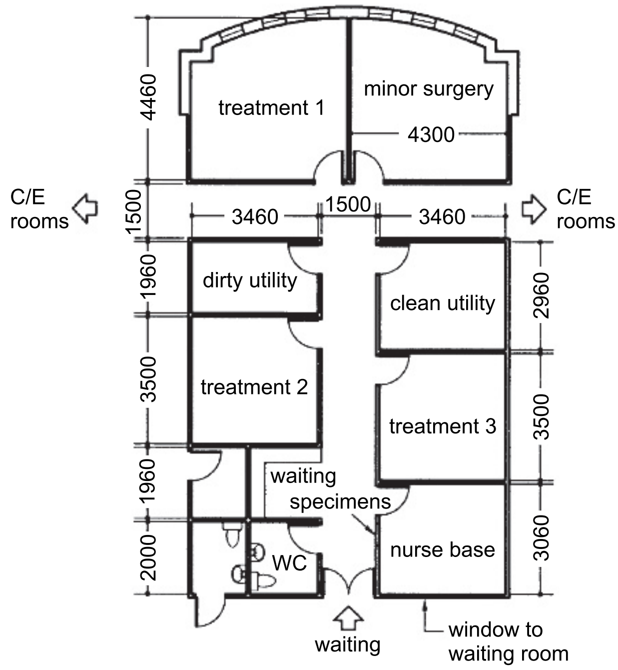
1 *Bracket for sphygmomanometer*
2 *Ceiling mounted curtain track*
3 *Coat hooks*
4 *High level storage*
5 *Worktop*
6 *Low level storage*
7 *Wash hand basin*
8 *Writing shelf*
9 *Mirror*
10 *Paper towel dispenser*
11 *Chair*
12 *Disposal bin*
13 *Instrument/equipment trolley*
14 *Examination couch*
15 *Mobile examination lamp*
16 *Swivel chair*
17 *Desk*
18 *Couch steps*
19 *Waste paper bin*
20 *Scales*
21 *Couch cover dispenser*
22 *Built-in work surface with storage under*
23 *Shelving*
24 *Sink and drainer*
25 *DDA cupboard*
26 *Refrigerator*
27 *Stool*
28 *Warning light*
29 *Lockable cupboard for scheduled poisons*
30 *Pedal waste bin*
31 *Dental equipment cabinet*
32 *Space for anaesthetic machine*
33 *Dental chair*
34 *Dental unit*

7.14 Interview rooms

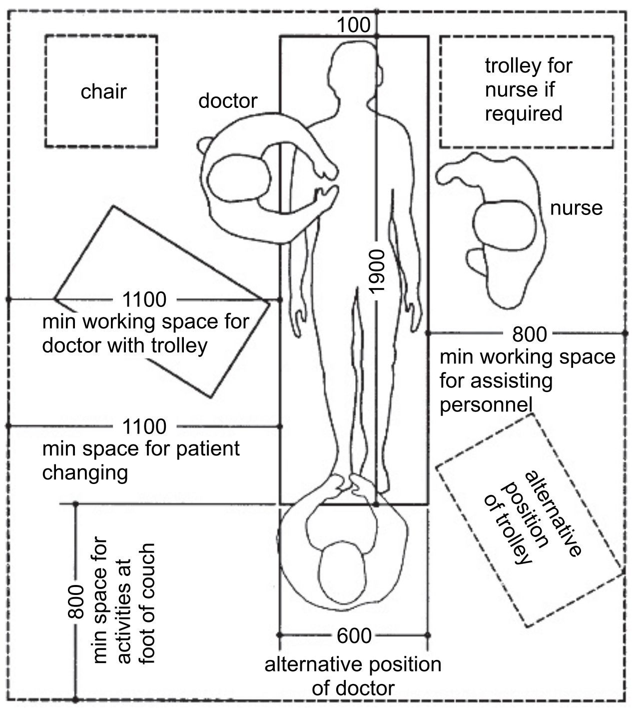
These are small rooms for two to four people to speak privately in a relaxed atmosphere. It is ideal if these are located near the reception counter so that they can also be used by receptionists.

7.15 WCs for patients

These must include at least one WC for wheelchair users; and facilities for baby changing. Patients may be required to produce urine specimens. A hatch can be provided between a WC and the dirty utility room (or treatment room if there is no separate dirty utility room). Patients should not be required to walk through



24.6 *Plan of a treatment suite*



24.7 *Space requirements for treating a patient on a couch*

public areas with specimens. The number and location of WCs required will depend on the design.

7.16 WCs for staff

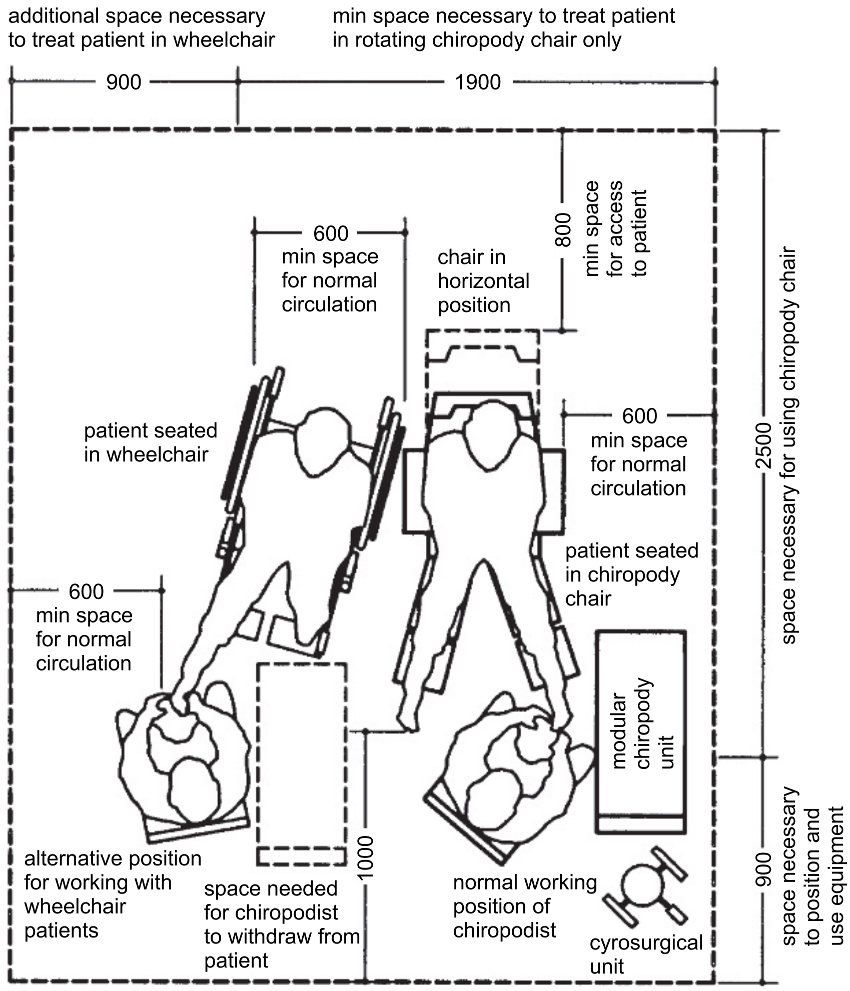
These should be conveniently near working areas and common rooms.

7.17 Staff amenities

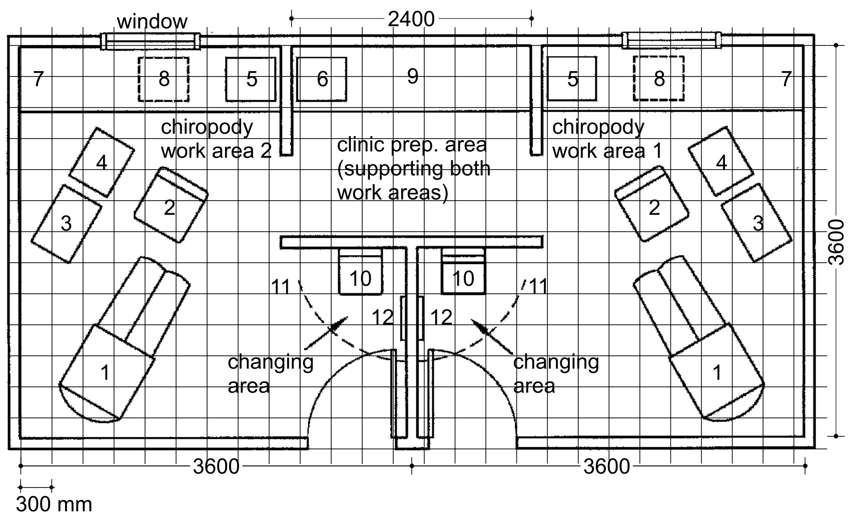
Kitchen and beverage facilities are usually provided. A shower is desirable. Lockers are needed for staff with no secure office base.

7.18 Out-patient consulting and diagnostic facilities

These should be to the same standards as in hospital out-patient departments (see Chapter 17).



24.8 *Space requirements for chiropody*



1 *Chiropody couch*
2 *Operator's chair*
3 *Unit with lamp and drill*
4 *Instrument trolley*
5 *Handwash*
6 *Instrument wash*
7 *Knee hole under*
8 *Cupboard under mirror on wall*
9 *Storage cupboards above and below worktop (including lockable pharmacy cupboard)*
10 *Chair*
11 *Curtain*
12 *Grab rail*

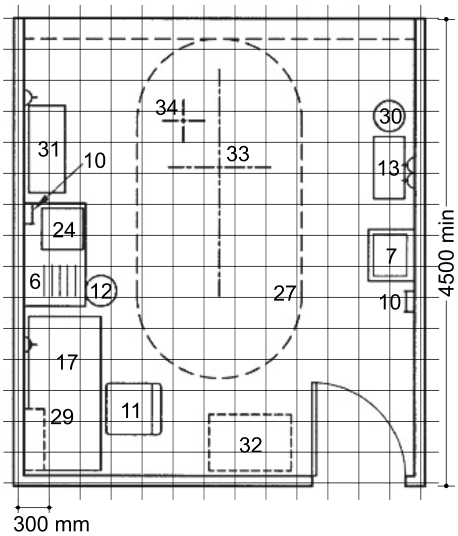
24.9 *Plan of a chiropody suite with two rooms*

7.19 Beds
Ward provision should usually be to community hospital standards with appropriate support facilities.

7.20 Educational facilities
Seminar and other teaching spaces should be to normal education standards. A student or students in a clinical area requires the room to be enlarged so that the clinical activity is not compromised.

7.21 Storage
Requirements for storage must be established and quantified for each of the services.

7.22 Building service requirements
Space requirements for heating, ventilation, electricity, telephone, security, computer, intercom and call systems will be determined by the operational policies.



24.10 *Plan of a dental surgery*

7.23 Grouping of spaces

In grouping rooms within the building, consider the activities that spread across several spaces, for example, a baby clinic may use the waiting/multipurpose, consulting/examination and treatment rooms. Parts of the building may be in use when the rest is closed; for example, GP Saturday and evening surgeries, educational facilities, drop-in treatment facilities, health education or community groups in a multipurpose room.

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Scottish Out-patient Building Note

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25 Hospitals

David Clarke

CI/SfB: 41
UDC: 725.51

David Clarke is an architect with a background in hospital design. Formerly of Nightingale Associates, he now runs his own consultancy, Clearwell Healthcare Planning Ltd

KEY POINTS:
- *Health services are trying to move closer to the patient*
- *More work is being undertaken in the primary sector*
- *Shorter stays in hospital are the norm*

Contents

1 INTRODUCTION

1.01
The provision of health services, and therefore the design of hospitals and other health facilities, has long been a politically charged issue which is subject to frequent policy change; the agendas and administrative structures which govern the provision of healthcare in the UK obviously impact on the design of the health estate, but this is a subject which is far too vast and changeable to set in detail here. The broad principles of hospital design, and notions of best practice, described below were accurate at the time of publication.

A healthcare building includes a large number of functions and activities across a range of healthcare provision services and non-healthcare support services such as laundries, kitchens, supplies and disposal services and estates maintenance facilities. These were previously collectively known as departments. We would like to avoid the use of this term as it has its history in an inflexible organisational structure. This is reflected in a building based on historic concepts of standard sized, standard types of healthcare buildings. District General Hospitals, Teaching Hospitals, Community Hospitals, **25.1**, are examples of these stereotypes. The terminology will continue in use for some time but this chapter aims to separate out activities and the physical requirements for these activities. In some cases, these will be rooms, in others suites. Each could be applied in the context of a larger or smaller facility.

The almost universal use of market tested subcontracting of some services has also changed the key drivers in the design of elements such as catering facilities which are now largely briefed and designed in detail by the partner organisation responsible for the provision of the service. Some elements straddle clinical and non-clinical support services such as Pathology services, this particular service is subject to a Department of Health mandate for the provision of central services supporting a number of different healthcare facilities in an area. Similarly sterilising services, known as centralised facilities, pathology and equipment sterilisation (CSSD) or HSDU are now considered under the heading of decontamination and are subject to a similar strategic approach by the Department of Health. This is also a separate area which will not be covered in detail by this chapter. Other facilities such as Pharmacy services are heavily influenced by technology, in this case robotic dispensing, and a categoric template is determined in conjunction with providers of such equipment.

2 SERVICES DELIVERY

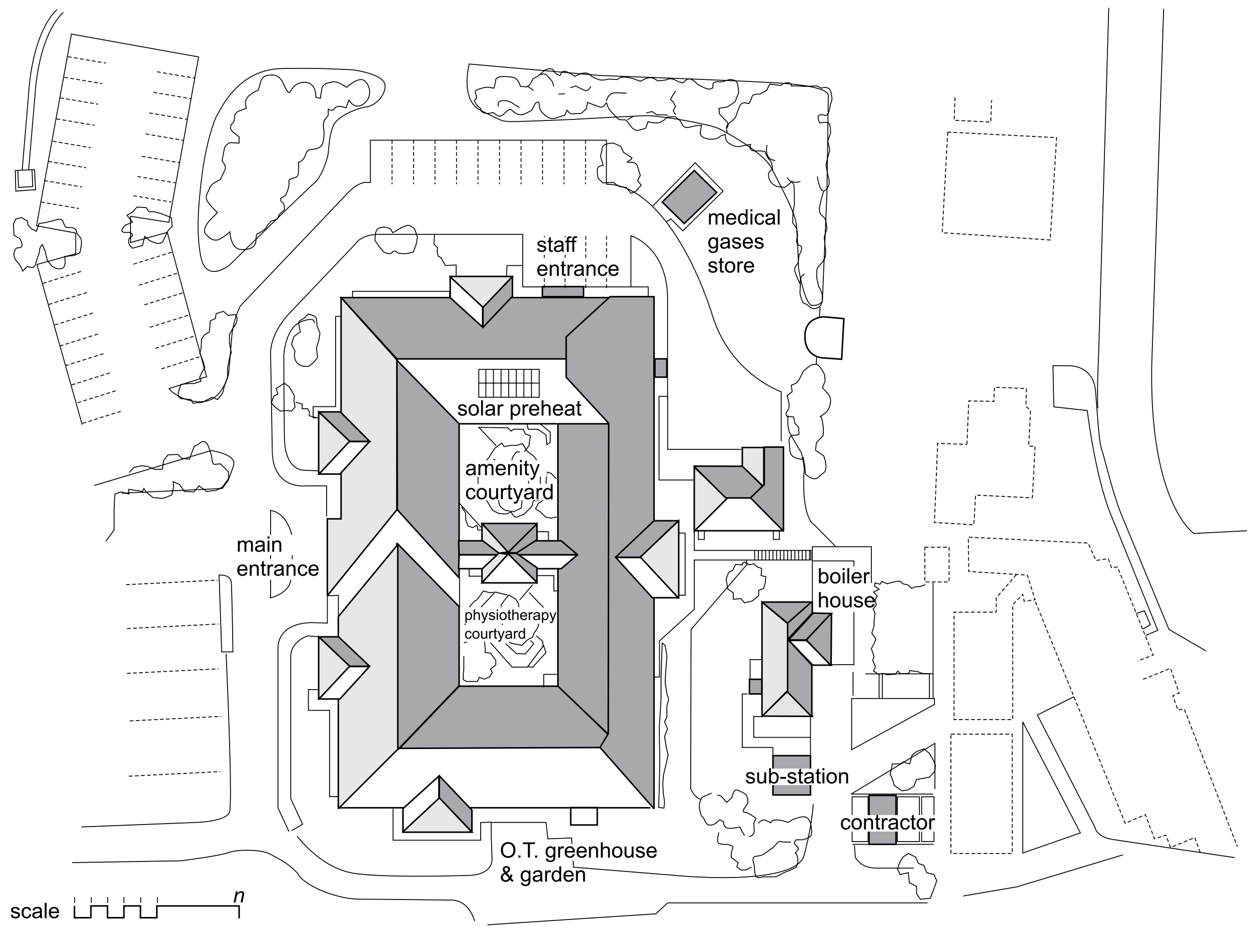
2.01 Drivers of change
In the search for ways of containing health service costs, health care delivery through the hierarchy of the organisation and the corresponding hierarchy of building types is also being reappraised. The aspirations of an extensive assessment of patient needs and wishes was the subject of a review entitled Your Health, Your Care, Your Say, this extended the momentum towards providing services which are devolved from the expensive acute sector out towards primary care organisations, community services and even into the home.

Similarly, the length of patient stay in hospital is being reduced; patients are being required earlier than before to recover at home, where they need additional community support; and many basic diagnostic and treatment procedures are being tested in the primary care setting. One consequence for the acute hospital is that patients who remain are, on average, more dependent and the procedures, on average, more sophisticated and complex.

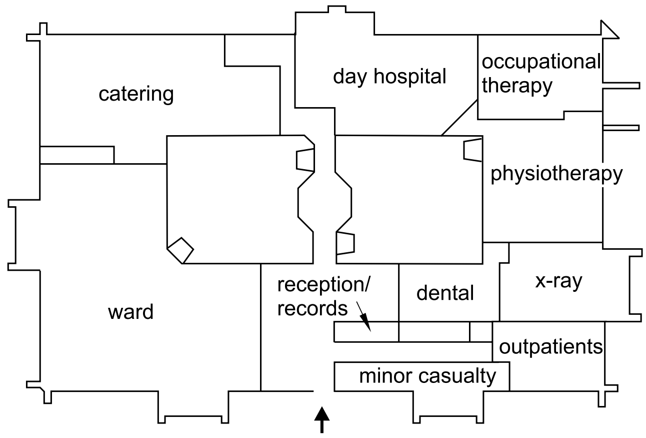
2.02 The hospital and the patient
Management concern for patients' response to the hospital service and environment encompasses such diverse issues as first impressions, signposting, waiting times in out-patient and accident departments and relationship with the ward nurse. It has recently been extended to reassessment of the basic relationships between treatment departments and the in-patient areas they serve. The idea of a hospital organised so as to ameliorate some of the more distressing aspects of patient stay – being shunted around the hospital, waiting in strange departments, disorientation and lack of a sense of place which is their own – found expression in the 1980s–1990s as a 'patient-focused hospital'. Often renamed in the UK as a 'patient centred hospital'.

The principle which relied on the decentralisation of diagnostic services towards, principally, ward areas to reduce the amount patients needed to travel around the hospital also required a degree of multi-skilling which resulted in only limited implementation. Some physiotherapy, which had previously been centralised moved to ward areas and bed areas but this was carried out by roving members of the physiotherapy team. The result has been a substantial increase in the required size of a bed bay to accommodate these activities, Table I. Bed bay areas have also increased as the impact of lifting patients, use of hoists and more demand for the safety of nursing staff have come forward as priorities.

2.03 Information technology
The implementation of information technology has not had the substantial impact on the design of the building that had been anticipated. The dramatic reductions in the size of computer equipment, almost universal use of flat-screen displays and the relatively slow implementation of Patient Records systems and its evolution to the use of hand held pads rather than conventional computers has not generated significant effects. Medical records are still kept in paper form and the most appropriate future provision is for such areas to be located and able adapt to future alternative uses.



a *Site plan*



b *General areas*

25.1 *Community Hospital in Mold. Clwyd Architect: William H. Simpson, Chief Architect, WHCSA*

3 FACILITIES DESIGN

3.01 Design drivers for the patients experience

The Patients Charter, first published in 1991, set out objectives for the health service based on identified reasonable expectations of patients. These included timescales for delivery of services and importantly issues related to privacy and dignity that should be afforded to patients, particularly during a hospital stay.

It is now paramount, although often not achievable in older hospital premises, that toilet facilities are immediately available to patients, not only in single bedrooms but in multi-bed bays if provided. It is not acceptable for patients to walk through or be seen by patients of the opposite sex in order to visit bathroom areas.

An example of a four-bed bay with ensuite accommodation has been developed by Nightingale Associates to suite a number of issues related to multi-bed ward design, **25.2**.

Single bedrooms have advantages for privacy, dignity, confidentiality and safety. However, surveys have identified that by no means all patients wish to be in a single bedroom. A four-bed ward generates not only a small community with opportunities for companionship, but also a support structure in the event of a patient requiring assistance while being unable to use the nurse call

Table I Hospitals, typical room dimensions

	Suggested areas for clinical and clinical support rooms with dimensions					
	Room type	**Width**	**Length**	**Area**	**Notes**	**Areas where used**
1.01	Consult/Exam Two Side access	4.3	3.9	16.6		
1.02	Consult/Exam Single Side access	3.8	3.9	14.6		
1.03	Interview Room	3.3	3.3	10.6		
1.04	Treatment Room	4.2	4.0	16.8		
1.05	Venepuncture Room	2.7	3.0	8.1		
1.06	Patient Recovery (2 patients)	5.0	4.4	21.8		
1.07	Near Patient Testing Room	3.0	2.4	7.2		
1.08	Clean Supply Room	3.6	4.2	14.9		
1.09	Clean Utility Room	3.5	4.2	14.7		
1.10	Dirty Utility (Outpatients)	2.8	3.0	8.4		
1.11	Dirty Utility (Inpatient)	2.9	4.2	12.2		
1.12	Cleaners Room	2.3	3.0	6.9	Dependant on FM provider	
1.13	Disposal Hold			10.0	Dependant on FM provider	
1.14	Relatives Overnight Stay	3.7	3.7	13.7	Access to ensuite required	
1.15	Pantry/Refreshment Area	2.9	2.4	6.8		
1.16	Staff Rest Room	4.3	8.4	35.7		
1.17	Mini Kitchen (within Staff Rest)	2.2	0.6	1.3	Requires adjacent handwash	
				0.0		
2.01	Ambulant WC	1.1	1.7	1.8	Assumes concealed cistern not included in dimensions	Only areas for staff
2.02	Semi-Ambulant WC	1.2	1.8	2.1	Assumes concealed cistern not included in dimensions	All patient access ambulant WCs
2.03	Independent Wheelchair Accessible WC	2.0	1.9	3.8	Equivalent to Disabled WCs in public areas	
2.04	Assisted WC	2.8	2.7	7.6	Allows access for 2 assistants	
2.05	Standard Shower Room	2.3	1.1	2.5	Only suitable for ambulant	
2.06	Semi-ambulant shower room incl. WC	2.6	2.5	6.5		
2.07	Wheelchair Access Shower	2.6	2.0	5.2	Independent wheelchair user, no WC	
2.08	Assisted Shower & WC	2.3	3.1	7.1		
2.09	Ensuite full access WC/Shower	2.3	2.1	4.8	Assumes overhead hoist and door + folding door access	
2.10	Semi-ambulant accessible bathroom	2.3	2.7	6.1	Also possible with bidet at 2.4 × 3.1	
2.11	Independent Wheelchair Accessible Bathroom	2.7	3.3	8.9		
2.12	Assisted Bathroom Side Access	2.4	4.9	11.8	Assumes largest hi-lo bath Min. 1.7 × 4.65 m	
2.13	Assisted Bathroom End Access	2.9	5.1	14.6	Assumes largest hi-lo bath Min. 2.9 × 4.83 m	
2.14	Nappy Change	1.7	2.6	4.4		
2.15	Child Change	3.3	3.3	10.7		
2.16	Changing Room – Standard	1.1	1.8	2.0		
2.17	Changing Room – Wheelchair	2.2	2.0	4.4		

system. A provision of single rooms is essential for those who either prefer that ward type or for whom it is a clinical necessity. Where multi-bedrooms are provided interview rooms are required for confidential discussions between the clinical staff and the patient. This will be disruptive to the doctors ward round but of importance to the wellbeing of the patient.

The drive towards 100% single rooms is laudable but not universally agreed upon as an objective. Current good practice is inclined to the provision of 75% single rooms with four-bed bays providing the balance.

High-quality architecture and internal environment is demonstrated not only to enhance the experience of patients, staff and visitors but also to reduce the recuperation time required by patients. There is clear evidence, for example, in Intensive Care environments, that daylight and external views improves recovery times.

3.02 Design agendas

Hospital design is also the subject of a variety of centrally driven design guides and 'agendas' via organisations such as the Commission for Architecture and the Built Environment (CABE), the Building Research Establishment (BRE) and the Construction Industry Council (CIC).

Two significant initiatives that have emerged over recent years are the 'AEDET' design toolkit and the 'NEAT' environmental assessment procedure:

AEDET ('achieving excellence design evaluation toolkit', now known as 'AEDET Evolution') evaluates a design by posing a series of clear, non-technical statements which encompass the three areas of Impact, Build Quality and Functionality. Each area is assessed across a range of specific criteria:

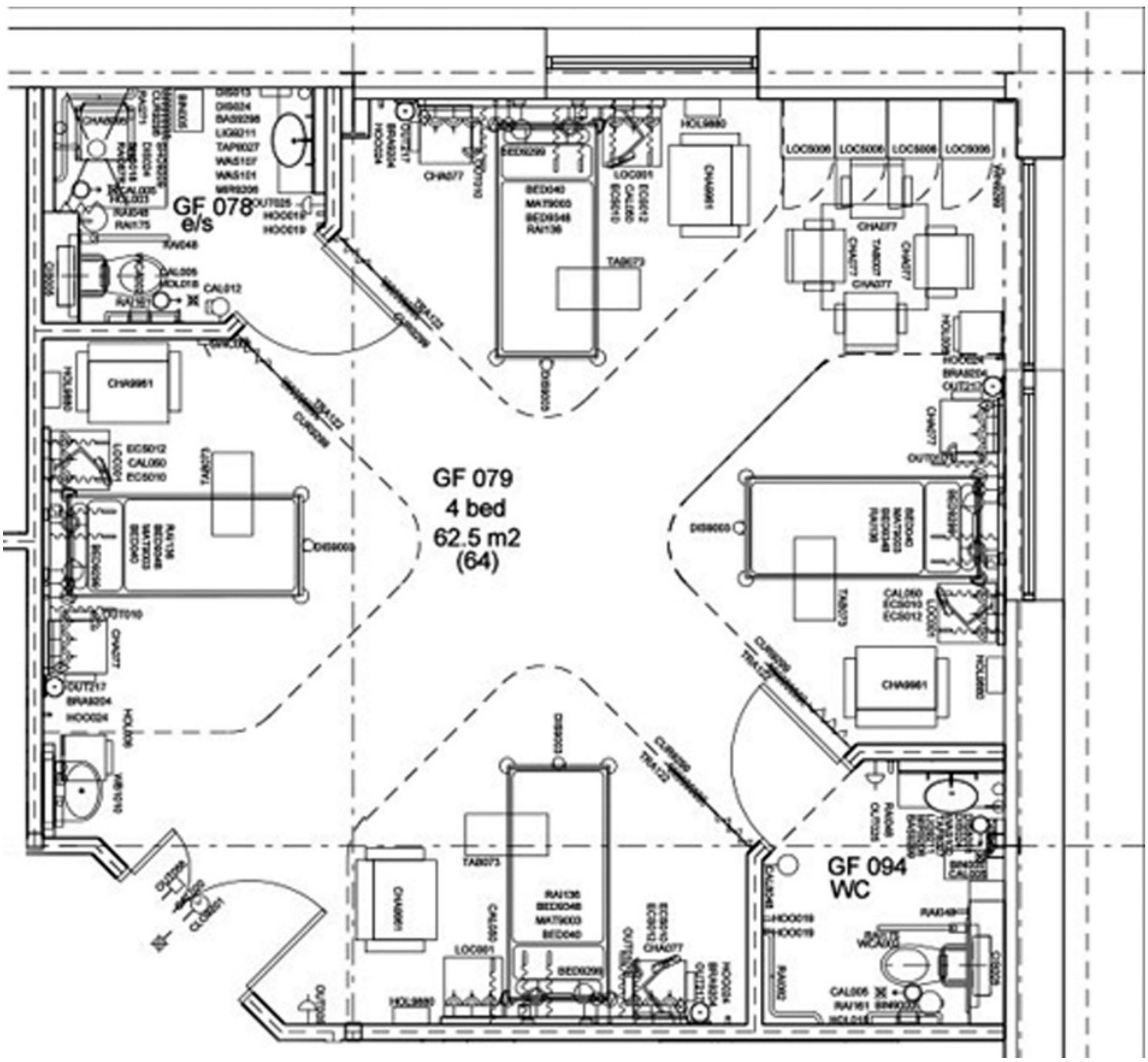
- 'Impact'
  - Character and innovation
  - Form and materials
  - Staff and patient environment
  - Urban and social regeneration
- 'Build quality'
  - Performance
  - Engineering
  - Construction
- 'Functionality'
  - Use
  - Access
  - Space

The idea is that if all three areas provide added value, the combined result will be excellence.

A further tool, ASPECT (standing for 'a staff and patient environment calibration tool') provides extra assessment processes which can supplement AEDET. Details of both tools can be found on the Department of Health's online portal http://design.dh.gov.uk

The NHS Environmental Assessment Tool (NEAT) is a self-assessment procedure, based on 'yes' or 'no' answers, that helps to assess the negative impact healthcare facilities may have on the environment. NEAT can be applied to any type of NHS healthcare facility. The Excel-based system issues a numerical score along the following lines:

- below 25% fail
- over 25% pass
- over 40% good
- over 55% very good
- over 70% excellent



25.2 *The four-bed 'New Nightingale Ward', designed by Nightingale Associates*

NEAT requires all new buildings achieve a rating of Excellent; refurbished buildings should achieve a rating of Very Good. NEAT covers 10 areas:

- Management
- Energy
- Transport
- Water
- Materials
- Landuse and ecology
- Pollution
- Internal environment
- Social factors
- Operational waste

The toolkit can be downloaded for DH websites.

3.03 Functional relationships in healthcare buildings

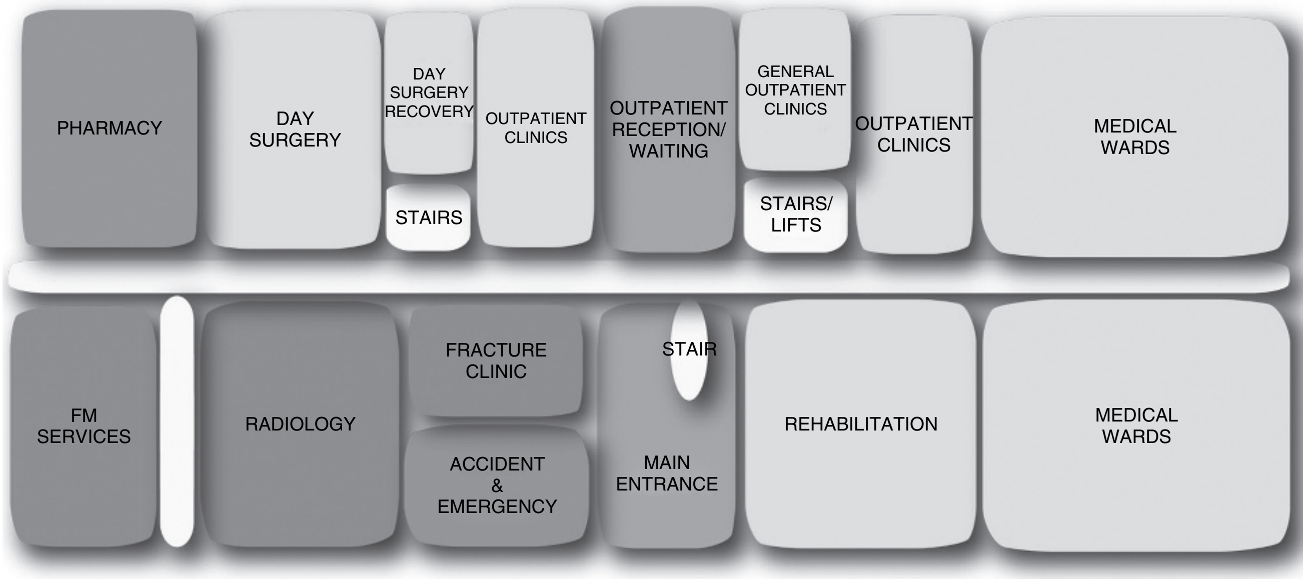
The discussions of individual clinical areas below includes reference to adjacencies appropriate for efficient usage of space and minimising unnecessary travel by patients and staff, **25.3**.

Logical adjacencies also ease the understanding of the building by patients, visitors and staff who are unfamiliar with the layout. Clear signposting, or Way-finding, is obviously essential but the principle that 'people do not read signs' should not be dismissed. Table II illustrates some of the relationships between major activity spaces and their associated activities.

3.04 Future proofing – designing for change – growth and shrinkage

The delivery of healthcare services and the consequent healthcare estate configurations will continue to change. As more acute services are delivered closer to home, or at home, different building types will appear. Increased partnerships with the Private Sector will develop alongside partnerships with leisure, commerce and retail delivering healthcare closer to the places people spend their days.

While the concept of flexibility has for many years been a criteria of judgment about the quality of a healthcare building design, it is now recognised that flexibility, and its consequent cost penalties, should be considered more in the context of adaptability. The continued use of steel and concrete frames for the primary structure in major healthcare buildings provides the greatest level of adaptability although within these two principles there are significant variations which, in themselves, increase or decrease adaptability. Hospitals are very intensive in their requirements for penetrable floor slabs, walls tend to follow column lines and it must be recognised that the least penetrable locations in a floor are likely to be around columns and along the line of major structural beams. The introduction of penetrable zones in these



25.3 *Relationship diagram of Darent Valley Hospital in Dartford Kent, an early PFI hospital designed by Paulley Nightingale Architects and completed in 2002*

Table II Hospitals department relationship in an acute hospital

Activities	Access requirements	Location	Relationship	Notes
Department Relationships in an acute hospital				
In-patient services				
1 Adult acute wards		Level not important	Surgical beds to theatres	
2 Children's wards	To outdoor play area	Preferably ground floor	Theatre Includes parents overnight stay	
3 Geriatric wards		Preferably ground floor	Geriatric day hospital Rehabilitation	
4 Intensive therapy unit		Level not important	Accident dept; theatres	
5 Maternity dept			Antenatal clinic in OPD	
5.1 Wards			Delivery suite	
5.2 Delivery suite	Ambulance access may be required for dept as a whole	Level not important	Wards, theatres SCBU	Area includes dept. admin, etc.
5.3 Special care baby unit			Delivery suite	
6 Psychiatric dept	External access	Self-contained units may need private internal access		
6.1 Wards				
6.2 Day hospital				
7 Isolation ward	Private external access for infected cases	Level not important, but see 'access'	Children's dept	
Diagnosis and treatment				
8 Operating dept		Level not important	Surgical beds; accident dept	Special ventilation needs include refrigeration
9 X-ray dept		Usually ground floor	Accident dept; fracture clinic	Special ceiling heights and heavy equipment
10 Radiotherapy		Level not important	X-ray dept	
11 Pathology dept	External supply access may be required	Level not important but see 'access'	Radio isotopes, outpatient dept	Special attention to ventilation of noxious fumes
12 Mortuary and postmortem	Private external access for undertakers' vehicles	Level not important, but see 'access'	Morbid anatomy Section of pathology	Special attention to ventilation of postmortem area
13 Rehabilitation	Ambulance access	Ground floor	Medical and geriatric beds	Includes physiotherapy gymnasium (extra height), hydrotherapy pool (special engineering requirements) and occupational therapy
14 Accident and emergency	Ambulance access for emergency cases	Usually ground floor – see 'access'	Direct access to X-ray dept, fracture clinic, main theatres, intensive therapy unit	Relationships assume no separate X-ray or theatres in accident department
15 Out-patient department including fracture clinic, antenatal, dental, clinical measurement, ears, nose and throat, eyes, children's outpatients and comprehensive assessment	Pedestrian and ambulance access for large numbers, approx. 300–400 morning and afternoon	Main reception and waiting area usually ground floor but parts may be on other levels	Fracture clinic to accident dept, convenient access to pharmacy, good access to medical records dept-often adjacent	
16 Elderly day hospital	Ambulance access, access to outdoor area	Usually ground floor – see 'access'	Elderly wards, rehabilitation dept	
17 Adult day ward		Level not important	Theatres, X-ray, pathology	Includes additional space for 'sitting' cases

(Continued)

Table II (Continued)

Department Relationships in an acute hospital				
Activities	**Access requirements**	**Location**	**Relationship**	**Notes**
Support services				
18 Paramedical:				
18.1 Pharmacy	External supply, access may be required	Usually ground floor – see 'access'	OPD. hospital upply routes	
18.2 Sterile supply dept	External supply access	Usually ground floor – see 'access'	Hospital supply routes, operating dept	Special ventilation needs – wild heat problems
18.3 Medical illustration		Level not important		Often using digital images anywhere in the hospital
18.4 Anaesthetics dept		Level not important	Theatres, intensive therapy	
19 Non-clinical:				
19.1 Kitchens	External supply access	May be ground floor (for supply access) above ground (nearer to bed areas)	Hospital supply routes and bed areas served – dining room servery	
19.2 Dining room		Level not important but see 'kitchens'	Access from kitchen to servery, good staff access from whole hospital	
19.3 Stores	Supplies vehicle	Usually in services area, ground door	Hospital supply routes	Special height may be needed for mechanical handling, increased use of 'Just in Time' provisions
19.4 Laundry	Supplies vehicle	Ground floor, service area	Hospital supply routes	
19.5 Boilerhouse – fuel storage	Fuel delivery vehicles	Usually ground floor in services area but may be elsewhere (e.g. rooftop) depending on choice of fuel	Work and transport dept	
19.6 Works – transport dept	Vehicle parking	Usually ground door in services area	Boiler house	
19.7 Administration		Level not important (tel. exchange ground floor)		Includes telephone exchange Purely administration functions could be off site
19.8 Main entrance accommodation	External access for inpatients, visitors, perhaps out-patients and staff	Usually ground floor – see 'access'	In-patient reception area or medical records main hospital horizontal and vertical communication routes	Also includes facilities such as bank, shops, etc.
19.9 Medical records		Level not important, Ground floor suits ground floor – see 'relationships'	Hospital communication routes	Only short term 'live' records on site, 24 h call up for others
20 Staff:				
20.1 Education centre		Level not important		
20.2 Non-resident staff chaning		On route between staff entrance and departments served, level not important	Hospital supply route for clean and dirty linen	
20.3 Occupational health service	Level not important			May be in OPD complex
21 Miscellaneous: This will include car parking, garages, medical gas installation, recreational buildings				

areas will substantially improve the ease with which future adaptations can be made.

Expansion zones at the perimeter of buildings must be considered, with the capability of major circulation routes extending beyond the envelope without significant disruption. Expansion also occurs within the building for particular activities. Some specialties can be reasonably predicted as likely to expand, radiology and day surgery for example. Some can be predicted as likely to reduce, medical records for example. Some are likely to be relocated, CSSD being an example. Placing facilities likely to expand alongside those that will contract enables an inbuilt flexibility which can minimise the effect of disruption in the future.

Services may also contract. As more activity moves out of an acute hospital environment, they may not be replaced by an increase in the remaining acute services. The capability for both expansion and contraction are required to be demonstrated at business case stage and considered as part of the Strategic Outline Case.

3.05 Fire design

Healthcare buildings have to comply with requirements for fire safety and means of escape: those for hospitals are set out in Firecode published by the Department of Health. This guidance is covered by the Documents HTM 05-01, HTM 05-02 and HTM 05-03 in various sections. This guidance is deemed to satisfy Building Regulation Part B requirements. The major change is in the responsibility of the NHS client in England to prepare a Fire Safety Policy in response to HTM 05-01 Managing Healthcare Fire to inform the design process. The requirements for Scotland and Wales may differ, the 05-01 process is also not mandatory for Foundation Trusts. Some of the requirements influence overall form and will be dealt here; others affect internal organisation and will be dealt below.

Relationship of departments by fire characteristics

The risk to human life is greatest in those areas where patients are confined to bed and especially where they would be incapable, in the event of a fire, of moving to a place of safety without assistance. Those areas are termed Normal Dependency called independent or Very High Dependency departments.

Departments posing the fire threat are those such as supply zones, fuel stores and other materials stores containing large quantities of flammable materials and those in which ignition is more likely such as kitchens, laundries, laboratories and boiler houses, referred to as Hazard Departments. The principle to be followed is that independent departments should not be placed adjacent to or above Hazard Departments unless protected by a 60 min barrier auto suppression in the Hazard Department is required in some instances.

Very High Dependency departments, such as ITU, Operating Theatres or Special Care Baby Units should not be located adjacent, vertically or horizontally to Hazard Departments. These requirements are noted in Table 1 in Section 3 of HTM 05-02.

Hospital Streets

The Hospital Street, a primary circulation route between areas of the hospital, can form a major fire-fighting platform. It also provides an alternative to an adjacent department for the purposes of progressive horizontal evacuation. Hospital Streets have particular requirements of maximum travel distances defined within Firecode. It is not necessary to provide a designated Hospital Street but a central circulation spine would naturally fall into this category.

Where a Hospital Street is designated, and in major units it has significant advantages for fire design and fire fighting, particular rules apply. The street must have a minimum width between handrails of 3 m. On the ground floor it must have at least two final exits no more than 180 m apart. On upper levels a minimum of two staircases are required at a maximum distance of 60 m apart. The distance from a department entrance to a staircase should be no more than 30 m. This is not an exhaustive list of requirements, reference to HTM 05-02 paras 5.40–5.45 should be made.

Compartmentation

Compartmentation of a large building into areas of limited size, divided by fire-resisting partitions, allows escape away from the fire source into a nearby place of relative safety in the initial stages of the fire. In a hospital, it is essential that this movement is horizontal. Lifts cannot generally be used in a fire and staircase evacuation of physically dependent patients takes far too long to be a practical means of escape in this first stage.

The primary compartment is by floor, each floor being a 60 min fire compartment unless the building is above 30 m or nine stories in height in which case it is 90 min.

On each floor, the compartments are limited to 2000 m^2 in area and a minimum of three for each floor, one of which may be the Hospital Street, are required to satisfy the above conditions.

In practice, it is unusual to have a compartment as large as this. The requirements of section 5 for compartmentation by department boundaries will generally generate compartments of about 1000 m^2 as a maximum.

If a compartment is larger than 750 m^2, or which provides access to more than 30 patients, there is a requirement to sub-compartment the area. In general, more compartments should be provided on each floor, particular attention should be made to vulnerable patient groups such as the elderly and those with limited mobility such as orthopaedic patients. Further compartmentation is necessary in Very High Dependancy departments such as Operating Theatres and other critical care areas.

Sprinklers are not normally used in hospital buildings but in central urban areas may be required. Firecode includes requirements for both circumstances.

In a single storey construction, the maximum compartment area is 3000 m^2 although similar departmental rules apply as noted above.

Travel distances and escape routes

There is a limitation on maximum travel distance within a compartment and sub-compartments. Within a compartment the maximum distance is 60 m, within a sub-compartment 30 m. There is also a limit on travel distance to a major escape route. The escape route is a protected, smoke-free path leading to an unenclosed space at ground level and the main Hospital Street is commonly designed to satisfy these criteria. A general rule is that a compartment should have an exit to either two adjacent departments or one department and a Hospital Street.

It should be noted that most areas of a hospital are occupied by trained staff for substantial parts of the day and in some cases 24 h. Unoccupied rooms such as stores and rooms which have a hazardous function, such as kitchens, or contain flammable materials represent the greatest fire risk and are designated a Fire Hazard Rooms. These rooms are required to maintain 30 min fire integrity and insulation.

3.06 Control of infection

The control of infection is a vital part of healthcare provision, and measures include behavioural and procedural ones (including the frequent washing of hands, use of alcohol gel and access restrictions) to design tactics (everything that is designed will have to be cleaned – all surfaces should be accessible to cleaning teams).

It should be recognised that infection by different pathogens can be minimised by different methods. Alcohol gel, for example, can work against MRSA but not C. Difficile which required meticulous hand washing. The design of the environment cannot in itself eliminate the risk of infection but the strategic placement of hand wash basins and alcohol gel dispensers can enable good management by encouraging good practice.

Horizontal surfaces which are difficult to clean represent a hazard, radiused skirtings and the elimination of inaccessible areas, behind WCs for example, assist a cleaning regime in being effective.

The presence of highly infectious and dangerous pathogens such as MRSA and C. Difficile is a constant concern for medical staff and patients, and the situation regarding these bacteria is very changeable. Designers should be mindful of the dangers these bacteria pose and should take advice from medical and infection control experts at all stages of the design process.

4 HEALTHCARE PROVISION – ACTIVITIES

4.01 Emergency care

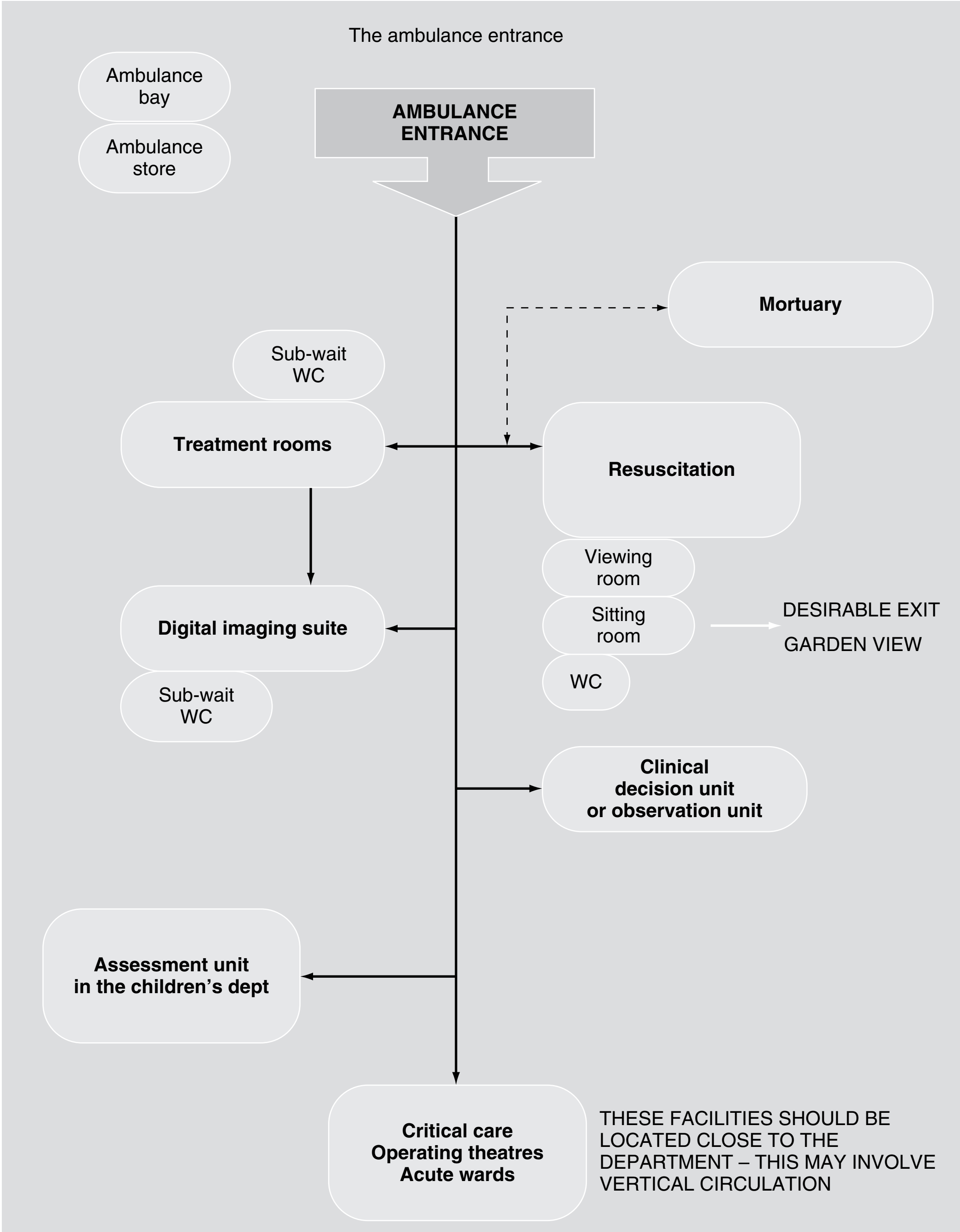
The provision of facilities for emergency care has evolved to enable cost-effective provision to be provided as quickly as possible. Greater emphasis is placed on para-medic services by response teams to emergency calls and on the provision of facilities for minor injuries, Minor Injury Units (MIU) are providing services between approximately 8.00am–11.00pm for patients not requiring the full scope of emergency care. This requires a degree of ‘self diagnosis’ and has yet to achieve its full potential in efficiency savings.

Emergency care is increasingly being associated with other elements of critical care such as Intensive Therapy and Operating Theatres as a management unit and the overall facility is now under the umbrella of Critical Care. Emergency care has an obvious requirement for ground-floor access, operating theatres, being highly dependant on mechanical ventilation provisions tend to be at an upper floor. Dedicated vertical circulation is therefore important between the Accident & Emergency (A&E) and Operating Theatres. An alternative would be the provision of an interstitial plant floor. The Intensive Therapy Unit (ITU) would usually be co-located with the Operating Theatres and would share this vertical access from the A&E, **25.4** and **25.5**.

Specialist A&E facilities for Cardiac care may be provided

Because of the urgent nature of a high proportion of accident cases, the relationship with supporting departments is crucial. In particular, there should be direct access – by separate entrance if necessary – to the X-ray Department for speedy diagnosis; alternatively separate X-ray facilities can be provided within A&E. Circulation of patients on beds or trolleys means that dimensions for these items are critical, **25.6** and **25.7**.

If X-ray facilities are not integral to the A&E facility a means of providing 24 h access to a limited section of the X-ray Department will be required.



25.4 *Diagram showing the relationships between spaces in a hospital emergency facility for patients arriving by ambulance. Source: Health Building Note 22*

Close proximity is also required to the Fracture Clinic because of the weight of traffic.

As direct access as possible should be provided from the A&E Department to the Operating Department although its location has to respect the overriding needs of surgical wards and the ITU.

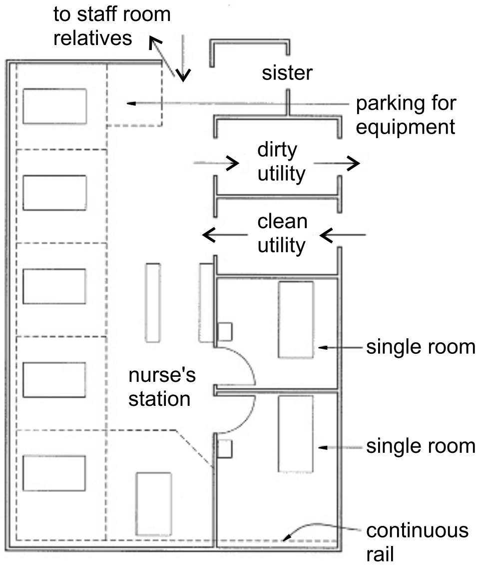
Out-patients should have access to the OPD directly through the Main Entrance. The OPD has the largest single daily requirement for provision of patients' records but whether this dictates a close relationship with Medical Records Department depends on the organisation and form of the records themselves.

There will be considerable traffic from the OPD to the X-ray Department and to the Fracture Clinic (which is usually shared with the A&E Department). Until recently, a large proportion of out-patients called in at the Pharmacy with their prescriptions but patients are now encouraged to use external community pharmacies and the location of the hospital department is not so critical, although it should be reasonably easy to find.

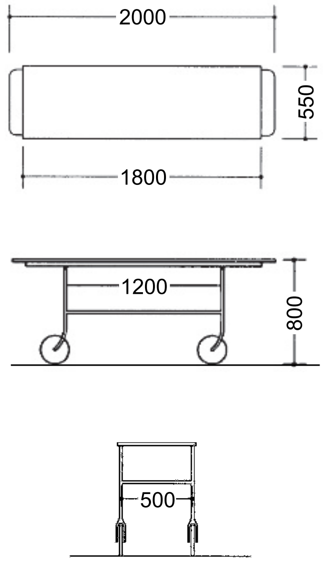
4.02 Invasive medicine

An operating department consists of one or more operating suites together with common ancillary accommodation such as changing and rest rooms, reception, transfer and recovery areas. An operating suite includes the operating theatre with its own anaesthetic room, preparation room (for instrument trollies), disposal room, scrub-up and gowning area and an exit area which may be part of the circulation space, **25.9**. An operating theatre is the room in which surgical operations and some diagnostic procedures are carried out.

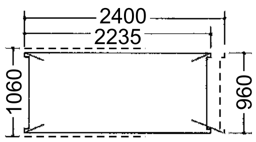
Infection control is one of the key criteria in operating department design and this is one of the few departments requiring air conditioning that includes humidity control. To assist infection control, four access zones are defined: operative zone (theatre and preparation room); restricted zone for those related to activities in the operative zone who need to be gowned (scrub-up, anaesthesia and utility rooms); limited access zone for those who need



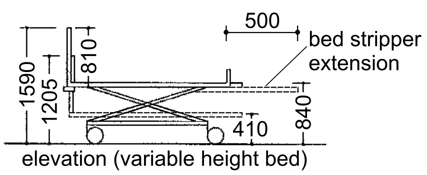
25.5 *Intensive therapy unit (ITU). Cubicle curtains are not used but movable screens may be. The location of the bed within the space varies with needs of patient, staff and equipment*



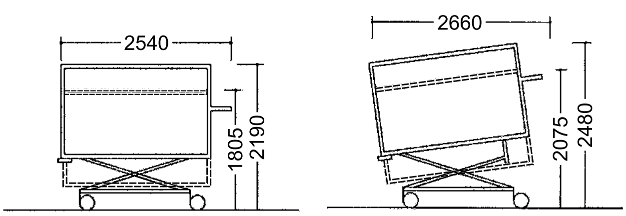
25.7 *Hospital trolley*



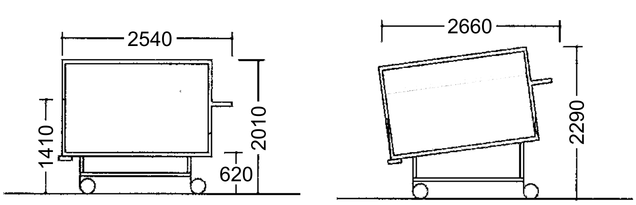
a *Plan*



b *Elevation of the variable height bed*



c *Elevations of the variable height bed with balkan beam*



d *Elevations of fixed height bed with balkan beam*

25.6 *King's Fund bed; critical dimensions given. These are likely to occur frequently and/or importantly. They may be increased by the various accessories which are available*

to enter areas adjacent to the above (recovery, mobile X-ray store, darkroom, staff rest, cleaner); and general access zone to which anyone is admitted (staff changing, porters base, transfer area, stores).

Separate 'clean' and 'dirty' corridors are no longer required for infection control reasons, although the four major components of traffic (patients, staff, supplies and disposal) may be segregated, in a number of possible combinations, into two corridors – on either side of the theatre – for reasons of good workflow.

There are strong economic arguments for centralising operating facilities in one department, located on the same floor as the surgical beds and in particular paediatric surgical beds should be on the same floor located as close as is feasible.

The ITU which should be immediately adjacent with direct access which does not require usage of the main hospital circulation routes.

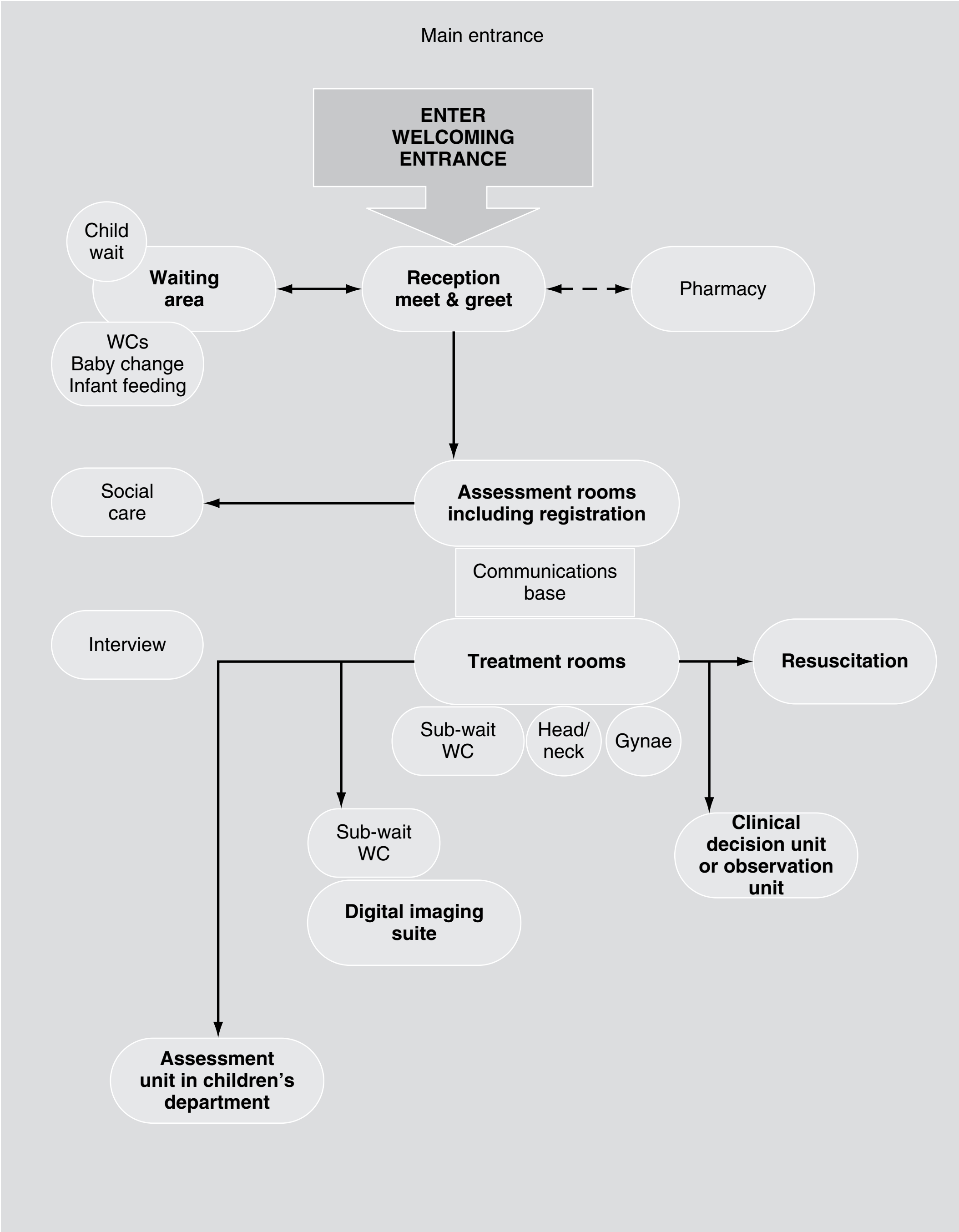
The journey from the A&E area should be as direct as possible although it may not be feasible for them to occur on the same floor.

4.03 Diagnostic imaging

Also known as radiology, this is usually taken to refer to the use of X-rays for diagnostic imaging; when used for treatment, the term radiotherapy is used, **25.10**.

In addition to the conventional techniques for imaging bone structures, supplemented in the case of soft organs by the use of radio-opaque materials such as barium, an X-ray Department will now generally accommodate a computerised tomography (CT) scanner which builds up three-dimensional images and a unit for magnetic resonance imaging (MRI).

CT and MRI have a significantly increased purpose in the rapid diagnosis of tumors and are used in increasing numbers by emergency services, particularly associated with head injuries and for cardiac patients. Although MRI does not use X-ray radiation, very particular design requirements are needed for the MRI Examination rooms because of the magnetic field generated by the magnet. The influence of the magnet extends beyond the Examination Room to an extent dependent on the power of the magnet and the amount of shielding built into the enclosure. All materials within the examination room need to be non-ferrous and MRI compatible. CT does use X-ray radiation and, since it uses 'slices' to build up a three-dimensional image a CT investigation



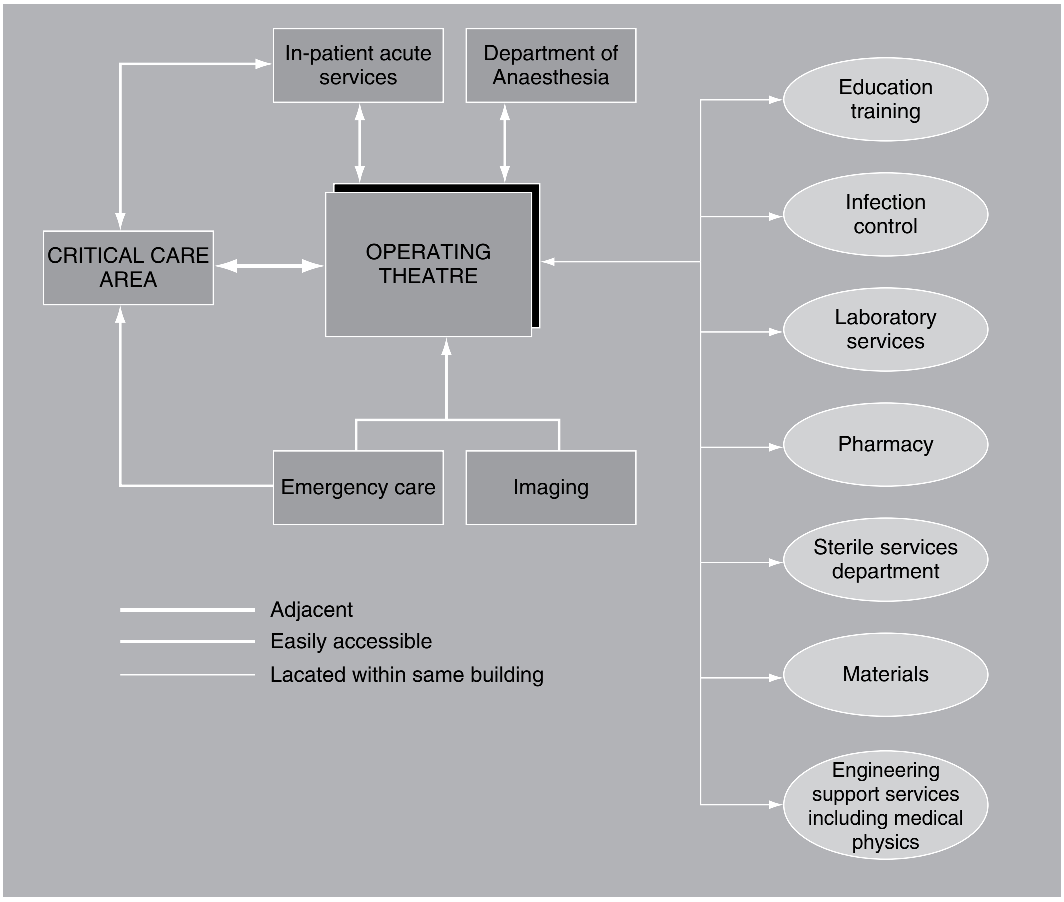
25.8 *Relationship diagram, illustrating the emergency-related spaces for patients arriving by public or private transport. Source: Health Building Note 22*

will result in a far higher dose of radiation for the patient than a conventional X-ray; for this reason, it is used as sparingly as possible on one patient.

Of even greater impact in terms of throughput – and still growing – is imaging by ultrasound, which is simpler (not needing the protective measures demanded of X-rays), cheaper, faster and not requiring as much space.

Each of these services requires its own reception, waiting and changing areas. The X-ray services may in addition be grouped into, for example, specialised rooms, general-purpose rooms and barium rooms although the X-ray reception desk would probably be common to all. Where there are a large range of possible investigations departments are sometimes split into 'fast-flow' and 'slow-flow' areas depending on the throughput level of the area. The increased use of Picture Archiving and Communication Systems (PACS) has resulted in a reduced need for film processing and storage within the Imaging area, reporting can similarly be carried out in locations remote from the radiology facility, away from the hospital, or in a different country. This facility greatly enhances the possibility of using remote expertise to quickly arrive at a diagnosis which would not otherwise be achievable. The introduction of PACS has also had an impact on the take up of a more 'paperless' hospital environment although the full development of patient records available across the healthcare community remains fraught with technical, ethical and confidentiality issues.

The department should be located next to the A&E and near the OPD with as direct an access as possible for in-patients. (Satellite departments in, for example, the AED are not generally cost-effective.) The layout should allow access to some diagnostic rooms outside working hours without opening the whole department, **25.11** and **25.12**.



25.9 *Diagram illustrating the relationships between an operating theatre and other hospital services. Source: Health Building Note 26 volume 1*

4.04 Inpatient nursing care

The ward concept

Beds for in-patients in hospitals are grouped, for effective management, into wards of anything from 20 to 36 beds, under the charge of a sister or charge nurse who is supported by a team of qualified nurses, student nurses and aides. This team has to ensure that patients are monitored, fed, allowed to sleep and use toilet facilities, kept clean, treated if required and encouraged to move around, **25.13**.

Patients will be taken from the ward to other departments for more complex diagnostic testing and treatment. Doctors will visit ward patients at least daily and other staff will come to administer treatment such as physiotherapy.

The ward will be supplied with food, linen, pharmaceuticals and sterile goods and will hold equipment such as wheelchairs, drip stands and walking frames. Used returns and refuse in various categories will be collected on a regular basis.

Two factors have come to radically influence the design of in-patient hospital wards in recent years.

Firstly, the recognition that, although beds may be grouped in clusters of 20–30 the nurses responsibility is allocated to a smaller number of patients, normally around 12. Thus, the historically centralised staff base has been replaced by a number of smaller bases, each allocated to a nursing unit of around 12 beds. These contain the necessary facilities for managing the allocated group of patients but the clerical component of the ward administration is centralised to a facility for the Ward Clerk, usually at the entrance to the ward to allow monitoring of visitors to the ward area. A group of these clusters, containing up to 60 beds provides a manageable unit for the provision of facilities management services such as catering and cleaning.

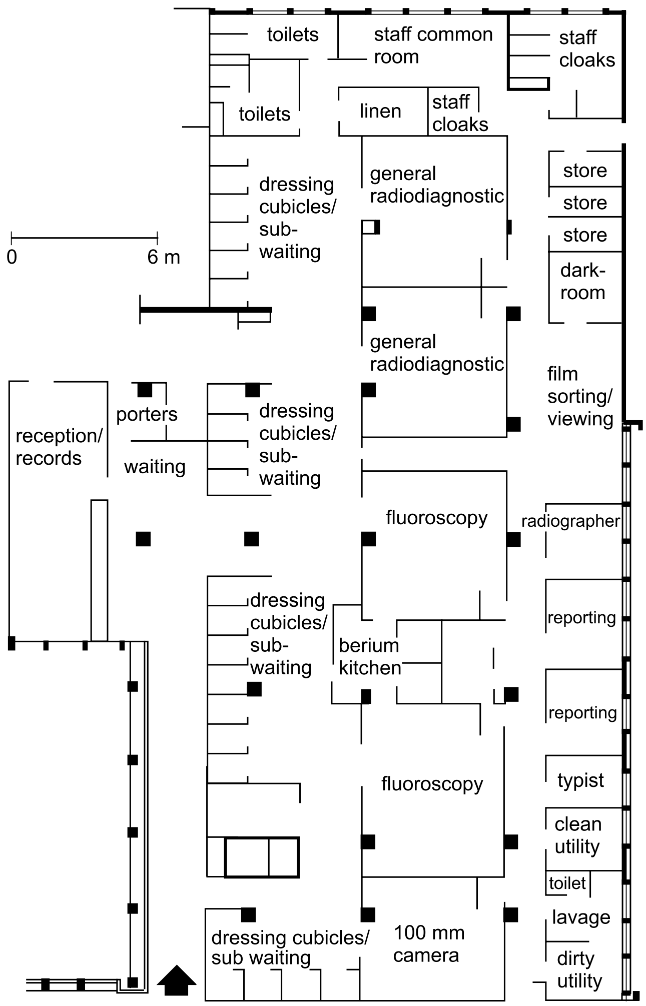
The second and more significant debate revolves around the provision of single bedrooms and multi-bed bays. Previous use of six-bed bays, heavily utilised by Best Buy and Nucleus together with other standard template designs is no longer acceptable. More significantly strong arguments have been made about the use of 100% single bedrooms. Clearly, the capital cost is higher but the counter arguments around control of cross infection, ability to isolate Hospital Aquired Infection (HAI) patients, reductions in medication errors, more dignified and quieter patient environments, more confidential discussions between patients and clinicians, all combine towards a strong case for 100% single rooms. Ideally, each room should have a similar plan for, i.e. not being a pair of handed rooms.

There are arguments against single room provision. Companionship in a strange and stressful environment is a benefit to many. Patients within a multi-bed ward also support each other when necessary, summoning staff, for example. The debate will continue but experience in Europe, particularly Denmark, indicates that such provision is a tangible, and provable in terms of Evidence-Based Design, factor in the elimination of HAI.

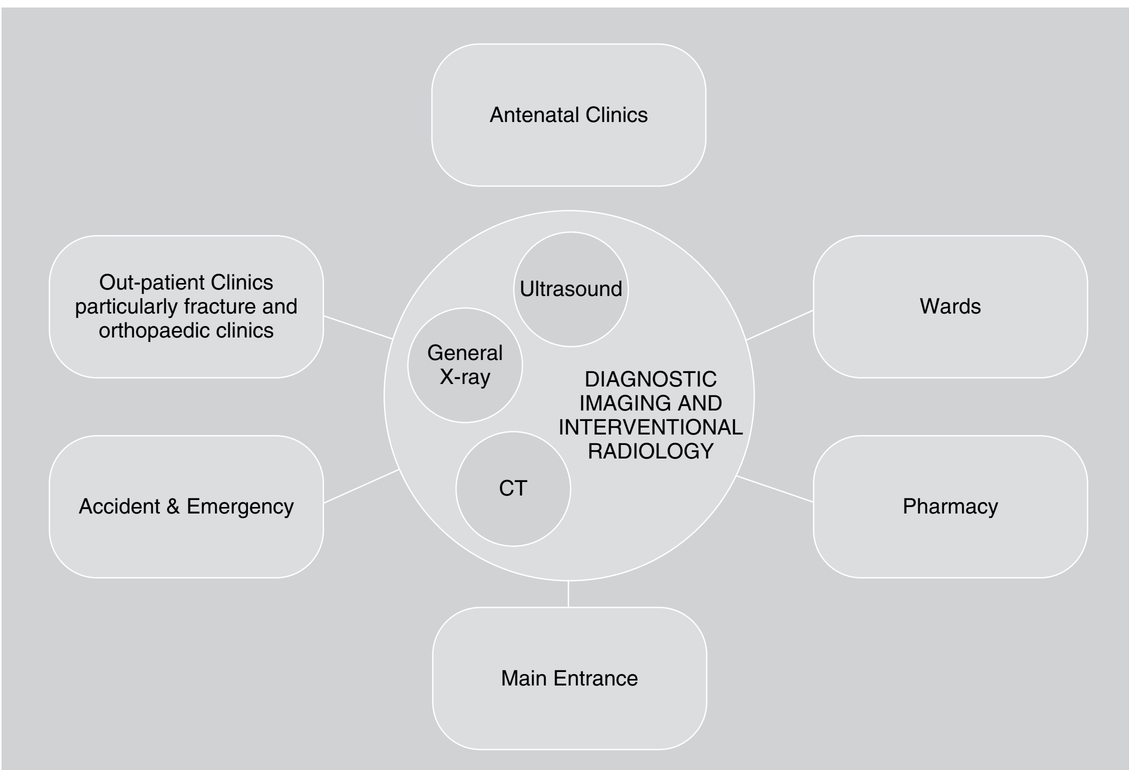
With so much claim on ground-floor locations, wards tend to be on upper floors unless, like geriatric and children's wards, they have a particular need for access to outside space.

Wards occupy about half the total area of a hospital so it is not possible for all wards to be adjacent to the most relevant departments. For surgical wards, location on the same floor is generally considered satisfactory on the grounds that horizontal travel is more predictable than vertical travel by lift. This is particularly pertinent to paediatric wards where lift travel following surgery is considered a high risk.

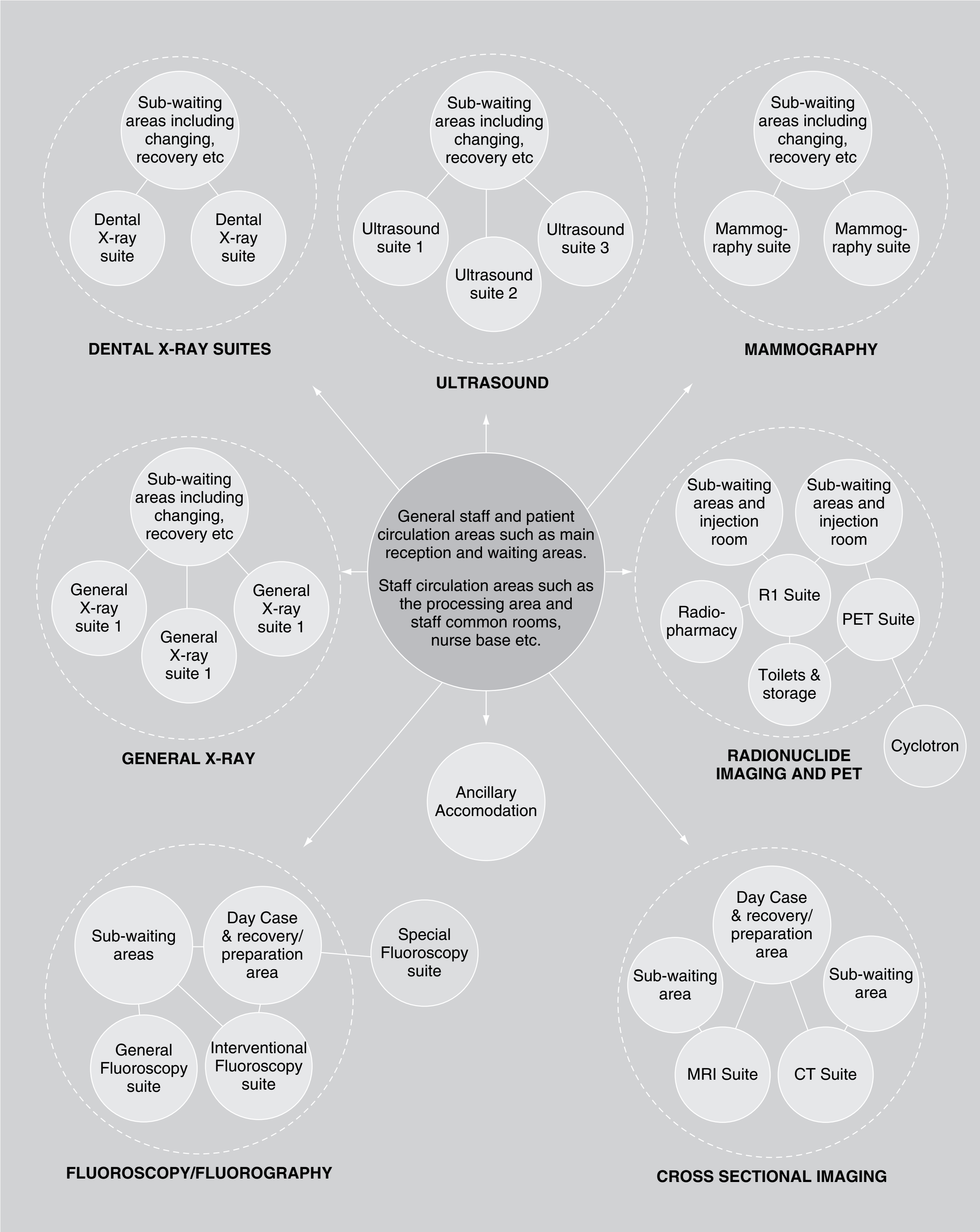
Wards cater for many types of patient such as surgical, medical, paediatric (children), elderly, intensive therapy but it is important that a common general pattern be adopted as far as possible so that



25.10 *X-ray Department at King Edward Memorial Hospital, Ealing. This illustration depicts a film approach to taking and developing X-rays. Digital techniques (known as Picture Archive and Communication, PAC, facilties) are more flexible*



25.11 *Diagram showing relationships between diagnostic imaging departments and other hospital units. Source: Health Building Note 6*



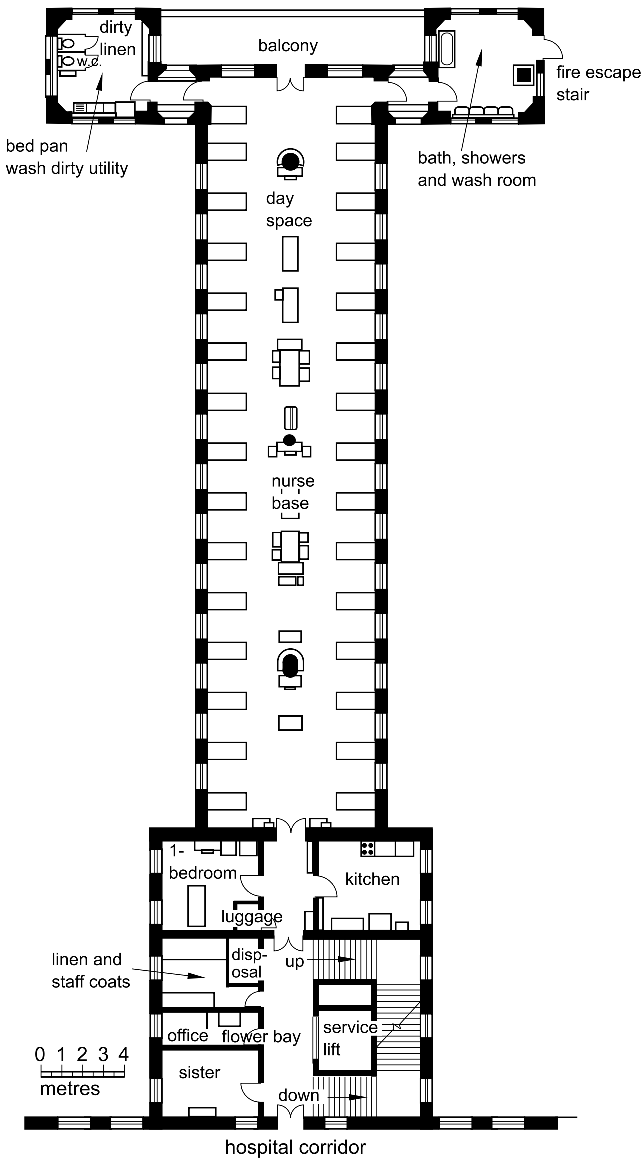
25.12 *Diagram showing relationships between different imaging areas within a hospital. Source: Health Building Note 6*

changes of use can be made without disruption. High-dependency provisions including Intensive Care have such specific requirements that they cannot generally be provided within an acute ward design. Paediatric wards also have particular requirements such as overnight accommodation in the bed area for carers and are generally subject to specific design solutions.

Architects should refer to Health Building Note 4 for further details on ward design.

Ward types

- *Adult acute wards* accommodate general medical or general surgical patients. Although a ward generally will accommodate either one or the other (for doctors' convenience and efficiency of location) there is no significant difference in their facility needs and the ward is standard in its area provision and layout. Between half and three quarters of a hospital's beds are to be found in these wards. Stroke rehabilitation wards would also



25.13 *Nightingale ward in St Thomas' Hospital. Although the traditional Nightingale Wards provided excellent observation for nurses and some reassurance for patients, lack of privacy (and perhaps dignity) and increased disturbance was felt to be compromised*

generally follow the pattern of a general acute ward. Cardiac wards can generally be of a similar format to a general acute ward although the provision of telemetry to monitor vital signs to a central location provides for greater flexibility in the use of single bedrooms, **25.14**.

- *Children's wards* vary from adult acute wards in the greater areas devoted to day/play space and the need for access to an outside play area, the provision of education facilities and, of course, the specially designed fittings and furniture. Separate provision for adolescents is an important consideration as educational and recreational provisions are not compatible with lower age ranges. Provision for separate accommodation for males and females becomes significantly more important for this age range.
- Wards for *elderly people* again have more day space than adult acute wards because these patients spend longer in hospital and are ambulant for more of the time. Providing dignity and separation of sexes can be preserved, accommodation for elderly patients may benefit from a limited provision of multi-bed accommodation.
- The *intensive therapy and high dependency* units hold seriously ill patients, often transferred direct from the operating theatre. Significantly more space is required around the bed for monitoring and other equipment. Bed centres of 4.5 m are required for Intensive Care compared to 3.3 m in acute care. No day space is required, and the bed areas are designed primarily for efficient nursing. Because of the high staff/patient ratio, the size of the ward is usually limited to about 20 patients and a more usual provision at a district hospital (i.e. serving a population of 300 000) is between 10 and 12 bed spaces. The Planetree Foundation in the USA have devoted particular effort to providing critical care facilities which enable the patient to be nursed in a highly technical clinical environment but providing accommodation for relatives and carers to be in close contact without compromising care or hygiene requirements. Refer to Griffin Hospital, Derby, CT.

4.05 Outpatient services including pharmacy

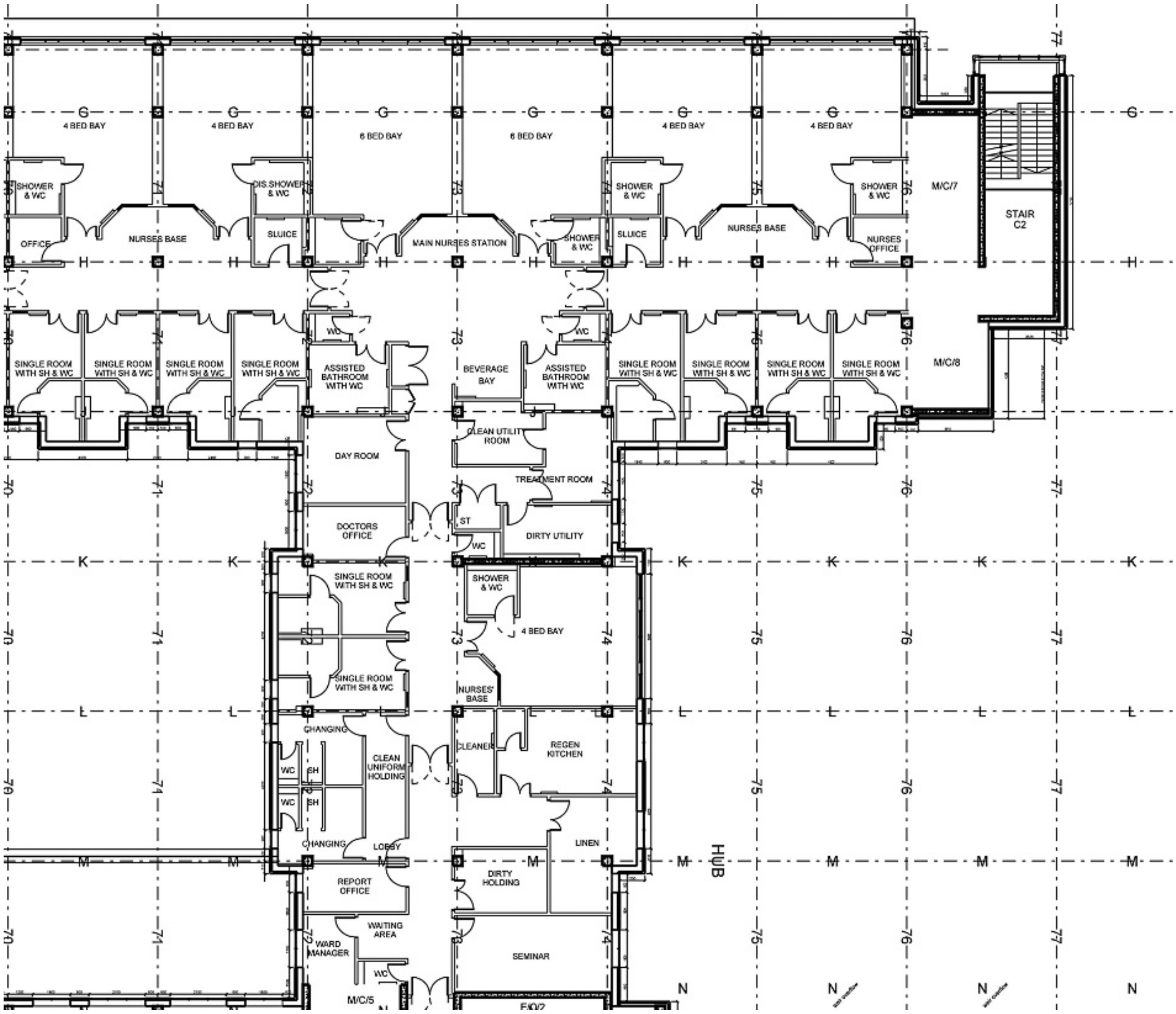
The function of the OPD is to diagnose and treat home-based patients and if necessary admit them as in-patients. It is one of the largest departments in the hospital and is visited by the greatest number of patients daily. It is, therefore, best accessed directly from the main hospital entrance. Separate OPD facilities for children may be considered in the context of a hospital wide policy for children's services.

The patients' first point of contact is the main OP reception desk from which they are directed to the sub-waiting area serving the suite of consulting rooms in which their clinic is being held, **25.15**. The building block of the department is the consulting/examination suite which can be a number of combined Consult/Examination (C/E) rooms or some combination of consulting rooms and examination rooms. Combined C/E rooms are generally described as single or two sided, depending on the provision of permanent access to one or both sides of the couch. Typically single sided access requires 14.5 m^2 and two sided 16.5 m^2. The side to the right of the patient is prioritised for the staff.

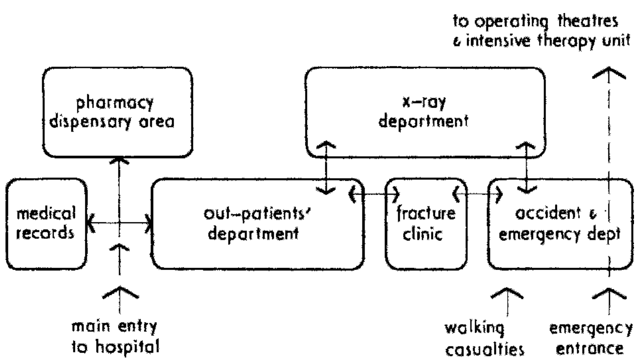
In the combined C/E room, the doctor will both consult with the patient and examine the patient on a couch; while the patient is dressing, the doctor may move to an adjoining C/E room to deal with another patient and the rooms should, therefore, have interconnecting doors. Issues of confidentiality between rooms needs to be carefully considered in these circumstances as without intrusive acoustic protection privacy will be compromised. In the consulting room + examination rooms arrangement, the patient moves to the separate room, undresses and waits for the doctor. The normal provision is an examination room either side of a consulting room. Because of the greater flexibility of space the C/E room provision is considered to have better utilisation. In a clinic where there is rapid throughput, a consultant, registrar and house officer may occupy a string of six or seven combined C/E rooms; where the throughput is slower (e.g. psychiatry), each doctor will occupy one room only.

To provide such flexibility, strings of at least 6 rooms, and preferably 12, are required. This can, however, make it difficult to provide an external view for the sub-waiting area, a provision valued more highly in Scottish guidance. The potential further flexibility of these rooms being used, or converted for use as treatment facilities suggests that this consideration be made at an early design stage. In particular, the room size and ventilation requirements. All consulting rooms should have an external wall location with natural ventilation and consideration of privacy needs to be made when overlooking may occur, in particular across a courtyard.

A move towards Rapid Diagnostic and Treatment Centres (RDTC) has resulted in the increased provision of facilities where the concept of a 'one stop shop' mean that in some cases diagnosis and treatment can occur within the same visit. All diagnostic tools are provided within the facility and although the patient visit lasts longer, up to 5 h, consultation, diagnostic procedures and treatment in one visit substantially improves that patient experience.



25.14 *General acute ward at The University Hospital of Coventry and Warwickshire. This could be split down the middle as the wards are a matching unit. Architects Nightingale Associates*



25.15 *Relationship diagram of out-patient and accident cluster*

Orthopaedic and fracture clinics are often provided as part of the A&E Department since many of their patients are receiving follow-up treatment resulting from injuries and some accommodation, like the plaster room, can be used in common.

Centralised Pharmacy services, which may include manufacturing and preparation of intravenous fluids, are making increased use of robotic dispensing, particularly for outpatients and ward boxes. It is less necessary for the pharmacy to be located adjacent to the outpatient service although the provision of a dispensing facility close to the main access point for outpatients is necessary.

See **25.16–25.20**

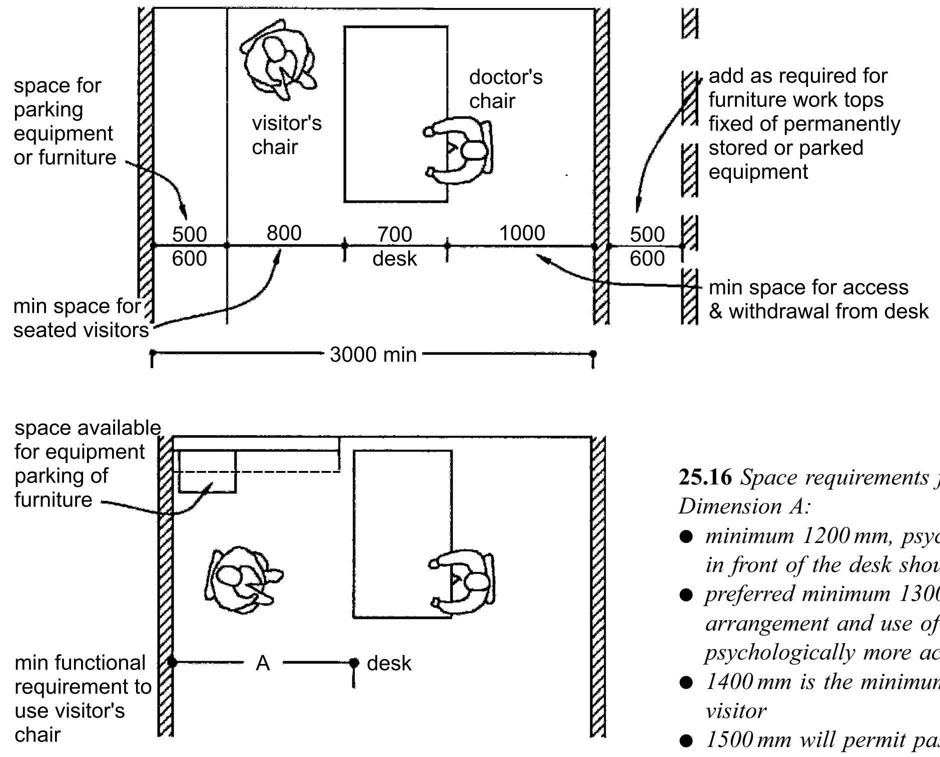
4.06 Day patient services including ISTCs

Improvements in anaesthetic techniques and the vastly increased use of 'keyhole surgery' endoscopy and laparoscopy together with laser surgery have enabled routine invasive and ophthalmic procedures to be carried out in one day meaning that a patient does not require an overnight stay.

Day surgery operating theatres are generally designed and equipped to a similar level as inpatient theatres and often include an ultra clean hood. A ceiling mounted enclosure which provides a highly effective low-velocity hepa filtered environment, sometimes to the extent that surgical staff wear full body ventilated suits. Such provisions were previously exclusive to orthopaedic surgery and are still critical to this specialty but are in more general usage.

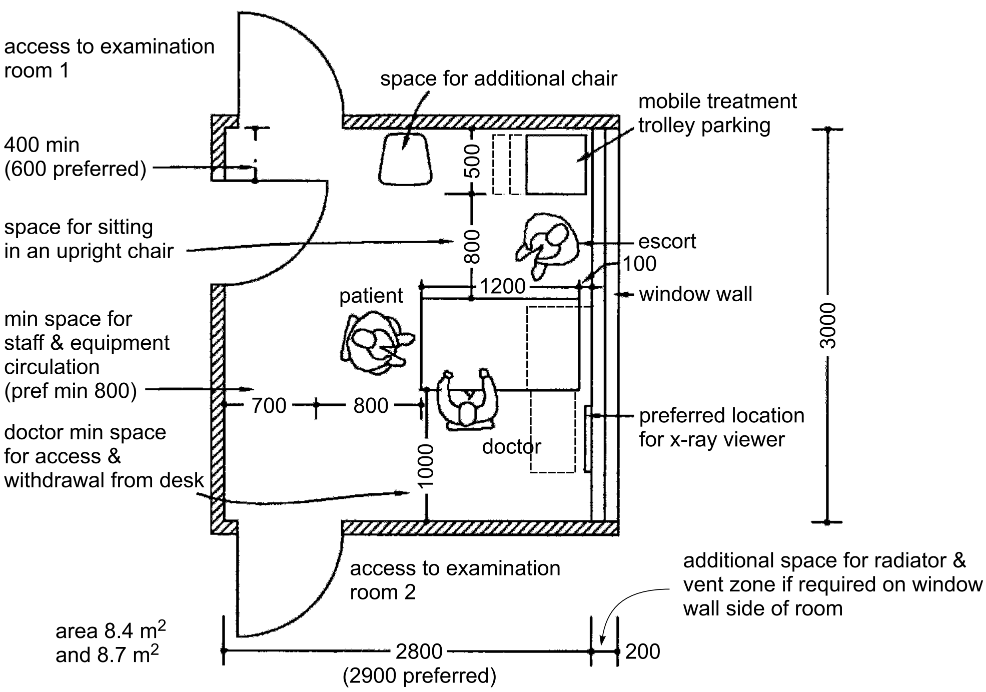
Day surgery theatres may be provided within the main operating department; however, the principle of day surgery facilities is to separate the elective (i.e. planned) service from the disruption caused by emergency admissions and procedures. Although potentially less efficient in theatre useage, day surgery theatres are often located adjacent to the outpatients department providing a centralised service for all non-inpatient clinical interventions. Such facilities are known as Ambulatory Care Centres.

Pressures on waiting lists have generated an increased scope for partnership between the NHS and the private sector. One such instance is the Independent Sector Treatment Centre (ISTC). These are facilities, including staff, are provided by the private



25.16 *Space requirements for room width in consulting areas Dimension A:*

- *minimum 1200 mm, psychologically unsatisfactory. The space in front of the desk should be larger than that behind*
- *preferred minimum 1300 mm giving more flexibility in arrangement and use of the space in front of the desk, and psychologically more acceptable*
- *1400 mm is the minimum permitting movement past a seated visitor*
- *1500 mm will permit passage behind a seated visitor*



25.17 *Separate consulting room*

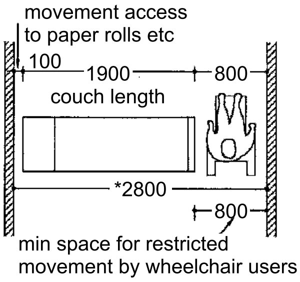
sector and the private sector partner is contracted to provide a prescribed service level over a prescribed period in a contract which transfers the estate related risks to the private sector. There are a number of ISTCs currently in operation.

Increasingly minimally invasive surgery (keyhole surgery) is likely to be used in the future, and as the trend towards moving care closer to the patients home continues will move into locations further removed from acute hospital sites.

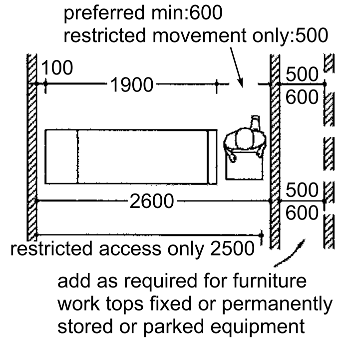
4.07 Rehabilitation services

To encourage an integrated approach to patient treatment, the rehabilitation department encompasses a number of therapies:

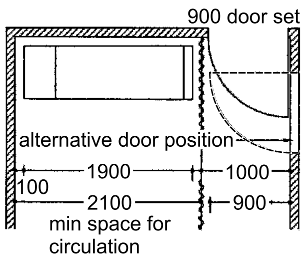
- *Physiotherapy*: Dealing with problems of mobility and function using natural approaches such as movement and manual therapy, supported by electrotherapy, cryotherapy and hydrotherapy.
- *Occupational therapy*: Improving patients' function and minimising handicaps through the holistic use of selected activities, environment and equipment adaptation so that they can achieve independence in daily living and regain competence in work and leisure.
- *Speech therapy*: Dealing with communication problems, either individually or in groups, if necessary by introducing alternative methods of communication; family members may be involved and family counselling plays an important part.



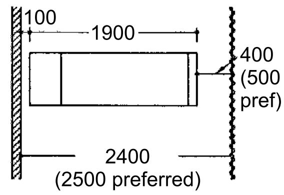
a *Access at foot end of couch for wheelchair movement. *2800 mm is also the preferred minimum dimension room length when standing workspace at foot or head ends of couch is required*



b *Where wheelchair movement at foot end not required*

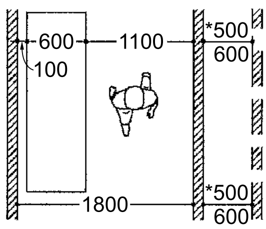


c *No access across foot end of couch*

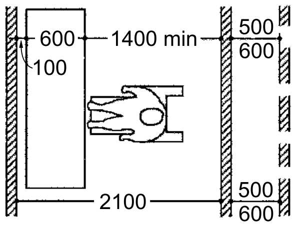


d *Minimum for restricted sideways access within curtained area*

25.18 *Space requirements for room lengths in examination areas*

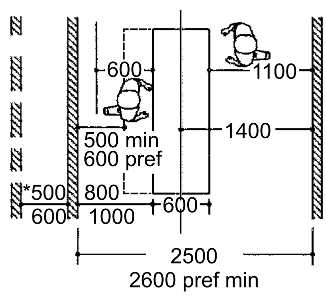


a *Access to one side of couch only. 1100 mm is the minimum space for an ambulant patient changing*



b *Access to one side of couch only. 1400 mm is the minimum space for a wheelchair patient changing*

25.19 *Space requirements for room width in examination areas*



c *Access to both sides of couch*
600 mm is the essential unobstructed space for access and examination
1100 mm is the space at the side of the couch for changing
1400 mm is the space at the side of the couch for wheelchair access
800 mm to 1000 mm is the clear workspace at the side of the bed or couch for examination and treatment, preferred minimum 900 mm
**add as required for furniture, workshop or equipment, which may be fixed, permanently stored or parked.*

In addition, accommodation is needed for consultant medical staff.

Patients may be disabled: the department may need its own entrance if it is remote from the main entrance and must be near to car parking.

In some instances, staff from the unit may require regular visits to outlying areas to provide services at home or in local healthcare facilities. This may include the transport of equipment and the co-location of parking facilities for these peripatetic activities should be considered and discussed with planning authorities.

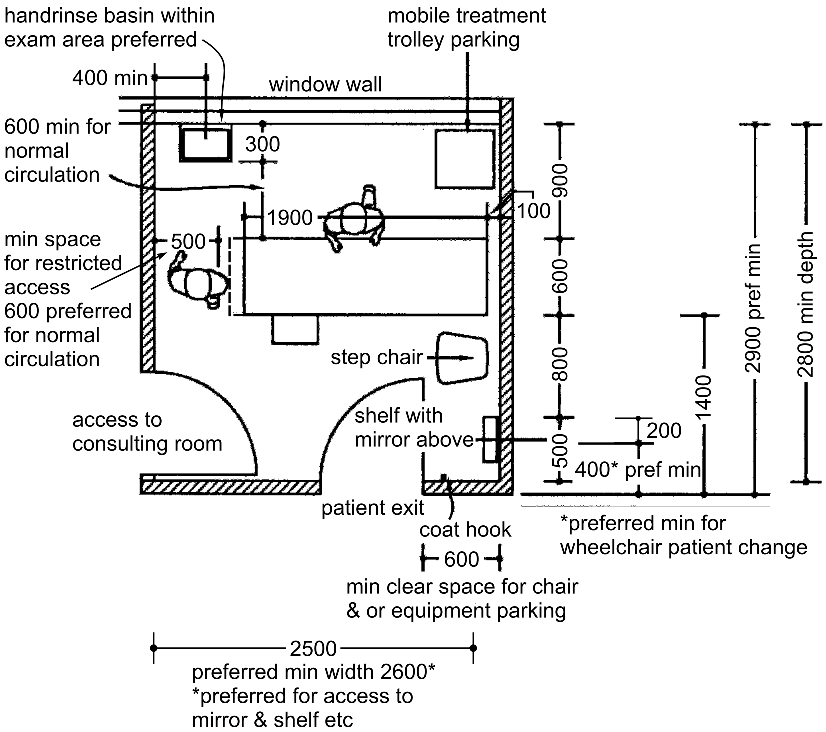
There are no strong internal relationships except between hydrotherapy and physiotherapy and between the central waiting space and all treatment areas. This generally means a close association with the Outpatients department or Ambulatory care unit described above.

4.08 Children's services

The needs of children are best met by having them together in children's units, nursed by staff with the relevant qualifications. Accommodation is required for out-patient facilities; comprehensive assessment and care (for the investigation, treatment and diagnosis of children who fail to develop physically or mentally); in-patient facilities in 20-bed wards; and a day care unit.

The out-patient unit and assessment accommodation should be on one floor, either at ground level or served by a convenient lift, near to public transport and car parking. The out-patient unit should be near the plaster room and fracture clinic and could adjoin the main OPD.

In the children's ward, the need for observation is greater than in an adult's, but the need for privacy is less and more partitions can be



25.20 *Separate examination room: area 7 m*^{2} *and 7.6 m*^{2}

glazed at both high and low level. All bedrooms should consider the need for a parent to stay with a child. Play space is required and space for teaching and physiotherapy, this should include outside areas, although these may double with other functions such as eating.

Avoiding an institutional atmosphere in the design is important in adult wards but even more so in children's: a light and sunny atmosphere should be the aim. Graphics and themes should be developed to stimulate, enable an understanding of the areas of the unit without the assumption of reading ability, and enable children to associate themselves with a particular area and become more confortable with their environment. The Evelina Childrens Hospital at St Thomas' Hospital by Hopkins Architects and RKW is a good example of the development of the brief and the accommodation in consultation with children.

The accommodation generally will need to provide for infants, toddlers, school-age children and adolescents: the design should as far as possible take account of their varying needs.

4.09 Older peoples services

More 'acute' elderly patients – those undergoing assessment or rehabilitation – are in most respects satisfied by the design for adult acute wards.

The development of Hospital Trusts and the separation of services into acute and mental health provided by separate Trusts has inevitably resulted in the dislocation of the services, often to different sites. It should be recognised, however, that elderly patients often have mental health difficulties alongside medical episodes. The reverse is also the case that mental health patients have medical demands in addition to mental health problems and facilities for the management of these issues should be considered as a component part of the accommodation.

Longer stay elderly wards, including those for the mentally infirm, should be more like home than hospital and include a higher variety of room types to accommodate different preferences, and more day space. More storage space is required for storing patients' belongings, including suitcases, mobility aids, continence aids, etc.

4.10 Maternity services

Policies concerning maternity care can vary widely and client policy towards the whole maternity process should be established at the outset. Co-location of Womens' services, and the co-location of Womens' and Childrens' services should be considered.

Nearly all births take place in hospital but current trends are towards increasing antenatal testing and, on that basis, prioritising cases so that low-risk ones can be delivered in the community (at home or in a community hospital) while higher-risk cases are dealt with in the hospital where operating theatres and other back-up facilities are closer to hand.

A strengthened community care service, with midwives accommodated in community clinics or local health care resource centres, could deal with most of the antenatal care process and minimise the need for visits to the hospital antenatal clinic. Such buildings would incorporate spaces for antenatal exercise classes and mother and baby clinics.

A number of philosophies concerning delivery may be encountered. Traditionally, the woman would be admitted direct to the delivery room or, if admitted early, to an antenatal ward. During labour, she would move to a separate delivery room – perhaps in a suite, central to all the maternity wards and near to the neonatal unit for the nursing of small or ill babies – for delivery of the baby, then returned to a postnatal ward which would be designed to allow rest following birth and to allow the mother to get to know her baby.

An alternative, used routinely in the USA, is the 'complete stay room' (or LDRP room – labour, delivery, recovery and postpartum) in which the whole process is enacted and which may include accommodation for the mother's partner. The provision of a birthing pool is another option with implications for the structure and infection control issues.

Within this range, there are many possible scenarios, each with its own implications for ward facilities (such as day rooms and sanitary provision) and for provision for abnormal delivery.

Occupancy of maternity wards is variable, throughout the year and with population changes. In principle, they should, therefore, be planned for easy conversion to adult acute use, although this might be difficult with some options such as the complete stay room. In the postnatal ward, the baby will be nursed in a cot alongside the mother, although nursery accommodation should also be provided to enable the mother to get some much needed rest on occasions.

The out-patient suite will incorporate a suite of consulting/examination rooms and supporting facilities; waiting areas which can double as space for classes and clinics; and a diagnostic ultrasound room with associated changing and waiting areas.

The design approach in all maternity accommodation should centre around the fact that the pregnant woman is not sick but undergoing a natural function: there is no strong reason for the environment to be particularly clinical in appearance. Concealing obvious clinical elements such as medical gas outlets behind removable folding panels greatly reduces the clinical appearance.

4.11 Mental health services

The scope of facilities for mentally ill people on the hospital site is subject to local initiative. It is, however, likely to include accommodation for the assessment and short-term treatment of adults, including the elderly, who are acutely mentally ill: this group of patients is most likely to need the support of diagnostic services and access to general acute facilities. They also gain from sharing catering, supply and disposal services.

The primary elements in the department will be the wards of 15 beds for adult patients and 20 beds for elderly patients and the day hospital which includes consulting, treatment and social areas together with occupational therapy. Very few adults will remain in the wards during the day but if ward and day hospital are intended to share day, dining, sitting and recreation facilities, experience has shown that full integration is required for this to work successfully.

The department should ideally be integrated into the hospital so as to facilitate communication but be independent enough to have its own (not too clinical) environment, although comments above under older peoples services should be noted. Its configuration is unlikely to match that of other wards and evening activities may be disturbing to other in-patient departments. One solution is to plan it as a satellite with its own entrance, perhaps linked to the main hospital and possibly sharing some accommodation with an adjacent rehabilitation department. Although there are exceptions a ground-floor location with good access to safe, secure and observable external spaces is a high priority.

Within wards, the current recommendation of Building Note 35 is for 100% single rooms. This caused some concern related to staffing levels and observation when introduced but has generally been accepted as the norm and has not shown substantial increases in staffing requirements. The wards should consider the needs of patients with varying levels of dementia. Functional and Organic dementia provoke very different responses by patients to their environment, however it is still standard practice to nurse both groups of patients in the same ward area. For this reason, all wards should consider patients needs for wandering, continuous walking, often on a circular, racetrack type route, and a variety of environments which provide either stimulation or a calming effect. Clinical discussions and handover between shifts, because confidential, tend to take place in the sister's office which, therefore, needs to be larger.

Psychiatric out-patient clinics are generally held in the main OPD. Many patients never enter the psychiatric department but others may attend the day hospital from one to 3 days a week, undertaking various types of occupational therapy and group therapy. They are also given a mid-day meal in two sittings. These activities can be accommodated in a number of rooms with comfortable sitting space for 10–20 people. Electro-convulsive therapy (ECT) may need to be accommodated: it requires treatment and recovery rooms but they would only be in use for perhaps 4 h a week and should be usable for other purposes.

Environmental design generally, particularly of the interior, is of even more importance in this department than elsewhere. Providing a non-institutional appearance, domestic scale and a 'sense of place' should be high priorities. Soft floor coverings may be appropriate for some non-wet areas but the need for cleaning after 'accidents' has resulted in a preference for a hard but non-institutional surface, hardwood floors are particularly successful; divan beds and careful choice of soft furnishings are crucial in creating a suitable atmosphere. Sound attenuation is needed for all rooms used for confidential interviewing; noisy areas (e.g. music room, workshop) should be located to reduce nuisance.

4.12 The Hi-tech specialties

A number of Hi-tech specialties are being introduced, some more quickly than others. These are dependent on specialist design and not within the scope of this chapter.

Robotically Assisted Surgery, almost exclusively using the 'Da Vinci Surgical System' – however, the costs associated with this technique are immense and it is not anticipated to be in general use for more than a very limited number of specialties.

Imaging, particularly interventional radiology, open MRI, which is less claustrophobic for the patient, and the co-location of MRI and Cardiac Catheterisation are developing activities which will see an increase in the shorter term.

Some subjects, such as 'Barn' theatres where a number of operating tables, with ultra clean hoods are located in the same room, have had a small impact on service delivery. Space savings are achievable though not considerable and the opportunity for surgeons to work across more than one table without leaving a sterile area have advantages.

5 SUPPORT SERVICES – OUTSOURCING

The following services are either now outsourced facilities (i.e. provided externally by third parties) or require little direct architectural input.

- Sterile services/decontamination
- Pathology – hot, cold, automation
- Catering
- Linen service
- Supplies and disposal/clinical waste management
- Health Records (policy debates regarding the retention of paper records or transferal to a digital database are ongoing)

6 PUBLICATIONS AND GUIDANCE

The Department of Health and previously NHS Estates have over years produced much valuable reference and guidance material. However, the very extensive scope of this material, the changing methods of service delivery and technological advances has meant that keeping the publications up to date is a task that has not been universally successful. Two key components of the guidance, Health Building Notes (HBNs) and Health Technical Memoranda (HTMs) are fundamental, however, both are currently subject to a major review being carried out in 2006–2008.

Both HTMs and HBNs have been contained within briefs for new hospitals either as mandatory or advisory documents. Such usage is unfortunate as although parts of the documents can reasonably be considered as mandatory, those related to infection control for example, it is rare for a whole document to be relevant. This has lead to a demand for derogations and a loss of the spirit of most of the material which is intended to be for guidance and modification to suit particular circumstances.

It is, however, essential to have access to these documents in order to engage in informed dialogue during the design process. The documents are available online to the NHS only via the Department of Health Knowledge and Information Portal (KIP) but only available outside the NHS via third party construction industry information suppliers.

It is essential to discuss the relevance and status of the guidance with the Department of Health at the time of design.

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26 Payment and counselling offices

Derek Montefiore

CI/Sfb: 315, 336, 338
UDC: 725.12, 725.24

Derek Montefiore is a director of Montefiore Chartered Architect

KEY POINT:

- *These are all facilities where security is a major consideration*

Contents

1 INTRODUCTION

1.01

This chapter includes retail premises which do not involve the selling of actual goods to the public. They are generally characterised by the need for greater security for staff and premises than shops selling goods; either because of the attraction to the criminal of the money, etc. held in quantity, or (as in the case of Jobcentre Plus offices) because the customers may be sufficiently distressed to attack the staff.

1.02

In this general category are included:

- Banks
- Building societies
- Post offices
- Governmental and local governmental public access offices

The common factor between all these facilities is, as described above, the particular need for security for both staff and public. The methods of achieving such security vary both from time to time, and also between different organisations – even within the same sector.

1.03

While the need for additional security has affected all these facilities, so has a new attitude to the customer. It has now been accepted that he or she is not an interruption to the work of the organisation, but its very *raison d'être*. A more welcoming aspect is the common factor of current designs, with soft furnishings and floor coverings taking the place of intimidating and fortress-like interior designs.

Another change is the opening-up of the interiors to the street by large shop windows. This both aids security and contributes to the welcoming-in aspect. Supplementary customer facilities such as lavatories, catering and even TV are provided where waiting times are significant – mainly in government and local government offices. Smoking, of course, is now prohibited in offices such as these.

1.04 Banks

The great change in the last ten years has been the universal adoption of the ATM, or automatic teller machine, commonly known as a cash dispenser (or colloquially as 'hole-in-the-wall'). This has reduced the need for counter service and has led to a shrinkage in both the number and size of bank branches. Further reductions may follow from similar automatic paying-in facilities such are already provided by some building societies.

Bank sizes fall into three categories of key branches, middle-range branches and sub-branches. Obviously staffing levels and customer requirements vary between these types. It should be noted that each bank company has a different opinion on priorities and layouts, and has its own laid-down design policy and manual. Consequently, the diagrams are indicative only.

1.05 Building societies

Building societies are becoming more like banks: some are even abandoning mutual status. Their operation has also been streamlined by the provision of ATMs, and they also often have automatic facilities for paying in funds.

1.06 Post offices

Post offices differ from the other types of facility in this section by not having to provide any counselling facilities. However, they do need to be able to handle quite bulky parcels (often in both directions), and a special position is provided for passing these through the security screen. The Post Office is continually reassessing customer/staff relationships and is attempting to break down physical barriers by opening up serving positions and introducing more retail business.

Main post offices are usually sited in city and town centres as a normal retail outlet, and there are occasional sub-post offices in residential areas incorporated into shops. Some new main post offices are franchised inside supermarkets, stationery shops, etc. These are larger and more comprehensive than existing sub-post offices.

A rule of thumb to access the allocation of space within a main post office is 40 per cent customer area, 40 per cent staff area and 20 per cent welfare. Where a post shop is included, 45 m^2 additional space is provided to the customer area. The sizes of offices vary in each location and an operational assessment is required to calculate the number of serving positions. Once this has been done a factor of 26 m^2 is used per serving position. To this is added the additional space for the post shop if this is required.

1.07 Public offices

The principal types of governmental and local government public access offices are:

- Council housing offices
- Council rate and rent payment
- Department for Work and Pensions (DWP) and Jobcentre Plus (the successor of Benefits Agency) offices
- Law Centres
- Community Health Council (CHC) offices.

Rent and tax payment offices are very similar to banks and building societies in their requirements. Housing offices, Law Centres and CHC offices are similar in that they are concerned principally with counselling small numbers of people. DWP and Jobcentre Plus offices have to provide counselling for larger numbers and require somewhat different treatment.

1.08 CHC (and similar) offices

The main function of a CHC office is to give guidance and assistance to those members of the community who are finding it difficult or frustrating to comprehend or understand their National Health Service rights. Similar functions are provided in housing offices and Law Centres.

CHC offices are situated in town centres or shopping precincts, where access is easy.

The problem may result from language difficulties, frustration in being unable to comprehend a form to be filled in, or queries on access to or experiences of local health services. No money passes hands, but the staff do have to deal occasionally with very distressed individuals. In this respect a pleasing environmental atmosphere is important, and the security of the counsellors must be considered. Mothers and children are welcomed so that it is ideal to have a corner for toys and nappy-changing area in the toilet facilities, though it is emphasised that a crêche is not necessary.

1.09 Department for Work and Pensions and Jobcentre Plus Offices

Branch Jobcentre Plus Offices have been reappraising their image; future designs are expected to be as user friendly as possible. More so than most other organisations, they have to deal on occasions with customers who become violent. Staff safety and security are paramount, so that screens are an unfortunate but necessary part of reception areas.

Both customer and staff areas are close carpeted; easily replaceable carpet tiles are used in customer areas. Customer surveys have identified that they give a high priority to personal privacy. This is reflected in the design of reception points and interview rooms.

Jobcentre Plus offices are situated in town centres or where lines of transport converge such as at bus or railway stations.

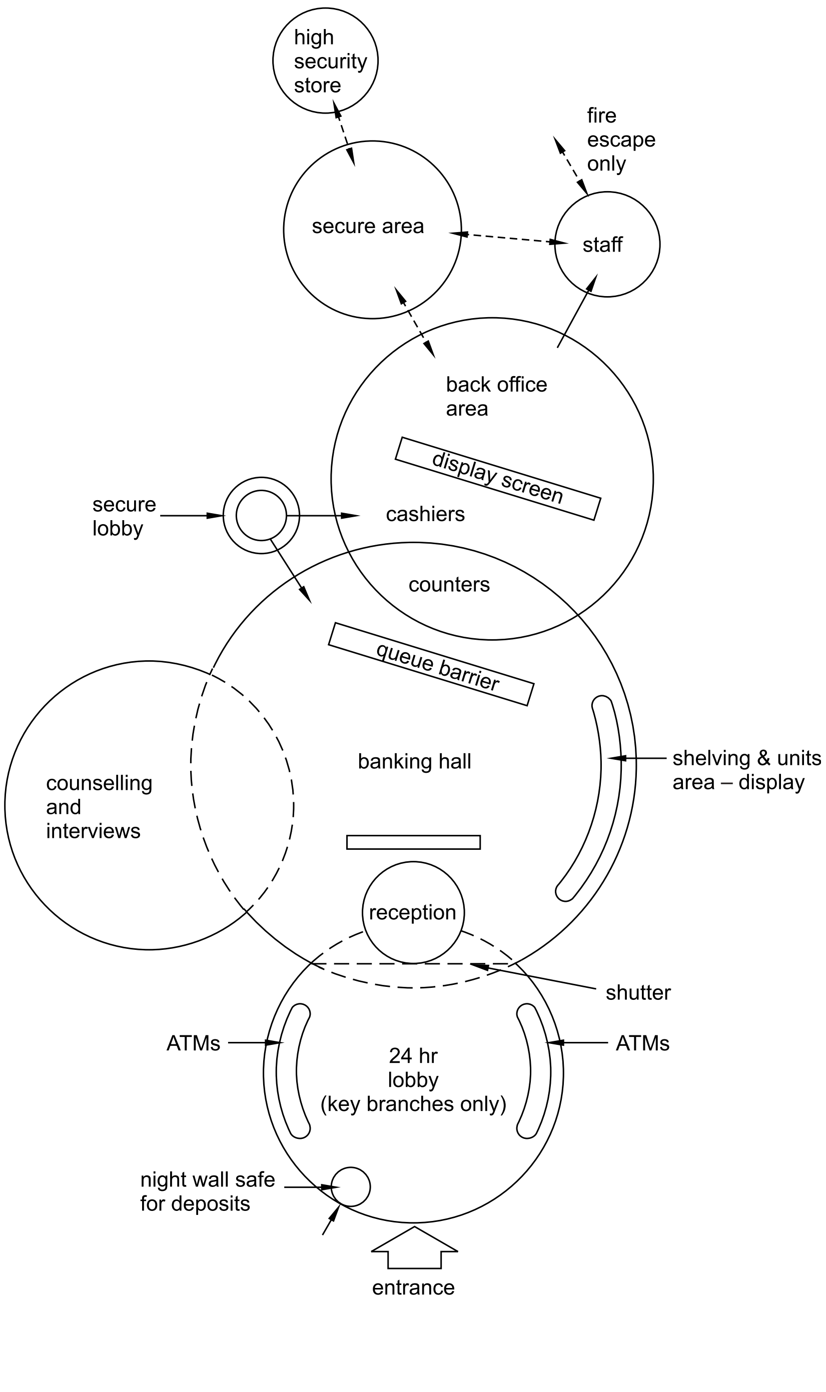
2 GENERAL AREAS

2.01 Banks

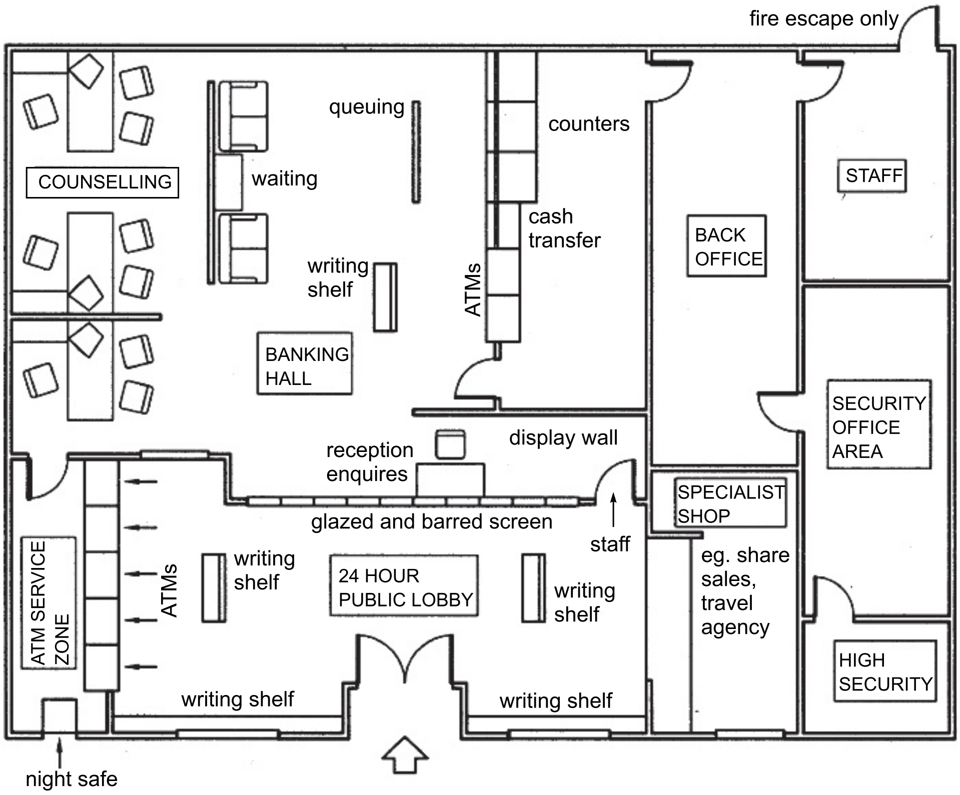
The general arrangement for banks is shown in **26.1**. The main area is the banking hall. This is an open space divided by a security screen into customer and staff areas.

There are two basically different arrangements used by banks:

- Open counters and/or desks within the customer area where no money is handled, plus a small number of cashiers' points behind the security screens



26.1 *Relationship and zoning diagram for a bank*



26.2 *Middle-range bank branch*

- All positions behind security screens, with flexibility as to whether they are used for handling money or for giving advice, etc.

Some banks install staffed reception/enquiry facilities in prominent positions adjacent to the entrance, or even outside within the 24-hour public lobby (see Section 3). In the customer area, there must be sufficient space for queueing, and positions for writing. As part of their more customer-related policies, bank managers and staff now come out from behind the security screen to meet and talk to them, and perhaps spend a considerable time helping them solve problems. The counselling areas and interview rooms should open directly off the banking hall and be closely connected to them.

The back-office area is often part of the banking hall, but is generally (but not always) screened from the customers. With the advent of computers there is less need for this space, which is becoming minimal.

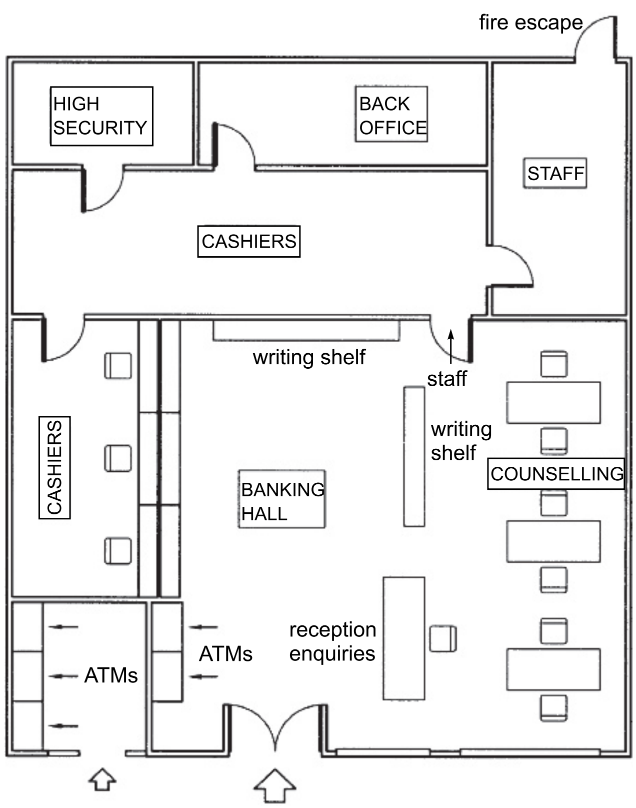
Despite the growth of transactions on paper and 'plastic', the banks and other payment offices still have to deal with fairly large sums of money. To cope with these there must be a secure back-office area for staff and a high-security area (strong room or safes) off the back-office area where deliveries are made and cash is stored. The banks, for obvious reasons, are reticent about the details here, both of the planning and also of the arrangements, ensuring only authorised staff can gain access to the various areas. Architects are often asked to provide space only, the fitting-out being done by bank staff themselves after the main contract handover.

Staff facilities such as rest-rooms, toilets, etc. are also provided behind the back office. A fire escape from the area behind the security screen is essential, but this introduces a security risk. It is not usual to provide any entrance to bank premises other than through the front door. There is no reason why the security and staff areas could not be on different levels to the banking hall.

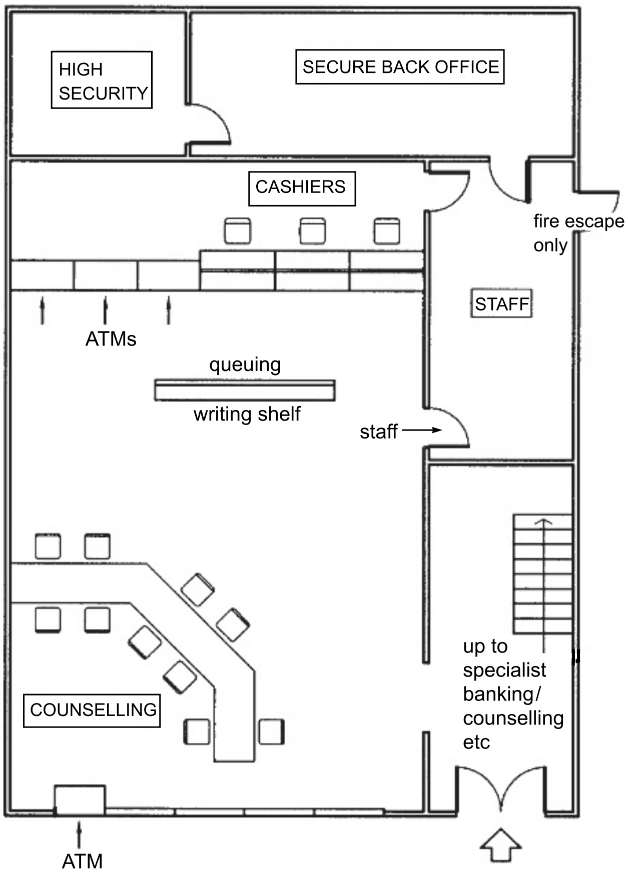
Plans of some actual banks (which cannot, of course, be identified) are given in **26.2**, **26.3** and **26.4**.

2.02 Building societies

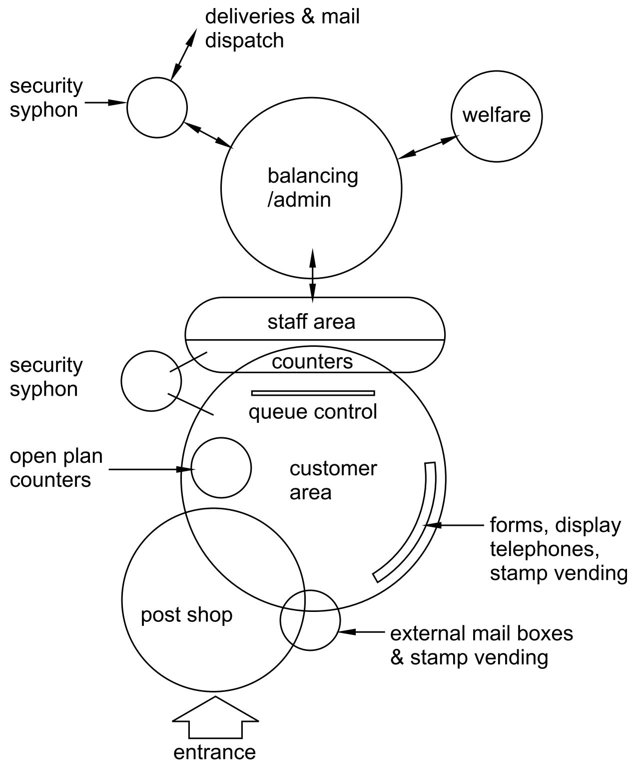
The arrangement of building society offices is generally the same as for banks, although the smaller offices dispense with some of the areas. **26.5** is a plan of a building society office.



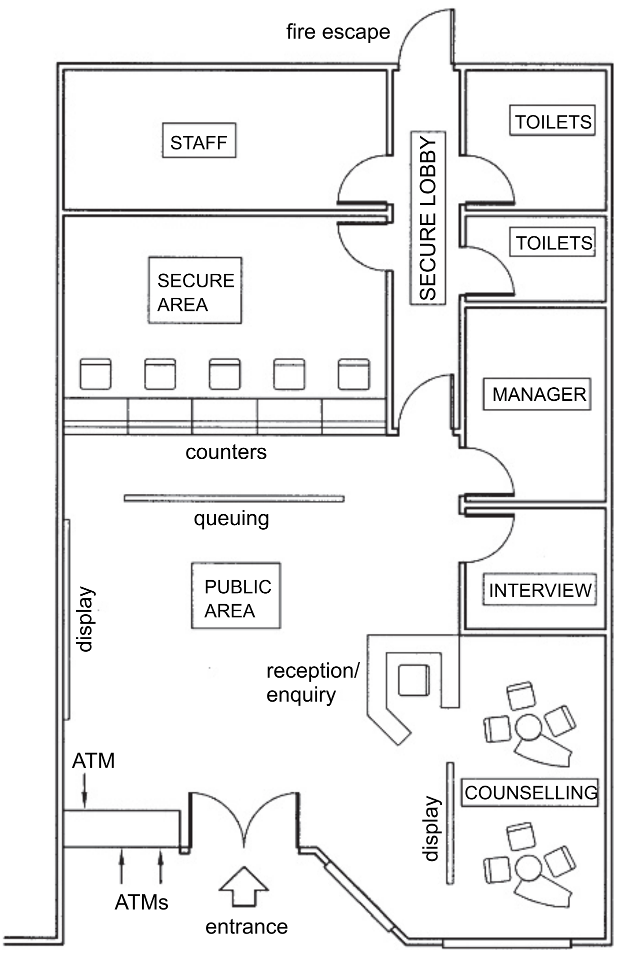
26.3 *Bank*



26.4 *Bank*



26.6 *Relationship and zoning diagram for a post office*



26.5 *Building society*

2.03 Post offices

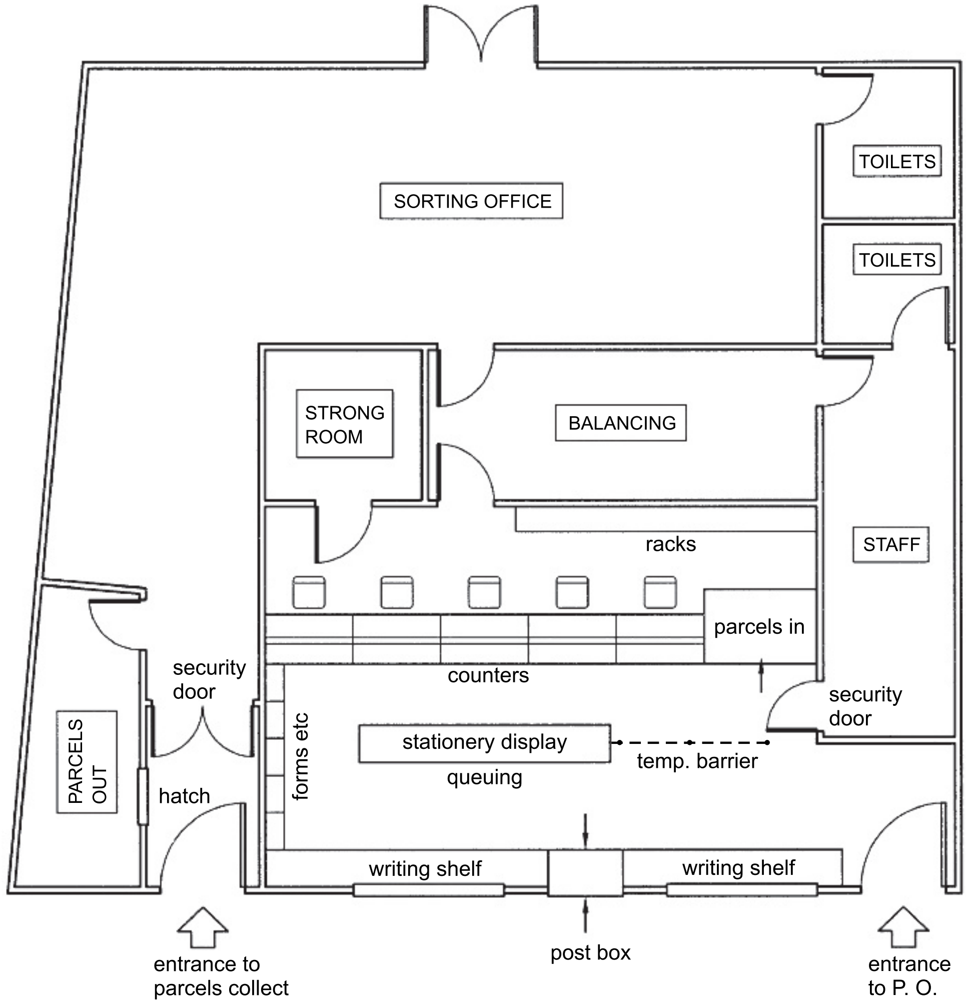
The arrangement of a typical main post office is shown in **26.6**. The balancing area was where the counter staff periodically checked their book keeping and balance their day's takings. With the advent of universal computing systems much of this is no longer necessary. However, a small area screened from public view is usually provided. There are also safes or strong rooms as necessary – dependent on the size of the post office.

The syphon zones are secure areas and cannot be entered except by authorised personnel. The counter service consists of secure transactions such as cash for pensions, social security, etc. and non-secure transactions such as stamps, bill paying, vehicle licences and passports. Behind the counters there are racks for forms and each counter position has its own lockable facilities. **26.7** is a plan of a medium-size main post office.

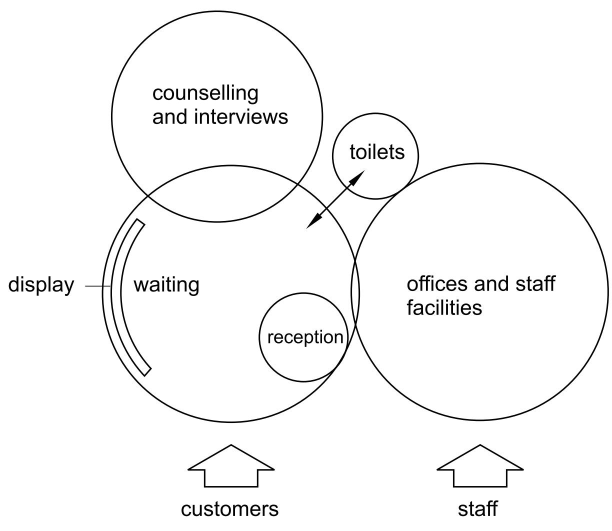
There are proposals in hand which will radically change the way Post Office Counters operate, and therefore the design of their offices. Within the open customer area an operator will accept the customer's form and code it into a teller cash dispenser (TCD) similar to an ATM, which will supply the customer. This will reduce the number of fortress positions necessary, offer more flexibility to the layout and provide quicker and pleasanter service. Similarly, other transactions will be dealt with by automated dispensers, saving both queueing and staff time and numbers.

2.04 Community health council offices

26.8 is a zoning plan for a CHC office, and an actual office is shown in **26.9**. Near the entrance is an enquiry desk which also doubles for reception interviews or individual counselling. Adjacent to this is a reception/waiting area with display walls and brochure racks. There is also a private zone where further counselling takes place around a low table. The office accommodation can be adjacent or on another floor and is generally about the same area as the entrance waiting and consulting areas. This office area also deals with telephone enquiries.



26.7 *A post office associated with a sorting office and a parcel-collect facility*



26.8 *Relationship and zoning diagram for a Community Health Council office*

2.05 Jobcentre Plus offices

26.10 is the zoning plan for a Jobcentre Plus office, while **26.11** illustrates one of these. The reception is the first port of call where customers are advised on whether they can be dealt with at a counter or make an appointment for interviewing. The counters deal with general queries, clerical matters and queries on form filling.

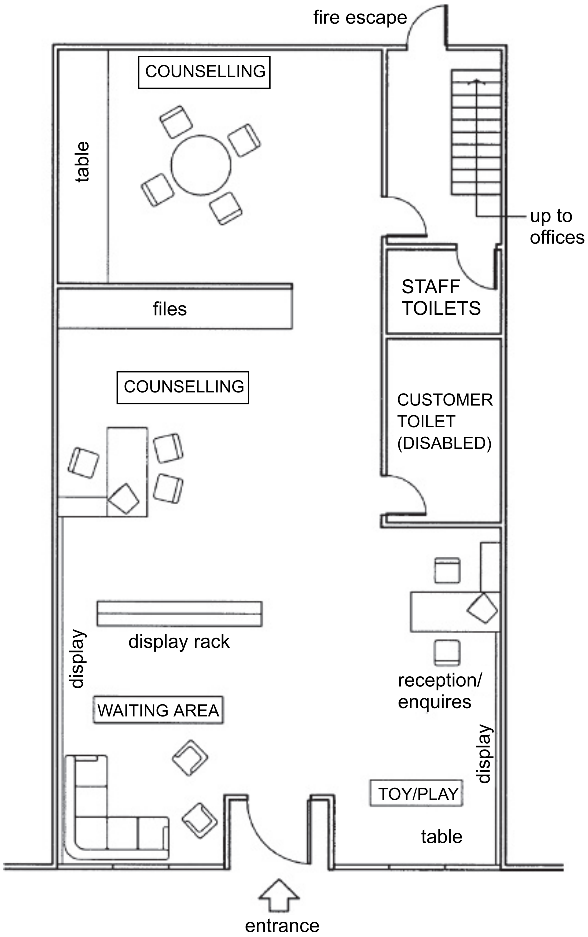
Customers requiring counter service stay in the waiting area until there is a position free. Queue control is by ticket, and waiting times can be considerable if the office is particularly busy. Toilet and baby-changing facilities for the customers are therefore essential.

A psychological approach has to be considered within the design to cope with extended waiting periods. It is helpful if seats are arranged to avoid eye contact and thus the likelihood of raising tension. They should also be spaced to avoid a rear seat occupier using the seat in front as a footrest. It has also been found that television helps to pass time and reduces tension. Smoking and intoxicant drinking are forbidden on the premises, and this has a market effect on maintaining a cleaner and more pleasant atmosphere and ambience. Offices are generally equipped with machines vending soft drinks and snacks. A guard is provided with a position from which all the customer areas of the office are directly visible, or can be monitored by closed-circuit television.

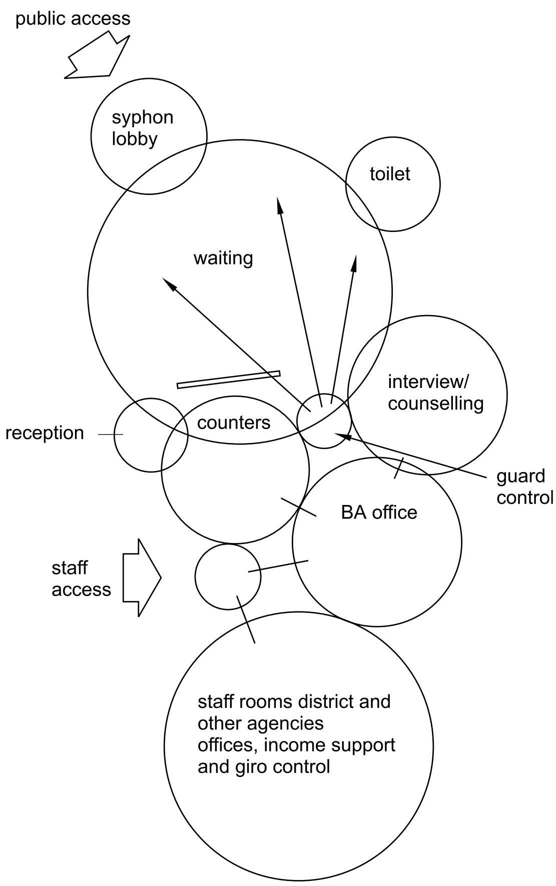
More detailed interviews are dealt with in sessions on an appointment basis. There are four different organisations who all use the counters or interview rooms, although they may also visit customers' homes:

- Benefit advisers
- Contributions Agency (part of HM Revenue & Customs)
- Child Support Agency
- Fraud investigators

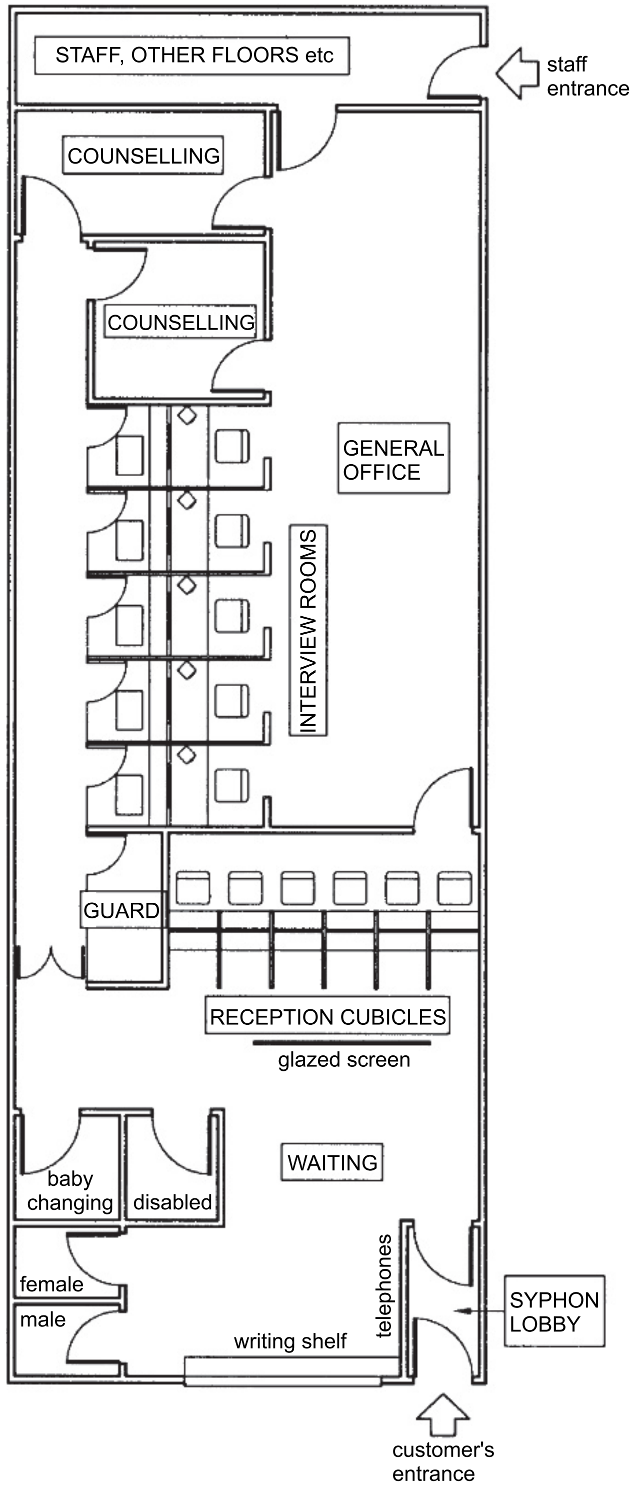
Depending on the depth of the interview taking place on the premises, a counter or a separate interview room will be used.



26.9 *Community Health Council counselling office*



26.10 *Relationship and zoning diagram for a Jobcentre Plus office*



26.11 *A Jobcentre Plus office*

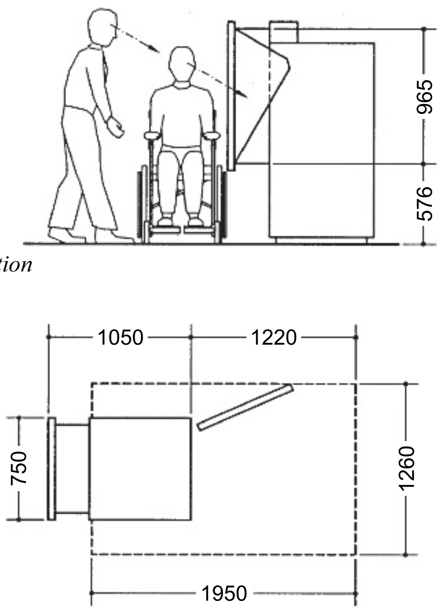
3 AUTOMATIC TELLER MACHINES (ATMs) AND 24 HOUR LOBBIES

3.01

26.12 shows a current design of ATM. ATMs are usually installed within the street frontage of the payment office, accessed by the public from the highway. This sometimes leads to obstruction by queues, and it is perhaps a matter of time before additional planning rules will be imposed.

3.02

However, it is becoming more common with banks for lobbies to be provided within the building, but generally accessible 24 hours a day. Sometimes these lobbies are fully open to the street, in other



a *Section*

b *Plan*

26.12 *An ATM cash dispenser designed to be easy to use from a wheelchair*

cases access is obtained using a bank card, though this in itself can involve other problems: such as the area being used for student parties – this has yet to be overcome!

3.03
Only a few of the larger building society branches are using lobbies at present, but as they become more like banks it is certain that more will do so.

3.04
In the daytime the public lobby area is opened up to the banking or building society hall, with perhaps a reception and enquiry desk. Quick enquiries can be dealt with here, and behind the desk and in a position of major visibility will be an information screen giving latest marketing suggestions.

3.05
In 24-hour lobbies a number of machines both for drawing cash and for paying-in are usually provided. Continuous video surveillance and recording facilities are provided. Customers' access to bank night safes must be off the street – and not from within any 24-hour public lobby. ATMs have to be arranged so that the information projected can only be seen by the user, this is both a prudent security precaution and also a Data Protection Act requirement.

3.06
Banks which operate a 24-hour lobby normally use a glass screen between it and the banking hall. This permits vision into it, and folds completely away during normal banking hours. Access for staff and bullion and cash delivery to banks is always via the front access. A door is provided in the glass screen for when the bank itself is closed to the public.

3.07
ATMs require frequent filling with cash and also need occasional maintenance. These functions are preferably done from the rear, but for awkward situations (such as in **26.3**) designs serviceable from the front are available. Rear servicing can be from a service corridor as in **26.2**, or from one of the main bank or building society areas as in **26.4**.

3.04
As both banks and building societies seek to decrease their overhead costs by reducing staff and closing branches, it is likely that 24-hour lobbies will be installed in shopping areas with no staffed branches associated with them. The design of such lobbies need not vary significantly from the type in **26.2**.

4 COUNTERS

4.01
The major changes in recent years in the design of counters have been:

- The introduction of security screens
- The universal provision of computer terminals

Unfortunately, the perceived increase in lawnessness has extended the use of security counters even beyond banks and the like. Such facilities are now also provided in railway and bus stations. Significantly, railway ticket office positions are twice as long as those provided in banks, building societies and post offices, although there appears to be little functional reason for this.

4.02 Security screens
Bank counters used to be open and post office counters used to have wire grilles. Neither is now acceptable by staff as giving them sufficient protection. Screens of bulletproof glass are now ubiquitous. Communication is sometimes through protected apertures above or through the screen, often by means of microphone/speaker systems. Documents and cash are passed through trays, carefully designed not to compromise the security arrangements.

An alternative system which is available but appears to be rarely used is the rising shutter. This is a solid steel shutter contained within the counter. It is operated by a compressed-air mechanism, which when activated by a panic button, causes the shutter to shoot vertically upwards instantaneously.

4.03
Where there is little fear of firearms, but the possibility still exists of physical assault (such as in council housing offices), counters can be designed to be higher and deeper than normal, making it difficult for the enquirer to reach the staff. Staff can either stand or sit on low platforms behind the counter.

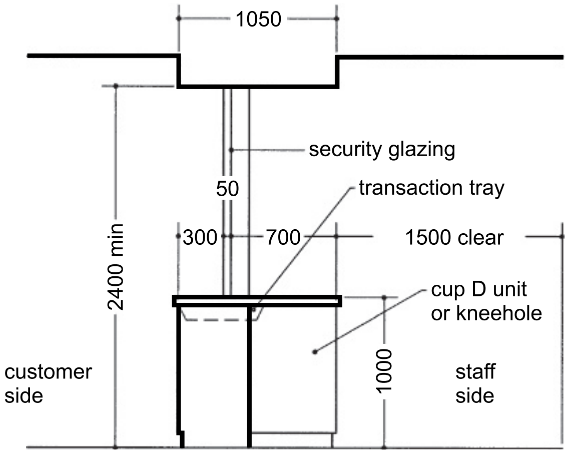
4.04
Counter positions for bank, building society and post office staff require much the same facilities:

- Cash storage tray
- Computer terminal
- Storage for forms, stamps, postal orders, cheques, etc.
- Personal storage (minimal)

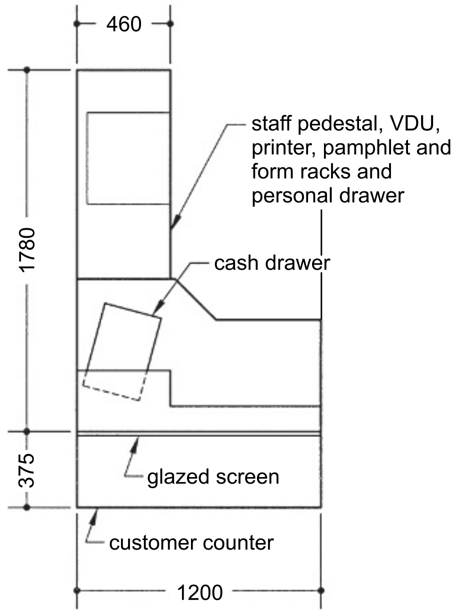
In building societies where pass-books are used and cheques are issued for customers' use, space is also needed at the counter position for a printer linked to the computer. In banks printers are usually placed in the back area, and in some cases cashiers are not even provided with personal terminals.

4.05
Counter designs are of two basic types:

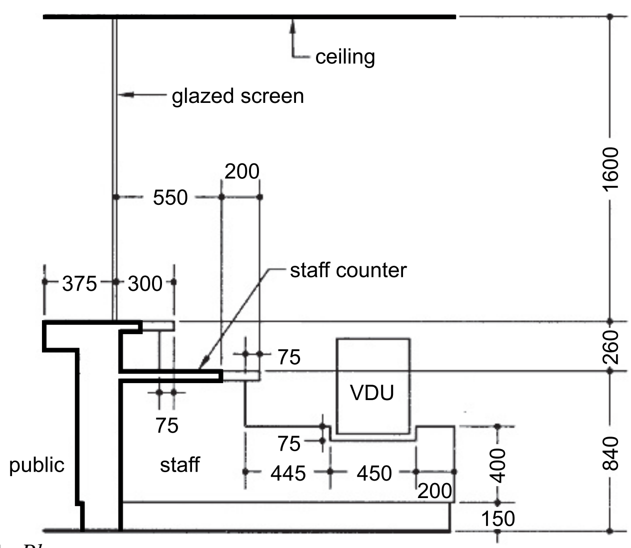
- Continuous counter, **26.13**. This is used where no computer terminal is required such as in some banks, or where the terminal requires minimal space, such as in a post office.
- L-shaped work position, **26.14**, providing additional space for terminal and printer. This design is appropriate for building societies.



26.13 *Section through a counter of continuous type. Allow a length of 1400 mm per staff member*

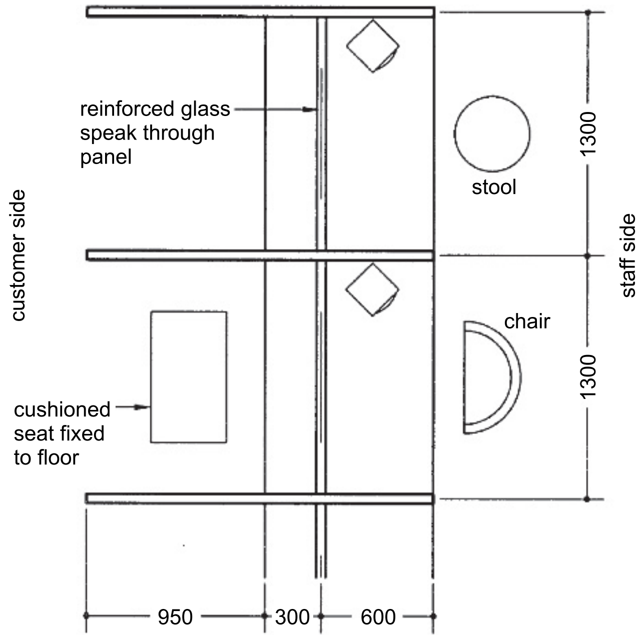


a *Section*

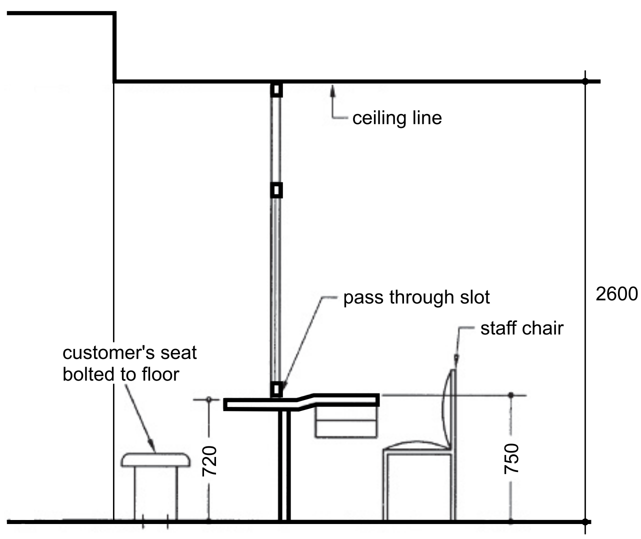


b *Plan*

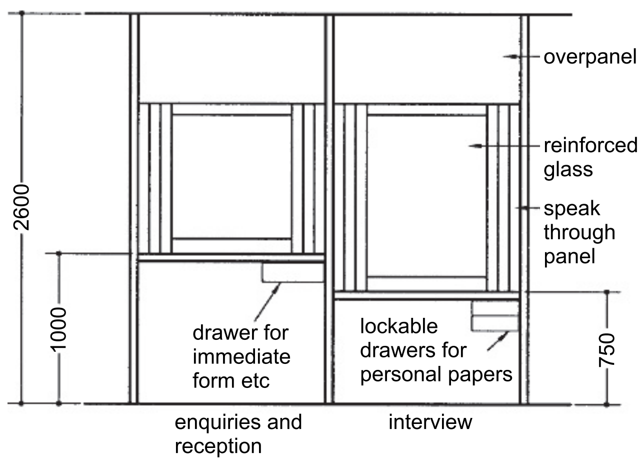
26.14 *An L-shaped desk and counter*



a *Plan*



b *Section*



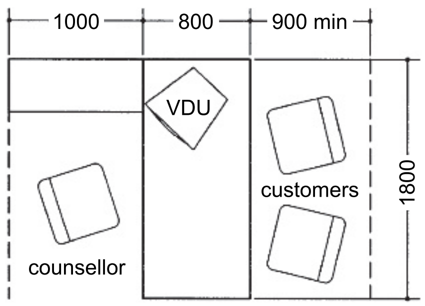
c *Elevation from the staff side*

26.15 *A counter in a Jobcentre Plus office*

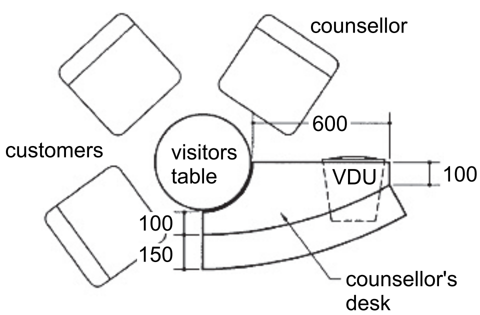
4.06
The two types of counter used in Jobcentre Plus offices are shown in **26.15**. The reception desks are for short-term enquiries and are, therefore, at standing height. General counters are at sitting height and the customers' bench is large enough to sit two people. All furniture is robust which allows for considerable wear and tear; all seats are fixed to the floor and all covers are removable for cleaning or replacing if damaged.

5 COUNSELLING

5.01
All these facilities except for post offices need provision for counselling. Banks and building societies advising their customers on their investments or loans are tending away from the 'two sides of a desk' system as in **26.16** (although in some circumstances this is still appropriate) and try to foster a more congenial atmosphere. The pod in **26.17** is one example.



26.16 *At-desk counselling*



26.17 *Counselling pod*

In CHC offices counselling is often carried out in even more homely surroundings, sitting around low tables in easy chairs.

In Jobcentre Plus offices when the interview rooms with security screens are not used, interviewers still prefer to sit behind a desk rather than use a more informal method.

All these areas have to be private, so that no conversation can be overheard. Equally they should not be oppressive or secretive. Acoustic confidentiality is achieved by glazed screens, or by distance. However, some bank customers may not wish to be observed talking to their manager, so at least one of the counselling rooms should not have clear glass between it and the banking hall.

6 PROVISION FOR PEOPLE WITH DISABILITIES

6.01
Operatoirs of this kind of facility are now very aware of the problems experienced by people with disabilities. It is now unusual for payment or counselling offices to be situated above ground-floor level, and level access to the counters and ATMs for people in wheelchairs is all but universal. ATMs and counters are at a height suitable for people in wheelchairs – so they are often uncomfortable for ambulant tall people to use!

6.02
However, ATMs are not at present suitable for people with severe visual impairment, and they need to use the services of a cashier. People with both hearing and seeing deprivation are not, unfortunately, at present well catered for in most payment offices. Sanitary facilities for the public are not provided in payment offices; they generally are in counselling offices where waiting times can be considerable. Where sanitary facilities are provided, disabled toilets and baby-changing facilties need to be included (the latter accessible to both men and women).

6.03
When planning banks or building society offices on more than one level, it should not be forgotten that there may be disabled people on the staff. All areas, including the high-security zone, should be accessible to wheelchairs.

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27 Public buildings

CI/SfB: 314, 317, 372, 373, 374
UDC: 725.13, 725.15, 725.191, 614.88, 725.188

KEY POINTS:

- *Many of these functions are tightly controlled by regulation*
- *Flexibility is needed to accommodate likely future change*
- *Value-for-money is a major design criterion*
- *The need for security against attacks from people both inside and outside while ensuring full access to those entitled makes design increasingly difficult.*

Contents

1 TOWN HALLS

1.01

Town halls have a variety of functions to fulfil, and many of their parts are covered in other chapters of this handbook. The principal constituents of a town hall are:

- A council chamber, with associated lobbies
- A civic suite, or mayor's parlour
- A number of committee rooms
- An assembly hall
- Offices (see Chapter 12)
- A public reception and information desk
- A cash reception and disbursal facility (see Chapter 26)

1.02 Elected members' accommodation

The core of any town hall, county hall or city hall is the accommodation for those elected by the public. Apart from the council chamber itself, space is needed for the Mayor, the party leaders and for informal gatherings of the members. In addition, delegations of the public and visiting dignitaries of all kinds have to be received in suitable surroundings, **27.1**. **27.2** is by no means an over-elaborate arrangement; what cannot be seen from the drawing is the magnificence of the finishes!

1.02 Council chamber

Few local government bodies emulate the House of Commons in their council chambers. Their forms are mostly segmental or horseshoe, **27.3**, and the seating provides at least some accommodation for documentation, **27.4**. They are sized to seat every Councillor plus a number of Council officers, and incorporate speech-reinforcement systems. Some chambers are tiered to aid visibility, and have imposing seating for the Mayor, but others are flat-floored with moveable equipment – rather more like a large boardroom. Some provision for the general public is essential, preferably well separated as in a gallery.

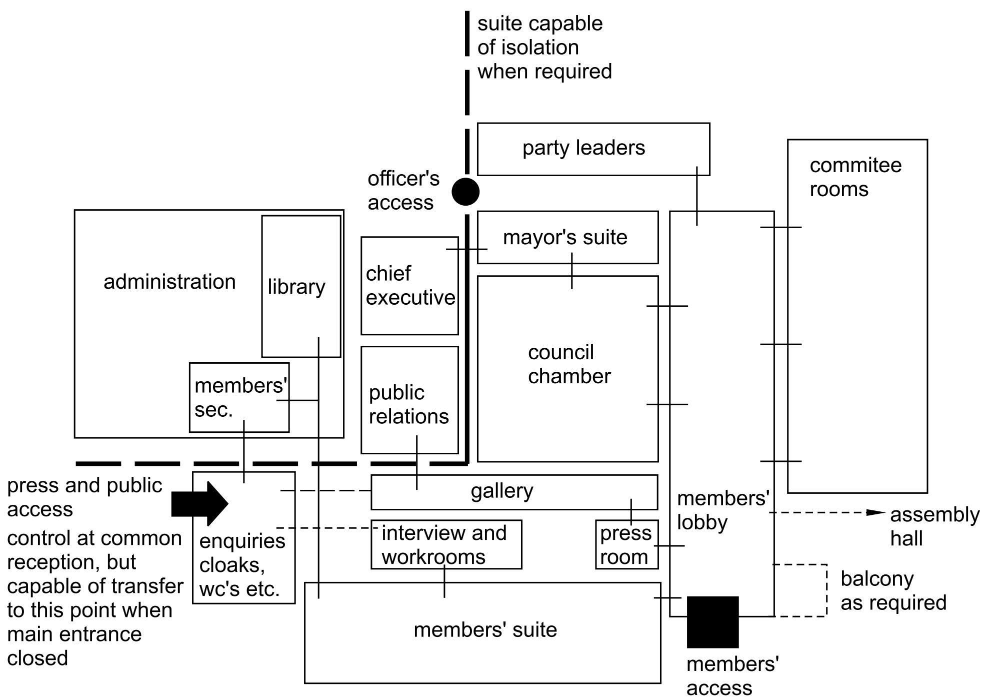
It is usual to have one or more lobbies immediately outside the chamber for informal discussions. Voting is usually by a show of hands, or using voting machines; not by trooping through lobbies.

1.03 Civic suite

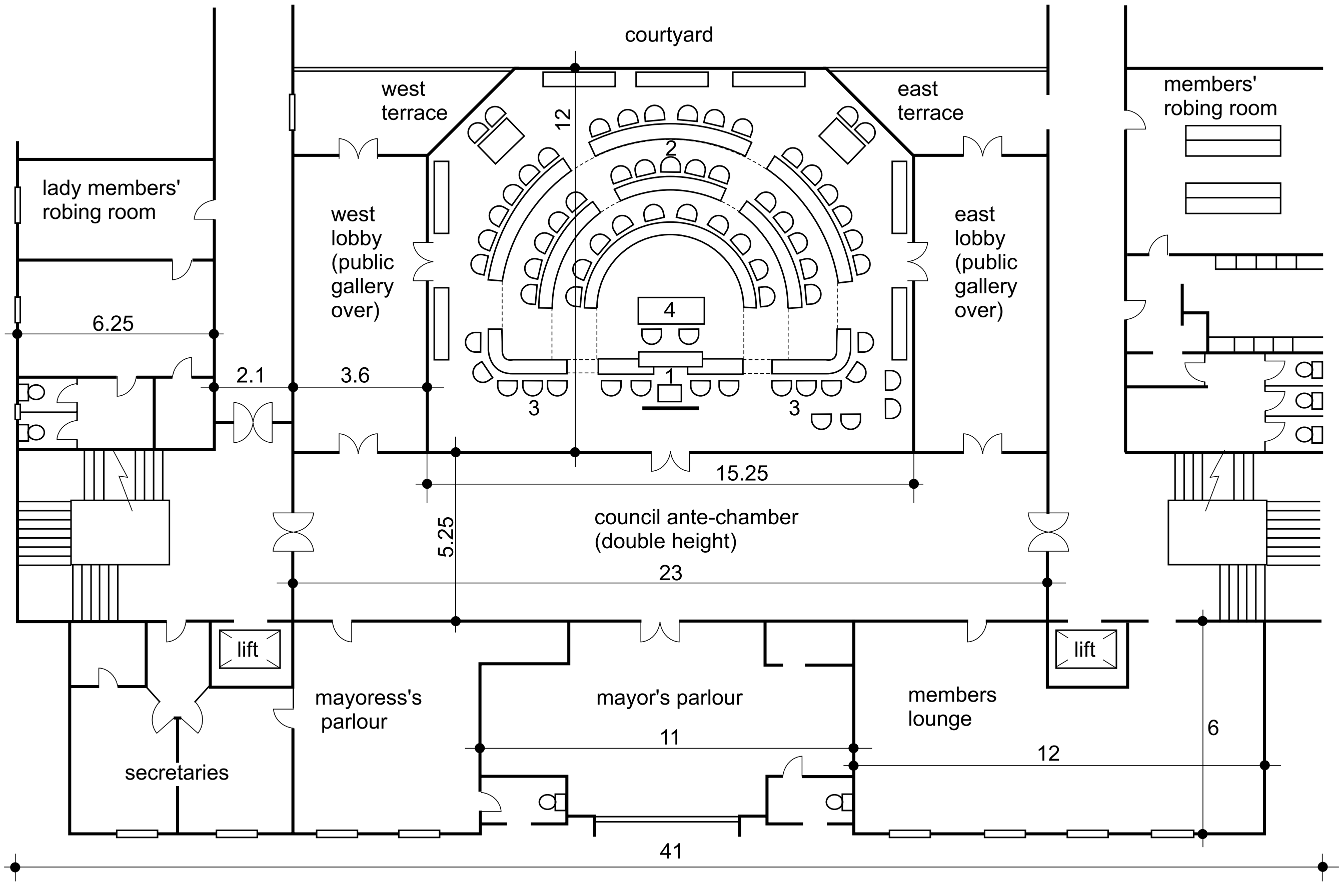
Some provision for entertaining important guests is essential, and this is often combined with the Mayor's office. This needs easy access to some form of catering facility.

1.04 Committee rooms

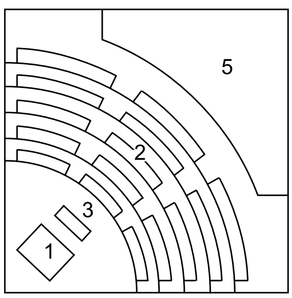
Local government business is conducted principally through numerous committees and sub-committees. Meeting rooms of various sizes are required; these (including the council chamber) are often available for letting by outside organisations, producing useful additional revenue for the Council. For this reason, if for no other, they should be well designed and fitted out.



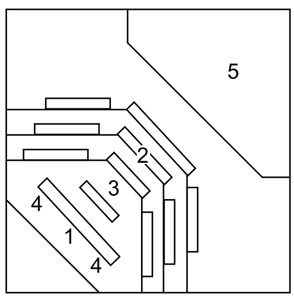
27.1 *Relationship diagram for the elected members' accommodation in town halls*



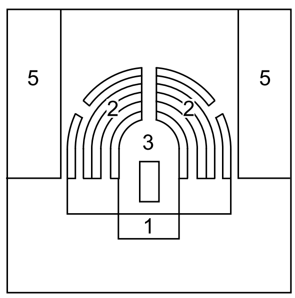
27.2 *Hammersmith Town Hall: Council Chamber suite*



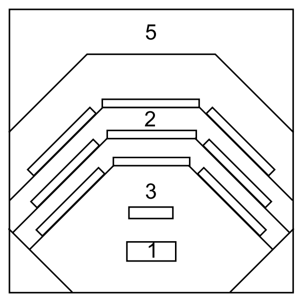
a *Approximately 300 seats in a five-tiered quadrant*



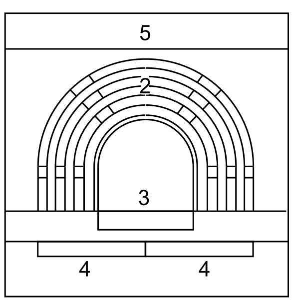
b *Approximately 60 seats in a three-tiered quadrant*



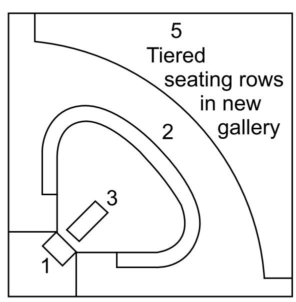
c *Approximately 30 seats in a two-tiered horseshoe*



d *Approximately 100 seats in a three-tiered segment*

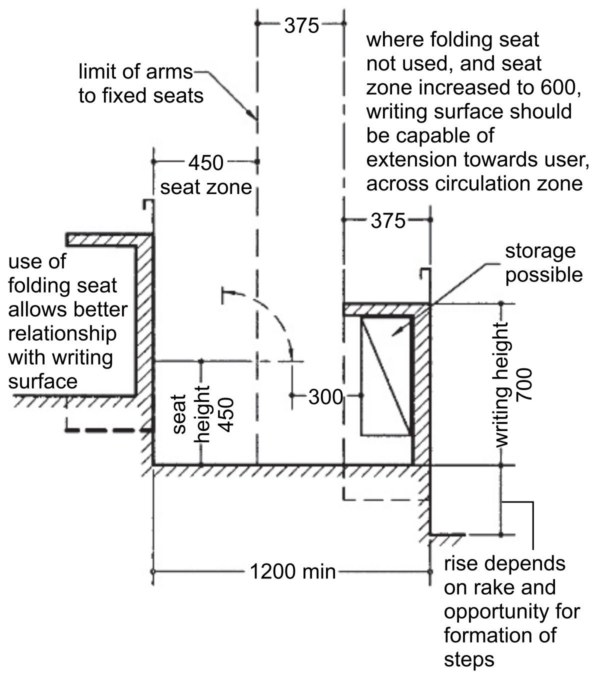


e *Approximately 60 seats in a three-tiered horseshoe*

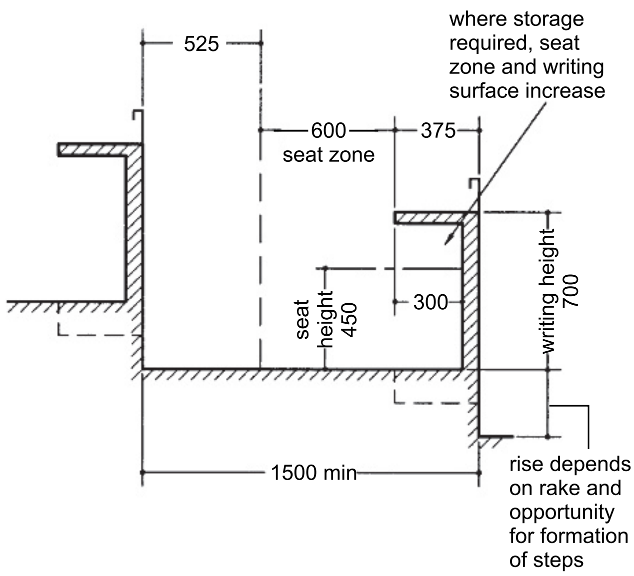


f *Approximately 30 seats on a level*

27.3 *Council chamber, various layout types:*
(1 = mayor, 2 = ordinary members, 3 = officers, 4 = committee clerks, 5 = press and public)



a *Section through fixed seating at 600 to 750 mm centres. Number of seats in a row limited to avoid disturbance*



b *Section through moveable seating at 750 to 900 mm centres*

27.4 *Council chamber seating*

1.05 Assembly Hall

While not essential, this is a most valuable asset to a Town Hall; it brings in further income and also familiarises the public with the building and its occupants. It may be used for dances, exhibitions, concerts and recitals; and should have some associated accommodation for artistes, etc.

1.06 Offices

The major need is for office space for the Council's staff. They may be centralised in one building, or dispersed over many, some leased from the private sector. The principal requirement is for flexibility as, like most organisations, change is the only constant.

1.07 Public reception and information

The current philosophy is for a 'one-stop shop'. Particularly where the Council's staff are centralised, the idea is that advice on all matters (planning, building control, council tax, education, social services, leisure) should be available from one counter. Where a matter is more complex than the receptionist can deal with, other staff members come to the enquirer instead of the reverse. A few small interview rooms are available for such consultations adjacent to the counter.

Literature relating to the facilities of the area should be displayed in the reception area; some but not all of this will free. It could be set out rather like a small bookshop.

1.08 Cash facility

Some Council business is still transacted with cash, and a secure facility will be found necessary. Ideally this should be adjacent to the public reception and information to continue the 'one-stop shop' theme.

2 LAW COURTS

2.01

The judicial system of England and Wales is in direct line of descent from that established by William I nearly a thousand years ago, subsequently modified by Magna Carta and many other reforms. Courthouses, therefore, are the visible manifestation of one of the most fundamental set of principles upon which our society is based.

How this is to be expressed in architectural terms is the particular challenge facing the designer of a courthouse. He or she will have to consider the contextual and environmental constraints that apply to any urban structure, especially those on prominent sites in town centres. Planning problems posed by the specific requirements for a courthouse must also be addressed, such as the four segregated circulation routes (for judge, jury, defendant in custody and public), the servicing of the many and varied spaces within a complex layout and the need for flexibility to accommodate future developments in information technology. Athough courtrooms built 200 years ago are still able to cope, the law is constantly evolving and both the courtrooms and the ancillaries need to be receptive to inevitable change.

2.02 Court System

The Court Service (formerly the Lord Chancellor's Department) has existed in various forms for over 900 years. It took on its present shape as a major government department with wide responsibilities for the administration of justice in England and Wales in 1972. Following the Courts Act 1971 it was given the task of running a new system covering all courts above the level of Magistrates' Courts. It is directly responsible for

- The Court of Appeal
- The Royal Courts of Justice
- The High Court
- The Crown Court
- The County Court.

The Crown Court is a national court which sits at different centres. Practically all its work is concerned with cases committed for trial or sentence from the Magistrates' Courts, or appeals against their decisions. Cases for trial are heard before a judge and jury. Centres are classified as first, second or third tier according to the nature and complexity of the court business.

2.03 The Courtroom

The Crown Court sits in a courtroom, the design of which will always be subject to the continuous adjustments dictated by changes in attitudes to child witnesses, the need to protect witnesses and jurors from possible intimidation and developments in technology.

The courtroom is the primary workspace and focal point in a courthouse, which is developed around it. It is the only place where all parties in a case are likely to meet. Of paramount importance is the need to segregate judge, jury, defendant and others in the courtroom and within the courthouse. Segregated circulation routes are provided so that the judge, jury and defendants (if in custody) make their way to the courtroom without meeting each other or any other users such as members of the public.

Dedicated entrances are provided for:

- Judge
- Jury
- Defendants in custody
- Public, witnesses and defendants on bail.

Some prosecution witnesses have to be protected from intimidation; a separate secure waiting room for them is often situated with its entrance off the vestibule provided between the public entrance and the courtroom itself. An alternative arrangement has a separate access from the secure waiting area into the courtroom adjacent to the witness box.

The public enter the court behind or to the side of the public seating at the rear of the courtroom; neither public nor witnesses pass areas dedicated to other participants (e.g. jury or defendants in custody) on entering or leaving the courtroom.

2.04 Relationships within the courtroom

Courtroom layout incorporates specific and well-defined relationships between the various participants by means of carefully arranged sight-lines, distances and levels. There are four main elements in Crown Court cases:

- Judge
- Jury
- Witness
- Counsel (barristers and solicitors).

Defendants do not take part except as witnesses. Each element must be closely related, and be able to see and hear each other clearly at all times without mechanical or electrical aids, and without excessive turning from side to side. The basic positioning of the occupants is shown in **27.5**. The theory behind these relationships can be summarised as follows:

- *The judge.* Presides over the courtroom, should be able to observe the whole of it, to see clearly the principal participants as well as the defendant in the dock and, when called, the antecedents and probation officers.
- *The court clerk.* Administers the case and needs to keep a watching eye over the court. He or she often advises the judge and should be able to stand up and speak to the judge without being overheard.
- *The exhibit table*. This is in front of the counsel benches for the display of exhibits put forward for evidence.
- *Counsel.* These are barristers and solicitors who represent the defendant or prosecution. They need to be able to see the jury, judge and witness to whom they address their remarks. The barrister at each end of the front bench should be able to keep every jury member and the witness on the stand within about a 90° angle to obviate too much turning to ensure that the judge, the other main party, shall have at least a part face view. The counsel benches are wide enough to hold the large, and numerous, documents and books that are often in use.
- *The defendant*. The defendant is assumed to be innocent until proved guilty and current practice is to reduce any prison-like appearance of the dock by lowering the barriers enclosing it as much as possible compatible with security. Defendants sit in separate fixed seats and if they are thought to be a security risk a prison officer will sit on a seat immediately behind, or at each side of him. The dock is controlled by a dock officer and situated at the back of the courtroom.
- *The jury.* This comprises twelve members of the public whose duty it is to reach a verdict based on the evidence presented. The jury sit opposite the witness stand and must be able to see the defendant in the dock, as well as the judge and counsel. They must have a writing surface and a place to put documents.
- *The witness.* The witness waits outside the courtroom; and when called gives evidence from the witness stand near to the judge's bench. The stand faces the jury who must be able to observe the his or her face. The witness is questioned by the barristers and occasionally by the judge. If the judge directs that a witness should be retained, he or she can wait seated within the courtroom.
- *The shorthand writer.* This official keeps a transcript of the trial and consequently must be able to see and hear everyone who speaks.
- *Probation and antecedents officers.* These give evidence from their seats after the jury have reached a verdict. This evidence is used to assist the judge in passing sentence.
- *The press.* These are not party to the proceedings, but they should be able to see the participants.
- *The public.* These are in court to see that 'justice is done'. They are placed at the near end of the courtroom and have a general view of the proceedings, but with the minimum possible direct eye contact with the jury to reduce the risk of intimidation. A public gallery over the jurors is the most effective method of eliminating possible intimidation; but access to such a gallery and the increase in height of the courtroom has to be considered. The glass screen between the public and the dock is partially obscured to prevent members of the public from seeing the defendant(s) (and vice versa) while seated.

2.05 The Courtroom Environment

The design of Crown courtrooms should seek perfection for their purpose. It should reflect the quiet dignity of the law rather than its power. A well-detailed, comfortable and quiet courtroom with efficient and simply managed ventilation, lighting and acoustics is the ideal.

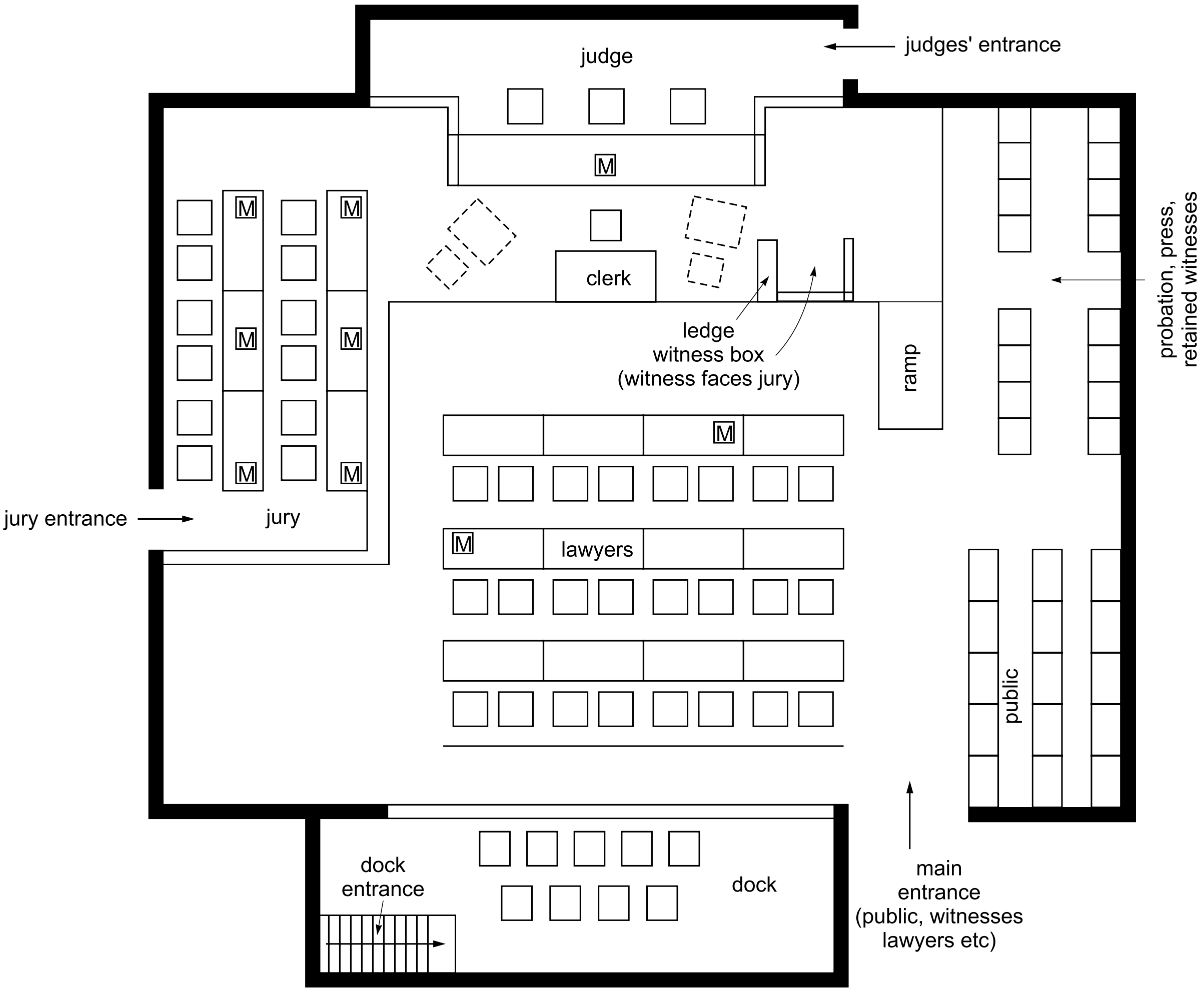
2.06 Ventilation

Well-balanced environmental conditions within the courtroom are essential to the smooth running of the court. They keep the participants comfortable and interested, and avoid distractions. The current trend, supported by most users, is for natural ventilation with openable windows. This will subject the courtroom to wider temperature fluctuations; but this can be minimised by integrated automatic control systems.

Mechanical assistance (or in extreme cases full air conditioning) will be necessary where there would be unacceptable noise intrusion; or where the courtroom cannot have the height to induce air flow by the natural stack effect. It is normally more economical and energy-efficient to have separate air handling units for each courtroom, managed by time switches and occupancy sensors.

2.07 Lighting

Daylight is provided if possible; but direct sunlight must be controlled and security risks avoided. The controlled use of daylight alone improves environmental comfort, but when it becomes for any reason insufficient, artificial lighting will be required. A combination of up-lighters and down-lighters reduces glare and contrast, and enhances the character of the courtroom. Lighting levels and colour should ensure correct colour rendering, and that all participants, exhibits and written evidence can be clearly seen without strain or dazzle.



27.5 *Standard Crown Courtroom*

2.08 Acoustics

The acoustics and noise levels should ensure that the proceedings can be heard in all parts of the courtroom; while avoiding distraction and annoyance from movement by the public, press or others. There may be a need for reflective or absorbent surface treatment to walls and ceilings.

2.09 Functional relationships Outside the Courtroom

Courthouse accommodation is divided into areas, each with its own self-contained circulation. Movement between areas is limited and restricted. Even those who need to move freely can only enter certain restricted areas by passing through manned control points or other secure doors. The relationship and pattern of movement between the elements is shown in the functional relationship diagram **27.6**.

2.10 Judiciary

The judiciary (judges, recorders, etc.) arrive at the court building and enter through a manned or otherwise restricted entry directly into their own secure area of the building. This contains the Judges' Retiring Rooms and all areas devoted to judicial use.

The only other users of this area in 'working hours' are the staff, i.e. ushers, court clerks, security staff and invitees, i.e. legal representatives, guests and some members of the public invited to a Judge's Room. Invitees will always be escorted, and access for all will be either via the Judges' entrance into court or through staff areas. Each entrance will be via a self-locking, secure door.

2.11 Jurors

Persons, the number depending on the number and size of trials programmed, are summoned to the court building. They enter through the main public areas until they reach the reception area to the Jury Assembly Suite where they are booked in.

They then wait in the lounge or dining area where refreshments are available until called upon to form a jury panel. The period of waiting is variable and can be all day. Highest usage is before courts sit, and during lunch periods.

Egress from the Assembly Area, other than back past reception, is into jury-restricted circulation, which leads to Court and Jury Retiring Rooms. These should be adjacent or close to related Court Rooms, and all capable of supervision by one jury bailiff.

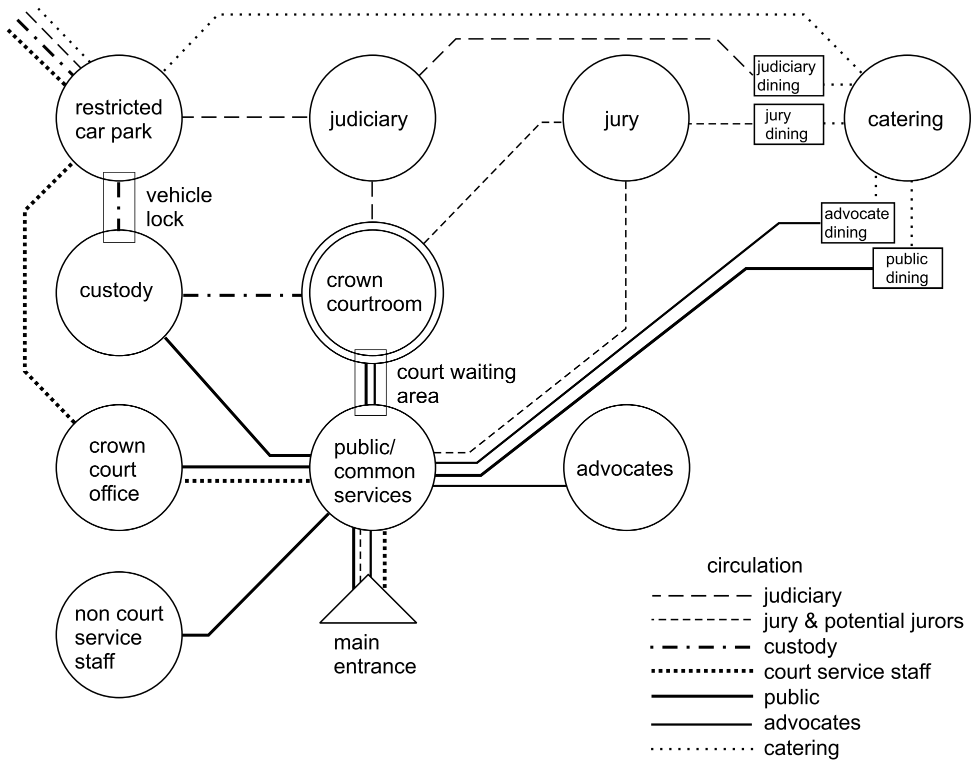
Once jurors have entered the Jury Assembly Suite they remain there, in court, or the Jury Retiring Room until sent home at the end of the day, or on dismissal.

2.12 Defendants

The Custody area is a self-contained compartment within the court building designated for the temporary use of prison governors in the discharge of their duties to the court to produce and retain prisoners in custody. It consists of the following principal parts, each separate from its neighbour and all non-custody uses:

- The custody core
- The vehicle entrance
- The visitors' entrance
- The courtroom entrance
- Three independent secure connecting routes:
  - custody core to vehicle dock
  - custody core to courtroom entrance
  - custody core to visitors' entrance.

While courts are sitting, the custody area is staffed and administered by prison officers. A principal or senior officer is in charge,



27.6 *Functional relationship diagram for a Courthouse*

supported by number of officers according to the number of courts and the level of risk. Some officers have fixed duties, for instance dock officer, cells officer; but the remainder are on escort duties.

Custody areas are designed and constructed to contain defendants, and to produce them to the court. Containment requires the meticulous and consistent application of passive security measures. Confinement and attendance at court for defendants is stressful, and this is compounded by natural frustration and anxiety.

The designer must:

- Give careful attention to all aspects of the design from the overall plan and its approaches, down to fixtures, fittings, fixings, finishes, alarms and communications
- Devise a layout that will achieve maximum control, make the best use of staff resources and maintain an acceptable level of safety and security
- Use the building fabric and the facilities within it to provide a secure envelope
- Deny the public direct view or contact with defendants while they are inside the custody area, except during authorised visits.

2.13 Public

The public areas with their associated circulation form the central core or axis from which most non-judicial functions of the court building radiate.

Except for the judiciary and specified car park users, all users enter the building by the main entrance door where space and facilities for security checks are provided. The arrival concourse contains the Information/Enquiry Point and the Cause List Display, both of which should be clearly seen on entering.

Public circulation then leads to Court Waiting Areas. These may be combined with associated circulation to form concourses off which are located the courtrooms and consultation/waiting rooms. Waiting areas should be visually interesting, preferably with external views.

Public circulation also gives access to private and semi-private accommodation occupied by Court Service (CS) staff, non-CS staff, the Probation Service, Custody Visits and to refreshment facilities. Access must also be available to the Crown Court Office counters. Direct access from the arrivals concourse to the Jury Assembly Area is desirable.

2.14 Advocates

Advocates enter the court building by the Main Entrance, reaching their suite via the public circulation. This is the area reserved for solicitors and barristers preparing for court, combining Lounge/Study/Retiring Room for relaxation and quiet study in comfortable conditions, and for assembly, discussion, robing, etc. Lounge and Robing Room should if possible be contiguous otherwise direct access should be provided.

The suite has easy access to courtrooms via the public concourse where advocates meet clients, and to the Advocates' Dining Room. The Advocates' Clerks' room is closely related and shares the same private 'Advocates' circulation.

2.15 Crown Court Office

The Crown Court Office is occupied by executive and administrative staff engaged in the general administration of Crown Court business.

The General Office counter must be conveniently located to allow easy access for the public and for the legal profession; payment of expenses to jurors and witnesses may be made here.

There should be separate circulation to other staff areas and for direct access to the judges restricted circulation by ushers. Within the Crown Court offices, accommodation is provided for some more specialised groups:

- Court Clerks who are responsible for business in specific courtrooms and who spend part of their day in court
- Ushers who spend part of their time in court and also attending to judge and/or jury but will also do minor clerical work
- Listing Staff who are responsible for the planning and programming of the court timetable (lists of cases).

2.16 Non-courts Service Users

Non-courts Service Users includes Police, Crown Prosecution Service, Probation Service and Shorthand Writers, concerned with the running of the Court.

The Police area consists of two sections:

The Police Liaison Unit. This is the suite of offices for police staff attached to the courts and providing antecedents, etc. Included is a room where police witnesses can assemble and change if necessary.

The Police Law and Order Unit. This suite of offices is for police who maintain security or 'Law and Order' in the building

The Crown Prosecution Service is responsible for the prosecution of defendants in court. It needs an office for law clerks to perform casework arising during the progress of the case, and to consult with members of the legal profession and witnesses.

The Probation Service, as attached to a Crown Court, will be active where persons have been made subjects of probation orders or inquiry reports at Court, although they may do some paperwork on other cases. The Probation Suite is a separate individual unit and where Night Reporting Facilities are required, must be able to operate in isolation while full security to the remainder of the court Building is maintained.

Shorthand writers are usually hired directly or via a service firm to take notes and transcribe Court proceedings.

2.17 Catering

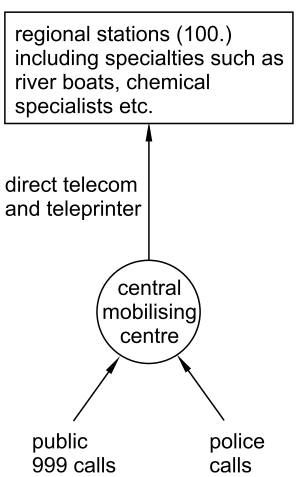
Catering within Crown Courts involves self-service facilities for advocates, jurors, public and court staff, together with waitress service from a sideboard or servery for the Judiciary. The catering area should be sited on one floor with easy access for all court users, maximising usage and minimising operating costs. Multilevel catering areas should be avoided as less convenient and more expensive to operate.

3 FIRE STATIONS

3.01

Fire stations are required to fulfil efficiently the functions laid down by the national, regional and metropolitan bodies that supervise their work. Each fire brigade has a detailed brief for the design of new fire stations with the aim of dealing with each incident as soon as possible after the emergency call is received in the control room, **27.7**, and this must be within the government's laid-down maximum response time.

Paramedics are now to be trained within the fire service; provision needs to be made for them in new stations. Fire Rescue Units may also need to be garaged.



27.7 *Diagram of communications centre control operations*

Firefighters' operational activities are grouped into:

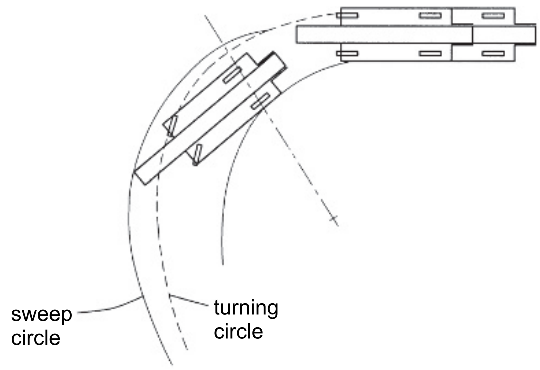
Wet/Dirty: mobilisation, call out training and drill cleaning and maintenance.

Clean/dry: administration public interface stand-down/recreation arrival for duty.

A fire station may be built as part of a commercial development, but its long-term use must be assured, particularly in regard to ease of access and egress, radio communications reception and Fire Standards. Conversely, there must also be no interference with TV reception in adjacent properties.

3.02 Appliance areas

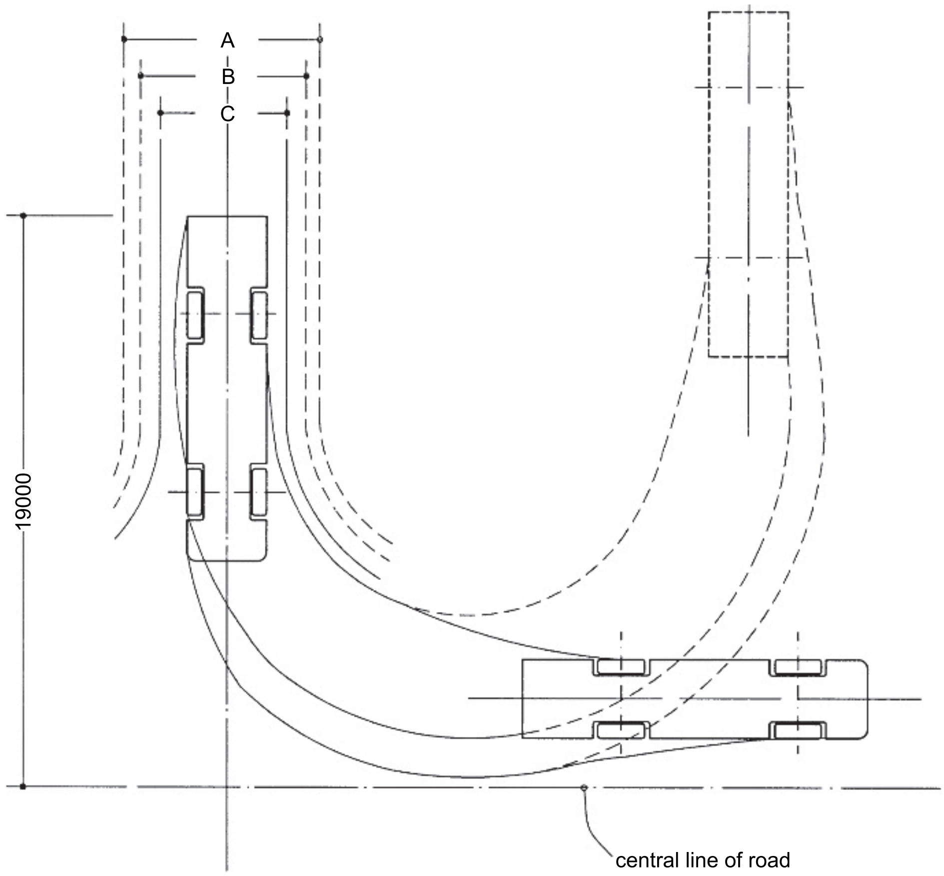
Most stations have two or three appliance bays. The usual appliances are pump ladder appliances and turntable ladders mounted on the basic chassis, and there are other appliances such as bulk foam pods or mobile training pods mounted onto the standard heavy-duty chassis. New stations must also be designed to accommodate aerial ladder platforms (ALPs), which are very large, **27.8**. ALPs are like large 'cherry-pickers' with hydraulically raised platforms but also incorporating ladders. Some will also accommodate special appliances outside the normal categories. The appliance area has a minimum headroom of 5 m. Appliances always face outwards and have a direct rear access to avoid reversing.



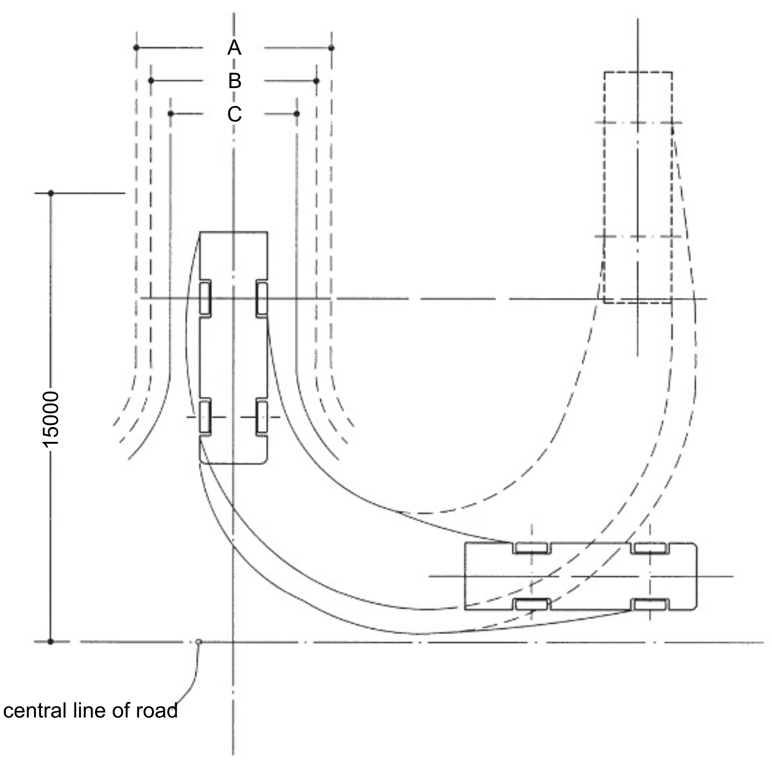
27.8 *Hydraulic platform (cherry-picker), turntable ladder and aerial ladder platform: appliance footprint (path):*
Roadway width 6 m, turning circle 22.5 m, sweep circle 25.2 m. Max. length 11.3 m, max. height 3.77 m, max. width 2.5 m, max. width with jacks out 6.05 m
Laden weight 28.2 tonnes, max. loading weight on either front axle 6.5 tonnes, on either rear axle 10.5 tonnes, max. single pressure on one extended jack with boom extension at maximum 12.4 tonnes
Max. length wheelbase 5.6 m, track of rear wheels 2 m, minimum ground clearance 229 mm

When a call is received the appliances need to get onto the road as quickly as possible. A separate route and maximum visibility are required for each appliance leaving the station. Appliances must be able to turn without crossing the crown of the road, **27.9** and **27.10**, which implies the need for a forecourt so that they can start to turn on exiting the bay doors. A forecourt 9 m deep permits appliances to pull clear of the automatic time-controlled doors. Returning appliances should also be able to drive easily from the return access to the covered washdown area, stopping on the centre line of its respective appliance bay.

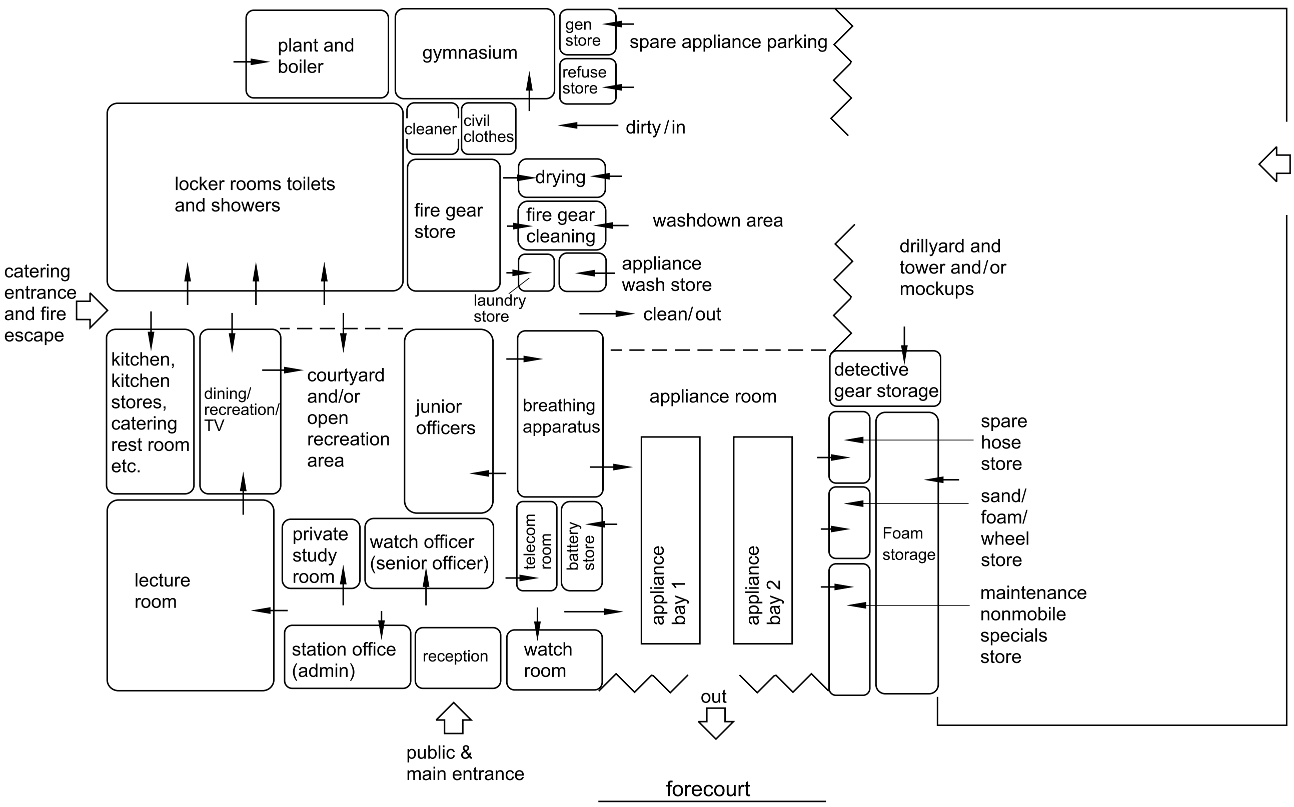
All areas traversed by appliances must be capable of bearing the load of the heaviest appliance and the pressure of out-riggers; and also withstand close turning movements and braking stress.



27.9 *Hydraulic platform (long chassis model) turning circle:*
Bay width with no forecourt 6.5 m
Bay width with forecourt 5.5 m
Minimum door width 4.2 m



27.10 *Pump ladder turning circle:*
A = Bay width with no forecourt 6.5 m
B = Bay width with forecourt 5.5 m
C = Minimum door width 4.2 m



27.11 *Relationship diagram for a two-appliance fire station on one level*

3.03 Station building

The public, particularly small boys, are not allowed into the fire station except when accompanied by a firefighter. While the appliances are out on a call the station is empty. All doors are automatically operated on electric controls with photo-electric cells and they close automatically after the appliances have left. This is important to avoid theft or damage to the building, particularly when paramedics are accommodated on the station as they need to store drugs for immediate use.

Everything in a fire station has to be very robust with the toughest finishes, easy to clean and maintenance free.

27.11 is a room relationship diagram for one type of fire station. Table I gives recommended areas for some of these spaces. **27.12** shows the necessary provisions to be made for rapid mobilisation, and **27.13** the almost equally important arrangements for standing down.

Lockers and ablutions

Toilet and changing facilities must allow for the fact that there are now more women in the fire service.

Fire stations work on a four-watch duty system. Each watch consists of from 12 to 15 firefighters and a station commander. Each firefighter has their own locker and gear hanging space.

Taking into account junior officers and standby staff, at least 50 lockers should be allowed for; preferably a few more as there will be some staff on sick or general leave, retaining their individual lockers. Their temporary replacements will require their own lockers. The area required relates to the specific need of the particular station.

Under present policy men and women share locker rooms with changing cubicles, but have separate ablutions. This simplifies matters as the male/female ratio is never constant.

On-site sleeping accommodation is no longer provided. This has eliminated much of the need for recreational facilities, as the firefighters are either on duty or away from the station with very few waiting or resting periods.

Recreation

A fully equipped gymnasium is required to facilitate firefighters achieving the level of physical fitness which their job demands. Television and darts are two other activities for which space is usually allocated within the dining/recreation area.

Station office

The administration in a fire station is covered by the station clerk who is sometimes non-uniformed. He or she deals with day-to-day routine and reports directly to the station commander.

Fire prevention office

The FPO relates to schools, scouts, etc. advises homes and businesses on dealing with the risk of fire. It will have leaflets on fire and smoke detectors, extinguishers, etc.

The function of the Fire Prevention Officer devolves on the fire station commander in some smaller stations.

3.04 Training facilities

Not all stations can sustain the full range of necessary training. Firefighting is now so hazardous, and includes many more dangers than straightforward fires, that firefighters tend to go on special courses to learn to deal with smoke, toxic fumes, ship fires, etc.

Static training for smoke and foam is required on each station. Many existing stations have very restricted external space, limiting the scope of on-station training to an unsatisfactory level. The minimum provision should not be reduced, even on a restricted site. The following three categories are a guide to what can be achieved, with approximate areas:

(a) *Two-appliance station with minimal training facilities:*

Site area approximately 945 m^2, the residual yard area approximately 400 m^2.

Table I Fire station accommodation

	Above ground level?	Two-appliance	Three-appliance
OPERATIONAL			
Appliance Room	N	160	248
Slide poles		7	7
Fire gear (uniform) store	N	30	40
Operational equipment and general storage	N	27	27
Split into wet, dry and clean zones			
Operational equipment cleaning	N	8	8
Clothes drying room	N	10	10
The four spaces above need direct access to and from the appliances, and quick access from the rest areas. There may also be a small laundry in this area			
Breathing apparatus room	N	13	13
Storing, testing and overhauling equipment			
Fuel storage/pump	N		
Required so that the appliances can be refuelled in their station. Safety regulations are rigidly followed.			
Oil/paraffin/propane storage	N		
Sand/foam/wheel store	N		
Foam trailer garage	N		
Spare hose store	N		
Defective gear store	N		
Maintenance of non-mobile specials store	N		
CONTROL AND ADMINISTRATION			
Watchroom or Operations Centre	N	10	10
A critical room off the appliance bay. Must include teleprinter, radio controls, telephones, maps and route cards. Directly linked to Central Control.			
Station office	Y	17	17
Stationery store	Y	11	
Waiting/reception	N	8	8
with entrance lobby for the public to visit the station and see exhibitions, etc. There should be a toilet here for wheelchair users			
Station Commander's office	Y	20	20
Watch Commander's room	Y	15	15
with wash area/toilet/shower and office with couch			
Commander's locker and washroom	Y	15	15
Fire safety office	Y	10	10
AMENITY			
Firefighters' lockers and changing room	Y	58	81
Ideally situated adjacent to the appliance room as the firefighters will change into uniform on arrival and after duty change back.			
Firefighters' toilets and washrooms	Y	32	41
Junior Officer study	Y	26	39
Junior Office toilet	4	4	
Lecture room	Y	45	75
Doubles as a rest area with fold-down beds for emergencies and extra standby shifts, video and TV, screens and whiteboards for teaching and debriefing. If a firefighter is killed or badly wounded a debriefing may involve several fire stations so that this room should be sufficiently large.			
Lecture Storage	Y	10	10
Gymnasium	Y	38	38
Needs direct or pole access to the appliance area			
Quiet/Study Room	Y	15	15
May double up as the Fire Prevention Office for public relations			
Kitchen	Y	25	25
Dining/TV viewing	Y	35	40
Needs direct or pole access to the appliance area			
Cleaner	Y	6	6
Consumables	Y	2	2
SERVICES			
Electrical Intake	N	3	3
Standby Generator	N	12	12
Boiler Room	N	15	15
Refuse Chamber	N	4	4
Gas Meter	N	1	1
Communications	Y	5	5
with BT/Mercury equipment linked to the Watchroom			
Water Meter	N		
Total		692	865
Total including 30% circulation (except to appliance room)		850	1050

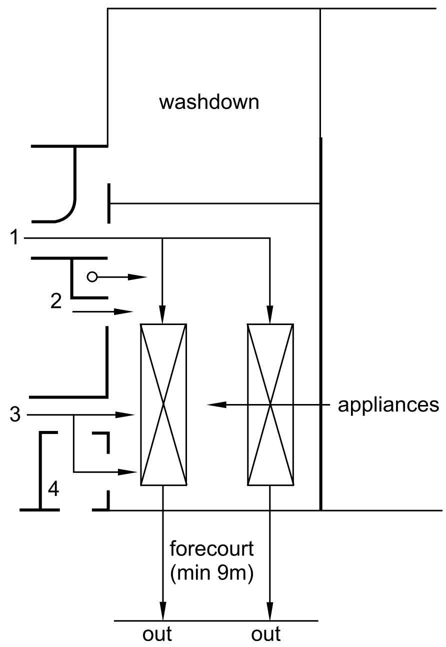
Facilities on such a site will be adequate for continuation training to be carried out at station level without the frequent need to go elsewhere:

- Training facility of three floors (which could form part of station accommodation), with the ability to test equipment (particularly ladders)
- Small yard with a single hydrant and as much space as possible for parking
- Gym and lecture facilities available nearby.

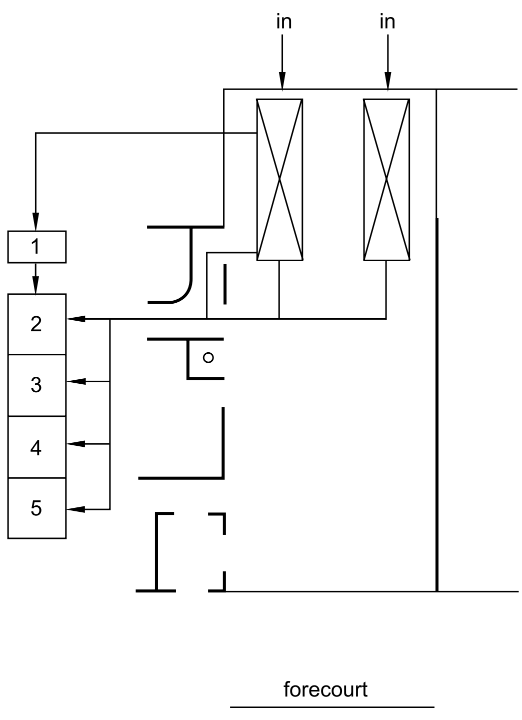
(b) *Two appliance station with basic training facilities:*

Site area approximately 1800 m^2, residual yard area approximately 700 m^2.

- Purpose-built training facility using a full range of standard ladders
- Separate gym and lecture room
- Drill yard with a single hydrant and pumping well, sufficiently large to enable the testing of ladders and the execution of drills using ladders and hose. When not required for training purposes it will provide car parking for station personnel.



27.12 *Diagram of circulation routes for mobilisation:*
1 *Firefighters to appliances, rear access*
2 *Staircase or pole access when multi-storeyed*
3 *Firefighters to appliances, front access*
4 *Duty firefighters to watchrooms and appliances*



27.13 *Diagram of circulation routes on return to fire station:*
1 *External rear access*
2 *Operational equipment store*
3 *Operational equipment cleaning*
4 *Breathing apparatus room*
5 *Lockers and washroom*

(c) *Three appliance station with full training facilities:*

Where there is a demonstrable strategic area training need.

Site area approximately 3100 m^2, residual yard area approximately 1400 m^2.

- Training tower of four floors, incorporating a dry rising main and additional breathing apparatus training facilities
- Drill yard with two hydrants, pumping well and space for the partying out of comprehensive drills such as water relays. The yard will be sufficiently large to accommodate the turning circle of the largest fire appliances, the testing of equipment and the execution of combined drills
- Roof ladder training facilities
- Separate lecture room equipped with audio-visual aids
- Gymnasium enlarged for the training of physical training instructors
- Derv pump and underground tank.

3.05 Drill yard

This area at the rear or side of the station serves several functions that cannot take place inside the appliance bays and ancillary accommodation:

- Vehicle return access to covered washdown area and appliance bays
- Drill/practice/instruction
- Fuel delivery
- Essential car parking.

The drill yard size and shape will be determined by the site constraints. Apart from routine training, it may also be used for special instruction incorporating a mock-up ship, factory or traffic situation to enable the trainees to gain experience of particular difficult and dangerous conditions.

The drill yard and tower must not cause nuisance to adjoining properties, and should not be overlooked by them. Firefighters under drill or training would not appreciate an audience, and the control of water jets in these situations is not always predictable.

Training involves the use of ALPs. The drill yard must be designed to take their heavy point loading as well as heavy vehicles. It should have a minimum fall of 1:50 to drain off the large quantities of water and foam to suitable gulleys.

3.06 Drill tower

Drill towers were previously used for drying hoses as well as training. Hoses are now made of plastic and do not require drying out. Thus towers are not always provided in new stations.

Where a tower is provided, it will include dry risers, firefighting lids, sprinkler systems, different types of windows and artificial smoke conduits for smoke exercises and use of breathing apparatus. There is less use of hose reels, now that Building Regulations have become so sophisticated.

A tower can be either part of the station building or free-standing. A number of features must be provided:

- Up to three working faces, each at least 3.2 m wide in one plane without copings or mouldings
- At least three drill platforms at heights approximately 3 m centres, each with at least 4.65 m^2 clear non-slip (even when wet), drainable working surface with a minimum width of 3.05 m across the face of the tower
- Orientation to avoid direct sunlight which could be dangerous during certain drills
- Clearance at the base of the working faces of at least 6 m free from hazards such as manholes, hydrant covers and bollards
- Ladders must continue through hatchways above drill platforms level to a point where the top rung is at least 1.5 m above the platform levels. The ladder apertures to be at least 840 × 840 mm, and access only by stepping sideways (never backwards). Ladders must comply with Health and Safety Standards as to rung spacings, wall distances and safety rails. Protected stepping off points to be provided at least 760 mm width
- Instead of ladders, a staircase could be used. In the case of a tower integrated into a station building, the staircase is acceptable as a secondary means of escape

- Cleats and anchor plates or points should be provided on each working face with shackle points of suspension fitted beyond any sill projections capable of withstanding test loads of 1 tonne
- A section of roofing should also be available to train firefighters in ladder craft, roof drills and particularly safe transfer of personnel from vertical ladders to inclined roof ladders. Safety walkways and protective railings should, however, be included for the full width of the roof, and safety handrails fitted along two of the inclined edges. In integrated towers the main building roof can be utilised as a training roof.

4 AMBULANCE STATIONS

4.01

Ambulance stations are either control stations or their satellites. The control stations contain larger store areas and a divisional office, and may have dining, recreation and activity areas. On-site sleeping accommodation is no longer required. Satellite stations have from two to six ambulances and deal only with accident and emergency calls. They do not require dining or recreation facilities, as off-duty time is spent off the premises, but a rest room will be needed for waiting and relaxing between calls.

Because drugs may be stored on the premises all doors need to be lock controlled.

Like the police, more and more control equipment such as faxes, trackers and radios are in the ambulance, permitting greater use of these facilities with no need to return to base. However, to provide adequate hospital cover, ambulances are stationed there for half-hour periods.

4.02

Apart from accidents and emergencies, the larger stations also cover:

- Patient transfer
- Hospital to hospital
- Home to hospital for consultancy
- Taxi service

4.03

Regions are split into about four divisions with a central control. Each division normally consists of about six larger stations and twelve satellites, varying according to population density. All accident and emergency calls are received at central control.

4.04 Provision for vehicles

In small stations with less than seven ambulances, vehicles will be reversed onto their parking bays. The station will have an easy-to-open individual exit door to each bay, **27.14**. Larger stations use echelon parking with in-and-out access. There must be sufficient space behind the parked ambulance to permit easy removal of equipment.

Large stations require a fuel loading bay, but not the smaller stations. The current trend is towards using petrol rather than diesel, for smoother running and fewer fumes. A vehicle wash-down is required for each station.

4.05 Vehicle workshops

Vehicle maintenance is carried out in separate workshop buildings, **27.15**, covering at least six stations. It does not need to be on the same site as an ambulance station.

A workshop normally caters for up to six vehicles at a time, so front access only is required. Larger workshops are designed for echelon parking with a through-access system. All workshops will be capable of carrying out day-to-day maintenance and repairs, including the equivalent of MOT testing, standard servicing and body repairs. They are not expected to replace engines or crankshafts or do heavy repairs. Finishes must be robust and durable and floor surfaces non-slip.

4.06 Duty rooms

Duty rooms should be close to the garage, have adequate wall space for maps and natural lighting and ventilation. Staff in the rest room must be able to see what is happening in the duty room, so it should be adjacent with a glazed screen between.

4.07

Lockers and changing facilities are linked to showers and toilets. In the smaller stations unisex toilets and showers are acceptable. Elsewhere they should be designed to facilitate adjustment when the male/female ratio changes.

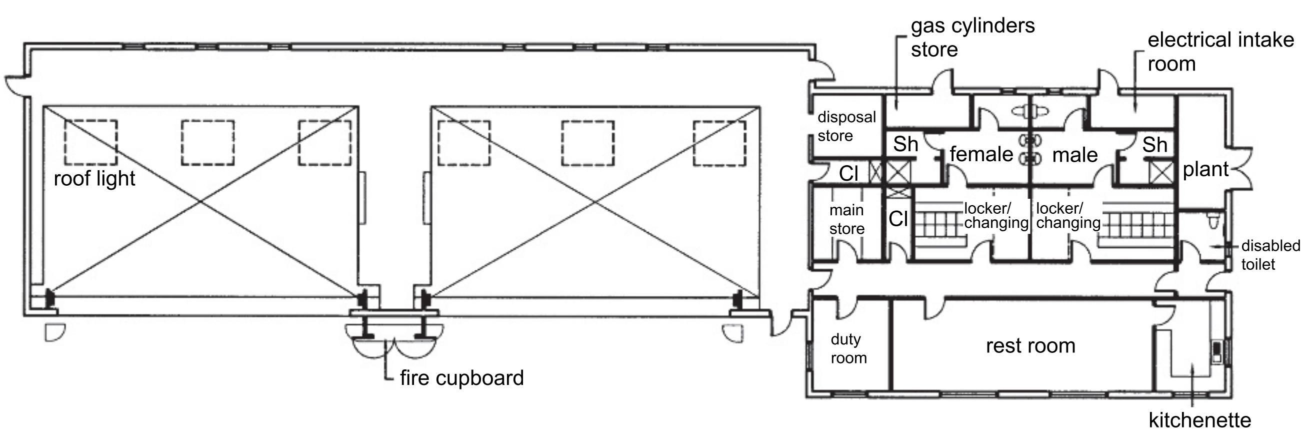
4.08

A toilet for wheelchair users and other disabled people is needed although the ambulance operatives themselves need to be fully able-bodied. This is because members of the public have come to expect such a facility to be provided at an ambulance station!

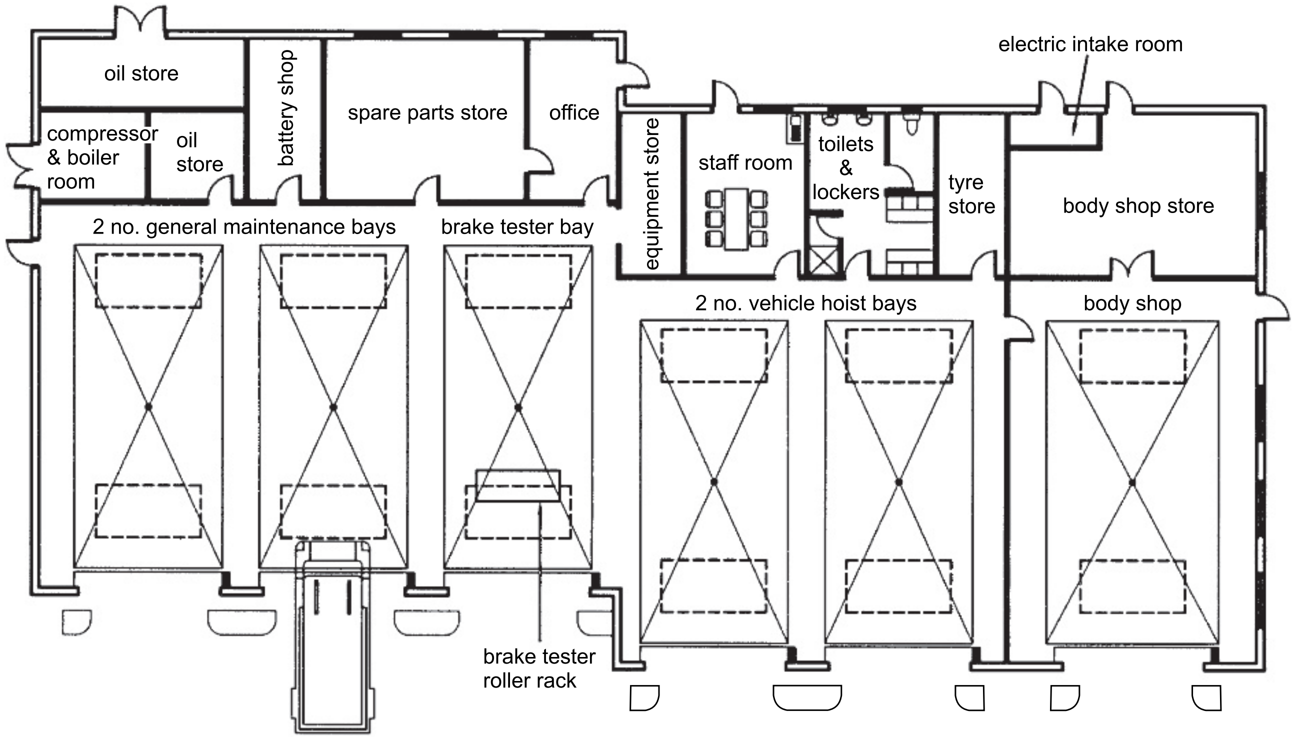
4.09 Stores

The main store needs to be a secure facility close to the garage. It will accommodate the following in a single area or in separate stores:

- Linen such as blankets, sheets, pillowcases and towels
- Medical supplies such as first-aid dressings, bandages and splints



27.14 *Layout of an ambulance station with six vehicles*



27.15 *Layout of a workshop for servicing ambulance vehicles*

- Paramedic equipment such as defibulators and resuscitators
- Spare items to replace equipment normally stored in the ambulance
- Trolleys, stretchers, etc. belonging to de-kitted vehicles
- Expendable items and documents, log books and files.

A separate store within the main store is required for drugs. This is separately lockable and alarmed to the duty room.

Blankets should be kept well ventilated and heated.

Dirty blankets, linen and contaminated clothes are temporarily kept in containers in a disposal store until they can be sent to a laundry. This disposal store should be near the ambulance parking, but away from clean stores and other clean areas. The same place can also be used for storing general refuse awaiting removal. Medical materials including used needles must be in separate containers for special disposal.

The gas store holds entonox and oxygen in small cylinders for use by paramedics. This store must be warm and well ventilated with easy access to the ambulances.

4.10

Some regions still require a small blanket laundry in the larger stations. However, due to health and safety legislation, with stringent regulations relating to temperature controls, cleanliness and hygiene, there is a strong move towards using contract cleaning companies instead.

5 POLICE STATIONS

5.01

The police aim to foster public goodwill; their buildings should be as pleasing and friendly to the visitor as possible compatible with essential security requirements.

The Home Office has produced most detailed and comprehensive guides covering legislative requirements, cost and design. New stations should be based on the *Home Office Building Guide 1994*, modified to suit the individual local requirements.

5.02 Organisation

Over the last few years there has been radical change in organisation. Some forces still maintain divisions and subdivisions; others have gone over to regions and areas. Some police forces collaborate with others to provide support services for their joint use. Regional crime squads come under this heading.

Because so much of the work has become extremely technical and specialised, many of the specialities are accommodated away from the custody and public departments.

The different levels of the organisation require different building types:

1 Headquarters buildings with control extending over a force area,
2 Divisional HQs
3 sub-Divisional HQs, which may be located separately or may be combined.

Headquarters buildings and police stations are all based on the same principles, and only vary according to need. A facility like a custody suite or communications centre is located in the most suitable place regardless of the rank of the building.

5.03 Siting

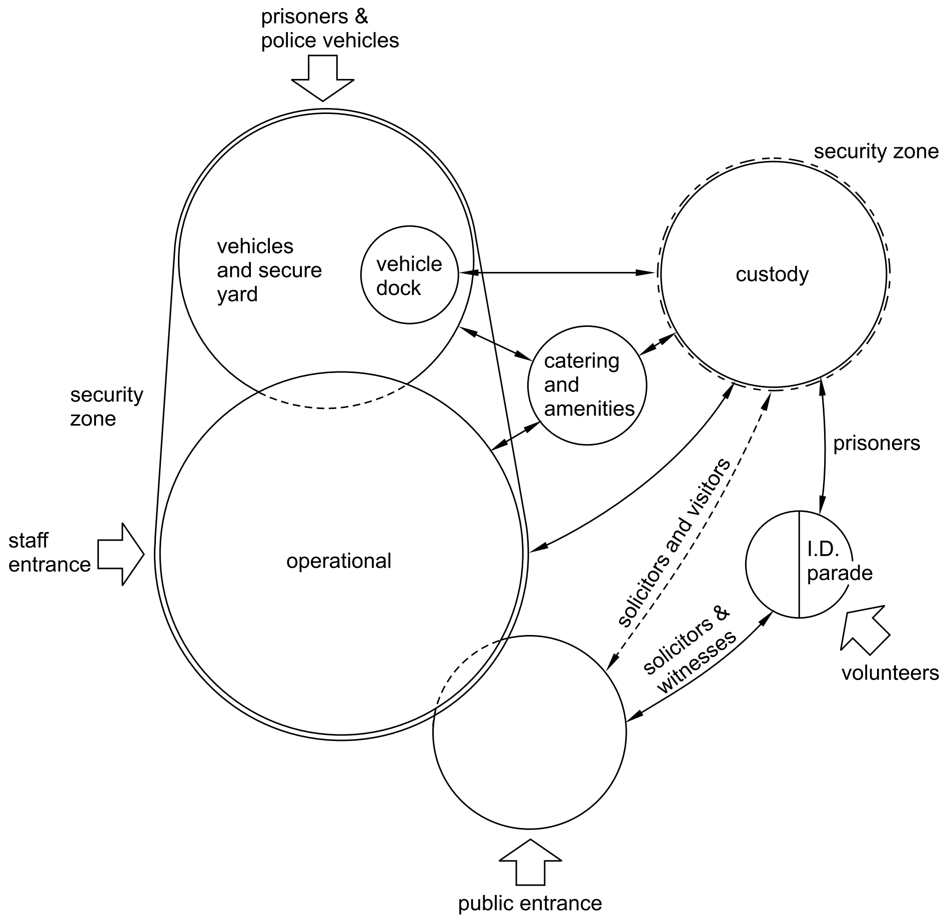
Stations should be near public transport, readily available both to the local inhabitants and easily found by strangers. They no longer need to be near magistrates' courts. However, when they are, they should be totally separate with no shared facilities.

In busy shopping centres and high streets police posts with direct communications to their headquarters are proving popular with both police and public, who provide information there that might never be otherwise obtained. The authorities are even considering having police posts in supermarkets.

5.04 Design of the station

The zoning diagram, **27.16**, is a guide to circulation.

The public area must be designed with an awareness of the dangers posed by explosives and people with weapons. It should still try to maintain a pleasing and welcoming atmosphere. It must be easily accessible from the police area. Access and toilet accommodation for disabled people is essential.



27.16 *Relationship and zoning diagram for a large police station*

The reception counter should be located to permit officer-on-duty supervision of the building entrance. A security screen between counter area and waiting is desirable in some circumstances, so that only a limited number can enter at a time. This provides both privacy and security. Where there is no screen a privacy booth in or on the counter is desirable.

Waiting areas are provided with seating and notice boards for posters on road safety and crime prevention, etc.

The public interview area is entered off the waiting area. Interview rooms should be large enough to take several people at a time and are fitted with taping equipment.

The victim examination suite should be adjacent to the public entrance and is for interviewing and medical examination of assault, child molestation or rape victims. It must be pleasantly designed in order to reduce stress, **27.17**.

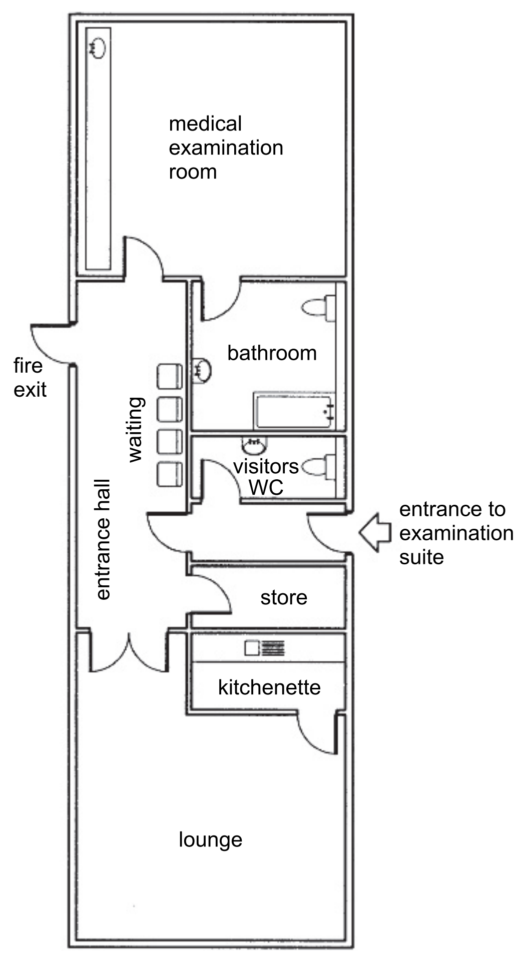
Found property

This is an area accessible only to the police for storing unclaimed stolen property and items handed in by the public or found by the police. No live animals are kept there, although some stations do have special facilities for animals.

People seeking lost property enquire for it at the reception counter, so this should have easy access to the found property store. Its size will depend on local requirements. Some forces use warehouses due to the very large quantities that are collected. Where no large store or warehouse is available, bulky items such as bicycles are usually stored in out-buildings.

Assembly room, lockers, changing and drying rooms

They should be located close to the police entrance. Showers and toilets should be adjacent to the lockers and to the drying areas which should be operational in summer as well as winter.



27.17 *Plan of a victim examination suite*

Report writing room
These should be adjacent to the assembly room. Booths and acoustic treatment are advisable.

Communications and control are central to the police function. Workload is extremely heavy and the working environment should be designed to mitigate stress, **27.18**. The control room deals with force or area-wide facilities including VHP radio, and has direct access to police resource information and criminal records. Communications rooms are principally used for message transfer and receipt of information.

The location and design of the central control room should be such as to frustrate any deliberate attempt to dislocate its vitally important functions by physical or electronic attack. Its vehicular access must ensure an uninterrupted road in an emergency; but no parking should be allowed within 15 m of its perimeter.

Major incident room
A force will on occasions need to work on serious crimes requiring extensive investigation, civil emergencies or major incidents. Accommodation with easy communication connections will be required for temporary use by CID, traffic or uniformed branches; when not so required, it will be designated for an alternative function such as a gymnasium.

Criminal justice office
This is for documentation of cases to be brought before the courts.

Criminal Investigation Department (CID)
In some cases CID would have their own unit separate from the police station.

Operational group provides office accommodation for

- Beat patrols
- Uniformed section
- Operational control
- General administration.

Administration covers general administration as opposed to operational dependent administration and activities.

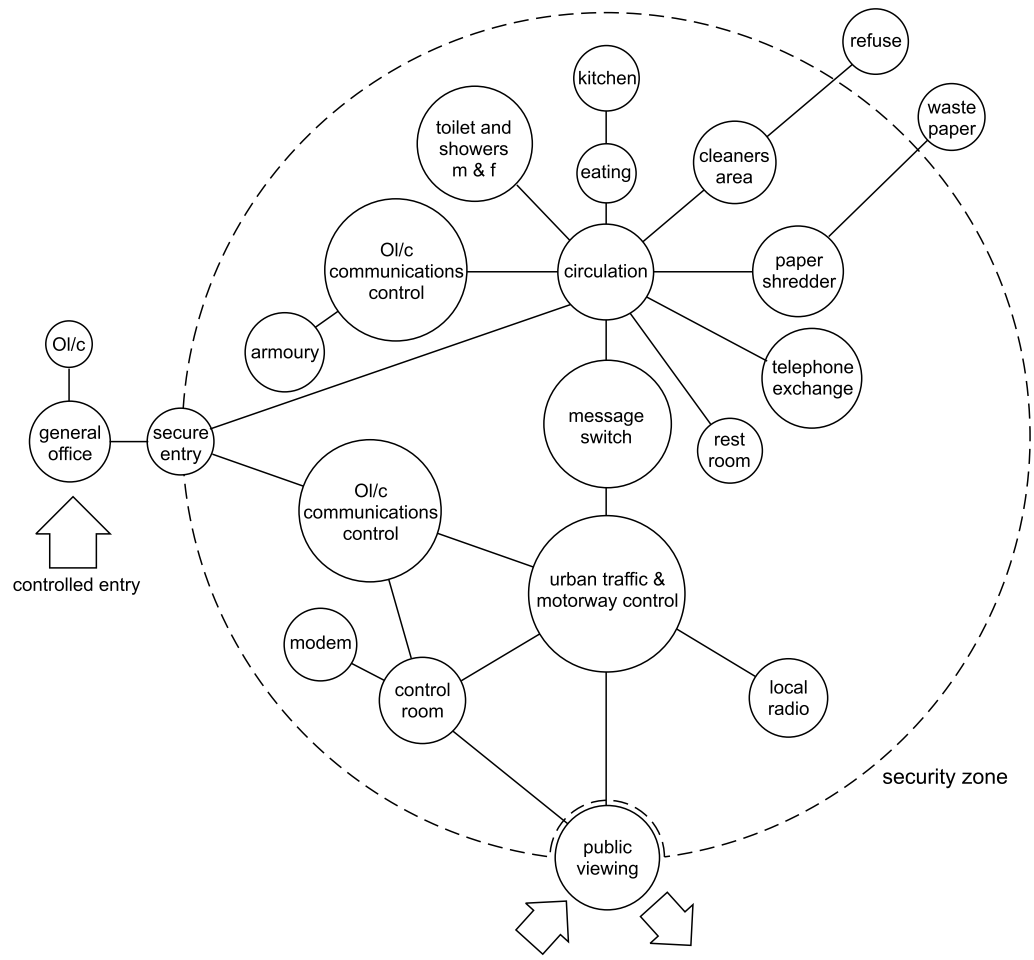
Traffic includes accommodation for motor patrols, traffic wardens, garages and workshops.

Garages and workshops may be on the same site as the station, or be a separate unit with attached accommodation for motor patrols depending on the size of the area and the number of vehicles. It is preferable not to have this unit in a busy city centre where it would add to congestion, and also hinder police cars quickly reaching the scene of an incident. If the police area includes motorways the unit should be sited near an access point, or even within a motorway service area.

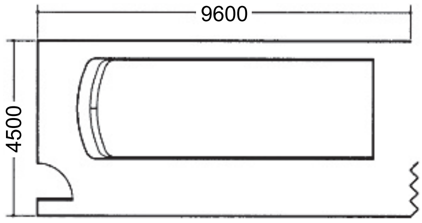
The police car is becoming more 'high tech', with built-in computers in addition to two-way radios. It is becoming an office in its own right, so that there is less need for the occupants to report in person to a police station.

Prisoners' vehicle dock
This must be provided away from the main police vehicle yard; totally secure and adjacent to the prisoners' entrance to the building, **27.19**. **27.20** gives data for the prisoner transport vehicle.

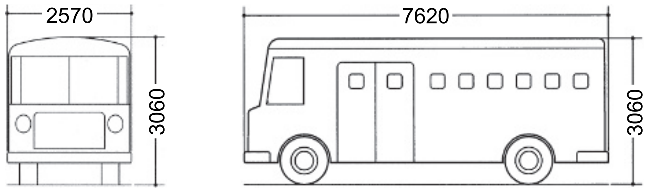
Identification parade facility
This has to be carefully sited outside the custody area but linked to it by a secure access route. Witnesses should be rigidly segregated



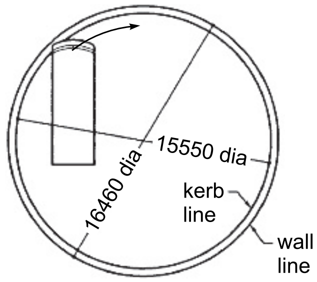
27.18 *Relationship diagram of a Control Room suite*



27.19 *Plan of a prisoner transport vehicle dock*

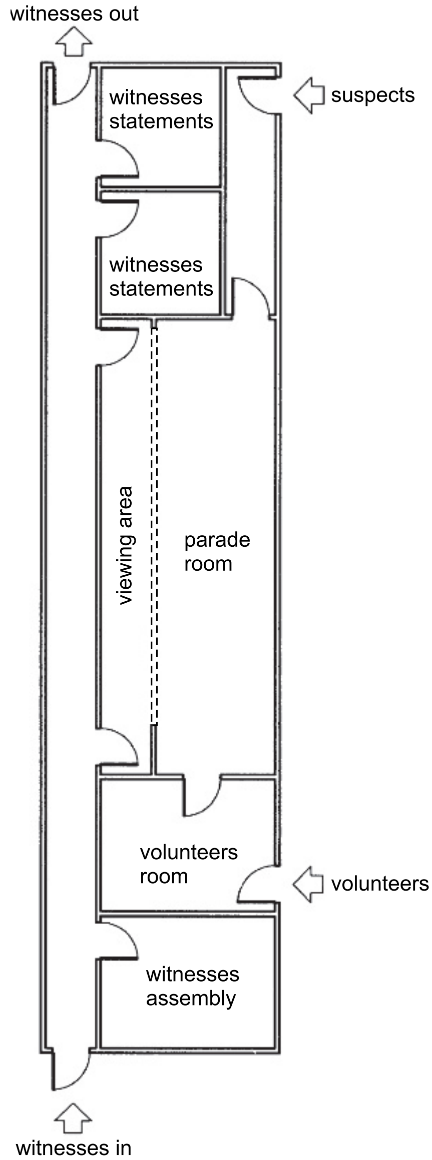


a *Dimensions*



b *Turning circles*

27.20 *A vehicle for transporting prisoners*



27.21 *Plan of an identity parade suite*

from each other, and from all members of the parade before, during and after the parade; there must be no possibility of physical contact at any time, or visual contact except during the parade itself, **27.21**. Toilet facilities should be available for witnesses and volunteers.

Messing and recreation

Catering is usually provided by self-help appliances such as frozen packaged food with grills or microwave ovens and hot/cold drink dispensers. In large stations there may be a canteen, but 24-hour operation is easier to control through packaged meals.

Toilets

Lavatory accommodation is related to size of station and disposition of rooms. Separate provision is made for:

- Male sergeants, constables and civilian staff
- Female sergeants, constables and civilian staff
- Senior officers
- Chief constables and assistant chief constables have en-suite facilities
- Visitors, usually located at the public entrance
- Disabled people, also close to the public entrance
- Cell accommodation.

Blast proofing is now mandatory for all police stations; no car parking should be positioned within 15 m of the buildings, 10 m for operational vehicles.

Mechanical ventilation and cooling is provided for information and communications accommodation without natural ventilation.

Emergency electrical supply is essential throughout, not only for power failure but also in the event of fire. In large stations it will be necessary to ensure continuity of supply to the custody suite, radios, computers, teleprinters, and communication service equipment, and must have 'direct on-line automatic start'.

An uninterrupted power supply (UPS) will be required for computer areas.

4.05 Custody suite

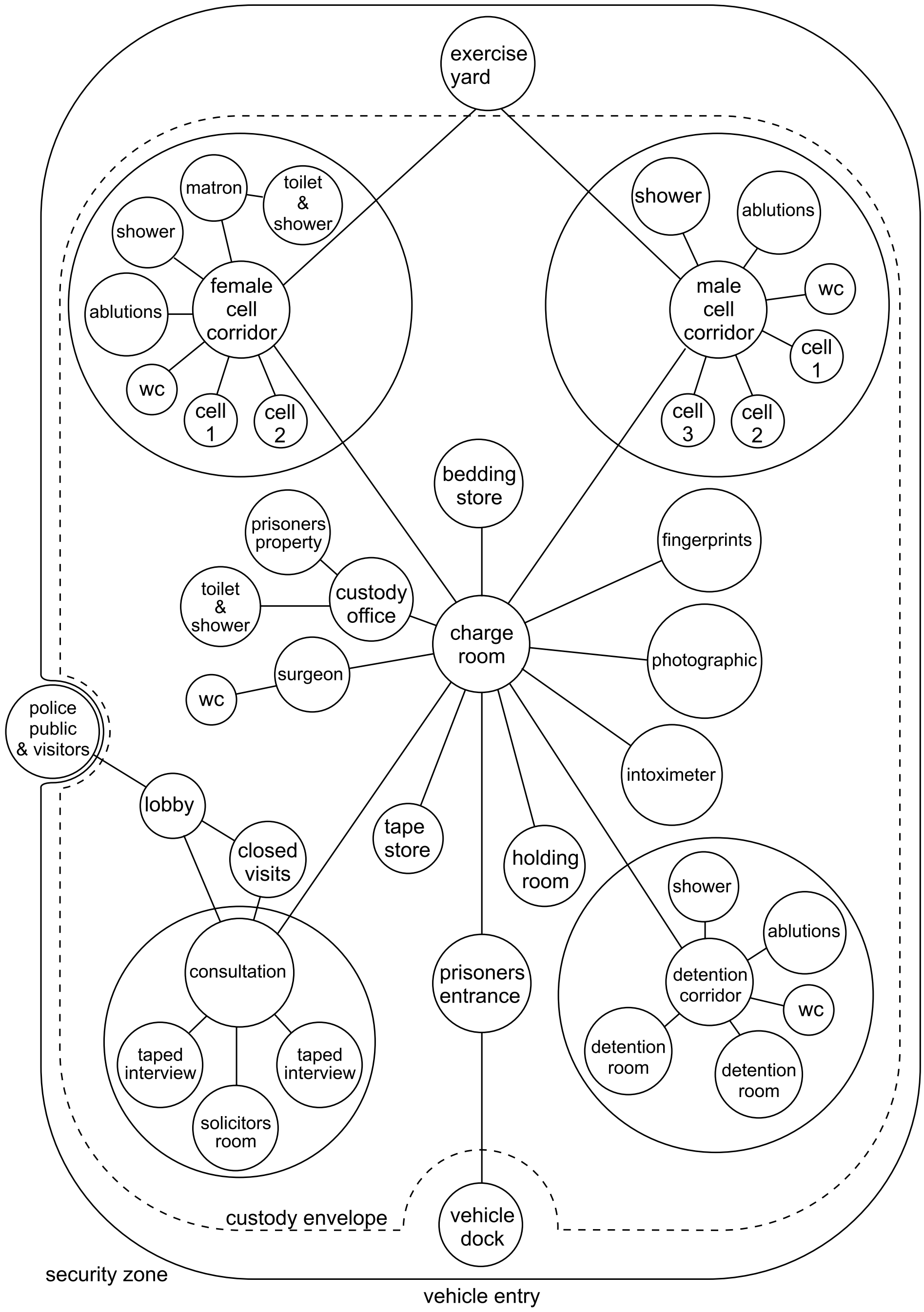
This includes detention rooms, charge desk(s) and ancillary accommodation, **27.22** and **27.23**. The police have to be alert to the possibility of someone in custody attempting suicide. Care needs to be taken to avoid this eventuality particularly in the design of the cells (see *Section 5.06* below).

The custody area should be securely separated from other parts of the building. It should be located on a single level to avoid moving prisoners up and down stairs which should be avoided at all costs. Where minor changes in level are unavoidable internally or externally, ramps should be used.

Corridors and cells for female prisoners should be segregated from those for male prisoners. Each should have separate access to the exercise yard. Detention rooms for juveniles should also be separate from adult areas.

Catering

Prisoners and police within the custody area need to be fed. However, a kitchenette within the custody area is undesirable as it would divert the custody officer from essential tasks and also be a fire risk. The



27.22 *Relationship and zoning diagram for a custody suite*

self-catering facility in the amenity area is also unacceptable as it would take officers away from the custody area. There is little alternative, therefore, to a staffed kitchen immediately outside the custody area preparing food in compliance with food hygiene regulations and providing the meals close to the users. If there is a canteen which is fully staffed for 24 hours, this may be used.

Detention suite

This is a facility where the WC is outside the cell, **27.24**, where additional washing facilities can be securely provided.

WCs

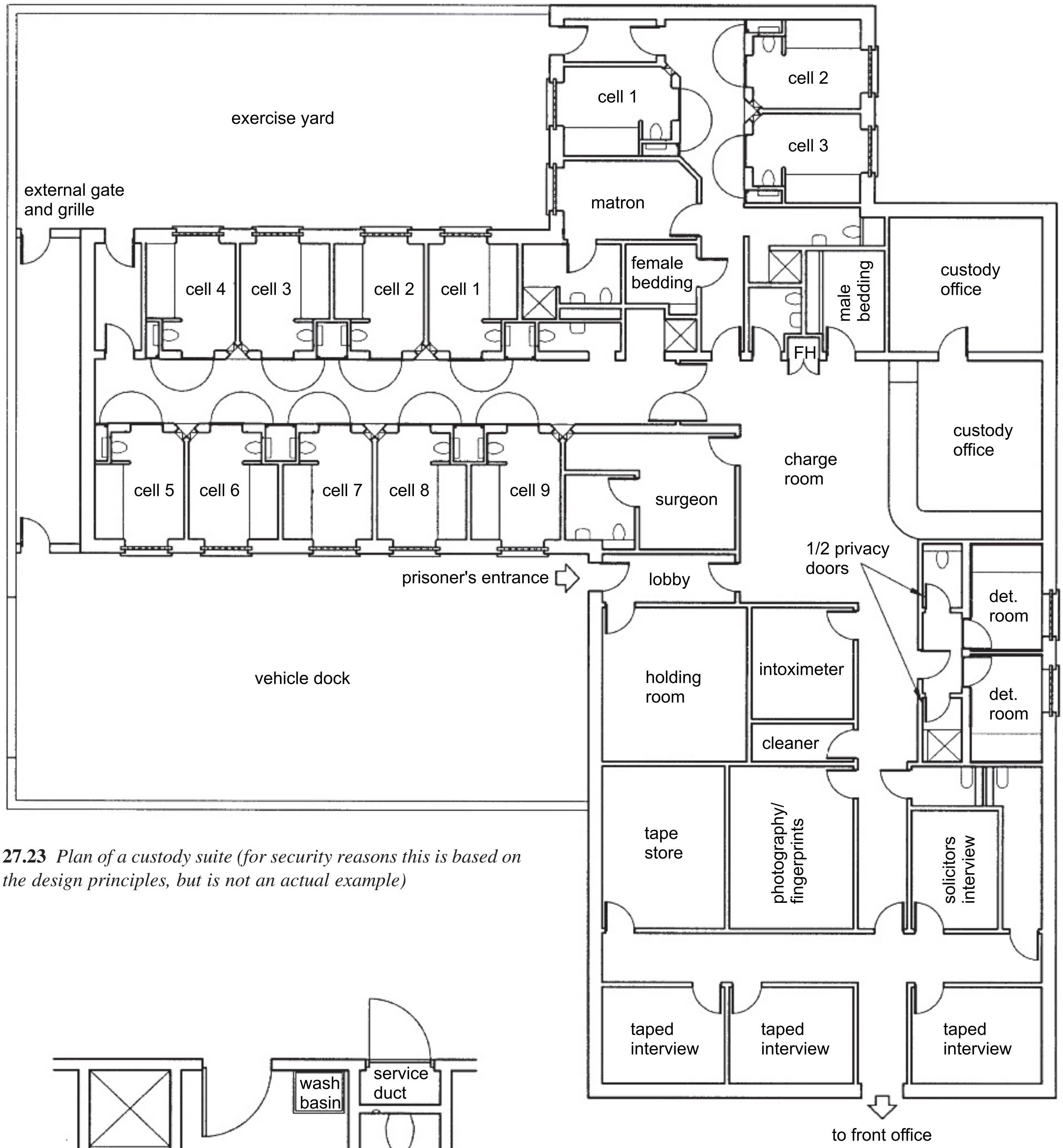
The compartment should have a stable-type hinged door, not a sliding one, with an observation aperture. The cistern should be outside the compartment with secured access and a protected flushing pipe. The flushing device should be outside the reach of a prisoner attempting suicide by drowning, and should not be a chain or project from the wall. There should be no projecting toilet roll holder, exposed overflow pipe, bracket, service pipe or stopcock. Fittings should be not be able to be broken or extracted to make tools or weapons.

Washing facilities

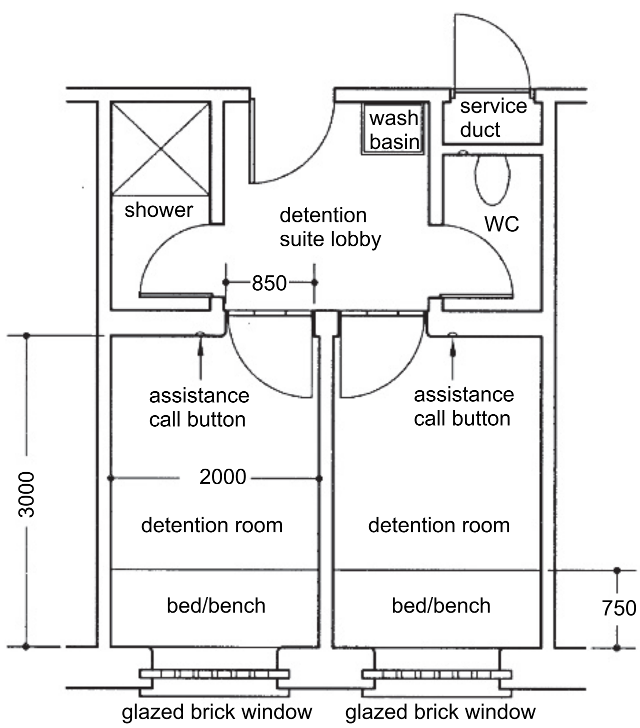
Basins should not be inside cells. They should be supported on metal stands, not cantilever brackets, and provided with captive plugs without chains. Towel holders are not used as the towels could be used to facilitate suicide, and the holder would provide points to which a ligature could be attached. Facilities for female prisoners must be properly screened. For use inside cells, prisoners are provided with disinfectant/cologne-impregnated washpads as on aircraft.

Cell corridor

The entrance should be fitted with an iron gate. The corridor should have alarm pushes for the custody officer's use if attacked. There should be no exposed pipes, valves, electric cables or conduit, and any thermometer should be outside the reach of a passing prisoner.



27.23 *Plan of a custody suite (for security reasons this is based on the design principles, but is not an actual example)*



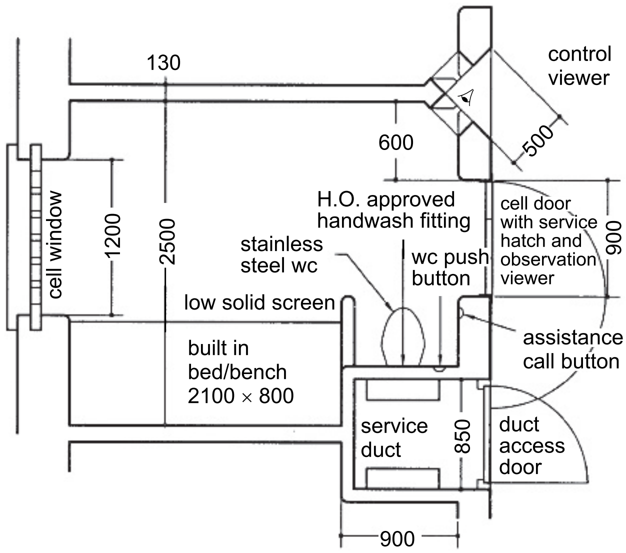
27.24 *Plan of a detention suite*

Exercise yard

The walls should be high enough to prevent a prisoner escaping, at least 3.6 m. There should be no ledges or other features which enable a prisoner to climb. However, where for any reason the height and detailing of the walls are deemed insufficient to prevent escape, a top cover may be used. There should be no doors or windows opening into the yard which might enable a prisoner to reach the top cover, nor any unlockable inspection chamber covers or gully gratings which could be lifted. Rainwater and soil pipes should be flaunched up in cement mortar to obviate handholds.

4.06 Cell design

The Police Design Guides are explicit in their requirements reflected in a typical design, **27.25**.



27.25 *Plan of a custody cell*

Windows
Cell windows which are unguarded and with openable panes should not overlook roads or other public areas. Windows overlooking exercise yards should be both guarded and screened to prevent observation. Windows to ancillary accommodation within the cell suite such as blanket store, property store, cell corridor, gaoler's room, toilets, etc. should all be guarded. The glazing should be of toughened opaque glass fitted flush to the wall with no protrusions to facilitate injury or suicide, or ledges facilitating escape and attacks on officers. The thickness of the glass increases with larger panes. Glass should not be replaced for ventilation purposes with, for example, perforated zinc.

Ceilings
Most suspended ceilings can be easily broken, giving access to other parts of the building and possibly providing improvised tools or weapons.

Doors
All doors should be prisoner-proof and flush.

Cell furniture
These should not be of timber or able to be prised loose to make a tool or a weapon.

Ventilation
Casings to trunking should be secure against breakage and use by prisoners to facilitate suicide. Grilles under cell benches should be securely fixed using non-withdrawable screws. High-level airvents with perforations should not be larger than 4.7 mm diameter, of a material that will break under load and fitted flush with the wall surface.

Lighting
Cell light fittings should be fitted flush with the ceiling with unwithdrawable screws. They should have twin lamp holders and plastic lenses. Electrical supplies should not be exposed and the switches should be outside the cell with cover plates that cannot be removed to gain access to live parts.

Heating
Electric radiant heaters with exposed wiring should not be used to heat cells, neither should exposed hot water radiators. There should be no protrusions of any kind to which a ligature could be attached.

Cell call system
This should comprise a press button within the cell fitted flush with the wall operating a bell and indicator light externally. It should be on a separate circuit from the lighting, and the indicator light board should be under constant observation by the officer-in-charge.

Maintenance
Damaged cells should be withdrawn from use.

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28 Museums, art galleries and temporary exhibition spaces

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Uniclass: F754 & F755

KEY POINTS:

- *The expansion policy*
- *The circulation system*
- *The storage system*
- *Environmental control*

Contents

1 INTRODUCTION

1.01

'A museum is an institution which collects, documents, preserves, exhibits and interprets material evidence and associated information for the public benefit' (Museums Association (UK), 1984).

1.02

The design of museums, art galleries and the temporary exhibition spaces associated with similar organizations involves the housing of a wide range of functions broadly indicated in the common definitions of a museum. Museums, however, vary considerably in size, organization and purpose. It is important therefore to consider the particular context and features that characterize a museum in the process of developing concepts.

1.03

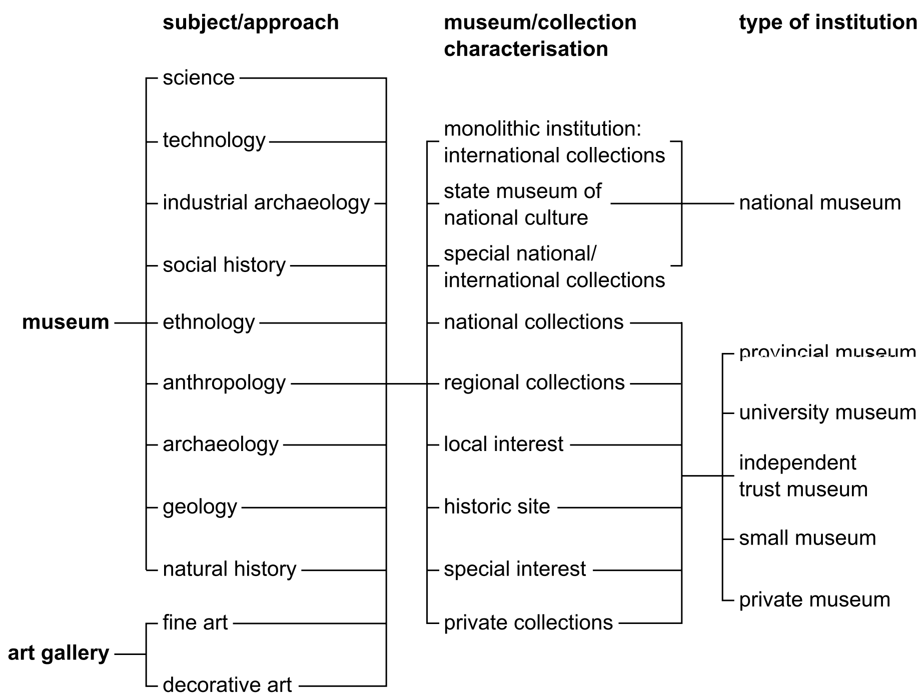
Collections in national museums are very large and varied in material and generally of international importance. The National Maritime Museum in Greenwich, for example, houses collections of machinery, boats, costumes, medals, ship models, paintings, silver, weapons, and scientific instruments, among many other types of material. Such museums are staffed by a wide range of highly qualified experts in collection management, research, conservation, public relations and marketing.

In some local and private museums collections are small, specific in material content and of specialist or local interest. Many such museums have only one qualified curator to oversee management of the collections and public services, and many of the specialist functions may be provided by outside bodies such as the Area Museum Councils. **28.1** shows a typology of museums based on subject/museological approach, collection characterization, and type of institution.

2 AREA DATA

2.01

There is no convenient formula for determining the areas to be devoted to the different functions. The client's intentions in respect of public access to collections, information and staff, and of commitment to research and conservation will provide an initial guide.

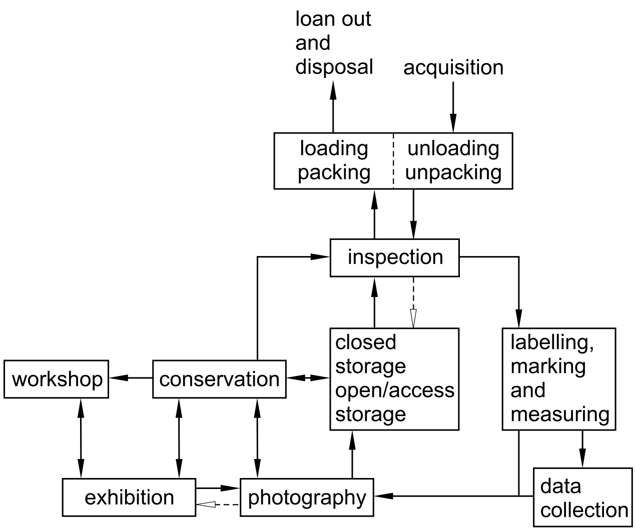


28.1 *A museum typology based on: museological approach/interpretive discipline; collection characterization; and institution characterization*

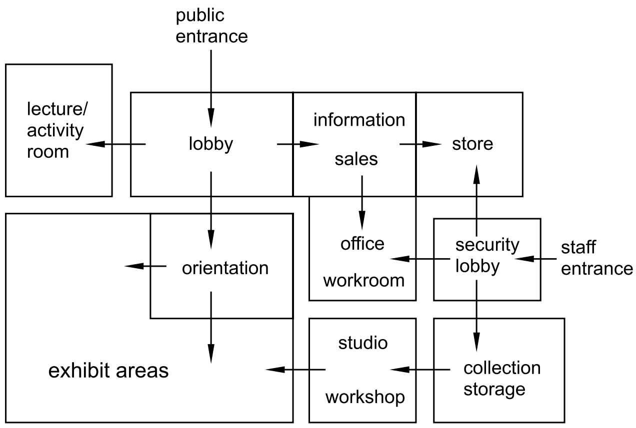
2.02
Some museums may have only a small proportion of the permanent collections on public exhibition at any one time, the bulk remaining in storage and accessible for research and conservation purposes only. Well-serviced temporary exhibition space may be a priority in such cases. Other museums may have smaller collections attractive enough to the visiting public to warrant the development of sophisticated exhibitions with a designed life of several years. In such cases storage space may be needed primarily for the expansion of the collections, and considerable effort may be made to develop educational programmes.

3 GENERAL PLANNING

3.01
The relationships between functions are common to all museums and art galleries. The flow diagram **28.2** shows collection item movements in the operation of collection services, but note that not every operation necessarily requires a separate space, and some services may be provided by outside agencies. As far as possible, collection movement and public circulation should be kept separate. **28.3** shows one approach to zoning and expansion based on this principle. **28.4** shows a possible layout for a small museum in which interpretive exhibitions and educational programmes are central to its operation. Where a museum is to be developed around a large-scale permanent installation this should be integrated into the interpretive scheme at an early stage. Examples are Jorvik Viking Centre's archaeological site and the National Railway Museum's turntables.



28.2 *Flow diagram of collection item movements in the operation of collection services: exhibitions, conservation and collections management*



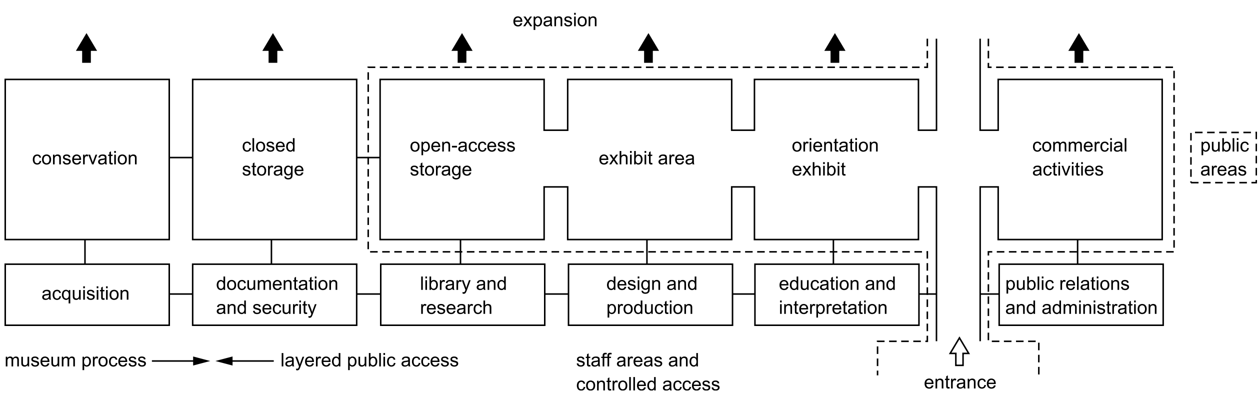
28.4 *A possible layout diagram for a small museum*

3.02
Museums are long-term developments: concepts for layout and massing should therefore be capable of expansion in all areas and a degree of internal rearrangement, particularly in work and ancillary areas. **28.5** shows possible massing concepts, and **28.6** illustrates the three methods of expansion.

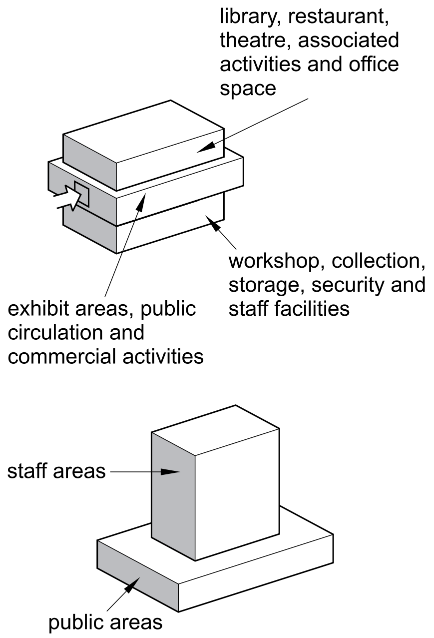
4 EXHIBITION AND COLLECTION STORAGE SPACES

4.01
The layout of public areas in a museum, **28.7**, may be based on a simple concept of free circulation around a single open-plan exhibition space, **28.7a**, or on more complex concepts related to generic interpretive structures. It is important to consider the nature of the narratives appropriate to the museum's objects of interest. The storyline of an exhibition may be translated into:

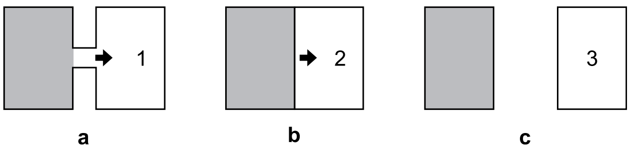
- A *linear* arrangement of spaces with beginning, middle and end, **28.7b**
- A *loop* where the essentially linear storyline leads naturally back to the beginning, **28.7c**
- An arrangement of *core and satellites* where each theme or detailed treatment of a subject leads back to a central introductory or orientational area, **28.7a**
- A more *complex* scheme combining linear, loop and core-satellite arrangement of spaces which is specifically structured to account for more or less stable relationships between collections and interpretive themes, **28.7d** or
- A *labyrinthine* arrangement where the relationships between areas can be varied from exhibition to exhibition by managing the public circulation, **28.7e**.



28.3 *A layout concept showing a clear relationship between museum functions and an approach to zoning and expansion*



28.5 *Two basic massing concepts that allow public areas to be organised on one level*

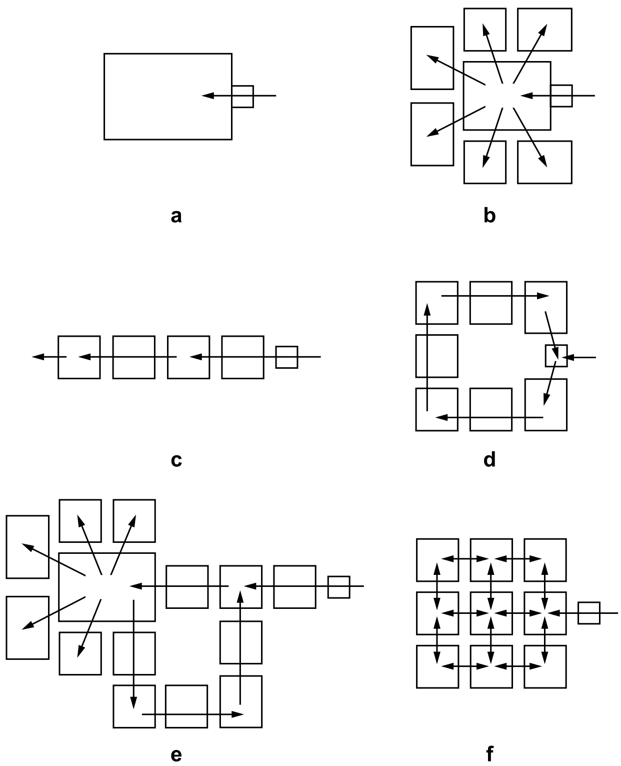


28.6 *Three modes of expansion:* **a** *Block addition;* **b** *Extension;* **c** *New building*

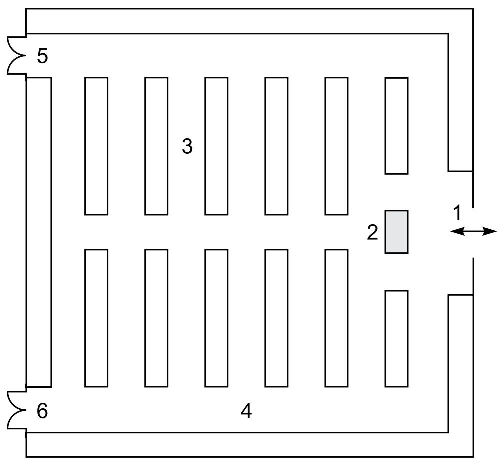
4.02

In any arrangement of exhibition spaces consider the problem of orientation, at the entrance to the museum and at key decision points in the museum information and visible clues should be provided to enable the visitor to grasp the organization of the collections, the interpretive scheme, and the public services offered by the museum. The aim of orientation is not only easy understanding of the building layout but more crucially to facilitate access to collections, information and museum services.

Many museums carefully control access to all collection storage spaces. However, it is increasingly worth considering the provision of open-access storage areas particularly for collection study. The former requires that storage areas are made secure and that visitors are closely supervised. Open access, on the other hand, requires that secure forms of storage equipment and furniture are arranged in very compact layouts. **28.8** shows a typical layout for a storage area fitted out with ranks of secure display cases. **28.9** shows a secure storage area with open-floor storage for larger collection items.



28.7 *Genetic plans for exhibit and open-access storage areas:* **a** *Open plan;* **b** *Core + satellites;* **c** *Linear procession;* **d** *Loop;* **e** *Complex;* **f** *Labyrinth*



1 *Entrance from main exhibit areas*
2 *Orientation point*
3 *Ranks of cases glazed on all sides*
4 *Full-height wall cases*
5 *Fire exit*
6 *Controlled access to staff areas and secure storage*

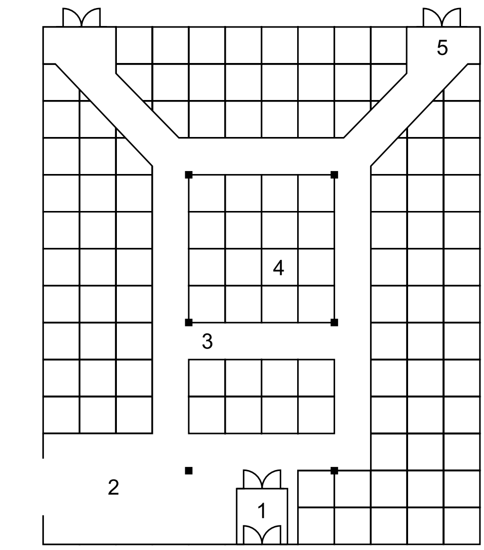
28.8 *Method of layout in open-access storage areas*

5 INTERPRETATION, COMMUNICATION AND DISPLAY

5.01

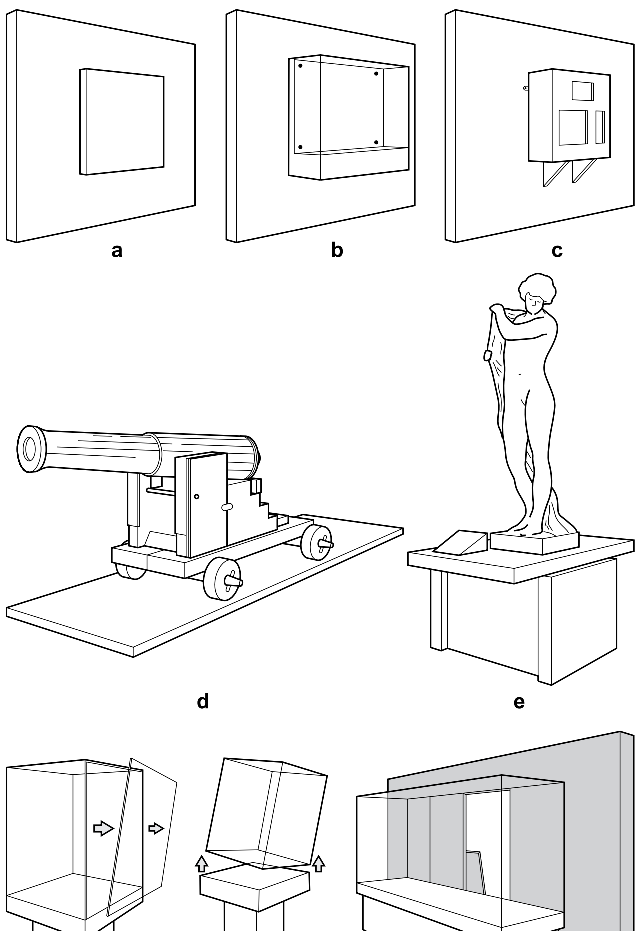
At an early stage the communications strategy of the museum should be determined. The relative importance and coordination of exhibition, education, publication, live interpretation and other forms of direct communication with the public are the essential factors that will determine the interface between staff and public. It is not sufficient to consider only the relationship between visitor and displayed collections, a wide variety of media are now used in museum exhibitions to facilitate communication with the visiting public – graphic display, audio-visual, theatre, video, computer graphics, animatronics, tableau and reconstruction, and working environments. Once beyond the stage of producing a general scheme it is important to consult an exhibition designer and a museum consultant to explore the matrix of interactions between people, information and collections that must be accommodated.

A wide range of academic expertise may be brought to bear in the interpretation of collections for exhibition purposes. Within the framework that the initial consultations provide, informed decisions may be made regarding the interpretive process and

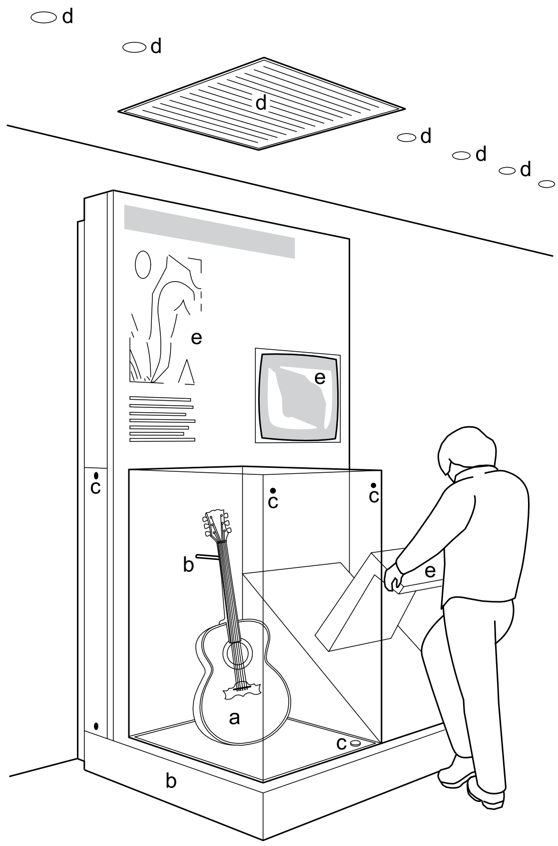


1 *Controlled entrance lobby*
2 *Inspection area*
3 *Clear aisles*
4 *Grid marked on floor, e.g. 1.5 m squares lettered in one direction, numbered in the other*
5 *Fire exit*

28.9 *Grid system for open-floor secure storage area*



28.10 *Exhibits may be of four basic types:* **a,b,c** *Hanging or wall mounted;* **d,e** *Free-standing and open exhibits;* **f,g,h** *Contained exhibits and display cases*



28.11 *Each of exhibit types in* **28.10** *may have any combination of the following elements:* **a** *Item or items from the collection;* **b** *Fixing mount, support or plinth;* **c** *Preservation: protection of vulnerable or removeable parts, lock, alarm, barrier, glazing, thermo-hydrometer (contained exhibits may have buffering material against changes in relative humidity);* **d** *Lighting;* **e** *Interpretive material: label, graphic information, sound, audio-visual, kinetic device, interactive device*

techniques, and the choice of media and types of exhibit to be employed. **28.10** shows a broad typology of exhibit and media installations, and **28.11** indicates the physical elements associated with exhibits. Reference should be made to the anthropometric data in Chapter 2 in determining coordinating dimensions; for example, the range of eye levels represented in the visiting population.

6 ANCILLARY ACCOMMODATION

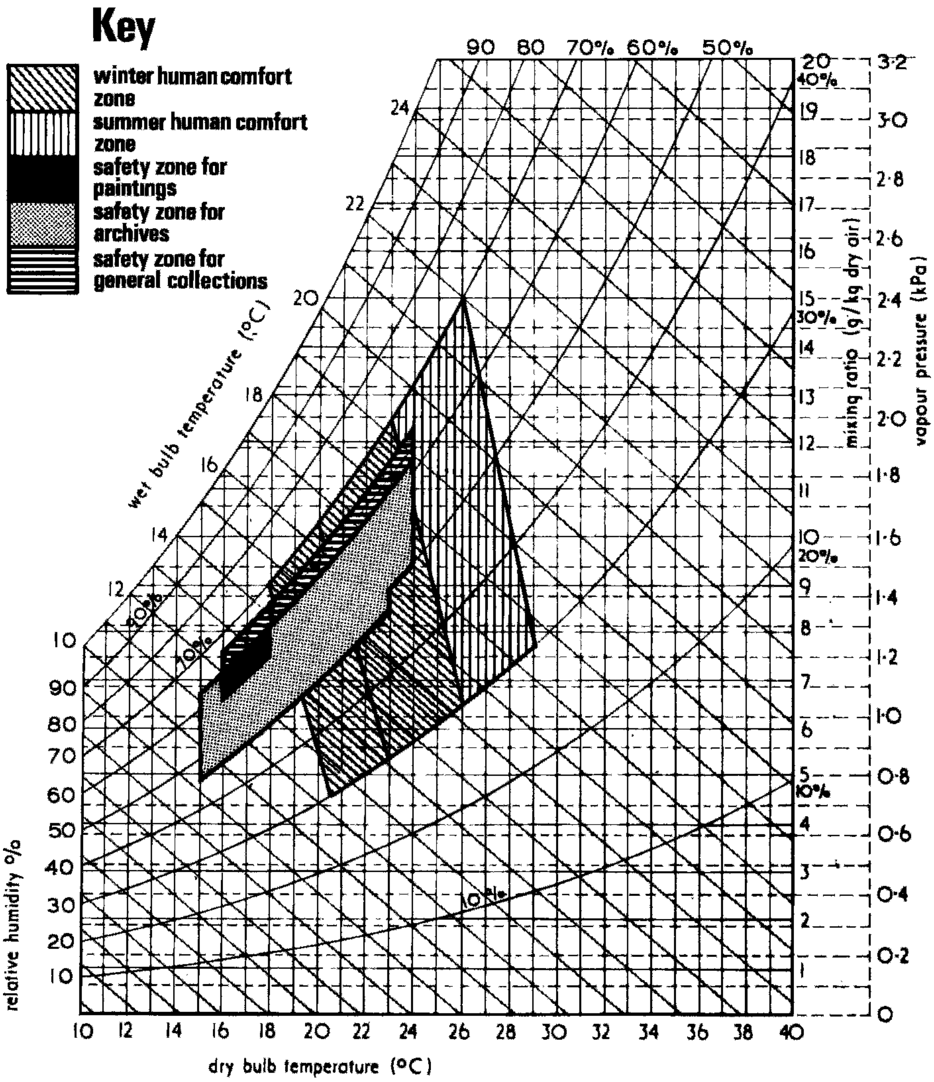
6.01

For guidance on space requirements and design criteria for offices, catering facilities, sanitary installations and cloakrooms, circulation spaces, loading bays, retail areas, auditoria, educational facilities, laboratories, and libraries reference should be made to other chapters in this book.

7 ENVIRONMENT AND CONSERVATION

7.01 Relative humidity and temperature

Special consideration must be given to proper control of relative humidity, temperature and air pollution in all collection areas of a museum or art gallery. This includes: exhibition areas; collection storage; and conservation, display and photographic work areas. Passive, low-tech approaches may be considered where climate and the inertia of the building allow. Full air conditioning may be required to cope with climatic extremes, even in this case the building envelope should provide a sufficient buffering effect to



28.12 *Psychrometric chart showing safety and comfort zones for museums, art galleries and archives*

prevent sudden changes in relative humidity during periods of repair or maintenance. **28.12** shows suitable conditions in museums, while Table I gives the ranges of museum interior temperature and relative humidity recommended in various climatic zones.

Table I Recommended temperatures and relative humidities in various climatic zones

Climate	Temp (°C)	RH (%)	Notes
Humid tropics	20–22	65	Acceptable for mixed collections. However, RH too high for iron and chloride-containing bronzes. Air circulation very important
Temperate coastal and other non-arid regions	20–22	55	Widely recommended for paintings, furniture, wooden sculpture in Europe, satisfactory for mixed collections. May cause condensation and frosting difficulties in old buildings, especially inland Europe and northern North America
Temperate inland regions	20–22	45–50	A compromise for mixed collections and where condensation may be a problem. May be best level for textiles and paper exposed to light
Arid regions	20–22	40–45	Acceptable for display of local material. Ideal for metal-only collections

7.02 Air pollution

Information about local air quality should be sought and used to decide on the appropriate approach to control. If air filtration is necessary it should not be of the electrostatic type, as malfunction can result in the generation of highly damaging ozone levels.

7.03 Light and lighting

Museum lighting is a complex subject. It is important, particularly in art museums, to determine a clear policy on the approach to natural and artificial lighting. Direct sunlight should not fall on any collection item and UV radiation must be effectively eliminated from all light reaching a collection item: at the higher energy end of the spectrum light is very effective in initiating chemical change in vulnerable materials. The maximum light dosage recommended for different categories of collection item is summarised in Table II. These dosages are normally achieved by limiting the level of illumination on collection items during visiting hours to 50 lux per annum on the most sensitive material such as paper, textile, watercolour and 200 lux on other sensitive materials such as wood, leather, oil paint.

The eye has a limited ability to adapt to changes in brightness, and as the visitor moves through the museum sudden changes in lighting levels and extreme contrasts of brightness in the field of view should be avoided. However, a reasonable range of contrast should be maintained in conditions of low illumination to prevent a dull effect and possible problems of visual accommodation.

Table II Recommended maximum light dosages

Type of collection	Dosage (kilolux-h)	Notes
Objects specially sensitive to light, e.g. textiles, costumes, watercolours, tapestries, prints and drawings, manuscripts, miniatures, paintings in distemper media, wallpapers, gouache, dyed leather. Most natural history items, including botanical specimens, fur and feathers	200	Usually only possible to achieve with artificial lighting
Oil and tempera paintings, undyed leather, horn, bone and ivory, oriental lacquer	650	If a daylight component is used great reduction of UV is necessary
Objects insensitive to light, e.g. metal, stone, glass, ceramics, jewellery, enamel, and objects in which colour change is not of high importance	950	Higher dosage is possible but usually unnecessary

7.04 Acoustics and zoning

The transport of sound through structure should be controlled. Functional zones should be provided with surface or sub-surface materials that dampen impact sounds and isolating cavities to interrupt the structural transmission of sound. Noise levels should be controlled within zones by appropriate choices of material finishes on floors, walls and ceilings, and the shaping of interior spaces to prevent flutter and unwanted amplifying effects. To generalise and simplify, the penetration of low-frequency sound is lessened by structural mass, of middle frequencies by diffusing and absorbing surfaces, and of high-frequency sound by the elimination of small-scale air gaps in doors, windows and partition walls.

8 SECURITY AND SERVICES

8.01 Security

Many security problems can be avoided by keeping the number of access points to the site and to the building to a minimum. The ideal is one public entrance monitored by information staff and/or attendants, and one staff entrance controlled by the security staff responsible for key control and the checking of deliveries and outside contractors.

8.02 Secure areas

The health and safety of the public and the staff and collection security are the prime considerations in determining the zoning of the museum into secure areas. During open hours it may be sufficient to separate public and staff areas. When the museum is closed to the public it is normal to secure more specific zones, for example:

1 Entrance, orientation/information, shop, café and toilets/cloakrooms
2 Temporary and permanent exhibitions – in larger museums subdivided into several secure exhibit areas
3 Educational facilities, lecture theatre, study collections
4 Offices: administration, curatorial, conservation, design, etc.
5 Conservation workshops, laboratories, photographic facilities
6 Collection storage, security staff areas, collection packing and inspection areas
7 Exhibition and maintenance workshops.

8.03

Security staffing is also considerably more effective and economic if all exhibition and open storage areas are on one level.

8.04 Services

For general guidance see appropriate chapters in this book. In addition, special consideration should be given to minimising the risk to the collections when locating service installations and routing service ducts. For example, water and waste pipes should not be routed near collection storage and exhibition areas.

8.05

Risk management is also greatly enhanced if a separate heating/air conditioning system or independent control system is provided in collection areas.

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29 Libraries and information centres

Brian Edwards with Ayub Khan

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KEY POINTS:
- *The community role of public libraries is changing rapidly*
- *Information is delivered in all kinds of media, not just paper*

Contents

1 INTRODUCTION

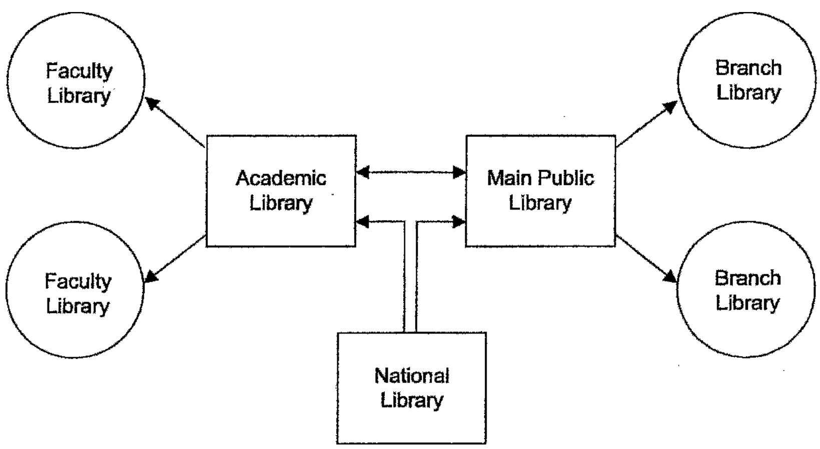
1.01
The developing role of the library has created a set of new and complex challenges for those delivering library buildings and services. The libraries of the twenty-first century are no longer simply familiar repositories for books. They have changed and expanded, been rethought and redesigned. Libraries now provide an increasingly wider range of different services, using a multitude of media, and reach a more diverse audience than ever before; see Table I and image **29.1**.

1.02
After years of relative neglect as a building type, the library enjoyed a renaissance towards the end of the twentieth century. Interesting new solutions to the architecture of the public library appeared at Peckham, London to designs by Will Alsop and in Vancouver to designs by Moshe Safdie. In parallel, national libraries underwent exciting transformation as in Paris to designs by Dominique Perrault. The libraries of colleges and universities were also transformed into dramatic enclosures for knowledge dissemination, research and learning such as at Thames Valley University designed by the Richard Rogers Partnership.

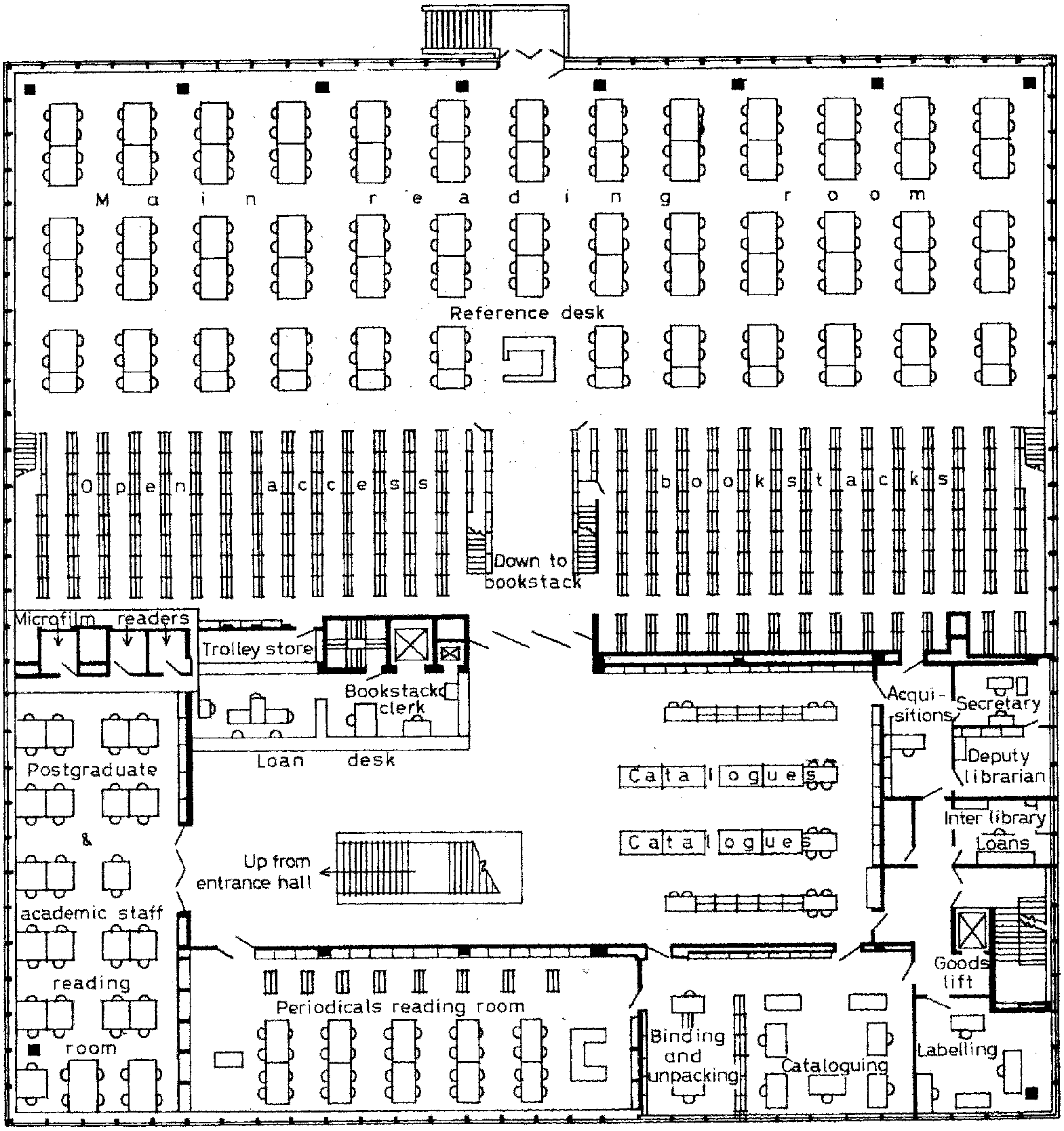
1.03
The reasons for the revival of interest in the library were threefold. First, new media technologies, particularly IT-based knowledge packages, led the government and universities to reassess the role of libraries in a digital age. Second, the resurgence of interest in other cultural building types – notably the museum and art gallery – encouraged clients and their architects to see libraries as buildings to visit in their own right rather than merely providing a desk from which to borrow a book **29.2**. Third, the expansion of universities worldwide led to a radical reassessment of the role of the academic library in teaching and learning, and this in turn changed attitudes in the public library – Table II. So, there emerged a new generation of libraries such as the Idea Stores in East London and the Discovery Centres in Hampshire where the focus is on community wellbeing rather than the individual reader.

Table I

Main types of library	Key features
National library	• National collections of books, journals, maps, etc. • Research focused • Conservation element • Specialist readership
Public library	• Collections primarily for loan • People's Network of computers • Wide range of material including local interest • Community information base • Often integrated with other 'cultural' buildings • Wide range of customer base
Academic library	• Study support for teaching and learning • Research collections • Large computer areas • 24-h access
Professional and special libraries	• Specialist collection of books and professional journals • Often contains rare material • Limited access facilities • Conservation element • Closed community of users



29.1 *Ideal pattern of public library interrelationships (Brian Edwards)*



29.2 *Typical mid-twentieth century library plan. Sheffield University Library, 1958. Gollins, Melvin, Ward & Partners (D Insall and Partners)*

1.04 Changing nature of library architecture

In a recent publication on library design (Cabe and Resource, 2003), the changing nature of library architecture was neatly summarised as follows:

Traditional	Modern
Hierarchical design and circulation	Open plan design and circulation
Imposing steps and entrance	Street level, retail entrance
Domes & Rotunda	Atriums and top floor cafes
Restricted access to books	Open access to books and other material
Temple of knowledge	The 'Living room' in the city
Institutional furniture	Domestic or club furniture
Stand alone building	Shared space with other services
Librarians as knowledge custodians	Librarians as knowledge navigators
Child free	Child friendly
Galleries and mezzanines	Escalators and lifts
Individual study carrels	Seminar rooms and computer suites

By the early twenty-first century, libraries with exciting public spaces, interesting exterior forms and more 'market place' interior qualities had begun to appear. Typical examples in the UK were Brighton Public Library by Bennetts Associates and in Seattle by Rem Koolhaas. What these had in common was their attention to urban design as well as building design, the creation of reading rooms, which invited contemplation, reflection and information exchange across media types, and the abandonment of the sterile silent world of the typical library. As a result, different areas of the libraries took on the qualities of bookshops and cafes on the one hand, and computerised trading halls on the other.

Table II Main factors leading to change in design of library buildings

- New information technology especially electronic data collections
- Greater community and educational role for libraries
- Expansion in higher education and growth in life-long learning
- Impact of popular culture on libraries

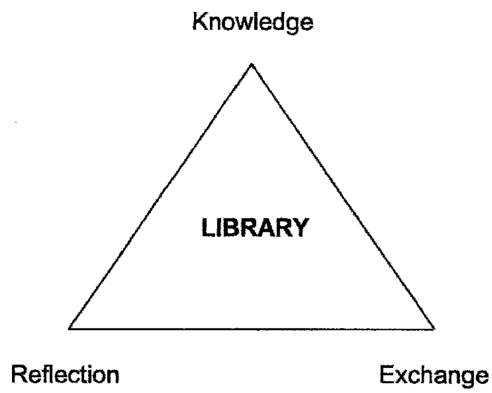
1.05 New generation libraries

In a generation, libraries have changed from being depositories of books, newspapers and journals to being local knowledge centres playing their full part in the modern digital age. Today, the typical library is an interactive network, which encompasses books, journals (many of which are electronic), CDs, videos, Internet sources and sometimes special collections. Increasingly, the network contains links to the home and study centres, thereby supporting life-long learning and reinforcing the role of schools and colleges in the community. This social role has been accompanied by a change in design values and a broadening of the brief of a typical library, see Table III.

Table III Contemporary role of the public library

Buildings which help cement together a community
Buildings which are meeting places
IT learning and support centre
Complements art gallery and museum
Access point to council services
Life-long learning centre

Rather than leading to the obsolescence of the library, new technology has liberated the library from increasingly unpopular stereotypical forms, and altered the fundamental assumptions behind their design. One such is the requirement for silence in all but designated areas. The strategy today is to encourage the sharing of knowledge and to welcome the use of the spoken word either between individuals or in groups. Since the library is often used for teaching and learning within the community, silence is expected only in private study areas. Elsewhere, the pleasure of discovery and exchange is welcomed, as is the talking computer and the tapping of keyboards. Restricting silence to special areas allows the remainder to become a place for sharing ideas and jointly pursuing knowledge **29.3**.



29.3 *Key relationships in the library (Brian Edwards)*

1.06 Lifelong learning

Another change is the assumption that the book is dominant: although books remain vital to the library, the first point of contact is often the computer screen. The interaction between digital knowledge and the printed word is a dynamic one, which requires space characteristics different from the traditional library reading room. Many modern libraries place the computer screen at the front door thereby encouraging the reader to pass through a diversity of knowledge types as they navigate the library. The role of library staff is to aid navigation through modes of knowledge rather than exercise security or merely sit behind a desk stamping the books as they are borrowed. In directing readers to the material, there is a great deal of interaction both verbal and digital, which inevitably affects the interior layout.

Another significant shift over the past two decades has been the increasing role of libraries in life-long learning, in providing community information, and in supporting the needs of the elderly. By 2020, 50% of Europeans will be over 50 years old, and here the library has particularly important services to provide. This has ramifications for the design and layout of library buildings, the level of lighting and provision of such things as toilets and disabled access. For people who do not possess English as their first language, for the poor seeking welfare support and for individuals who are newly arrived in an area, the library is often the first point of contact with a neighbourhood. Hence, the qualities and values expressed through architectural design leave a lasting impression. For these reasons, the library today is seen as a gateway to learning and a shop window of both knowledge and community services.

2 COMMUNITY ROLE OF LIBRARIES

2.01 Community engagement

Emerging multi-ethnic populations in many communities and the increasingly urgent need for literacy and ICT skills are new trends requiring changes in the design of library buildings. Early consultation with communities is essential and community views should be reflected in the art collections and choice of architect for the building. Long-stay use of libraries for study purposes will require appropriate support facilities, e.g. café, toilets and baby-changing facilities. In some cases, libraries may offer facilities akin to a 'members' club'. Libraries could become key communication centres for mobile populations, and their design will need to reflect the different 'levels and layers of entry' or different temporal zones: hot-desking, browsing, long-term study. The continued rise of the one-person household (from 18% of households in 1971 to a projected 36% in 2016) is encouraging public libraries to become meeting places for their communities. Involving the community in the design and running of libraries is a condition of the award of a number of Lottery grants for such buildings.

2.02 Young people and children

Young people should be actively involved in the design of the service offered to them. Children's services will grow in importance as the library becomes a secure, electronic safe haven in communities. Projects such as 'Bookstart' have demonstrated how important the library experience can be for very young children. The needs of children, young people and their families are constantly changing and these must be reflected in the design of libraries. Security and safety have become the key issues to be resolved in any library design for young people.

2.03 Serving conflicting community needs

The design of areas of the library will depend on the philosophy of the service and the needs of the community to be served. Many needs may appear to conflict, for example:

Study	*versus*	storytime
Privacy	*versus*	Safety
Procedures	*versus*	physical barriers

It is important to think creatively about reconciling apparently conflicting needs, most obviously through use of different zones or timing of events. Alternatives to traditional library issue or enquiry desks should always be considered, for example, 'pod' style desks, which avoid a barrier between customer and staff. The problem for the architect is how to bring the library and non-library functions into a coherent whole: Table IV.

Table IV Typical services provided within a public or academic library

Access to and loan of books
Access to journals and newspapers
Use of workstations
Access to the Internet and e-publications
Electronic access to research journals
Guidance to sources of information
Community and visitor support
Café and refreshment area
Group study activity areas or rooms
Meeting and performance spaces

The terms 'relationships' and 'adjacencies' are sometimes used to refer to the space-planning process in interior design. Careful planning of relationships within a library will ensure that a facility functions successfully both for users and staff. The relationships within a particular library are determined by studying the library's philosophy of service, its use of materials and services, and its policies and procedures.

It can be useful to draw an adjacency matrix for each area and function of the library, e.g. meeting rooms, children's library, administration, stacks, computer area. These can be grouped as follows:

- Positive adjacency – spaces are directly related
- Neutral adjacency – spaces share no common relationship
- Negative adjacency – spaces should be separated.

This will help in the final design and layout of the library space.

3 LIBRARY DESIGN

3.01

The design of library buildings should be addressed at the following levels:

- Urban design
- Access
- Building design
- Interior design

Each has specific requirements, which involve dialogue with user and interest groups, and each level has its own exacting demands, which cannot be overlooked. Library design is more than an exercise in architectural form making in spite of the growing interest in typological reinvention.

3.02 Multifunctional libraries

Different types of library have different spatial and environmental emphases, and it is only too easy for an architect to assume that the experience of designing one type of library can be used, with only small adjustment, in designing another. Fundamentally, a library is not a building but a service organisation. It also needs to be borne in mind that, in recent years, there has been a growth in multifunctional libraries, for example, combined university and public libraries, and the combining in Local Authorities of libraries with other council services as 'one-stop shops'. This is the approach adopted in the Idea Stores concept.

3.03 Site selection

Site selection is often part of a wider development, for example, in the expansion of a university or as part of urban regeneration. The head librarian is normally consulted on the choice of site and usually leads the development of the brief. Matters to consider are:

- **Access** – e.g. nearness to other civic, retail or institutional amenities preferably on foot.
- **Location** – satisfactory and acceptable to the population being served.
- **Traffic flow** (ingress and egress) and traffic controls – accessibility by public transport and car.
- **Site availability** – the site needs to be available for immediate use/purchase. Consider environmental hazards, constraints on historic buildings and limits on maximum area or height of building.
- **Topography** – grading needs and other natural features that might affect the development.
- **Solar and wind orientation** – much of the energy demand in buildings is for light and climate control. The site should allow for maximum use of natural light and ventilation. The effect of the sun's glare on the building will also need to be assessed especially in the context of PC screens.
- **Visibility** – the site should be in a prominent position, i.e. with natural views to and from the site.
- **User and staff safety** – the site will need to be safe and secure at night and well-lit. Parking should be accessible nearby and child safety considered in terms of proximity to major roads.
- **Community synergy** – it is crucial to check the proximity of other community (institutional) amenities, perhaps as part of a cultural quarter or retail area. Consider current known footfall in the area.
- **Size for growth** – ability to accommodate expanded library facilities if required in the future, e.g. an extension to the building or further parking.

3.04 Standards

Standards and specifications vary and do not exist for every type of library design. There are no absolute standards on the amount of public library space per capita. The international guidelines (IFLA, 2001) state that because needs vary so much 'it is not possible to propose a universal standard on the space required for a public library'. Within the UK, the Department of Culture, Media and Sport (DCMS) has suggested a figure of 23 m^2 of new library space per 1000 population as a potential public library standard. Archive and other specialist libraries have their own needs and are covered in BS5754.

3.05 Urban design

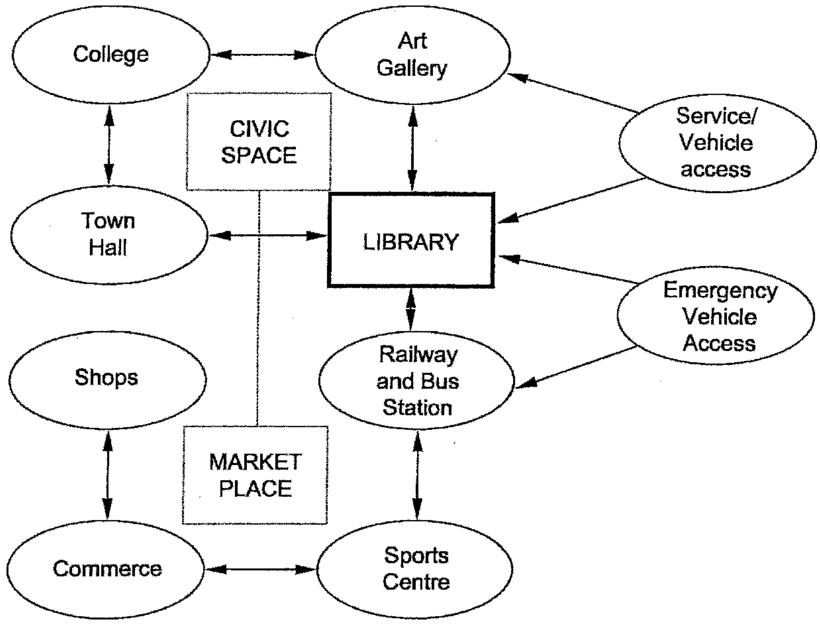
The public library needs to be well connected to civic life and the academic library located at the centre of the college or university. Table V summarises considerations. Good access to pedestrian flows and public transport is essential, as is the ability to service libraries with their ever evolving collections and needs. Hence, there will normally be a public front and a service rear or undercroft. However, the public entrance is not normally the library door but a gathering space immediately outside it. This should be designed with the characteristics of a public square with attention to landscape design, public comfort (i.e. seats) and community or personal safety.

The library 'square' is where users will meet, escape from the confines of the library to reflect on the material, take short breaks to eat sandwiches or visit local cafes or other cultural facilities, and engage in the ambiance of the public realm. Aristotle defined the city as 'a collection of buildings where men live a common life for a noble end' and nowhere is this more evident than in the public library, **29.4**.

The external library space should be free of cars although public modes of transport can (and often should) pass nearby. There also needs to be provision for disabled access and facilities for the storage of bicycles. The trend towards co-locating libraries with other commercial or cultural facilities means there are often common entrance and service areas. The growth in 'wifi' has an important impact on library site choice.

Table V

Principal site planning considerations	Issues to consider
Civic presence	Relationship to other public buildings Visible presence
Public access	Access to public transport Disabled access Proximity to retail areas
Service access	Access to road system Delivery and storage areas
Urban design	External public gathering space Safe, secure and legible routes



29.4 *Conceptual diagram of the relationship of library to other civic functions (Brian Edwards)*

3.06 Access
There are many issues around access to library services, dominated by the legislation enshrined in the Disability Discrimination Act (DDA) of 1995 requiring adequate access for those with mobility and sensory impairments. Access is required not only to the physical building but also to the collections, including computer resources.

New buildings need to be 'DDA-compliant'. The following issues need to be addressed:

- Accessing the library and accessible routes
- Décor and signs, including lighting, switches and controls and signage
- Facilities such as toilets, furniture and fittings, emergency systems
- Information access and assistive technology.

Level access is preferable and ramps essential where changes of level are inevitable. The public space alongside the library entrance provides an opportunity to make a statement of the building and this in turn can help signal the significance of the library. It also provides the chance to incorporate sculpture or other forms of public art into the city – some of which may contain text references to the library collection.

3.07 Academic library siting
With University libraries, the building needs to be centrally placed on the campus and located where 24 h surveillance is possible. There is often a plaza at the centre of campus where other academic institutions are located such as senate house, refectory, gymnasium and registry. This provides an opportunity for the formation of a student-centred academic mall, which ties together the key shared facilities with links to the separate faculty building further afield. Hence, one role of the academic library is to define the centre of the campus both spatially and in terms of building hierarchy.

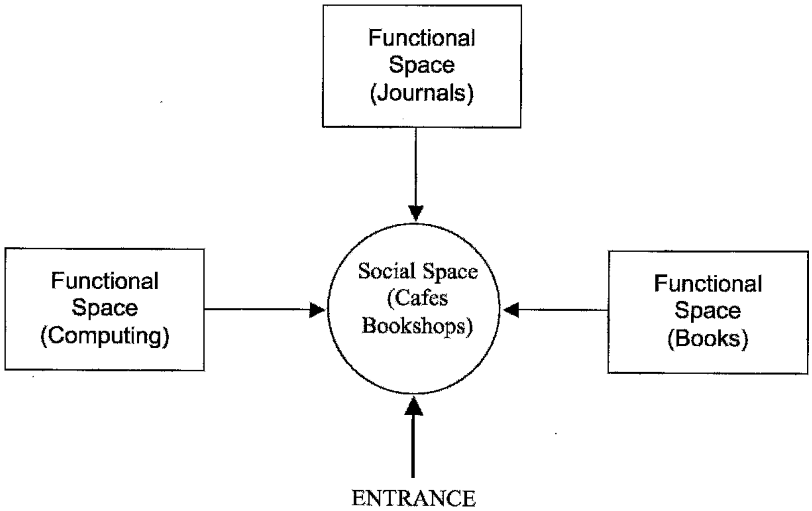
3.08 External relationships
The flows from the external pubic space to the main building entrance are more clearly defined if attention is paid to urban design at the briefing stage. The choice of site often dictates external relationships. Proximity to public transport and existing pedestrian or cycle flows is imperative. There are parallel flows too which need to be considered such as the delivery of books, newspapers, furniture and access for staff. The service entrance needs to have good road access and delivery and parking space. Increasingly, information is electronically delivered using wire or wireless technology and this eases the demand upon physical service areas. However, delivery and storage of the library material is a major consideration at the site planning level.

3.09 Building design
The external square or set back public space leads the library visitor immediately to the entrance doors. These need to be inviting, wide and transparent, and arranged so that the interior can be viewed immediately upon arrival. It should also be possible to view the major library spaces from the outside, thereby providing links to the life of the city. Too frequently, the demands for security interrupt the physical and visible flows between the inside and outside worlds.

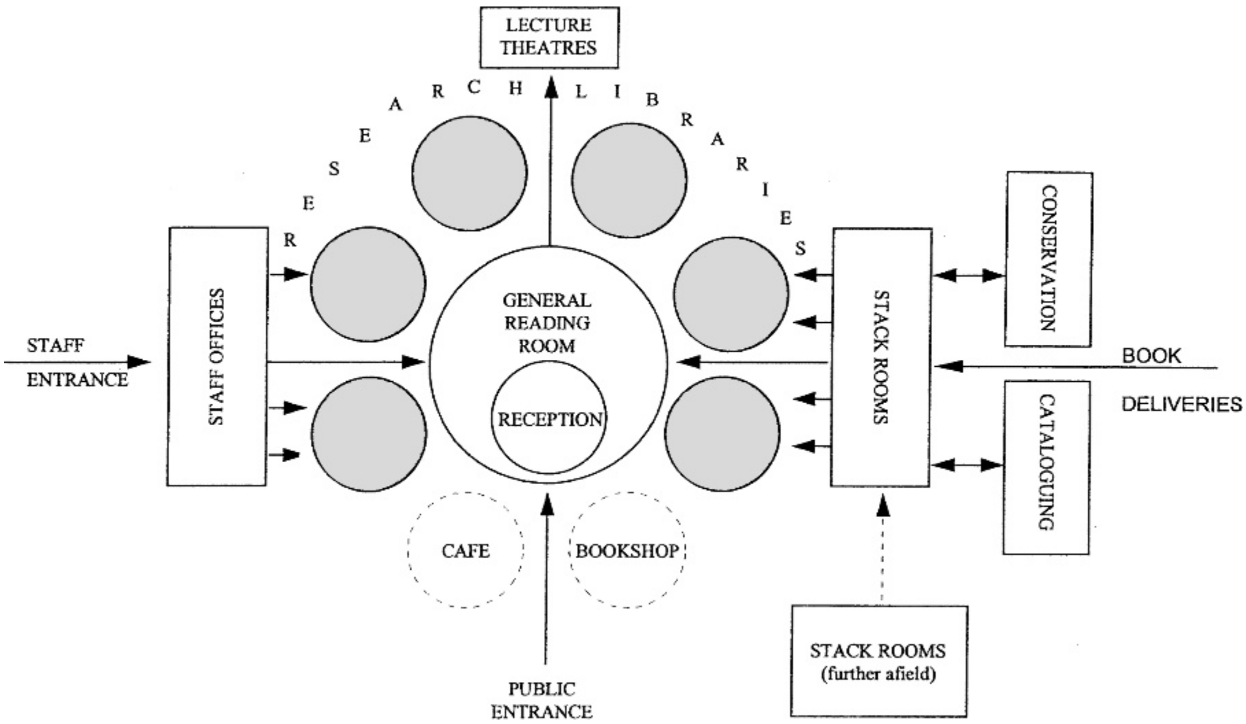
Once inside the library, the user should be able to comprehend the key spaces and principal routes. Hence, the library desk should not form an impervious wall but provide an inviting permeable barrier through which visitors pass. The control desk where books are checked in and out should remain part of the entrance experience, not the sole or dominant element for the visitor. The trend towards self-issue and return systems (using RFID technology) makes the control element less evident and releases library staff to aid the reader rather than exercise security.

In large libraries, it is often possible to form an inner foyer before the user reaches the library desk. Here, there may be lockers, information boards relating to community activities, a café and sandwich bar, exhibition area and meeting rooms, **29.5** and **29.6**. This transition space between the inner and outer worlds requires particular attention in order to avoid disruption to the library. However, it is often the point where non-traditional users engage in the community facilities which libraries are increasingly providing.

3.10
The library desk and control barrier provides an essential element in the working of many traditional libraries. The library information desk is the main point of contact between users and library staff. The spoken word is essential to aid navigation through the collection, augmented by the catalogue and various subject specific guides. Increasingly, the next point of contact is with the computerised catalogue or the IT support area, which is



29.5 *Relationship between the functional and social zones in the library (Brian Edwards)*



29.6 *Diagrammatic layout of a national library (Brian Edwards)*

usually nearby. To counter the dominance of digital information systems in some libraries (which can deter the elderly), there is often a magazine or newspaper area nearby.

3.11 Academic library book collection layouts

In academic libraries, there are two main strategies for arranging the book collection. The first is to stack the books near the centre of the library arranging reading tables around the edge where there is good access to natural light and external views. The second is to place the books around the perimeter with a large multipurpose space often lit from above in the centre. The latter provides the opportunity to create an interior volume where readers can interact and move freely between paper and electronic media. The integration of modes of knowledge and types of media, however, is often difficult in practice because of the specific requirements of computers and the nature of some paper-based collections such as old newspapers or photographs. So, in spite of the ideal of integration, there are often special study areas dedicated to types of media or study material.

3.12 Design characteristics and flexibility

Since the storage and use of knowledge is changing rapidly, libraries need to retain a high level of flexibility. The ability of the building to change over time without compromising the key attributes of what constitutes architecturally a ‘library’ is an important consideration at the design stage, Table VI. Libraries are the

Table VI Key design characteristics of libraries

Visible, recognisable and legible as a type
Adaptable to new information technology and physically extendable
Adaptable to new user needs
Comfortable and disabled friendly
Inviting, safe and secure for users
Protection and security of the collection

recognisable buildings where spaces like the reading room help to define the type. To provide flexibility at the price of character is to remove the civic dimension which increasingly is required of clients and users. However, libraries need to be able to adapt to changing information technologies and their evolving cultural or social role if they are to achieve their full relevance in the twenty-first century.

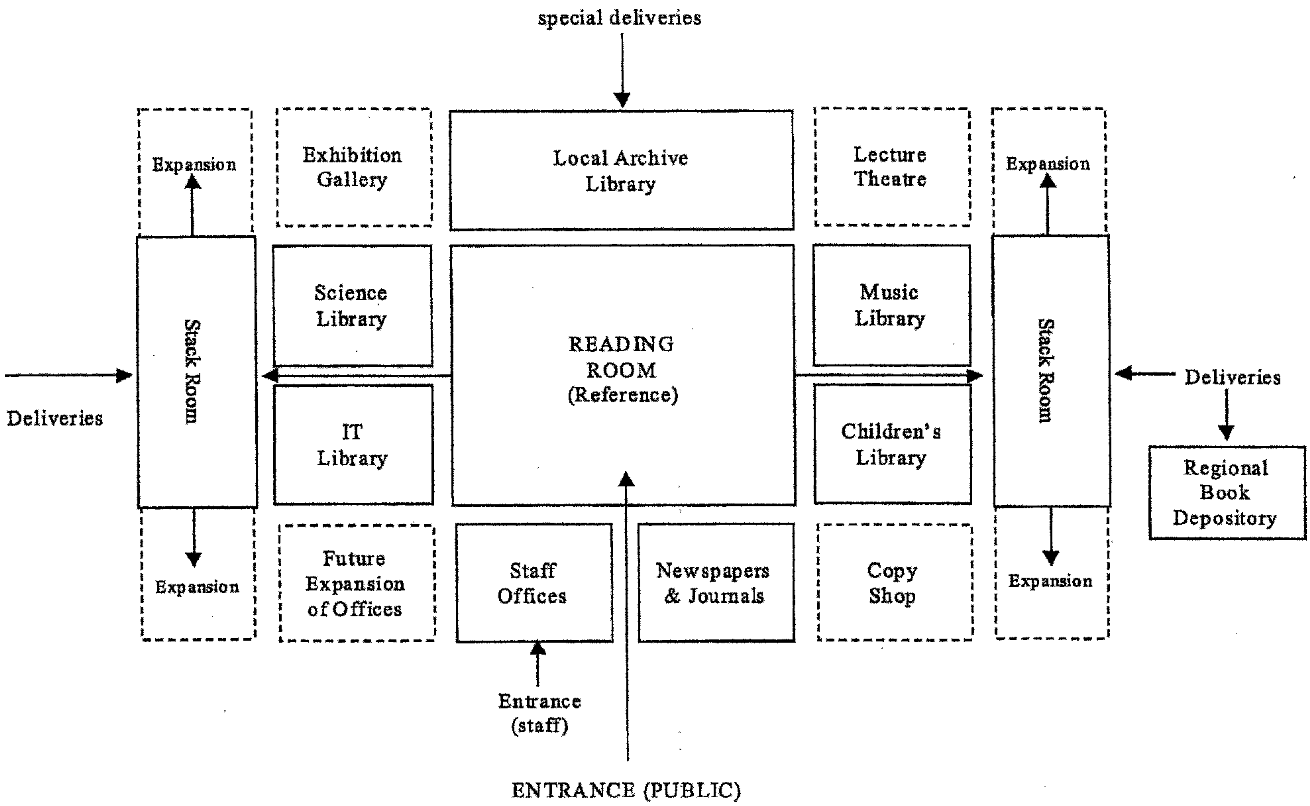
3.13 Interior zoning

Although in an ideal world, paper and electronic sources are physically integrated on the reader's desk, in reality the technical demands and characteristics of different types of media result in separate zones being allocated for each. There is usually a zone or room for computer users, a separate area for those referring to journal or newspapers, the library book stacks and collections of reading desks and perhaps special study carrels. In public libraries, areas are often zoned, for example, children's area, activity space, teen area, local studies collection, reference, tourist information, **29.7** and **29.8**. The separate zones may be distinctive functional areas but they are generally linked perceptually. It is an arrangement which allows one area to adopt a different policy on noise or security than another, it permits internal change without disruption to the whole, and it allows different users to employ the library resources in different ways.

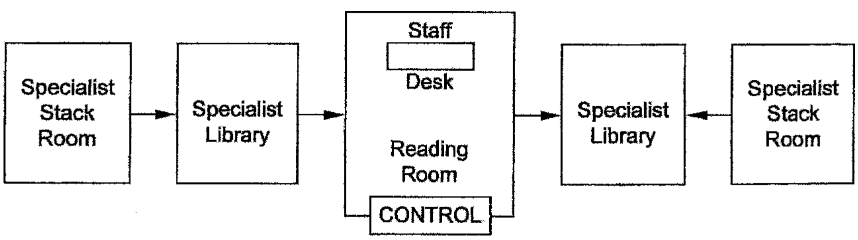
3.14 Collaborative learning

However, it is important for library designers to be aware of a move in academic circles towards collaborative learning. Groups need space for five to ten people to work together in order to discuss a project often referring directly to the study material in the library. Space for one-to-one training in the use of ICT may also need to be provided.

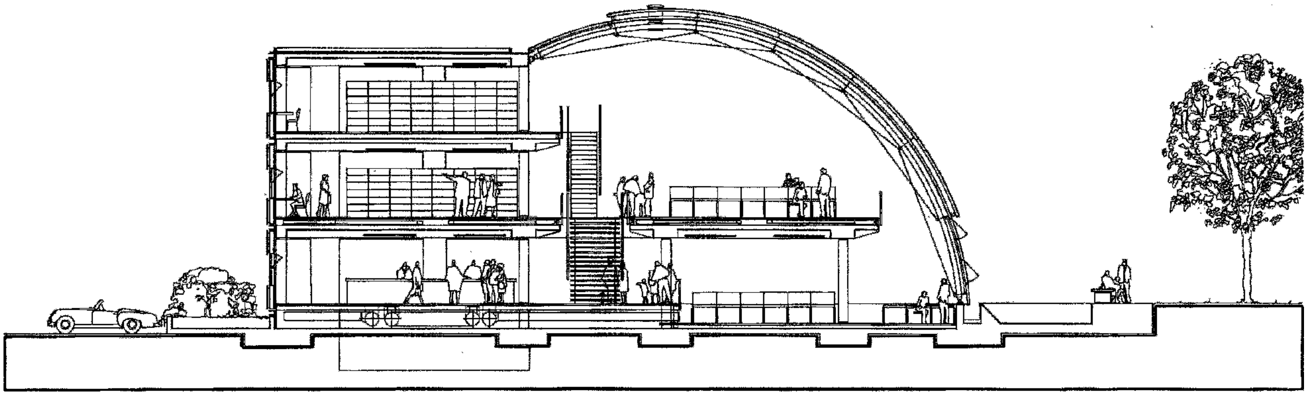
It is also important to provide informal spaces where people can meet and talk, whether a public, school, or academic library. Computers, too, can be used collaboratively, so should be included in the planning of group spaces **29.9**. Another development has been the gradual disappearance of the lines separating different media. Libraries no longer require separate, specialised areas for users to listen to audiotapes or watch videos. Media equipment tends to be multifunctional, so service points should also be multi-functional and service desks combined to enable response to a range of enquiries and customer needs. In Europe, libraries are now being renamed 'mediatheques' to reflect this change in usage.



29.7 *Diagrammatic layout of a central library (Brian Edwards)*



29.8 *Diagrammatic layout of a branch library (Brian Edwards)*



29.9 *Traditional library structure (left) and computer and discussion space (right) are combined effectively in the Learning Resource Centre at Thames Valley University (Richard Rogers Partnership)*

3.15 Interior design culture

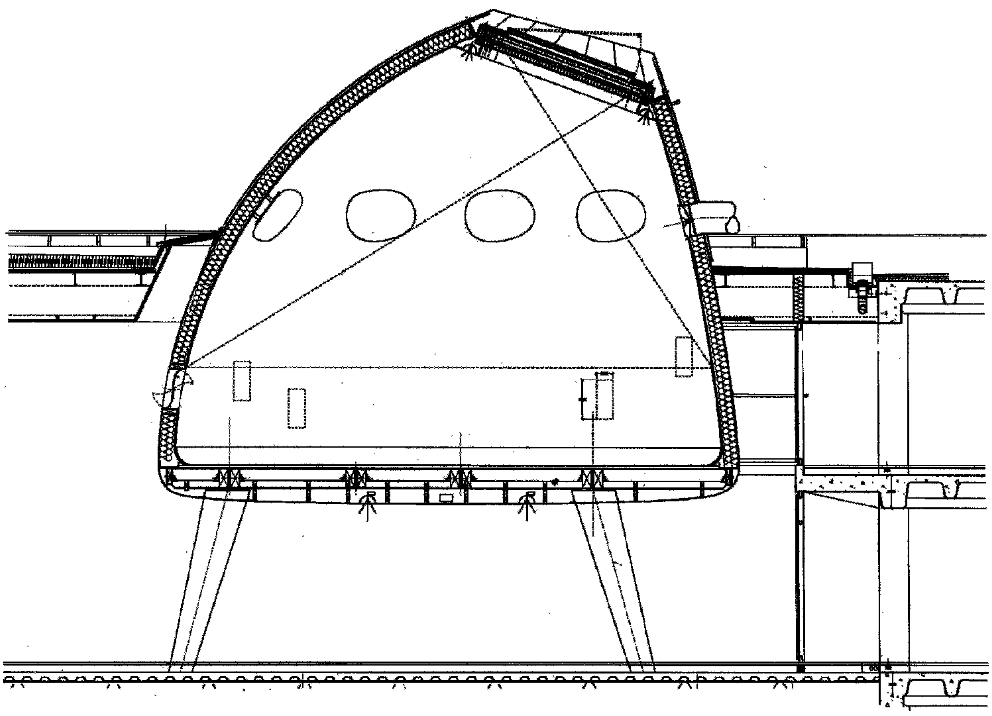
A varied interior culture is preferable to one where there is a corporate standardisation across the whole estate. Such variety can be engineered or left to grow as the nature of users and the collection changes. At Peckham Library, there are three pods within the main book areas designed specifically to house the special collections, **29.10** and **29.11**. Zoning the interior of the library into distinctive areas rather than separate rooms is the policy generally adopted in all but national libraries. Here, the nature of the collection or its conservation requires much more attention to security and environmental stability. Elsewhere, integration is the norm within the constraints imposed by noise, computer screen conditions and general comfort. It is important that the interior layout provides space for reflection on the library material employed rather than its use in strictly functional terms, Table VII. Hence, the nature of the spaces, particularly how they are lit and furnished, and the interior views available, all deserve attention. Even if the information sources cannot be gathered into one place, the reader should be encouraged to use imagination to join them together. This is the basis for the traditional domed reading rooms of public libraries.

Table VII Key factors to consider in interior design

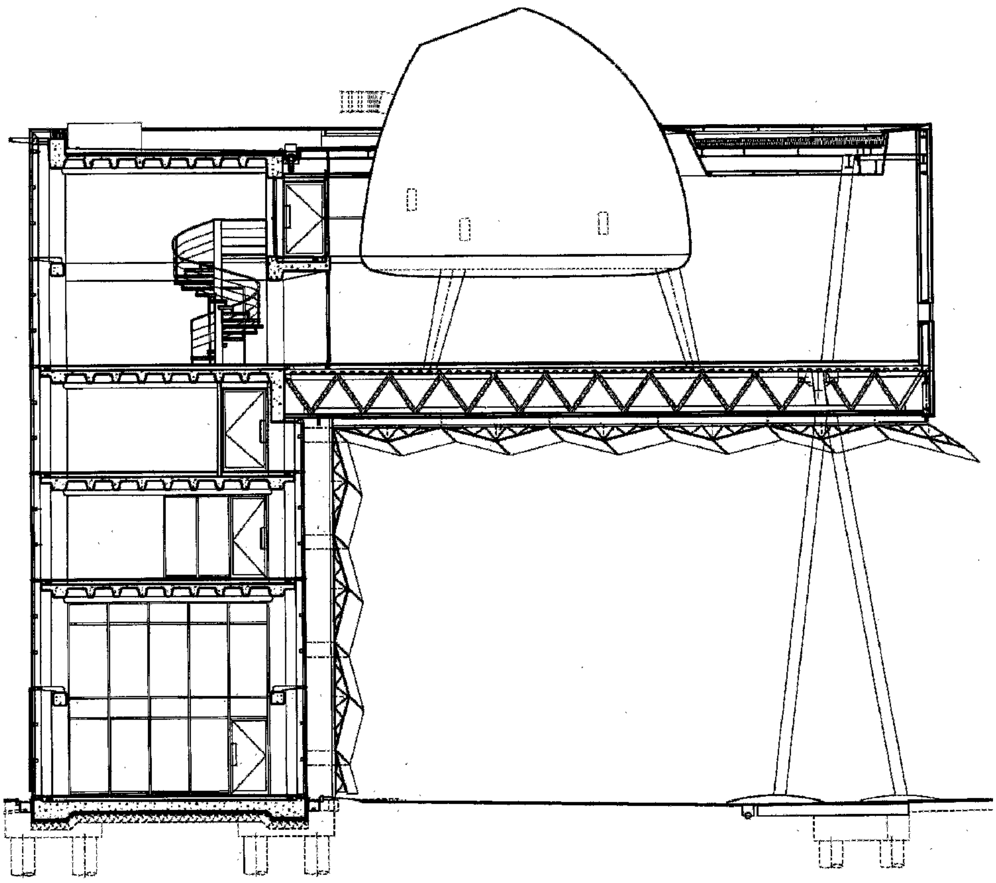
Technical
Are the floor loadings adequate for the collection?
Is the wiring layout suitable for future IT needs?
Are the environmental conditions acceptable for the planned use?
Is the collection secure from fire or theft?
Aesthetic
Is the building welcoming as well as functional?
Are the routes and major spaces legible to the user?
Is there space for reflection?
Do readers have good access to daylight?

3.16

The library is a building type where users often spend a great deal of time in private study. For many students, the bulk of their study time is spent in libraries and for the general public the library is often a place where many hours are devoted to intellectual pursuit. There is, therefore, growing demand to provide facilities of a non-library nature within the building. This normally consists of a café and sandwich bar but can also include gallery space for showing local art works or displaying community projects.



29.10 *Section of a study pod*



29.11 *Peckham Public Library section showing the distinctive study pods (Alsop and Störmer)*

As libraries broaden their social role to become 'Idea Stores' there is pressure to increase the extent of non-library accommodation within their walls, **29.12**.

4 ROOM LAYOUT, FURNITURE AND SHELVING

4.01

Most libraries are sub-divided by book stacks, which provide the basis for zoning areas into functional parts, Table VIII. The stacks provide also acoustic protection, **29.13** and **29.14**, have important environmental qualities (they provide thermal mass) and help define routes through the library. The position and type of shelving is essential to the smooth operation of a library and needs to be located carefully in relation to the fixed parts such as columns, lifts, stairs, walls and doors. The book stacks also dictate the layout of seating, tables and the position of workstations. Bookstacks are best grouped together in order to provide space for study and group learning.

4.02 Table layout

Table layout is an important consideration since the distribution of reader spaces can influence the configuration of columns and interior walls. The layout of tables and shelves is largely dependent upon the type of library in question. Libraries with large book collections increasingly store less frequently used material in basement areas or in other locations. Here, modern rolling book stacks can be employed, thereby saving on space and cost. Basement storage is useful because the high loadings can be more readily accommodated than on upper floors and the reader is not kept waiting too long for the material to be accessed. Reader tables, rather than individual study desks are the norm, and these are usually placed near the perimeter of the library or in special reader rooms. Tables usually have the facility to use a laptop and often there is a desk lamp and small storage area provided per reader space on a shared table of perhaps eight seating positions. Much depends upon the type of library and the proximity to specialist IT areas.

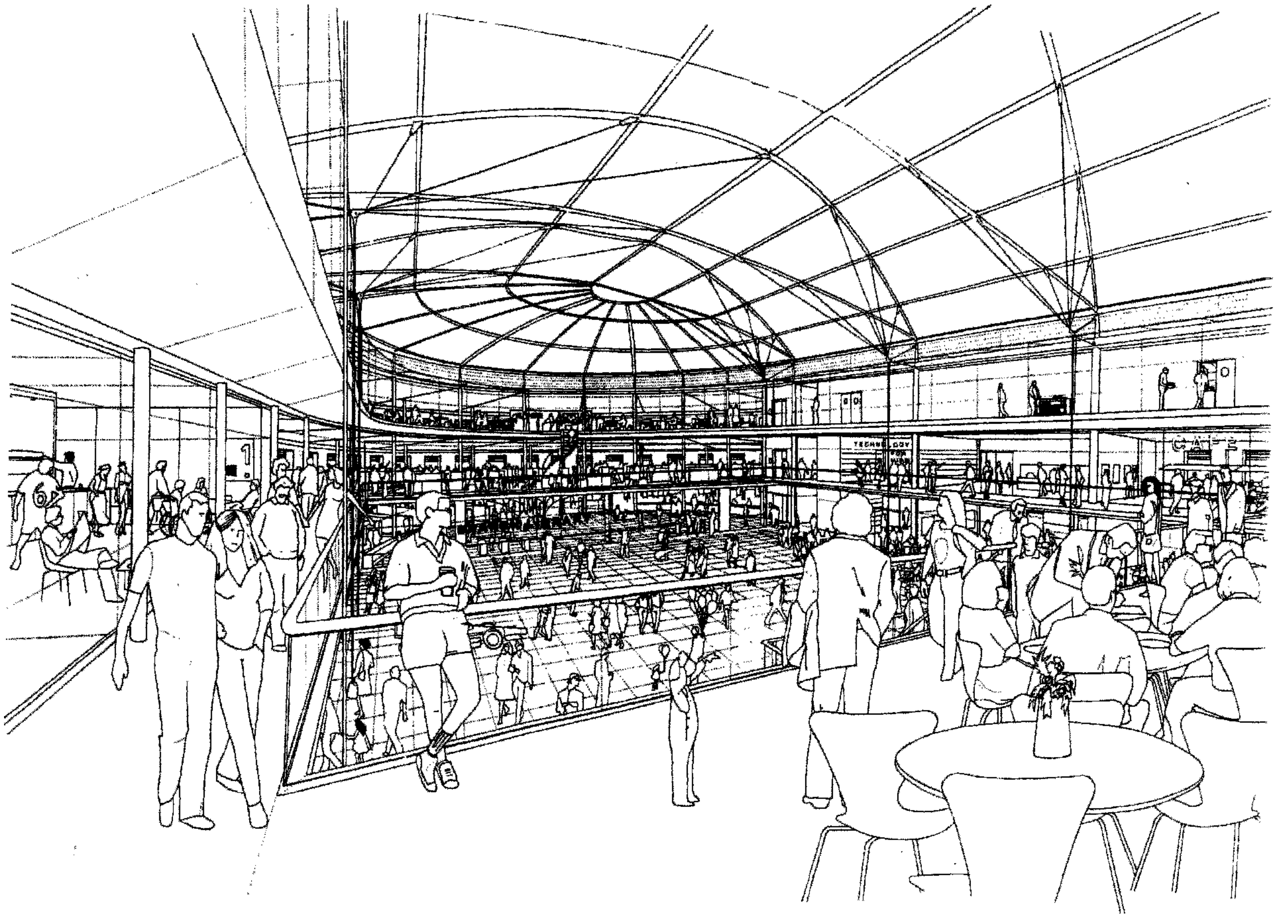
An area needs to be set aside also for special library use such as employing large atlases or maps, broadsheet newspapers and archival material. There may be security issues to consider as well as furniture needs such as large tables. Often there is the need to make copies and this can pose a noise and environmental problem. In public libraries, there is often a sharing of tables for a variety of purposes but in academic and professional libraries, study areas are set aside for specific purposes. Table IX summarises key issues.

4.03 Reading and literacy skills

The development of reading and literacy skills are now central services offered by libraries to their communities. Power displays and face-on shelving are important in highlighting stock. Stack area should have overhead line-of-sight subject signs in the aisles so that users can navigate through the library. The design brief for a new library should explore the means to achieve maximum capacity while displaying stock in an attractive manner. Libraries should take note of ways in which the retail sector displays its signs and products, and provides customer access.

4.04 IT provision and electronic media

Growth in IT provision is sometimes at the cost of areas for book storage. As a result, shelving is often closely spaced and increasingly the bulk of the book collection is stored elsewhere. Growing use of libraries is sometimes at the expense of space standards, both in seating areas and library shelving. Designers need to



29.12 *Norwich Public Library (Michael Hopkins and Partners)*

Table VIII

Considerations for layout of book stacks	Secondary issues
Position book stacks to define routes through library	Ensure safety exits are visible
Use book stacks as acoustic barriers	Consider acoustic and thermal properties of book stacks together
Compress stacks to create reader areas at perimeter of building	Provide adequate space for safe use in dense stack areas
Provide light sensors in deep stack areas	In large libraries, lighting is the major energy user
Ensure floor loadings are adequate for dense book stacks	Changing internal layout can be constrained by structural limitations

consider both the needs of readers and staff who have the task of servicing the collection. Although books are generally decreasing in size, art books are getting larger, and whereas PCs are also shrinking with growing use of laptops, the number of readers who arrive armed with the latest digital technology is increasing rapidly. Hence, layouts, service points and wifi provision need to reflect these changes.

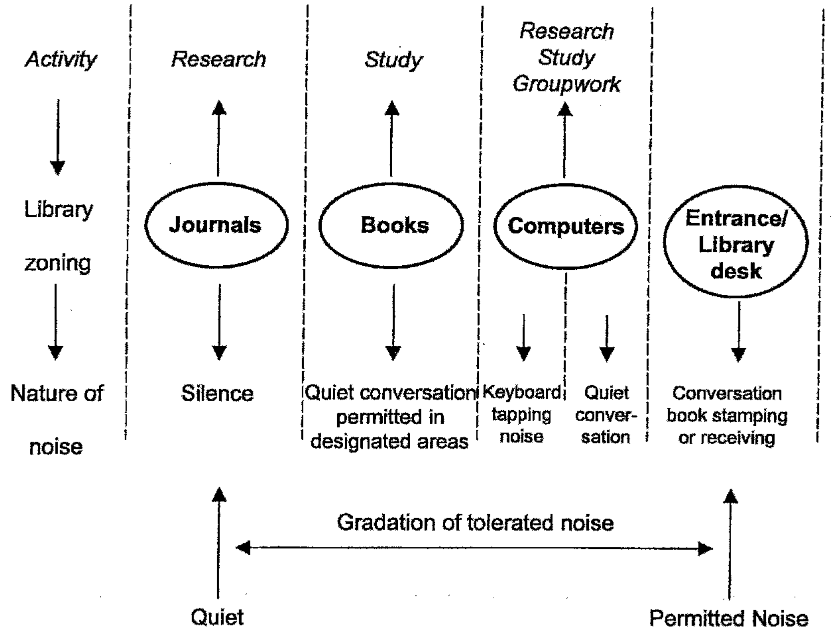
Academic libraries provide much more computer space than public libraries. In some university libraries, the areas given over to IT-based learning resource centres can exceed that of book and journal storage. The use and loan of CDs, the development of a learning rather than teaching culture, has led also to the academic library being extensively employed in group teaching. Rooms are set aside for seminars within the library itself, and often the Internet provides the main resources on which students draw. As a result, the nature of the interior spaces change into a hybrid between the traditional library reading room and something more akin to a stock market trading floor. The use of the library for seminar type teaching also puts pressure on the lifts, stairs and corridors at the end of timetabled teaching and this can disrupt private study areas.

Dedicated areas for the use of electronic media are increasingly provided in libraries of all types. Although the integration of digital- and paper-based systems is the ideal, often the constraints of security, noise and readership needs leads to the zoning of an area for the prime use of CDRoms and other forms of electronic media. In many academic libraries, a dedicated learning resources centre is provided catering specifically for computer use often with associated mixed media, printing and teaching spaces. These areas require provision not unlike that of the most advanced international call centres. Hence, the design breaks the mould of the traditional library in the type of lighting, wiring layout and acoustic provision. As a result, there is often a library and IT learning centre side by side either as two joined buildings under the same envelope (Thames Valley University) or two separate but adjacent buildings (University of Sunderland). In public libraries where the level of IT provision is lower, the two activities are normally integrated. Whatever the layout, it is imperative that users can move smoothly between paper and the various ICT modes now available.

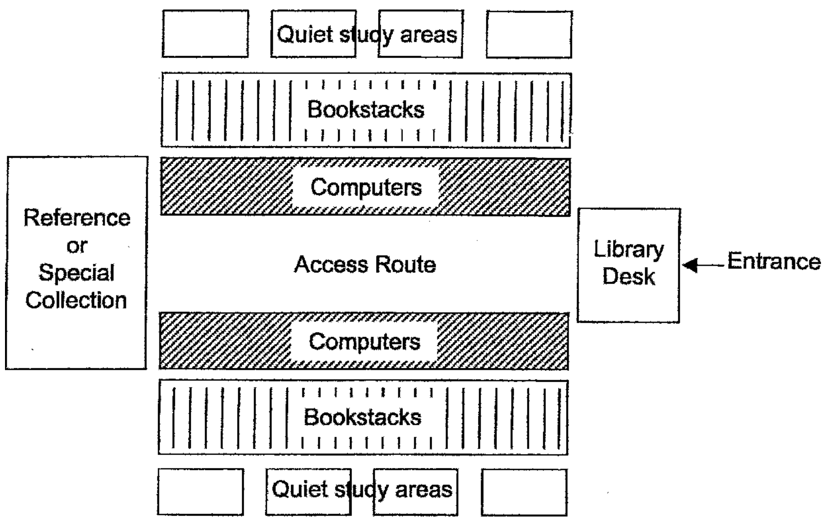
5 SPACE STANDARDS

5.01 Space types

There are no international standards for space in relation to public libraries, as the range of groups served is deemed to be too variable (IFLA, 2001). Schools and academic libraries do have some recommended space allowances related to the numbers of students, Table X. For all types of library, there are several guides available on the Internet to help work out the space required for a new or



29.13 *Noise zoning in a typical academic library (Brian Edwards)*



29.14 *Noise planning in a typical academic library (Brian Edwards)*

Table IX

Considerations for layout and design of library furniture	Secondary issues
Provide visible staff desks on each floor to guide readers	Library staff should be visible to aid readers
Provide reader tables in areas well served by natural light	Place tables at edge of library or in internal atria spaces
Divide large reader tables into personal study areas	Provide separate power points along length of table
Ensure mix of table sizes and layouts to suit nature of collection	Atlases and newspapers require different table designs
Ensure tables are connected to IT systems	Encourage mixture of media usage at study tables
Provide soft seating areas by magazine and journal stacks	Avoid the area becoming a refuge for the homeless

Table X Space Standards

Public Libraries
- 30 m^2 for every 1000 population
- 5 reader spaces per 1000 population
- Storage of 110 volumes/m^2
- Circulation areas around 20% of total floorspace
- 1 staff member per 2000 population

Library provision for Colleges
- 1 m^2 for every 10 students
- 1 study space per 10 students
- Library floor area approximately 10% of total college floorspace
- Library floor area approximately 20% of total teaching area
- 2.5 m^2 study space per student

Library provision for Universities
- 1 m^2 for every 6 students
- 1 study space per 6 students
- Library floor area approximately 12–15% of total university floorspace
- 4 m^2 study space per student

refurbished building. In the context of the whole space required, various sources agree on the following seven types of space to be considered in a new library building:

- *Collection space* – to take account of books (open access and closed), periodicals (display and back issues) and non-print resources. Digital resources may need some space allocation.
- *Electronic workstation space* – for staff use, public use in the main areas as well as any need in meeting room areas. A public access catalogue used from a seated position requires 4 m^2.
- *User seating space* – at tables or alone. Plan for 5 seats per 1000 users. Table seating requires 2.5 m^2 per reader, a study carrel 3, and lounge chairs 3–4 m^2. A useful average is 3 m^2 per seated reader.

- *Staff work space* – including areas in the public part of the library and separate work room facilities. Fifteen square meters per staff work area (e.g. issue counter, help desk) is a good planning guide.
- *Meeting space* – including conference space, a lecture theatre or a room for children's activities. When calculating seat space, the square footage for lecture-style chairs would be the total number of chairs multiplied by 10. For conference-style seating, the figure would be multiplied by 25. Seating for children's activities would require 1.5 m^2 per child. Space would also need to be allocated to other functions like cafes with storage space for equipment.
- *Special use space* – e.g. a local history room, job centre, tourist information centre or special collection with appropriate facilities for users to access the material. Generally, suppliers of equipment should include this detail in their catalogues.
- *Non-assignable space* – including toilets, stairs, lifts, corridors and space required for heating or other systems on which the library depends. In general, non-assignable space accounts for between 20 and 25% of the gross floor area of a typical library.

5.02 Usage data

Current library data should be taken into account in the specification for a new library relating to:

- Opening hours (all or part of the library including out-of-hours)
- Peak usage times
- Usage broken down by hours
- Days of the week library open
- Times of the year (particularly for university/college libraries)
- Number of users (preferably separate figures for each part of the library)
- Associated activities, e.g. meeting rooms, exhibition area(s)
- Facilities, e.g. toilets, vending area, café
- Staff services to users – how many staff will be on duty/service points, security points
- Staff facilities, e.g. workroom, offices, post room, services, storage.

5.03 Public libraries

There are no absolute standards on the amount of public library space per capita. The 2001 International Federation of Library Associations guidelines state (p. 43) that: 'The amount of floor space required by a public library depends on such factors as the unique needs of the individual community, the functions of the library, the level of resources available, the size of the collection, the space available and the proximity of other libraries' and they go on to say that because these elements vary so much, 'it is not possible to propose a universal standard on the space required for a public library'.

The publication 'The Public Library Service: IFLA/UNESCO Guidelines for Development' includes (in Appendix 4) a set of guidelines produced for Ontario Public libraries in 1997, which states that, for a community under 100 000, the appropriate amount of floor space for public libraries is 56 m^2 (600 ft^2) per 1000 capita. This set of guidelines goes on to prescribe:

- Collection space: 110 volumes/m^2 (10.8 ft^2)
- User space: five user spaces per 1000 capita, user space = 2.8 m^2
- Staff space: 16.3 m^2 (175 ft^2) per member of staff (assuming 1 member of staff per 2000 population)
- Multipurpose rooms: depends on community service and programme objectives
- Non-assignable space (staircases, toilets, etc.): 20% of net space (= space taken by first four categories)

In 2001, the DCMS consulted on a net figure of 23 m^2 of new library space per 1000 population as a potential public library standard. No standard along these lines was, however, introduced. Analysis shows that figures currently in use for planning purposes are in the 28–32 m^2 per 1000 population range. There has been a tendency for the figure to rise through time, not least because libraries are acquiring more functions, often at the behest of central government. Thirty square meters per 1000 population is a good rule of thumb.

5.04 Secondary school libraries

On the subject of library space, secondary school guidelines from the Chartered Institute of Library and Information have a chapter devoted to facilities management, which includes a section on space requirements. This chapter refers to DfES recommendations for space in schools, which have now been superseded. The current guideline documents for secondary schools can be downloaded from the teachernet website at Building Bulletin 98: Briefing Framework for Primary School Projects.

At the time CILIP's secondary school guidelines were being written, the DfES guidelines were being revised and CILIP issued guideline figures. These differ slightly from the new DfES recommendations. CILIP's guidelines are given in Table XI.

Table XI Guidance for secondary school libraries*

Students	Min Library accommodation, m^2	Max Library accommodation, m^2
800	340	370
900	370	400
1000	400	440
1100	440	475
1200	470	510
1300	500	550
1400	535	580
1500	570	620

* The second column (Min.) is intended for 11-16 schools, whilst the third (Max.) is intended to reflect the additional space required when the population includes post-16 students.

5.05 Primary schools

CILIP's primary school library guidelines discuss (p. 3) the issues to consider when designing the location of primary school library accommodation, and the amount of space required, though they do not provide guideline figures. This section also refers to DfES recommendations for space in schools, which have now been superseded and replaced by the DfES Building Bulletin 99: Briefing Framework for Primary School Projects.

5.06 Academic and college libraries

CILIP's Guidelines for colleges recommend the following:

- 1 seat per 10 full-time students in further education
- 1 seat per 6 full-time students in higher education
  - 2.5 m^2 per student workspace in resource-based learning rooms or learning resource centres
  - between 2.5 m^2 and 4 m^2 per student workspace in higher education
  - reader modules minimum 900 mm × 600 mm
  - ICT/ILT spaces minimum 1200 mm × 800 mm
  - circulation space (gangways) of 1200 mm minimum (1800 mm preferred); access to desk or workstation requires 1000 mm minimum; private space for user 600 mm outward from desk.

6 ENVIRONMENTAL CONSIDERATIONS

6.01 Natural light and ventilation

Natural light and ventilation are preferable, especially in the reader areas, but security and plan depth can make this difficult to achieve. As a result, most libraries employ a mixed-mode ventilation system, which incorporates a mixture of natural and mechanical systems, often employing atria spaces and sometimes wind turbines, **29.15–29.17**. Since libraries use a great deal of artificial lighting, solar heat gain can be a problem especially where large areas of glazing are provided on south facing elevations. It is better to avoid a southern orientation but where unavoidable solar screening or special glass may be required. However, the use of solid facades to exclude adverse external conditions is not advisable if the library is to assume a level of social engagement.

6.02 Artificial lighting

As matter of course, low-energy light fittings and sensors should be fitted in all areas. The use of task lighting can result in lowering general light levels but with a growing elderly population reducing overall light levels can result in accidents and poor user satisfaction. Light reflection on computer screens is also a consideration and generally results in PCs being in more central areas.

In order to maximise natural light and ventilation, the plan depth should not exceed 15 m. However, this is difficult to achieve in all but the smallest of libraries, and hence artificial conditions are provided in most areas. Since most libraries are constructed in urban centres, the main environmental factors are normally external air and noise pollution. Hence, a great deal of attention should be directed to site choice and layout, the design of external facades and the internal zoning of the building. For example, by placing book stacks against noisy external walls a more satisfactory level of comfort is provided internally.

As general rule readers like to work in natural light. This normally results in the perimeter placing of reader tables. Some seating areas can also be provided in inner sunlit spaces, particularly where magazines and newspaper are read. The creation of relaxation areas in atria spaces, as distinct from study areas, should take into account the different environmental conditions **29.18**. See Table XII.

7 FINANCING AND RESOURCES

7.01

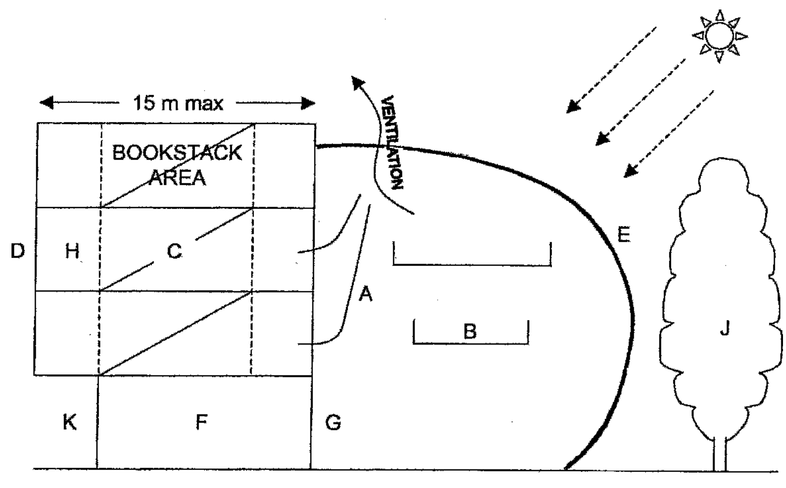
Amid the enthusiasm that accompanies the planning of a new library, it is hard to remember that libraries can also experience difficult times. When there may have been staffing cuts, cuts in book fund or the need to cancel journal subscriptions, a building project induces an artificial atmosphere of plenty amid harsh financial constraints.

7.02 Operating budgets

The problem in many new library projects is that the construction budget (for a larger building) is not always reflected in the library's operating budget. When the new library opens its doors, the public will flock in to enjoy its many attractions, but if there is no budget to support new or expanded services, this can lead to difficulties. In a recent example, a new central library was planned with staffing based on a projected 5000 visitors a day. However, the day after opening, the number jumped to 9000. Moving the existing collection also required many additional staff hours, as did setting up and configuring the large amount of state-of-the-art equipment. Long queues became common at the checkout desk, and for a period of time it took more than a month for checked-in books to be returned to the shelves.

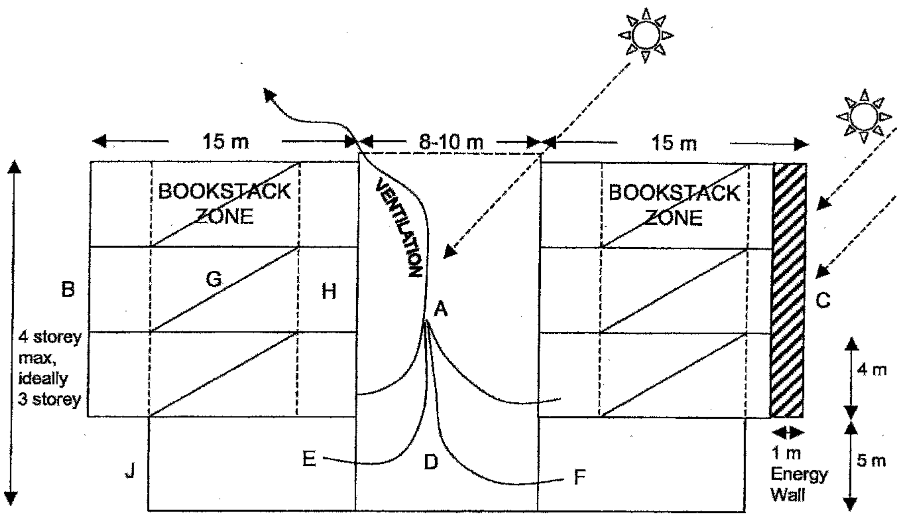
7.03 Efficient staffing

When considering for hard times, it is critical to plan for efficient staffing. Library staff numbers are reducing, while new electronic resources take an ever larger proportion of the budget. It is important to design a library that can be staffed safely and efficiently by



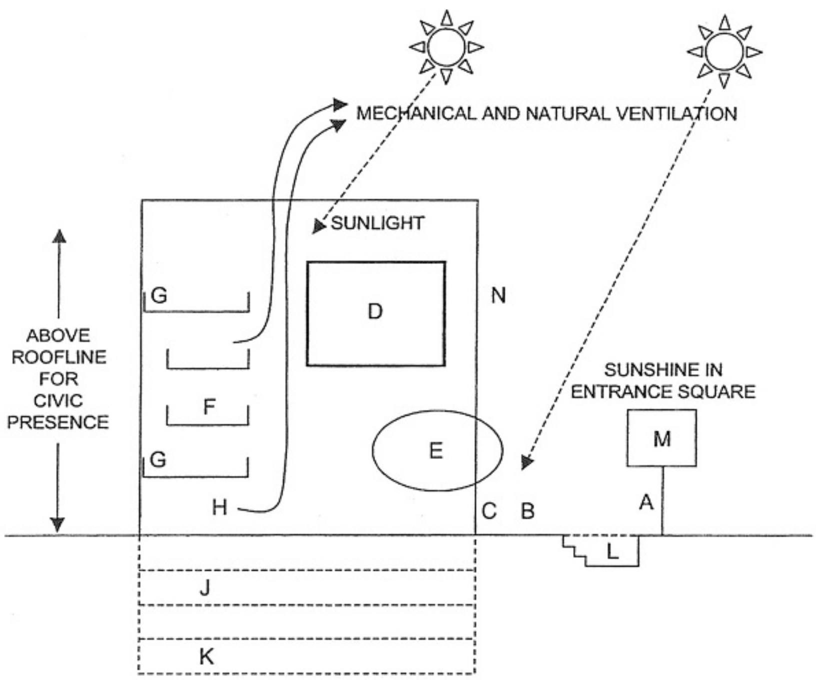
A - Open Plan Learning Resource Centre
B - Banks of computers on decks
C - Library floors, bookstacks in centre
D - Fully glazed north façade
E - Solar protected south façade, freely ventilated at top
F - Café, exhibition area
G - Entrance into library at central point
H - Reader carrels at building periphery
J - Planted shade on south side
K - Sheltered routes to library

29.15 *Ideal template for design of academic library (Brian Edwards)*



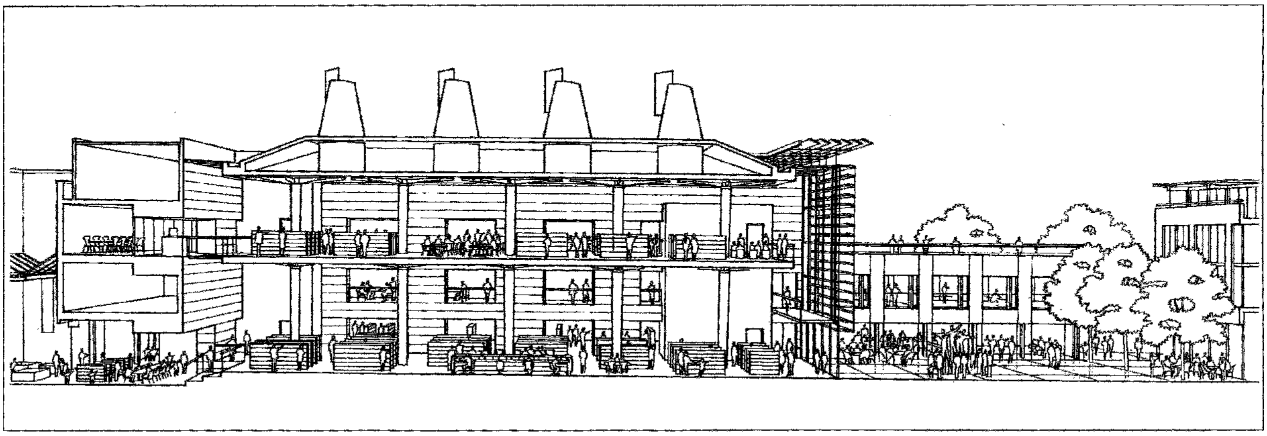
A - Atrium in centre for stairs and lifts.
Direct sunlight and natural ventilation.
Acoustic ceiling and walls.
B - Fully glazed north façade.
Reader desks against periphery
C - Solar protected south façade.
Shaded reader desks against periphery.
D - Well identified, sheltered entrance.
Disabled friendly, pram and bicycle Storage.
E - Café and exhibition space.
F - IT Resource Centre.
G - Library floors, bookstack in centre for Thermal capacity.
H - Computer terminals in bays around atrium.
J - Sheltered routes to library.

29.16 *Ideal template for design of public library (Brian Edwards)*



A - civic presence on street.
B - gathering square.
C - spacious entrance with exhibition space.
D - special collections readily identified.
E - auditorium near entrance.
F - library floors by subject.
G - reader spaces against perimeter.
H - computer catalogue access and toilets.
J - conservation.
K - storage of research collection.
L - amphitheatre for external performance.
M - conference.
N - energy conscious façade.

29.17 *Ideal template for design of national library (Brian Edwards)*



29.18 *Brighton Public Library is designed with both access and environmental concerns in mind (Bennetts Associates)*

Table XII Environmental considerations

Restrict plan depth to 15 m for maximum daylight penetration
Create internal atria in large depth libraries
Provide solar shading and internal blinds on large south facing glazing areas
Use external light shelves to increase daylight penetration
Place reader tables in well lit areas
Avoid air conditioning except in 'hot spots'
Employ mixed-mode ventilation systems
Maximise natural ventilation in public areas

the smallest possible number of people. For example, stacks and work areas need to be arranged so that staff can use their time more efficiently, and light panels, security monitors, and other equipment need to be centralised so that the building can be adequately operated. However, it is worth noting that a well designed library of today is able to achieve lower staffing levels than a poorly designed library from the 1970s or 1980s.

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www.cilip.org.uk

Designing Libraries Database
http://www.designinglibraries.org.uk/

Ontario Libraries clearinghouse of professional information
Selection of links to a variety of sources to help libraries in planning and assessing facilities.
www.library.on.ca/links/clearinghouse/facilities/index.htm

Planning and Building Libraries
This site has been created for librarians, architects, design consultants, and students interested in all aspects of planning and building libraries http://www.slais.ubc.ca/resources/architecture/ index.htm

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Whole Building Design Guide (WBDG) – A site containing detailed information on design of a range of public buildings. Includes sections on public, school and academic libraries.
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30 Terminals and transport interchanges

CI/SfB 114, 124, 144
UDC 725.3

KEY POINTS:
- *This building type is subject to constant evolution and change*
- *Terminals are now more like shopping malls than Victorian railway stations*
- *Intermodality between all forms of transport is a critical consideration*
- *Safety and security are now key components of terminal and interchange design*

Contents

1 INTRODUCTION

1.01

This chapter addresses the aspects of passenger requirements which are common to all terminals where passengers board aeroplanes, buses and coaches or railway trains or transfer between them. (Note that for practical purposes the consideration of baggage systems is limited to the airports section.)

1.02 Space standards

One person's congestion is another's profit: space standards are variable and subjective. The objective solution is to quote from the concept of Standard of Service. The application of this is common to all terminals and interchanges, and the differences arise, for example, from the amounts of baggage involved. Table I shows levels of service related to unit space standards in different types of space. For many passengers the criterion by which terminals such as airports are judged is the walking distance between one mode of transport and another. Although there is an inevitability about the length of a railway station platform or an airport pier, design can mitigate the strain of walking distance by providing passenger conveyors (see Chapter 5).

1.03 Security

In the case of air travel in particular but also in principle for long-distance rail and sea travel, the checking of passengers and their possessions requires the installation and manning of suitable equipment and the strategic location of the check point in order to both ensure that no passengers evade or avoid the checking procedure and that the procedure is carried out in the most efficient manner. Terminals and interchanges should be designed to minimise discreet locations where suspicious packages and baggage containing ''improvied explosive devices'' can be hidden; buildings should be designed so that, in the event such a device does explode, it remains structurally sound, thereby preventing further loss of life due to building collapse.

1.04 Border controls

Quite apart from security considerations, many terminals occur at national borders and therefore are the point of entry to or exit from sovereign areas. Accordingly, customs and immigration controls need to be conducted.

1.05 General legislation

Places of assembly of large numbers of people require special consideration of means of escape in case of fire as well as the normal controls on the standard of building construction.

1.06 Intermodal relationships

As the demand for efficient public transport systems returns after a phase when priority has been given to personal transport in the developed world, so the demand builds up for interchange between different modes. On the one hand, this can be for the reason of choice: allowing passengers to board Channel Tunnel trains in London or to drive on to them at Cheriton. Otherwise it can be for reasons of necessity: airports are located outside metropolitan areas and therefore need adjacent bus stations and railway stations, or even sea terminals in the case of Venice or Hong Kong.

1.07 Commercial opportunities

Wherever large numbers of people assemble and particularly wait, they need catering and business facilities. If they are by their very nature 'moneyed' there will be any number of shopping opportunities.

Table I Levels of service and space standards

Level of service		A	B	C	D	E	F
Criteria	Service level	Excellent	High	Good	Adequate	Unacceptable	Total breakdown
	Flow	Free	Stable	Stable	Unstable	Unstable	Congestion
	Delays	None		Acceptable	Some	Some	Unacceptable
	Subsystems	In balance	In balance	In balance		Not in balance	Total breakdown
	Routes	Direct					
	Comfort level	Excellent	High	Acceptable	Acceptable for short periods	Unacceptable	Unacceptable
Area with trolley per passenger (m^2)	Check-in and baggage reclaim	1.6	1.4	1.2	1.0	0.8	–
	General waiting concourses	2.7	2.3	1.9	1.5	1.0	–
	Confined waiting	1.4	1.0	1.0	0.8	0.6	–

1.08 Terminal operator's requirements

The owner and/or the operator of the terminal will be out to make the maximum return on his or her investment and this will probably involve collecting revenue from the transport operator and the commercial concessionaire rather than the passengers or the public.

1.09 Transport operator's requirements

On the other hand, the transport operator will want to get the passengers through the building as quickly as possible. Functional performance is paramount and related to speed, and the requirement for speed and efficiency is accentuated by the transfer facility. For example, the transfer time between connecting flights at airports is being increasingly reduced to provide a 'hub' and as different transport systems are integrated interchange times between, for example, train and plane need to be improved.

30.1 and **30.2** illustrate the interchange facilities at Heathrow Terminal 4 air/rail/bus.

2 AIRPORT PASSENGER TERMINALS

2.01

The airport terminal has been an established building type for only seventy years since London's airport was at Croydon, but many building forms have evolved. Each has been a response to the needs of the moment, but the speed of development of air travel has meant that buildings have rapidly become obsolete and needed either replacement or reconstruction.

2.02

A notable early example is the original terminal at Gatwick Airport, **30.3** which offered passengers in 1936 a direct and sheltered route from railway to terminal and from terminal to aeroplane. It was therefore an early true interchange facility.

2.03 Airport terminal planning

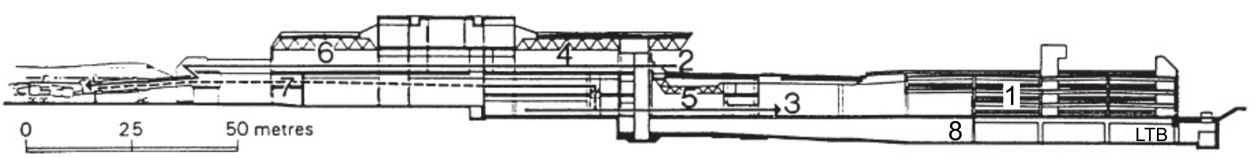
There are two major influences on airport and terminal size:

- Population demand, and
- Airline traffic scheduling.

Other factors and forms are listed and described in this section.

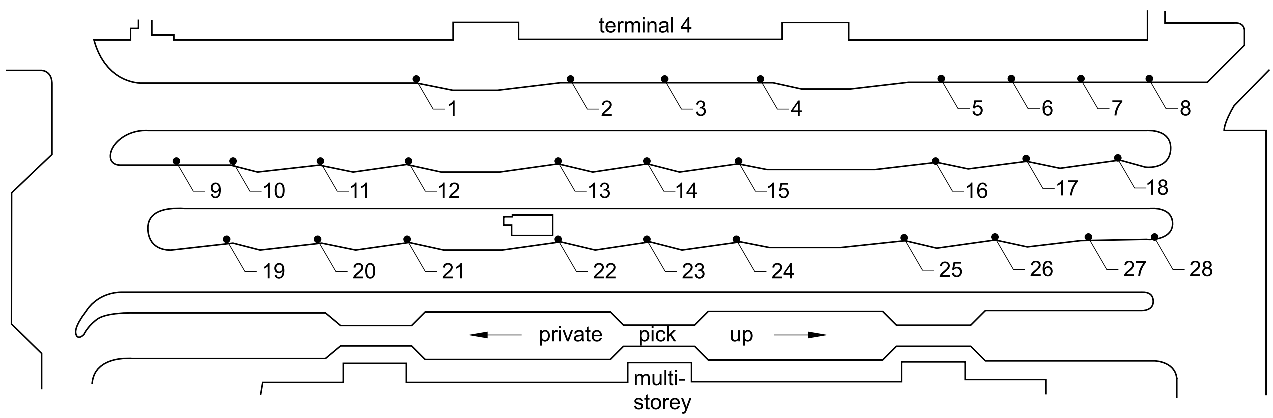
2.04

Worldwide each metropolis and major population centre has by now a giant airport in its vicinity. Most cities have airports appropriate to their needs. Either because the numbers of passengers, flights and choices of destination have increased to a certain level or because of its 'crossroads' location, a particular airport and its one or more terminals can take on a secondary growth pattern. Traffic attracts more traffic, since a wide range of airlines and destinations in turn attracts passengers from a larger area, possibly away from what would otherwise be their nearest airport, and also attracts airlines to feed connecting flights. Ultimately high volumes of traffic attract airlines to use their routes and facilities to the maximum by creating *hubs,* junctions for radiating routes with convenient transfer facilities for passengers. (See **2.15** below for more about hub terminals.)



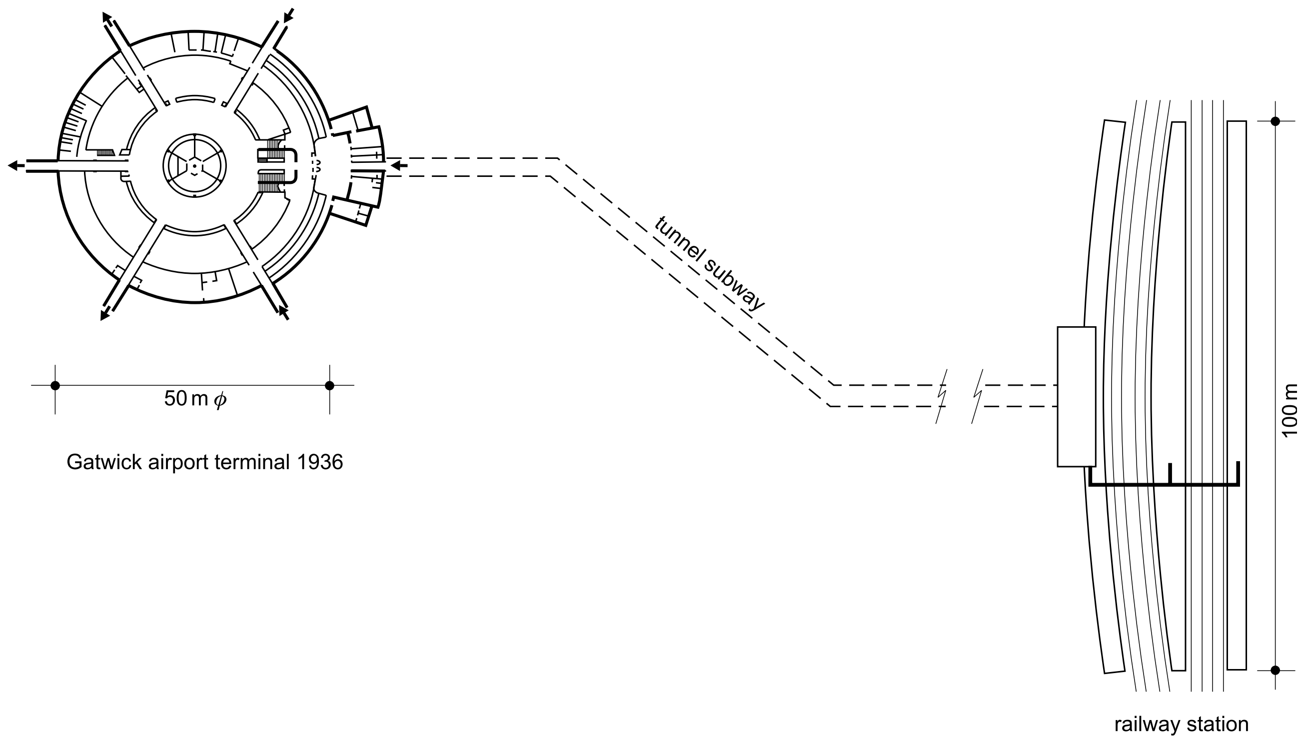
Key:
1 *Multi-storey car park*
2 *Departures forecourt*
3 *Arrivals forecourt*
4 *Departures concourse*
5 *Arrivals concourse*
6 *Airside concourse*
7 *Arrivals corridor*
8 *London Underground station*

30.1 *Heathrow Terminal 4 cross section: Architects Scott Brownrigg & Turner, Guildford*



Key:
1 *Taxis*
2 *Railair/Rickards/Alder Valley*
3 *Long-term car park*
4 *Car rental concession*
5 *Transfer to Terminal 1*
6 *Transfer to T2 and T3*
7 *Alder Valley/Careline*
8 *Staff car park*
9 *Jetlink*
10 *National Express*
11 *City of Oxford*
12 *Speed link*
13 *Flightline*
14 *Flightline/Airbus*
15 *Airbus*
16 *Flightlink*
17 *National Express*
18 *Southend/Premier*
19–24 *Group travel*
25 *Green line*
26 *London Country*
27 *Local hotels*
28 *Off airport car parking/rental*

30.2 *Heathrow Terminal 4 arrivals forecourt plan*



30.3 *Gatwick Airport Terminal, 1936*

2.05 Airport terminal capacity and size
Passengers per year and passengers per hour are the key factors in terminal design. Large peak concentrations will produce a high hourly demand in relation to the annual traffic. A substantial constant traffic level will produce a high annual rate in relation to the hourly demand. Table II gives examples of predicted figures which determined the design of those terminals.

UK air travel has increased five-fold since the mid-1970s; half the population now flies at least once a year. Freight traffic at UK airports has doubled since 1990. The US Federal Aviation Administration estimates that passenger numbers will increase by 3–5% annually for the foreseeable future.

2.06
Sophisticated mathematical models can be used to represent the flow of passengers. Where appropriate, standards are applied to various future times; for example, five years on and a further prediction ten years ahead.

2.07
The term *standard busy rate (SBR)* is used in terminal design, and is the number of passengers predicted in the thirtieth busiest hour of scheduled use. This means that for 29 hours in the year the facilities will not match up to the requirement, but reasonable standards and economy are balanced.

Table II Annual and peak traffic at typical airport terminals

	Type	Passengers per year	Passengers per hour at peak
Manchester Terminal 2 Phase 1 Heathrow Terminal 4 Gatwick North Terminal (completed)	International terminals	6–9 million	1850–2500
Zurich Terminal B	Major city	6 million	3500
Hanover	Major city	4 million	2000

2.08
Other factors to be considered are:

- *Aircraft movements*: number of arrivals and departures per hour, aircraft sizes, number of stands for each size or range of sizes, passenger load factors
- *Baggage quantities*: number of pieces per passenger, by class of travel and traffic (international/domestic)
- *Visitors*: number of accompanying visitors with departing and arriving passengers by class of traffic (international/domestic)
- *Employees*: number and proportion for airport, airline, concessionaire, control authorities, etc. and proportion of males and females
- *Landside transport*: number of passengers visitors and employees arriving by private vehicles (note ratio of owner-drivers), by public transport (note ratios by bus, coach, hire car, taxi, train, etc.)

2.09 Constraints on building form
In the 1930s multiple runways were common, but by the 1950s a pattern was emerging of single or twin runways. As traffic has grown so have the technical aids to support that growth. A single runway can now manage between 30 and 40 aircraft movements per hour, giving an airport capacity of about 25 million passengers per year.

A runway's capacity is affected by its independence from neighbouring runways, by the mix of aircraft and by the air traffic control system. Where a single runway is inadequate, a pair of parallel, and therefore independent, runways separated by at least 1600 metres is used. This allows the terminal buildings to be located between the runways, with minimal cross-runway aircraft movements.

Short runway airports or *STOLports* (short take-off and landing), limited to small aircraft, are appropriate for some locations.

2.10

Clearances are laid down between taxiing aircraft and both parked aircraft and buildings: a series of imaginary surfaces are defined based on standards of instrumentation. These surfaces define the permissible height and position of buildings, and lines of sight from control towers and other key installations.

2.11 Ownership of terminal

- *Airport authority*: terminals are built and owned by the airport authority to ensure that the terminal is non-specific and therefore likely to be more able to cope with changing demands.
- *Airline*: terminals built by and for an airline tend to be designed to meet that airline's specific short- and medium-term requirements

2.12 Type of traffic

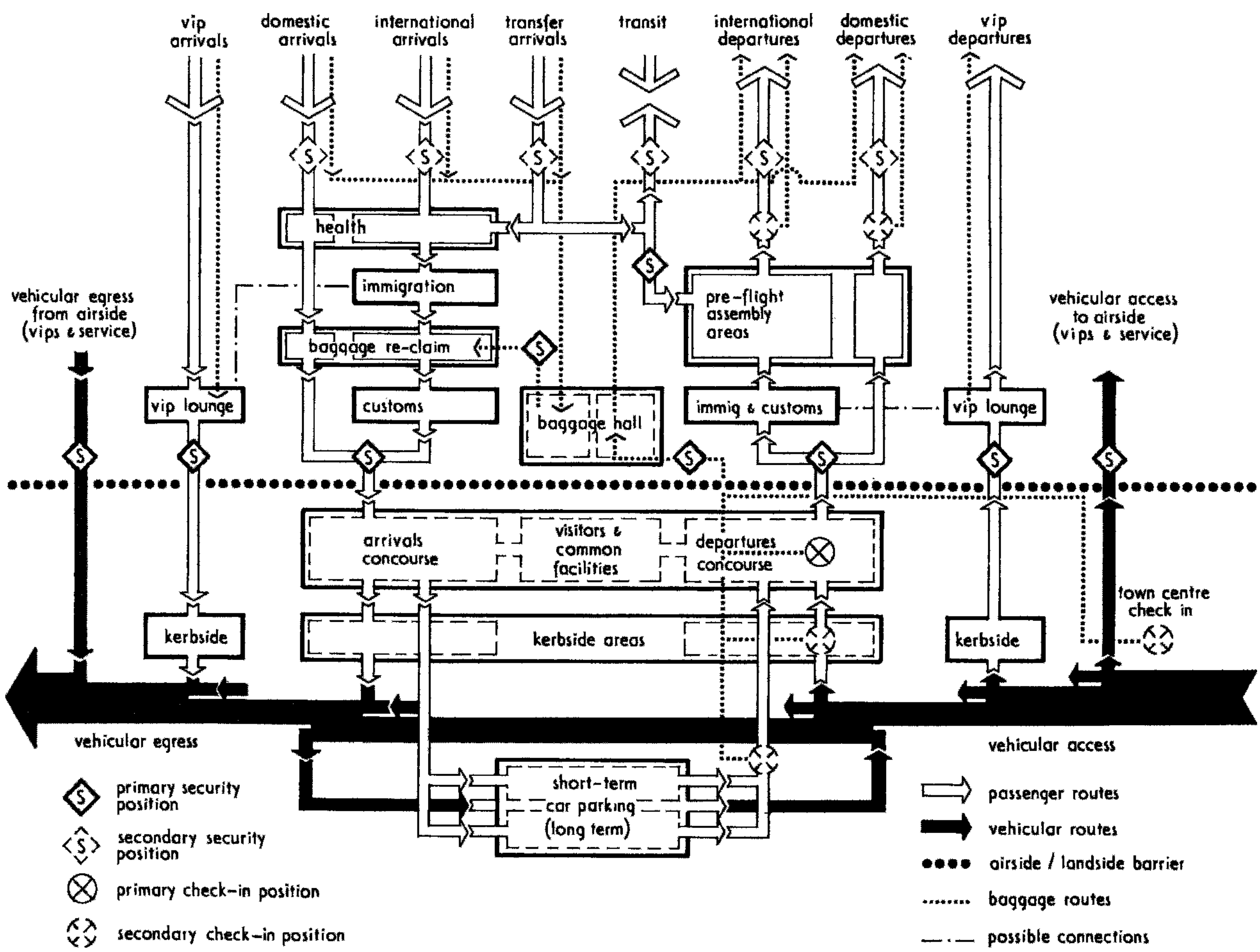
- *International*: international terminals involve customs and immigration procedures.
- *Domestic*: domestic terminals do not. They can therefore be simpler buildings. However, increasing need for passenger and baggage security has caused the grouping of facilities and channelling of passengers, and has reduced the distinction between the two types.
- *Combined international/domestic,* **30.4** is a flow diagram for such a terminal.

2.13 Level organisation

- *Side-by-side arrivals and departures on a single level,* **30.5a**. Suitable for the smaller-scale operations where first-floor movement of passengers from terminal to aircraft via telescopic loading bridges is not justified.
- *Side-by-side arrivals and departures on two levels,* **30.5b**. This avoids the need for elevated roads because all kerbside activity takes place at ground level. Escalators and lifts are provided to take departing passengers up to the boarding level.
- *Vertical stacking of arrivals and departures,* **30.5c**. Most larger terminals now adopt this configuration. Departures facilities are invariably at the high level with the baggage handling and arrivals facilities below. It is economic and convenient for both passenger and baggage movement: departing passengers arrive at an elevated forecourt and move either on the level or down a ramp to the aircraft loading point. Arriving passengers also move downwards to baggage reclaim and landside facilities.
- *Vertical segregation.* High passenger volumes, particularly with wide-bodied aircraft on long-haul routes, are best served by unidirectional circulation. Segregation could be either vertical or horizontal, but in practice the it has been found most feasible to have departing routes at high level with downwards circulation to the aircraft, and arriving passenger routes below.

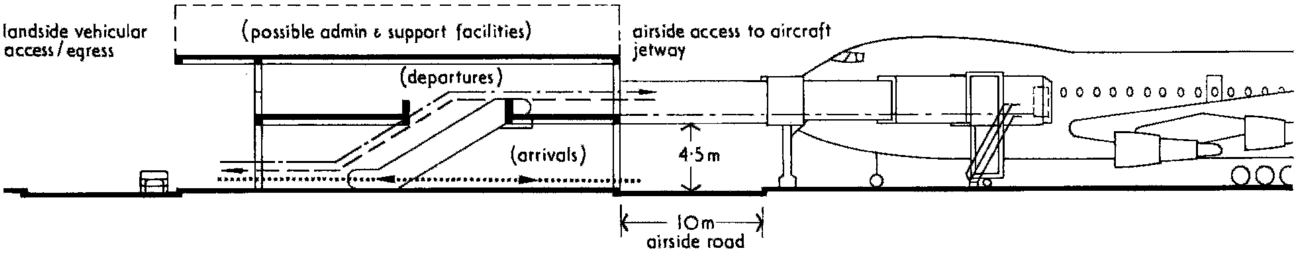
2.14 Centralised or decentralised?

Most terminals are centralized – **30.6** to **30.8** – with groups of functions, commercial, passenger and baggage processing, airline operations, etc. Centralisation gives economy of management if not passenger convenience. However, where control authorities are not needed as in domestic terminals, or where the prime concern is for passenger convenience, decentralisation has proved beneficial.

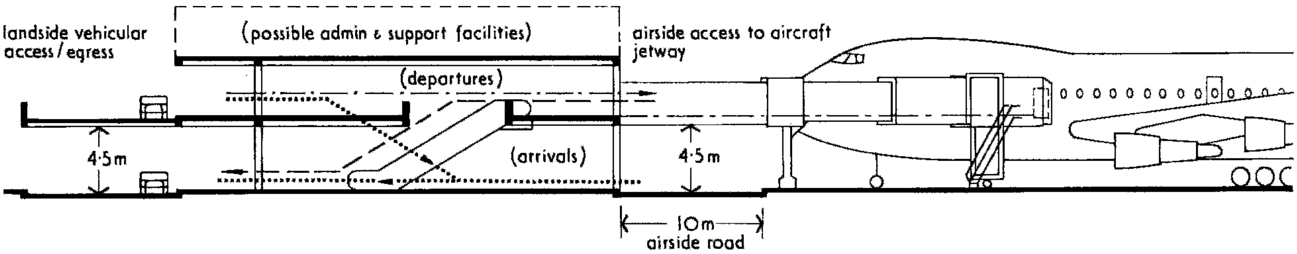


30.4 *Diagram showing both passenger and vehicular flow patterns for a international plus domestic airport terminal*

a *Single-level terminal, generally applicable to small or domestic terminals Arrival and departure routes split horizontally as flow plan diagram* **30.4**

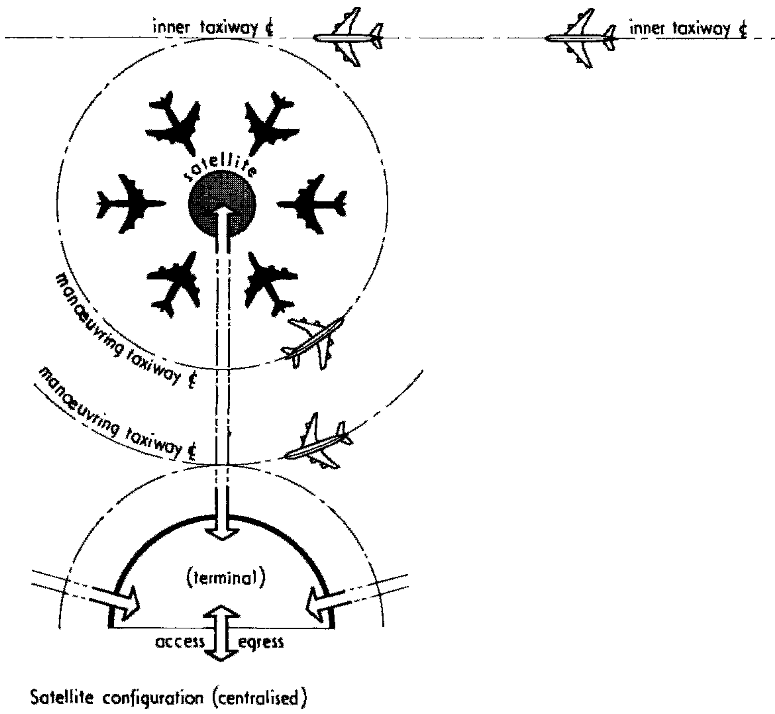


b *Two-level terminal – jetway type (horizontal split)*

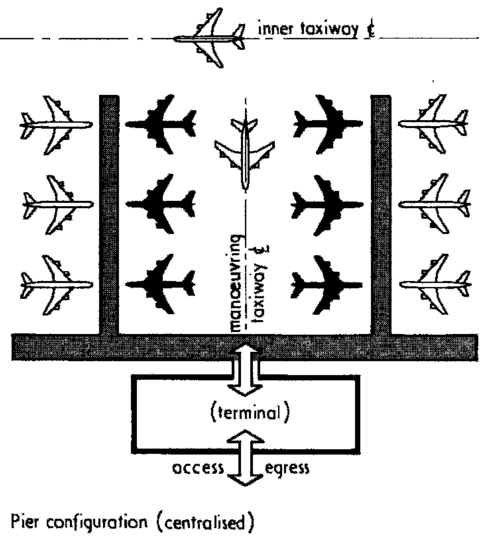


c *Two-level terminal – loading bridge type (vertical segregation)*

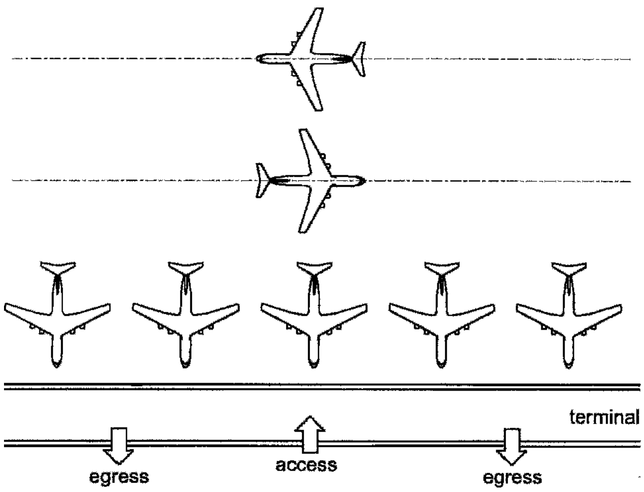
30.5 *Forms of typical terminals shown by cross-sections*



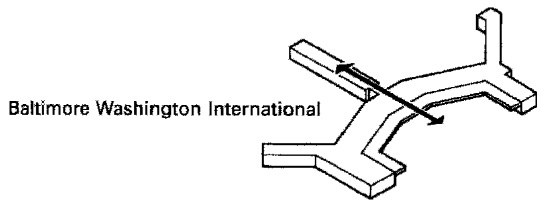
30.6 *Satellite configuration: Charles de Gaulle, Paris, France*



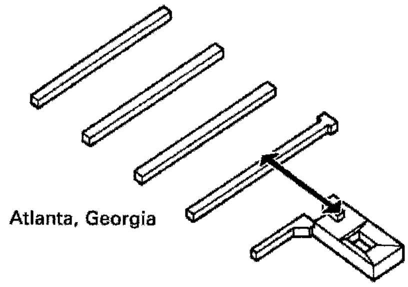
30.7 *Pier configuration: Heathrow, London, UK*



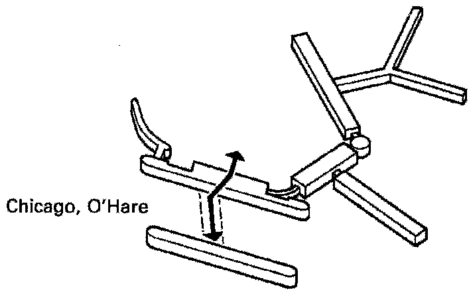
30.8 *Linear: New Munich Airport, Germany, opened 1992*



a *Common landside with piers: Baltimore Washington International Airport*



b *Common landside with satellite: Atanta Airport, Georgia*



c *Unit terminal: O'Hare Airport, Chicago*

30.9 *Hub terminal forms from US examples*

2.15 Hub terminals

A *hub terminal* is defined as one supporting a number of scheduled flights converging on an airport all within a short space of time in order to catch another series of onward flights also within a short space of time.

The flights are the spokes and the terminal is the hub. Short interchange periods can take place several times in one day.

The distinction needs to be drawn between transfer passengers who change planes and transit passengers who stop at the airport but do not change planes.

Most hub terminal experience worldwide is based on domestic traffic where the movement of passengers is not governed by frontiers with immigration and fiscal control. When and where airlines operate a mixture of international and domestic routes in a hub situation, passengers change from being international to domestic and vice versa.

As well as the full normal range of facilities for originating passengers, hub terminals need facilities for disembarkation and reboarding of aircraft for the transfer passengers. Normally when no flights have been delayed, transfer passengers move rapidly between flights. Most will have no hold baggage, being business travellers using frequent services on heavily trafficked routes between business centres. The rest with hold baggage may need to reclaim it for customs control. Especially for them, walking distances and queueing times must be kept short.

2.16 Hub terminal baggage handling

Successful terminals are said to depend on their baggage systems; hub terminals are no exception. Speed is even more vital in them; the transfer passenger is there only because the airline is unable to carry him or her directly from A to B. Transferring baggage from one aircraft to many others in a short time is very different from conventional manual or automatic sorting and make-up following check-in.

2.18 Hub terminal types

Rarely will the whole operation be hub-based, so the systems for interchange and for other passengers have to related. There are two fundamentally different principles:

- The hub terminal is part of a larger terminal, sharing kerbside, check-in, etc. with other airlines, or
- It is a unit terminal exclusive to the hub airline.

30.9 illustrates three forms as US examples applicable to Britain. **30.9c** was the solution adopted for Birmingham.

2.19 Aircraft docking, terminal or remote

The number of aircraft parking places needed normally requires extended structures such as piers or satellites to provide sufficient frontage. Consideration now needs to be given to the new generation of double-deck aircraft represented by the Airbus A380, which will typically accommodate 555 passengers who will ideally enter and exit the aircraft over two levels. Stands not connected physically to the terminal use coaches to carry passengers to and from it. Often these are superior types special to airport operation or mobile lounges which raise and lower to serve terminal and aircraft doors.

3 LANDSIDE FUNCTIONS

3.01 Arriving at or leaving the terminal by car or public transport

These are the factors to consider:

- *Security*: avoid vantage points useful to terrorists (see section **4.14** for further details on security).
- *Commercial*: the whole forecourt or at least the private car section may be incorporated into the short-term or nearest car park. This will force motorists to pay for the privilege of parking close to the check-in area.
- *Baggage*: baggage trolleys should be available for passenger use. For heavy package tours traffic, with coaches setting down large pre-sorted amounts of baggage, a dedicated area and route to the baggage areas may be desirable.
- *Airline needs*: in large terminals shared by many airlines, signed sections of forecourt may be appropriate.
- *Predicted changes*: allow for predictable changes in traffic mix which may affect the modal split (the percentages of passengers arriving by car or bus).

3.02 Quantities to be assessed

- *Hourly passenger flows*: in the case of a combined departures and arrivals forecourt a planned two-way rate will be relevant.
- *Estimated dwell time*: an average of 1.5 minutes may be allowed for cars and taxis.
- *Modal split*: subject to local conditions, 50 per cent of passengers may use private cars and taxis. Many buses and coaches will call at the departures forecourt, but do not need dedicated set-down positions. To provide the shortest route for the greatest number of passengers, coach and bus bays should be nearest to the doors. However, in a single-level forecourt, designated pick-up and set-down bays for specific buses and coaches may be appropriate.

3.03 Typical space calculation based on 2000 originating passengers/hour:

- Number of passengers/hour at kerbside for cars + taxis: 1000
- Number of passengers per car or taxi: 1.7, say
- Number of cars and taxis: 1000/1.7 = 588 per hour
- Time spent at kerb by each vehicle: 1½ minutes, say
- Number of cars and taxis at one time: 588/40 = 16
- Length of kerb per vehicle: 6 m + 10 per cent
- Length of kerbside for cars and taxis: 105.6 m
- Overall rule of thumb: 1.0 m of total kerbside (including public transport) per 10 passengers/hour

3.04 Waiting in a landside public concourse

Policy decisions to be applied:

- Security: entry to the concourse can be controlled by a security comb, but this is unusual as it does involve searching passengers and visitors alike.
- *Commercial*: shopping and catering facilities will be appropriate here, together with bureau de change (international terminal only), flight insurance sales office (departures), hotel bookings, car hire desks (arrivals) and post office. Provision for spectators may be made as well as a car park pay station for the benefit of car drivers seeing passengers off and meeting passengers.
- *Baggage*: all circulation areas should make allowance for baggage trolleys.
- *Government controls:* access to airside for staff.
- *Airline needs*: airlines require ticket sales desks and offices.
- *Information systems*: public display of information on flights and information desk.
- *Predictable situations*: provision may be needed for exceptional conditions occasioned by delayed flights, with additional seating and extra catering space, which may also be usable as airside.

3.05 Quantity factors to be assessed

- Hourly passenger flows: two-way flow will be relevant where there is to be a combined departures and arrivals area.
- Visitor ratio: a common ratio in the West would be 0.5 to 0.2 visitors per passenger (with even lower ratios for certain domestic traffic) and in the East or Africa 2.5 to 6 or even higher.
- Estimated dwell time: a common time would be 20 minutes in departures or, in arrivals, 10 minutes for passengers and 30 minutes for meeters and greeters.

3.06 Typical space calculation based on 2000 originating passengers/hour

- Number of people per hour: 5000 (1.5 visitors/passenger)
- Number at one time (peaking factor, say 50 per cent in 20 minutes): 2500
- Space per person (level of service A): 2.7 m^2
- Area required: 6750 m^2. Some area may be in shops and catering spaces.

3.07 Typical space calculation based on 2000 terminating passengers/hour:

- Number of people per hour: 5000 (1.5 visitors/passenger)
- Number at one time (2000/6 + 3000/2): 1833
- Space per person (level of service A): 2.7 m^2
- Area required: 4949 m^2. Some area may be in shops and catering spaces.

3.08 Checking-in, with or without baggage

Here passengers show their tickets, have seats allocated and if necessary have large items of baggage weighed (and possibly security screened) for registration and loading into the aircraft hold.

Policy decisions to be applied:

- *Security*: procedures are now being introduced whereby all baggage is searched by the airline's security staff at entry to their check-in area, or by the check-in and security staff at the desk by means of X-ray units at or near the desk. The constraint is that the owner of the bag must be at hand at the moment of search in the event of a problem arising.
- *Baggage*: one or more delivery points may be required for out-of-gauge baggage.
- *Government controls*: a customs check facility for certain heavy items of baggage may be provided in the check-in area.
- *Airline needs*: offices for airlines and handling agents will be needed with close relationship with the check-in desks and preferably with a visual link.
- *Information systems*: common user terminal equipment will make it possible to allocate desks to any airline at any time, thereby reducing the number of desks needed. Otherwise the number of desks required is the sum total of those required by each handling agent.
- *Predicted changes*: the biggest single change will arise from the predicted advent of automated ticketing and issuing of boarding passes. Information technology which links the manual (conventional check-in system with baggage registration) and automated system (where the passenger simply communicates with a small machine) will make it possible to reduce the number of check-in desks while retaining the necessary central control which check-in clerks have always had.

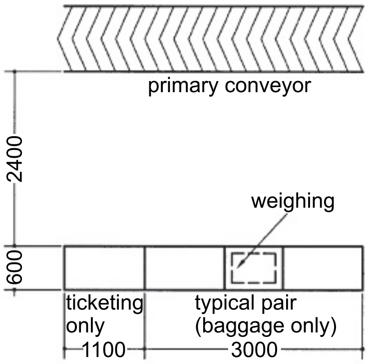
3.09 Quantities to be assessed

- *Hourly passenger flows*: if CUTE is in use the total hourly flow to all desks can be used to compute the number. Landside transfer passengers to be included.
- *Processing rate*: commonly about 1.5 minutes/passenger, with faster rates for domestic passengers.
- *Estimated dwell time*: this is dependent upon the number of staffed check-in desks for each flight, but all check-in layouts have to make provision for queueing. Assume a wait of 20 minutes is acceptable to passengers.
- *Percentage of passengers using gate check-in*: this is a new facility and trends have yet to be established. Ten per cent usage of gate-check-in would be a reasonable assumption where the facility is provided, although it may only be available there for certain flights.

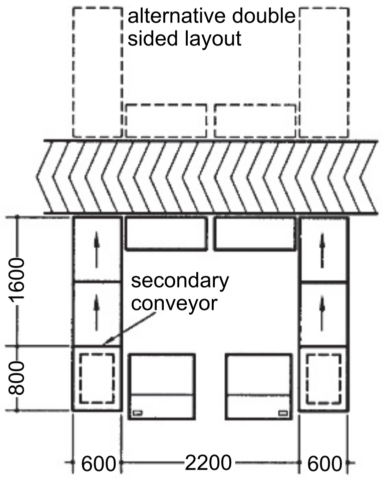
3.10 Typical space calculation based on 2000 originating passengers/hour: central check-in:

This will be irrespective of the configuration of desks, **30.10**.

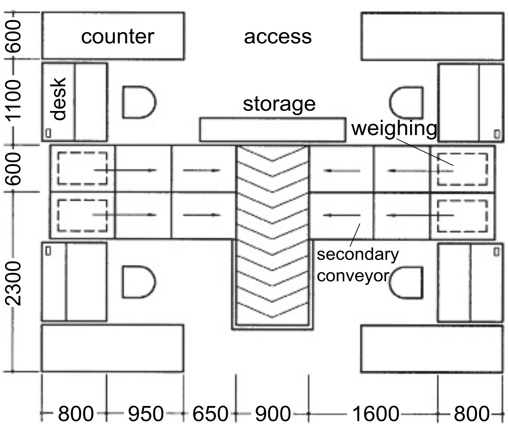
- *Number of passengers per hour*: 2000 excluding transfers and including gate check-in numbers
- *Equivalent number/hour* (peak factor, say 50 per cent in 20 minutes): 3000
- *Number of desks*: 3000/40 = 76



a *Linear, with manual handling*



b *Linear, with power handling*



c *Island*

30.10 *Check-in installations without security control*

- *Queue depth* might be 20 passengers at 0.8 m per person with check-in desks at approximately 2.0 m centres (max.)
- *Space per person* (level of service A): 1.6 m^2
- *Total queueing area*: $76 \times 2.0 \times 16 = 2432\ m^2$. Note that a discrete area is only applicable if there is a security-based separation between the landside public concourse and the check-in area.

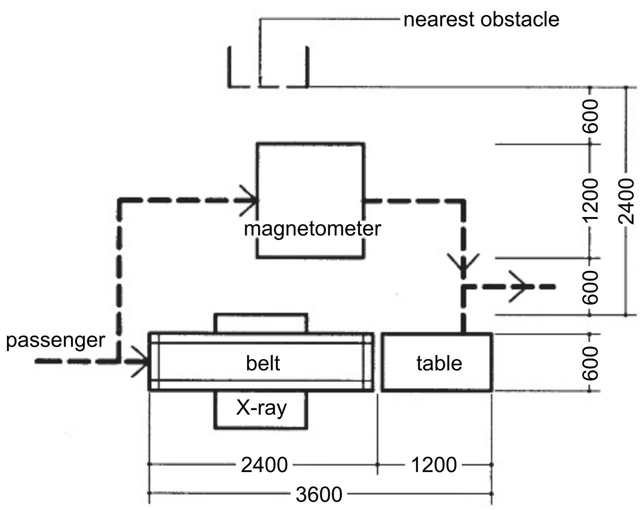
3.11 Pre-departure security check

Factors to be considered:

- *Baggage*: in the case of central security, take account of baggage belonging to passengers using the gate check-in facility.
- *Government controls*: security control will be the responsibility either of the government or of the airport authority.
- *Airline needs*: some airlines conduct their own additional security checks.
- *Predictable changes*: as the demand for security increases changes can be expected.

3.12 Quantities to be assessed

- *Hourly passenger flows*: for central security and for gate security allow for transfer passengers.
- *Processing rate*: X-ray units handle 600 items per hour, with two X-ray units per metal detector archway, **30.11**.
- *Estimated dwell time*: this is not calculable, since a problem item or passenger can rapidly cause a queue to build up. The security check should not unduly interrupt the flow of passengers. In reality staffing levels cannot totally eliminate queueing, and space for a long queue must be provided to avoid obstructing other functions.



30.11 *X-ray unit search of passengers and baggage*

3.13 Typical space calculation

This is based on 2000 originating passengers/hour at a central security check, **30.12**.

Assume two items of baggage or hand baggage per passenger

One set of equipment consisting of a personnel metal detector and two 2 X-ray units can handle 600 passengers per hour.

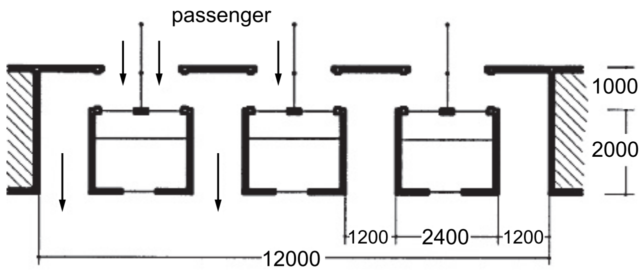
2000 passengers per hour, excluding transfers, require 4 sets.

4 AIRSIDE FUNCTIONS

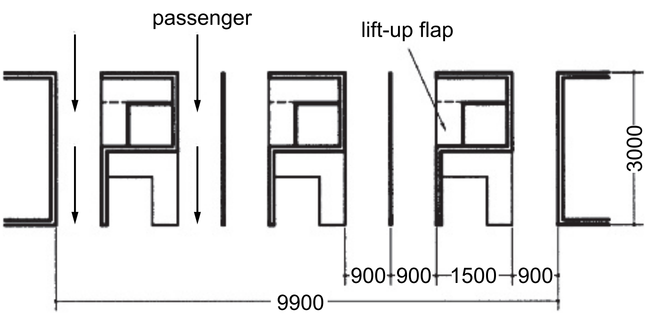
4.01 Immigration check

Factors to be considered:

- *Security*: a central security control brings this area under surveillance.
- *Government controls*: national policy determines the allocation of separate channels for different passport holders. There may also be customs checks here for which offices and detention rooms will be required.
- *Predictable changes*: changes to border controls within the European Union are an example of the effect of international policy making.



a *Frontal presentation*



b *Side presentation*

30.12 *Immigration control desks, booths or open plan passenger*

4.02 Quantities to be assessed

- *Hourly passenger flows*: include landside transfers.
- *Processing rate*: commonly 10 seconds/passenger for departures, 30 seconds/international passenger and 6 seconds/domestic passenger for arrivals.

4.03 Typical space calculation based on 2000 originating passengers/hour

- Number of passengers per hour: 2000 excluding transfers
- Number of desks required: 5.5, say 6
- Area required at 25 m^2 per desk: 150 m^2, **30.12**.

4.04 Airside public concourse

Here passengers wait, shop, eat, drink and move sooner or later to their flight departure gate. That point may be the people-mover leading to a satellite or the coach station serving remote stands.

Factors to be considered:

- *Security*: no further security checks will be needed where there is comprehensive centralised security at entry to the airside. Otherwise checks may be made at each gate or entry to a lounge.
- *Commercial*: there will be shopping and catering facilities here, particularly duty-free.
- *Airline needs*: airlines will have specific requirements at the gates. They often have CIP (commercially important passengers) lounges for first-class and business-class passengers.
- *Information systems*: full information on flight numbers, departure times, delays and gate numbers must be provided, throughout but especially at the entries.

4.05 Quantities to be assessed

- *Hourly passenger flows*: include landside and airside transfers.
- *Estimated dwell time*: commonly about 30 minutes.

4.06 Typical space calculation based on 2000 originating passengers/hour

- *Passengers per hour*: 2000 excluding transfers.
- *Passengers at one time*: 1000
- *Space per person* (level of service A): 2.7 m^2
- *Area required*: 2700 m^2. Some may be in shops and catering spaces.

4.07 Gate holding areas

These should be able to hold 80 per cent of the number of passengers boarding the largest aircraft which can dock here.

- *Space per person* (level of service A): 1.4 m^2.
- *Area for 400–seater aircraft*: $320 \times 1.4 = 448\ m^2$.

4.08 Baggage reclaim

Here passengers await and reclaim their luggage which has been unloaded from the aircraft while they have been through the terminal and passing through the immigration control.

Factors to consider:

- *Baggage*: some means of delivering outsized luggage to the passengers is required. Also some passengers need to claim their baggage after they have passed through to the landside, either because they have forgotten it or because for some reason it has arrived on a different flight.
- *Information systems*: display the numbers of reclaim units against the arriving flight numbers, particularly where passengers enter the reclaim area.

4.09 Quantities to be assessed

- *Hourly passenger flows*: passengers transferring on the landside need to reclaim their baggage.
- *Processing rate*: there are several ways of calculating throughput in baggage reclaim, but the one used here is from the *IATA Airport Terminals Reference Manual.* Reclaim devices should have a length of 30–40 m for narrow-bodied aircraft, 50–65 m for wide-bodied. Average occupancy times are 20 and 45 minutes respectively.
- *Estimated dwell time*: Commonly about 30 minutes.
- *Number of checked-in bags per passenger*: average 1.0, depending on whether the flight is long haul or short haul, although the flow calculation method used does not depend upon this factor.

4.10 Typical space calculation based on 2000 terminating passengers/hour

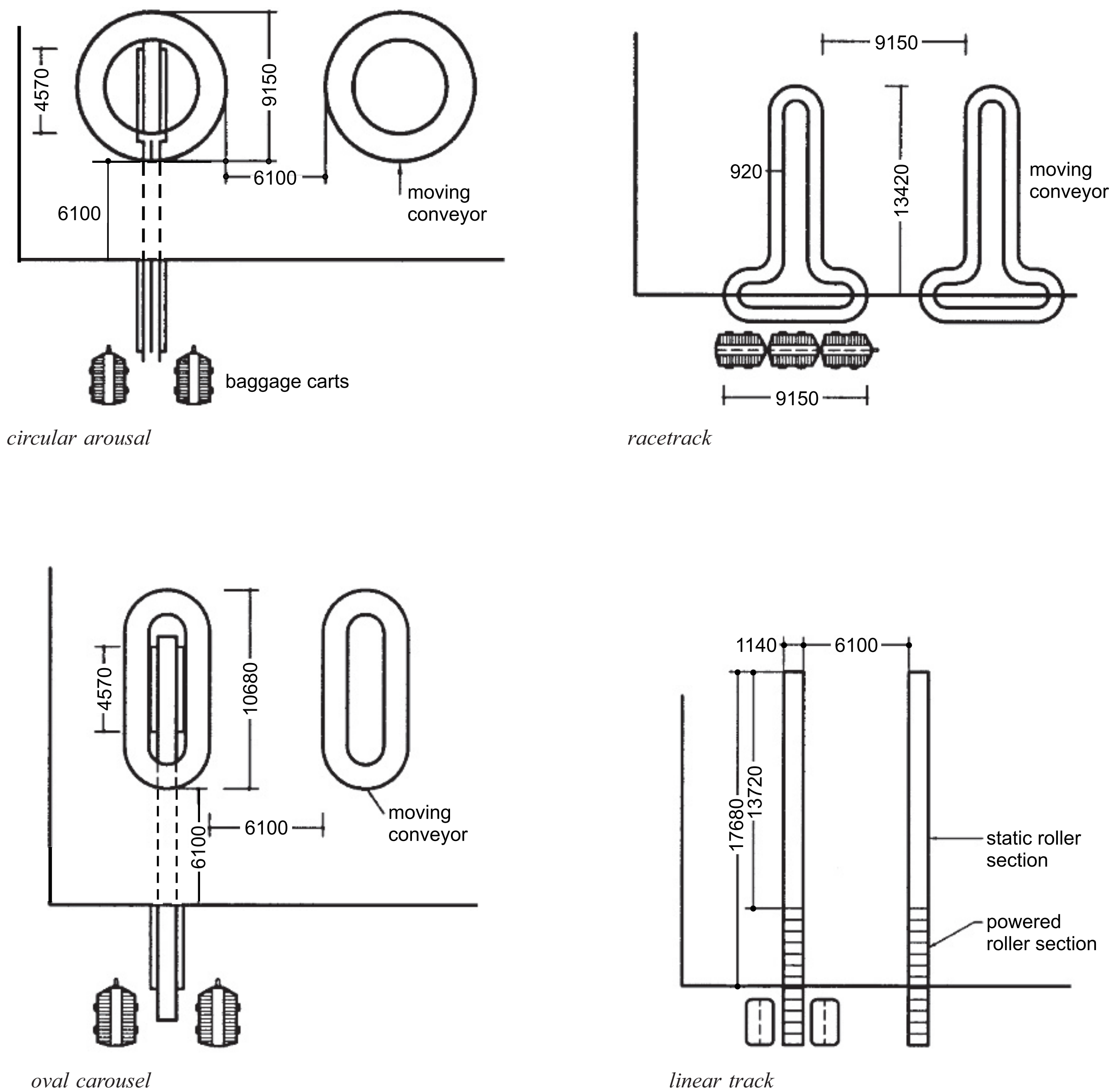
- Number of passengers per hour: 2000 excluding transfers
- Number of passengers at one time: 1000
- Space per person (level of service A): 1.6 m^2
- Area required: 1600 m^2 (a minimum inclusive of waiting area).

However, the important calculation is for the required number of reclaim units and the space round each for a flight load of passengers waiting:

Assume 50 per cent of passengers arrive by wide-bodied and 50 per cent by narrow-bodied aircraft.

- *Number of passengers* per narrow-bodied aircraft at 80 per cent load factor: 100
- *Number of passengers* per wide-bodied aircraft at 80 per cent load factor: 320
- *Number of narrow-bodied devices*: $1000 \div (3 \times 100) = 3.3$, say 4
- *Number of wide-bodied devices*: $1000 \div (1.33 \times 320) = 2.35$, say 3
- *Space per person* (level of service A): 1.6 m^2
- *Waiting area* for narrow-bodied device: 160 m^2
- *Waiting area* for wide-bodied device: 512 m^2
- *Total waiting area*: $4 \times 160 + 3 \times 512 = 2176\ m^2$ (excluding central waiting space at entry to baggage reclaim area)

30.13 shows types of baggage reclaim installation.



30.13 *Four types of baggage reclaim installation*

4.11 Inbound customs clearance

Factors for consideration:

- *Security*: customs officers are increasingly on the lookout for narcotics, weapons and explosive devices rather than contraband.
- *Government controls*: offices and search rooms will be required. Determine type of surveillance.
- *Predictable changes*: changes to border controls within the European Union post-1992, and the introduction of the blue channel for EU citizens moving freely between member states are an example of the effect of international policy making.

4.12 Quantities to be assessed

- *Hourly passenger flows*: include landside transfers.
- *Processing rate*: allow 2 minutes per passenger searched.

4.13 Space calculation based on 2000 terminating passengers/hour

- *Area required* if rule of thumb is 0.5 m^2 per passenger per hour: 1000 m^2.

4.14 General security considerations

Planning for security should be a priority in the design of any transport facility; designing a terminal or other transport-related building without considering security could result in costly (and unsightly) retrofits. Advance planning is essential, and designs should be drawn up within a predetermined vulnerability and security assessment.

It is worth bearing in mind that one of the most effective ways of ensuring security is the alertness of staff and passengers; buildings need to be designed to allow security personnel and other staff to do their jobs effectively by, for example, maximising clear views. Security is also enhanced by making the boundaries between different zones clearly identifiable.

On the other hand, security cannot become the overwhelming design priority such that airport operations are unacceptably compromised, the passenger experience becomes unacceptable and costs become prohibitive. Although it is physically possible to design a terminal in the manner of a highly-secure fortress, there is a balance to be struck.

One of the most vulnerable areas of an airport terminal is the landside zone where many hundreds of people are dropped off and gather with large items of luggage. Trying to ensure that people do not enter the terminal with weapons or explosives may mean moving security screening facilities to the 'front door' to create a 'sterile' terminal. This creates significant design issues, which includes the separation gap between vehicles and the terminal itself.

Designers of airport buildings must now consider the effects of a bomb blast. US authorities consider that ensuring terminal buildings are provided with a 'medium' level of blast protection is sufficient; this means accepting that serious damage may be sustained, but that the primary structure will remain standing and possibly even be reuseable after a blast. Key facilities, such as the air traffic control tower and fuel depots, as well as key power, communication and telecoms facilities, need to be given a high degree of protection and located away from public access.

5 AIRCRAFT AND APRON REQUIREMENTS

5.01 Baggage handling

30.14 shows a container and trailer used to assemble baggage. The manoeuvring of trains of these trailers determines the layout of baggage loading and unloading areas.

5.02 Loading bridges

30.15 shows three types of loading bridges, otherwise known as airbridges, air-jetties or jetways, which connect terminal to aircraft.

5.03 Apron servicing

30.16 shows apron servicing arrangements with all necessary vehicles clustered around a parked aircraft. They determine the space requirement. Alternatively, fuel can be supplied by sub-apron hydrants and power by connection through the loading bridge.

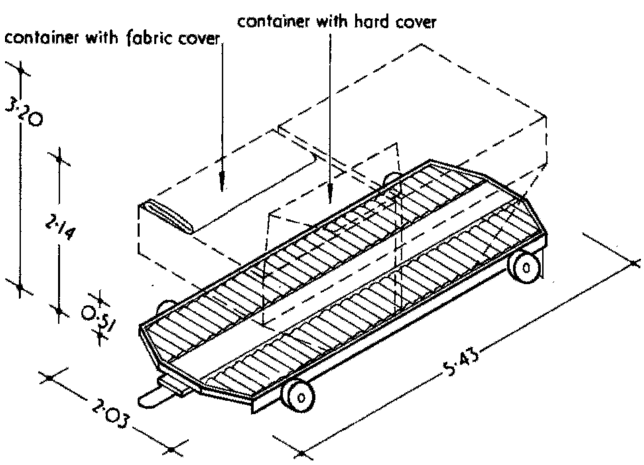
5.04

Office, workshop, store and staff facilities will be required adjacent to the apron.

6 BUS AND COACH STATIONS

6.01

A bus station is an area away from the general flow of road vehicles, which enables buses and coaches, to set down and pick up passengers in safety and comfort. The best locations are near shopping centres or other transport terminals. An airport terminal bus station is shown in **30.2**.



30.14 *Baggage handling transport: double container dolly*

Two particular trends have affected urban bus and coach operations:

- One-driver buses for economy, and
- Deregulation with new companies with new operating methods and equipment such as minibuses.

6.02 Vehicles

A variety of bus and coach types are now used, **30.17** to **30.19**. Turning dimensions are shown in **30.20** to **30.22**. A kerbside bus stop in a layby is shown in **30.23**.

Overall length is $A + n\,B + C$, where n is the number of buses to be accommodated. So for one stop 44.6 m, two stops 56.8 m and three stops 69 m.

6.03 Factors affecting size of station

Apart from the physical site constraints, station size is governed by the following:

- *Number of bays to be incorporated* (the term *bay* is used in bus stations instead of bus stop), determined by the number of services operated from the station; and by how practical it is, related to the timetable, to use each bay for a number of service routes.
- *Vehicle approaches to the bays.* Three types of manoeuvre are used, **30.24**. The 'saw-tooth' is further explored in **30.25** and **30.26**.

The choice of manoeuvre will be influenced by the size and shape of the available site, the bus operators' present and anticipated needs, and in particular the preference of their staff. Some will accept the saw-tooth arrangement while others prefer the drive-through.

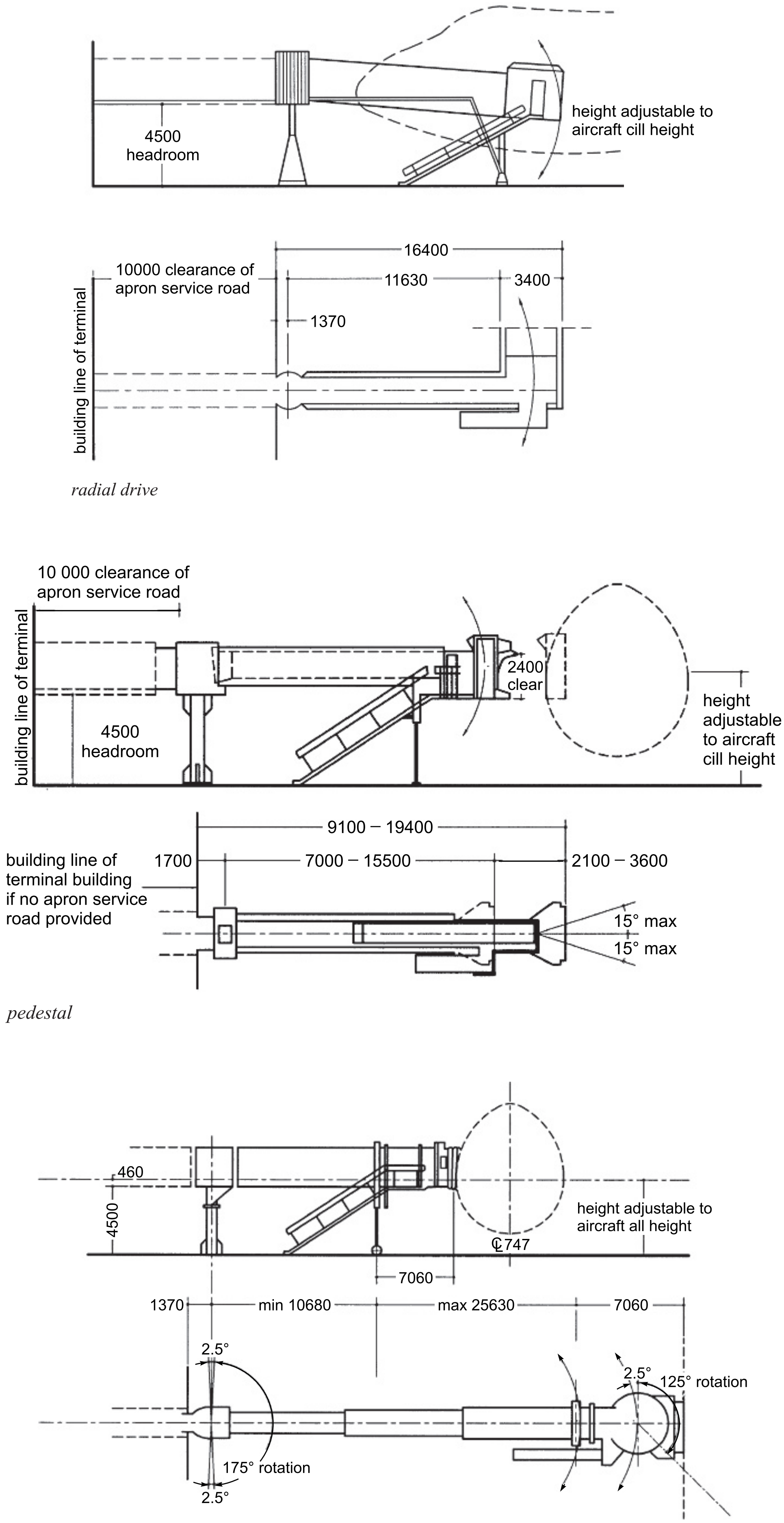
The required area of the site is further increased by the need for *lay-over*. This is when vehicles are parked after setting down passengers, but which are not immediately required to collect more passengers. The layout for this should be as for parking, **30.27** and **30.28**, preferably so that no vehicle is boxed in or interferes with other bus movements.

Economy of space may be achieved, again dependent upon timetables, by using spare bays for lay-over purposes.

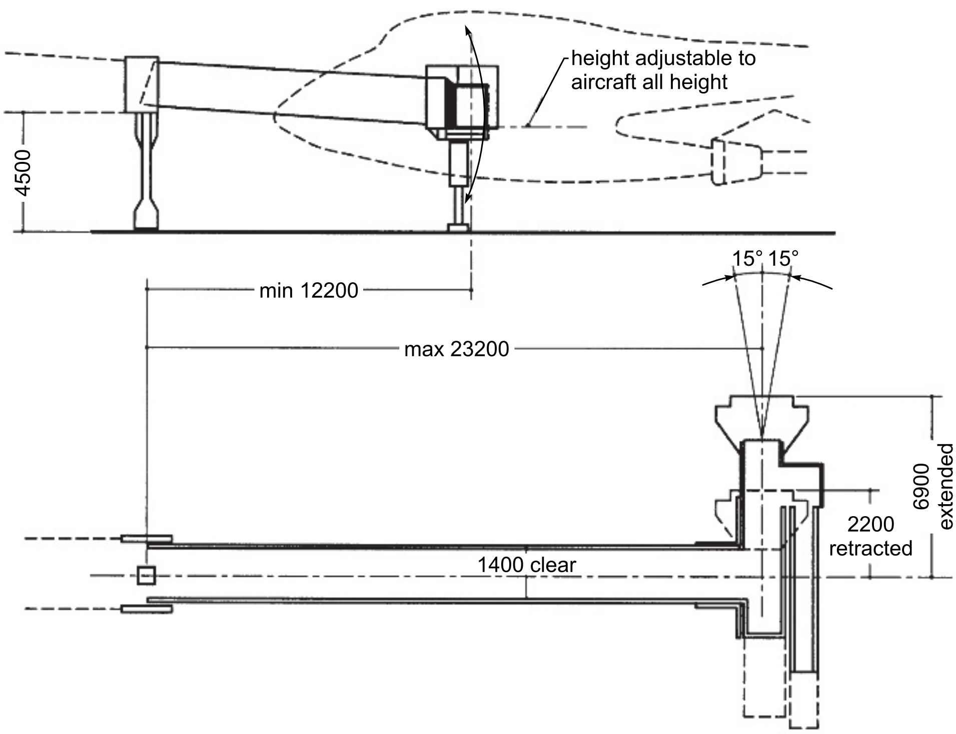
- *Facilities for passengers*: these will depend entirely upon anticipated intensity of use and existing amenities. If, for example, there are already public toilets, a bus and coach information centre and cafés nearby, then these will not be required on the station concourse. However, waiting room facilities may be required with someone on hand to give information and supervision. In more comprehensive schemes consider:

  Waiting room
  Buffet
  Public toilets
  Kiosks
  Enquiry and booking
  Left luggage
  Lost property.

- *Facilities for staff*: there are invariably inspectors who, as well as assisting passengers, are primarily concerned with organising the movements of vehicles, and supervising their drivers and conductors. If there is a depot near the station then staff facilities will be provided there. If not, canteen and toilets facilities will be needed for staff on the station site, so that during breaks and between shifts they do not need to get back to the depot until they return their vehicle for long-term parking. Should the depot be even more remote, all facilities should be provided at the station and only basic amenities at the depot. In addition to those listed above these include a recreation area, locker rooms and a facility for paying in takings. This would be an office where drivers or conductors

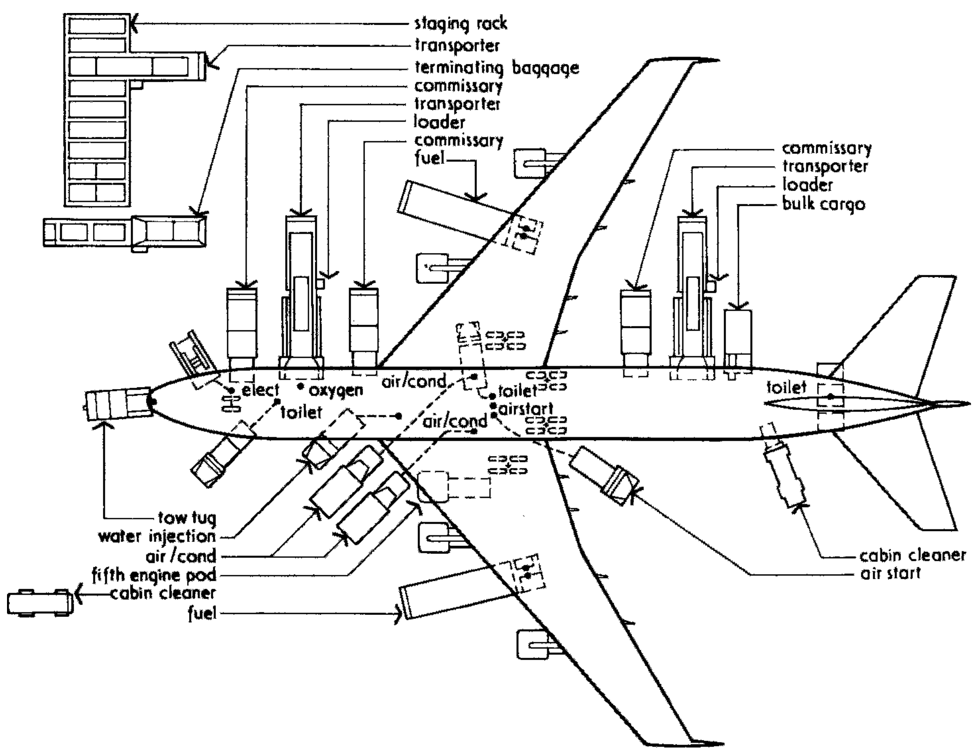


30.15 *Loading bridge types: plans and elevations (continued over)*



elevating

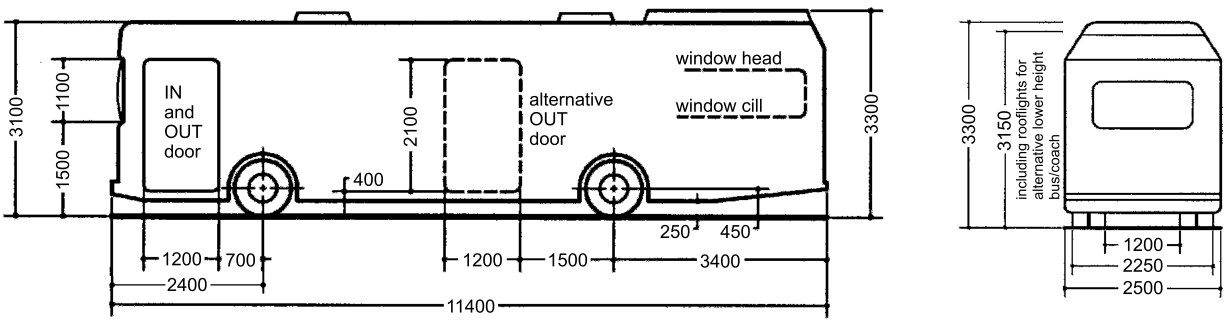
30.15 *Continued*



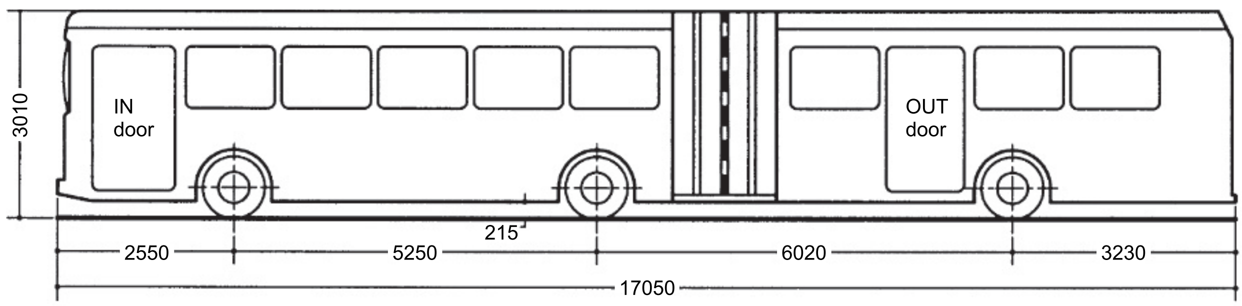
30.16 *Servicing arrangements for passenger model Boeing 747–100/200B + C. Under normal conditions external electric power, airstart and air conditioning are not required when the auxiliary power unit is used*

check, then hand over monies taken as fares, which in turn are checked and accounted for by clerical staff. Secure accommodation for any cash that cannot be immediately banked will be needed.

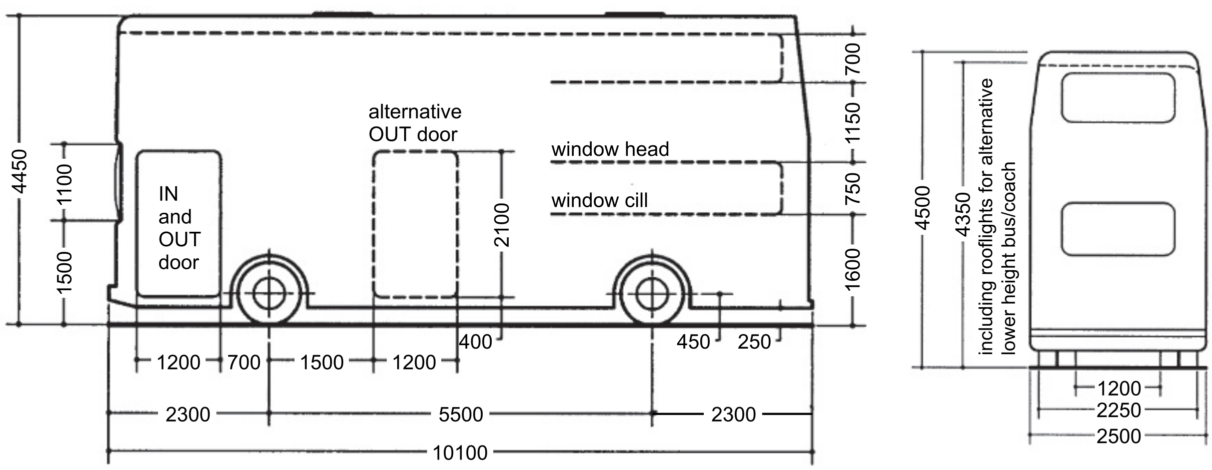
- *Facilities for vehicle maintenance*: the inspection, repair and servicing of buses and coaches is an integral part of an operator's responsibility. Normally such work would be carried out at a local depot, with a repair workshop together with fuelling, washing and garaging facilities. The provision of any such facility within a station complex is unusual, but not unique. For a new town bus station or one where it will be difficult and time consuming to drive to and from the station and depot because of traffic congestion, it would be advantageous to provide at least a workshop.



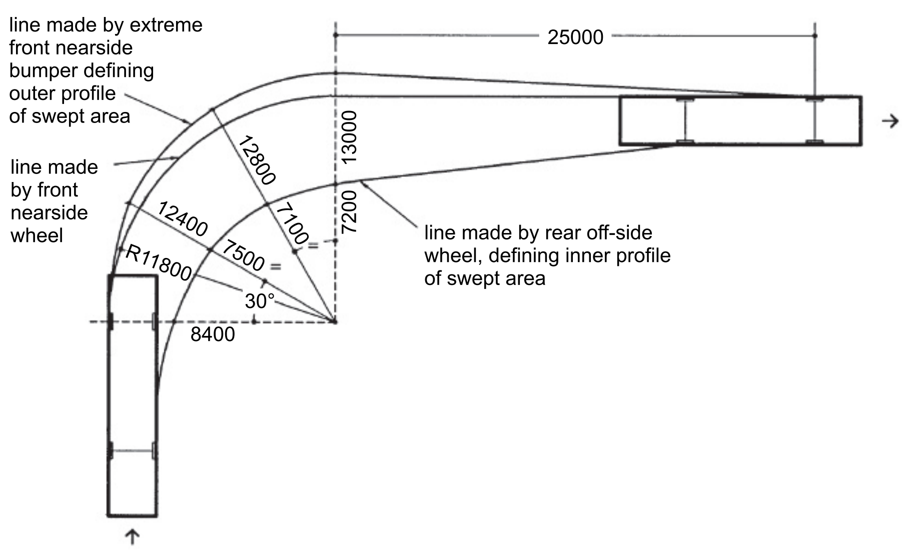
30.17 *Single-decker bus*



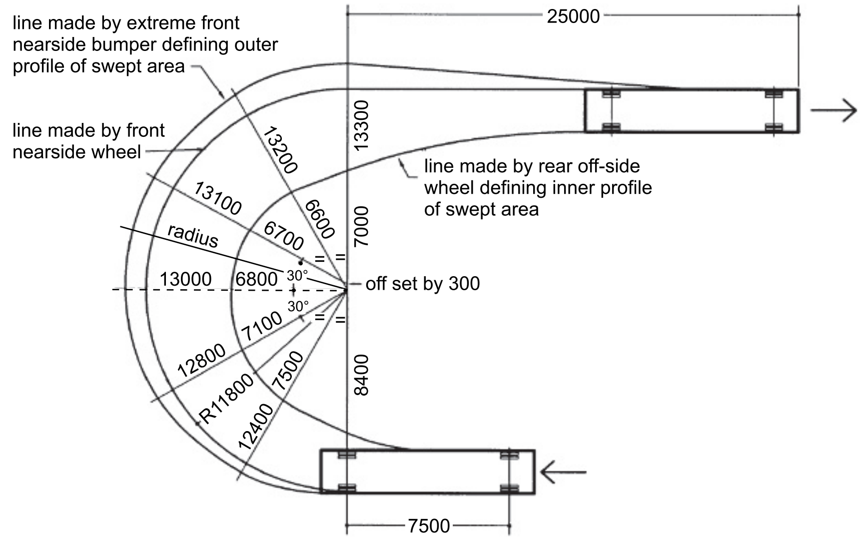
30.18 *Articulated bus*



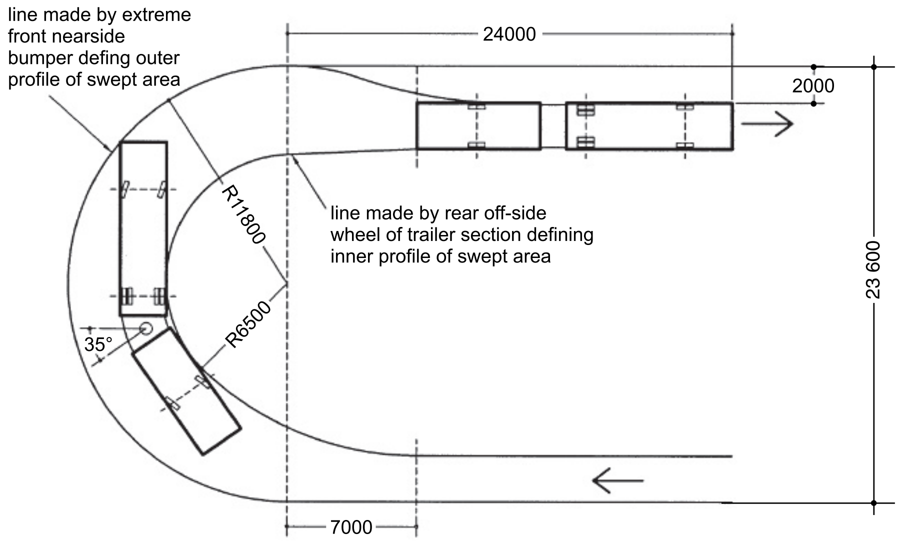
30.19 *Double-decker bus*



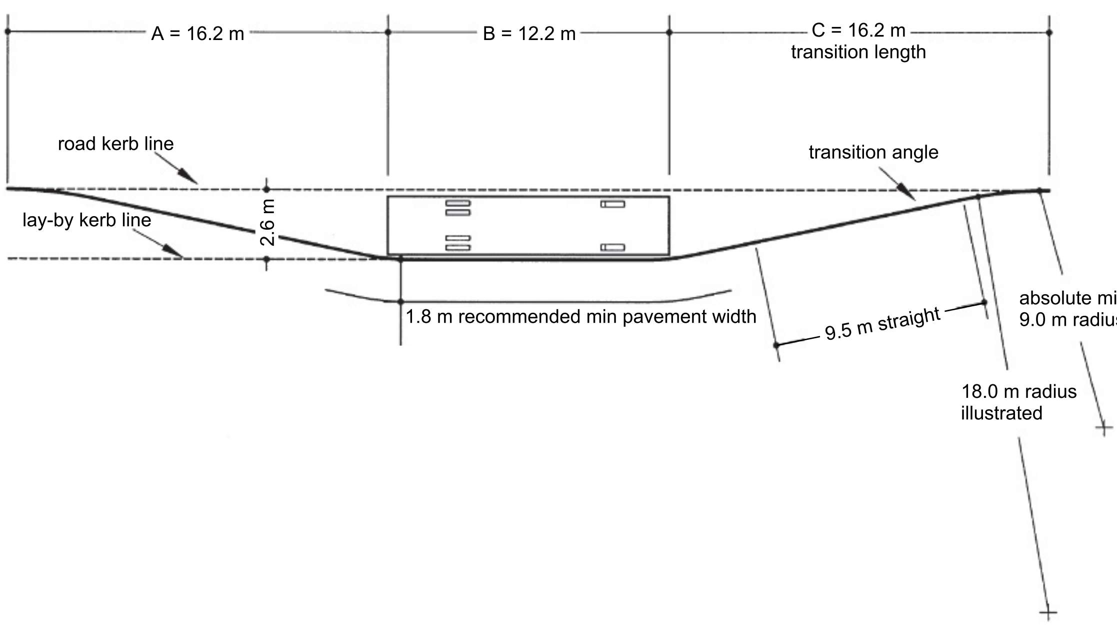
30.20 *Rigid 12 m vehicle turning through 90°*



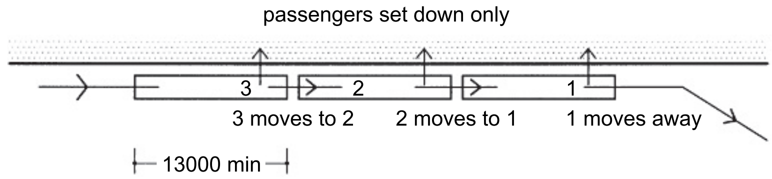
30.21 *Rigid 12 m vehicle turning through 180°*



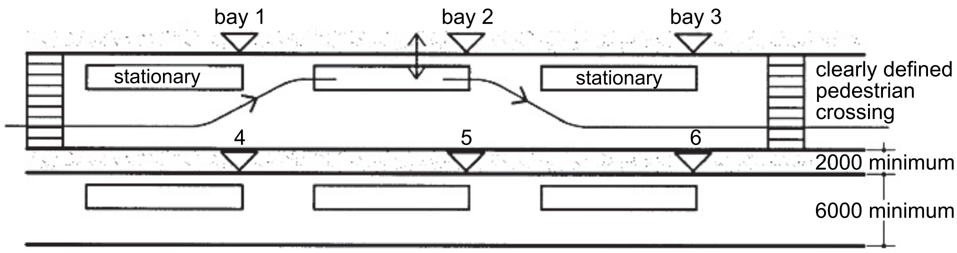
30.22 *17 m articulated vehicle turning through 180°*



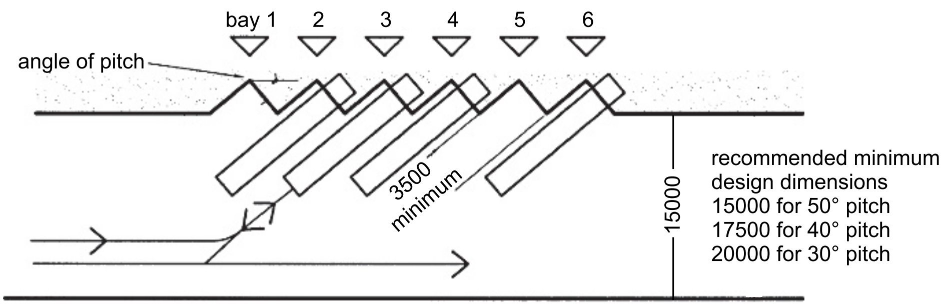
30.23 *A lay-by with one bus stop, assuming normal urban speed of approach. The transition length of 16.2 m is the minimum for a 12 m rigid vehicle. Three bus stops is the desirable maximum in a lay-by, the maximum comfortable distance for a passenger to walk*



a *Shunting, where a vehicle only sets down passengers on the concourse before moving off to park pick up more passengers. This avoids waiting to occupy a pre-determined bay, and reduces effective journey time*

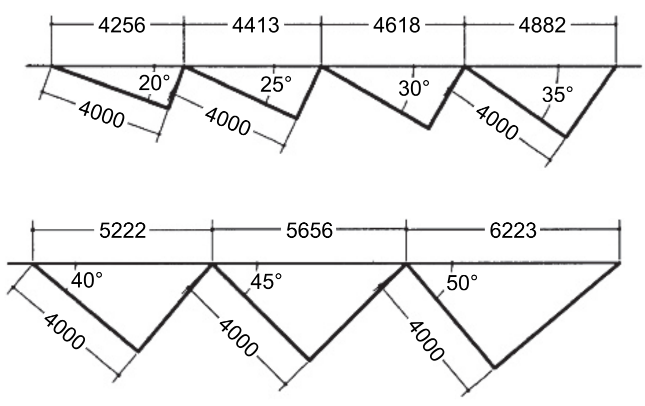


b *Drive-through bays are fixed positions for setting down and/or collecting passengers. They are in a line, so a vehicle often has to approach its bay between two stationary vehicles. In practice it is often necessary to to have isolated islands for additional bays, with the inevitable conflict between passenger and vehicle circulation*

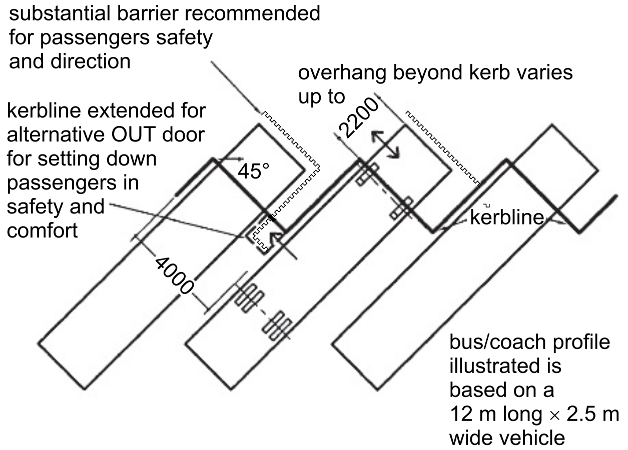


c *'Saw-tooth' layouts have fixed bay positions for setting down and/or collecting passengers with the profile of the concourse made into an echelon or saw-tooth pattern. In theory the angle of pitch between the vehicle front and the axis of the concourse can be anything from 1° to 90°; in practice it lies between 20° and 50°. The vehicle arrives coming forward, and leaves in reverse, thus reducing the conflicts between vehicle and passenger circulation, but demands extra care in reversing*

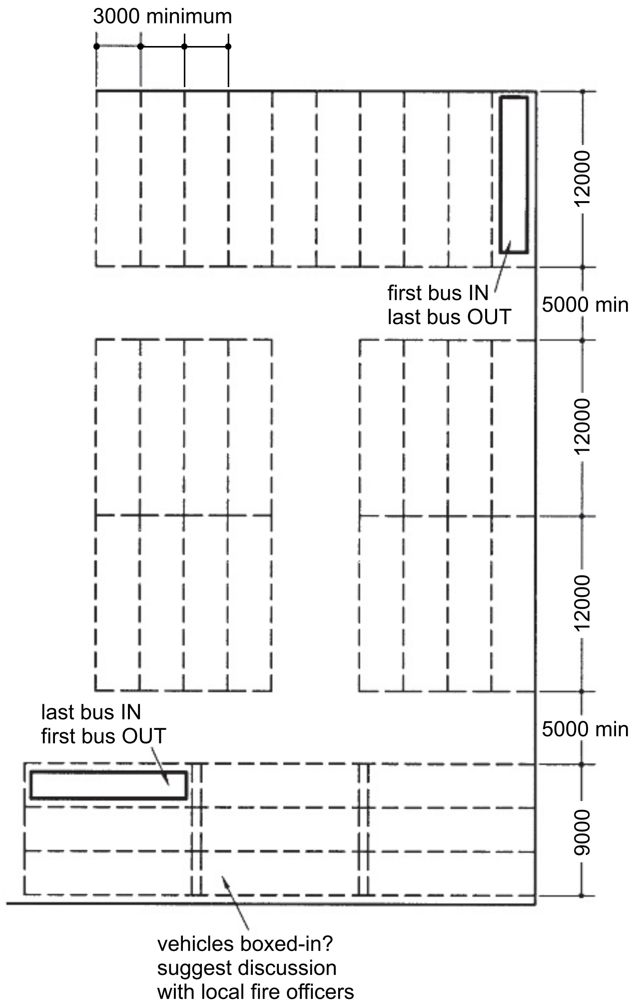
30.24 *Vehicle manoeuvres used in approaching parking bays*



30.25 *As the angle of pitch in saw-tooth bays increases so does the distance between each bay*



30.26 *Passenger safety and control are particularly important when detailing saw-tooth bays*



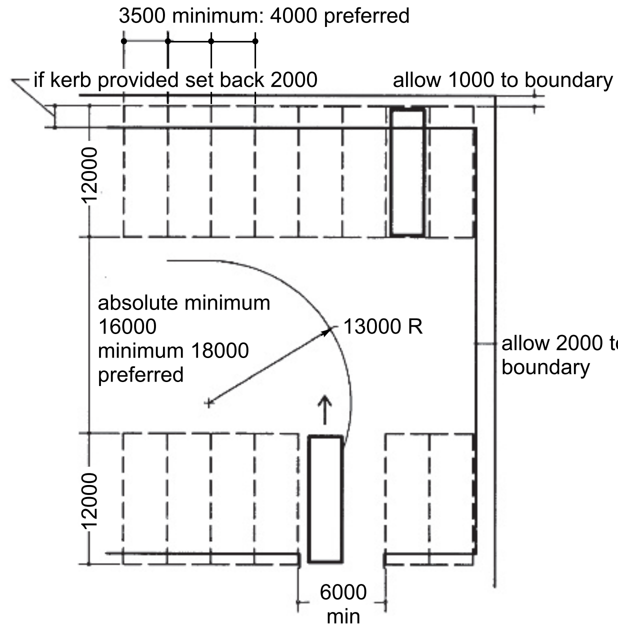
30.27 *Bus garaging layout for where the buses are parked in a pre-determined order to get the maximum number of buses in the available space, subject to the fire officer's limitations*

6.03

Whatever facilities are to be provided on the station site, the final arrangement must be carefully planned, **30.29**.

6.04 Joint company use

If two or more bus and coach companies operate from the same station, this can mean that different types of vehicle manoeuvre are used on one site. **30.30** is based on a proposal for a new station



30.28 *Coach park for random arrival and departure of vehicles. The larger bay size (4 m) is necessary if coach parties enter and leave the coaches in the park*

within a centre-town commercial development in the south-east of England, and illustrates this. The predominant company (which is a local one) favoured the saw-tooth layout, while the other preferred the drive-through arrangement. Full use has been made of a restricted site, and conflict between passenger and vehicular circulation has been minimised.

7 RAILWAY STATIONS

7.01

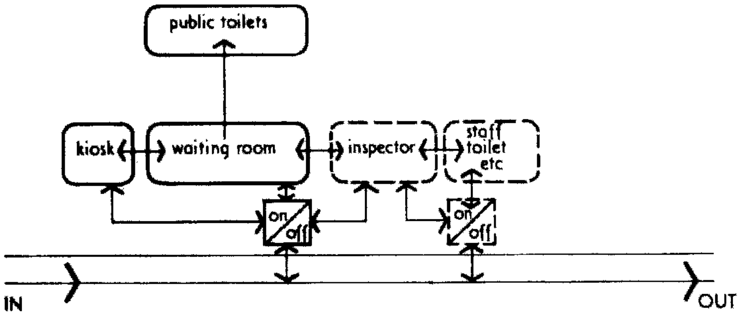
This section covers platform and related bridges only. In other respects railway stations have the common components of all passenger terminals: concourses, ticket offices, commercial outlets and catering and sanitary facilities.

7.02 Dimensional standards for railways

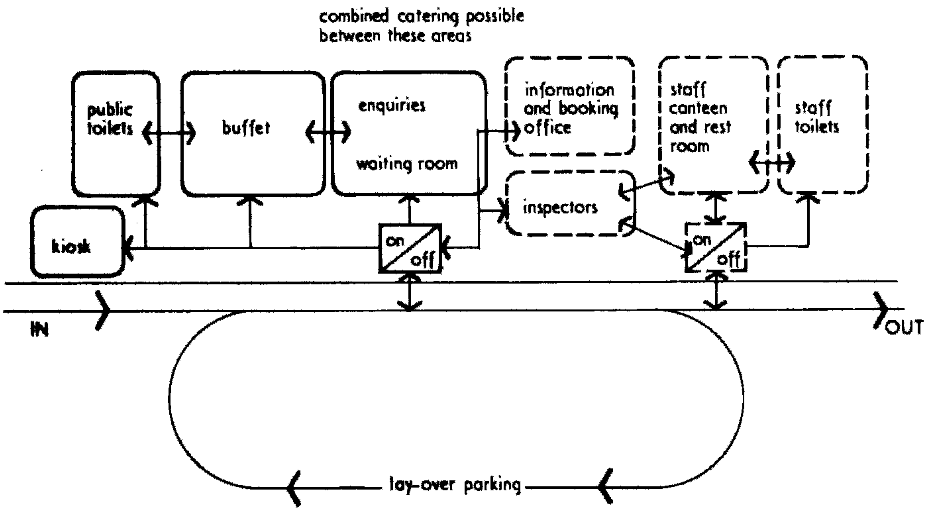
These have progressively converged in Europe ever since the days of 'the battle of the gauges'. However, the near-standardisation of the wheel gauge has not been matched by the loading gauge. Mainland Europe has built coaches and freight containers to larger cross-sections than in the UK. The advent of the Channel Tunnel in 1994 has highlighted the two principal standards for all-purpose stock while at the same time setting new and quite different standards for dedicated railway stock. The tunnel can accommodate 800-metre long trains of freight wagons 5.6 m high, but the passenger coaches in these trains are built to the British standard to fit under British, and therefore all bridge structures.

Note that clearance dimensions are valid for straight and level track only. Due allowance must be made for the effects of horizontal and vertical curvature, including superelevation. Note that the DoT standard states that, to permit some flexibility in the design of overhead equipment, the minimum dimension between rail level and the underside of structures should be increased, preferably to 4780 mm, or more, if this can be achieved with reasonable economy

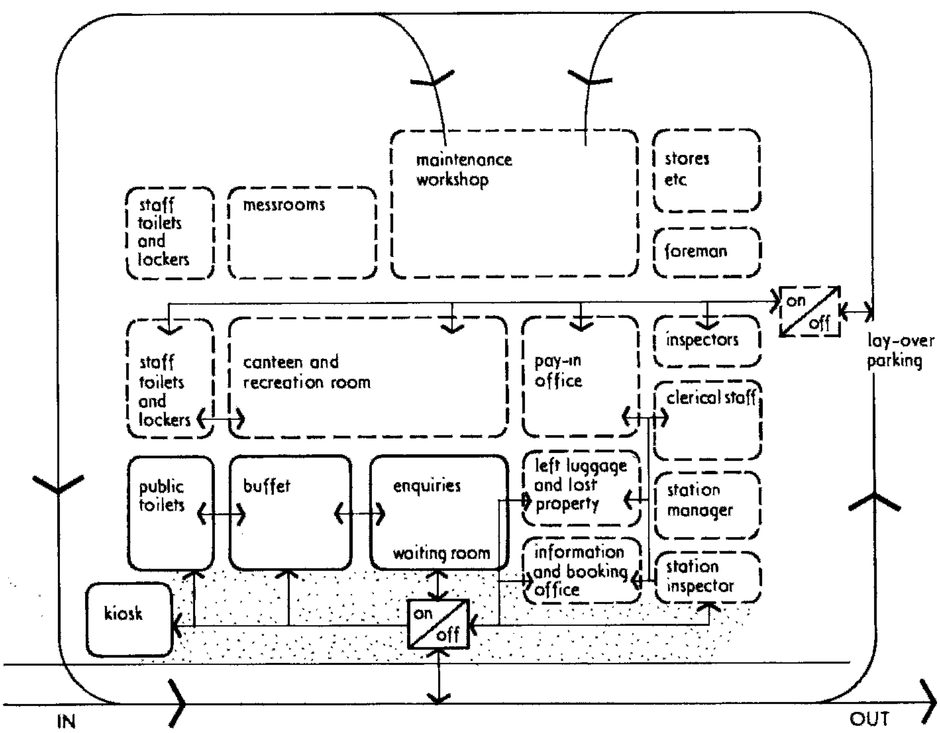
30.31 and **30.32** show European and British platforms and bridge structures in section. Platform heights in freight terminals are shown in **30.33**. Platform lengths can vary, but 250 m is common for main-line stations. The Eurostar London–Paris and London–Brussels services exceptionally use trains 400 m long.



a *In a small town where all services run through*

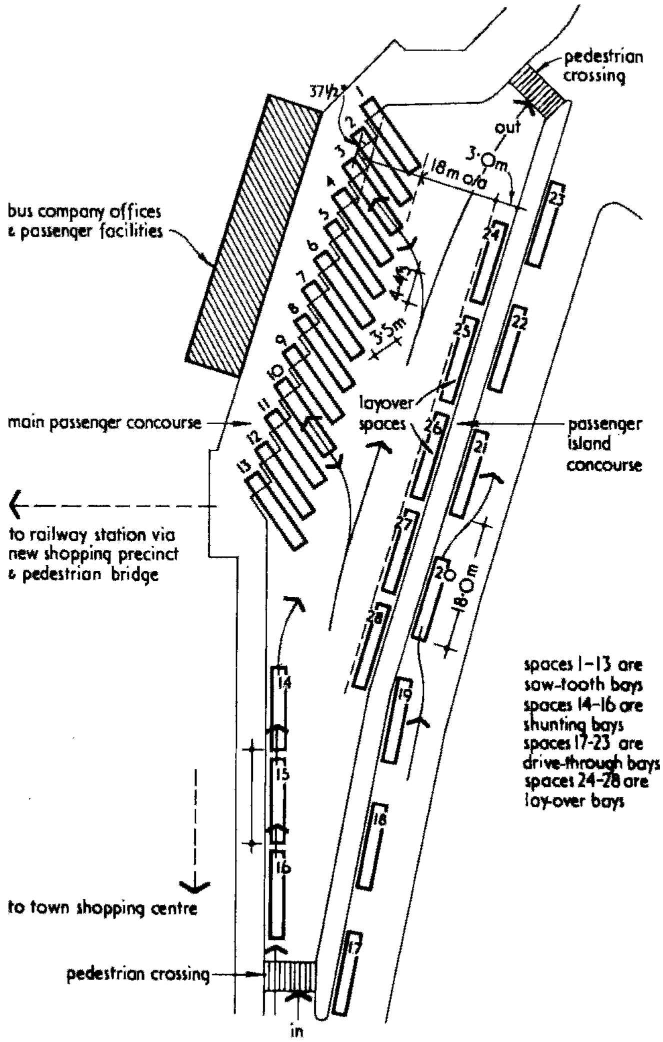


b *For a medium-sized town with both terminal and intransit services*

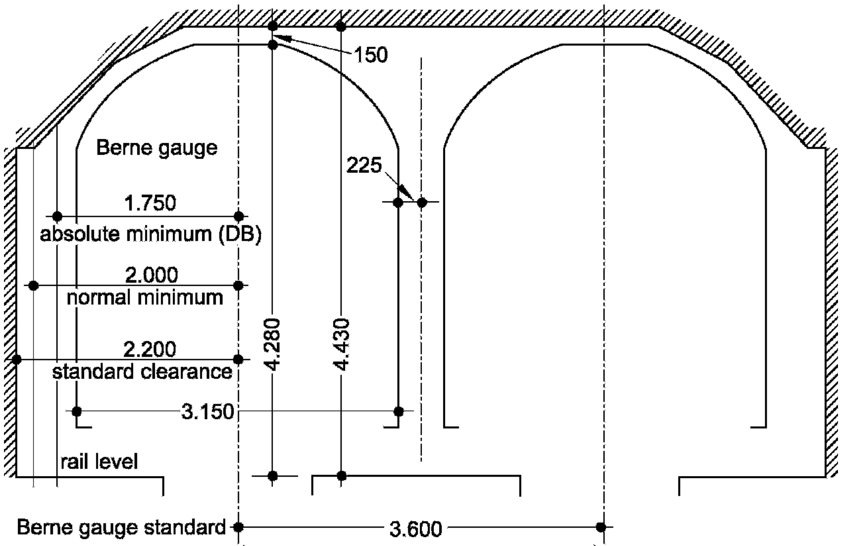


c *For a large new town*

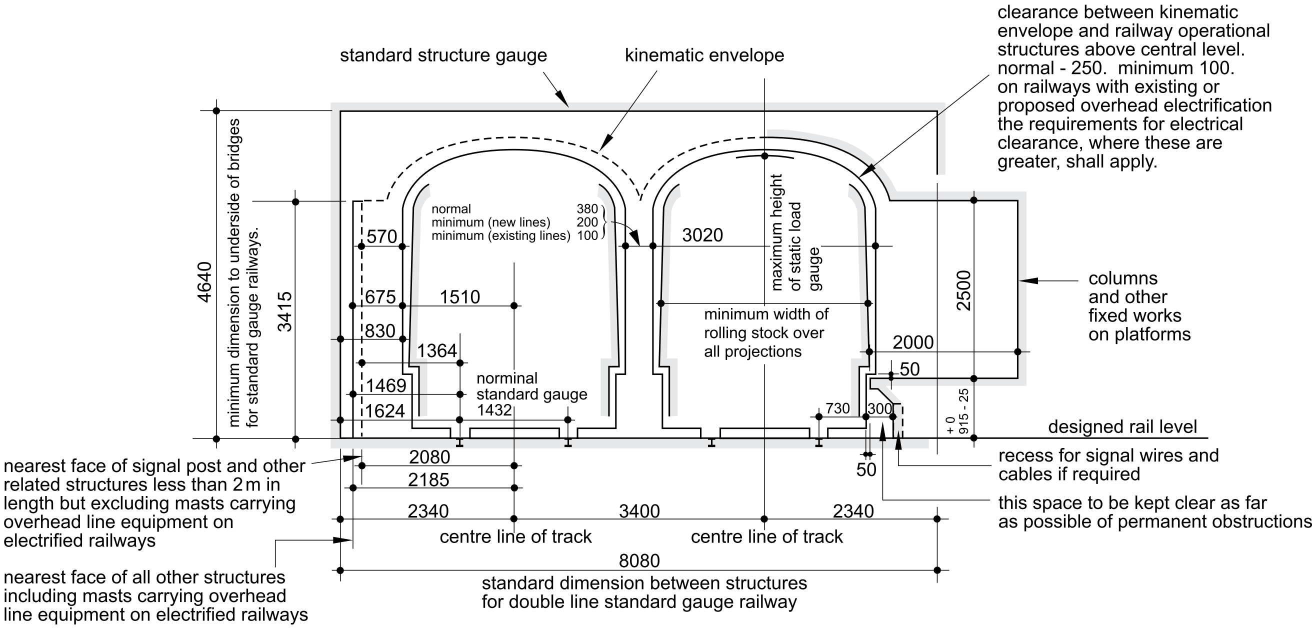
30.29 *Relationship diagram for different types of bus station*



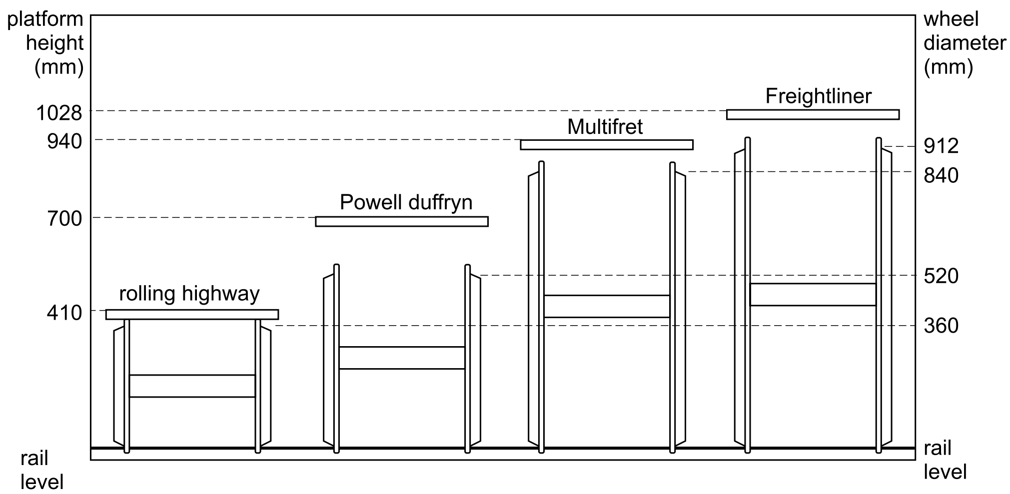
30.30 *Bus station accommodating two bus companies, each with different bay requirements*



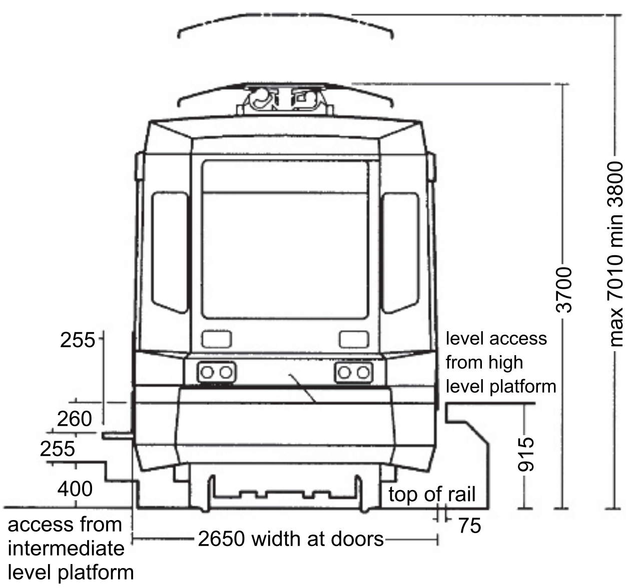
30.31 *Cross-section: controlling dimensions for railway structures, European (Berne gauge) standard*



30.32 *Cross-section: controlling dimensions for railway structures, BR standard*



30.33 *Container waggon floors have different heights, and may also vary up to 100 mm in laden and unladen conditions*



30.34 *Manchester Metrolink: a typical modern tramway system. Frontal view of a car, showing level access for wheelchairs from a high-level platform*

8 TRAMS AND LIGHT RAIL

There are a wide variety of these installations. **30.34** shows a typical light rail car designed to facilitate use by wheelchair users.

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9.02 Specialist journals

Airports International

Jane's Airport Review

Passenger Terminal World

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31 Designing for vehicles

CI/SFb 12
UDC 656.1

KEY POINTS:
- *Commercial vehicles are getting larger and heavier*
- *Better provision for bicyles is being made*
- *More consideration is being given to the needs of pedestrians*
- *Better facilities for disabled people including wheelchair users and people with visual impairment are becoming essential*

Contents

1 VEHICLES

1.01 Scope
This section deals with data on:

- Cycles
- Motor-cycles and scooters
- Automobiles: cars and small vans up to $2^1/_2$ tonnes unladen weight
- Commercial vehicles up to 10 tonnes unladen weight
- Public Service Vehicles (PSVs): buses and coaches
- 'Juggernauts', large commercial vehicles maximum 40 t. This class includes those with draw-bar trailers (see **31.1**).

1.02 Dimensions
The dimensions of some examples of each class are given in **31.1**. In any specific case, the manufacturer's data should be consulted.

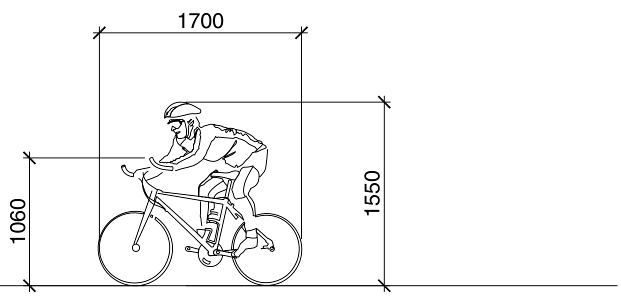
1.03 Unit construction
In the field of the larger commercial vehicles, unit construction is now almost universally employed. In this system a given chassis can be fitted with a variety of body shells for specific purposes and loads, mainly of standard dimensions. The body can be changed at will, permitting one body to be loaded while the chassis is on the road with another body delivering goods elsewhere.

A particular example is the standard container, which is used on lorries, ships, railways or even as a storage unit in the open, **31.2**. As this system was first developed in the USA, the standard dimensions are imperial, but the German railways developed a parallel version.

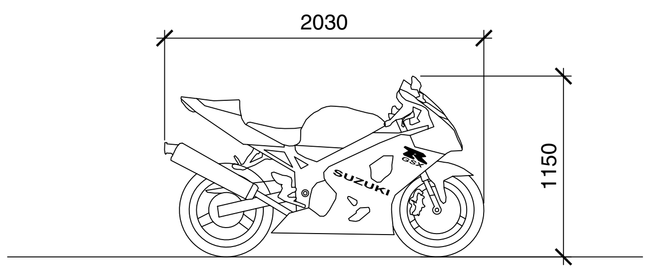
1.04 Turning circles
Apart from the physical dimensions, it is necessary to know the critical characteristics of the vehicle in motion, particularly when manoeuvring while parking or preparing to load. These characteristics are complicated, and usually the manufacturer will quote solely the diameter of the turning circle, either between kerbs or between walls.

Manoeuvring diagrams have been published for various vehicles for the following operations:

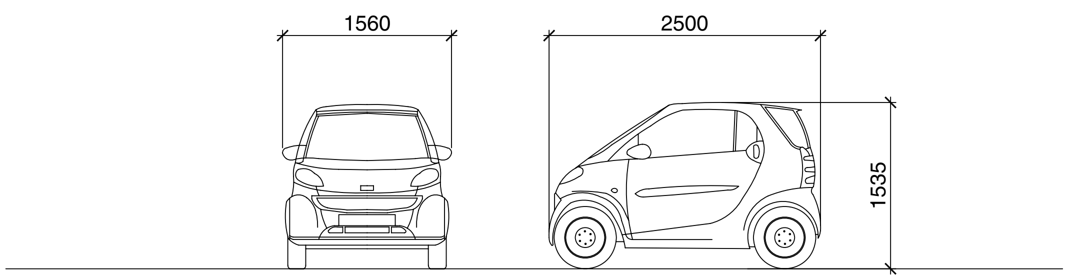
- Turning through 90°
- Causing the vehicle to face in the opposite direction by means of a 360° turn in forward gear
- Ditto in reverse gear



a *Bicycle*

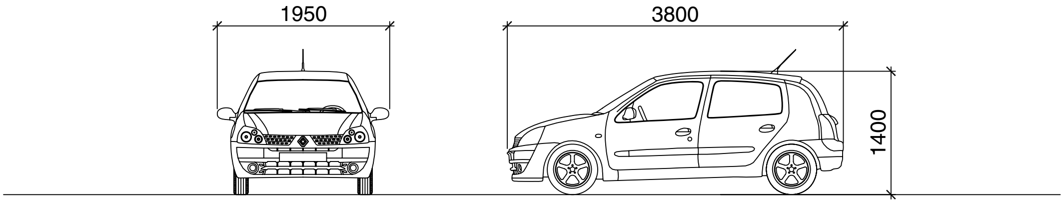


b *Motorcycle*

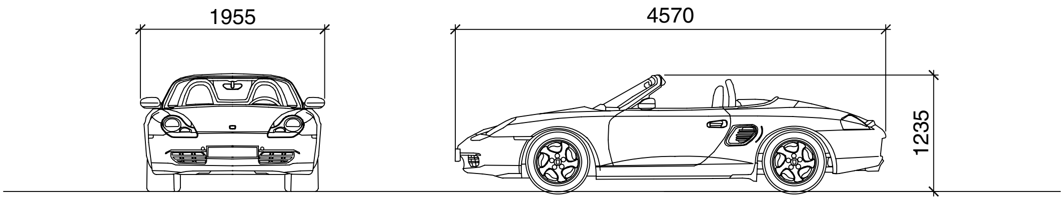


c *Small low emission two seater car*

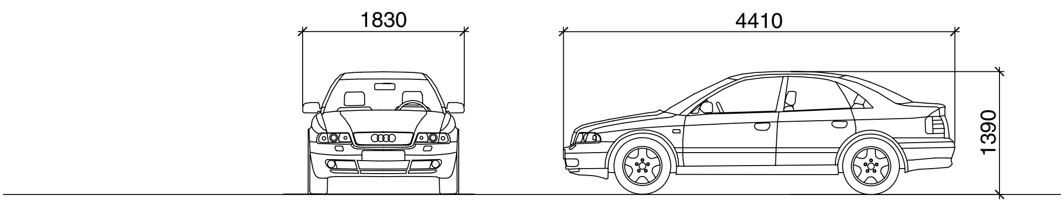
31.1 *Dimensions of typical road vehicles (continued over)*



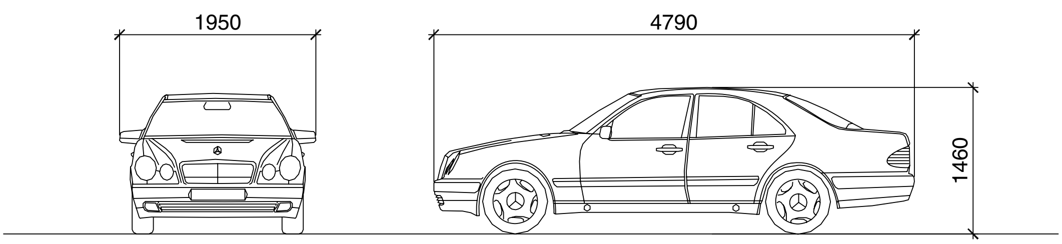
d *Small car*



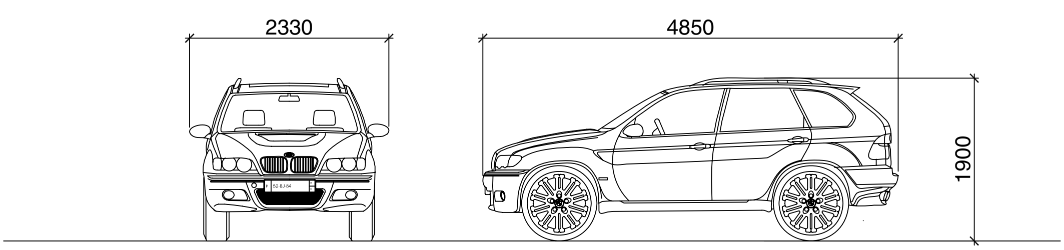
e *Sports car*



f *Family saloon car*

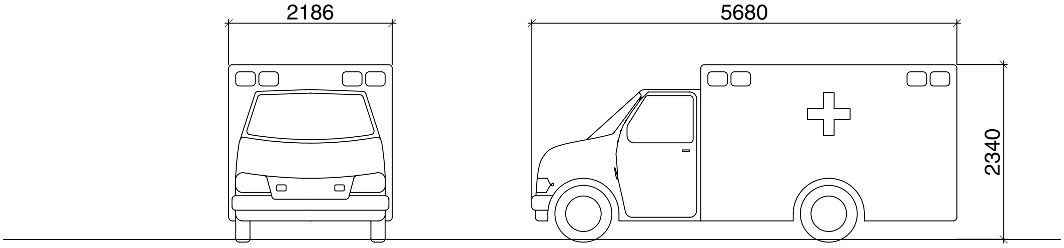


g *Luxury saloon car*

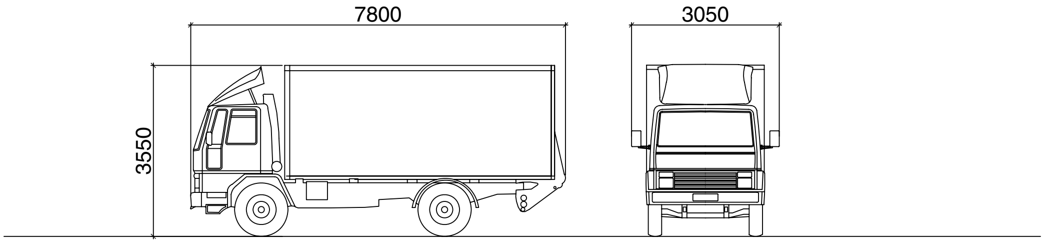


h *4 wheel drive car*

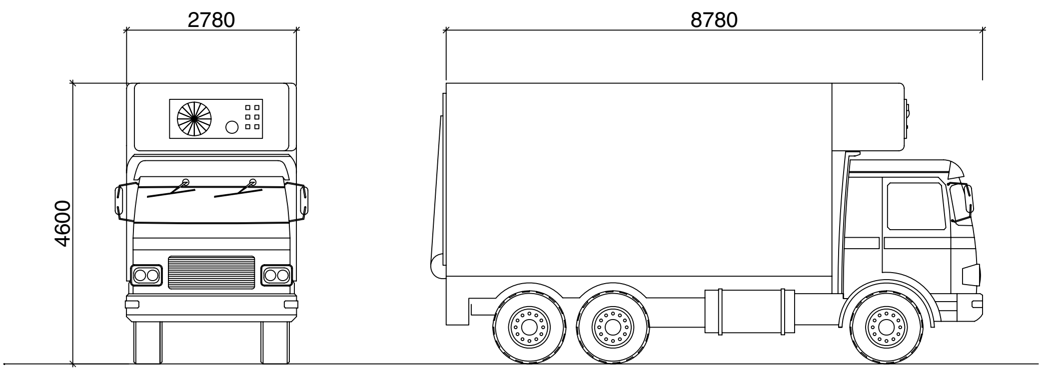
31.1 *Continued*



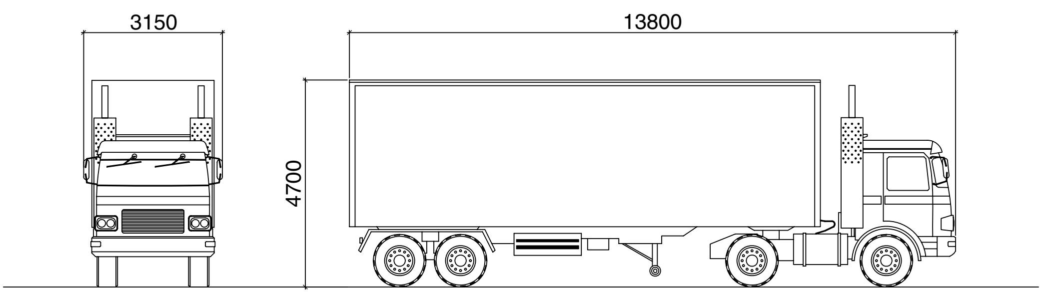
i *Ambulance*



j *2 axle rigid-body lorry*

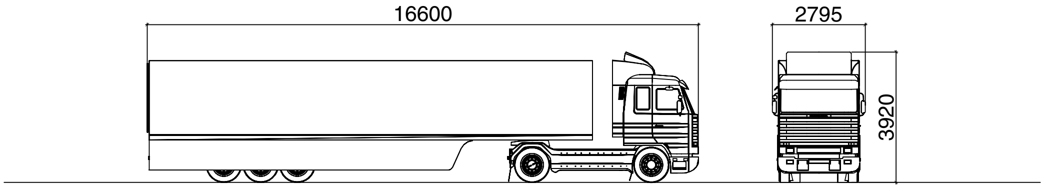


k *3 axle rigid-body lorry*

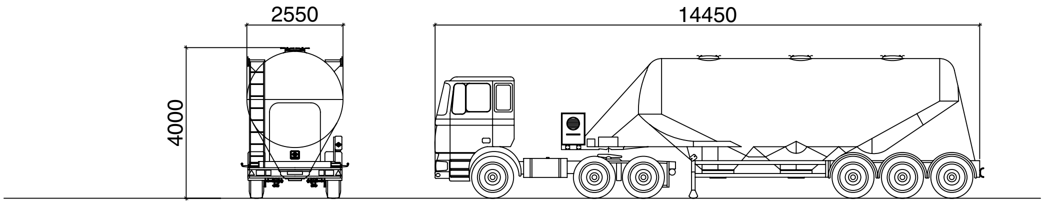


l *4 axle articulated lorry*

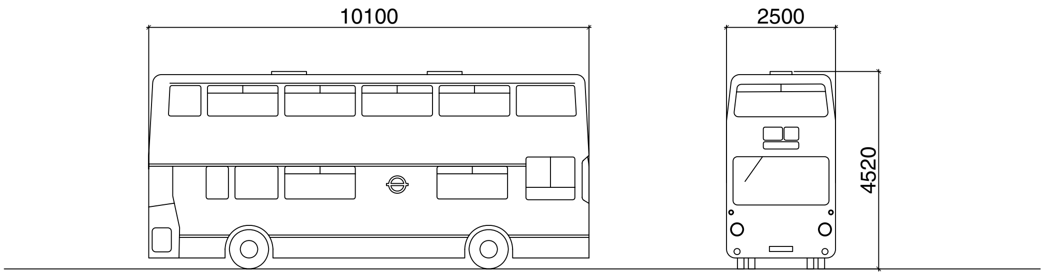
31.1 *Continued*



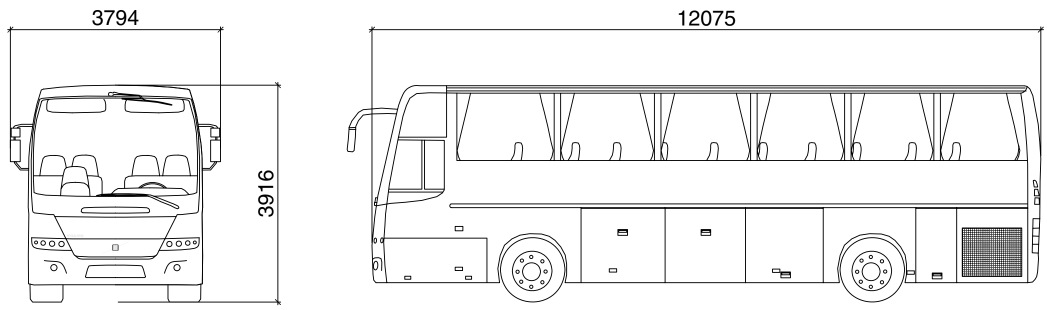
m *5 axle articulated lorry*



n *6 axle articulated tanker lorry*



o *Double-decker bus*



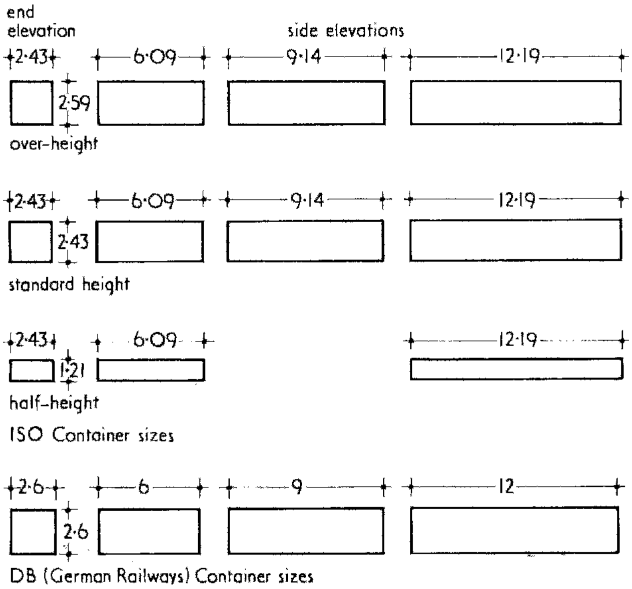
p *Passenger coach*

31.1 *Continued*

- Causing the vehicle to face in the opposite direction by means of both the forward and reverse gears (three-point turn), in T-form
- Ditto in Y-form
- Ditto in a forward side turn
- Ditto in a reverse side turn.

31.3 shows the 90° turns for some of the common vehicles. The other diagrams will be needed for the design of turn-rounds in culde-sacs, etc. The use of the published turning circle sizes is not sufficient for the following additional factors:

- The distance required for the driver to turn the steering wheel from straight ahead to full lock depends on the speed, which for the purposes of **31.3** is between 8 and 16 km/h.
- The radius of turn differs between a right-hand and a left-hand turn.



31.2 *Dimensions of standard containers*

- The path traversed by the rear wheels is different from that by the front wheels. In a commercial vehicle travelling at slow speed, the rear wheels follow a smaller are to the front wheels, the amount depending largely on the distance between the axles. The divergence between the arcs of the wheels on the same side of the vehicle is termed the 'cut in', and value of this determines the total track width of the turning vehicle, always greater than when on the straight.
- While few vehicles have a measurable side overhang of the body beyond the wheel track, many have considerable overhang at front and rear. This is important at the front: the extra width beyond the wheel tracks described by the body is known as 'cut-out'. Allowance should be made for front and rear overhang when designing turn-rounds, etc. by having no vertical obstructions within 1.2 m of the carriageway edge.

2 ROADS IN GENERAL

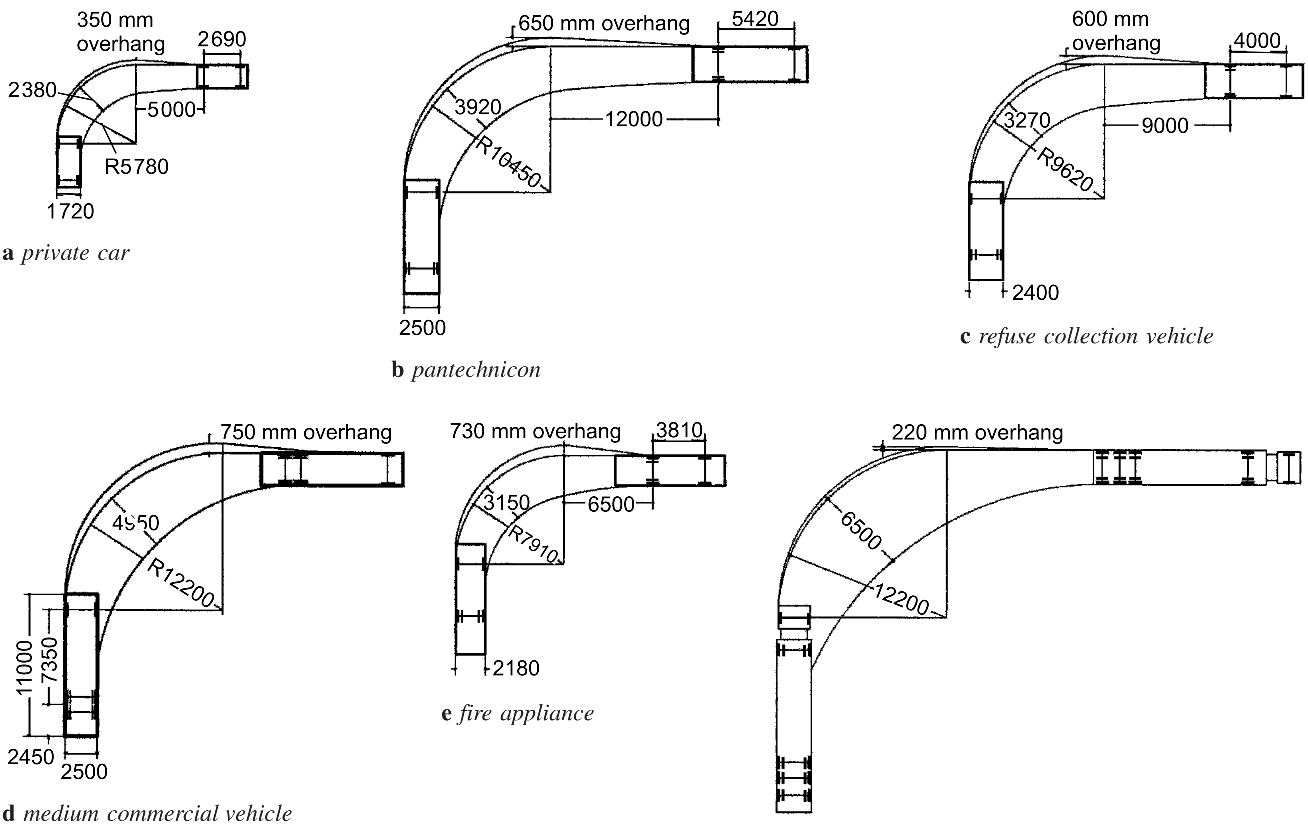
2.01 Hierarchy

- The broad hierarchy of roads is:
- Motorways and trunk roads
- Distributors (primary, district and local)
- Access roads.

This chapter will generally deal only with roads and facilities within development sites, such as industrial parks and housing estates. Public roads are not normally the concern of the architect, but Table I gives the recommended carriageway widths for most road types.

2.02 Definitions

Carriageway: the area of road surface dedicated to vehicles
Carriageway width: the distance between the kerbs forming the carriageway edges
Dual carriageway: a road with a central reservation, each separate carriageway carrying traffic in the reverse direction lane: a width of carriageway capable of carrying a single line of vehicles, usually delineated with white-painted dashed lines on the carriageway surface



a *private car*

b *pantechnicon*

c *refuse collection vehicle*

d *medium commercial vehicle*

e *fire appliance*

f *largest commercial vehicles*

31.3 *Geometric characteristics of typical vehicles turning through 90°*

Table I Recommended carriageway widths

Road type	Recommended carriageway width (m) between kerbs or edge lines	
Primary distributor	One-way, four lanes	14.6
	Overall width for divided carriageway, two lanes each way with central refuges	14.6
	Two-way, four lanes total, no refuges	13.5
	One-way, three lanes	11
	Two-way, three lanes (recommended only for tidal flow)	9
	One-way, two lanes	7.3
District distributor	One-way, two lanes	7.3
	One-way, two lanes if the proportion of heavy commercial traffic is fairly low	6.75
	Two-way, two lanes	7.3
Local distributor and access road in industrial district	Two-way, two lanes	7.3
Local distributor and access road in commercial district	Two-way, two lanes	6.75
	Minimum two-way, two lane back service road used occasionally by heavy vehicles	5
Local distributor in residential district	Two-way, two lanes used by heavy vehicles minimum	6
Access road in residential district	see text and 31.5	
	Where all vehicles are required to be able to pass each other	5.5
	Where a wide car can pass a pantechnicon	4.8
	Where two wide cars can pass each other, but a pantechnicon can only pass a cyclist	4.1
	Where a single track only is provided, as for a one-way system, or where passing places are used	
	for all vehicles	3
	for cars only (drives)	2.75
Rural roads	One-way, four lanes	14.6
	One-way, three lanes	11
	Two-way, three lanes	10
	One-way, two lanes	7.3
	Two-way, two lanes	7.3
	Motorway slip road	6
	Minimum for two-way, two lanes	5.5
	Minimum at junctions	4.5
	Single-track between passing places	3.5
	Overall at passing place	6

Lane width: since the maximum vehicle width permitted is 2.5 m, and the minimum clearance between parallel vehicles is 0.5 m, the minimum lane width is 3 m. However, vehicles travelling at speed require greater clearance and large vehicles need greater widths on curves, so faster roads have wider lanes
Cycle track or cycle path: a completely separated right-of-way primarily for the use of bicycles
Cycle lane: a portion of a roadway which has been designated by striping, signing, and pavement markings for preferential or exclusive use by cyclists
Shared roadway: a right-of-way designated by signs or permanent markings as a bicycle route, but which is also shared with pedestrians and motorists
Footway: an area of road devoted solely for the use of pedestrians, including those in wheelchairs or with prams, and running alongside the vehicular carriageway. In Britain the footway is also called the 'pavement', in the USA the 'sidewalk'
Footpath: a facility for pedestrians not forming part of a road.

3 ROADS IN RESIDENTIAL AREAS

3.01 Environmental areas

This section focuses mainly on roads in residential areas and in housing estates. However, the principles are the same in industrial and business areas, only the details will differ.

An 'environmental area' is surrounded by distributor roads from which access to the properties within is gained solely via the access roads within it. The access road network is designed with the following in mind:

- Road access to within 25 m (or 15 m in certain cases) of each house
- Road access to all private garages, whether within curtilages or in garage courts; and to all parking areas
- Through traffic from one distributor road to another, or to another part of the same road (avoiding a traffic blockage) is either impossible, or severly discouraged
- Necessary tradesmen, e.g. 'milk-rounds', calling at all or most properties in sequence, are not unreasonably diverted
- In general, traffic is not allowed to proceed too fast, but visibility at all times is at least the stopping distance for the possible (not the legal) speed limit.

31.4 illustrates typical access road layouts.

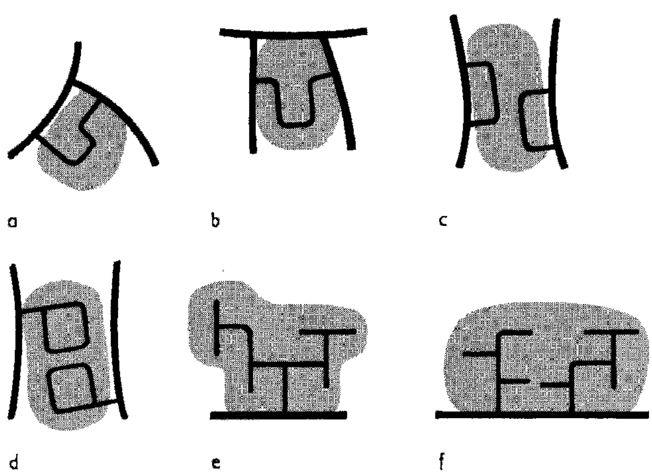
3.02 Types of access road

Access roads in residential areas are of three types:

- *Major access roads (or transitional).* These are short lengths of road connecting a distributor road with the minor access road network, the latter at a T-junction. They are normally 6 m wide, have no direct access to property along their length, and serve from 200 to 400 dwellings.
- *Minor access or collector roads.* These form the backbone of the network, will serve up to 200 dwellings and be 5.5 m wide with only one footway. Occasionally a single track 'car way' 2.75 m wide is used for access to about 50 dwellings, in conjunction with a separate footpath system.
- *Shared private drives, mews courts, garage courts and housing squares.* Generally these facilities serve up to 20 dwellings, and are designed for joint pedestrian/vehicle use with hard surfaces, no upstand kerbs and no footways. Access to them from the collector roads is marked by some device such as a short ramp or rough surface material, with the purpose of slowing down the traffic.

3.03 Designed controls

Conventionally roads were designed so that cars could be parked on both sides, and two cars could still pass. This encouraged use by



31.4 **a** *and* **b** *ore through roads, so tortuous as to discourage through traffic;* **c** *and* **d** *are non-through systems, but avoid the need for hammer-head turnrounds;* **e** *is a cul-de-sac system, but will have substantial traffic at the entrance;* **f** *is to be preferred on this count, although both systems post problems for the 'milk round'* vehicles trying to avoid congestion on main roads, with excessive speed and consequent nuisance and danger to the inhabitants. **31.5** shows the characteristics of the various carriageway widths.

While legal penalties can apply to misuse of these roads, these require enforcement resources which are rarely available. It is therefore the designer's responsibility to build-in the discouragement required. Closures, narrowing and speed humps are now used in existing roads; but these have unwanted side-effects such as complications for ambulances, fire engines and even local buses. In new developments it should be possible to avoid these measures and still provide sufficient restraints.

31.6 to **31.8** show typical arrangements of humps. The slowing effect of various ramps is detailed in **31.9. 31.10** and **31.11** give the Department of Transport requirements for hump dimensions.

There are considerable disadvantages to the use of humps. Vehicles, such as delivery vans, that are continuously using roads with humps find that maintenance costs on tyres, wheels and suspensions are significantly increased. Buses and ambulances find that their passengers experience discomfort and even danger. An alternative slowing device to the hump is the 'chicane', examples of which are shown in **31.12**.

Once garages and visitors' parking spaces are provided, kerbside parking may be discouraged by constructing one-way roads with minimum carriageway widths. However, occasional access by large furniture vans (and, unfortunately, fire appliances) will be necessary; and regular visits by refuse collection vehicles have to be as trouble-free as possible. For example, local authorities dislike cul-de-sacs with end turning areas permanently obstructed by parked cars, and may well insist on residents bringing their refuse to the entrance of the road.

Refuse vehicles and delivery vans blocking narrow roads cause annoyance to other residents trying to pass; consider having at least two routes of access/egress for most parts of the area.

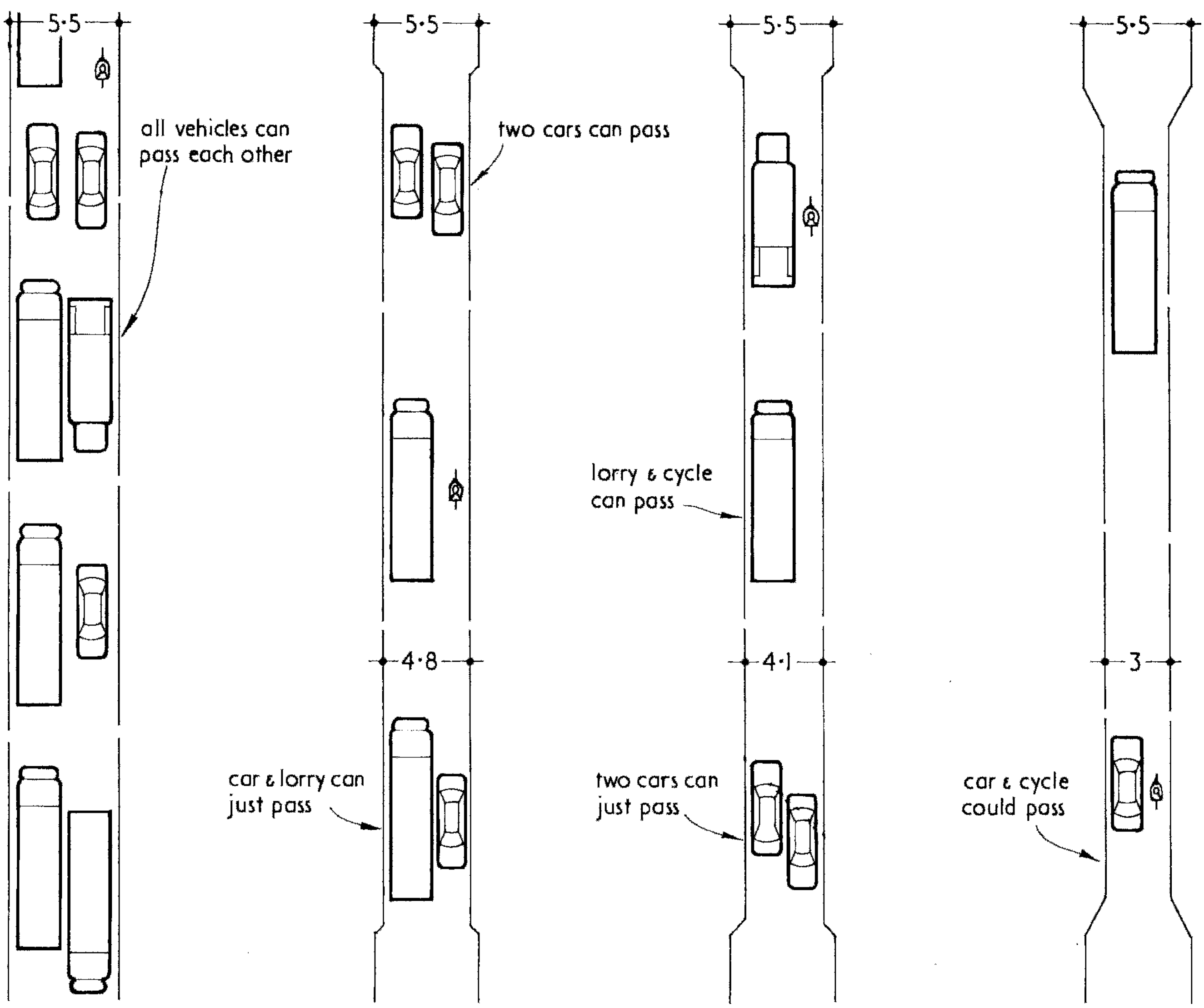
4 ROADS IN INDUSTRIAL PARKS

These must provide for use by the largest vehicles, but otherwise pose the same problems as roads in housing estates. Layout should discourage traffic using the roads as a cut-through, and should also ensure that the speed of the legitimate traffic is kept low. This is not a simple matter, as corner radii cannot be too sharp when heavy vehicles constitute a substantial proportion of the traffic.

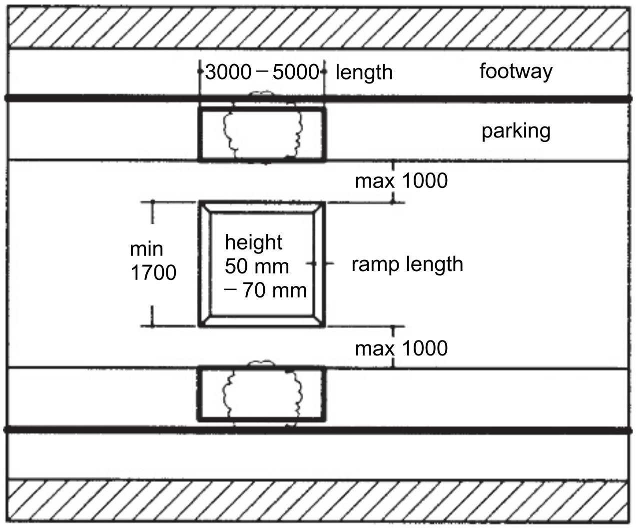
5 ROAD DESIGN DETAILS

5.01 Visibility and stopping distance

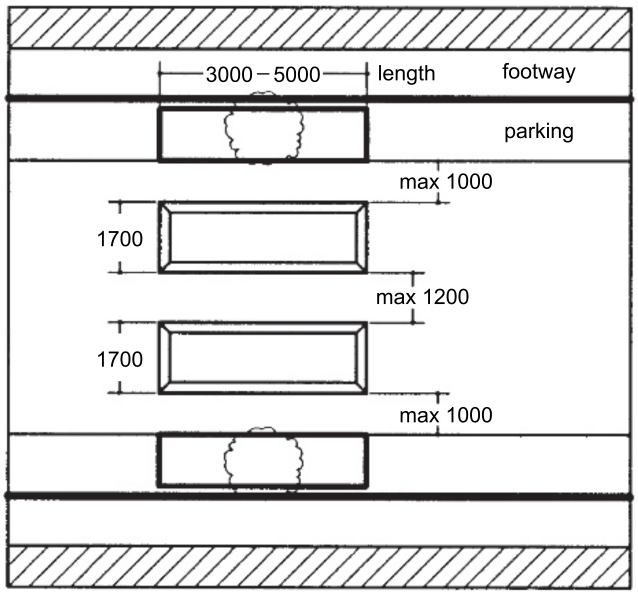
It is an axiom of road design that the driver should be able to see a distance at least as far as the distance he or she needs to stop in. If the object seen is also a moving vehicle, the sight distance must allow both vehicles to stop before colliding.



31.5 *Characteristics of various carriageway widths on two-way roads*



31.6 *Cushion hump*



31.7 *Double cushion humps*

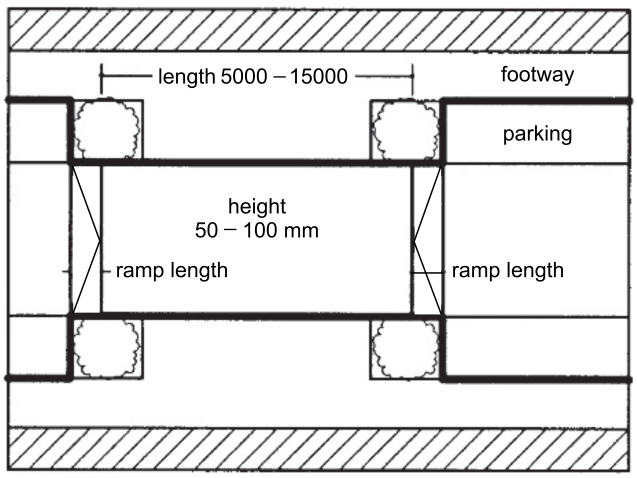
31.13 gives the design stopping distances for speeds up to 110 km/h (approx 70 mph). These distances are about $2^1/_4$ times the stopping distances given in the *Highway Code* for vehicles with good brakes in ideal conditions. This is to allow for reduced brake performance, poor weather conditions and impaired visibility. When emerging from a side road onto a through road the driver must be able to see a vehicle on the through road a distance of that vehicle's stopping distance. When crossing a footway the driver should be able to see 2.4 m along it. Where small children are to be expected this visibility should be to within 600 mm of the ground; but where there are no small children (such as in industrial areas) 1050 mm will be sufficient. **31.14** and **31.15** indicate the areas that must be free of obstruction, and Table II gives some recommended standards in residential areas.

5.02 Curves

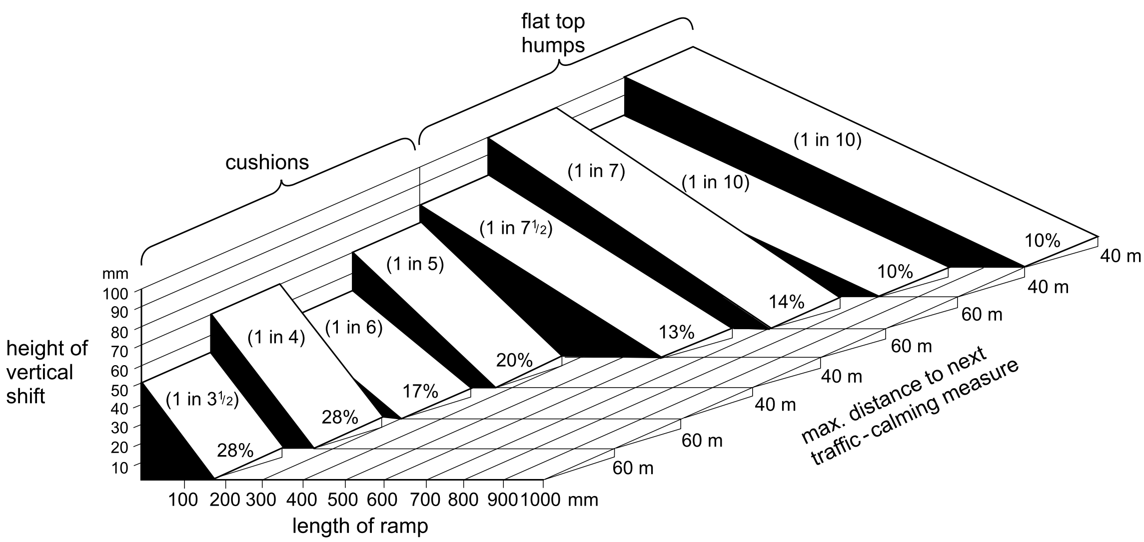
As mentioned in Section **1.04**, when a vehicle travels round a curve the road width it occupies is greater than the track width on the straight. Table III combined with **31.16** indicates the magnitude of this – the width of carriageway should be increased on curves to compensate.

5.03 Corners

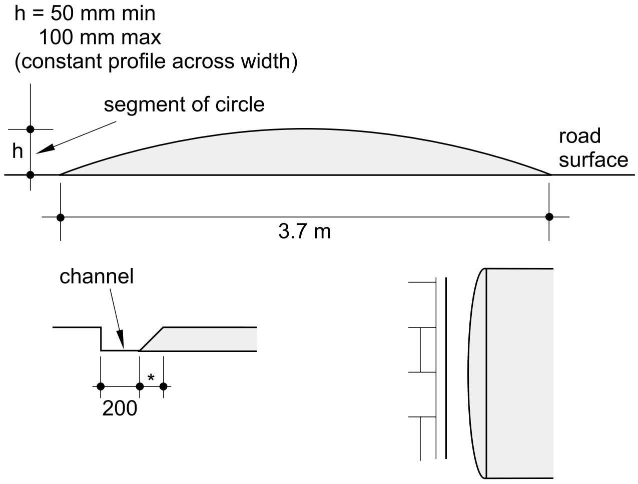
Since the internal radius of turn of a large commercial vehicle is about 8 m, it will be seen that a kerb radius of 10 m will be needed for such vehicles to maintain a constant distance from the kerb while turning the corner, also allowing some spare for the distance



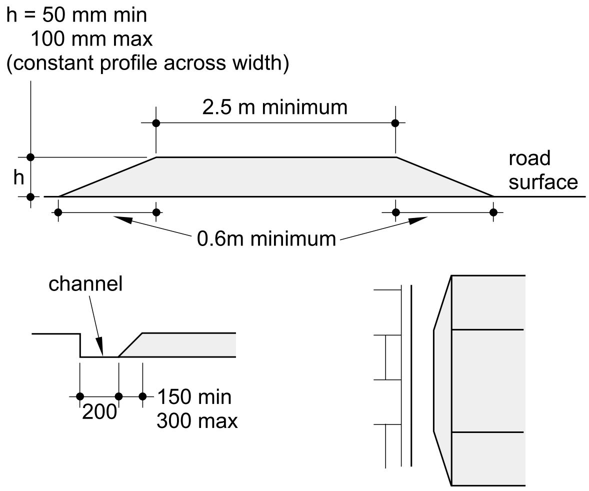
31.8 *Flat top hump used as a pedestrian crossing*



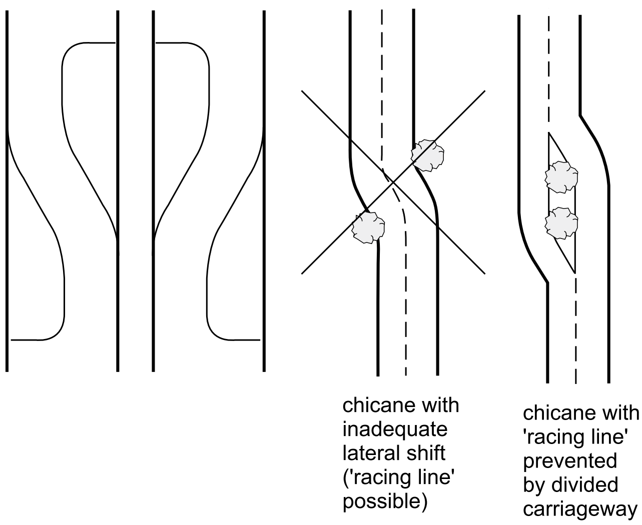
31.9 *Results of research into ramp dimensions for 85 percentile speed of 32 kph (20 mph)*



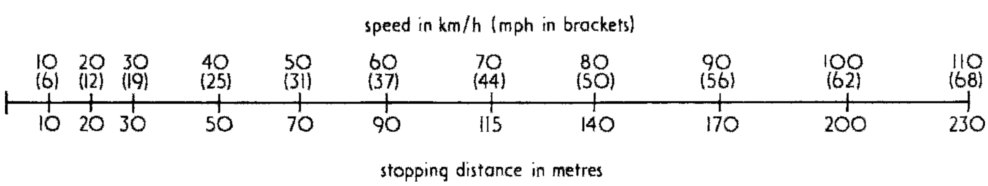
31.10 *Dimensions of round toproad hump from the Highways (Road Hump) Regulations 1990*



31.11 *Dimensions of flat-top hump from the same source*



31.12 *Chicane types of traffic slowing device*



31.13 *Design stopping distances*

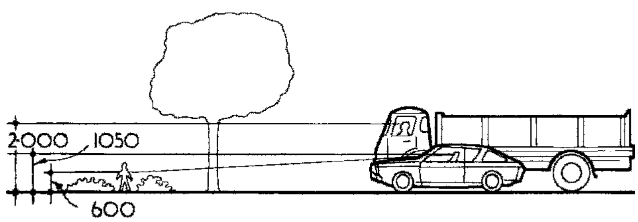
covered while turning the steering wheel. A kerb radius of 10 m in all cases would mean large areas of carriageway at junctions, and would be inappropriate in scale in many places, particularly in residential areas. Where traffic volumes are low there is no reason why the occasional large vehicle should not encroach on the opposite side of the road, provided that clear visibility is maintained so that vehicles affected by the manoeuvre can take avoiding action in time. **31.17** illustrates the effects of using radii of 10, 6 and 4 m.

5.04 Turn-round areas

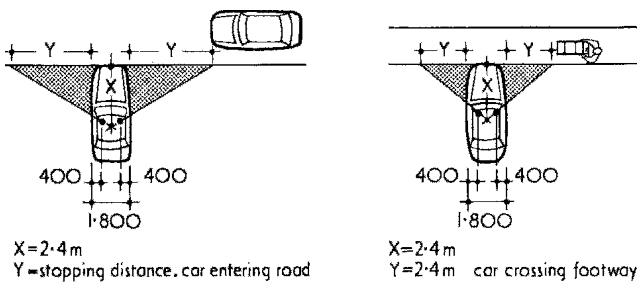
Where conventional arrangements are used in turn-round areas in mews courts and housing squares, the minimum standards in **31.18** can be employed. Some local authorities require more generous minimum standards for their refuse collection and fire-fighting vehicles. In cases of doubt, use the specimen vehicle track diagrams in **31.3**.

5.05 Gradients

Acceptable gradients are hard to define. What would be quite normal in the Peak district would be considered horrendous in Lincolnshire. Consider the likelihood of snow and icy conditions in winter, when anything greater than about 12 per cent becomes impassable without snow tyres or chains. Most general-purpose roads are now constructed to 7 per cent or less. Ramps to lorry loading bays and car parking garages are limited to 10 per cent. Some car parks in basements or multi-storey have gradients up to 15 per cent (and occasionally beyond). These steep gradients require vertical transition curves at each end to avoid damage to vehicles. Also, steep gradients either up or down should be avoided close to the back of pavement line or road edge, as it is difficult to see clearly, or to take preventative action if needed.



31.14 *Required heights for unobstructed visibility*



31.15 *Required distances for unobstructed visibilitys*

Table II Recommended standards in junction design

Junction type		Radius (m) R	Minimum junction spacing (m) adjacent	Opposite	Sightlines(m)	
Road A	**Road B**				**X**	**Y**
Local distributor	Any other road	10	80	40	5	60 in 30 mph zone 80 in 40 mph zone 100 in 50 mph zone
Minor access road	Major access road	6			2.4	40
Minor access road	Minor access road	6	25	8	2.4	40
Minor access road	entrance to mews or garage court	4.2	25	8	2.4	40
Single track road	entrance to mews or garage court	8 & 5 Offset	25	8	Junctions must be intervisible	
Mews or garage court	entrance to mews or garage court	4.2			2.4	10

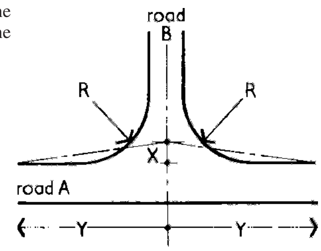
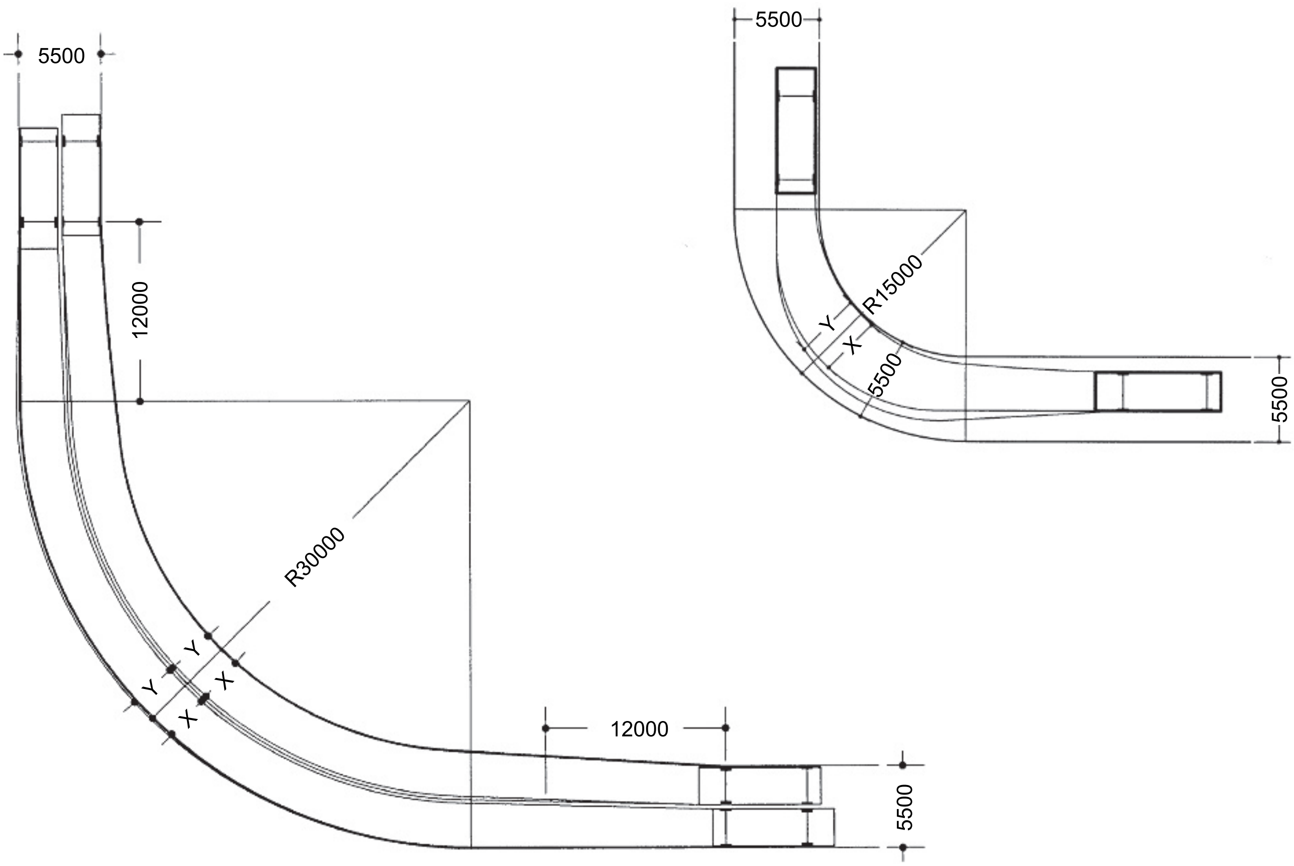


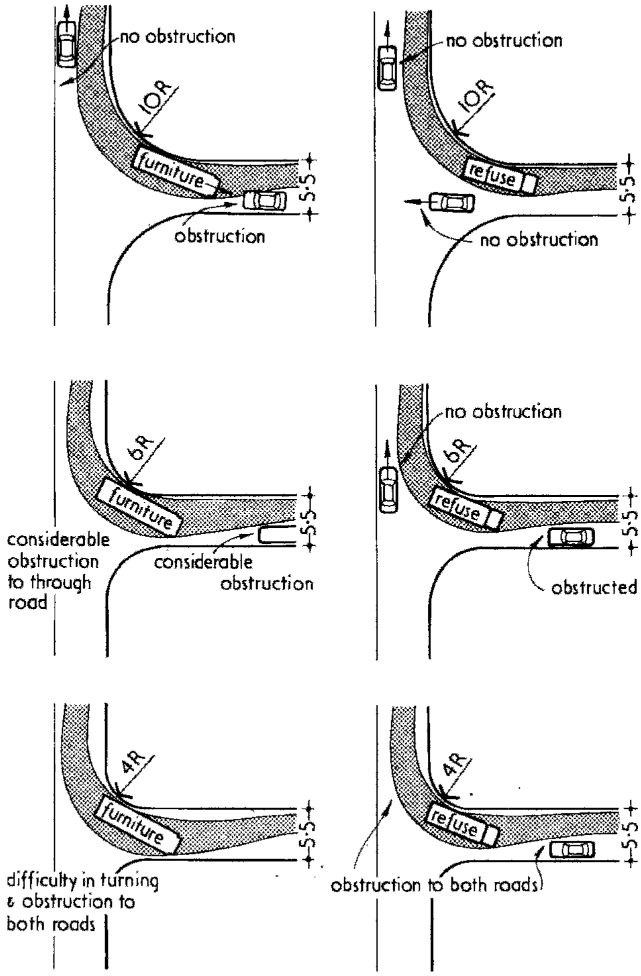
Table III Outside turning radius of front axle (m)

Minimum radius			15		30		45		60		75–400		400+		
R	**X**	**Y**	**X**	**Y**	**X**	**Y**	**X**	**Y**	**X**	**Y**	**X**	**Y**	**X**	**Y**	
10.45	3.92	4.57	3.44	3.89	2.96	3.19	2.80	2.95	2.73	2.84	2.68	2.77	2.53	2.54	Pantechnicon
9.62	3.27	3.87	2.94	3.33	2.66	2.85	2.58	2.71	2.53	2.63	2.50	2.58	2.42	2.43	Refuse vehicle
7.91	3.15	3.88	2.67	3.06	2.42	2.61	2.34	2.47	2.30	2.40	2.27	2.35	2.19	2.20	Sightlines(m)
5.78	2.38	2.73	1.96	2.10	1.84	1.91	1.80	1.85	1.78	1.81	1.76	1.78	1.73	1.74	Private car

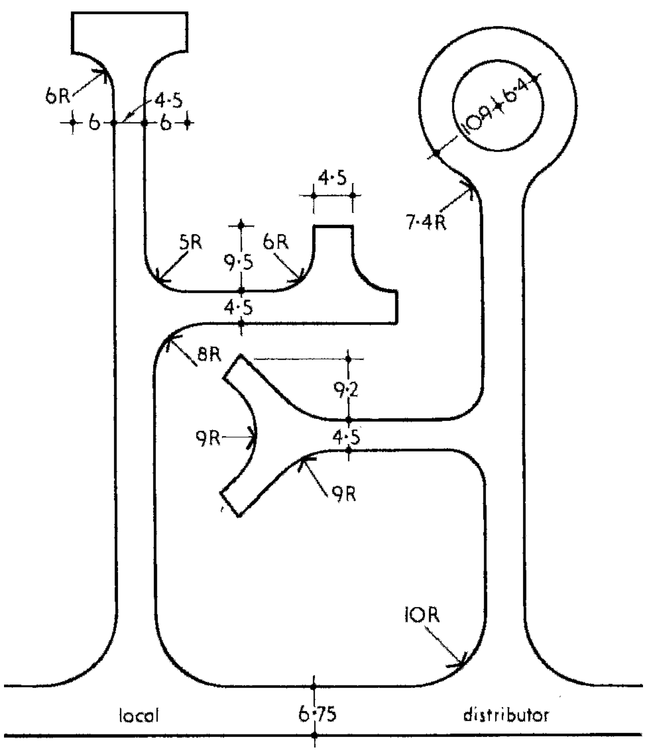
X = Maximum width of wheel path
Y = Maximum width of wheel path plus overhang



31.16 *Widening on bends; dimensions X and Y are given in Table III*



31.17 *Junction design; the effect of kerb radius on traffic flow at the T-junction of two 5.5 m wide roads*



31.18 *Typical recommended dimensions for use in urban areas*

5.06 Verges

Where there is no footway, a soft verge of 1 m width should be provided for the accommodation of services (water, gas, electricity, communications, etc.) and to allow for vehicular overhang.

6 BIKEWAYS AND CYCLE PARKING

6.01

For definitions see Section **2.02**.

6.02 Gradients

Cyclists will avoid steep gradients. Studies show that if gradients exceed 5 per cent there will be a sharp drop in the length of uphill grade that cyclists will tolerate. **31.19** illustrates commonly accepted maximum uphill grades based on length of grade; downhill gradients of 6.5 per cent are acceptable.

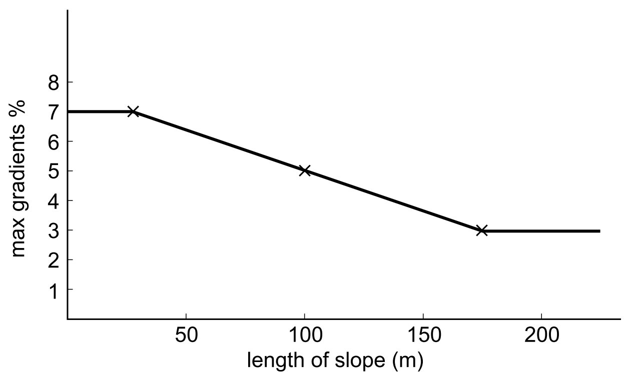
6.03 Width

Factors to consider when determining widths for bikeways must include:

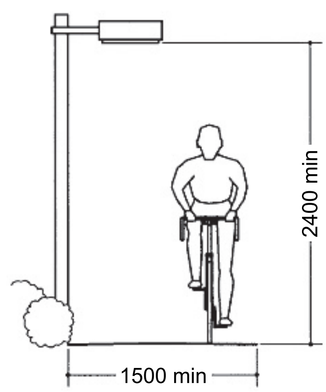
- The dimensions of the cyclist and the bicycle
- Manoeuvring space required for balancing
- Additional clearance required to avoid obstacles.

A width of 2.75 m is recommended for single-track bikeways, although 1.8 m, **31.20**, is acceptable. For two-way traffic 3.6 m is advisable. **31.21** shows a two-way right-of-way based on US practice. There should be no obstruction within 1.2 m of the edge of the riding surface, as this could be a danger. If the path is alongside a wall or fence, ensure that a line is painted on the surface at least 300 mm from it.

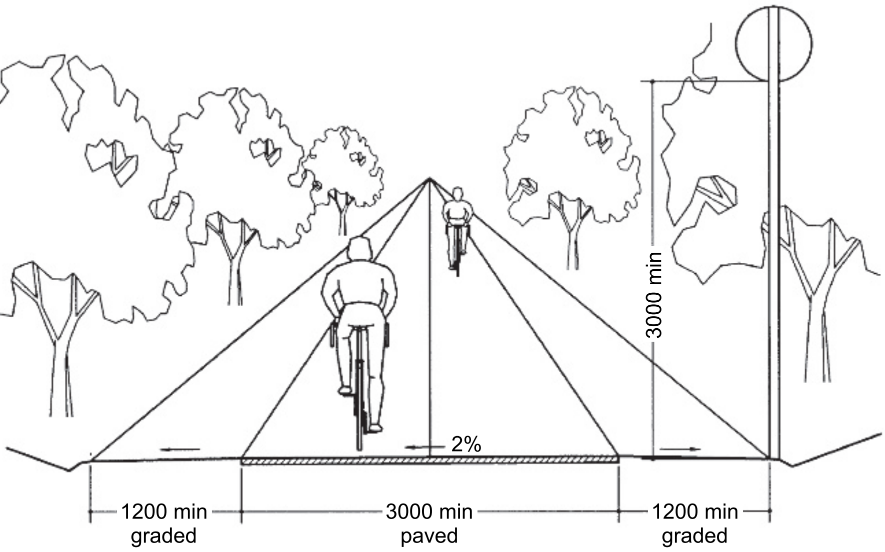
In almost all cases two-way travel will occur on cycle paths regardless of design intentions; appropriate widths should be provided. **31.22** illustrates a typical path where cycles share with pedestrians, and **31.23** a cycle lane on the near side of an all-purpose road.



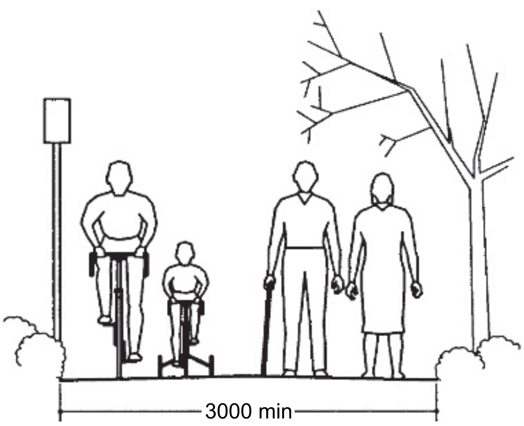
31.19 *Acceptable gradients for bikeways*



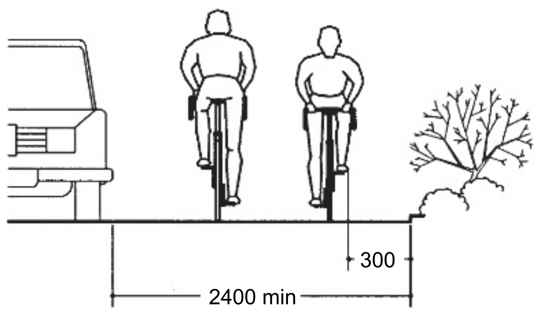
31.20 *Single-track cycle path*



31.21 *Two-way bicycle path on separated right of way*



31.22 *Cycle path shared with pedestrians*



31.23 *Cycle lane on all-purpose roadway*

6.04 Surfacings

A separate bikeway should have a smooth non-stick surface and have a thickness capable of supporting maintenance vehicles. Asphalt, concrete, gravel and stabilised earth are materials commonly used.

6.05 Drainage

Surfaces should have a crossfall of at least 2 per cent to provide positive drainage. Drainage grilles should have their slots diagonal to the route of the cyclist and be designed and located to minimise danger.

6.06 Cycle parking

This should be located as close to destinations as possible without interfering with pedestrian traffic; and where visual supervision, lighting and shelter from inclement weather can be achieved. It is essential to provide facilities for securely locking the bicycle frame and the front wheel wheel to something immoveable. The favourite is the Sheffield stand **31.24** or in certain situations, wall bars **31.25**. The groove in the concrete paving slab illustrated in the previous edition of this book is to be deplored: it provides no security, and can easily damage the wheel. In extreme cases, lockers large enough to contain a bicycle can be provided. **31.26** to **31.29**, show arrangements where larger numbers of cycles are expected. See Section 7 for suggested scale of cycle parking provision.

7 PARKING

7.01

A clear parking policy for each area is an essential. Many facilities now provide little or no parking in order to discourage the use of private transport. This is only effective if it is clearly impossible to park on the adjacent roads, and if there is adequate public transport available. Consider also the needs of disabled people.

There are no statutory requirements and few guidelines for the scale of parking provision. Table IV gives recommendations, but each specific case should be examined to determine expected requirements. Some planning authorities now restrict parking provision for cars in order to give a measure of restraint to traffic.

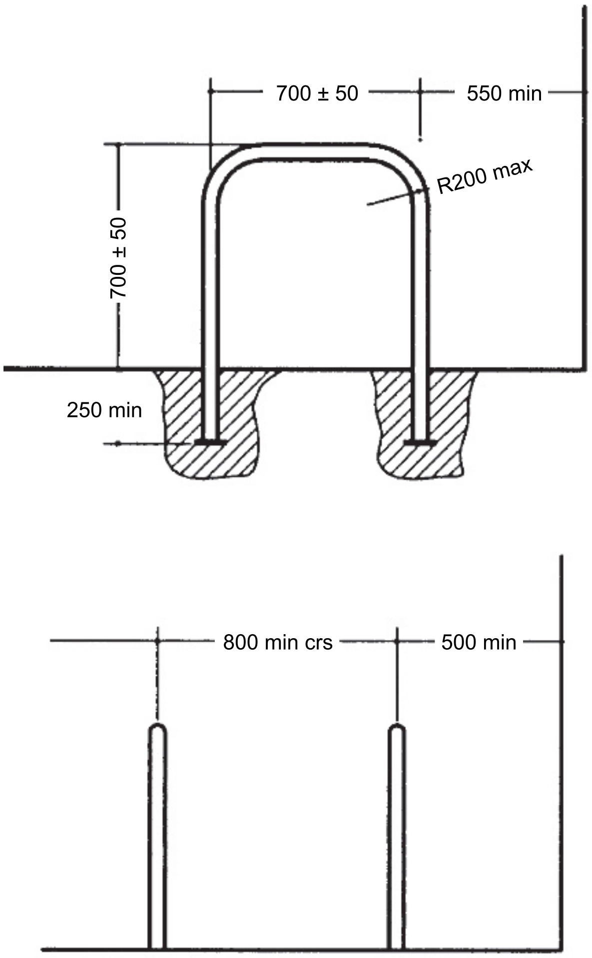
Table IV also includes recommendations for the scale of bicycle parking. These are quite generous so as to encourage greater use of bicycles. However, account should be taken of the local conditions – in places such as Cambridge where there are substantially more bicycles than average, greater provision should be made.

7.02 Domestic garages

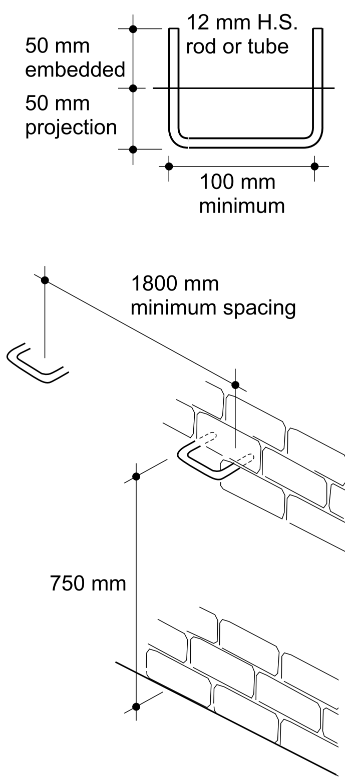
The domestic garage is the basic provision for residential areas. This can be:

- Within the envelope of the house or block of flats
- A separate detached building or
- One of a number in a garage court.

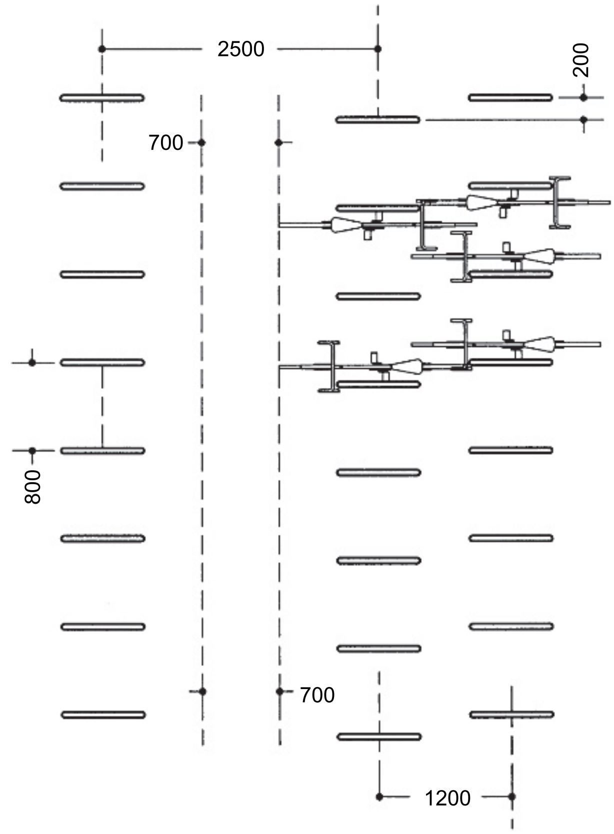
31.30 to **31.36** show a number of typical arrangements.



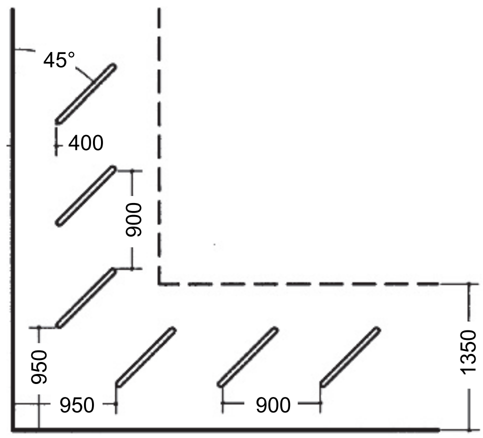
31.24 *Basic Sheffield parking stand*



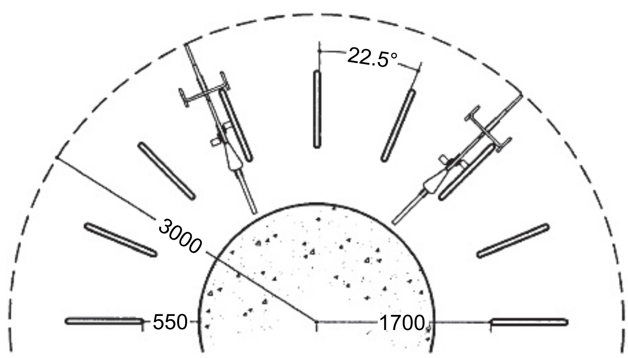
31.25 *Wall bar, suitable for smallparking spaces where short-term parking is required*



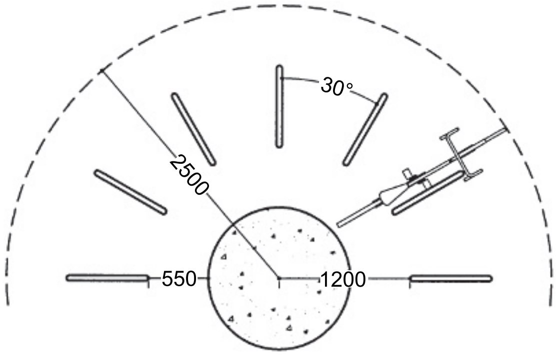
31.26 *It is important that arrays of Sheffield stands make best use of space. Attempts at closer spacing than shown will not succeed due to blocking of some positions by carelessly parked cycles*



31.27 *An arrangement in an angle between two walls*



31.28 *Circular array with a capacity for 32 cycles*



31.29 *Circular array with a capacity for 24 cycles*

7.03 Car parks

Once the scale of provision has been decided, the form will depend on the size and shape of the available area, and also on the type of vehicle expected. **31.37** and **31.38** give examples of various arrangements, but again, these should be taken purely as a guide. This type of car park assumes that vehicles arrive and leave in a random fashion. In some situations, such as sporting events, a dense arrangement can be adopted which means that all vehicles have to leave approximately in the sequence in which they arrived.

31.39 shows various types of multi-storey garage. No dimensions are shown as these vary with the site. An additional type, not illustrated, incorporates a mechanical stacking system operated by attendants. In practice, this rarely shows any advantage over conventional types.

Table IV Parking and loading/unloading requirements

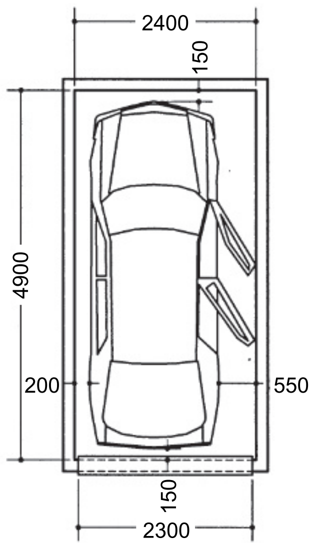
Type of building	Car parking provision	Loading/unloading provision		Cycle parking
Normal housing	Residents: one garage space for each occupancy, (preferably within the curtilage) Visitors: where houses are served directly from a road, driveways provide a minimum of one car space within curtilage of each Where visitors cannot park within curtilage, one off-street space per four dwellings	Refuse collection vehicle within 25 m of each disposal point (dustbin position). Some authorities require vehicle within 15 m. Where communal containers (paladins) are used, maximum distance 9 m Furniture removal vehicle as near as possible, not further than 25 m		
Minimum-cost housing	Space should be provided, if not laid out, to allow for one resident's or visitor's parking space per dwelling, provided public transport is available	As above		
Old people's housing	One garage space per two dwellings	As above		
Sheltered housing	Resident and non-resident staff: one car space per two members present at peak period Visitors: use empty staff places, but provide one additional place per five dwellings	As above, plus provisions for special passenger vechile with tail lift, etc. Minimum provision for daily loading/unloading 50 m^2		
Shops	Staff: one car space (preferably in enclosed yard behind shop) for each 100 m^2 gross floor area or, if known, one space per managerial staff plus one for every four other staff Customers: one space for each 25 m^2 gross floor area. In superstores with gross floor area exceeding 2000 m^2 allow one space per 10 m^2. (Not appropriate when goods sold are obviously bulky, e.g. carpets, boats)	See diagrams of loading bays. General minima as follows: Gross floor space not exceeding: 500 m^2 1000 2000 each additional 1000 m^2	Minimum space required: 50 m^2 100 150 50 m^2	1 per 200 m^2 with minimum of 4
Banks	Staff: one space for each managerial or executive staff, plus one per four others Customers: one space per 10 m^2 of net public floor space in banking hall	Minimum 25 m^2		2
Officers	Staff: one space for each 25 m^2 of gross floor area, or one space for each managerial and executive staff, plus one space per four others Visitors: 10% of staff parking provision	General minima: Gross floor space not execeeding: 100 m^2 500 1000 each additional 1000 m^2	Minimum space required: 50 m^2 100 150 25 m^2	1 per 200 m^2 with minimum of 4
Production buildings (factories)	Staff: one car space per 50 m^2 of gross floor area Visitors: 10% of staff parking provision	See loading bay diagram. Provision to be commensurate with expected traffic General minima as follows: Gross floor space not exceeding: 100 m^2 250	Minimum space required: 70 m^2 140	1 per 500 m^2 with minimum of 4
Storage buildings (warehouses)	Staff: one space per each 200 m^2 of gross floor space	500 1000 2000 each additional 1000 m^2	170 200 300 50 m^2	1 per 1000 m^2 with minimum of 4
Hotels, motels and public houses	Resident staff: one space per household Non-resident staff: one space for each three staff members employed at peak period Resident guests: one space per bedroom Bar customers: one space for each 4 m^2 of net public space in bars Occasional diners: no additional provision required If conferences are held in the hotel, space required should be assessed separately at one space for each five seats	General minima as follows: Gross floor space not exceeding: 500 m^2 1000 2000 each additional 1000 m^2	Minimum space required: 140 m^2 170 200 25	1 per 10 beds with minimum of 4

Table IV (Continued)

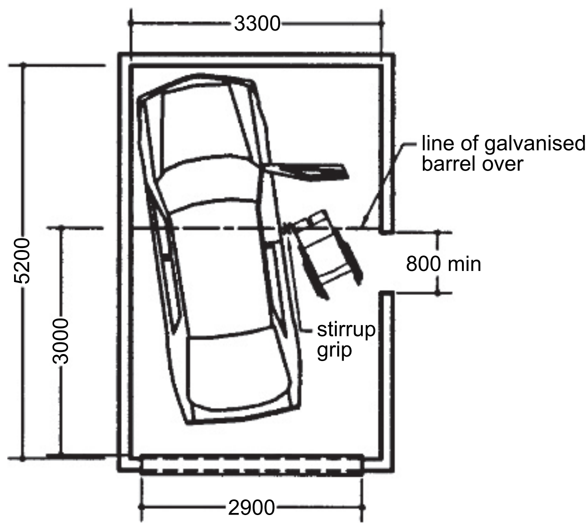
Type of building	Car parking provision	Loading/unloading provision	Cycle parking
Restaurants and cafés	Resident staff: one space per household Non-resident staff: one space per three members employed at peak period Diners: one space for each two seats in dining area (For transport cafés, the space should be a lorry space of 45 m^2, and the arrangement should be such that vehicles can enter and leave without reversing)	General minima as follows: Dining floor space not exceeding: / Minimum space required: 100 m^2 / 50 m^2 250 / 75 500 / 100	1 per 25 m^2 with minimum of 4
Licensed clubs	Resident staff: one space per household Non-resident staff: one space for each three members employed at peak period Performers: one space for each solo performer and/or group expected at peak Patrons: one space per two seats, or one space per 4 m^2 net public floor space	Minimum 50 m^2	1 per 25 m^2 with minimum of 4
Dance halls and discotheques	Staff: one space per three members at peak period Performers: three spaces Patrons: one space per 10 m^2 of net public floor space	Minimum 50 m^2	1 per 25 m^2 with minimum of 4
Cinemas	Staff: one space per three members at peak period Patrons: one space per 5 seats	Minimum 50 m^2 Space required within site by main entrance for two cars to pick up and set down patrons	1 per 100 seats with minimum of 4
Theatres	Staff: one space per three members at peak period Patrons: one space per 10 m^2 of gross dressing room accommodation Patrons: one space for each three seats	Minimum 100 m^2 Space required within site by main entrance for two cars to pick up and set down patrons	1 per 100 seats with minimum of 4
Swimming baths	Staff: one space for every two members normally present Patrons: one space per 10 m^2 pool area	Minimum 50 m^2	1 per 4 staff
Sports facilities and playing fields	Staff: one space per three members normally present Players: one space for each two players able to use the facility simultaneously, provided public transport is reasonably close. Otherwise two spaces for each three players Spectators: provide only if more than three times the number of players	Minimum 50 m^2	1 per 4 staff
Marians	Staff: one space per three members normally present Boat-users: two spaces for each three mooring-berths. (If other facilities are included, e.g. restaurant, shop etc., provide additional spaces at 50% normal provision for each additional facility)	Minimum 50 m^2	1 per 4 staff
Community centres and assembly halls	Staff: one space for each three members normally present Patrons: one space for every five seats for which the building is licensed	Minimum 50 m^2	1 per 4 staff
Places of worship	Worshippers: one space per ten seats in space for worship	Minimum 50 m^2 Space provided within site close to main entrance for two cars to set down and pick up worshippers	1 per 60 seats minimum 4
Museums and public art galleries	Staff: one space per two members normally on duty Visitors: one space per 30 m^2 of public display space	Minimum 50 m^2	1 per 300 m^2 minimum 4
Public libraries	Staff: one space per three members normally on duty Borrowers: one space for each 500 adult ticket holders with a minimum of three spaces. If there are separate reference facilities, provide additional spaces at one for each ten seats	Minimum 50 m^2	1 per 300 m^2 minimum 4
Hospitals	Staff: one space for each doctor and surgeon, plus one space for each three others Outpatients and visitors: one space for each three beds	General minima as follows: Gross floor space not exceeding: / Minimum space required: 1000 m^2 / 200 m^2 2000 / 300 4000 / 400 6000 / 500 every additional 200 m^2 / 100 m^2	1 per 12 beds
Health centres, surgeries, clinics	Staff: one space per doctor etc. Patients: two spaces per consulting room	Sufficient for requirements specified, including if necessary space for special vehicle for non-ambulant patients	4
Special schools, day-care centres and adult training centres	Attenders: in many cases these will be transported to the centre. For certain centres for the physically handicapped, allow one space for special or adapted self-drive vehicle per four attenders	Accommodation for special passenger vehicle Space provided within the site for cars and/or buses to set down and pick up	1 per 6 staff

Table IV (Continued)

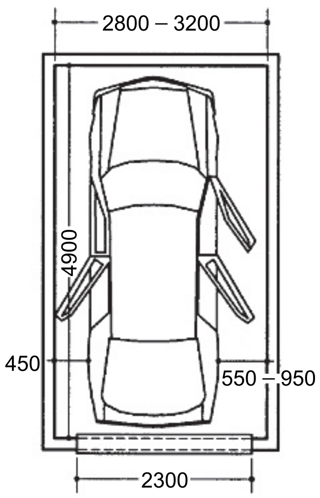
Type of building	Car parking provision	Loading/unloading provision	Cycle parking
Nursery and primary schools	Staff: one space per two members normally present Visitors: two spaces Hard surface play area used for parking on open days etc.	Minimum 30 m^2	1 per 6 staff
Secondary schools	Staff: one space per two members normally present Visitors: schools with up to 1000 pupils – four spaces, larger schools – eight spaces. Hard surface play area used for parking on occasion	Minimum 50 m^2 Space provided within site for school buses to set down and pick up	1 per 6 staff 1 per 3 students
Sixth form colleges	Staff: one space per two members normally present Visitors: colleges with up to 1000 pupils – five spaces, larger schools – ten Hard surface play area used for parking on occasion	Minimum 50 m^2	1 per 6 staff 1 per 3 students
Further education colleges and retraining centres	Staff: one space for each member normally present Students and visitors: one space for each three students normally present	Minimum 50 m^2	1 per 6 staff 1 per 3 students



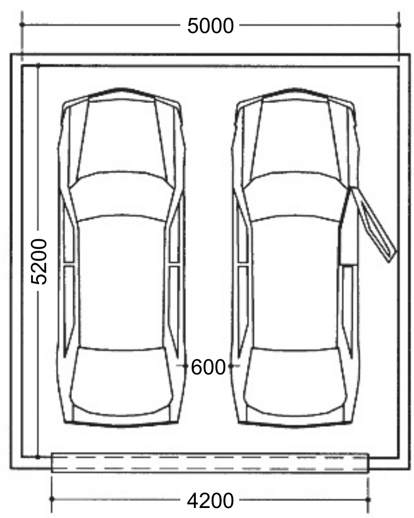
31.30 *A domestic garage of minimum dimensions*



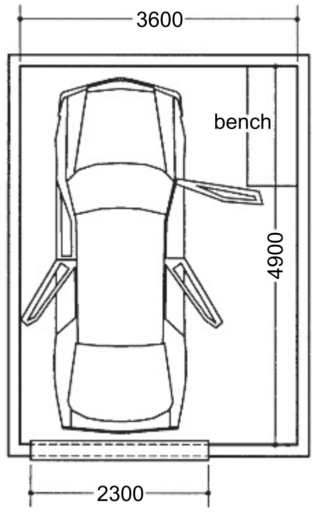
31.32 *Garage for a driver who is a wheelchair user (for an ambulant disabled driver, a width of 2.8 m is adequate)*



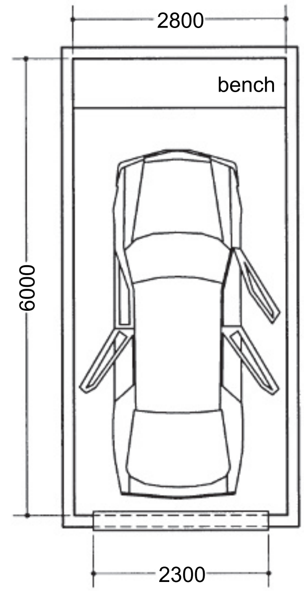
31.31 *A more generous garage permitting passenger access*



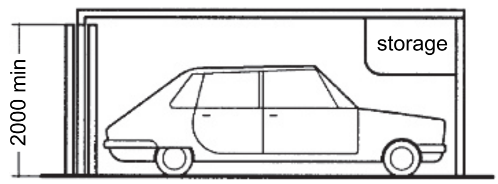
31.33 *A garage for two cars*



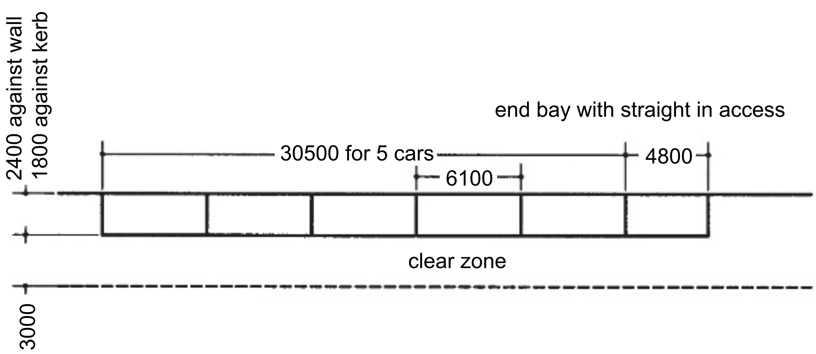
31.34 *A garage of minimum length but width sufficient for a workbench*



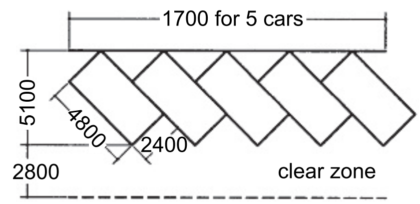
31.35 *A garage with a workbench at the end*



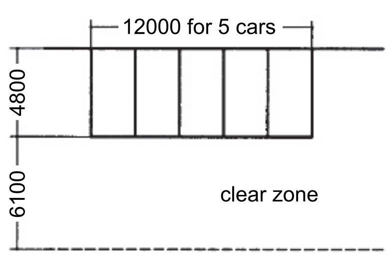
31.36 *Cross-section through a garage showing raised storage area*



a *in-line parking 20.1 m² per car against kerb, 23.8 m² against wall*

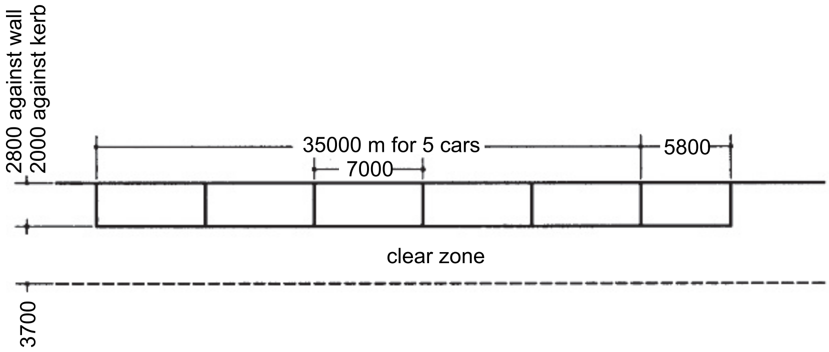


b *echelon parking at 45° (other angles can be used): 22.1 m² per car or 19.2 m² where interlocking in adjacent rows*

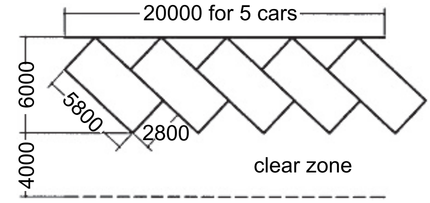


c *head-on parking, 18.8 m² per car*

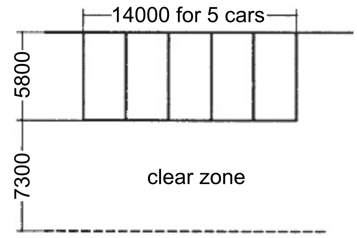
31.37 *Basic parking dimensions. Standard European parking bay or stall 4.8 × 2.4, allow 24 m² per car, including half the clear zone but no access gangways*



a *in-line parking 27.0 m^2 per car against kerb, 32.6 m^2 per car against wall*

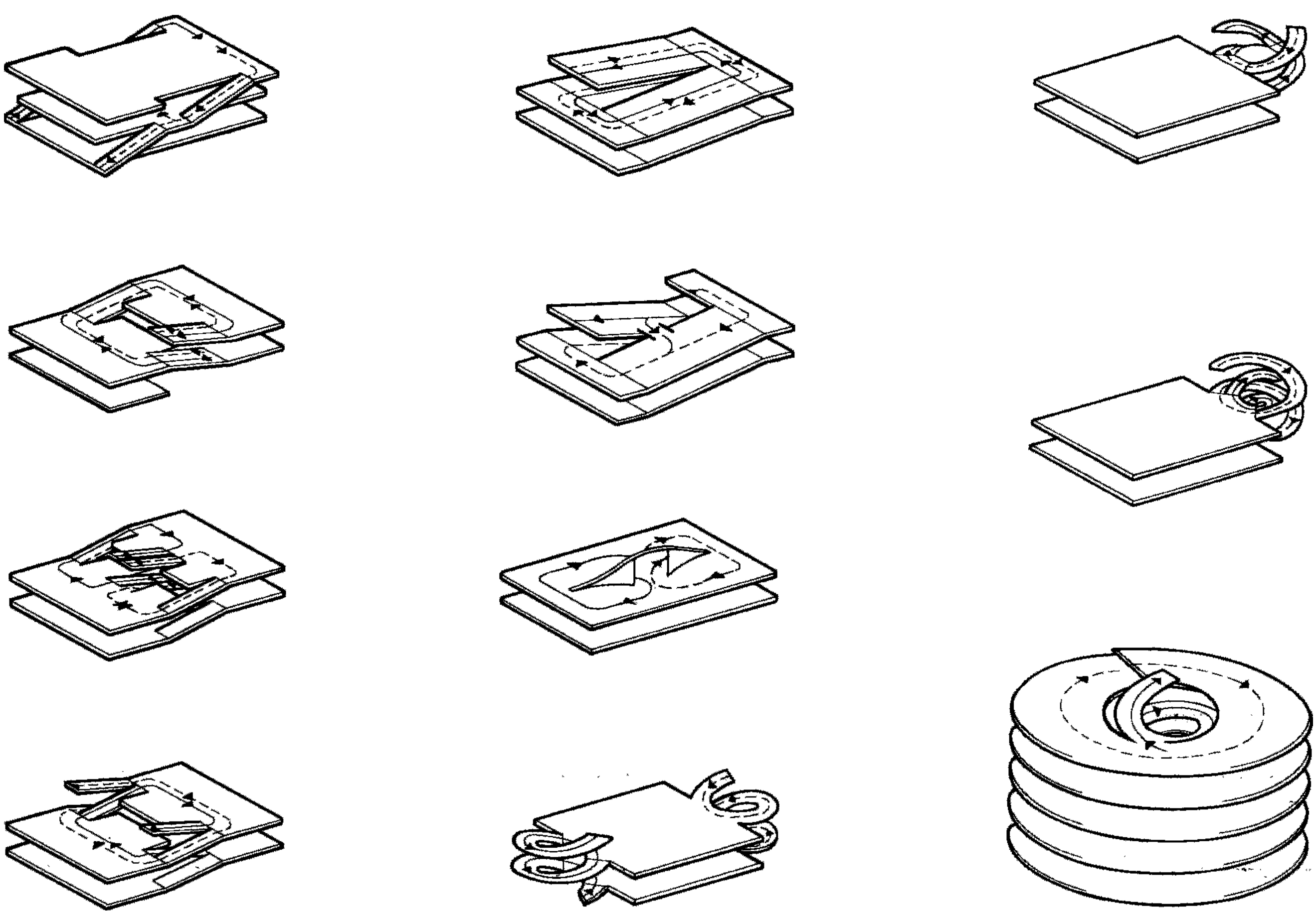


b *echelon parking at 45° (other angles can be used): 32.0 m^2 per car or 28.0 m^2 where interlocking in adjacent rows*



c *head-on parking, 26.5 m^2 per car*

31.38 *Basic parking dimensions. Large European parking or American bay or stall 5.8 × 2.8, allow 33 m^2 per car, including half the clear zone but no access gangways*

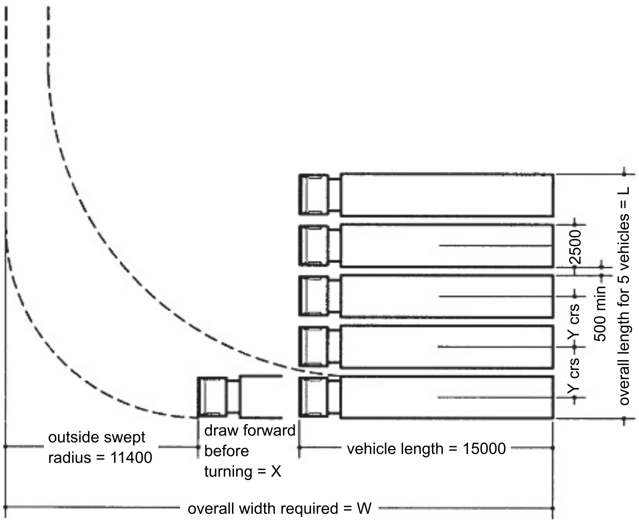


31.39 *Types of multi-storey car parks*

Wherever public or private parking facilities are provided, appropriate arrangements for disabled people, whether drivers or passengers, should be made. Disabled parking bays should be as close as possible to the place that the user needs to go, and preferably under visual supervision to discourage misuse by others. Bays should be at least 800 mm wider than standard, to permit manoevring of wheelchairs for transfer, and any kerbs should be ramped.

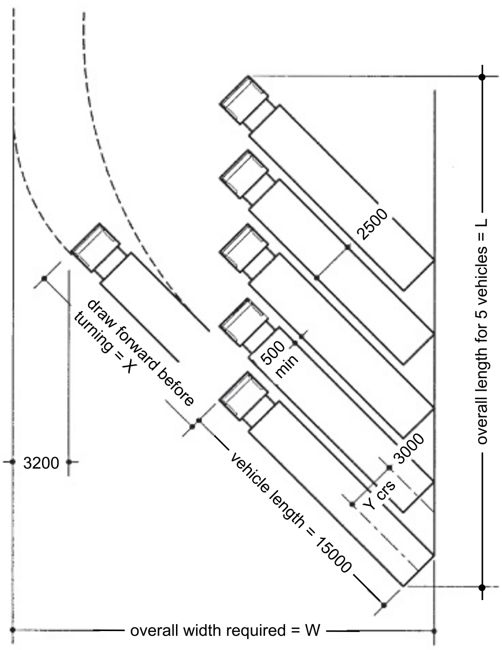
8 LOADING AND UNLOADING

31.40 to **31.45** show requirements for loading, unloading and parking large vehicles.



X draw forward	Y centres	W o/a width	L o/a length for 5	Area per vehicle (m^2)
1	5.0	27.4	22.5	123
2	4.4	28.4	20.1	114
3	4.0	29.4	18.5	109
4	3.7	30.4	17.3	105
5	3.4	31.4	16.1	101
6	3.0	32.4	14.5	94

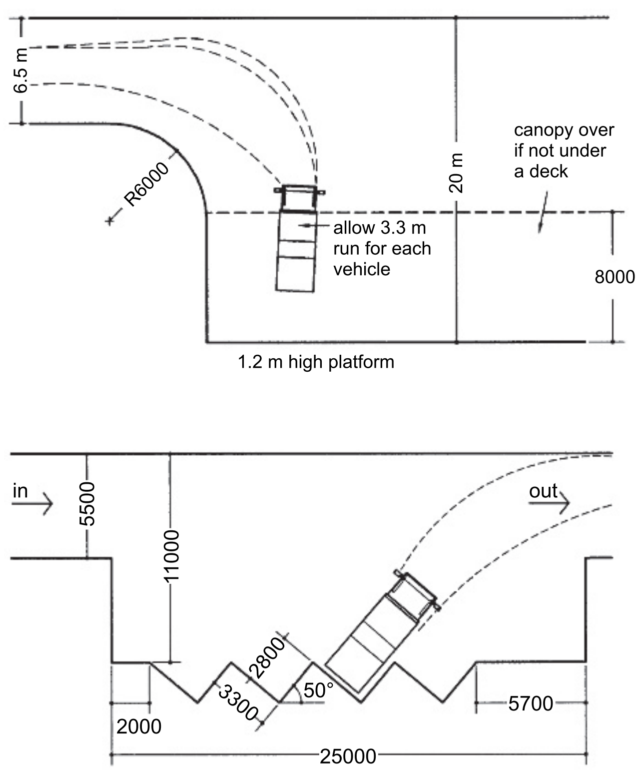
31.40 *Lorry parking and loading bays: head-on for the largest vehicles*



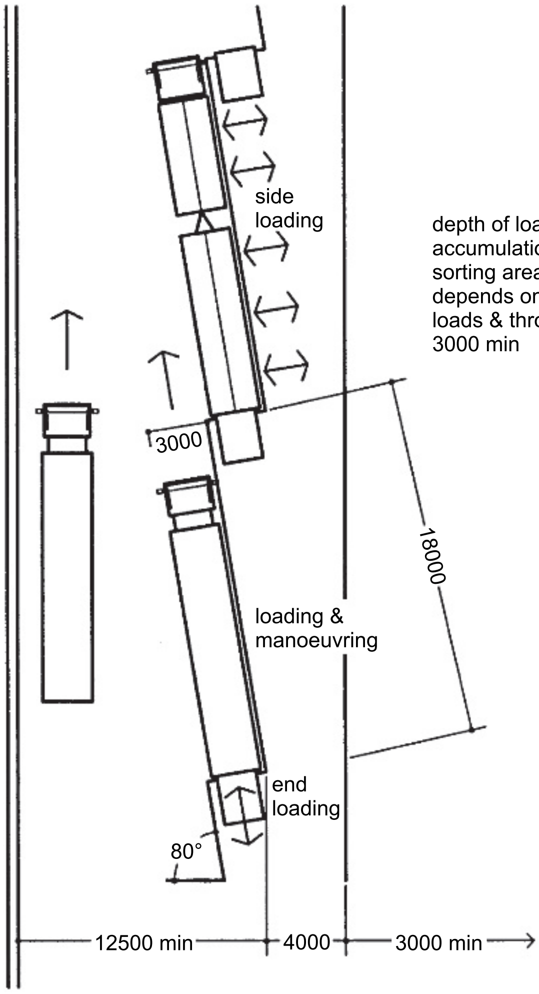
X draw forward	Y centres	W o/a width	L o/a length for 5	Area per vehicle (m^2)	
				gross	net*
4	4.8	18.4	39.5	145	113
5	4.5	19.1	37.8	144	111
6	4.2	19.8	36.1	144	108
7	3.9	20.5	34.4	141	105
8	3.6	21.2	32.7	139	101
9	3.4	21.9	31.6	138	100
10	3.2	22.6	30.5	138	98
11	3.1	23.4	29.9	140	99
12	3.0	24.1	29.3	141	99

*Excluding the empty triangles at each end.

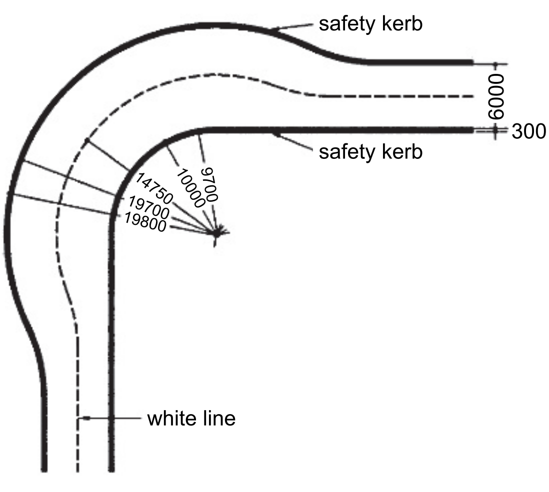
31.41 *Lorry parking and loading bays: diagonal (45°) for the largest vehicles*



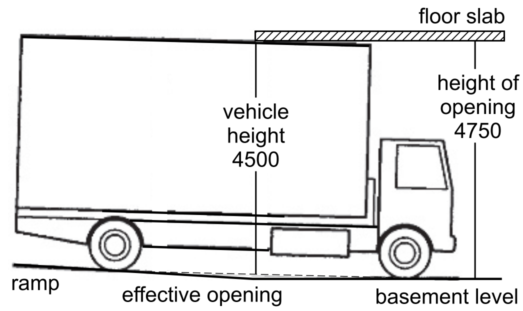
31.42 *Minimal loading docks appropriate for limited number of vehicles per day, extremely high land costs or other physical restraints*



31.43 *Finger dock, where manoeuvring depth is limited and side loading is required as well as end loading. Very fast turnround times are possible although capacity is small*



31.44 *Ramp on a sharp curve, such as access to a shopping centre loading dock. Maximum gradients 10 per cent on straight, 7 per cent on inner kerb*



31.45 *Headroom criteria for covered loading docks*

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32 Studios for sound and vision

David Binns

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CI/SfB 528
Uniclass D527
UDC727.94

KEY POINTS:
- *Avoidance of extraneous sound is essential*
- *Production staff need both full observation and easy access to the studio floor*

Contents

1 INTRODUCTION

1.01 Scope

A TV studio is an area in which activities are performed specifically for observation. (Television cameras are also used outside studios for surveillance in stores, banks and so on.) A sound studio may be used for live broadcasts such as news bulletins, but is most likely to be required for making recordings.

1.02 Broadcasting studios

The greatest differences between studios will be in the ancillary areas rather than the studio *per se.* These differences reflect the nature and attitudes of the client: the BBC in the UK, for instance, is a public service organisation whereas the independent companies are not (although they must adhere to standards set by the Independent Broadcasting Authority).

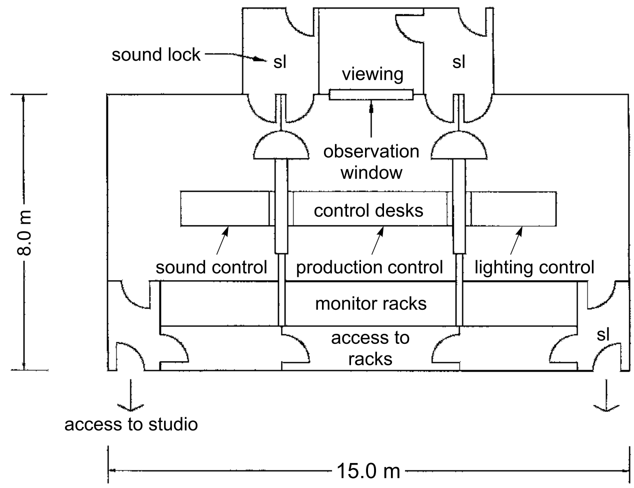
1.03 Independent and educational studios

There are now many small independent studios, operating for private commercial use, for making programmes under contract, and for making educational and instructional videos. Some are attached to higher-education institutions.

2 STUDIO TYPES

2.01 Sound studios

Small sound studios may be used for such purposes as local broadcasting and for recording advertisements and jingles for commercial radio. **32.1** shows the scheme for such a facility. Where larger spaces are required, for example for recording orchestral music, studoios primarily designed for TV might well now be used. The principles behind both sound and TV studios are similar, although sound studios are more likely to have direct vision windows.



32.1 *Relationship diagram for sound recording studio suite*

2.02 Multi-purpose TV production studios

Previously, TV studios differentiated between music and drama. Now, all are multi-purpose largely due to economic pressures. They have accepted acoustically 'dead' conditions, reverberation or presence being added electronically. Greater use of zoom lenses in preference to camera tracking means microphones are located further from performers, necessitating low reverberation times and background noise levels. Camera tracking requires a floor laid to very precise tolerances (currently ±3 mm in 3 m). The floor is normally heavy duty linoleum sheet laid on an asphalt mastic screed; it requires a specialist floor laying contractor to achieve these fine tolerances.

Studio length-to-breadth ratio should be in the region of 1:1.5. The minimum practical floor area for a small commercial TV studio would be 60 m^2 with static cameras. TV station studios range between 200 and 400 m^2. The studio height is determined by the clear space required below the lighting grid (a function of the longest camera angle). The minimum height for a small studio is 4 m; in the larger studios 11 m to the grid with a clear height above of 2.5 m, making something over 13.5 m overall. In these studios an access gallery is required *at grid level approximately 4.5 m above studio floor level.* This is normally to avoid obstruction of access doors and observation window. Access to the galleries from studio floor level is mandatory and direct access to lighting grid level is desirable.

A cyclorama or backdrop cloth is suspended below lighting grid level. It should be at least 1.25 m away from the walls to allow a walkway around the studio and is on a sliding track with radiused corners to enable it to be stored.

2.03 Interview and announcers' studios

These studios range in size from 30 to 60 m^2 with a height of 4 to 6 m. Static cameras and a simple form of lighting grid combined with floor lighting stands are used.

2.04 Audience participation studios

Some productions require audience participation and fixed theatre-type seating on terraces is provided. In smaller studios this is demountable, so storage space has to be provided. Audiences place more stringent demands on the planning of a TV complex, as segregated access and emergency escape routes have to be provided (see Chapter 33, Auditoria).

3 PLANNING

3.01 Layout

A typical layout for a TV broadcasting studio complex is shown in **32.2**. Larger installations will have workshop facilities adjacent to the scene dock and if flats and backdrops are made on-site a paint frame will need to be the full height of the cyclorama curtain. Further details of such facilities will be found in Chapter 33.

Equipment areas

Ancillary equipment areas will include separate areas for VTR (video tape recording) and telecine (transference of filmed material to video). The machine operator should be able to hear sound track and cues above the noise of other machines in the room which are usually enclosed in open-fronted cubicles with heavily acoustically treated walls.

Master control room

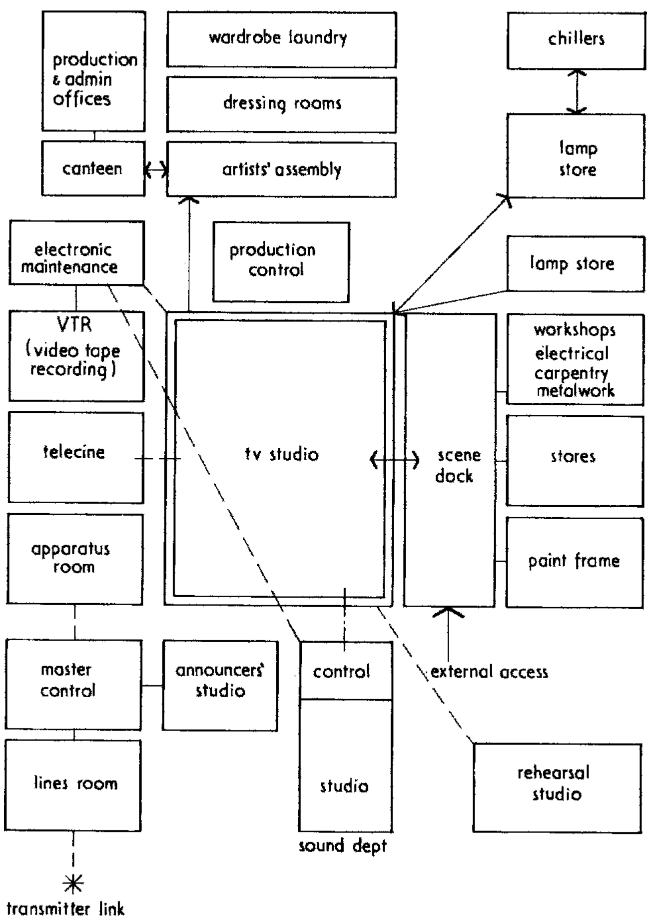
Adjacent to these equipment areas will be the master control room, which is the last monitoring link in the video and audio chain before transmission. Here programme material, either recorded (VTR and telecine) or live from the studios, will be linked with continuity from the announcer's studio.

Dressing rooms

Artists' facilities adjoining the studio will include dressing rooms with associated wardrobe and laundry, rest and refreshment areas (see Chapter 33).

Rehearsal spaces

Separate rehearsal spaces are required as there is considerable pressure on studio floor time (much of which is used in setting and striking scenery, and setting up lighting and cameras for productions). These need not be the full studio size as several sets will occupy the studio floor and scenes are rehearsed individually, often in remote assembly halls.



32.2 *TV studio complex; block planning diagram*

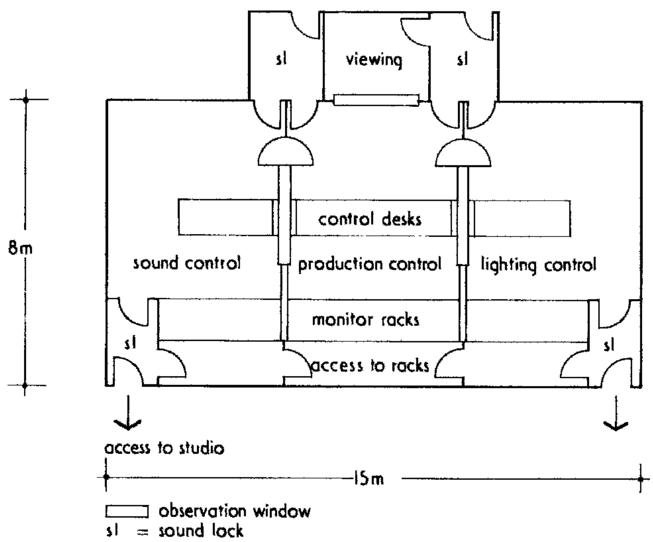
Service spaces

In addition to the areas detailed in **32.2**, space will be required for a sub-station, emergency generator and tape stores. The small commercial and education studios which do not broadcast will have simpler planning arrangements.

3.02 Control suites

TV control rooms do not now overlook the studio they monitor for the following reasons:

- The cyclorama track and studio scenery are likely to interfere with the producer's view; production decisions are made off monitor screens.
- The chroma of glass in the observation windows must be adjusted to confirm colours reproduced by TV monitors. This is done using an applied tinted finish which requires frequent replacement.
- Windowless production suites do not need to be elevated, hence production staff have direct access to the studio floor. A typical control suite layout of this type is shown in **32.3**.



32.3 *Layout of a production control suite with no direct visual access to studio*

Minimum clear height in the control room, including a false ceiling for services, is 4 m.

Separate control areas for production, lighting, and sound are required with 25 dB insulation between each and visual contact via observation windows. A viewing area for visitors separate from that for production staff is desirable.

The disadvantages of such a layout is that the producer has no direct visual contact with the floor manager or performers.

4 SERVICES

4.01 Lighting

Television studio lighting is highly specialised. The large production studio will have a remotely operated lighting grid, whereas the small studio will have a simple pre-set system.

Lamp support systems

There are three basic types of lamp support systems:

- The most elaborate is a grid of 'railway' tracks covering the whole studio. On these tracks run carriers which have a telescopic arm holding the lamp. The arm is motor driven (either electrically or hydraulically) and lowers the lamp to studio floor level for setting and adjustment. Each lamp can be separately panned, tilted and dimmed remotely. An additional overhead rail at the perimeter of the grid will carry carts on to which the 'monopole telescopes' and lamps can be run off the grid to a lamp store. Where several studios exist this rail will interconnect them all via a central lamp store. The latest grids are equipped with an electronic memory to enable a whole production of lighting settings to be stored.
- A simpler form has lighting bars which can be raised or lowered electrically or manually fixed direct to the studio. The bars take several forms from the 'lazy scissors' principle to a simple bar on cables and pulleys.
- The third and simplest type is a fixed barrel grid. As in the second type no space is required above this grid for access as lamps are clamped direct to the bars and set from studio floor level.

Lighting to equipment and control areas needs to be carefully studied to avoid reflections and provide correct levels for viewing. Special fittings are often required.

4.02 Air conditioning

Air conditioning presents the designer with a number of unique problems: the large volume, the high heat loads generated by lamps, low background noise levels and the need to provide comfortable conditions in parts of the studio obscured in all but one plane by scenery. Low air speeds have to be used to achieve the noise levels. The most successful system has been the 'dump' system where cooled air is fed from a large plenum chamber above grid level and returns via natural convection of heat from the lamps to a similar exhaust plenum at an even higher level. Plant rooms, unless remote from the studios, require structural isolation to prevent vibration transmission (see para **5.03**); adequate space must be allowed for attenuation. Mechanical engineers are familiar with duct-borne noise problems, but do not normally investigate noise break-in through duct walls or the architectural acoustic problems. The architect should make certain that this forms part of the specialist consultant's brief.

4.03 Technical wiring

Extensive provision has to be made for power, audio and video wiring connecting the studio to control suites and equipment areas. Camera cables are approximately 50 mm in diameter and have a minimum bending radius of 0.5 m. Power wiring, which may include low-voltage power, has to be run in separate trunking from audio wiring to avoid interference. Trunking is often concealed within the acoustic finishes and all perforations of the studio enclosure have to be sealed airtight to avoid sound transmission.

4.04 Other services

Large production studios will require compressed air, gas, water (including drainage) and a smoke-detection system, in addition to electrical services.

5 ACOUSTICS

5.01 Identify standards

The standards to be achieved should be identified by the specialist consultant and agreed with the client at the outset. The two main sources are the BBC and the ISO (International Standards Organisation).

5.02 Airborne sound insulation

For every location a full one-third octave band, site noise level survey must be carried out to determine the design of the enclosing structures. Additionally, all internal transmission loss defined by frequency should be established and can be extended to provide the mechanical engineer with the requirements for in-duct crosstalk attenuation. For this it will be necessary to establish the maximum permissible noise levels from all sources in each room.

5.03 Vibration isolation

The noise and vibration levels of all mechanical plant should be studied and the architect must identify who should be responsible for defining maximum permissible levels and designing to achieve them. Structure-borne sound transmission, particularly on the upper levels of framed buildings, may necessitate the 'floating' of plant rooms and noise-protected areas.

This involves isolating the walls, floor and roof from the surrounding structure. The walls are built off a secondary floor bearing on steel spring or rubber carpet mountings designed to a maximum natural frequency not exceeding 7 to 10 Hz. Footfall impact noise often requires floors to be carpeted with heavy underfelt or in extreme cases, the floating of studios.

5.04 Reverberation time

32.4 relates reverberation time to volume for television studios. Calculation will indicate the amount and type of absorption required. Details of a typical wide band modular absorber are shown in **32.5**. Approximately 200 mm should be added to the clear studio height and to each wall thickness to accommodate the acoustic treatment. Sound control rooms need to be similarly treated, with the other production control rooms and technical areas made as dead as possible.

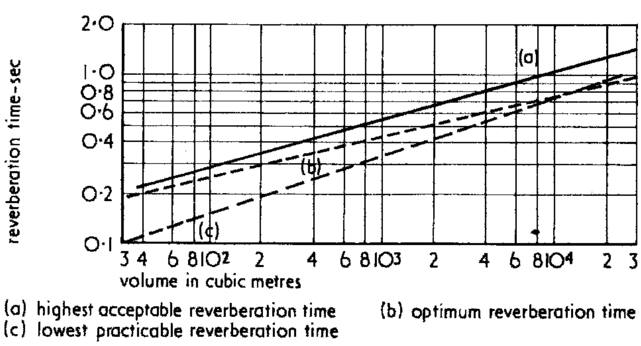
5.05 Background noise levels

Maximum permissible background noise levels are shown in **32.6**. These should be related to the external ambient levels and to noise from air-conditioning plant. In certain situations where plant rooms are adjacent to noise-sensitive areas, maximum permissible noise levels at intake and extract louvres should be specified to limit this noise breaking back in through the external skin, particularly at windows.

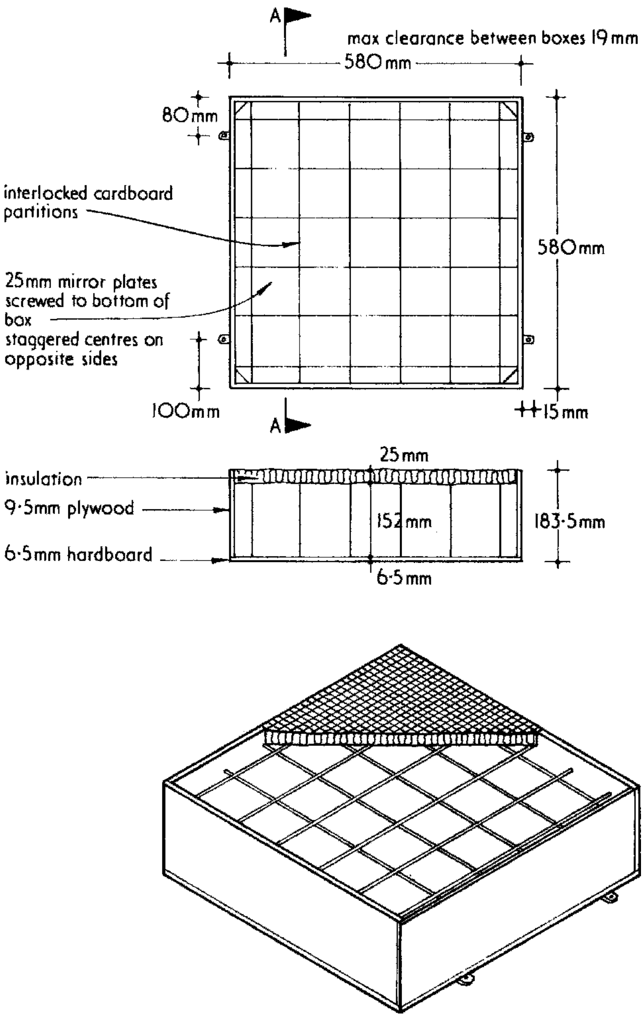
5.06 Special details

Acoustic doors and sound lock

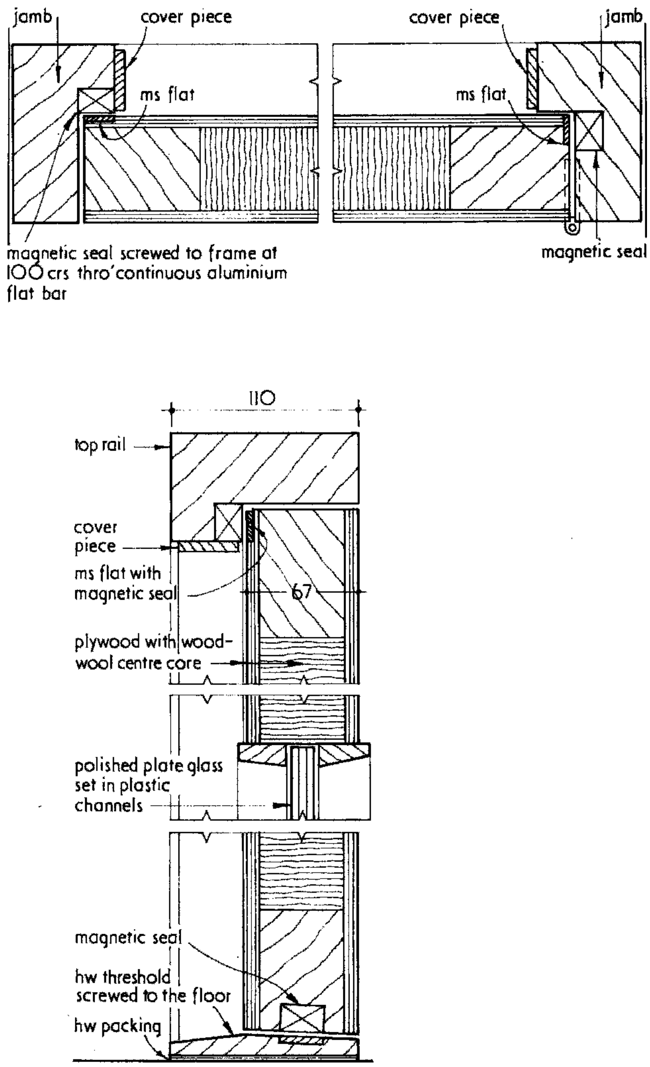
Typical details for an acoustic door and an observation window are shown in **32.7** and **32.8**. All noise-sensitive areas should be approached via a sound lock lobby consisting of acoustic doors, with either end of the lobby treated to be acoustically dead. The mean sound transmission loss of each door is 33 dB and sealing is affected by means of magnetic seals.



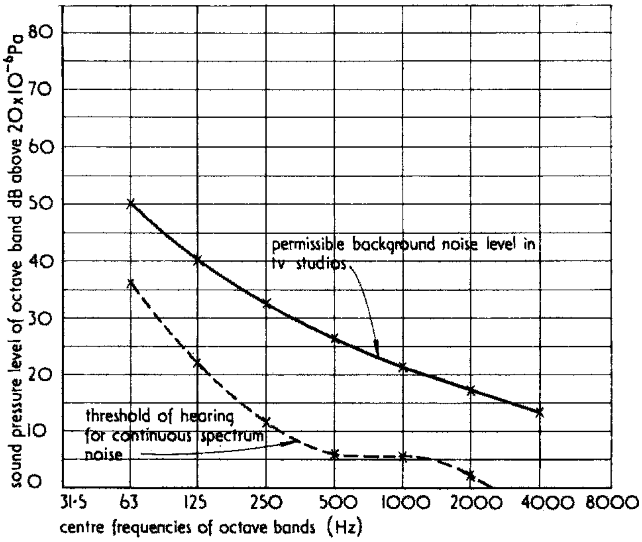
32.4 *Reverberation times for TV studio*



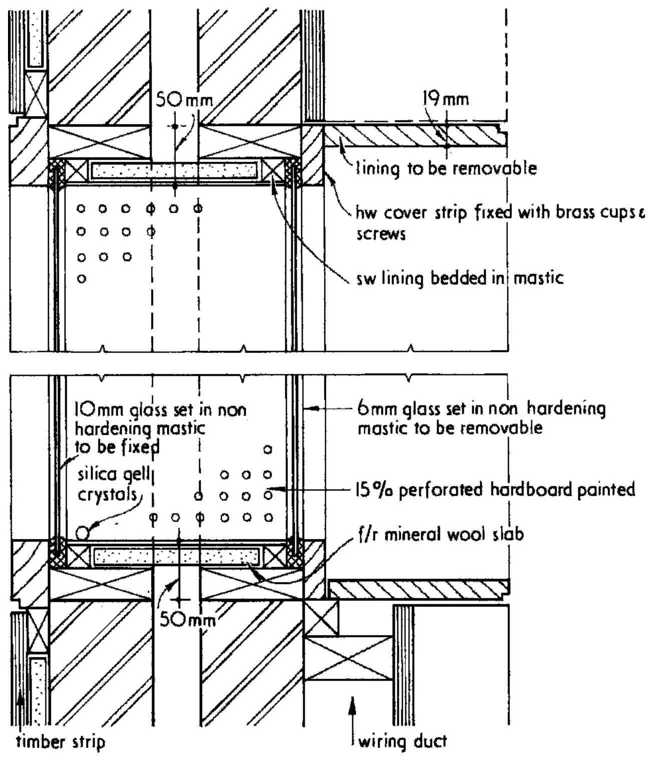
32.5 *Modular sound absorbing unit*



32.7 *Acoustic door construction*



32.6 *Background noise levels*



32.8 *Observation window*

Scenery doors

The transfer of scenery into the studio requires an opening in the region of 5 m high by 5 m wide with a sound reduction index between 50–60 dB. This door will almost certainly be of steel construction. Hinged doors have been used but the forces required to ensure that the edge seals close airtight produce operational difficulties. A 'lift and slide' door is more satisfactory. An electric or hydraulic drive opens and closes the door while radius arms lower it inwards and downward to compress the edge seals all round. This type of door does not require an upstanding threshold as does the hinged door, and this is a considerable operational advantage.

6 STATUTORY REQUIREMENTS

Careful examination should be given at the planning stage to means of escape and fire resistance. Statutory requirements vary considerably in all parts of the world, but the most stringent are those operated in the UK where Class O flame spread may be required for all finishes and up to a four-hour fire separation for the studio walls. This necessitates double steel roller shutters on all perforations through walls. Smoke vents are sometimes required and these must be designed to match the sound insulation of the roof.

33 Auditoria

Ian Appleton and Stefanie Fischer

CI/SfB 52
Uniclass D524 D525, D741
UDC 725.8

Ian Appleton is a partner in The Appleton Partnership. Stefanie Fischer, who contributed the section on cinema design with input from Ron Inglis of Mayfield Arts and Media, and Richard Boyd, technical director, BFI Southbank, is a principal of Burrell, Foley Fischer LLP

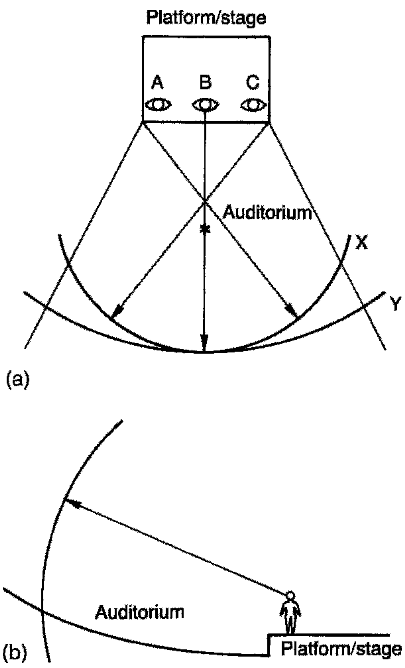
KEY POINTS:

- *Each member of an audience should clearly see a performance, screen or speaker, as well as clearly hearing speech, music or sounds.*
- *Auditorium design must consider audience comfort, fire safety, acoustic quality, sound insulation, sound systems, lighting, receptive atmosphere and access to technical equipment.*
- *Stage and audio-visual technologies are constantly evolving.*

Contents

1 INTRODUCTION

The three-dimensional volume of an auditorium is conditioned by the need for all members of the audience to be able to see the whole of the platform or stage; and to hear the actor, singer, musician or speaker, **33.1**. Seating density, floor rake and seating layout are partly determined by this, partly to give the audience an appropriate level of comfort and essentially to ensure a means of escape in an emergency, such as a fire, within the time required by safety considerations and by legislation.

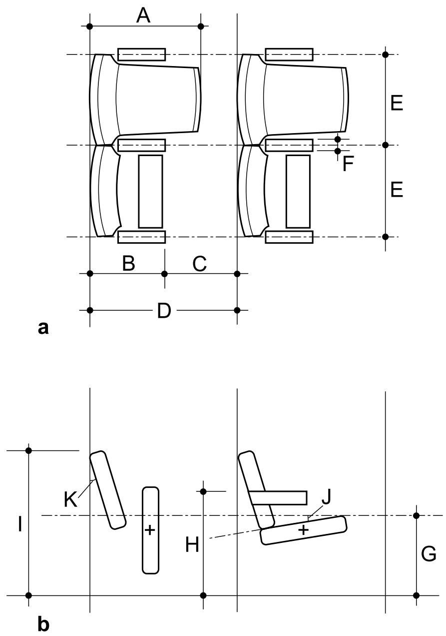


33.1 *Visual and aural limitations:* **a** *Plan: for a performer at centre stage B there is an arc Y beyond which visual and aural perceptions are impaired. However, for performers nearer the sides of the stage at A and C produce more restrictive curves X.* **b** *Section: Similarly, visual and aural limits in section also set an arc centred on the performer*

2 SEATING

2.01 Design of the auditorium seat

The aim is to provide an appropriate standard of comfort. The range of human body dimensions is wide; while in most auditoria a single size of seat is provided, **33.2** and Table I. Tolerance levels vary: young people can tolerate simple seating found less comfortable by



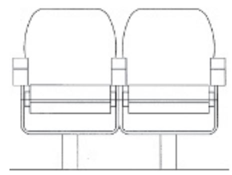
33.2 *Auditorium seating: definitions of terms and dimensional information (to be read in conjunction with Table I):* **a** *Plan.* **b** *Section*

Table I Dimensions of auditorium seats

Dimension	Description	Minimum	Maximum	Drawn as
A	Overall seat depth	600 mm	720 mm	650 mm
B	Tipped seat depth (same as length of arm)	425	500	450
C	Seatway (unobstructed vertical space between rows)	305		400
D	Back-to-back seat spacing	760		850
E	Seat width for seats with arms	500	750	525
	Seat width for seats without arms	450		
F	Armrest width	50		50
G	Seat height	430	450	440
H	Armrest height	600		600
I	Seatback height	800	850	800
J	Seat inclination from horizontal	7°	9°	7°
K	Back inclination from vertical	15°	20°	15°

older people. Those attending concerts of classical music seem to expect more comfort than those watching drama. Seats are generally designed for the average person expected to use it; this varies according to age and nationality. Minor variation is achieved by the upholstery and adjustment of the back and seat pan material when the seat is occupied: otherwise the seat selection is a common size within the whole, or part of, the auditorium layout. The best able to be achieved is in the order of 90% of the audience within an acceptable range of comfort.

33.5 a *Fixed continuous upholstered bench seating*



33.5 b *Fixed seating with pedestal support off floor or tread*

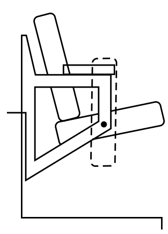
2.02 Working dimensions

Seat width: the minimum dimension as stipulated by legislation is 500 mm with arms and 450 mm without. For seats with arms a width of 525 mm is the least for reasonable comfort.
Seat height: 430–450 mm.
Seat inclination: an angle to the horizontal of 7–9°.
Back height: 800–850 mm above floor level (may be increased for acoustic reasons).
Back inclination: angle to the vertical of 15–20°.
Seat depth: 600–720 mm for seat and back depth overall, reducing to 425–500 mm when the seat is tipped. The seat depth varies and depends on thickness of upholstery and backing and if the rear of the seat contains the air-conditioning. For a modest seat with arms, the dimensions can be as low as 520 mm deep, 340 mm when tipped. The ability of the seat to tip, activated silently by weight when not occupied, allows a clearway (which is a critical dimension) to pass along a row while limiting row to row distance. Where space is severely limited such as in studio theatres, an especially slim seat, **33.3** can be used.
Arm rests: 50 mm minimum width, with the length coinciding with the tipped seat to avoid obstructing the clearway; the height about 600 mm above floor level; the upper surface may be sloped or not.

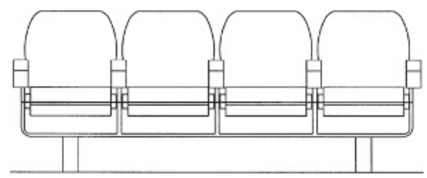
2.03 Supports

The permanent fixing of a seat can be:

- Side supports shared by adjacent seats, **33.4**
- A pedestal or single vertical support, **33.5**
- Cantilevered brackets fixed to riser (if of sufficient height) and shared by adjacent seats, **33.6** or
- A bar supporting a group of seats with leg or bracket support, **33.7**



33.6 *Fixed seating with cantilevered support off high riser without overlap of riser*



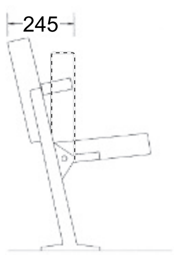
33.7 *Fixed seating with bar support off floor or tread*

2.04 Other factors

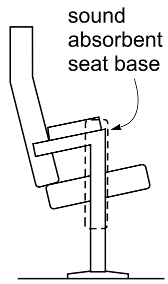
Acoustics: upholstery to satisfy the acoustic requirements, usually the level of absorbency when unoccupied, especially the case with music, **33.8**

Ventilation and heating: for air supply or extract under a seat, allow space in floor or riser to receive grille, **33.9**

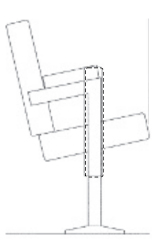
Upholstery: thickness of padding should provide comfort and avoid fatigue, but not encourage excessive relaxation; material of padding and finish must satisfy fire regulations.



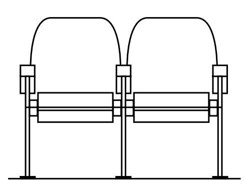
33.3 *A slim 'studio theatre' seat for use when space is limited*



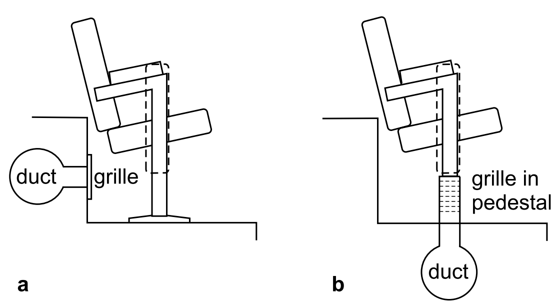
33.8 *Acoustic control seating (for when unoccupied)*



33.4 a *Tip-up seat*



33.4 b *Fixed seating with side support off floor or tread*



33.9 a *Ventilation grille below seat in riser or floor.* **b** *Ventilation grille incorporated into pedestal*

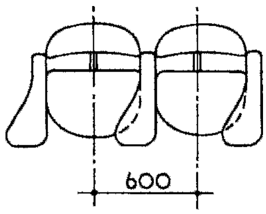
2.05 Writing surface

Conference use may require a writing surface for note-taking. The writing surface may be:

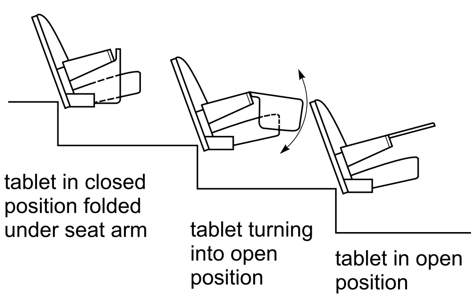
- A tablet fixed to each seat, **33.10**
- A removable tablet
- A tablet pivoted to slide away vertically, **33.11**
- A writing shelf on the back of the row in front, which can be fixed in position, hinged or retractable, **33.12**
- A fixed table with loose seat, or
- A fixed table with fixed pivoting or sliding seat, **33.13**.

Table seating has the advantage that delegates can pass behind the row of seats, and assistants can sit behind the delegates.

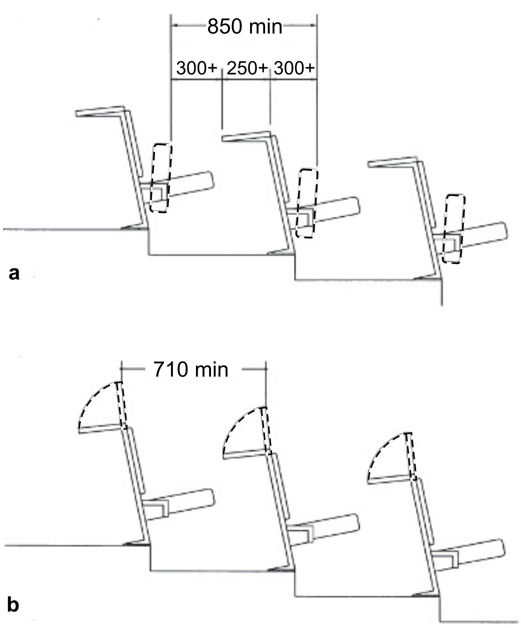
In a theatre or concert hall where there is occasional conference use every other row of seats can be used with temporary tables, **33.14**.



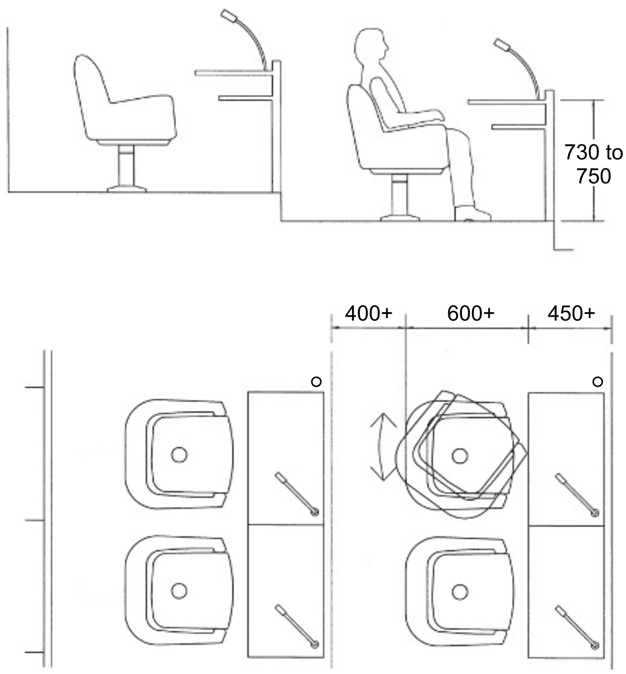
33.10 *Fixed tablet arm*



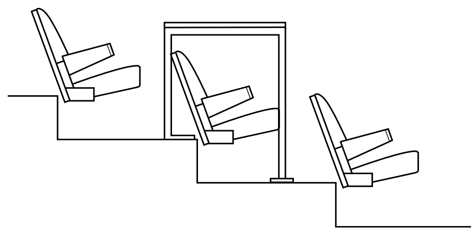
33.11 *Folded writing tablet under seat arm*



33.12 **a** *Fixed writing surface and tip-up seat.* **b** *Fixed seat and tip-up writing surface*



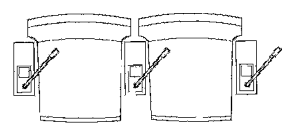
33.13 *Fixed writing surface, individual pivoting seats, section and plan*



33.14 *Table added to every other row of fixed seating in theatre or concert hall for occasional conference use*

2.06 Wired services

These may be required for conference use. They can be incorporated into the arm of the seat, **33.15** or into the rear of the seat or table in front. Further details will be found in para **7.04**.



33.15 *Controls and microphone in seat arm*

For music, drama and cinema there may be provision for earphones for people with hearing impairment, or this facility may be provided by an induction loop.

3 AUDITORIUM DESIGN

3.01 Audience requirements

As stated above, every member of the audience should be able to see and hear clearly whatever is happening on every part of the stage or platform. This is an ideal rarely (if ever) totally attainable in practice. However, a clear view for everyone of the main part of the stage or platform is normally achievable in modern auditoria. Where an existing building is undergoing renovation, further compromises may well be necessary for some seats.

The greater the encirclement of the audience of platform or stage, more people can be accommodated within the aural and visual limitations up to 180° encirclement. With a full encirclement, the distance from platform or stage should be restricted to six rows.

3.02 Visual limitations

Visual limitations determine the maximum distance from platform or stage at which the audience is able to appreciate the performance and for the performers or speaker to command an audience. This distance varies according to function type and the scale of the performance:

- For drama it is essential to discern facial expression, and the maximum distance should be 20 m measured from the setting line of a proscenium stage or geometric centre of an open stage.
- For opera and musicals discerning facial expressions is less critical and the distance can be 30 m.
- For dance the audience needs to appreciate the whole body of dancers and facial expression: the distance should not exceed 20 m.
- For full symphonic concerts acoustic conditions predominate.
- For chamber concerts acoustic conditions also predominate but visual definition assists achieving an intimate setting.
- For conference speaker and lecturer there are two scales: discerning facial expression, restricted by 20 m; larger scale where facial expression is not regarded as critical.
- For slide, video, television, overhead projector and other projections, visual limitations are determined by their respective technologies.

3.03 Aural limitations

This refers to the distances across which speech, singing and music can be clearly heard without the need for amplification, and beyond which they cannot. For drama, opera and classical music amplification is deprecated; but it is acceptable for variety and pantomime and essential for rock music.

For amplified sound the auditorium requires a dead acoustic with no reflected sound from the platform or stage and limited or no reverberation; loudspeakers are positioned to provide full and even coverage of the audience.

The volume and quality of the unamplified sound is dependent on the volume, shape, size and internal finishes of the auditorium, and on its resultant reverberation time. It is therefore not possible to lay down limits as for visual appreciation. Even experts in acoustics find that their predictions are not always borne out in practice, although they should be consulted and their advice followed wherever possible. It has been found feasible to improve the acoustic of existing auditoria; for example, the famous 'flying saucers' in the hitherto notorious Royal Albert Hall.

3.04 Levels in the auditorium

With a single level only, the pitch of the rake requires particular attention to achieve a sense of enclosure. The Greek amphitheatre is the exemplar.

Seating capacity within aural and visual limitations can be increased by the addition of one or more balconies within the overall permissible volume of the auditorium. Similarly, boxes, side galleries and loges can be added to the side walls, especially in the case of the proscenium format.

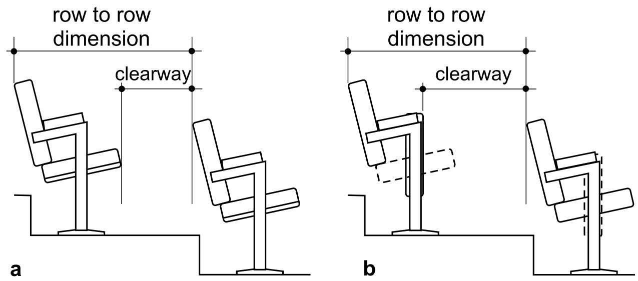
3.05 Number of seats in a row

With traditional seating the maximum number is 22 if there are gangways at both ends of the row, and 11 for gangway at one end. Thus in all but the smallest auditorium the gangways divide the seating into blocks.

Rows with more than 22 seats are permitted if the audience is not thereby imperilled. The term 'continental seating' is used for rows of seats with an increased back-to-back dimension extending the width of the auditorium with exits at both ends. This arrangement is usually only appropriate to proscenium stage, platform or cinema.

3.06 Row-to-row spacing

Spacing is controlled by the clearway between the leading edge of the seat (in an upright position, if tippable) and the rear of the back of the seat in front, **33.16**. For traditional seating the minimum clearway for people to pass along the row is 300 mm and this dimension increases with the number of seats in a row. For continental seating the clearway is not less than 400 mm and not more than 500 mm. Legislation also dictates the minimum row-to-row dimension at 760 mm: this is usually not adequate and the minimum should be 850 mm for traditional seating.



33.16 a *Row to row dimension and clearway with fixed seating.* **b** *Row to row dimension and clearway with tipped-up seating*

3.07 Gangways

As gangways are essential escape routes, their widths are determined by the number of seats served. The minimum is 1100 mm. They can be ramped up to 10%, but only 8.5% if likely to be used by people in wheelchairs. If the seating rake is steeper, gangways must have steps extending the full width and these must have consistent treads and risers in each run. This means that the row-to-row spacing and row rise should be compatible with a convenient gangway tread and riser; and this in turn means that the shallow curve produced by sightline calculations should be adjusted to a straight line.

3.08 Seating geometry

Seating is usually laid out in straight or curved rows focused towards the platform or stage. Further forms are the angled row, straight row with curved change of direction and straight rows within emphasised blocks of seats, **33.17** and **33.18**.

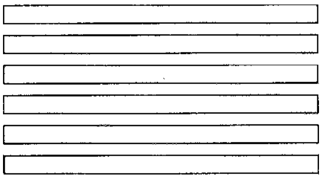
3.09 Seating density

Seats with arms and tippable seat can occupy a space as small as 500 mm wide (less for seats without arms) with a row-to-row dimension of 760 mm; but can be as large as 750 mm wide by 1400 mm, **33.19**. The area per seat therefore varies between 0.38 m^2 and 3.05 m^2. Increased dimensions reduces seating capacity. Minimum dimensions as laid down by legislation offer a low standard of comfort and should not be taken as a norm, but the social cohesion of the audience may be lost if the standards are too high.

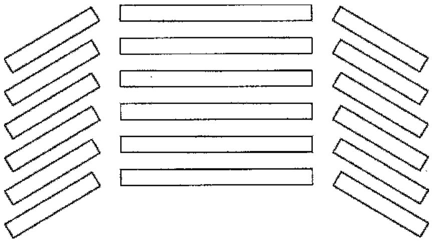
In conference halls where writing space is required, lower densities are inevitable, **33.20**.

3.10 Sightlines for a seated audience

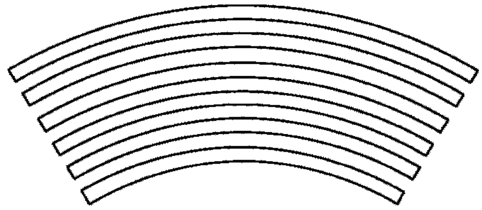
For every member of the audience to have an uninterrupted view of the platform or stage over the heads in front and clear of overhangs the section and plan of the auditorium need to conform to certain limitations set by vertical and horizontal sightlines.



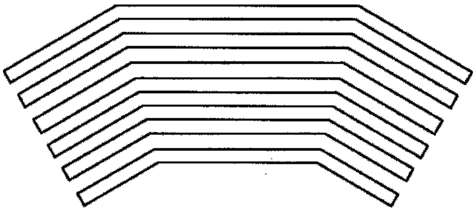
a *Straight rows on flat or sloping floor*



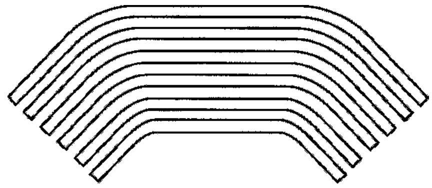
b *Straight rows with separate angled side blocks on flat or sloping floor*



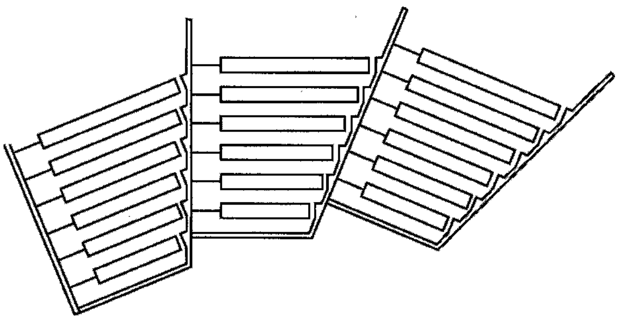
c *Curved rows on flat or sloping floor*



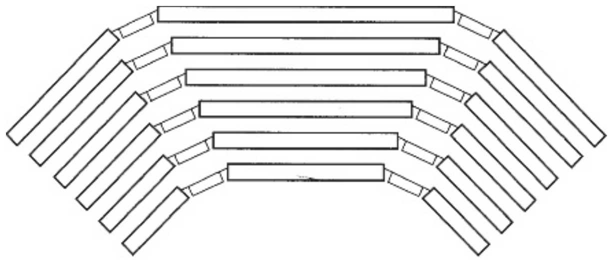
d *Straight and angled rows on flat or sloping floor*



e *As d but with curves at change of angle*

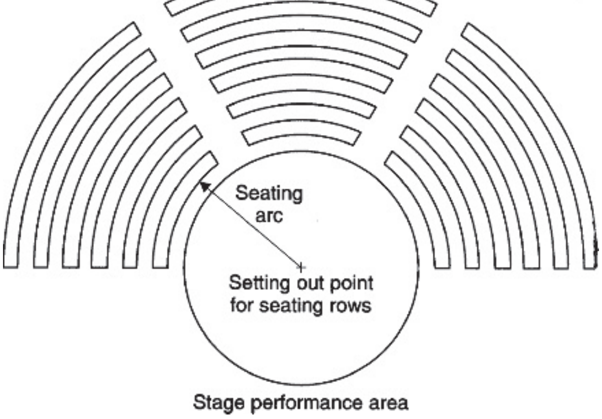


f *Separated stepped blocks focused on stage*

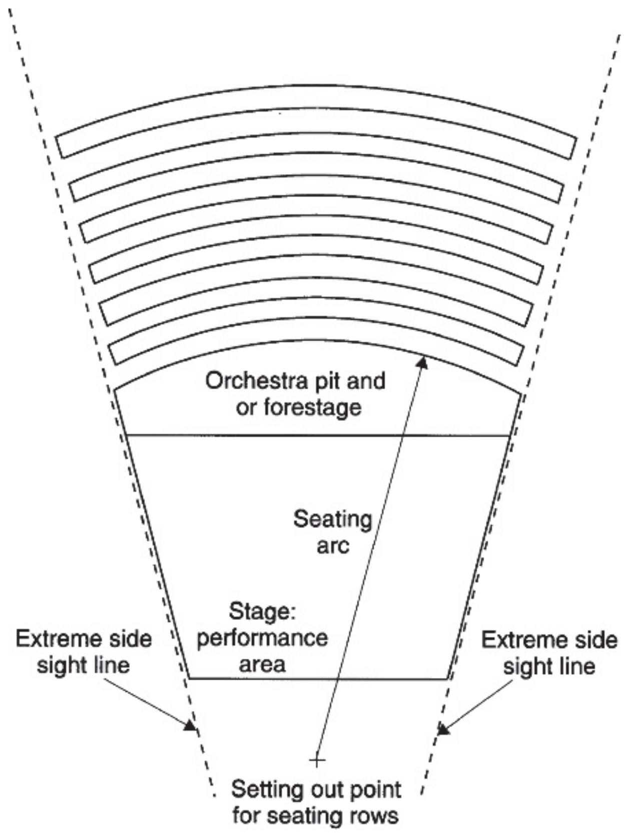


g *Straight stepped rows and separated angled side blocks*

33.17 *Alternative auditorim seating arrangements*

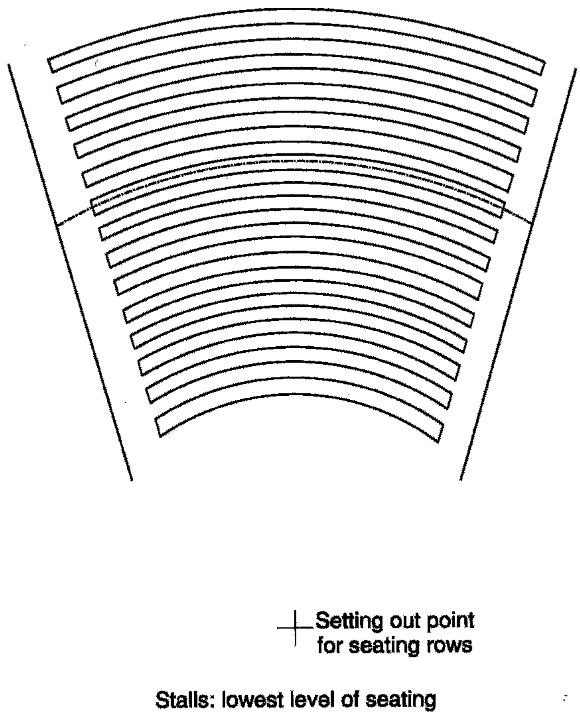


a *Open stage and theatre-in-the-round layouts*

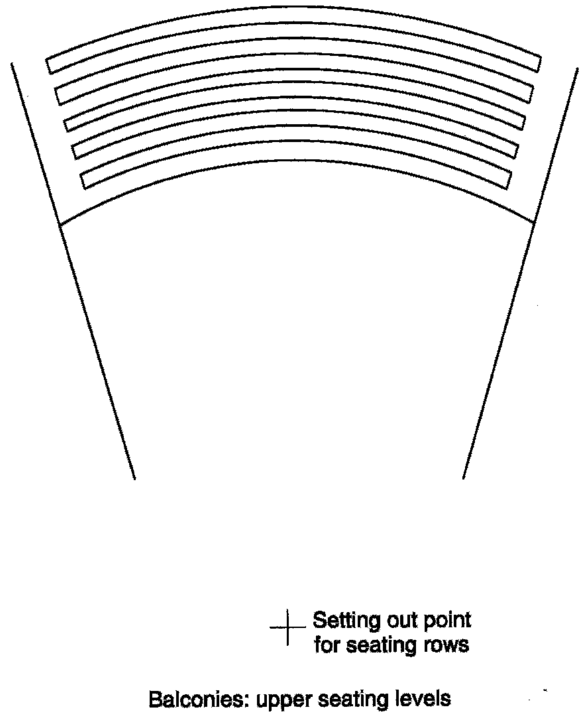


b *Proscenium layout*

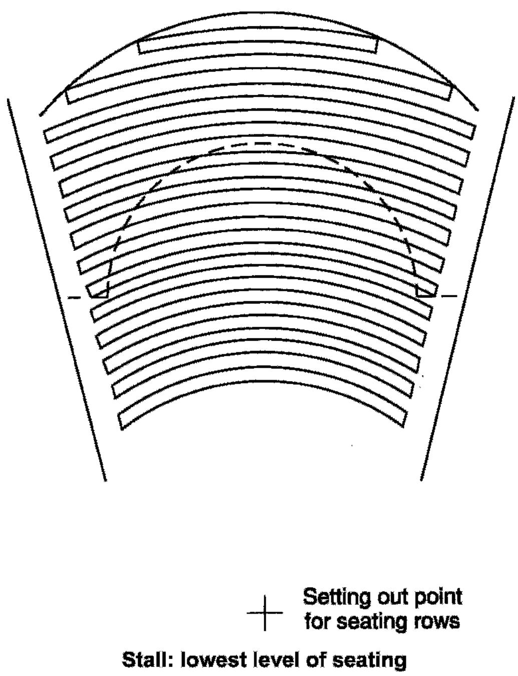
33.18 *Setting-out of auditorium seating rows (continued over)*



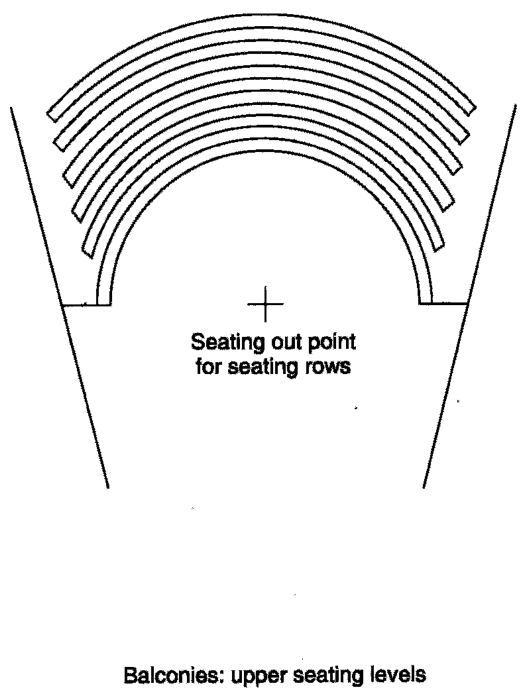
c *Proscenium and end stage layout 1: stalls*



d *Proscenium and end stage layout 1: balcony*



e *Proscenium and end stage layout 2: stalls*



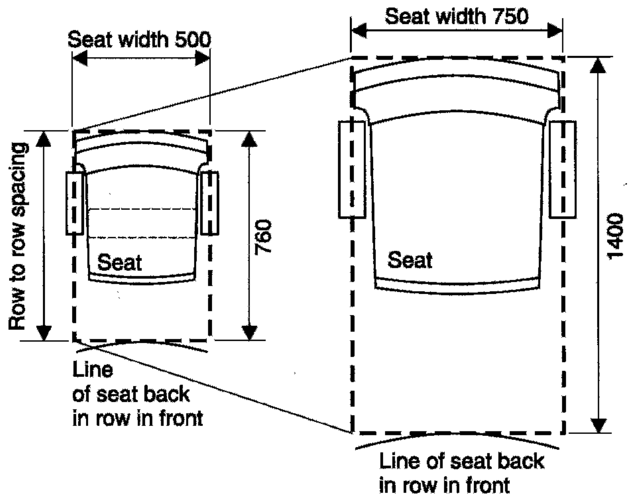
f *Proscenium and end stage layout 2: balcony*

33.18 *Continued*

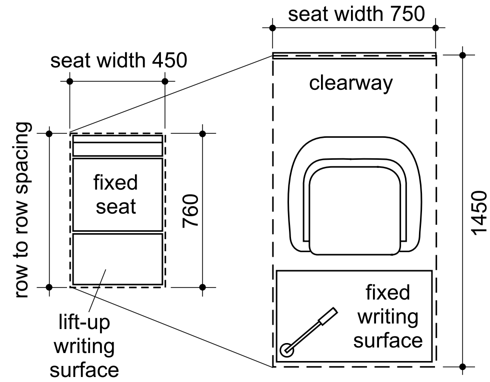
Vertical sightlines, **33.21**, may be calculated by establishing:

- P Lowest and nearest point of sight on the platform or stage for the audience to see clearly.
- HD Horizontal distance between the eyes of the seated members of the audience, which relates to the row spacing and can vary from 760 mm to 1150 mm and more.
- EH Average eye height at 1120 mm above the theoretical floor level: the actual eye point will depend on seat dimensions.
- E Distance from the centre of the eye to the top of the head, taken as 100 mm as a minimum dimension for the calculations of sightlines. For assurance that there is a clear view over the heads of those in the row in front this dimension should be a least 125 mm.
- D Front row of seats: the distance from point P to the edge of the average member of the audience in the front row. The relationship is shown in **33.21**.

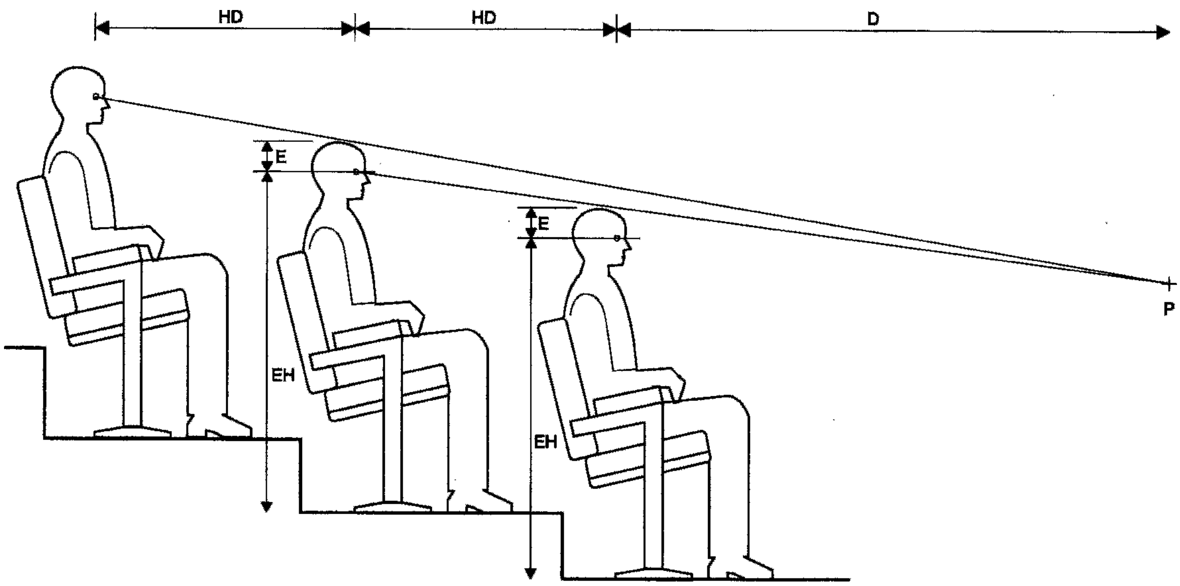
The longitudinal section is a parabolic stepped floor as a theoretical rake produced by the sightline calculation. This gives every member of the audience similar viewing conditions. This may be reduced to a single angle or series of angles.



33.19 *Seating density, from 0.38 m² to 1.05 m² per person*



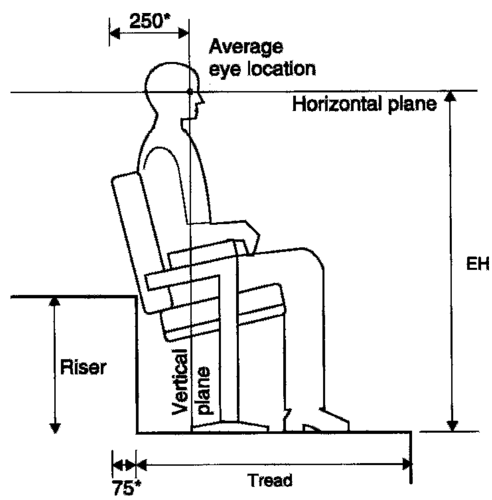
33.20 *Seating density in conference halls, from 0.34 m² to 1.09 m² per person*



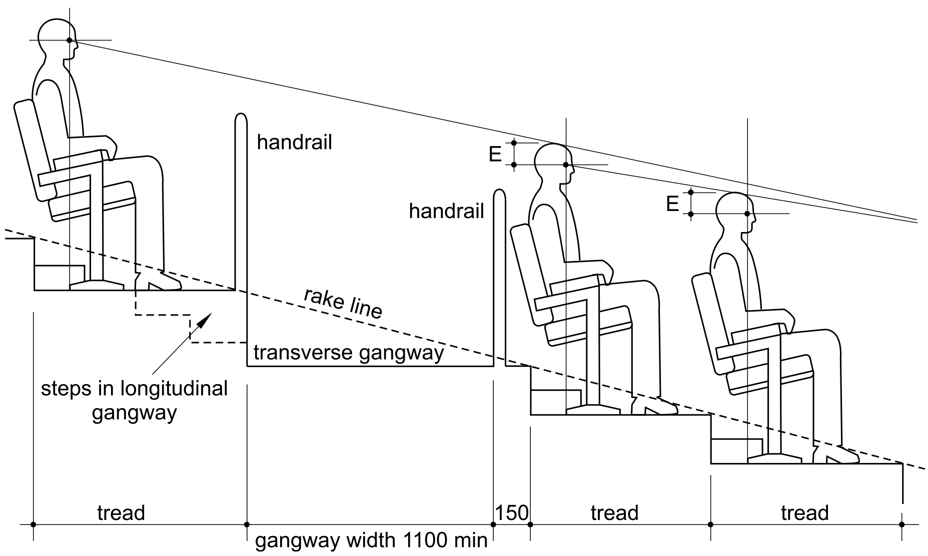
33.21 *Graphic representation of vertical sightlines, P lowest and nearest point on stage clearly visible by audience, HD horizontal distance between eyes in successive audience rows, EH average audience eye height above floor, E height between eye and top of head, D distance from eye of person in front row to P*

When applied as described the rake will also be steep. This is satisfactory for a single tier of seating with no balconies and is especially appropriate for open-stage formats. If a balcony or balconies are introduced, the rake of the lower bank of seats can be reduced, assuming vision to be every other row allowing for point P being seen between heads in the row in front. The vertical distance between point from eye to top of the head for calculation purposes can be reduced to 65 mm if seats are staggered. This is particularly applicable with the design of a large auditorium where, within the visual and aural limitations, the aim is to maximise the seating capacity. This implies a balance between sightlines, height of auditorium and seating capacity. Reducing the accumulative height of the lower level of seating allows more height for balconies.

With the smaller auditorium, especially with the audience partially or wholly surrounding the stage and a limited number of rows of seats, an increased height of the rake to the seating encourages a sense of enclosure of the stage, while providing good sightlines. **33.22** shows how the eye position relates to the seat and the stepped floor.



33.22 *Position of eye in relation to seat and stepped floor. Dimensions vary according to upholstery thickness, and inclinations of both seat and back. Working dimensions are starred**



33.23 *Sightlines at transverse gangway; the angle of the rake line is constant*

Cross-gangways

With *cross-gangways* the line of the auditorium rake must continue so that the audience can see the performance area above the gangway as below. With stepped rows there requires a handrail to the upper side of the gangway and, if a steep rake, a handrail to the lower side. See **33.23**.

Horizontal sightlines

Given a particular size and shape of the platform or stage, horizontal sightlines limit the width of the seating area in the auditorium. This is more critical with the proscenium stage and with film, video and slide projection.

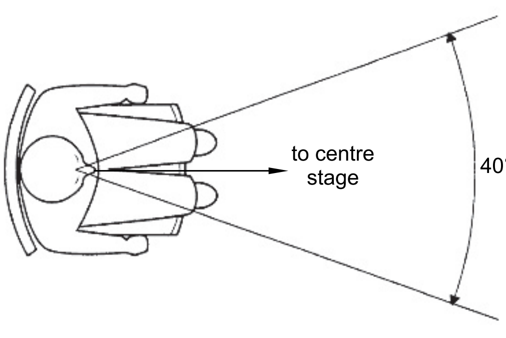
Without head movement, the arc to view the whole platform or stage on plan is 40° from the eye, **33.24**. Debatable is an acceptable head movement, where the seat is focused away from the platform or stage, such as with side galleries requiring the head to be turned by the member of the audience, **33.25**.

The horizontal sightline of the performer may also need consideration, **33.26**.

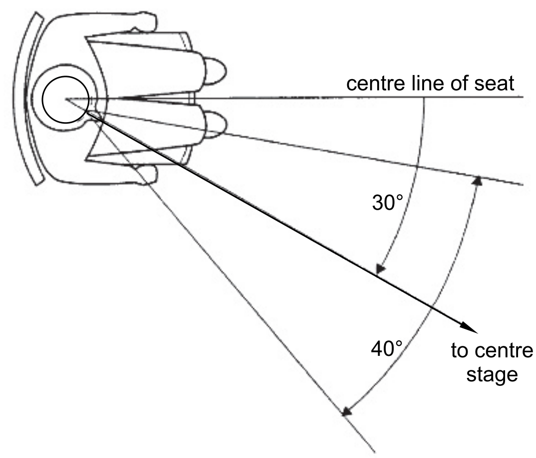
3.11 Wheelchair location

Regulations require a minimum of six places for wheelchair users, or 1/100th of the audience capacity, whichever if the greater. Their location as discrete areas can be at the rear, front, side or within the seating, **33.27**. Wheelchairs can be centrally positioned by forming a bay off a cross-gangway.

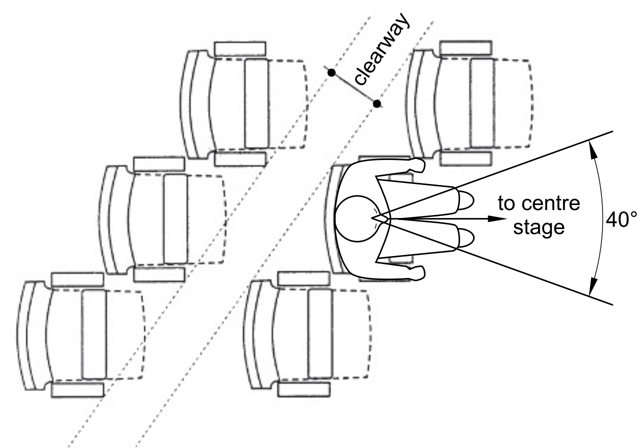
A wheelchair user should be able to sit with a party of friends not in wheelchairs, **33.28**. Sightlines from the wheelchair should be checked, as should the sightlines of those audience members behind. Some wheelchair users can transfer into auditorium seats.



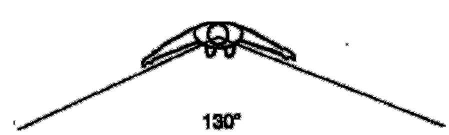
33.24 *The angle of horizontal vision for a stationary head is 40°*



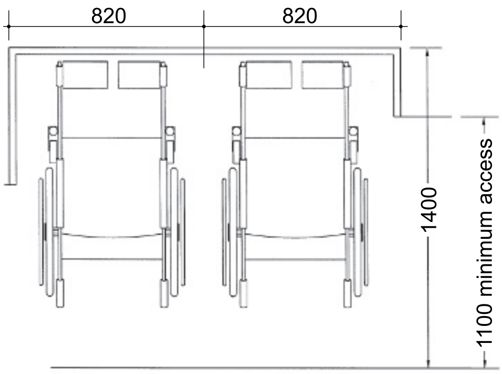
33.25 a *The maximum comfortable amount the head can be turned from the seat centreline is 30°*



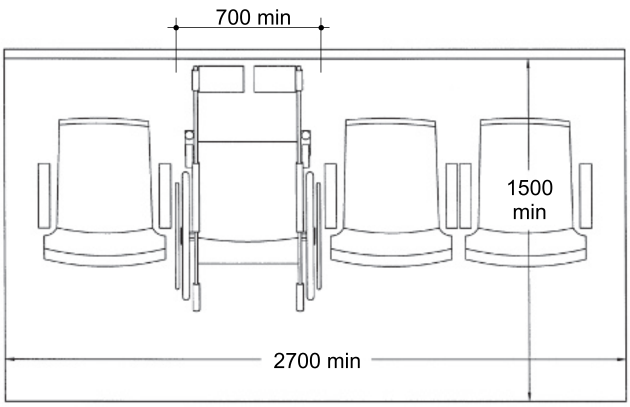
33.25 b *Where the head angle would exceed 30°, the seats may be angled within the row*



33.26 *Horizontal sightlines of the performer*



33.27 *Designated wheelchair area, required dimensions*



33.28 *Plan of a box designed for a wheelchair plus loose chairs*

3.12 Means of escape

The aim is for all in the auditorium to be able to escape to a place of safety within a set period of time. The escape route is from the seat, along the clearway and gangway, and through exit doors immediately, or through an enclosed corridor, to the place of safety.

Travel distance

The maximum travel distance from seat to exit within the auditorium is determined by the need to evacuate from each level of the auditorium within 2½ minutes. For traditional seating the maximum travel distance is 18 m measured from the gangway, for continental seating 15 m from any seat.

Exits

From each level of the auditorium two separate exits must be provided for the first 500 seats with an additional exit for each further 250 seats. Table II gives the minimum total of exit widths required by legislation. Each exit from the auditorium must lead directly to a place of safety.

Exit routes

The route must be a consistent width the same as the exit. There must be no bottlenecks and all doors within the route must open in the direction of escape. Routes within the building should have fire-resistant enclosures. There are special requirements for all doors opening onto fire escape routes.

Table II Total exit widths required by legislation

Numbers of people	Minimum total exit width (m)
up to 200	2.2
201–300	2.4
301–400	2.8
401–500	3.2
501–750	4.8
751–1000	6.4
1001–2000	14.4
2001–3000	20.8

Stairs

Staircase flights should have at least two risers and not more than 16. All treads should be 275 mm and risers 180 mm.

Ramps

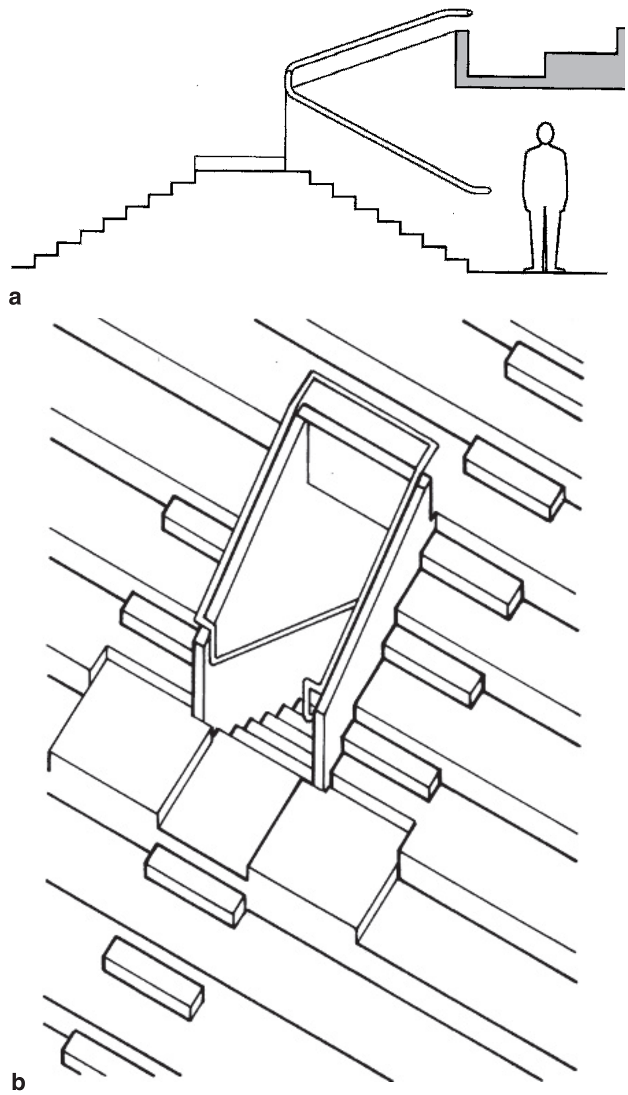
Wheelchair users should be provided with flat or ramped escape routes which may be separate from other routes. Ramps should not be longer than 4.5 m or steeper than 8.5%.

3.13 Circulation

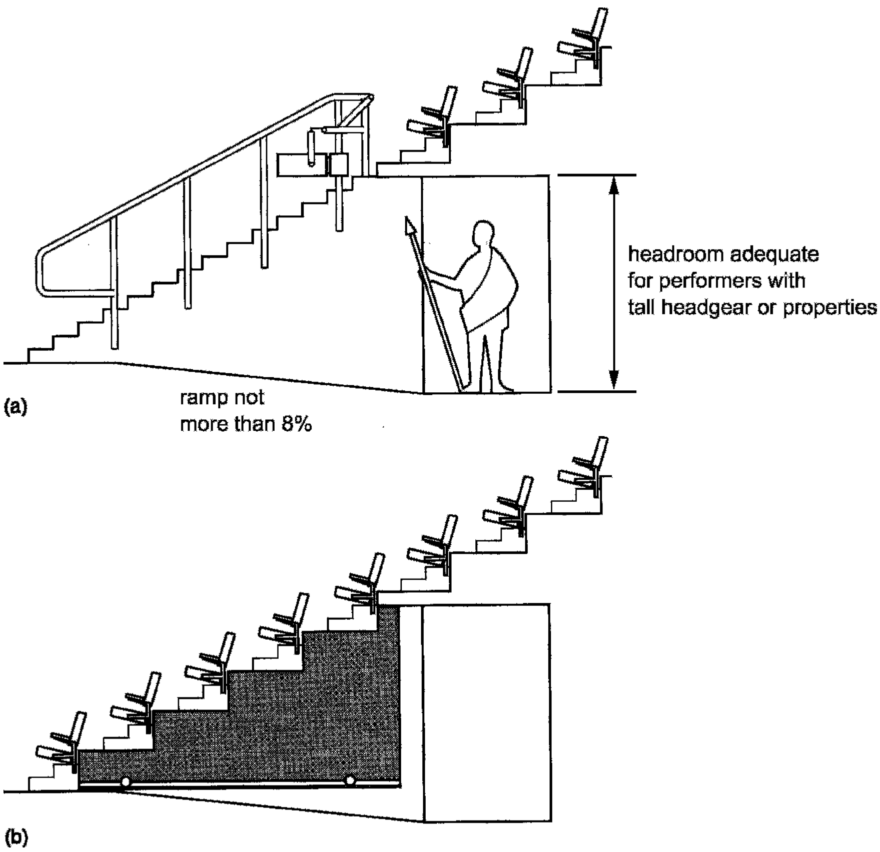
While gangway lengths and widths are calculated as part of the fire escape route, they also provide the circulation through the auditorium, with possible additional gangways from the audience entry points to individual rows and seats.

3.14 Entry points

The audience can enter the auditorium from the foyer at the rear, at the sides of the seating or from vomitories within the seating banks, **33.29**; and the entry points need to connect directly with the



33.29 *Audience vomitory: a public entrance to and exit from the auditorium through a seating block as distinct from through the side or rear walls:* **a** *Section.* **b** *Axonometric view*



33.30 *Performers' vomitory: access to the stage through a block of seating, usually in an open stage or theatre-in-the round format.* **a** *Section.* **b** *Section showing removable seating in place when vomitory not required*

gangways. There should be a threshold space at the entry points for ticket check, programme sales and for members of the audience to orientate themselves.

Sometimes, particularly in theatre-in-the-round, performers make their entrances from within the audience area, **33.30**.

3.15 Handrails

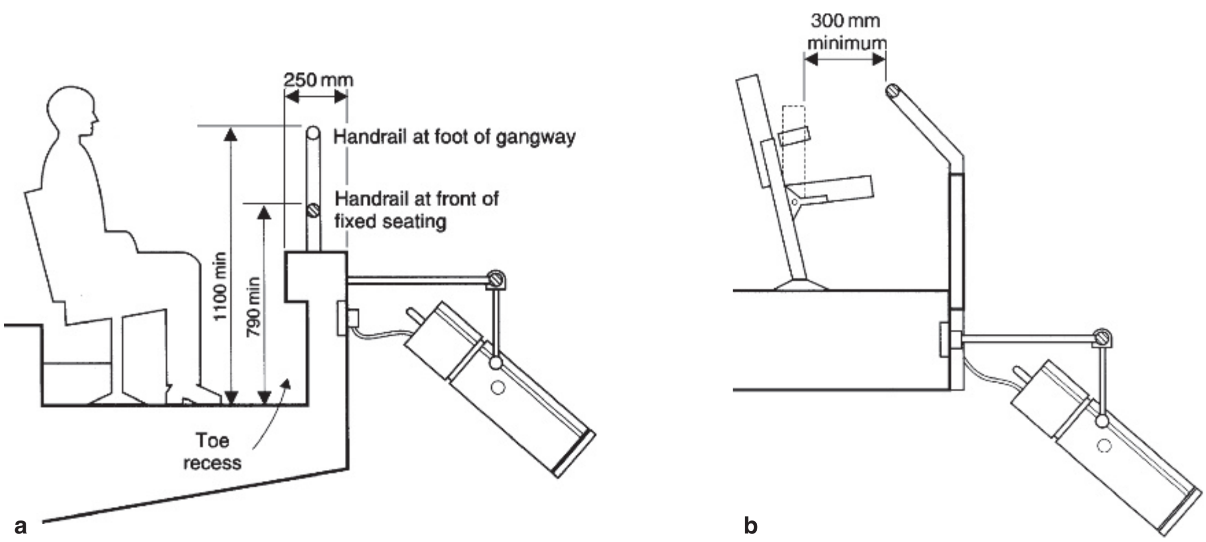
Balcony handrails, **33.31**, are specified by legislation covering height, width and structure: they must also not interfere with sightlines.

Handrails will also be required to stepped gangways:

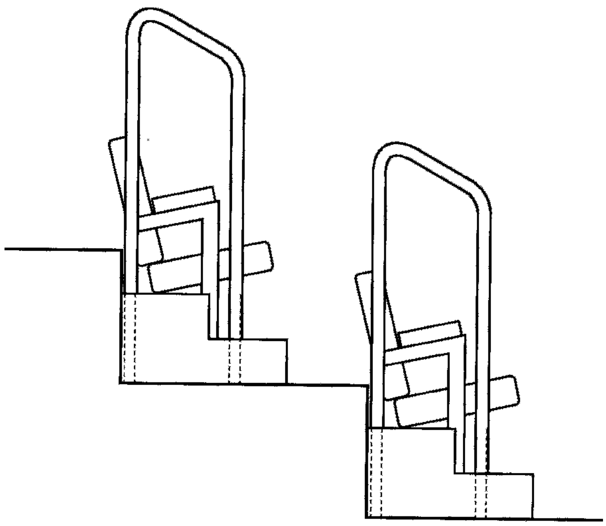
- Adjacent to enclosing wall, or
- If there is a drop at the side

They are also needed:

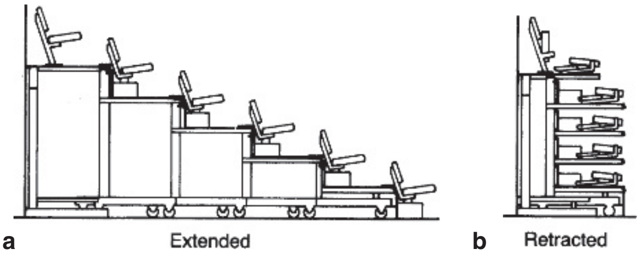
- At landings
- At the rear of rostra, and
- Where there is a drop of more than 600 mm.



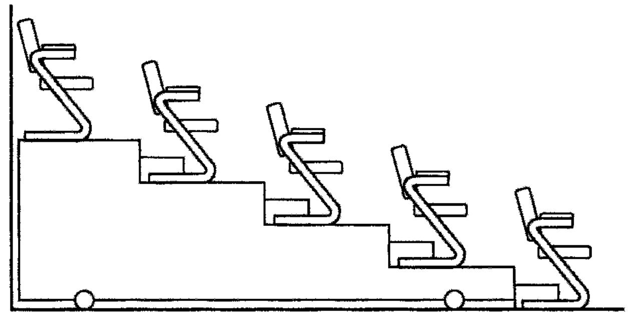
33.31 *The minimum balcony handrail height (BH) is set by legislation at 790 mm in front of fixed seating and 1100 mm at the ends of gangways. Balcony fronts are used to support performance lighting and need socket outlets connected to stage lighting controls:* **a** *Traditional balcony front incorporating shelf below handrail and adequate legroom.* **b** *Simpler front for side galleries with minimum clearway allowing the audience to lean on the handrail. This front is removable as part of a flexible auditorium*



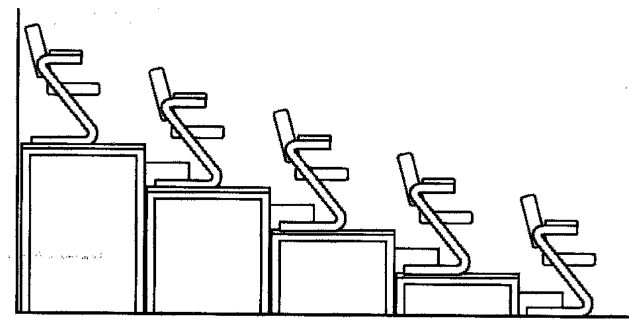
33.32 *Loop guardrail at the end of a row where the rake is steep*



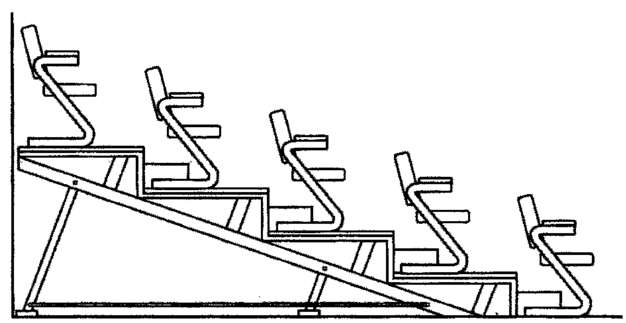
33.33 a *Bleacher seating: one of a number of proprietary systems of permanently installed retractable systems. The length of seating in a single unit is limited to 6 m. For tip-up seats with arms the minimum riser height is 250 mm.* **b** *Bleacher seating retracted*



33.34 *Large units on brakable casters or air cushions*



33.35 *Rostra: a set of metal or timber units built up to form a stepped floor on a flat base. Seats are secured onto floor or riser. Each rostrum unit collapsible for storage*



33.36 *Proprietary scaffolding-type system*

Where the rake of a gangway is above 25° the ends of the rows should have a loop rail, **33.32**.

Rails are usually 900 mm above pitch line and 1200 mm above landings, with infill panels that are solid or have no gap greater than 100 mm.

3.16 Floors

The floor of the auditorium is an acoustic factor in the success of an auditorium. Some venues now dispense with carpets as plain wooden floorboards offer a better acoustic for orchestral music. Consideration should be given as to whether the auditorium floor should be flexible to account for acoustic variability.

3.17 Latecomers

A waiting area at the rear of the auditorium either within the auditorium or in a separate enclosed space with viewing panel and tannoyed sound, or elsewhere with a closed-circuit television facility.

3.18 Attendants

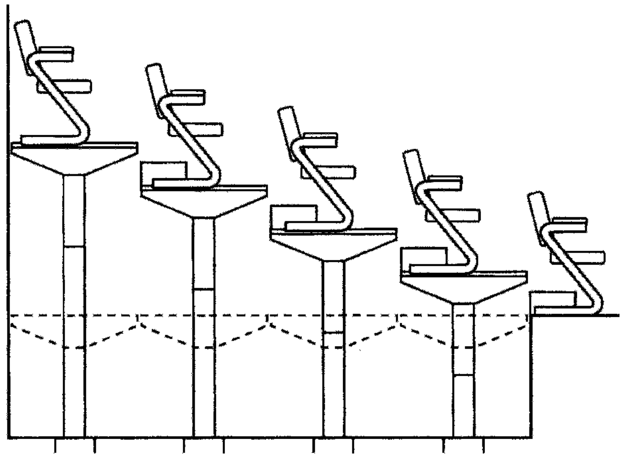
Legislation dictates a number of attendants present at public events, each requiring a seat in the auditorium.

3.19 Adaptation

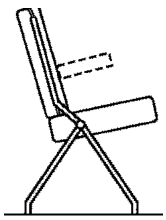
In multi-purpose auditoria where different formats or uses are combined or part of the raked seating will require to be moved. This can be achieved by forming structure off a flat floor, and methods include:

- Bleacher seating, **33.33**: telescopic structure with tippable upholstered seating with backs, able to be retracted into the depth of a single and highest row; rows are straight and the extended structure is a simple rectangular block, which places a discipline on the seating layout.
- Rostra, **33.34**: complete raked units with either permanent or removable seats, on wheels or air palettes for ease of movement into storage areas when not in use.
- Sectional rostra, **33.35**: a set of boxes able to be built up to form raked units with removable seats; storage requirements less than complete rostra.
- Kit of parts, **33.36**: scaffolding or equivalent set of components able to form raked levels to receive seating; the most flexible system, efficient storage requirements, but labour intensive.
- Hydraulic lifts, **33.37**: mechanical method of raising sections of the flat floor to form a rake floor to receive seating.
- Loose seats, **33.38**, secured in position when required for performances, can be used with functions requiring a flat floor.

Following a number of failures of such flexible spectator facilities, legislation has been tightened up and official inspections are often necessary whenever seating arrangements are changed. This means that it is not usually possible to stage a series of different events within a short space of time.



33.37 *Floor sections that can be raised and lowered hydraulically*



33.38 *Loose seating, capable of removal. May or may not have arms, and be stackable. Needs to be firmly fixed down when in public use*

3.20 Sound insulation from outside noise sources
The standards are expressed as Noise Rating (NR). To achieve the appropriate rating auditorium design may require:

- Isolation of the auditorium structurally
- Sound locks to all doors at point of entry
- Services acoustically sealed, and
- Noise reduction to air conditioning / heating / ventilation system.

3.21 Air conditioning, heating and ventilation
The design depends on the internal standards required in the auditorium, the thermal insulation of the enclosure and on the external climatic conditions. Ventilation needs to provide fresh air at a rate of change to achieve comfort conditions: rates are set down by legislation and include a proportion of recycled conditioned air which vary locally. A common condition is a minimum air supply per occupant of 8 litres per second, 75% of outside air and 25% recirculated.

Extract ductwork can be at ceiling level and under balconies with supply below the seating.

Plant should be remote from auditorium to avoid noise transmission.

3.22 Lighting
There are six different requirements for auditorium lighting.

Performance lighting
For theatre, opera and dance performance lighting is an integral part of the staging of productions, with lighting positions not only on the stage but also within the auditorium at ceiling level, on side and rear walls and balcony fronts. Further details are given in para **4.11** below.

For classical music and serious jazz sufficient lighting for the performers to see their music and the conductor (if any), and for them to be seen by the audience is usually all that is required. Similar lighting is required for the platform at conferences.

Pop music requires as complex lighting as for drama and opera – perhaps even exceeding that with elaborate effects.

House lighting before and after performance and during intervals
Illumination to enable the audience to move around, find their seats and read programmes; decorative lighting to emphasis architectural features. This form of lighting will also be required during conferences.

House lighting during performance
For cinema lighting is only for exit signs and escape routes. For the latter, small lights just above floor level have advantages in not obscuring the screen and being most effective in smoke-logged conditions.

For theatre a slightly higher level of illumination may be used, particularly if the performance demands a contrast with a time of almost total darkness. For classical music it is now usual to have sufficient lighting for near-normal vision and following scores.

Pop music may nowadays require house lighting as sophisticated as performance lighting, with strobe and laser facilities.

Certain lighting is required during performances to ensure safety in emergency, particularly the statutory exit signs. Other lighting may be required to come on automatically in emergency situations; this may work off a separate protected supply. Alternatively, each item can incorporate a battery and be programmed to come on when a failure in the mains supply is detected.

House lighting at other times
It should not be forgotten that the seating area will also require a working level of lighting for cleaning, maintenance and probably during rehearsals and auditions.

Front-of-house lighting
Escape routes have to be adequately lit at all times, during performances as well as before and after. Foyers, bars and ticket offices require careful lighting design to enhance their attraction.

Backstage lighting
Corridors are escape routes for the performers and service staff, and must be kept illuminated whenever the building is occupied. Dressing rooms and workshops will have normal lighting for such facilities, and may be fitted with proximity detectors to ensure that lights are not left on when the rooms are unoccupied.

3.23 Fire protection
Fire precautions should be discussed with the local fire authority and with fire insurers. Means of escape have already been covered in para **3.12**. However, it is important to consider four other factors:

Preventing fires occurring
- Non-combustibility of materials including finishes and seating
- Protection of electrical circuits
- Care with lighting, and
- Separation of hazardous processes such as scene-painting.

Detecting them early when they do occur
- Smoke and heat detectors backstage, in auditorium and all voids
- Alarms connected to the automatic detector system and central indicator panel, and possibly direct link to local fire station. These should be visual (flashing light) in auditorium and not audible.

Preventing them spreading
- Enclosing walls and floors to be fire-resistant
- Self-closing firedoors to openings
- Either a safety curtain to the stage area or special on-stage precautions.

Facilitating extinguishing

- Hose-reels
- Portable extinguishers
- Automatic sprinkler systems backstage (not allowed over seating areas).

3.24 Ceiling zone

Functional requirements cover:

- Acoustics: profiled reflector panels and possible adjustable diffusers. For non-amplified music, reflectors also over concert platform
- Lighting: bridges for access and support for auditorium lighting, working lights and emergency lighting as well as performance lighting
- Ventilation: air ducts and plenums, diffusers, noise attenuation and monitoring equipment, supporting hangers and means of access for servicing
- Production requirements: for operas, dance musicals and drama, a grid and pulley suspension for suspending scenery over forestage, including access by technicians
- Fire control: detection system in voids and fire dampers in ducts and
- Structure: support for roof, ducts, lighting bridges, etc.

4 THEATRE

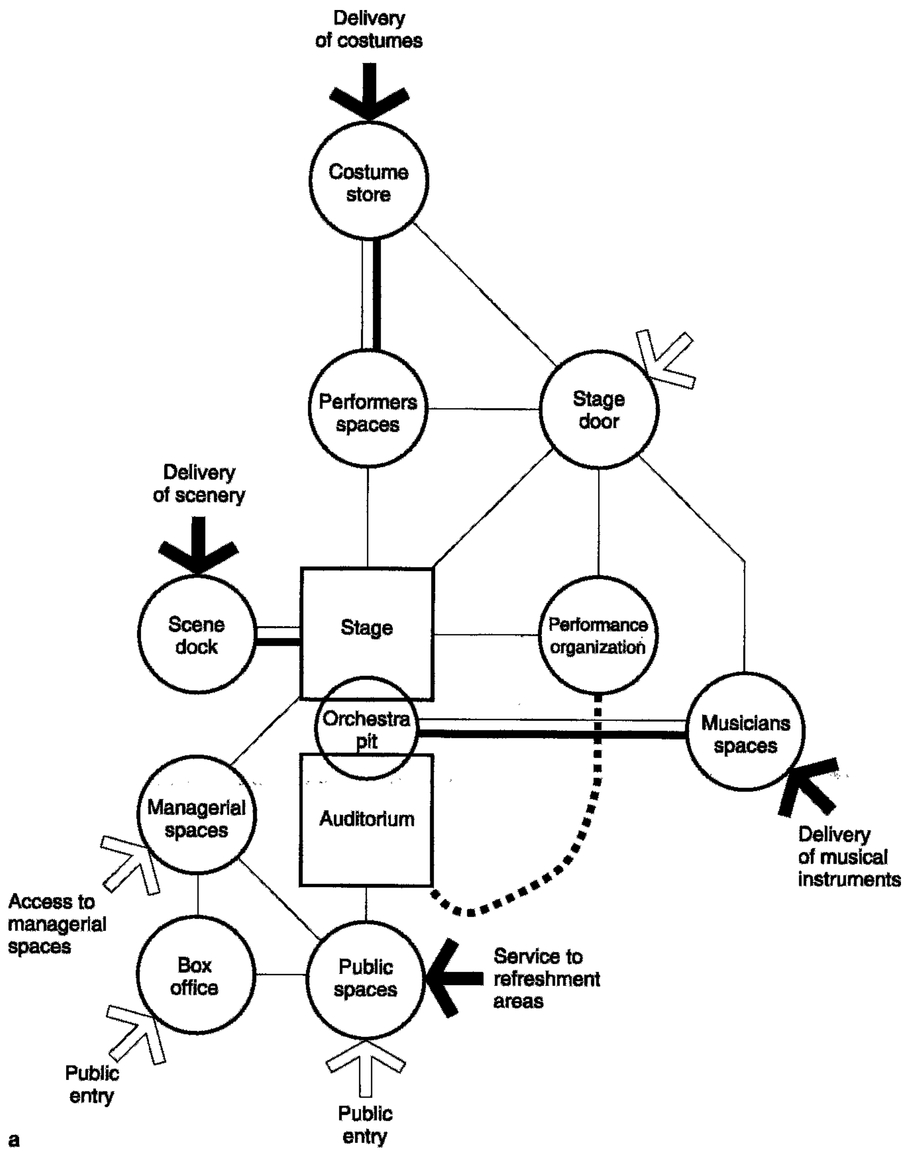
4.01 Range

Theatre covers productions of drama, opera, ballet, musicals, variety and pantomime, **33.39**.

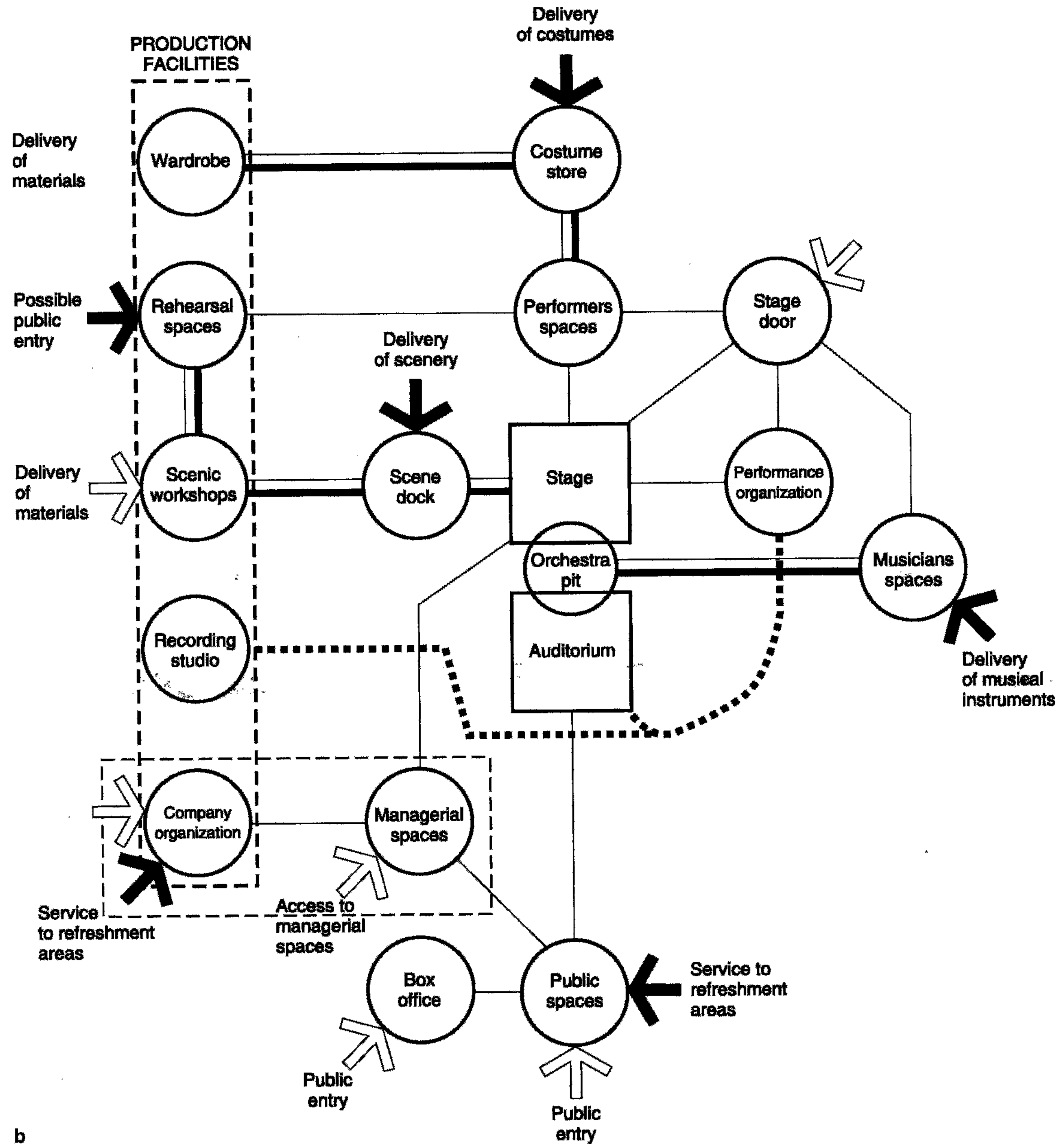
4.02 Types

Theatre structures are enormously varied and much alteration work is done in theatres during their working lives. This work usually includes upgrading or modernising the stage equipment, and improving the seating quality. The reasons are market driven: equipping to take larger or more complex productions, enabling more productions within a given time and labour-saving measures. Front-of-house improvements are made to attract greater attendance through increased facilities and comfort.

Theatres and studio spaces, which for these purposes also include 'fringe' venues formed out of existing buildings, also see themselves as fitting into a particular bracket, for example small, medium or large scale. These categories are determined by a sliding scale involving seating capacity, size of stage, backstage accommodation and even geographical location. The intended scale of use should be apparent in any brief, or should be clarified. It will need to be reflected in the design proposals.



33.39 *Relationship diagrams for buildings for opera, musicals, dance and drama. If for drama only, the orchestra pit and musicians spaces may not be required:* **a** *Where the building serves only touring companies or with a resident company whose production facilities are elsewhere.* **b** *Where production facilities are needed (continued over)*



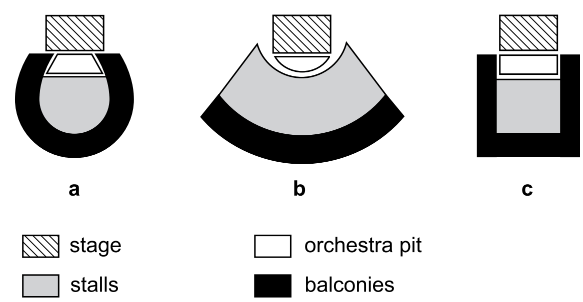
33.39 *Continued*

Medium-scale theatres would normally be considered as those with perhaps less than 1000-seat capacity, without a significant array of stage machinery, but provided with proper fly suspension systems and orchestra pit facilities suitable for taking smaller productions with cast not normally exceeding 20–25 individuals.

4.03 The proscenium

For most opera, dance and musicals, the formats are restricted to the proscenium and end stage. The proscenium form is a conventional arrangement placing the audience facing the stage, viewing the performance through an architectural opening. Scenery on the stage can be developed as a major design element. The traditional position is for the orchestra to be located in a pit between audience and stage, with the conductor in a pivotable location controlling orchestra and singers. The auditorium formats, **33.40**, include the horse-shoe, fan with or without balconies, and courtyard. The latter consists of shallow balconies of no more than three rows around three sides of the auditorium. The end stage is similar to the proscenium format but without the architectural opening, placing audience and performance in the same space and suitable for small-scale productions.

For drama there is a wider range of formats: the initial distinction is between the proscenium format and open stage forms.



33.40 *Auditorium formats for opera, dance and musicals on proscenium stages:* **a** *Horse-shoe form, shallow rear and side balconies.* **b** *Fan shape with 90° arc, with or without rear balcony.* **c** *Shallow rear and side balconies*

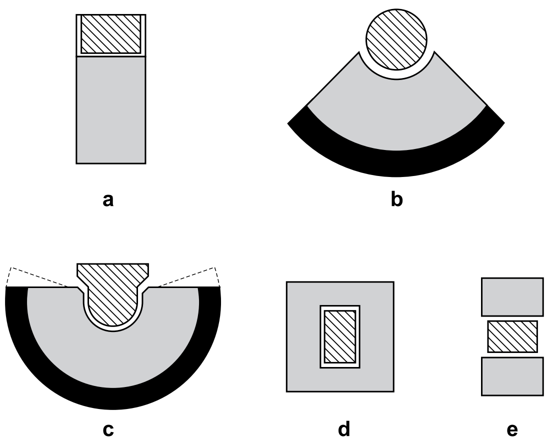
The proscenium format is outlined above. There are five variations of open stage formats, **33.41**:

- End stage
- Fan-shaped
- Thrust stage
- Theatre-in-the-round
- Transverse stage.

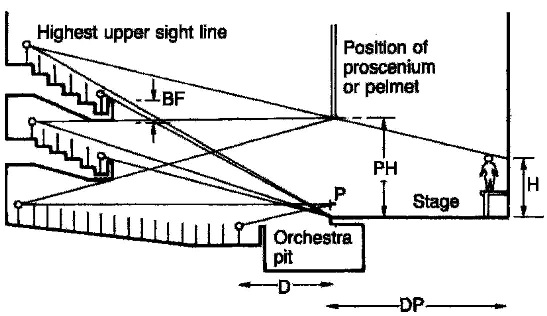
The viewing criteria in the auditorium will depend on the performance volume on stage, **33.42**.

4.04 Stage

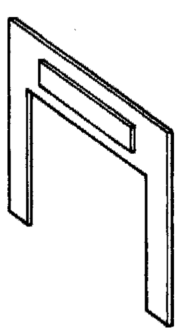
Stage refers to the main performance area and its associated flytower, side and rear stages and orchestra pit if these are provided.



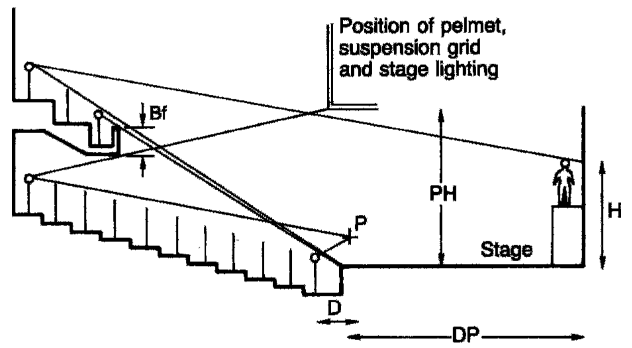
33.41 *Auditorium formats for drama on open stages:* **a** *End stage.* **b** *Fan shape, 90° arc with or without rear balcony.* **c** *Thrust stage, 180° + arc, with or without rear balcony.* **d** *Theatre-in-the-round.* **e** *Transverse: audience on sides of stage*



33.42 a *Vertical sightlines for proscenium stage*



33.42 b *Subtitle panel over proscenium opening: needs to be visible to whole audience. These are increasingly essential for opera, and when drama is performed in a language foreign to most of the audience*

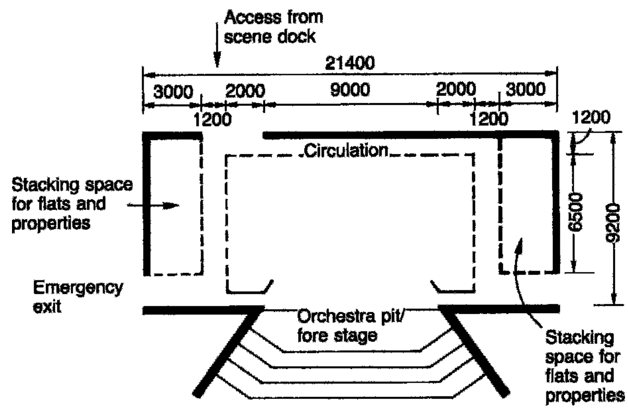


33.42 c *Vertical sightlines for open stage*

The stage floor is a vital part of the working system. It is essential that access can be made to the underside of the stage floor, and that it be constructed of such material that screws, nails etc. can be used with relative ease.

4.05 Proscenium stage without flytower

For the smaller auditorium without a flytower, suspension of scenery, curtains, pelmets, borders and lighting barrels above the stage, **33.43**, is necessary. Lines can be fitted to pulleys hung on a grid, with flying from a side gallery above the stage, or from the stage level. Side stages are required for stacking spaces for flats, properties and rostra, as well as circulation routes within the stage.



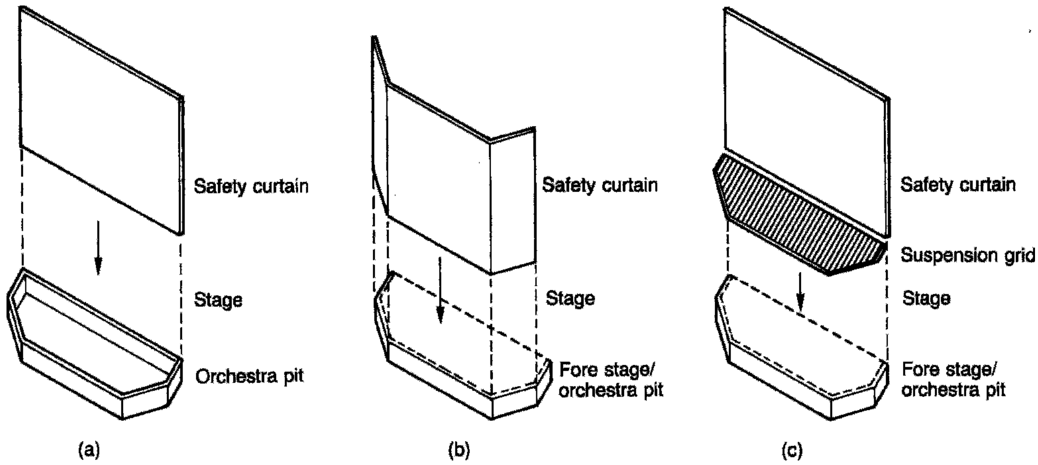
33.43 *Stage layout and dimensions for a medium-size theatre without flytower*

4.06 Proscenium stage with flytower

The dimensions and shape of the performance area are determined by the recommended proscenium opening as in Table III. A wider opening can be reduced by screens or curtains, so that an all-purpose stage should be sized for opera. Ideally, the depth of the performance area front to rear should be equal to the proscenium opening.

Table III Widths of proscenium opening in metres for various types of performance

	Small scale	Medium scale	Large scale
Drama	8	10	10
Opera	12	15	20
Dance	10	12	15
Musical	10	12	15
All-purpose	12	15	20



33.44 *Safety curtains, essential for a proscenium stage:* **a** *Simple flat design.* **b** *Cranked design for when orchestra pit is covered to make a forestage.* **c** *Flat design where scenery and properties on forestage are fully incombustible*

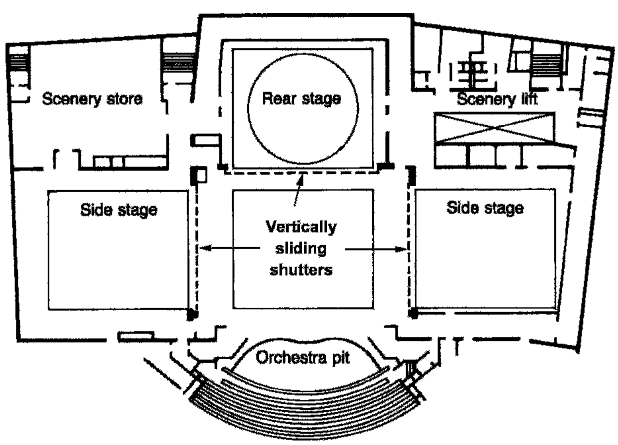
Raised stage
The height of the stage can be between 600 mm and 1100 mm with a straight, angled or curved front edge. The floor to the performance area, in part or total, may be a series of traps, that is modular sections usually 1200 mm square which can be removed selectively.

Side and rear stages
Sizes should relate to the size of the performance area. These areas may need to hold sets as on the performance area, with circulation all round. The clear height required to be the highest scenery plus 1 m.

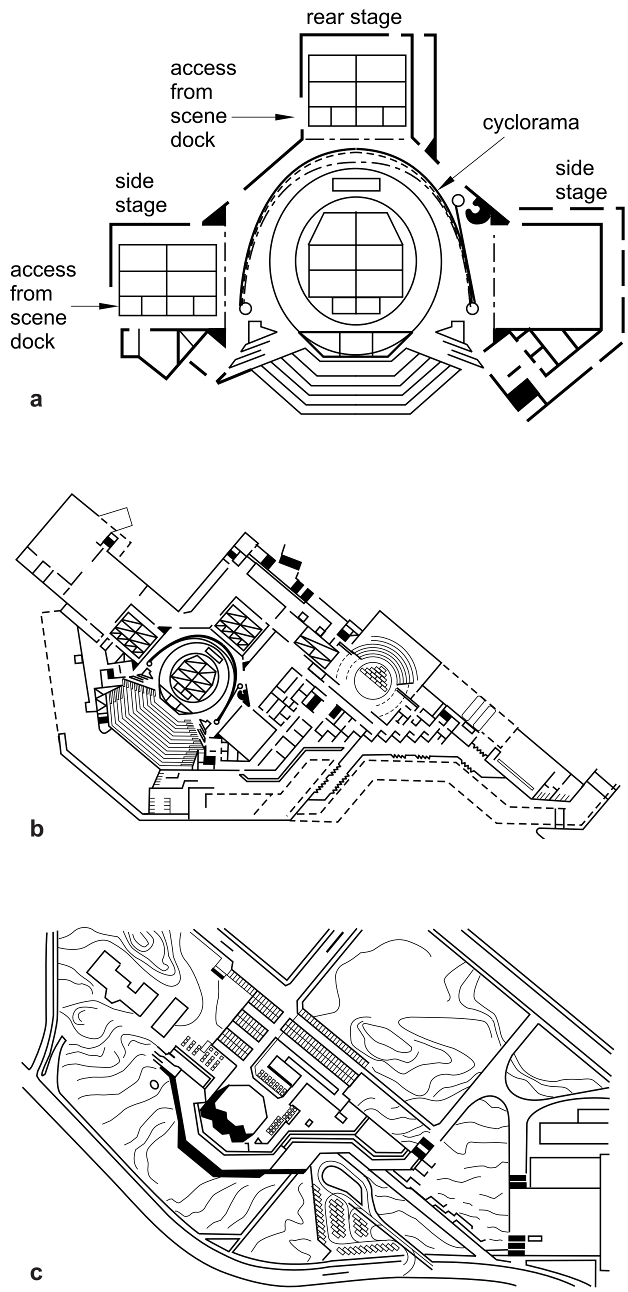
Stage basement
The space under the stage should be fully accessible with a minimum headroom of 4.5 m.

Safety curtain
In the case of fire on the stage it must be separated from the auditorium, with the proscenium opening being closed off by a safety curtain. The normal form is a rigid curtain suspended immediately behind the proscenium opening and dropping on the stage from the flytower, **33.44**. The fire seal must continue below stage level.

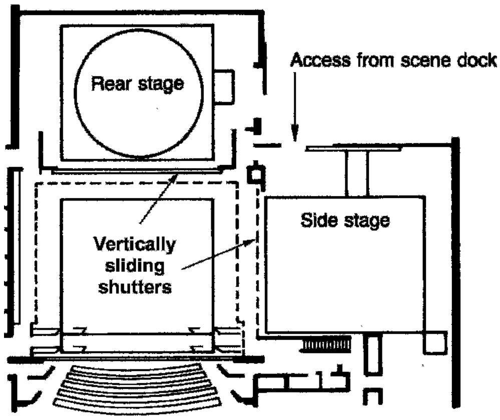
Examples of existing fly-tower stages are shown in **33.45–33.48**.



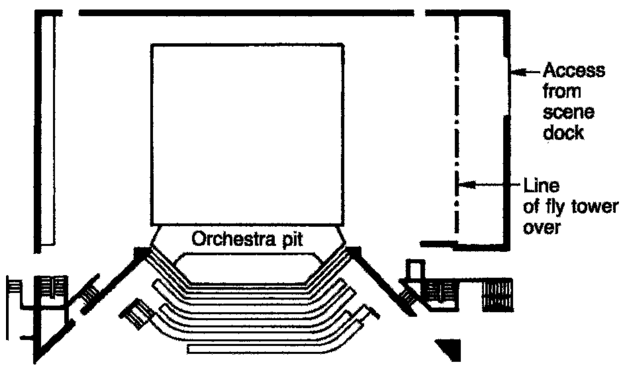
33.45 *Opera House, Essen: stage layout for a proscenium stage with a flytower for opera and dance*



33.46 *Civic Theatre, Helsinki: a proscenium stage with flytower for drama and dance:* **a** *Stage layout.* **b** *Plan at entrance level.* **c** *Site plan*



33.47 *Lyttleton Theatre, Royal National Theatre, London: proscenium stage with flytower for drama*



33.48 *Theatre Royal, Plymouth: stage for touring opera, dance, musicals, drama and concerts*

4.07 Stage machinery

Large dedicated buildings such as opera houses require an amount of stage machinery to be installed:

Bridges are long lifts which span the width of the proscenium opening, giving a rise and fall facility over the main acting area. They are driven by screw jacks, scissors, chain or hydraulic systems.

Revolving stages require to be set into the stage floor to provide a flush fit surface, but this can sometimes be organised to coincide with the system of lifts and bridges.

Wagon stages are large pallets capable of taking an entire set which may be moved into place behind the proscenium fully built, thereby saving labour during the performance period. If wagon stages are used, sound separation shuttering needs to be provided around the stage area to shut off the off-stage areas where work is going on to the wagon stages. Depending on the flying configuration, up to three wagon stage positions (left, right and upstage) may be involved in an immediate off stage situation. It is also possible to mount revolves in wagon stages. Much larger installations have in fact extended the wagon principle so that they are used as a system of gigantic palletised storage to store up to a dozen or more sets fully erected in large spaces below the stage, provision being made to have them lowered below the stage surface.

4.08 Flytower

Where there is a space dedicated for use as a stage, then it is essential to provide this with means of suspension overhead. This suspension to be used for both scenic and lighting instruments.

The grid above the stage from where the suspensions come should provide clear walking space above for personnel to move about over the floor area. The received wisdom is to place the pulleys supporting the suspension bridge at the high point (see diagram) with the walking grid space below it. The key to overhead suspension is the load and the frequency of suspension points. Multi-use, intensively used venues will have bars suspended every 200 mm with load capacity up to 500 kgf per bar. Less intensively used installations may have bars 300 mm apart and, depending on the nature of the performance to be given, the load capacity may come down to 350 kgf per bar.

It is essential that the means of suspension can be lowered to the floor. Depending on the frequency of usage, this suspension system can either be winched, or in smaller installations be operated using rope hand lines. In the theatre, all items suspended overhead are 'flown'. The space above the stage is referred to as the 'flys'. The greater the height over the stage is usually considered the better, offering greater flexibility for designers both of scenic and lighting disciplines. Where the scenic suspension system is raised considerably above the stage it can then be described as a flytower.

Conventionally the clear height of the flytower was 2½ times the proscenium height. Nowadays greater heights are usually demanded, with a minimum of 2½ the proscenium height to the underside of the grid and a clear 2 m above the grid.

There are different means of suspension: the main ones are counterweight and hydraulic systems.

Counterweight systems

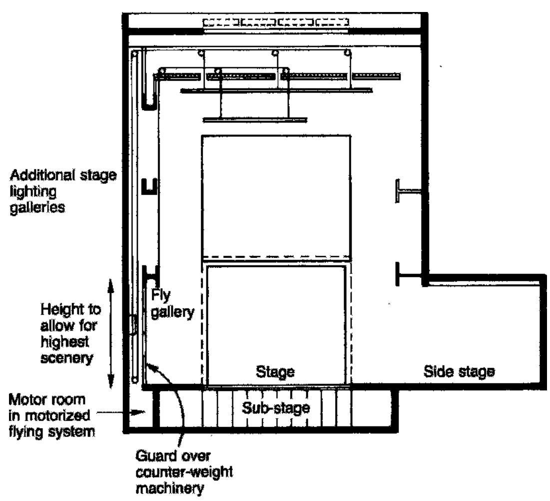
A 'cradle' laden with weights travels up and down special places vertically either side of the stage. There are two types:

- Single-purchase counterweights where the travel distance is equal to the height of the grid above the stage, **33.49**: a continuous vertical wall running higher than the grid is required for the guides.
- Double-purchase counterweights where the distance travelled by the counterweights is halved in relation to the distance of the suspension, **33.50**. This allows the operation to occur from a gallery above the stage level: an extra loading gallery is necessary between the flying gallery and grid.

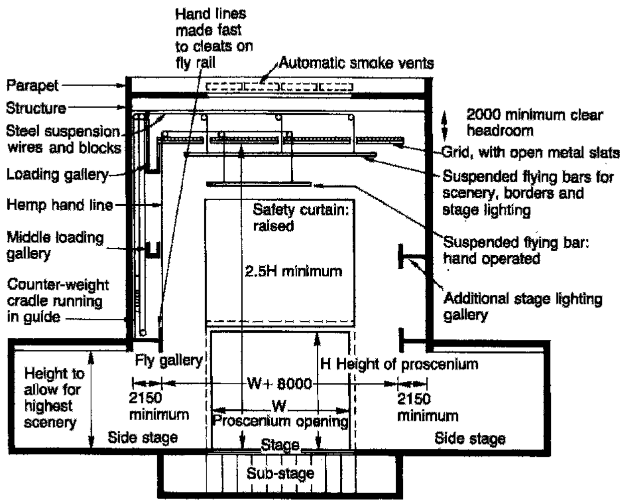
Hydraulic systems

These obviate the need for space for the cradles by containing the entire system at the very highest point in the building, opening up the possibility of side stages on either side.

It is important to locate flyfloors either side of the flytower to provide horizontal access above the nominal height of the scenery.



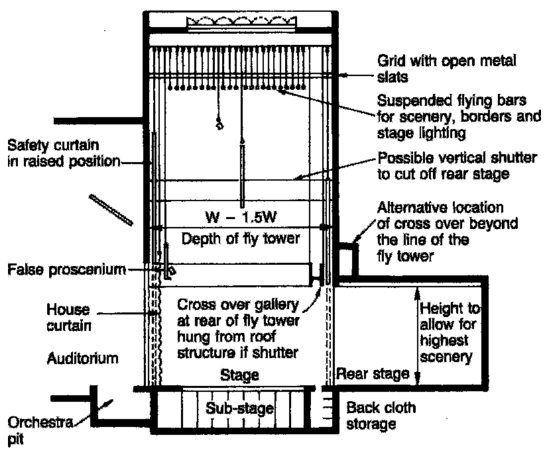
33.49 *Section through flytower showing single-purchase flying system permitting only one side stage*



33.50 *Section showing double-purchase flying system and side stages*

This is used by technicians to locate and control horizontal movement of vertically suspended components. If the building is likely to have dedicated usage by a single-occupancy user, then certain suspension positions may be dedicated for lighting systems, in which case a special provision may be made for horizontal access by personnel to reach these positions as well as their raise and lower facility. It will also be possible to feed the necessary electrical supply from directly above the position in a self-monitoring system which caters for the vertical movement. **33.51** shows a flytower stage with a rear stage.

An automatic smoke vent is required at the top of the flytower: regulations require the cross-sectional area of the vent to be a particular proportion of the stage – usually 10%.



33.51 *Cross-section showing rear stage*

4.09 Orchestra pit

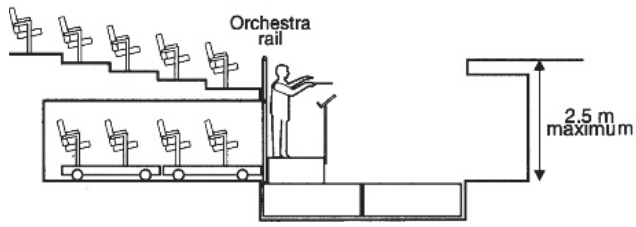
A limiting factor is for the conductor to be seen both by the singers and dancers on the stage, and by the musicians in the pit. The audience needs a balance of performance from stage and orchestra.

Allow $3.3\,m^2$ average per player, $5\,m^2$ for the piano, $10\,m^2$ for tympani and percussion, and $4\,m^2$ for the conductor. The conductor's eye level must not be lower than stage level when seated on a high stool. To minimise the gulf between stage and audience, the pit can extend under the stage front for a distance no greater than 2 m.

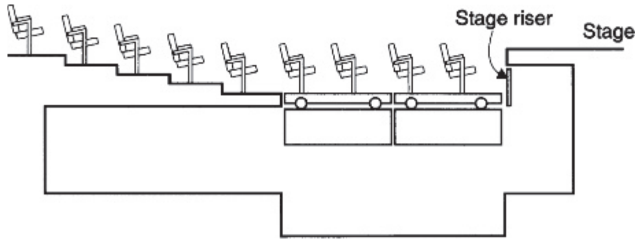
For opera, the pit requires to hold a maximum of 100 musicians, 60 for musicals, 60–90 for dance. The numbers can be less with touring companies. The pit should be horizontally reducible, with the floor level vertically adjustable.

Where there is a multi-use facility orchestra lifts, **33.52**, are common. These can provide:

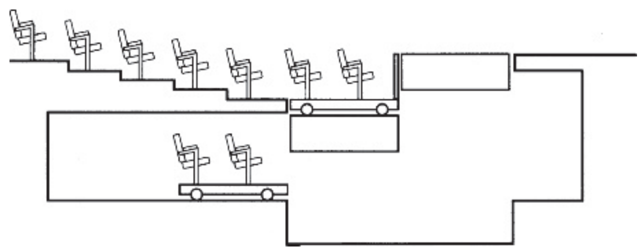
- A fore stage when elevated
- Two or three extra rows of seating when level with the auditorium floor or
- The orchestra pit when in the down position.



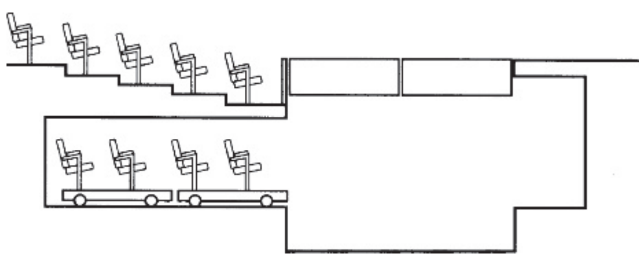
a *Lift in lowest position with seat waggons in store under fixed seating*



b *Lift partially raised for maximum additional seating*



c *Half lift raised for seating and half fully raised for stage extension*



d *Lift fully raised for maximum stage size*

33.52 *Orchestra pit lifts*

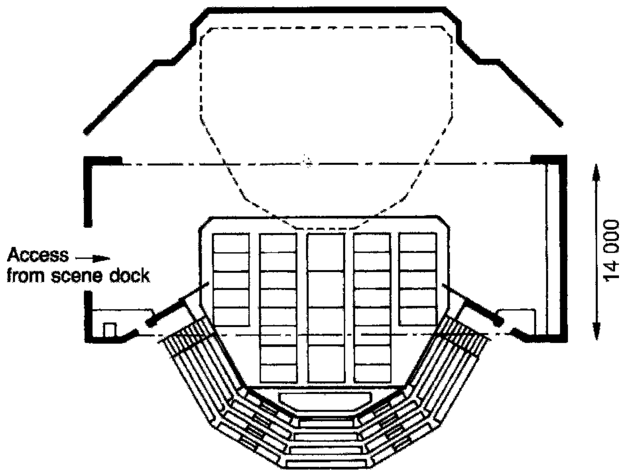
4.10 Open-stage formats

End stage

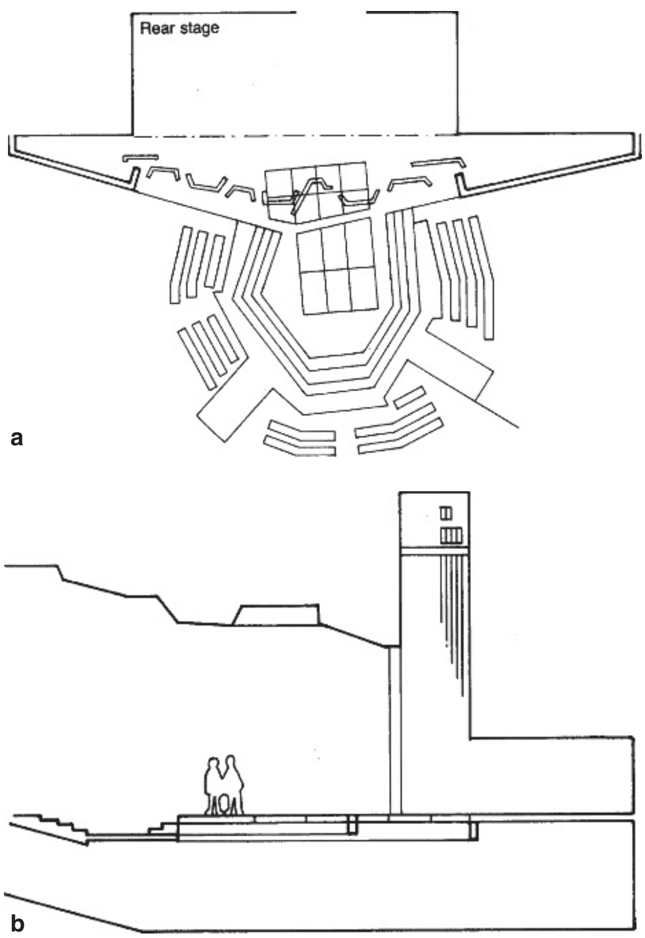
For dance and opera, the minimum performance area is 10 m × 10 m, for drama 10 m × 8 m. Modest side stages with masking are necessary for the storage of scenery as well as performers' entrances. Orchestra pit can be formed between stage and auditorium.

90° fan
Dimensions vary, based on a circle or faceted circle, with diameters ranging from 8 to 11 m, **33.53**.

Thrust stage
The performance area as a peninsula projecting from rear setting, **33.54**.



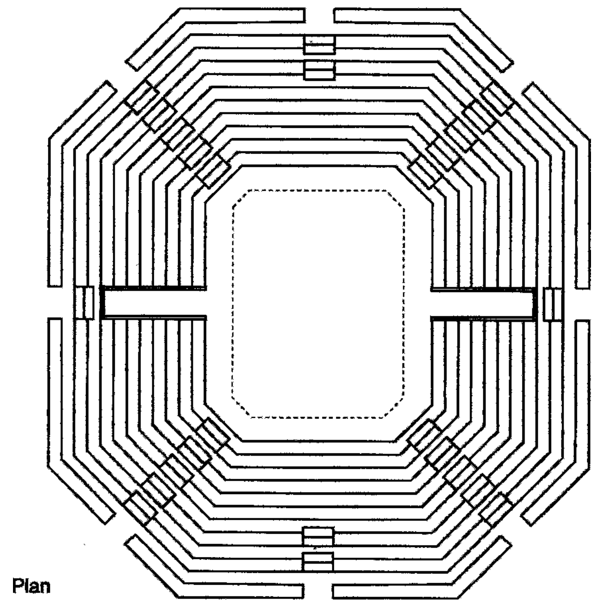
33.53 *West Yorkshire Playhouse, Leeds: plan of a stage where the audience encircles it by 90°. This theatre has a single-purchase flying system and a retractable wagon stage*



33.54 *Tyrone Guthrie Theatre, Minneapolis: thrust stage with steps at the edge permitting performers to access from various parts of the auditorium. The stage has traps, a rear stage and a backcloth flying system:* **a** *Plan.* **b** *Section*

Theatre-in the-round
The performance area can be circular, square, polygon, rectangular or elliptical, **33.55**. The performers' entry can be combined or separate from the public access.

The stage is usually not raised, but can be 300–750 mm with 600 mm a favourite dimension. The minimum clear height over the stage including scenery suspension grid and stage lighting is 6.5 m. The whole or part of the performance area can receive traps as previously described, with one 'grave' trap 1200 × 2400 mm as a minimum. If there are traps a basement will be needed with access for the performers and minimum ceiling height of 4.4 m.

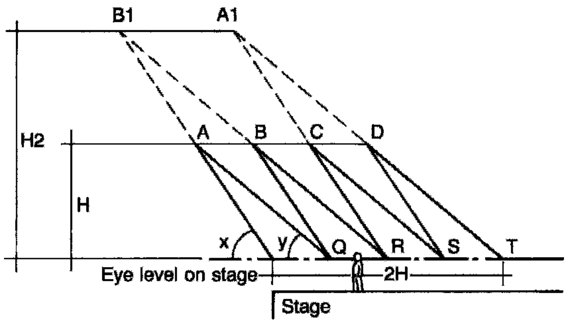


33.55 *Theatre-in-the-round with a rectangular performance area and performers entering at stage level from vomitories. The audience enters from rear of seating*

4.11 Auditorium lighting positions

There are three main factors governing these positions:

Ease of access is dependent upon the intended use of the auditorium. For intensively used auditoria, staff will require almost daily access to the instruments and this should be provided in such a way that they are not required to use loose ladders in order to carry out their functions. The access needs to be to the rear of the instrument with ample room for the staff to reach around the instrument to the front and also sufficient free space for the instrument to be readily demountable should repair be required. *Location.* Over a third of the total number of instruments in a modern rig are likely to be located in the auditorium area (front of house), **33.56**. The desired angle is normally between 42° and 44° at an angle to a horizontal plane emanating at the stage front. Lanterns are required at a high angle either side as well as across the main front area of the stage. Depending on auditorium design, lanterns are either housed on bridges which cross the auditorium, **33.57** or are attached to the auditorium structure itself. Provision for instruments on the auditorium side of the proscenium arch in a vertical plane is also recommended. Lighting design for theatre-in-the-round is particularly complex, **33.58**.
Integrity of design. Many people consider lanterns and their relevant bulky cabling and paraphernalia to be unsightly in the context of formal auditorium design and therefore steps need to be taken to provide housings for the instruments such that they are not normally in the view of the majority of the audience. However, auditoria which carry a 'high tech' design ethic will find it just as acceptable to place lanterns in exposed positions, provided they are sympathetically arranged as they then become part of the design



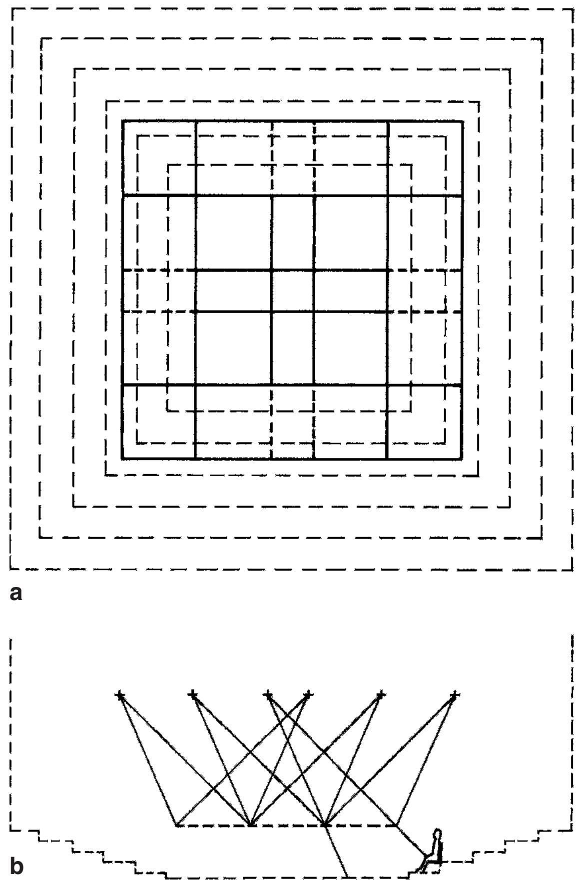
33.56 *Method of locating theoretical positions of spotlights. Spots at A will light a performer at stage edge at 55° in section, about 45° to 50° after crossing, but as the performer moves in from the edge the angle decreases. At Q it is only 40° in section, about 35° after crossing and this is the minimum. Another lighting position B must be provided to cover the area Q to R within the same range of angles, and then C and D to light areas R to S and S to T*

integrity. When considering lighting positions, account must be taken of the lanterns themselves intruding into the audience's line of sight, as well as providing a safe means of suspension.

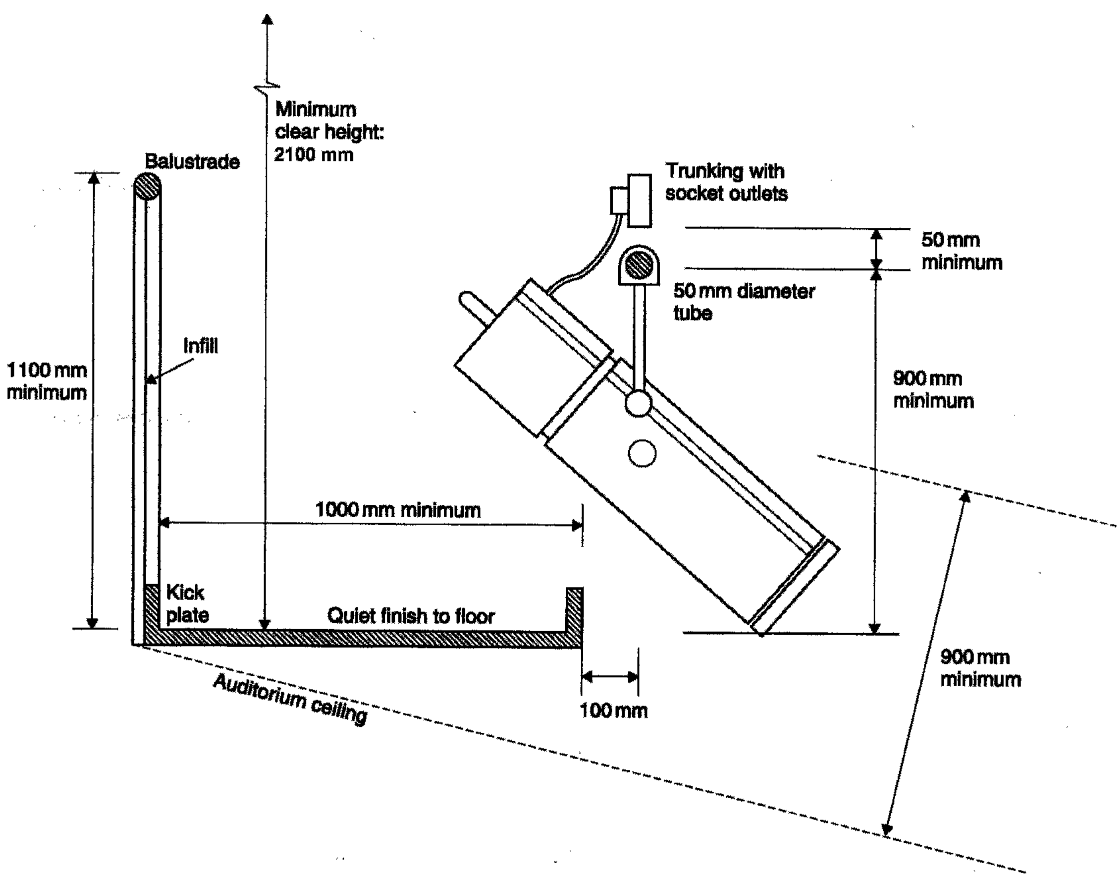
Follow spots

These are an integral part of much musical, ballet and operatic work. An operator directs a movable beam of light onto one or more performers during the course of the performance, **33.59**. Depending on the intended usage of the building, the provision of specific chambers at least 2 m square for this work should be located behind or over seating. The angle of the position to the stage should be around 45° or more, because the whole point of follow spotting is to isolate what is being lit in this way.

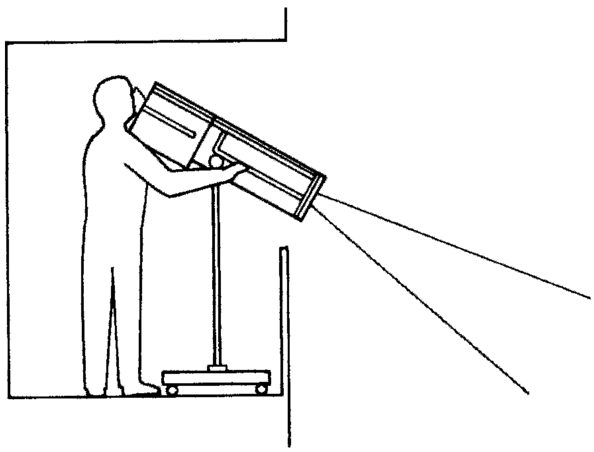
A pair of instruments located in a high central position allows the individual operators easy contact, especially if they are



33.58 *On thrust and theatre-in-the-round stages virtually all the lighting comes from overhead to avoid glare in the eyes of the audience:* **a** *Plan.* **b** *Section*



33.57 *Auditorium lighting bridge at ceiling level*



33.59 *Follow spot, minimum size for equipment and operator 1.5 m × 2 m*

separated by glass from the auditorium area. Provision should be considered for two further spotlight positions, either side of the auditorium, at a similarly high angle.

It must be noted that the position should be so that the lantern can reach most of the main acting area of the stage. Sometimes the lanterns are situated within the auditorium on specially constructed platforms at the expense of a number of seats. Provision has to be made for barricading the follow spot position from the audience.

Follow spots as instruments are becoming increasingly powerful and correspondingly larger. Some are more than 2 m in length. Therefore, the overall size of the proposed auditorium will be a factor in determining the size of the follow spot situation. Its position should allow for the instrument, the instrument to swing, and the operator to stand either behind or beside the instrument while this activity is going on. A place for the operator to sit and a local means of isolating the instrument should also be catered for.

4.12 Spaces associated with the audience area

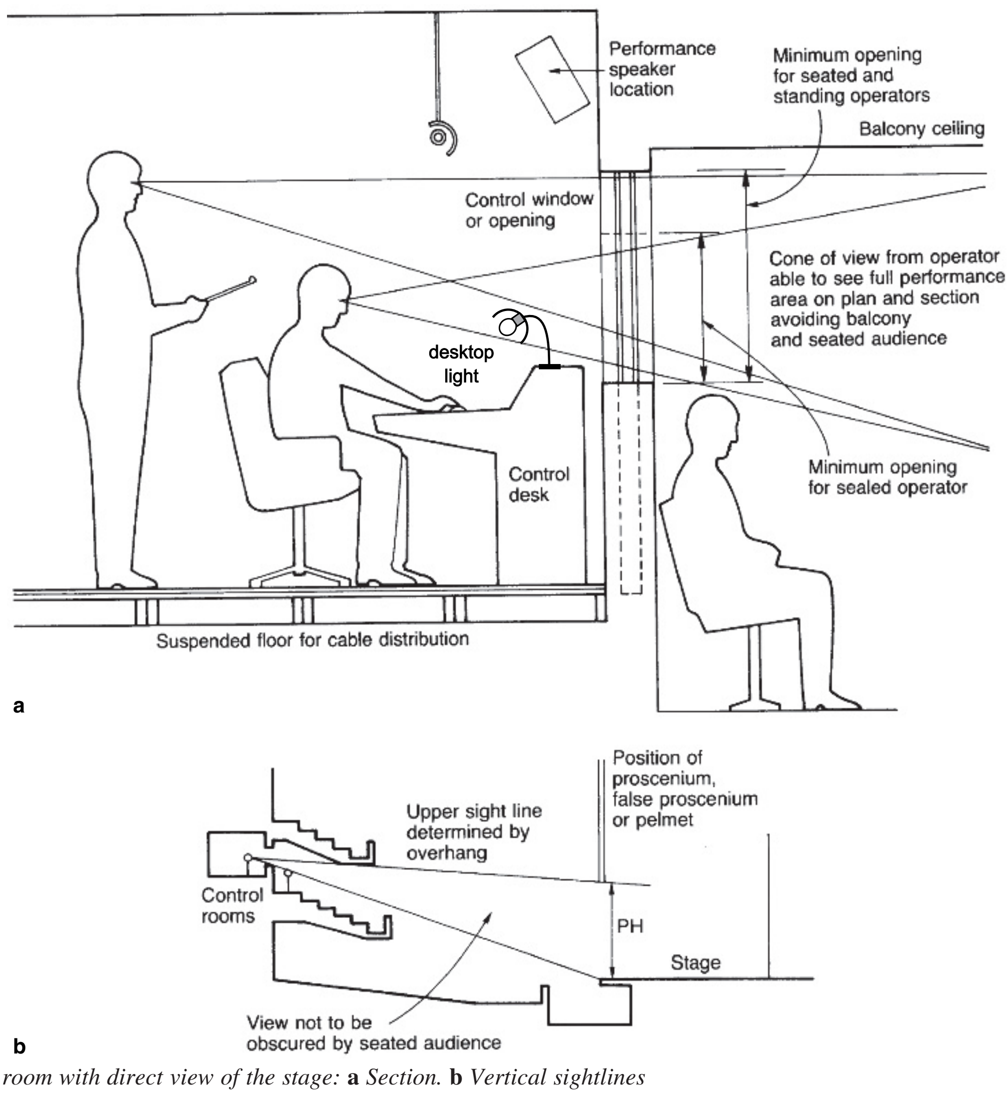
Lighting control room

A room centrally at the rear of the auditorium fully enclosed and sound-proofed with an observation window and space for the lighting control console and for the operator who needs to sit by the console and view the performance through the observation window which has an unrestricted view of the stage, **33.60**. There should also be space for an assistant, a worktop for plans and scripts. A minimum size would be 3 m wide 4.5 m deep and 4.4 m high.

Dimmer rooms

Space is required for the dimmer racks which are the direct means of control for all of the stage lighting instruments. The racks also contain the individual fusing for each stage lighting circuit. Mains cabling runs from the dimmer room to all outlets of the stage lighting installation, and also to the house lights, but the connection between the dimmer racks and the lighting control itself is not a mains voltage line.

The dimmer room should be placed so that quick access may be achieved either from the lighting control position or from the stage area. The dimmer room will also normally contain the mains isolation for the stage lighting system. In large installations



33.60 *Control room with direct view of the stage:* **a** *Section.* **b** *Vertical sightlines* which have a three-phase supply, each single-phase installation should be physically separated.

Sound control room
An open enclosure in a representative position within the auditorium. The operator requires an interrupted view of the performance area as well as being able to hear the performance. The room contains a control desk, equipment racks, monitor loudspeakers and worktop for scripts. The minimum size is 3 m wide, 4.4 m deep and 4.4 m high.

Auditorium sound-mixing position
For the mixing of amplified sound from the stage by an operator who requires to hear the same sound as the audience. The area requires to be flat, set within the seating area: minimum area of 2 m × 2 m, with mixer pad sound control desk and protective barrier.

TV, radio and recording control room
This is a separate soundproof control room, with observation window and clear view of the stage. It will accommodate announcers, and staff for balancing and directing transmissions and recording. A minimum area of 2 m × 2 m, but should be larger.

Observation room
Those associated with production may need to check activities on the stage from a room at the rear of the auditorium, with a clear view of the stage through an observation window, minimum area, 2 m × 2 m.

4.13 Stage-related spaces

Quick change
Separate rooms immediately off the stage, each with two make-up positions and hanging rails.

Properties room
This is a store room, opening directly off a side stage for properties for use during a performance. It requires a sink with hot and cold running water.

Scene dock
At the same level as the stage for storage of scenery.

Loading bay
For the delivery of scenery and properties into the scene dock. Allow for more than one pantechnicon to reverse.

Scenery
A repair and maintenance area at the side of the stage to maintain scenery and properties in use on the stage.

Piano store
For a grand piano when not in use. A separate room kept at a temperature similar to stage conditions; minimum area 4.5 m × 3.5 m.

Lighting equipment
Requires direct access off the side stage for chandeliers, hand properties, etc.

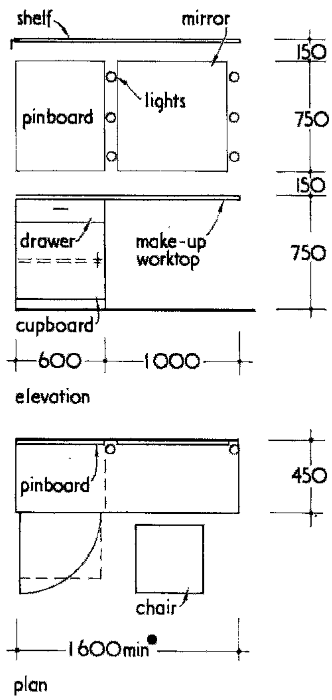
Sound equipment
Storage and maintenance space for such items as microphones, speakers, stands and so on.

Stage manager
Located stage left (facing the audience). Control equipment includes public address, safety curtain and/or drencher release, flytower vent release, and communication with lighting and sound technicians, fly gallery, conductor, etc. as well as cueing performers.

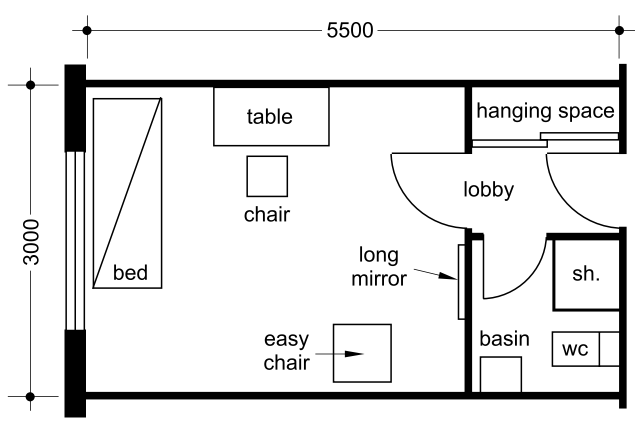
4.14 Spaces for actors, singers and dancers

Dressing rooms
Arrangements are illustrated in **33.61** to **33.69** covering single shared and communal occupancy rooms.

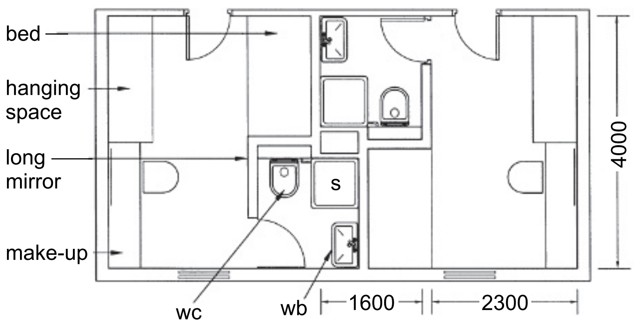
Green room with kitchen and servery: 3.4 m^2 per occupant.
Laundry for repair and maintenance of costumes, 20 m^2 minimum.
Costume store, including skips and rails
Costume delivery.
Specialist make-up room: 10 m^2 minimum per person.
Pre-performance practice room(s) (singers): 15 m^2 minimum.
Pre-performance dance studio (dancers): 1000 m^2 minimum.
Physiotherapy room (dancers): 15 m^2 minimum.
Wig store and hairdresser's room: 5–10 m^4.
Waiting area for visitors and dressers.
Offices: children's supervisor, company manager, touring manager, etc. 10 m^2 minimum per office.
Toilets.
Performers' assembly areas: at points of entry to stage.



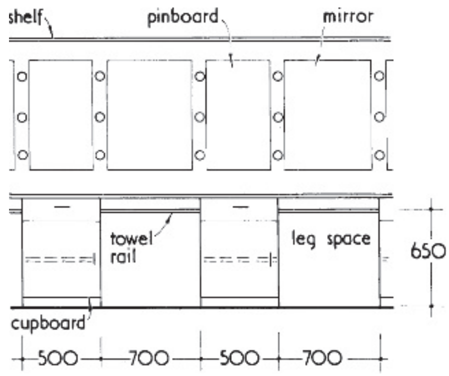
33.61 *Single dressing room:* **a** *Elevation.* **b** *Plan. Dimension marked • is minimum; a greater length is desirable to allow space for flowers, etc*



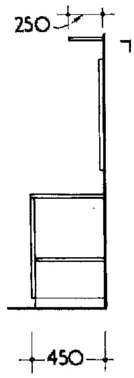
33.62 *Single dressing room with en-suite WC and shower*



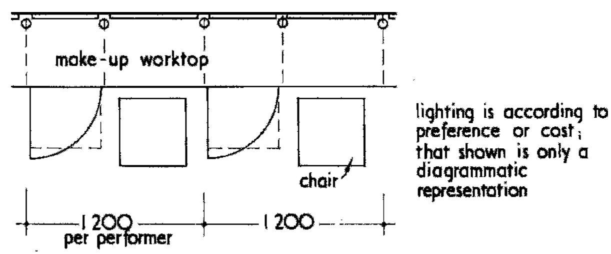
33.63 *A pair of single dressing rooms each 14.4 m²*



a *Elevation*

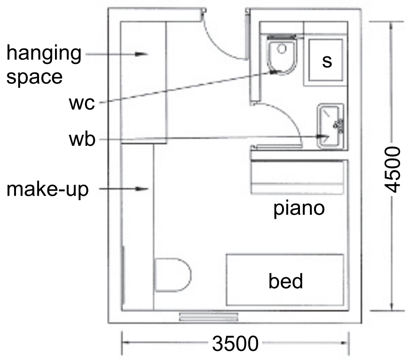


b *Section*

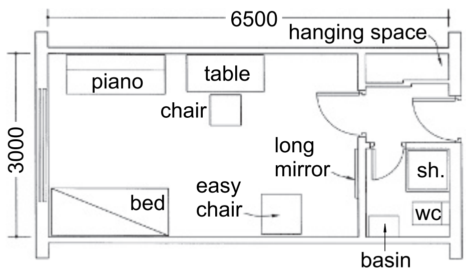


c *Plan*

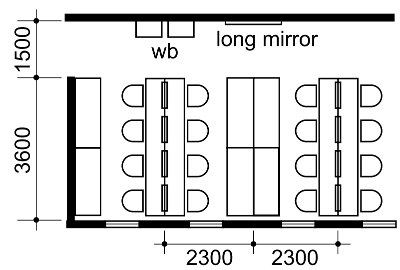
33.67 a–c *Shared dressing room*



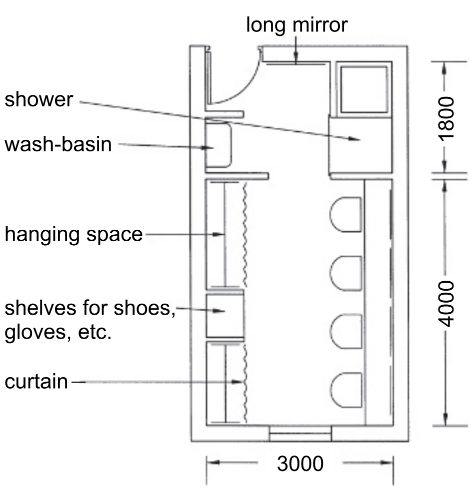
33.64 *Single dressing room with piano, area 15.7 m²*



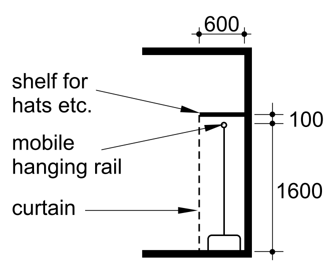
33.65 *Single dressing room with piano and en-suite WC and shower*



33.68 *Communal dressing room, area of each bay 8.3 m²*



33.66 *Dressing room for four, area 17.4 m²*



33.69 *Section through hanging space*

4.15 Spaces for musicians

Changing rooms: at least two rooms.
Musical instruments store: large instruments and their cases.
Pre-performance practice room(s).
Musicians' common room: 3.4 m^2 per occupant.
Conductor's room.
Offices: orchestra manager, tour manager, etc.
Musicians' assembly area: at point of entry to orchestra pit.

5 STUDIO THEATRES

5.01 Introduction

Studio theatres, by definition, do not contain moving stage machinery. They usually have some form of mobile or movable seating either to provide for different layouts or to clear the space for other uses at different times.

There are a number of well-developed, flexible seating systems offering great variety and compliance with normal seating regulations, with a foldaway and mobile facility. However, bleacher seating systems demand a dedicated space into which the seating can be concertina-ed when not in use. There is a significant point load factor under the supporting wheels. Bleacher seating arrangements do not offer flexible layout possibilities.

5.02 Access

Studio theatres should have different access points, allowing for seating and performer flexibility. A passage around allows performers to access any entrance. In all cases it is assumed that audience circulation and amenities are located adjacent to designated exits which should have immediate access to further doors on the outer side of the passage leading to the regulatory place of safety. Provision for drapes to be hung and moved around the walls offers the potential for varying the acoustic as well as the colour of the space. Either the walls or the drapes should be black.

Height is a key factor.

5.03 Lighting grid

One of the great selling points for the studio theatre is the speed and ease with which one can move from one production to another. Frequently this is serviced by having a grid made up of 50 mm OD tubing over the whole space from which lighting instruments can be hung in any location. It is doubly advantageous if this can be organised in such a way that there are walk gantries with lighting tubes either side, allowing the personnel to effect all the lighting changes without the use of access equipment and ladders, thereby allowing for completely different functions to be carried out at floor level simultaneously. If the gantry is not possible then it is essential that all of the lighting grid can be accessed from below by a mobile access system. From a desirable lighting point of view, the head of the instrument should not be less than 4 m above the nominal floor level.

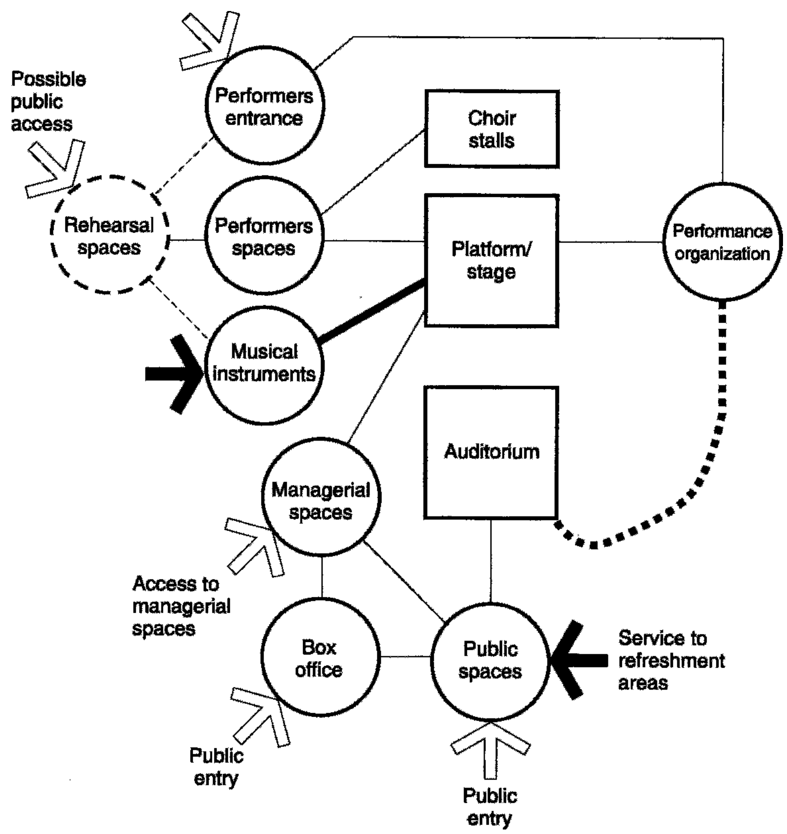
6 CONCERT HALL

6.01 Introduction

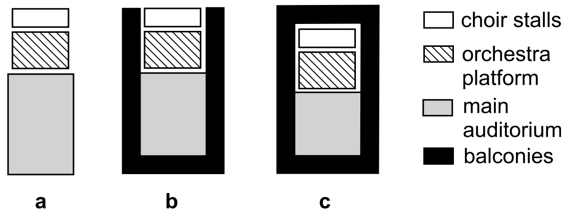
A relationship diagram for a concert hall is shown in **33.70**. For orchestral and choral classical music in concert hall or recital room there are three broad categories of relationships between audience and platform, **33.71**:

- Audience focused towards the orchestra and choir on the platform, with or without choir stalls, in a single direction, **33.71a**
- Audience on three sides semi-surrounding the platform, **33.71b**, and
- Audience surrounding the platform **33.71c**.

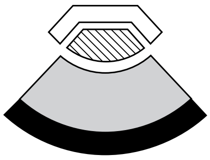
Types of single-direction relationship include the rectangular box as in the diagrams shown, variations on the rectangular box and the fan-shaped auditorium, **33.72**. The rectangular box is a simple well-established form. It allows full cross-reflection of audience, is central to the platform and receives a good sound balance. The fan-shaped auditorium is a particular variation on the rectangular box but suffers from the lack of side- and cross-reflection. Other shapes, **33.73**, include the coffin and elliptical.



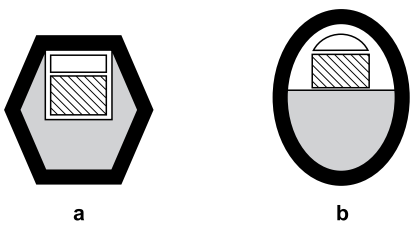
33.70 *Relationship diagram for buildings for orchestral and choral classical music with choir stalls, and for jazz and pop/rock music without choir stalls*



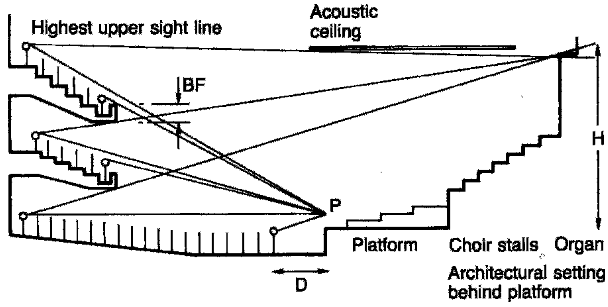
33.71 *Relationships between audience and platform in various rectangular formats:* **a** *Single direction.* **b** *Audience partially surrounding the platform.* **c** *Audience surrounding the platform. With or without rear and side balconies*



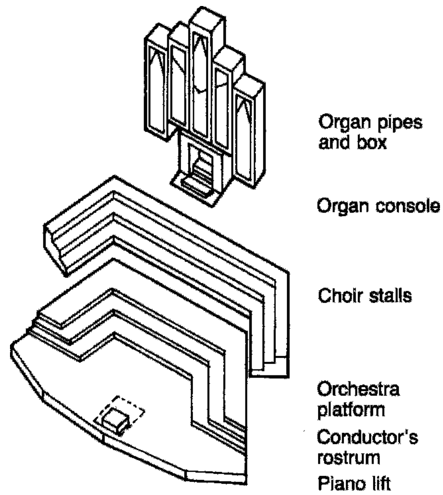
33.72 *90° fan shape, with or without rear and side balconies, in single direction relationship*



33.73 *Orchestral and choral music formats for audience surrounding the platform. With or without rear and side balconies:* **a** *Coffin.* **b** *Elliptical*



33.74 *Vertical sightlines through auditorium with concert platform. These need to include choir stalls, architectural setting behind the platform as well as the conductor, soloists and orchestra. However, acoustic requirements of direct and reflected sound may override sightline parameters*



33.75 *Components of the platform for classical music*

6.02 Viewing conditions
For vertical sightlines see **33.74**.

6.03 Platform design
The music components include orchestra platform, choir stalls and organ, **33.75**.

Platform design relates to orchestra size:

- Symphony orchestra and choir
- Symphony orchestra, 80–120 musicians
- Chamber orchestra, 40–50 musicians
- Small ensemble

For a chamber orchestra, the platform can be 6 m deep, 9 m wide and 900 mm high, for a full orchestra an area of 12 m × 12 m, with a platform height of 1000 mm. Various configurations are shown in **33.76** and a section in **33.77**.

6.04 Areas for individual musicians

- Violin players and small wind instruments 1000 × 600 mm; the horns and bassoons, 1000 × 800 mm
- 1200 mm tiers for string and wind players, including cellos and double base
- Tiers up to 2 m for percussion or concert grand piano: 2.75 m × 1.6 m
- Choir: 0.38 m^2 minimum per singer in choir stalls with seats. The longitudinal section can be flat and stepped transversely, rising from the conductor's rostrum.

6.05 Associated spaces

- Lighting and control room
- Dimmers
- Television and radio transmission and recording control room
- Follow spot
- Observation room

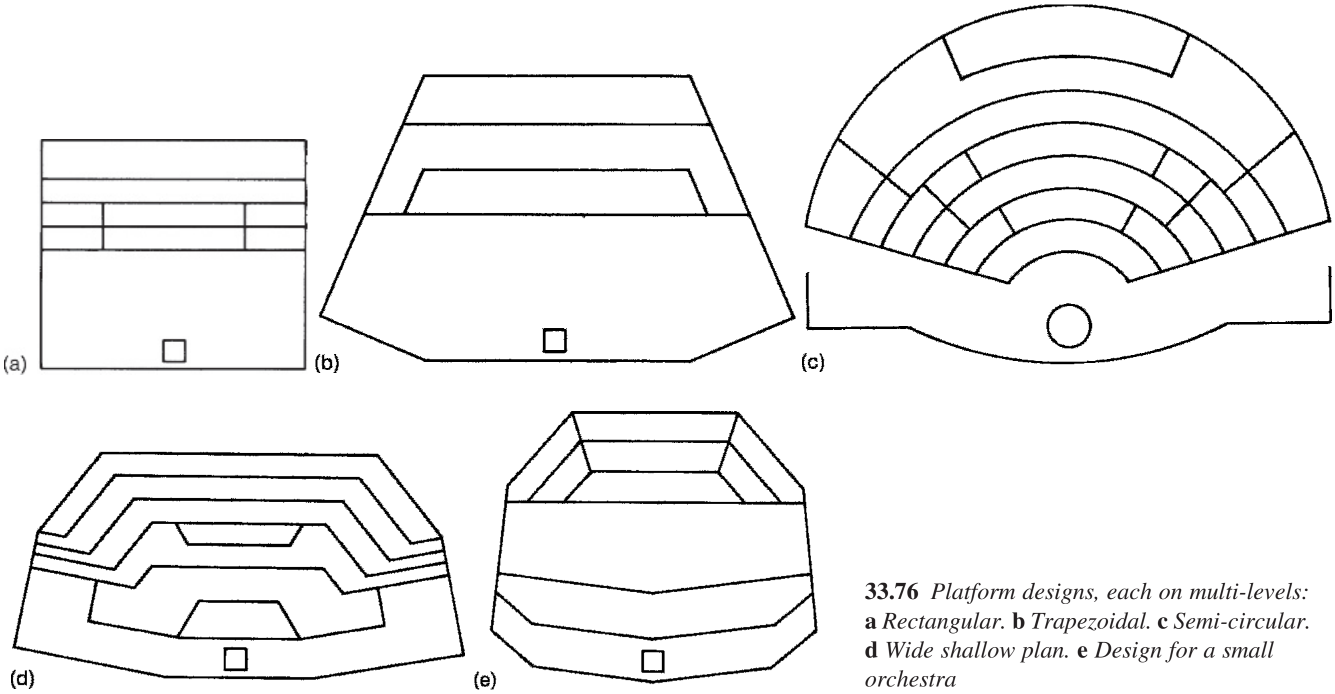
See also para **6.08** below.

6.06 Platform-related spaces

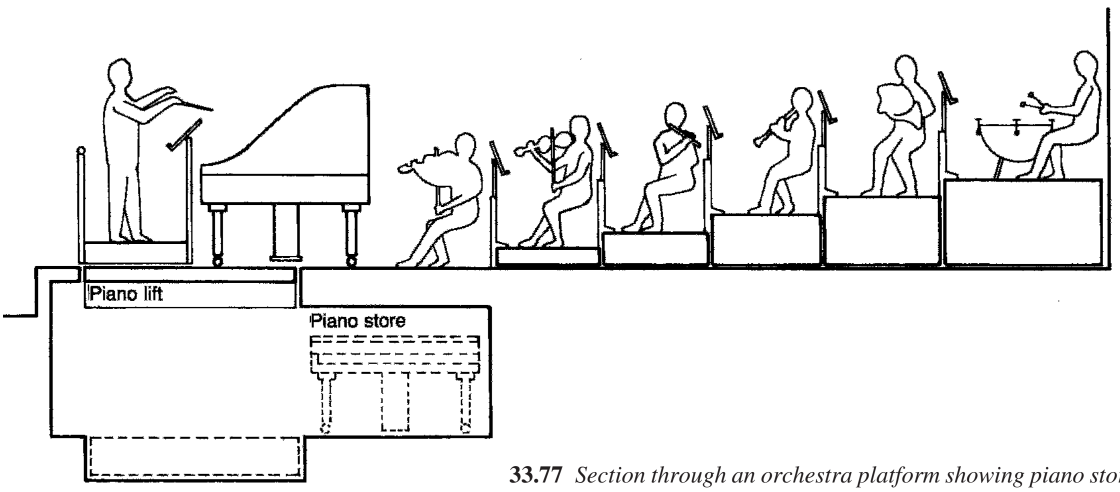
- Piano store
- Storage of musical instruments
- Delivery of musical instruments
- Access for deliveries
- Parking provision for touring vans
- Offices
- Technicians changing
- Electrical workshop
- Electrical store

6.07 Performers' spaces

- Changing rooms: not more than 20 people per room, 3.5 m^2 each
- Single rooms, **33.62**, 19 m^2
- Single room with piano, **33.65**, 23.5 m^2
- Single room with space for auditions 40 m^2
- Shared rooms 2 m^2 per occupant.



33.76 *Platform designs, each on multi-levels:* **a** *Rectangular.* **b** *Trapezoidal.* **c** *Semi-circular.* **d** *Wide shallow plan.* **e** *Design for a small orchestra*



33.77 *Section through an orchestra platform showing piano store and lift*

6.08 Associated spaces

- Conductor's green room
- Pre-performance practice room(s)
- Orchestra assembly area
- Choir assembly area
- Musicians' common room
- Orchestra manager's office
- Other offices (e.g. tour manager)
- Toilets

7 CONFERENCE HALLS

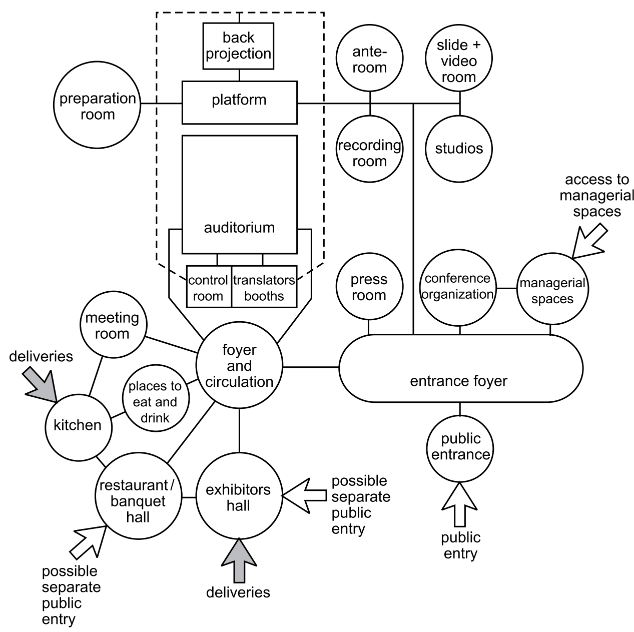
7.01 Relationships

33.78 shows the relationships between the parts of a conference suite.

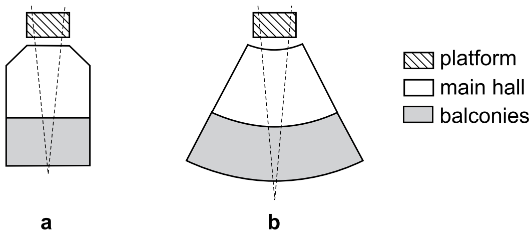
7.02 Formats

Formats depend on use:

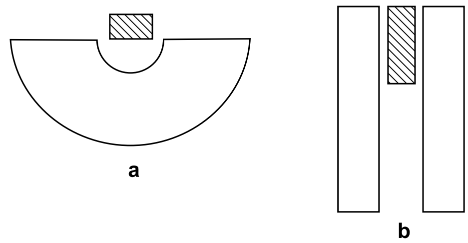
- Traditional lecture theatre formats with the audience focused towards a platform on which is provision for a speaker or speakers, possibly served by a range of audio-visual aids, **33.79**. The speaker is the controlling point with audience in a receptive role. Slide, film and video projection limit the extent of encirclement of the platform;



33.78 *Relationship diagram for conference hall*



33.79 *Conference hall formats for lectures requiring projection facilities:* **a** *Rectangular with or without rear balcony.* **b** *60° fan with or without rear balcony*



33.80 *Conference hall formats for debating:* **a** *Fan with 180° arc (US Senate).* **b** *Audience in two facing banks (House of Commons)*

- Participation by each member of the audience which suggest the debating formats of semi-circle, U-shape and circle, controlled by a chairman, with little or no audio-visual aids, **33.80**. The need for equal distribution and viewing of all delegates' facial expressions implies a single row only. However, it is possible to have up to six rows where delegates can still be aware of the spoken contribution of each.

The plan shape of the conference hall can be:

- Rectangular
- Fan-shaped, with angles of 135°, 90° or 60°. The last is best for screening
- Hexagonal
- Circular
- Oval, or
- Coffin.

7.03 Functional requirements

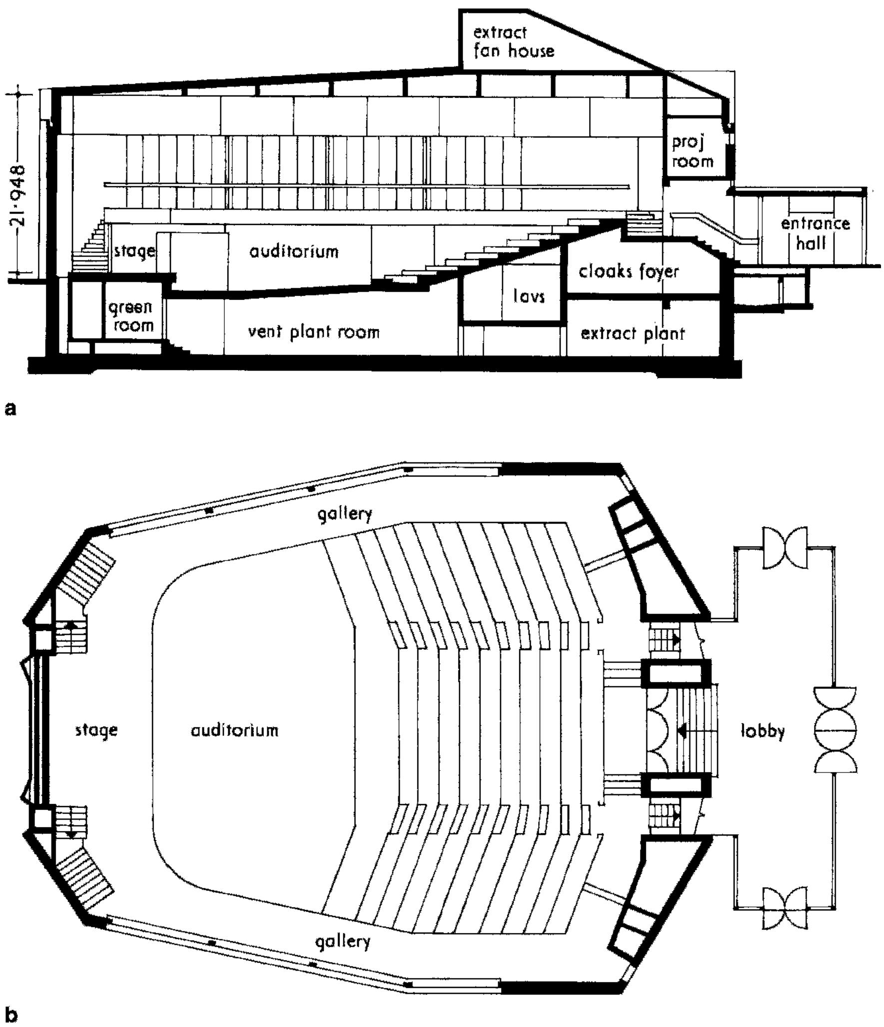
With the lecture format the functional requirements include:

- The audience needs to see and hear the speaker, chairman and panel of speakers in the various positions on the platform
- They need a clear view of screens, chalkboard and other visual displays: each has its own physical requirement
- Acoustic clarity of sound listening to speaker and to reproduced sound, and
- Adequate presentation and viewing of any demonstrations.

With the debating format:

- Awareness of the whole audience by every member
- The audience able to hear all speakers and chairman, and
- A clear view of the chairman.

An example of a facility used only for lecturing is shown in **33.81**.



33.81 *Lady Mitchell Hall, Cambridge. A large lecture theatre for 450 students. Architects: Casson, Conder and Partners:* **a** *Longitudinal section.* **b** *Plan of auditorium*

7.04 Audience facilities

Seating design for conference use is covered earlier in this chapter in para **2.05**. In fully equipped conference halls each person in the audience may be provided with:

- Voting buttons: yes, no and abstain
- Simultaneous translation headphones
- Headphones for the hard of hearing, and
- Small individual light.

The following is normally provided to be shared by two adjacent participants:

- Microphone controlled by the chairman from the platform, and
- Button for 'request-to-speak'.

7.05 Platform

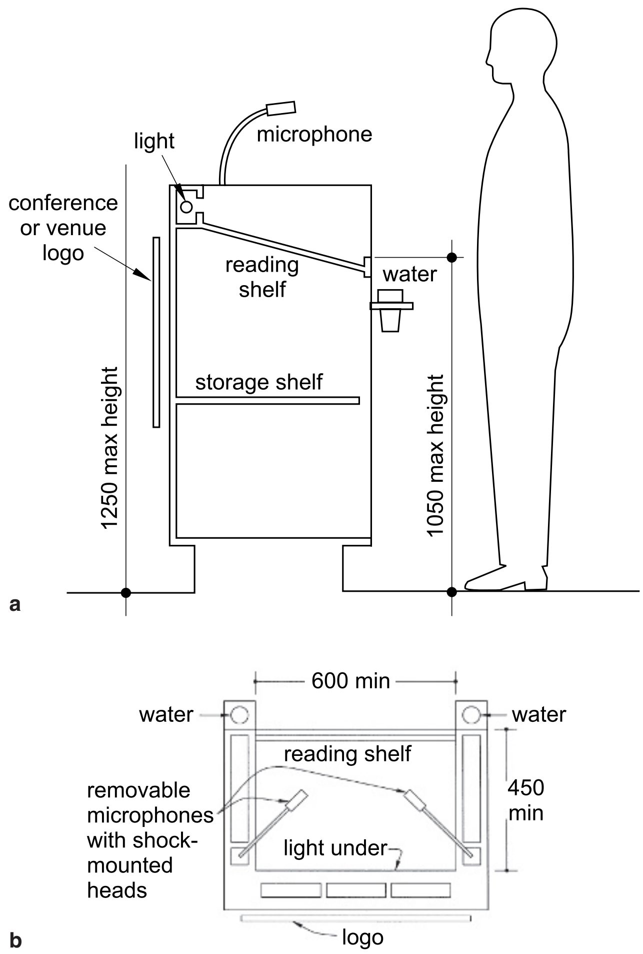
Height depends on hall capacity and sightlines:

- 300 mm up to 150 seating capacity
- 600 mm 150–300
- 750 mm over 300.

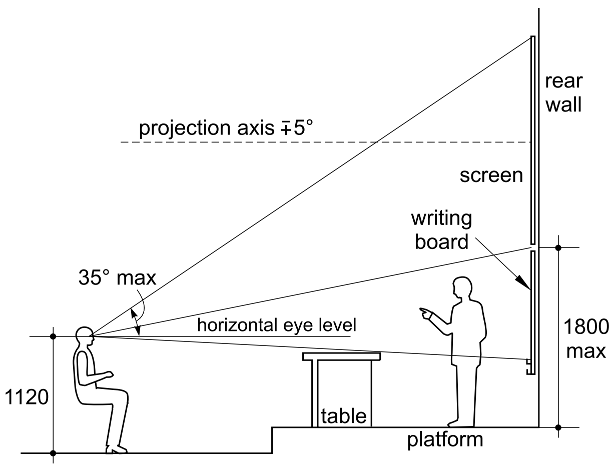
Steps are required from the auditorium to provide ease of access for speakers onto the platform at ends of gangways and front rows. Ramps may also be needed for wheelchair users.

Size and shape depends on extent of audio-visual aids, lectern, demonstration table, panel table and other equipment as well as sightlines and size and shape of auditorium.

The platform may need to accommodate only a single speaker at one time, with no (or limited) audio-visual aids as the least provision, **33.82**. In other cases it will require to allow for scientific demonstrations, a panel of speakers with or without a lectern, or major presentations as with commercial, political and institutional organisations. For major political conferences there can be as many as fifty people to accommodate on the platform.



33.83 *Lectern:* **a** *Section.* **b** *Plan*



33.82 *Section through lecture theatre showing platform and front wall arrangements*

The setting about the platform can be an architectural setting common to all types of presentations or a shell in which complete new settings can be constructed for each conference.

7.06 Lectern

This is the normal position for the speaker. The lectern, **33.83**, should have:

- A top sloping at 15° large enough for two A4 sheets
- An adjustable screened light to illuminate script
- A mounted microphone with switch
- A jack point for lapel microphone
- A microphone connection to simultaneous interpretation and/or recording systems
- A level surface for pencils and glass of water and jug
- Controls for dimming house lights
- Controls for remote operation of projectors and screens
- A manual or motorised raise and lower device for lectern stand
- A hand-operated light pointer
- A teleprompter screen (autocue)
- A clock
- Remote cueing
- Possibly red, yellow and green lights visible to both speaker and audience to indicate time available to speaker
- A shelf below the top for brief-case, demonstration items, etc.
- For presentations using laptop images to be operated by a speaker, horizontal table 900 mm high, adjacent to the lectern, would be necessary.

7.07 Other platform facilities

The chairman may introduce speakers from the lectern or a separate position elsewhere on the platform, with or without a lectern. It is usual for the chairman to remain in a prominent position on the platform during speaking, questions and discussion, unless slides or films are shown on a screen behind his seat. Anyone on the platform in that case will move to a reserve seat in the body of the hall.

Control panel

It is common to have a separate panel operable by the chairman. Alternatively, it could be duplicated at the lectern. This panel might incorporate:

- A buzzer to the projection room
- A telephone link to the projection room

- Remote operation to black out windows (if any)
- House lights dimmer
- Separate lighting over platform, and
- A teaching board light,

For the chairman only:

- Control for red, yellow and green lights on lectern
- Clock and/or timer
- Panel showing 'request-to-speak' indicators
- On/off control for individual audience microphones
- Voting numbers display (see para **7.04**), and
- Control of large audience voting number panel.

Demonstration bench
A 'laboratory' fully serviced bench on the platform for the scientific demonstrations, with the supply of electricity, gas, water and drainage. The bench should be able to be wheeled off the platform if to be used for non-demonstration presentations, with plug-in services: the bench can be stored in the adjacent side preparation room.

Panel table
For discussion and presentations by a panel of speakers and a chairman, a long table, parallel to the front edge of the platform, is a recognised format, with a chair and microphone for each panellist, and possibly simultaneous translation earphones. The table should be at least 750 mm deep, allowing 1 m length for each person. The name and details of each panellist may be mounted on the front edge of the table or on a stand in front of each. The lectern may or may not be used.

Rear and side walls of platform
Either a permanent enclosure with all or some of the following (see further details see below, para **7.09**ff):

- Chalkboards
- Projection screens
- Space for conference name, logo and setting
- Clock
- Fixed lectern, overhead projector, table
- Fixed or mobile demonstration table

Curtains, masking, sliding panels may be incorporated to cut off sections of side and rear walls when not in use. Alternatively, there may be a shell with rear and side walls and equipment constructed for a particular conference: similar to theatre open stage with suspension over platform for setting and lighting.

An easily visible place is needed for a person to stand to translate the speaker's words into sign language.

7.08 Translators' booths

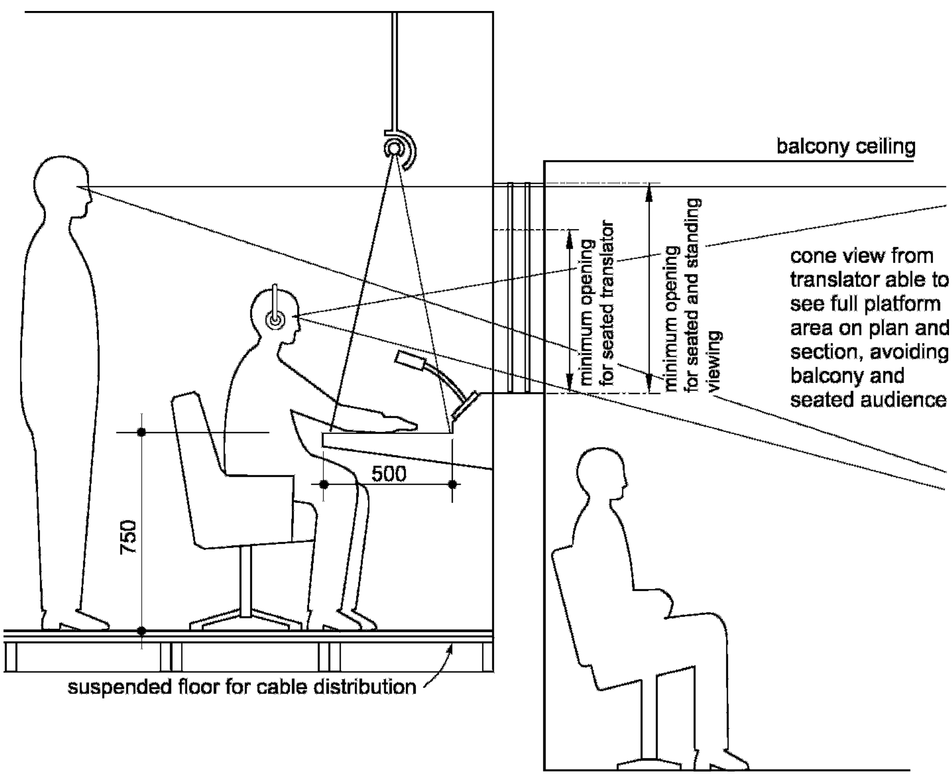
Conferences with international audiences will probably require simultaneous interpretation by translators in booths of those speaking in various languages.

Booths need to be located at the rear or perhaps the side of the auditorium with an unobstructed view by the translator of the speaker, chairman, projection screens and chalkboards as well as any visual display, **33.84**. The booths are soundproofed, with the translator listening to the speech on headphones.

Booths should be located side by side with acoustic isolation and small connecting windows. They should open off a corridor giving discreet but secure access from the public areas. Booth interior should have absorbentmaterial to walls, floor and ceiling, in dark matt colours.

Each booth needs to be able to accommodate two or three seated persons, minimum size 6.5 m wide and 6.4 m deep. The soundproof observation window can be full width of the booth, 800 mm high, and may be inclined to avoid acoustic reflections on either side. The translators need a clear working surface 500 mm wide in front of the window for scripts, notes, microphone, channel-selection buttons, indicator lights, etc.

Translators' ancillary rooms
A common room for translators should be located near the booths. This should have easy chairs, tables, telephones, cloakroom and toilets.



33.84 *Section through translators' booth at rear of auditorium*

Simultaneous translation systems in the auditorium
Available methods are:

- Induction loop: magnetic field transmission generated by a conductor looped around auditorium. Conference delegates have portable receivers.
- Infra-red: modulated light signals radiated from a number of sources. Delegates have portable receivers.
- Hard-wired: cable within underfloor trunking connected to panels in arm rest or back of each seat for heavily used conference facilities.

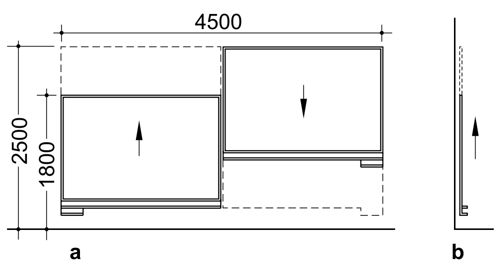
7.09 Audiovisual facilities

Writing boards
Conventional chalkboards are now uncommon as they have now been superseded by overhead projectors for which material can be pre-prepared. Where they are used they would be a black or white chalkboard, fixed to a rear wall or moveable. The audience viewing angle is critical to avoid glare and reflections. The visibility tends to be restricted to twelve rows. Chalk and pen channel to be incorporated, with a ledge for an eraser.

Boards can slide vertically or horizontally to increase writing surface within a restricted space, **33.85**, or they can revolve vertically or horizontally, if made of a rubber or plastic material.

The extent of chalkboard may be nominal, 1 m × 3.5 m for limited use by a speaker, or, in the case of the presentation of complex and mathematical formulae, a board extending the full width of the platform.

Small conference rooms are often equipped with whiteboards which are written or drawn on using special felt-tipped pens. These are permanently mounted on a wall, and have a ledge beneath for the pens and the eraser.

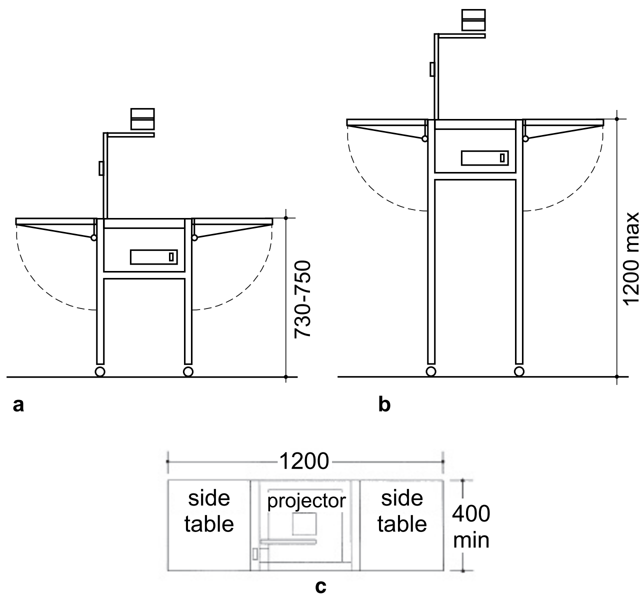


33.85 *Writing boards: vertically sliding:* **a** *Elevation.* **b** *Section*

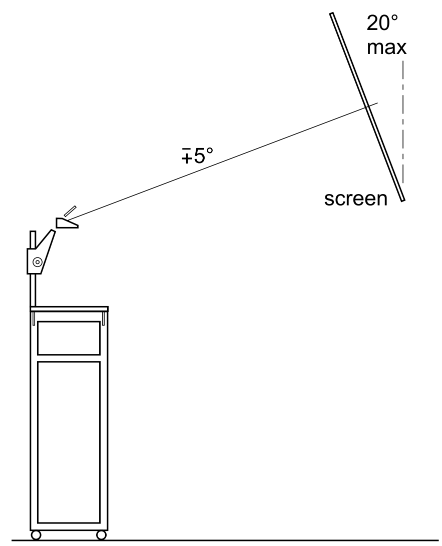
Flipcharts
Commonly used in small conferences and seminars, particularly in debating format. A1 size portrait orientation on a board 750 × 900 mm on a loose easel with ledge at 900 mm above platform. A storage space for this and for the pens etc. is useful. Sometimes they are fixed to a rear wall; good visibility is restricted to twelve rows.

Overhead projector
33.86 shows a projector on a stand. The image surface is 250 × 250 mm for writing on or for prepared images. A surface beside the projector is needed for the prepared acetate sheets and pens. The lecturer can be standing or seated. The projector may be located at a lower level in front of the platform to assist sightlines from the front auditorium rows to see the screen over the projector and speaker.

The screen needed to receive the image should be tipped forward to an angle of 20–25° to the vertical to avoid 'keystone' distortion, **33.87**; the distance from the projector to the screen equals the screen width. Such screens are available that can be swung or rolled away when the main projection screen is used.



33.86 *Overhead projector:* **a** *Elevation of a projector on a table for a seated speaker.* **b** *Elevation of a projector on a table for a standing speaker.* **c** *Plan of either*

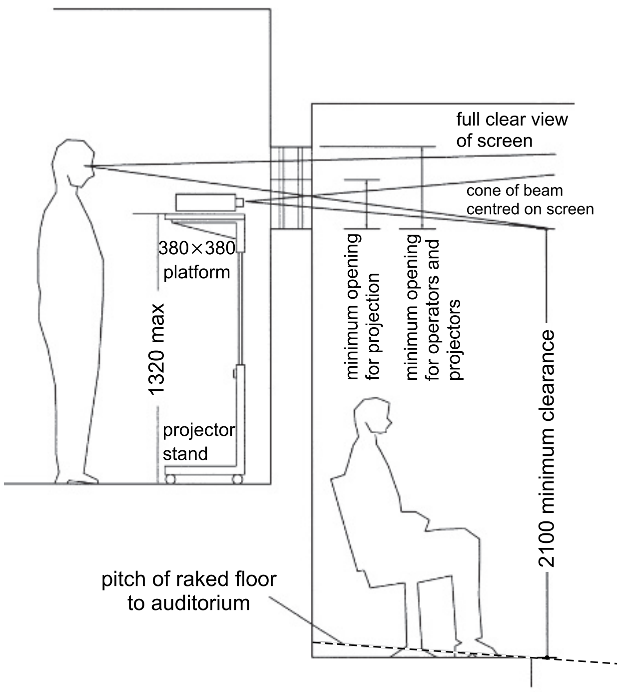


33.87 *Overhead projector screen: tilting helps to avoid the keystone effect*

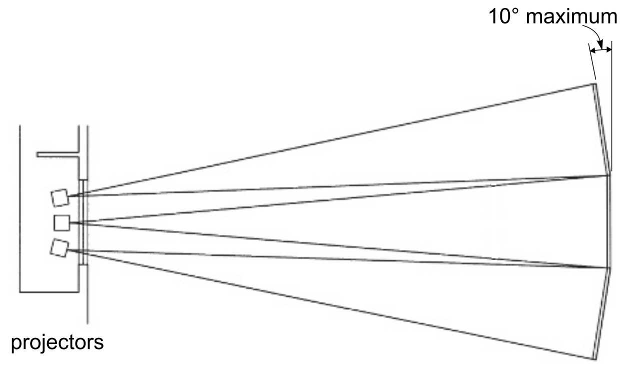
Projection room
A projection room, **33.88**, may or may not be needed. Its advantages are that:

- The operator and operations will not disturb the audience
- Noise is reduced or eliminated
- The equipment and the media are more secure from interference and theft
- It is easier to lift the projection beam over the heads of the audience.

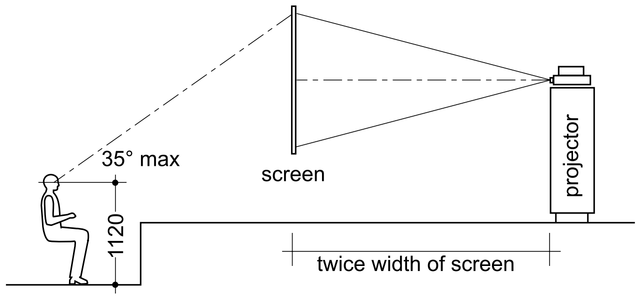
The equipment needs to be grouped near the axis of the screen(s). It is more convenient for it to be on loose mobile stands, and the beam should be above the heads of a standing audience. Each port should be provided with a separate black-out shutter. The room should have separate extract ventilation and should open off a ventilated lobby.



33.88 *Section through projection room at rear of auditorium (projecting slides)*



33.89 *Slide projection: multi-screen presentation*



33.90 *Back projection for slides and 16 mm film*

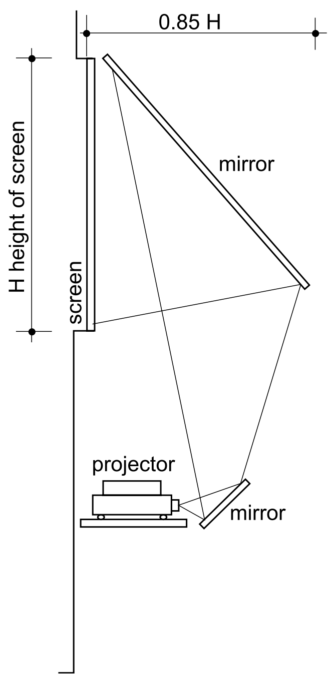
Lighting control room
This is a limited requirement for conferences, but lighting control could be incorporated into a projection room at the rear of the auditorium, minimum size 2 m × 3.5 m. In some cases a dimmer room may be needed (see para **4.10**).

Sound control room
In this case an open room preferably at rear of the auditorium adjacent to the lighting control room, minimum size 2 m × 3.5 m. Here the amplified sound from one or more speakers can be mixed and balanced. The sound control desk may alternatively be situated within the auditorium.

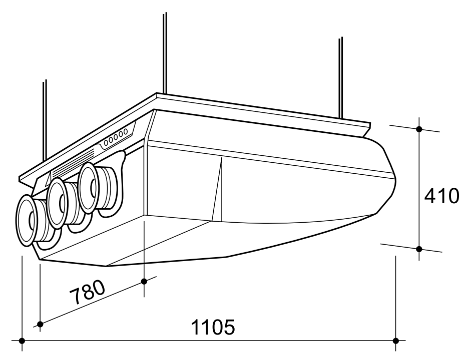
Screens
Increasingly, back-projection screens are being used. In this case the projection room will be behind the platform rather than behind the audience. Back projection for video, film and slide requires wide-angle lenses but allows more freedom for speaker. Where conventional screens are used, they will be mounted above the heads of seated people on the platform. If multiple slide projection is to be used, a wide-screen format is necessary. Sometimes the side screens are angled up to 60°; this tends to limit seating positions with good visibility. Where wide flat screens are used curtains should be provided to reduce the width of these for film and video projection.

Slide projection
One, two and maybe more projected images from 35 mm slides, **33.89–33.91**, able to be used individually or simultaneously; the usual type of projector is the carousel. High-intensity projectors allow some light in auditorium for note taking. Screen areas for projecting slides should be square, as slides may be in portrait or landscape format. For three-screen projection the side screens are sometimes angled as much as 30° from the centre screen.

Video, DVD, data and other projection
Projectors are now usually mounted at high level in the auditorium, **33.92**, on stands or behind the screen. Close-range projectors can



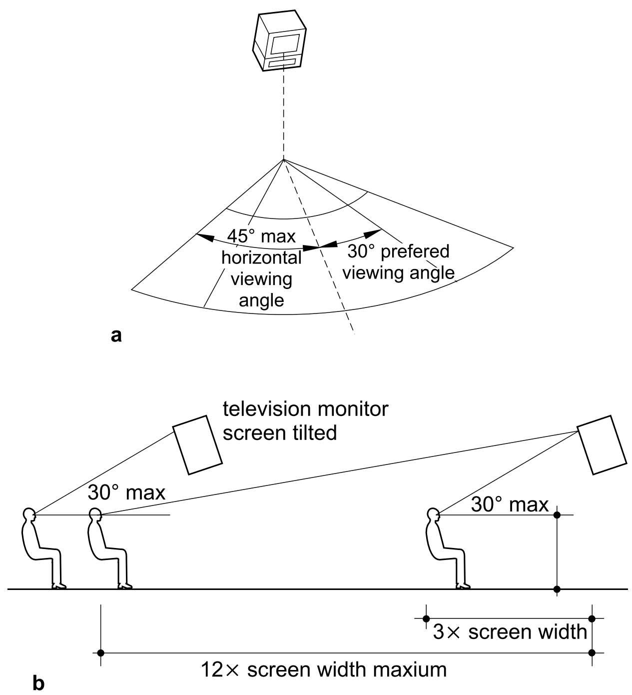
33.91 *Back projection of slides using mirrors*



33.92 *Video projector mounted at high level in auditorium* produce pictures up to 3 m high; they should be 3.5 to 3.6 times the picture width from the screen. DVDs, for example, may be loaded in a projection room, or from some position on the platform.

For a large screen a long-range projector is used producing a picture up to 7.5 m high. It should be housed in a projection room, with room for control and back-up equipment consisting of racks for VCR equipment, monitor screens, off-air times and ancillary control unit.

For small conference and seminar rooms, conventional TV sets can be used, **33.93**. Sometimes a number of these each serving a section of the audience are suspended at high level in a larger conference facility, but this is a somewhat primitive arrangement.



33.93 *Television viewing:* **a** *Horizontal angles.* **b** *Vertical angles*

Film projection
Where films are used they are rarely greater than 35 mm and are usually 16 mm: 8 mm is now uncommon as video has taken its place. Films can be projected from a position within the seating area, but care must be taken that the beam is not interrupted by standing or sitting members of the audience. It is preferable to use a projection room where the beam can be at a higher level, although here the video projector must be avoided. More details in para **8.02** of this chapter.

Television and film cameras
Conferences are frequently televised and recorded. Speakers and demonstrations are often projected oversize on screens both within the main conference hall and in overflow venues. Cameras are usually mobile, but require suitable floor surfaces.

A room may be required for recording and editing purposes, but this may not need direct vision of the conference, and could in fact be a remote studio.

Voting panel
This is a panel indicating electronically the numbers voting by pressing buttons at each seat, mounted above the platform and controlled by the chairman.

7.10 Platform: associated spaces

- Ante-room: reception and waiting areas for conference chairman and speakers, with lounge, changing facilities and toilets; sound and light lobby onto platform; access for guests from public areas
- Preparation room: preparation of scientific and other demonstrations in room immediately off the platform
- Slide and video room: viewing room for speakers, to sort and check slides, inspect videos and films, check overhead projector material
- Studios: television, film and still photography preparation
- Recording room: separate facility with tape-recording equipment linked to the auditorium and platform amplification system for the recording of the conference proceedings.

7.11 Conference organisation offices

- Offices with desks and chairs
- General office, with desks and chairs, fax machines, telephones, telex, photocopier, computers, typewriters, intercom, translations, secretarial work.

7.12 Press room

- General room: desks and chairs, telephones, fax machines, telex, computers
- Television and radio interview rooms

8 CINEMAS

8.01 Types of film and method of projection

Cinema projection is traditionally film based but is increasingly being supplemented or completely replaced by high definition digital projection technologies. Film projection in cinemas normally uses 35 mm film but can also use 70 mm (mainly for larger cinemas with wide screens) or 16 mm (generally for smaller or specialised cinemas). Large formats such as IMAX use special film projection systems to produce very wide and tall screen images. Digital projection systems are capable of replicating a similar range of screen formats to film projection at comparable or superior quality levels. Both film and digital projection systems can be adapted to produce 3D images. The various film and digital projection types are shown in Table IV.

8.02 Methods of projection

There are three methods of film projection:

- Direct projection from the rear of the auditorium onto the screen. The most common method by far
- Indirect projection, where the film projection requires one or more mirrors. This method is used where lack of space or structural difficulties make direct projection difficult to achieve. Mirror projection requires a powerful light source and the screen cannot be wider than 9 m
- Rear projection. Not possible with curved screen, but may be applicable for the smaller auditorium. For this method the picture needs to be reversed, for which mirrors are an economic solution.

8.03 Auditorium design

Functional requirements include:

- Every member of the audience requires an unobstructed view of the whole picture area on the screen, without visual and physical discomfort and picture distortion
- Picture sharpness and luminance need to be uniform and satisfactory, and sound reproduction needs to be distortion free
- Integration of seating for members of the audience with mobility disabilities.

Table IV Film type and application

Type	Projection	Application	Quality	Light source/screen size
35 mm	Usually permanent installation. Portable versions possible.	Multiplex, independent and specialist cinemas, arts centres, high quality lecture halls, TV	Excellent – a world standard for commercial cinema	Usually high pressure Xenon lamps. 1 Kw–7 Kw lamps. Older projectors may use carbon arc lamphouses. Long throw and large screen sizes require higher power lamps
70 mm	Usually permanent installation. Equipment will also project 35 mm	Mainly specialised cinemas and venues	Excellent – normally used for prestigious films	High pressure Xenon lamps
2 K and 4 K High definition digital cinema (D-Cinema)[1]	Usually permanent installation occupying similar space to 35 mm projectors. Smaller semi-portable projectors available for small/ mid-size auditoria	Multiplex, independent and specialist cinemas, arts centres, high quality lecture halls, TV	Excellent – rivals or exceeds 35 mm film quality	High pressure Xenon lamps. Certain models require high levels of ventilation. 1 Kw–12 Kw lamps
3D D-Cinema	As above	As above	Excellent	As above but with increased demands on lamp power and ventilation
1 K and 1.3 K High definition digital cinema (E-Cinema)	Portable or semi-portable projectors offering a lower quality image	Specialist cinemas, arts centres, lecture halls.	Very good – this standard is widely used by cinemas in Asia and South America. It is not considered acceptable for major Hollywood films.	Lamps usually rated below 1 Kw, consequently ventilation requirements are modest.
LCD/Data projectors	Portable projectors	Film clubs, lecture halls, conferences, business meetings	Varies from poor to satisfactory. Not acceptable for public cinema applications	Lamps usually rated below 1 Kw.

Note: [1] 2 K and 4 K refer to the number of horizontal pixels produced by the digital projector (2048 and 4096 respectively). 2 K projectors are considered to be the minimum quality standard for feature films by the major Hollywood studios.

8.04 Viewing conditions

Viewing criteria are shown in plan, **33.94**, and section, **33.95**. The size and shape of the screen must be related to the shape and rake of the auditorium floor. Seating rake is less critical than for concert halls and theatres as the screen can be elevated and sound comes from overhead speakers.

Seating arrangements

Few new auditoria are designed with galleries or balconies (unless the auditorium is required for other forms of performance). Steeply tiered stadia seating offers an opportunity for good sightlines onto a large screen relative to audience numbers.

In small auditoria, stadia seating may be arranged in a single tier in order to optimise seating capacity. In order to provide a choice of seating for members of the audience with mobility disabilities access should be provided for wheelchair users to the front and rear row.

In larger auditoria, access may be provided onto a cross aisle with steeply tiered stadia seating to the rear of the cross aisle and a gentle rake to the front rows. A choice of seating position for members of the audience with mobility disabilities can be on the cross aisle or in the front row.

Seating types

To meet expectations of comfort, seat centres are generally at least 550 mm. Seat tier widths are governed by expectations of comfort, choice of seat type and statutory requirements for minimum clear seatways.

The design of modern multiplexes has established an expectation in cinema-going audiences that seat tiers should be at least 1100 mm wide. This is wide enough to accommodate most comfortable models of cinema seats. With tip-up seats 1000 mm can be acceptable. Accommodating comfortable fixed cinema seats or small sofa style seats may require increases in the width of the tiers to 1200 mm.

To accommodate 'premium' armchair or sofa style seats offering extra comfort, seat tiers of up to 1500 mm wide may be required. A requirement to accommodate cup holders, bottle holders or small tables will influence the choice of seat, seat centres and seat tier widths.

In multi-use auditoria with a flat floor regularly used for cinema screenings, retractable seating systems with straight and curved rows, and comfortable cinema style seats are available.

Aisle arrangements

The maximum number of seats permitted in a row is not only governed by viewing criteria but statutory requirements. The aisle arrangement and clear seatway are critical factors. The maximum number of seats permitted in a row with a single aisle is 12, irrespective of the seatway width.

A single centre aisle is not favoured as it occupies seat positions with the best viewing conditions, as well as splitting the audience. An off set single aisle provides a more cohesive seating arrangement for the audience as a whole and provides an opportunity to accommodate seats for couples in the shorter row. The provision of two side aisles enables the numbers in a single row to be increased.

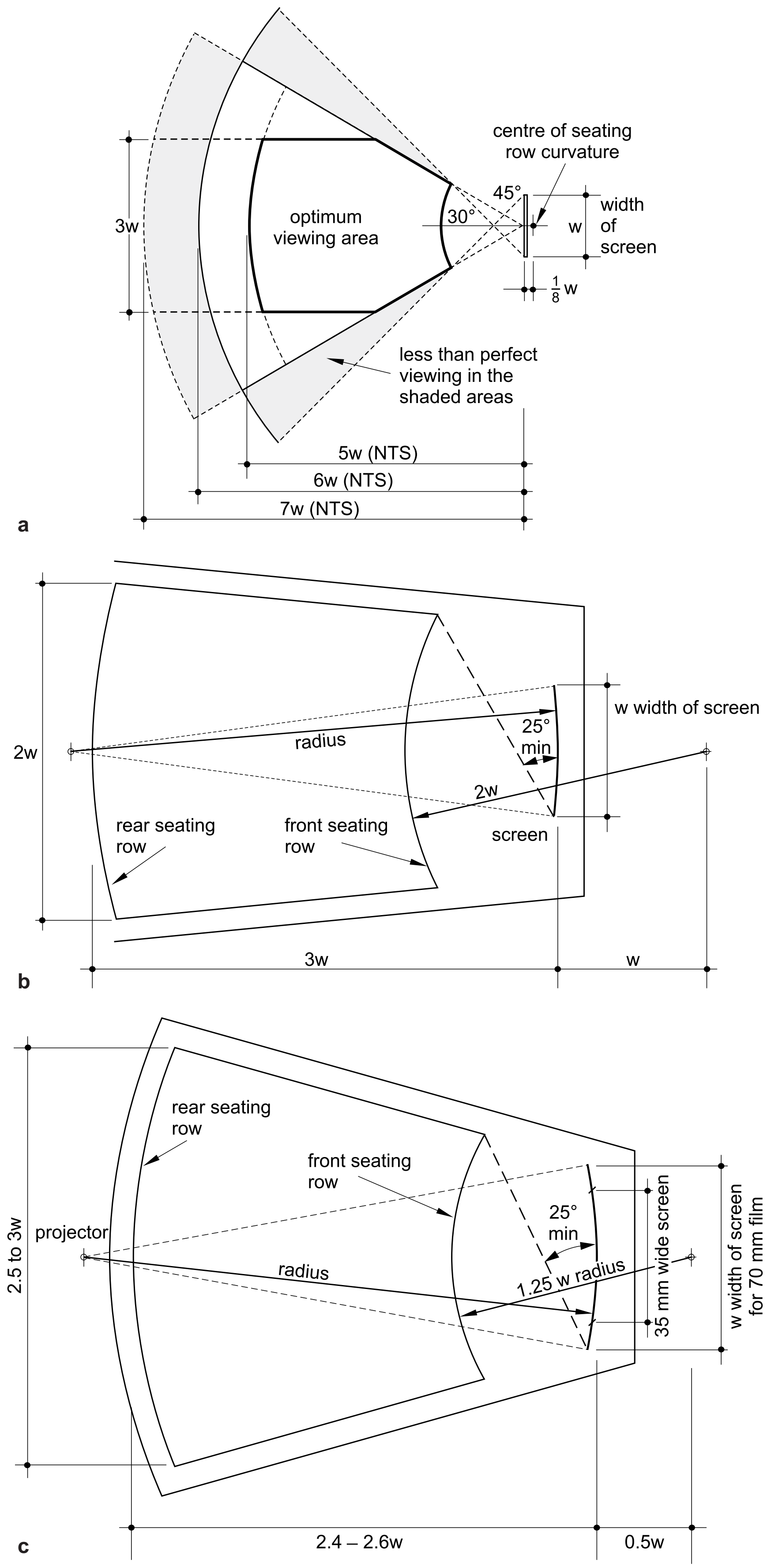
It is good practice to avoid entrances at the screen end of the cinema, so as to avoid disturbance by latecomers.

8.05 Acoustics for films

The sound track is an integral part of the audience experience and the quality of sound reproduction has vastly improved. Cinemas are now equipped with stereophonic sound systems which require acoustically dead auditoria; the ideal is a zero reverberation time. Hence all finishes – floor, walls, ceiling and seats – need to be sound absorbent. Side walls should not be parallel, and a fan shape is preferred. The auditorium should be structurally and enclosure-wise insulated from external noise. A suitable ambient noise standard for cinemas is NR30 to NR35. The volume per occupant should be at least 1.25 m^3 for large cinemas and 5 m^3 per person for small auditoria.

8.06 Access

The design of the auditoria should optimise the experience of going to the cinema for all members of the audience.



33.94 *Projection criteria for various formats:* **a** *16 mm film.* **b** *35 mm film.* **c** *70 mm film*

Mobility disabilities

A choice of position for wheelchair users should be provided, integrated within the main body of seating. Suitable positions on a level surface may include the front row, cross aisle or back row. It should be possible for a wheelchair user to sit next to a companion, whether another wheelchair user or not.

Visual impairment
Space should be provided for a guide dog at the end of a row. Facilities for screening films with audio description run off a CD for 35 mm Film with professionally produced audio description synchronised with the film. Audience members pick up head sets from the box office which run off one of the channels on the infra red system. Digital Cinema servers have additional channels which provide audio descriptions.

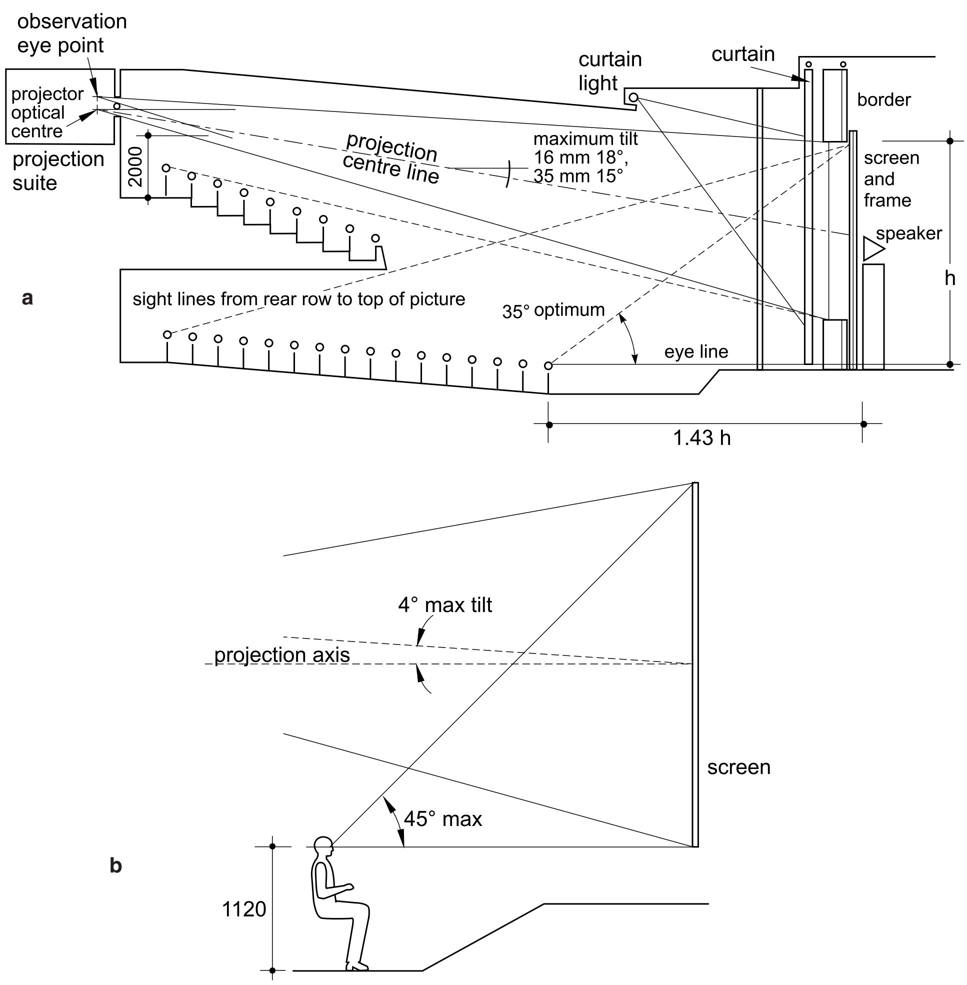
Low level lighting on stepped or raking aisles, with the light source located out of the line of vision of the screen is an aid to all members of the audience.

Aural impairment
Facilities may include inductive loops and/or infra-red systems. Ideally both systems should be installed to cater for different types of hearing impaired user. A system of superimposing a subtitle (soft title) by use of the video projecting onto a projected 35 mm image is also available for the profoundly deaf. This system is incorporated into a single digital cinema projector.

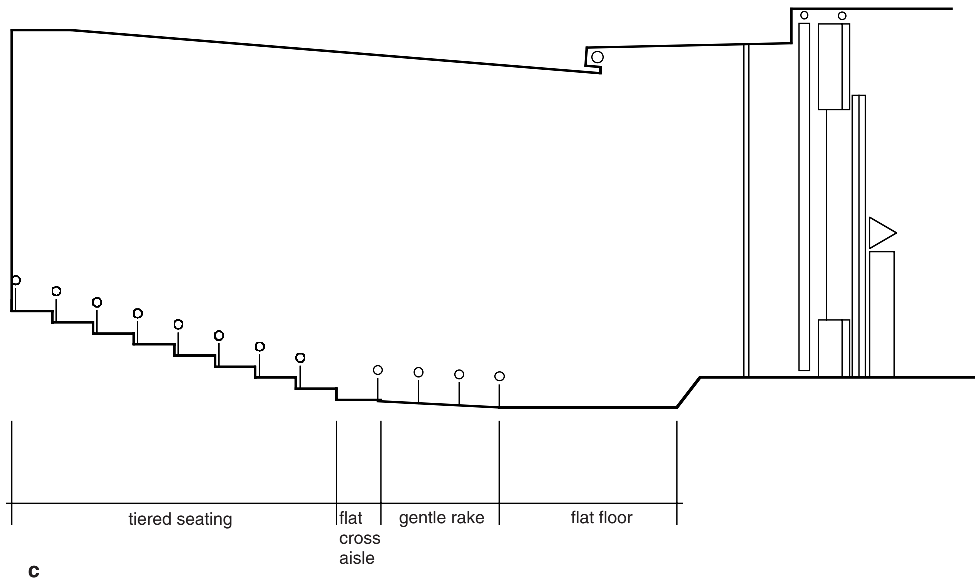
8.07 Lighting
The different types of lighting which need to be provided within a cinema auditorium are:

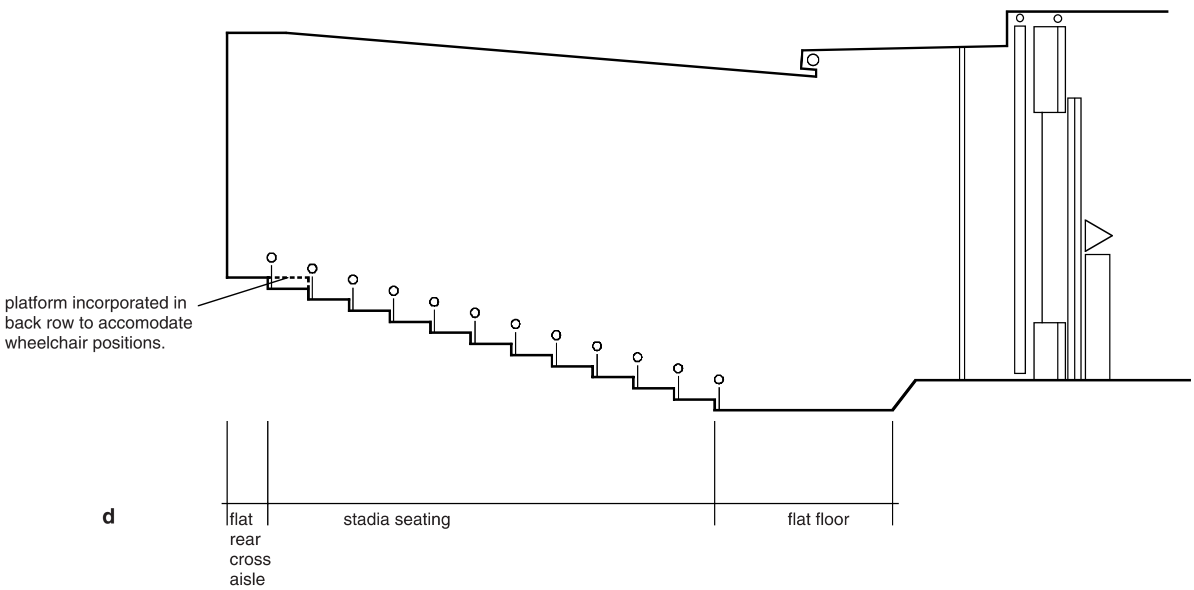
- *House lights.* These are the decorative lights which set the ambience of the auditorium when the audience enters and are gradually dimmed before the screening.
- *Curtain lights.* These highlight the screen curtains/screen surface prior to the screening and often have coloured gels.
- *Primary lighting.* These are mains powered and provide a low level of lighting during screenings, equivalent to the level of lighting provided by the secondary emergency lighting in the event of mains failure. It is essential that they are no brighter than required to meet statutory requirements in order to avoid distractions during screenings.
- *Secondary (emergency) lighting.* These are powered by a central battery or local battery packs and provide a low level of illumination in the event of mains failure.
- *Illuminated emergency exit signs.* These are dual fed, that is mains powered and powered by a central battery or local battery packs and remain illuminated during screenings and in the event of mains failure and an emergency. It is bad practice to locate exits and hence illuminated emergency exit signs within the same plane or in close proximity to the screen. Illuminated exit signs should be selected to minimise disturbance through light spillage during screenings.
- *Cleaners lights.* House lights that are energy efficient may double up as cleaners lights. Alternatively separate cleaners lights are installed. These need to be controllable from the projection room and the ushers position in the event of an emergency (other than mains failure) for example a medical emergency. Regard needs to be given to lamp life and ease of changing the bulbs when considering the location and specification of all light fittings within a cinema auditorium.
- *Speakers lights.* In auditoria used for awards ceremonies and panel discussions before or after screenings or for conference use, speakers lights should be provided.

8.08 Interiors
It is good practice to avoid light colours and reflective surfaces within a cinema auditorium, to avoid distraction during screening.



33.95 *Vertical sightlines:* **a** *16 mm and 35 mm.* **b** *70 mm film. Seating options:* **c** *tiered seating.* **d** *stadia seating (continued over)*





33.95 *Continued*

It is good practice for the lighting design and colour scheme on the approaches to the auditorium to assist members of the audience adjust to lighting levels within the auditorium.

8.09 Screens

Shape
Film and digital projectors may be required to project material in a variety of width-to-height ratios. Typical ratios for commercial cinemas are 1:1.66 1:1.85 and 1:2.39. Specialist cinemas and lecture halls may require ratios as low as 1:1.33 (described as 4:3 in video terminology) for archive, independent or television material. High definition television normally uses a 1:1.78 ratio (16:9 for video).

Size
The largest 35 mm screens will usually be less than 18 m in width. 2 K digital cinema projectors can now illuminate a picture size in excess of 25 m.

Curvature
For uniform focus a large screen should be curved to keep its surface equidistant from the centre of the lens.

Luminance
Screens may have a matt white surface or a special high reflectivity surface which is particularly suitable for larger screens where the luminance needs to be enhanced. Some 3D projection systems require a high reflectivity silver surface although these are unsatisfactory for conventional 2D projection.

Position
The centre of screen should be on the central axis of the auditorium seating

Masking
Mechanically adjustable black masking to the sides and top of the screen is normally provided to contain the picture surface and obtain maximum apparent brightness. The masking is usually

wool serge on metal rails, and the gear should be fixed at floor level for ease of maintenance. Movement is remotely controlled from the projection room.

Unmasked screens

Unmasked screens are used in many multiplex cinemas and some specialised cinemas. They are most suitable when used with digital projection systems which can produce a 'clean' picture edge.

Construction

Screen material is either PVC or metalised fabric, held by cord lacing to hooks on a metal lattice frame. Generally cinema screens are perforated to allow high quality sound reproduction from the speakers positioned behind the screen. Different sized perforations are available. Digital cinema projection and small auditoria usually require smaller size perforations. Unperforated screens may be used in specific circumstances such as lecture halls.

Temporary screens

In some multi-use auditoria screens may require to be easily and conveniently removed. A flat screen up to 6 m wide can be incorporated into a proscenium stage of a theatre form either housed, when rolled, in the stage or flown in the flytower. Curved screens could be flown, but take up much valuable space in the flytower; or they could be stored at the rear of the stage if fitted with rollers or castors for ease of movement.

Speaker installation

The speakers need to be located behind the screen, firmly fixed to the platform or screen frame. One speaker is needed for monophonic sound; for multi-channel and stereophonic sound from 35 mm film, three speaker units are necessary: one centrally placed and the others equidistant from it to the left and right. 70 mm sound production requires five symmetrically placed about the horizontal axis of the central speaker.

A sub-woofer low-frequency speaker is usually located centrally behind the cinema screen. Surround sound systems are widely used in cinemas and require a number of small or mid-size wall-mounted units on the left, right and rear auditorium walls.

Platform

The back of the screen frame, including the speaker, needs to be covered with heavy felt to absorb sound. Alternatively the entire wall surface behind the screen and speaker frame can be covered with black tissue faced insulation. The screen is set over a platform with a forestage, carpeted with black carpet to prevent reflection of sound and light. The forestage edge can be vertical, splayed or stepped. Some theatres now build baffle walls behind the screen which incorporate the theatre stage loudspeakers.

Stage for speakers

In cinemas used for speeches or panel discussions before or after screenings, awards ceremonies or occasional lecture or conferences it should be possible for all audience members to have a clear view of the speakers/panels faces.

Usually this will require the provision of a raised stage in front of the screen, although with steeply tiered stadia seating this may not be necessary.

AV and IT provision at the speakers position, linked back to the projection room needs to be considered. It is also useful to incorporate within the design of the cinemas a reasonable sized pipe such as a drain pipe so that A/V lines can be added on an ongoing basis from the projection box to behind the screen area.

Access to the stage for speakers or panel members with mobility disabilities needs to be considered.

8.10 Projection suite

A projection suite provides space for all the image projection and sound reproduction equipment in a cinema. Contemporary cinema design aims for a single projection suite to cover all the auditoria. Most cinemas provide automated systems which allow complete performance to be screened with minimal staff input. Specialised cinemas and lecture halls rely less on automated systems.

Digital cinema systems remove the need for film preparation and storage equipment and film transport systems therefore may require smaller projection suites.

Projection suites should be secure from access by the general public.

Digital Projection

Digital Cinema projectors have approximately the same footprint as 35 mm projection. 2 K and 4 K projectors can achieve image widths up of 25 m.

A single projector can be used for 3D projection, but has to produce approximately twice the light output as used for 2D projection. This could, in larger auditoria reduce the standard picture size; two projectors can be used to increase the luminance in the largest theatres. To achieve 3D in 4 K projection two projectors will be required. Some 3D equipment is fitted to the lens on 2 K projectors and requires approximately 500 mm from the projection lens to the porthole glass for installation and removal.

There are two types of 3D glasses in use, the disposable and reusable. It should be taken into account that glasses should be easy to distribute and to collect. The reusable glasses are expensive and security issues should be taken into account. Facilities will be required to wash dry and store the glasses.

A standard digital projection system is comprised of:

- A projection head, lamphouse and rectifier. These are usually housed together in a single module.
- Digital cinema film server and storage system can be rack mounted with the theatres sound processor and amplification system or in some cases under the projectors lamphouse. The film server will require an ADSL or IDSN connection to download security keys for diagnostic tests.
- In some theatres there may be a requirement to play alternative content, which are any image that is not high and digital cinema. This may comprise of corporate power point presentations, live concerts, DVDs, Playstation type gaming or other video formats.

Additional equipment may include:

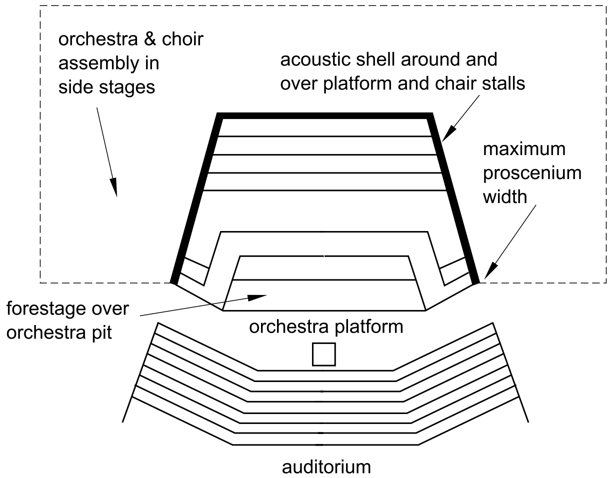
- Multimedia playback box, digital to analogue sound interface, audio delay, DVD playback, satellite dish and transcoder for live events and downloading digital cinema content, space for HD disc player/VR playback, monitor.

Digital cinema projectors require venting at approximately 600/650 cfm. Projection boxes should be cooled to approximately 21°C.

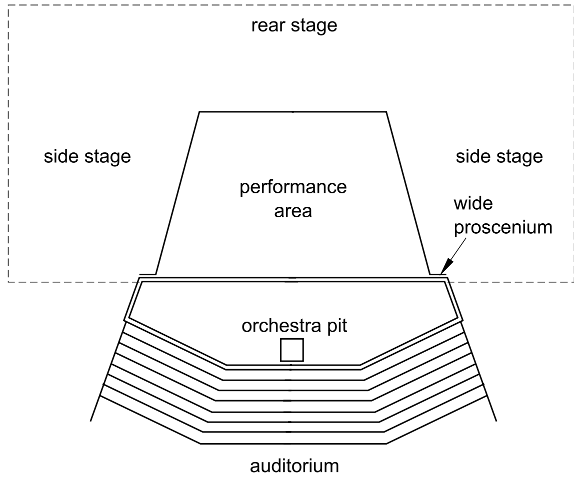
9 MULTI-PURPOSE AUDITORIA

9.01 Requirements

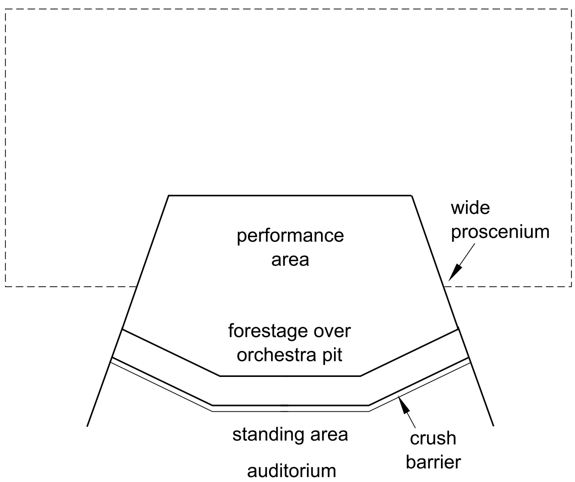
Multi-purpose auditoria refer to an approach where compatible activities are combined within one volume. An example, **33.96**, covers a single form with a modest level of flexibility while combining opera, dance, musicals and drama; as well as concerts, conference and film shows. This is a multi-purpose proscenium stage with flytower and a flexible proscenium zone; the seating in the auditorium can remain constant.



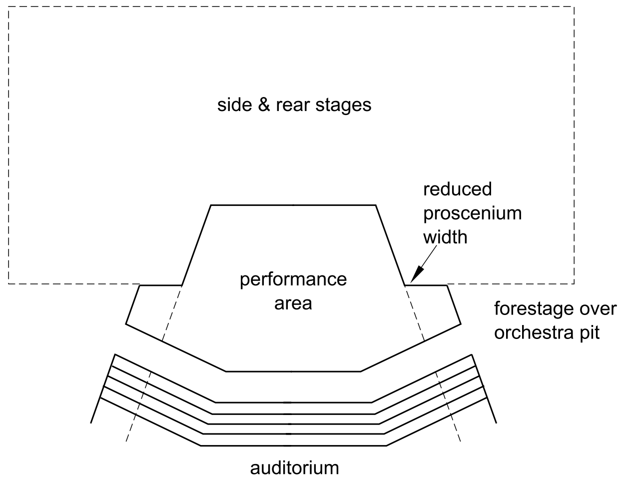
a *For orchestral and choral music*



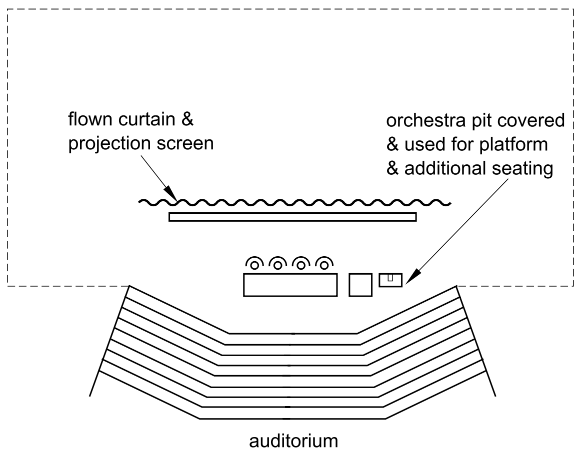
b *For opera, dance and musicals*



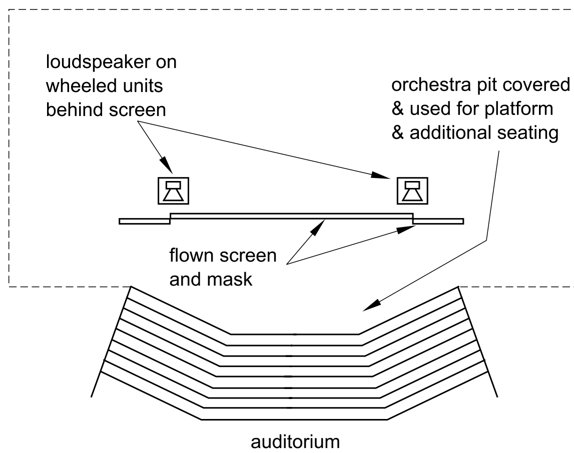
c *For jazz, pop and rock music*



d *For drama*



e *For conferences*



f *For cinema*

33.96 *Multi-use stage with flytower and flexible proscenium usable in the following ways*

9.02 Physical restraints

Problems can arise in combining different types of production in a single auditorium. Required volumes and reverberation times differ for speech and for music. To adjust the volume, arrangements to lower the auditorium ceiling can be incorporated into the design. Temporary alterations to the surface treatment of walls and ceilings can alter reverberation times, as can electronic 'assisted resonance'.

10 SUPPORT FACILITIES

10.01 Entrance doors and lobbies

These require:

- Ease of access from car parking and public transport
- Canopy: to provide shelter at entrance
- Provision for posters and other information
- Draught lobby
- Automatic sliding doors

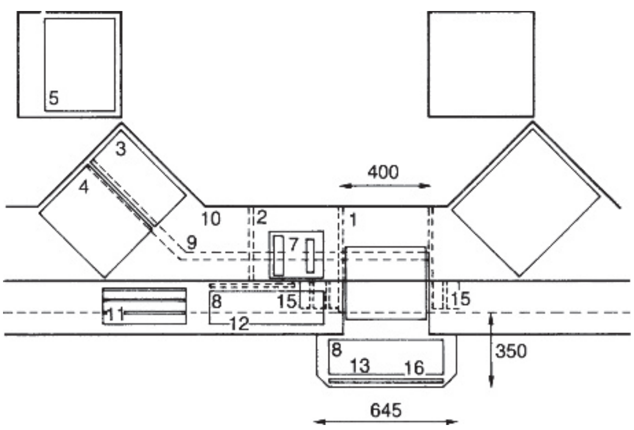
10.02 Entrance foyer

Box office, **33.97** (in theatre, concert hall, cinema): counter for the sale of tickets; computer ticket dispenser
Registration (conference hall): counter or table
Reception and information: counter
Cloakroom (not usual in cinema): attended or unattended, see Chapter 5
Creche: at least 6.5 m^2 per child
First-aid room: bed, washhand basin
Toilets: see Chapter 5
Foyer and circulation: table, chairs, display stands
Performance area: within foyer or separate area
Space and display for exhibitions: see Chapter 28
Auditorium lobbies: barriers to sound and light at entry points into the auditorium; the level of lighting should assist adaptation to and from dark auditorium and the brighter foyer lighting, as with a cinema.

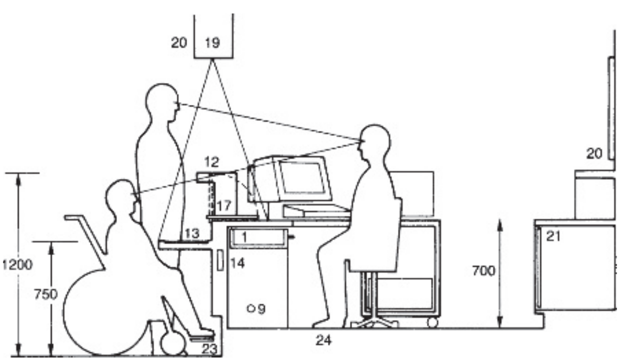
10.03 Places to eat and drink

- Coffee bar
- Licensed bar
- Cafeteria
- Restaurant
- Banquet room
- Private room
- Associated spaces: bar store, cellar, kitchen, storage, staff rooms, managers offices, delivery, refuse.

See Chapter 17.



a *Plan*



b *Section*

33.97 *Box office. KEY: 1 stationery drawer, 2 till drawer, 3 keyboard, 4 VDU, 5 mobile ticket printer, 7 telephone, 8 seating layout plans, 9 footrest, 10 writing space, 11 leaflets, 12 upper customer counter, 13 lower customer counter, 14 cable trunking, 15 pigeon holes for tickets and messages to be collected, 16 cheque writing upstand, 17 counter flap, 19 counter lighting, 20 display, 21 storage, 24 raised floor*

10.04 Sales

- Shops and merchandise outlets: display cases, shelving; office, storage, security; see Chapter 13
- Kiosk and other food outlets: display cases, shelving, microwave oven, stockroom (confectionery, drinks, etc.) with possible refrigerator; security.

10.05 Meeting rooms

Break-out rooms, sponsors' rooms; equipped for receptions, and small group lectures, discussions and workshops.

10.06 VIP rooms

Reception rooms for distinguished visitors; lounge and toilets.

10.07 Exhibition hall

Displays including trade exhibitions; storage, deliveries, possible separate public entrance, see Chapter 28.

10.08 Art gallery

Permanent and/or temporary exhibitions, see Chapter 28.

10.09 Office services

Conference halls: access by delegates to fax machines, telephones, photocopiers, translators, secretarial work, see Chapter 12.

10.10 Outdoor areas

Gathering area at front doors; associated with foyer and places to eat and drink as external terraces; store for outdoor furniture; landscaping, see Chapter 7.

10.11 Signage

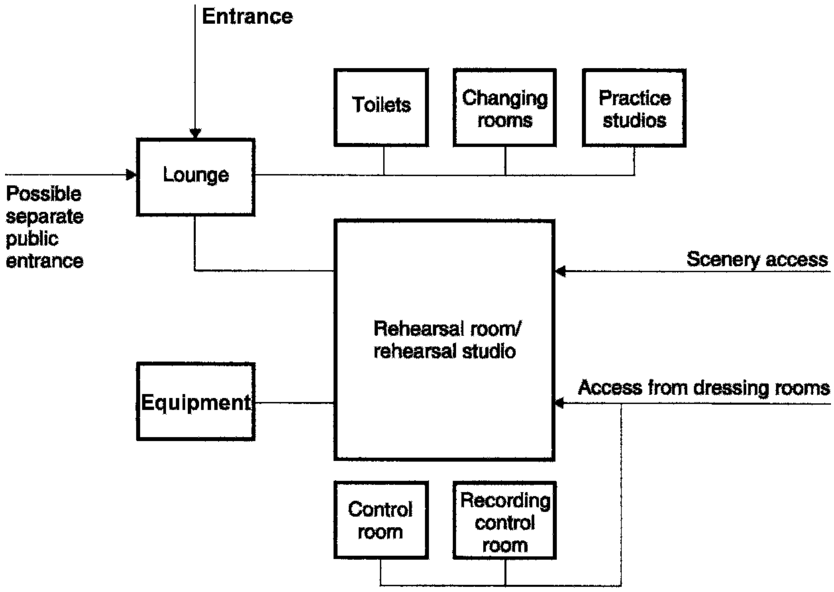
- External: name of venue, current and future events
- Internal: direction signs to the various public attractions.

10.12 Managerial spaces

Administrative offices

- Offices: functions may include policy, house management, accounts, personnel, marketing, press and publicity, development and community programmes, clerical work; see Chapter 12.
- Associated spaces may include boardroom, storage, strong room, office services and equipment, entrance and reception, toilets.

Box office: room for postal and telephone bookings, storage of sales records and accounts; access to changing, relaxation and toilet facilities.
Men's and women's staff rest rooms: lockers, lounge chairs, refreshments and toilets.
Sales and trays store: refrigerator for ice cream, shelves for confectionery, programmes, documents and other items for sale or distribution; storage of sales trays; table; washhand basin; located directly off the public areas.
Maintenance workshop, office and store: for the maintenance of the building fabric, equipment, emergency services, external works.
Cleaners' stores: central storage of materials and equipment; cupboards with sink, cleaning materials and equipment throughout building.
Security control room: surveillance monitors, fire-detection systems, alarms, service monitors, paging systems, locking devices.
Refuse: external provision for dust-bins, well ventilated and easily cleaned.
Catering facilities: the scale of the operation may justify the inclusion of catering facilities for all staff.



33.98 *Relationship diagram for a rehearsal room or studio*

10.13 Production spaces

For those opera, dance, musical and drama companies which initiate their own productions, the following spaces are required:

- Offices for the functions of artistic policy, direction, production development, instruction, design, production organisation, business management, development programmes and clerical work
- Associated spaces may include boardroom, library, music room, audition room, working conference room, model-making facilities, dark room, general storage, office services, refreshment areas, toilets, entrance and reception.

10.14 Rehearsal spaces

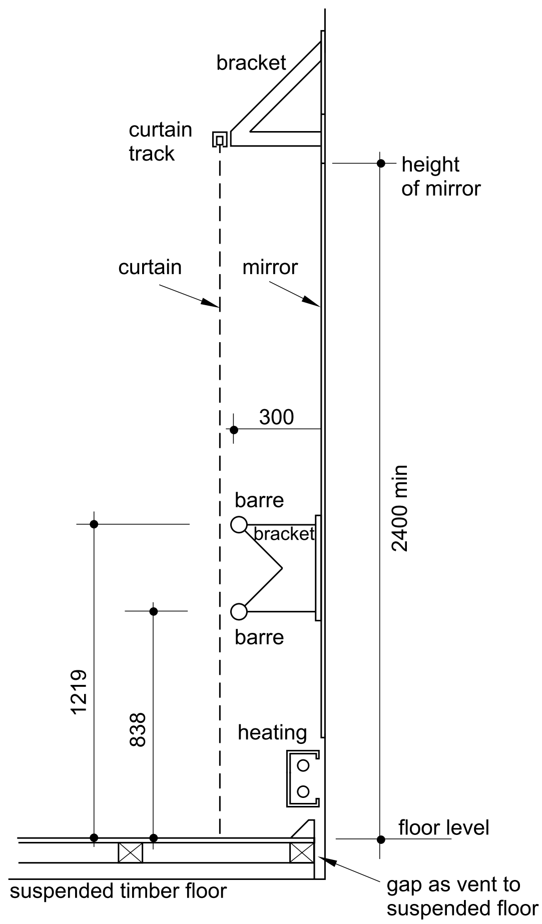
A relationship diagram for a rehearsal suite is shown in **33.98**.

- Rehearsal room or rehearsal studio able to accommodate largest performing area on the stage plus 2 m on three sides and 3 m on one long side as a minimum
- Practice studios for individual or small group practice, for example for dancers, **33.99**
- Associated spaces may include lounge, changing rooms, toilets, storage of equipment.

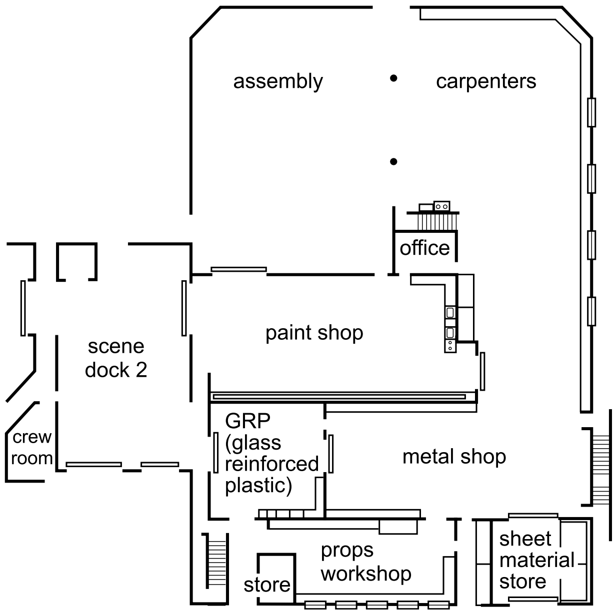
10.15 Scenery workshops

The substantial facilities required where the manufacture and maintenance of scenery is involved is well illustrated in **33.100**.

Offices: for head of carpentry workshop, head of paint shop, and head of property department.
Carpentry workshop: for the construction of scenery; power-operated tools (such as woodworking machine, mortise, circular and bandsaws and lathes); benches for carpentry, assembly and canvassing; storage of raw materials such as timber, sheet materials, rolls of materials, nails and screws and so on, including polystyrene sheets which may require a separate fire-resistant enclosure
Paint shop: for the painting of scenery, the method of painting backcloths and flats (flat on the floor, on mobile frame or fixed frame and gantry, and three-dimensional pieces: the extent of benches for mixing paints and other preparation and cleaning brushes; storage requirements for raw materials such as paints and fire-proofing, and equipment such as brushes and spray equipment. Paints may require to be stored in a fire-proof enclosure.
Metalwork shop: the use of metal in the preparation of scenery; provision for welding, cutting and fabricating metalwork items; benches, welding screens and bending machinery; storage of raw materials such as sheets, tubes and bars, bolts, nuts and screws.
Trial assembly area: area for the erection of a trial assembly of the set under construction, the size of the performing area of the stage.
Property department: worktops and storage of raw materials. Two separate workshops may be required: one for polystyrene and fibreglass work with associated fire-resistant requirements and extraction of toxic gases, the other for work with other materials.
Delivery and storage of raw materials to the carpentry workshop, paint shop, metalwork shop and property department, including unloading bay and parking of delivery vans and lorries.
Storage of scenery and properties for re-use.



33.99 *Section through wall barres in rehearsal studio for dance practice*



33.100 *Plan of workshops in the West Yorkshire Playhouse, Leeds*

10.16 Layout of workshops

A level floor is required through unloading bays, workshops, scenery store and stage; giving a clear, broad passage of movement of scenery onto the stage. Where a change of level is unavoidable a lift will be inevitable but is not recommended. If touring companies are anticipated, passage from the unloading bay to the stage should be direct without interfering with the workshops.

The paint frame and backcloth storage should be placed so that the rolled backcloths can be moved horizontally into position under the flytower or grid with the painted surface facing the audience. The large doors or roller shutters required for the movement of scenery should not also be used for people. The minimum dimensions of the openings should be determined by the maximum size of scenery expected.

The carpentry shop should be isolated from the paint shop to avoid noise and sawdust penetration, and both areas should be acoustically insulated from the stage. Scenery storage located between workshops and stage acts as a sound barrier.

10.17 Wardrobe

Space is required for:

- Making and fitting of performers' costumes
- Making and fitting associated items such as wigs
- Storing, repairing and cleaning costumes
- Making millinery and accessories
- Dyeing cloth and spraying materials
- Storing rolls of cloth and pattern paper
- Storing small items such as sewing materials, dyestuffs
- Delivery of raw materials including unloading bay and parking of delivery vans
- Office for costume supervisor.

Performers require easy access to the wardrobe for fitting costumes, while the distribution of finished costumes for, and their cleaning during, a production suggests a location close to the dressing rooms.

10.18 Recording studio

For sound effects and music. An isolated space, with control room. Associated areas may include a library of tapes and discs, entry lounge and lobby. Further details may be found in Chapter 32.

10.19 Common facilities

Provision for resting, changing, refreshment, toilets and showers.

10.20 Transport

Van or vans for the collections and delivery of goods, with parking spaces within the curtilage of the site.

11 FACILITIES FOR PEOPLE WITH A DISABILITY

Access

- Dedicated car parking spaces at public and staff entrances
- Drop-off points at entrances
- Wheelchair users use main entrance
- External and internal ramped access, handrails and lifts comply with Building Regulations
- Unrestricted access to all levels and non-public areas (it may not be feasible to provide access for people in wheelchairs to access such areas as the grid over a stage, or lighting walkways over an auditorium)
- Dedicated wheelchair spaces in auditorium seating areas
- Accessible toilets complying with Building Regulations
- Box office reception desk and information counter with accessible height and width.

Facilities for people with sensory impairment

- Induction loop system or infra-red hearing provision in auditorium
- Induction loop system in box office, reception desk and information counter
- Visual fire alarm system
- Braille/large print/tactile signs
- Audio description provision
- Facilities for guide dogs.

12 LEGISLATION

Local authorities have a responsibility for licensing places of public entertainment. It is essential that contact be made with the appropriate local authority before plans are too far advanced. Before taking any decision they would normally consult the fire authority and the Health and Safety Executive as well as their own safety officer.

The areas of particular concern will be inflammability of materials, seating layout, emergency lighting levels, escape routes, signage and building services. Reference BS5499 and BS5588.

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34 Places of worship

Leslie Fairweather, Ian Brewerton, Atba Al-Samarraie, David Adler and Derek Kemp

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CI/Sfb: 6
UDC: 726
Uniclass: F6

Contents

Part A Guide to Christian denominations

1 INTRODUCTION

1.01 Scope

This chapter will cover churches and places of worship for various Christian denominations, synagogues, mosques and Hindu temples. Places of local worship only are dealt with, not larger buildings like cathedrals or those with social spaces, which are not significantly different from social spaces in secular buildings, and for which Chapter 20 (Community Centres) provides further advice.

1.02 History and tradition

In the architecture of places of worship for the more established denominations the architect is bound to be more concerned with tradition than in other fields. Users are more conscious of history (and more sensitive about it) than most other clients: they will not allow an architect to ignore established precedents and will expect a full understanding of them. However many of the new 'Community Churches' expect to see a different approach more akin to performance architecture than established precedents. These new movements have also had a major impact upon the more established denominations and have resulted in a movement away from one-man ministry to more participation by members of the congregation. Large free-span structures are required to accommodate large congregation numbers, seating capacities of 500–1000 are not uncommon for which the conversion of redundant retail warehousing and similar structures are ideal.

Exact details of the forms of worship and building procedures should be discussed with the individual clients, and the architectural implications thoroughly understood. A fairly detailed general guide to the history, procedures and forms of worship (with architectural implications) of the Church of England, the Roman Catholic Church, the Presbyterian Church, the Salvation Army, the Methodist Church and the Society of Friends, is given in *Church buildings*, originally published as a series in *The Architects' Journal* and later in book form (now out of print).

1.03 Local ecumenical projects

Some protestant churches, particularly Methodist and United Reformed Church, are now uniting to form Local Ecumenical Projects (LEPs), both as a visible expression of church unity and in recognition of declining numbers and reducing resources. In these, the uniting congregations may either continue to worship separately in shared premises, or may unite to form a single congregation recognising the practices of each of the participant denominations. The building may be either that belonging to one of the congregations or (rarely) purpose built.

1.04

Such projects are set up under the Sharing of Churches Act which imposes some legal requirements in addition to the particular requirements of the participants. This may be relevant to designers, as the investment of capital in buildings is one of the areas dealt with in the Act. For every LEP there will (or should) be a formal 'Sharing Agreement' which sets out its terms. Architects involved in LEP's should take considerable time and care in formulating the brief, as there are often natural tensions within such a project.

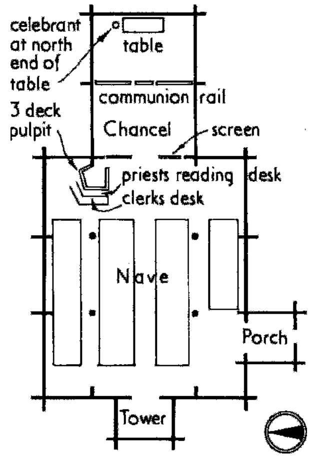
2 CHURCH OF ENGLAND

2.01 The buildings, and how they are used for worship

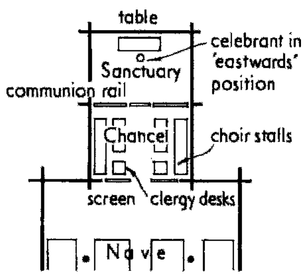
After the Reformation the Church of England inherited many medieval, mostly Gothic, buildings, strongly directional in their east-west orientation and with the main action remote from the congregation. The people therefore had lost the sense that they were engaged with the clergy in a common action and tended to become spectators with an individualistic rather than a corporate response to the liturgy. The church has now moved into a period of experiment in which it greater fuller expression of the corporate nature of worship and the equal importance of the Word (which must be heard) and of Sacrament within a building which remains true to the Anglican sense of proportion.

2.02 Altar, priest and people

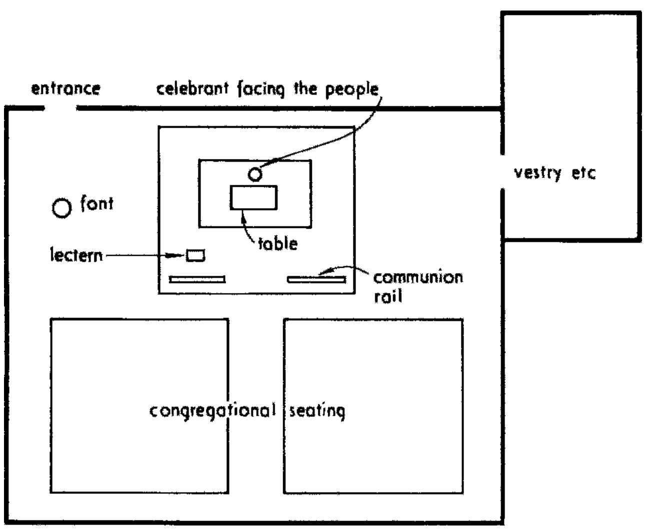
During the period of the Oxford Movement's influence the 'north end position', **34.1**, was largely superseded by the 'eastward position' in which the priest would face the altar with his back to the people, **34.2**. This way of celebrating the Eucharist is contrary to the spirit of the Anglican liturgy. The eastward position has largely been replaced by the one in which the priest faces the people across the altar, **34.3**.



34.1 *Communion table is placed against east wall, priest stands at north end*



34.2 *Eastward position: priest faces altar with his back to the congregation*



34.3 *One of the many variations of plan where the priest faces the congregation across the altar. The seating may extend around three sides of the altar*

2.03 The main services

The six main services of the Church of England are:

- The Eucharist
- The offices of matins and evensong
- Baptism
- Confirmation
- The solemnisation of matrimony and
- Burial of the dead.

If the architectural requirements of these are catered for, so will those for almost any other service likely to take place in the church.

2.04 Church design

Apart from the altar, the general principles of layout and design are the same as for the Roman Catholic Church and the Methodist church. These are shown, with separate altar details, in para **2.09**.

3 ROMAN CATHOLIC CHURCH

3.01 Worship as a corporate act

The term 'Roman Catholic' (or to members simply 'Catholic') denotes the Christian community which has continuously accepted the authority of the Pope. The chief problem of a community which is building a Catholic church is that, though its building must suit the liturgy as it now is, community and architect must also make some estimate of what the total ultimate change in form of services is likely to be.

The corporate nature of Catholic worship is again now being stressed. Catholic churchgoing has for centuries been highly individualistic. The congregation should participate in the liturgical action and not merely watch it. Baptism is being restored as the corporate act of the local assembly: but it is still conducted as a private ceremony held at a time to suit the parents and which only they and their friends attend. The architect must make corporate baptism possible in a church, even though it may not be practised for some time.

The existence of societies within the parish is always important in its social life and the architect should find out which they are, what they do, and whether they are to be accommodated in any way.

3.02 The main services

The six main services of the Catholic church are:

- Mass
- The Easter liturgy (Holy Week ceremonies)
- Baptism
- Marriage
- Burial of the dead and
- Devotions.

Other liturgical activities include: blessing, dedication, consecration, confirmation, ordination.

3.03 Church design

Apart from the altar, the general principles of layout and design are the same as for the Church of England. These are shown, with separate altar details, in paragraph **9**.

4 UNITED REFORMED CHURCH

4.01 Origins and buildings

This was established by merger of the Presbyterian Church of England and the Congregational Church of England, with most of the Scottish Congregationalists due to join shortly. It also merged with the Chruches of Christ a few years ago. A number of English Congregational Churches did not join the United Reformed Church (URC) and continue as the Congregational Union.

4.02
The Presbyterian Church of Scotland (PCS) remains separate; it claims to be a continuation of the Celtic church.

During the reformation one of the leaders, John Knox, became greatly influenced by the Swiss John Calvin and it was basically his system of church government and structure, as well as much of his theology, which he brought into the church. This system of church government by courts, basically government by the members of the church congregation, is known as 'presbyterian'; as opposed to 'episcopalian' which is government by an appointed heirarchy.

4.03
The Reformation established the doctrine of 'the priesthood of all believers': it was not necessary for any human being to come between God and a worshipper, and the only mediator accepted was Jesus Christ. There is therefore no good theological reason for a chancel in its literal sense of a 'railed-off area' in a URC or Presbyterian church.

All take part in the full worship and sacramental act. The sanctuary or chancel area is therefore now simply where the central act takes place, but the congregation are essentially participants in that act and the nearer they are to it the better. There is now a fairly general departure from the earlier rectangular form of church in favour of a more open form where the sense of gathering the people round the Word and sacrament, as represented by the pulpit and communion table, can be expressed.

Present thinking seeks to emphasise the close links between the worship room and the rooms for secular purposes, so that there may not be a complete divorce between the weekday and Sunday activities of the congregation. The economic situation may well lead to multi-purpose buildings where only a portion is kept entirely for worship, while the rest is used for other purposes, with the use of partitions and screens.

4.04 The main services
There is a wide variety of practices within the URC (reflecting Presbyterian, Congregational and Churches of Christ practices), and local churches can adopt their own practices. The types of services normally held are:

- normal morning public worship
- evening worship, which increasingly is taking a variety of forms, or may be largely a repetition of the morning service
- as above with addition of one or other of the sacraments, holy communion or baptism
- as above, with ordination of elders or admission of new communicants
- marriages

Funeral services are infrequent.

Following the merger with the Churches of Christ, the URC now recognises and practices both that denomination's adult baptism by immersion (for which a baptistry is required, see Section 7 below) and infant baptism using a font.

4.05
The ordinary conduct of worship is left almost entirely to the minister who may choose to remain in the pulpit for the whole service or may take part of the service from a prayer desk or a lectern, or from behind the table, using the pulpit only for preaching. The minister may move from the pulpit to the communion table to receive the offering, and will certainly do so to administer the sacrament. The font will of course be used for administering baptism, and the front of the sanctuary steps for admission of new communicants or for ordination of elders.

4.06 Church design
The elders in the URC (and the members of the Kirk Session in the PCS) normally sit among the congregation. While there is great variety in the way services are conducted, most of the speaking is normally done by the minister. The congregation sit for prayers and do not kneel in the pews. The pews are seen as an extension of the communion table, so the congregation is, in effect, sitting around the table. Worshippers remain in their seats throughout the services, the elements of communion being passed around by the elders.

Baptism must take place in the face of the congregation and the font or baptistry should therefore be visible to all. The font should be in advance of, and probably to one side of, the communion table and at a slightly lower level. It can be movable but should have a permanent site in the sanctuary. It need *not* be at the entrance to the church. There are no special design requirements for Christmas or Easter services.

A central aisle is desirable for marriage ceremonies.

The choir should be visible to the congregation but should not be in the sanctuary.

There is little social activity connected with worship but ancillary accommodation for social and educational purposes may be needed outside the hours of service.

Many aspects of design are similar to those for the Church of England. The main differences are listed below:

- The communion table is a table and not an altar. It is usually rectangular but other shapes are not precluded. Basic sizes are given in para **10**.
- A large lectern is not essential but where provided should be to the sizes shown in para **11**. Sometimes pulpit and lectern are designed in one piece with upper and lower levels.
- Pulpit may be centrally in front or to one side of the table or, more rarely, behind the table. It should not be more elevated than is required for the congregation to see the preacher. General design is as shown in para **11**.
- A chair for the minister is provided centrally behind the communion table with often at least one additional chair on each side for elders. Alternatively seats for elders may be provided against the back wall of the sanctuary.
- A meeting room should be provided in addition to a vestry. This is where the elders (or the Kirk Session in the PCS) meet before services and where communion is prepared.

5 THE SALVATION ARMY

5.01 Origins
The Salvation Army arose from evangelical meetings conducted in east London during 1865 by the Reverend William Booth, a minister of the Methodist New Connection. Booth decided to take the church to the people. His services were held in the open air, in tents and in theatres: later he built barracks and citadels in which his converts could hold their meetings. His services were sensational: he used brass bands playing secular tunes to accompany hymns; converts (soldiers) wore uniform. He became a 'general' and directed the organisation in quasi-military style. Men and women had equal rights in office. Booth regarded social work, care of the poor and rehabilitation of the outcast as an essential part of his Christian mission.

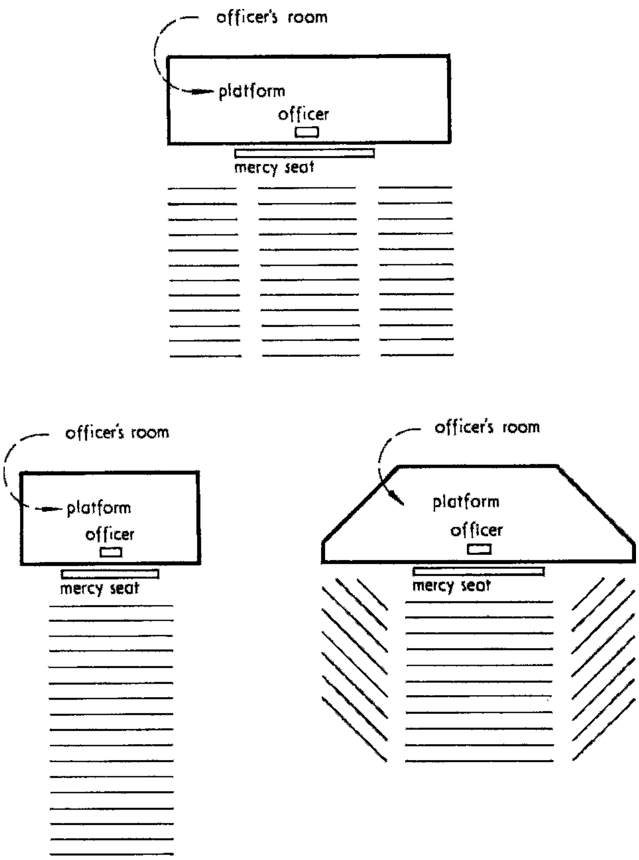
The Christian mission, as it was first called, grew beyond all expectations and in 1878 became known as the Salvation Army. In its belief, it is orthodox, evangelical and prophetic. The corps assembles for worship in a hall – a multi-purpose building sometimes called a citadel, temple or barracks. Sometimes within the complex there are two halls, for senior and junior soldiers respectively. Religious services and social activities may be conducted in either or both halls.

5.02 Ceremonies

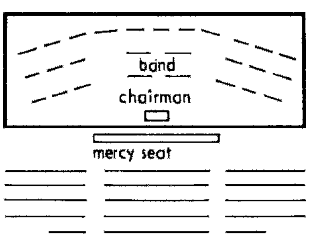
Ceremonies may be divided into two types:

- Ordinary services held on Sunday – morning, afternoon, and evening
- Ceremonies applicable to marriages, funerals, memorial services, covenants, swearing-in of soldiers and presentation of colours (these may be embodied within one of the ordinary meetings).

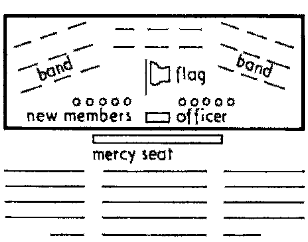
The architectural implications are shown in the series of diagrams **34.4** to **34.9**.



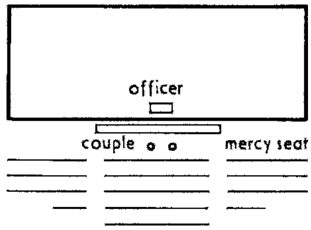
34.4 *Salvation Army: possible basic arrangements. Note that access from officers' room to platform may be on either a side or rear wall*



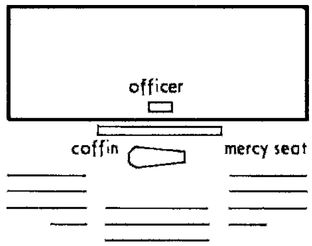
34.5 *Praise meeting or festival*



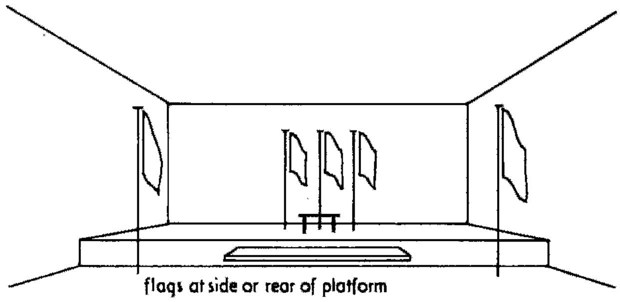
34.6 *Swearing-in ceremony*



34.7 *Wedding*



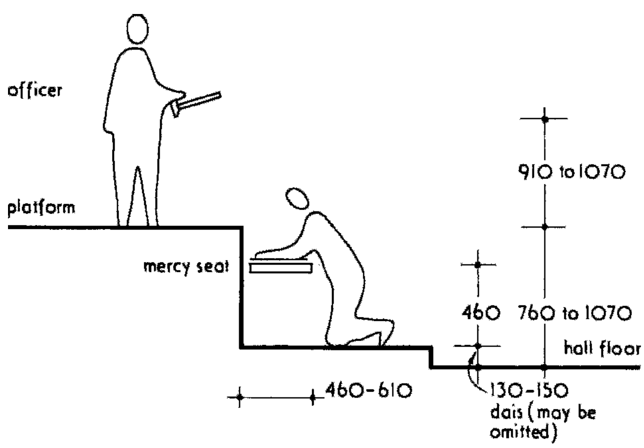
34.8 *Funeral*



34.9 *Presentation of colours*

5.03 Design of the assembly hall

There will be no communion service and visually there will be no elevation or placing of the sacred elements in a part of the building. The font, lectern, pulpit, communion table and altar are not essential to the Salvation Army form of worship. In every Salvation Army hall there is a place for the mercy seat, **34.10**. This is a simple wooden form, usually placed at the front of the platform in front of the congregation, and is a place where Christian and non-Christian penitents may kneel at any time.



34.10 *Mercy seat*

Platform

The platform will be required to accommodate, at various times, officers taking a leading part in the services; the band (possibly a visiting one which may be larger than that designed for); the songster brigade or a visiting choir.

The size of the platform will depend on local conditions and requirements but approximately 0.5 to 0.6 m^2 per person (seated in rows) should be allowed. The platform should not be less than about 4–5 m depth, but will normally be more. Its height above the hall floor should not normally be less than 760 mm or more than 1100 mm but sight-lines must be considered in relation to a level floor both on the platform and in the hall.

If there is a gallery there must be a view of the mercy seat from every seat. Movable seats, not fixed pews, are always used both on the platform and in the hall: flexibility is important.

Hall

As a first estimate for the overall area of the hall, allow 0.56 m^2 for each person to be accommodated. Aisles should not be less than 1.35 m wide. The space between the front edge of the mercy seat and the front face of the congregational seating should not be less than 1.5 m. A wide rectangle, polygon, or square will be a more satisfactory shape than a long narrow rectangle.

The requirements will be for a reasonable standard of acoustics for speech, choral singing and brass band playing. There should be a reasonable level of natural lighting and a reasonable standard of artificial illumination, both on the platform and in the body of the hall. The ventilation in most cases should be natural.

Officers' room

The officers' room (vestry) is used as a meeting-place by leaders or chairmen of meetings and officers of the Census Board who will assemble in the room before taking their place on the platform. The room should accommodate between two and ten persons. Corps records will be kept in this room. Lavatory accommodation will be required, normally one unit for each sex.

Cloakrooms

Lavatory accommodation should be provided for both sexes near or adjacent to the entrance vestibules of the senior or junior halls. This will be required for women in the songster room and for men in the band room.

Storage

Storage will be required in a band room for brass band instruments, music stands and music. The room will also be used for assembly, briefing and cloakroom. Minimum area shown usually be 23–28 m^2. Instruments are stored in individual lockers to suit sizes of instruments with a small store for reserve instruments and cupboard with shelves for music.

Storage will be required in a songster room for a wind-type portable organ or electric portable organ with amplifier, and music. The room will also be used for assembly, briefing and cloakroom for the women members who would number about 20 to 30 in an average-sized brigade: 18.5 m^2 would be a minimum area.

Where there are junior and senior corps activities, there may be a junior band and singing company (junior choir). Storage will be required for brass band instruments for this junior band and for music for the singing company.

Where there is a separate junior hall, storage compartments will be contained in that hall. Other social and club activities may also require storage.

6 METHODIST CHURCH

6.01 Origins

The Methodist Church grew out of the Church of England during the eighteenth century and was founded by John and Charles Wesley. A distinct feature of the new movement was the introduction of lay preachers or, as they came to be known, local preachers. The strong emphasis on evangelical preaching is rooted in the Methodist tradition. 'Methodism is nothing if it is not evangelical.'

The church or chapel is normally reserved for worship alone, although meetings, lectures and musical recitals of a specifically religious character may also take place there. A multi-purpose hall, with a sanctuary that can be screened or curtained off, may also be used for public worship during the early stages of the development of a local congregation. There may be other units within the complex such as classrooms, club rooms and assembly halls, both for religious and secular purposes.

6.02 Ceremonies and buildings

The kind of church required today will seat between 100 and 300 people. The influence of the liturgical movement is shown in certain specific ways, and particularly in a new emphasis on the place of the sacraments in the life of the church, and in the increasing use of set prayers and liturgical forms of service. The altar, therefore, is seen again as the Lord's table, used for the family. The font is no longer viewed as making possible a semi-magical act. It is the place at which and the means by which the person baptised, whether child or adult, is sacramentally incorporated into the body of Christ. This rediscovery of the laity, the Lord's table and the font has to be considered in designing a church, for in the end it is the function of the church which is of supreme importance.

These theological rediscoveries will affect the building of a Methodist church:

- In relation to the shape of the church
- In the arrangement of the sanctuary
- In the siting of the choir.

There are normally two services on Sunday, one in the morning and one in the evening. These are conducted by a minister or local preacher from the pulpit, though the earlier part of the service may be conducted from a lectern, the pulpit being used only for the sermon.

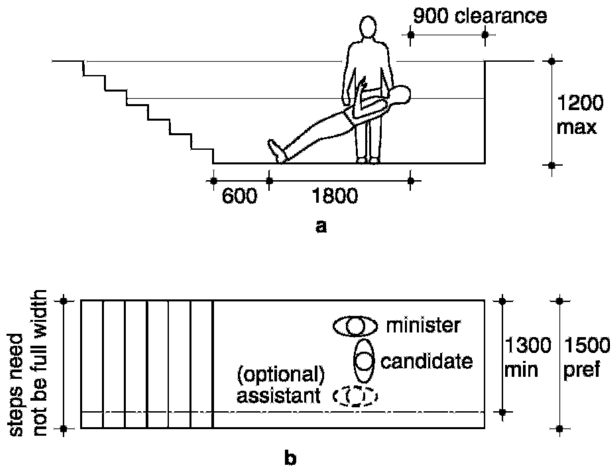
Holy Communion is normally celebrated once a month. In order to emphasise the theological statement that the ministry of the Word is of equal importance to the ministry of the Sacrament, pulpit and communion table may be placed close to each other. The minister dispenses the bread and the wine (the latter in small individual glasses) to each of those who have come forward from the congregation to kneel at the communion rail. A small trough or perforated shelf should be fitted to the inside of the communion rail, about 50 mm or 65 mm deep and slightly lower than the top of the rail, where communicants may place the empty wine glasses. See also paragraph **9**, for dimensions of communion rails.

All other main services are similar to Church of England practice and the architectural requirements are the same, although a credence table is not required near the communion table. Specific guidance is contained in *The Methodist Church builders' decalogue* (from the Methodist Property Division, Central Buildings, Oldham Street, Manchester MI IJQ).

7 BAPTIST CHURCH AND BAPTISTRIES

7.01

The chief difference in this denomination is the practice of deferring baptism to the age at which the person is able to make his or her own choices, normally 13 or older. This practice (often referred to as 'Believer's Baptism' is shared by other churches such as some of the URC and many independent churches.



34.11 *Baptistry pool for adult baptism as used in Baptist, some URC churches and a number of others:* **a** *section,* **b** *plan*

The adult, known as 'candidate', is baptised through total immersion in public ceremony in the context of a service of worship. This requires the church to have a baptistry appropriate for such use, **34.11**.

7.02 Baptism ceremony

The minister will enter the baptistry first, followed by the candidate. If more than one candidate is to be baptised they will be dealt with one at a time. The minister may speak briefly, and the candidate may also make a personal statement (or may have done so earlier in the service). It follows that that minister and candidate should be visible while standing in the baptistry, ideally from the shoulders up. If only the head is visible the effect can become somewhat incongruous. The candidate turns to face the steps (unless there are steps at both ends of the baptistry) for the practical reason that they will be unable to see clearly when leaving the baptistry, due to water in their eyes. The minister faces the congregation.

The minister then supports the candidate by the shoulders, pronounces a blessing, lowers the candidate backwards into the water, submerging them completely, and immediately raises them again. The candidate leaves the baptistry, usually supported or guided by the minister and/or other assistants, to ensure they do not trip or slip.

On occasions, and particularly if either minister is small in stature (and ministers in the denominations practising adult baptism include women) or the candidate is large in stature, the minister may be assisted by another member of the congregation. Exceptionally, if the candidate is infirm, they may kneel.

7.03 Key dimensions

Width, absolute minimum 1300 mm, but this is known from experience to be inadequate when an assistant is present, and 1500 mm to 1600 mm is better. The steps need not be the full width of the baptistry;

Length, about 3300 mm, determined by the tallest likely candidate (95th percentile) plus space to move and clearance at the 'head' end of the baptistry;

Depth (surrounding floor level to floor of baptistry), 1200 mm or a little less, determined by the shoulder height of minister and candidates (5th percentile);

Steps, suggested rise going and step profile to Part 'M' of the Building Regulations;

The diagrams show a rectangular plan, but other arrangements meeting the functional requirements are acceptable. The views of the local congregation should be sought.

7.04 Other functional requirements

The baptistry may be located either on a dais or in the body of the church; it is normally covered by a removable floor when not in use. In either case sightlines should be considered. If in the body of the church, consideration should be given to temporary edge protection when open to avoid accidents.

The removable floor sections should be as light and manoeverable as practicable. These will normally have to be moved by one or two of the congregation who may well be elderly or un-athletic, and the design of the floor sections should allow for this.

Floor surfaces. The baptistry base and the steps should have a non-slip finish. Adjacent floor surfaces may need protection.

Water supply needs to be available to fill the baptistry in a reasonable time (less than one hour), and drainage is needed to empty it in about half an hour. The floor of the baptistry should fall gently towards the outlet.

The drainage system should not be embedded or inaccessible. With infrequent use, water traps on the drainage line will tend to dry out. Any leak in the drainage system or the baptistry will be discovered at the most inconvenient moment. Suppliers should be asked to confirm that their specifications allow for long term dry conditions with occasional use filled. The design life of the complete baptistry installation should equal the design life of the building without any significant maintenance.

Water heating. It is normal to temper the water temperature; the water need not be warm, but should not make the candidates gasp on entry! It is probably inefficient to design the main heating and hot water system to supply such a large volume of slightly warmed water. Portable electric immersion heaters have been used, but all fittings will need to be to an appropriate IP rating.

Changing spaces are required for candidates and minister, separate for opposite sexes, and possibly for the minister. They should be close to the room containing the baptistry, and normally in multi-purpose rooms, but consideration should be given to privacy.

8 SOCIETY OF FRIENDS

8.01 Origins

The Society of Friends (Quakers) originated through the experiences and preaching of George Fox (1624–91). Early Quakers reacted strongly against the current religious practices and liturgy of the established church. All through their history, Quakers have been concerned with a sense of duty to the community.

Because Friends believe that God can communicate with man direct, they do not partake of the outward sacraments. They have no separated priesthood, they do not require their members to subscribe to a creed, and their worship does not make use of a liturgy. They are, however, in broad agreement with the main emphases of Christian belief, and would claim to be both orthodox and evangelical.

8.02 Ceremonies and buildings

In a meeting for worship, Friends gather in silence as a congregation of seeking souls, and 'wait upon the Spirit'. No one directs the worship. Out of the 'gathered' silence of united worship, one or another may be led to engage in vocal ministry or in prayer or to read from the scriptures. There is no music or hymn singing.

The building must be designed to help the quiet worship and the vocal ministry of the participants. There is no observance of the Lord's supper or orthodox communion service; no baptism or initiation ceremonies involving ritual. There will therefore be no need for font, lectern, pulpit or altar.

Sizes of meeting halls vary, but they will mostly be designed to accommodate fifty Friends or less. A square, rectangular or polygonal room may meet the requirements. It is likely that seating will be required in a square or a circle. Meetings may prefer fixed or movable, tiered or level seating.

There is no need for a table in the meeting room, though there normally is one to act as a focal point. The position is not usually literally at the centre of the room; the seating will be arranged in the way felt by the group concerned to be most conducive to a good meeting for worship, and the table, if placed anywhere, will be fitted in with the general arrangement of the room. Its main use is for business meetings.

Society of Friends meeting halls when not required for worship are often used by other denominations, or for secular purposes of an appropriate nature. Other accommodation might include a multi-purpose hall, library, small kitchen foyer and cloakrooms and a caretaker's flat.

9 PASTORAL CENTRES

9.01 Form and function

Pastoral centres are alternatives to conventional church buildings and are increasingly being considered where there is to be a large new population with non-existent or inadequate ministry and buildings.

A pastoral centre could take many forms – basically it would be a small building or suite of rooms with facilities for consultation, meetings, refreshments and occasional worship. It could be a modified house, a transportable structure or a specifically designed community building: it could even be a converted shop or a caravan. Its purposes would be to shelter a Christian 'presence', comparable to a doctor's surgery or a citizen's advice bureau: ministers would be present for counselling and office work at advertised hours. Small meetings could be held and modest hospitality offered. It could be used for acts of worship though it would be linked to a major worship centre elsewhere. It should be sited in the local centre and could be integrated into a complex of amenity buildings or a shopping centre. If resources were available, and if the population distribution were suitable, two pastoral centres might be provided in a neighbourhood of 6000 to 10,000 people.

Part B Design data

10 ALTAR OR COMMUNION TABLE

10.01 Symbolism

The altar symbolises three things:

- The body of Christ
- The altar of sacrifice
- The table of the last supper.

10.02 Canon law

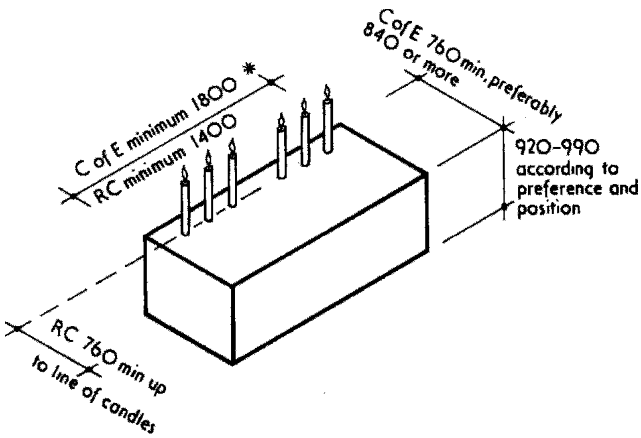
A Church of England altar may be of wood, stone or other suitable material and may be movable. It should be covered with silk or other 'decent stuff' during divine services and with a fair white linen cloth at holy communion. A Roman Catholic altar must be of natural (not reconstructed) stone with the top member (the mensa) in one piece and containing the relics of two canonised martyrs or saints. However, this requirement may be fulfilled by a small portable altar which is in effect an altar stone often about 300 mm square (or less) and 50 mm deep containing a sealed cavity (the sepulchre) for the relics. The altar may be fixed (stone cemented to the structure) or unfixed (timber with inset portable stone altar as described above). Only a fixed altar may be consecrated. Alternatively, relics may be sunk into floor below altar.

10.03 Position

The altar must be related to congregational seating in such a way that what is done at it is, and is seen to be, a corporate action of the whole assembly. Altars are being brought further forward in the sanctuary and with congregations grouped around, there is less need for the altar to stand so high as in the past, especially when the priest faces the congregation across the altar.

10.04 Size

For liturgical reasons, altars can be less long but possibly slightly deeper than in the past. Average sizes are shown in **34.12** and anthropometric data in **34.13**.



34.12 *Average size of altars. The exact proportions will depend on its position, and whether the priest is facing the congregation or has his back to them. Note that the tabernacle containing the reserved sacrament is not now normally placed on the altar (see section 12)*

10.05 Supports and coverings

Methods of supporting the mensa are shown in **34.14**. With the altar now normally nearer the congregation, the question of clothing the altar may need to be rethought. A traditional Church of England altar covering is shown in **34.15**.

10.06 Footspace

The platform or base on which the altar rests must be large enough for the number of priests expected to stand around while celebrating the Eucharist. It may be raised one or two steps above the level of the congregation, but in general the altar should be kept as low as possible to avoid any sense of separation between it and the people. Possible dimensions are shown in **34.16**.

10.07 Cross and candles

The exact requirements must be discussed with the priest. Candles and cross should not form a barrier between priest and people. Some possibilities for the cross are shown in **34.17** and **34.18**; and for the candles in **34.19**.

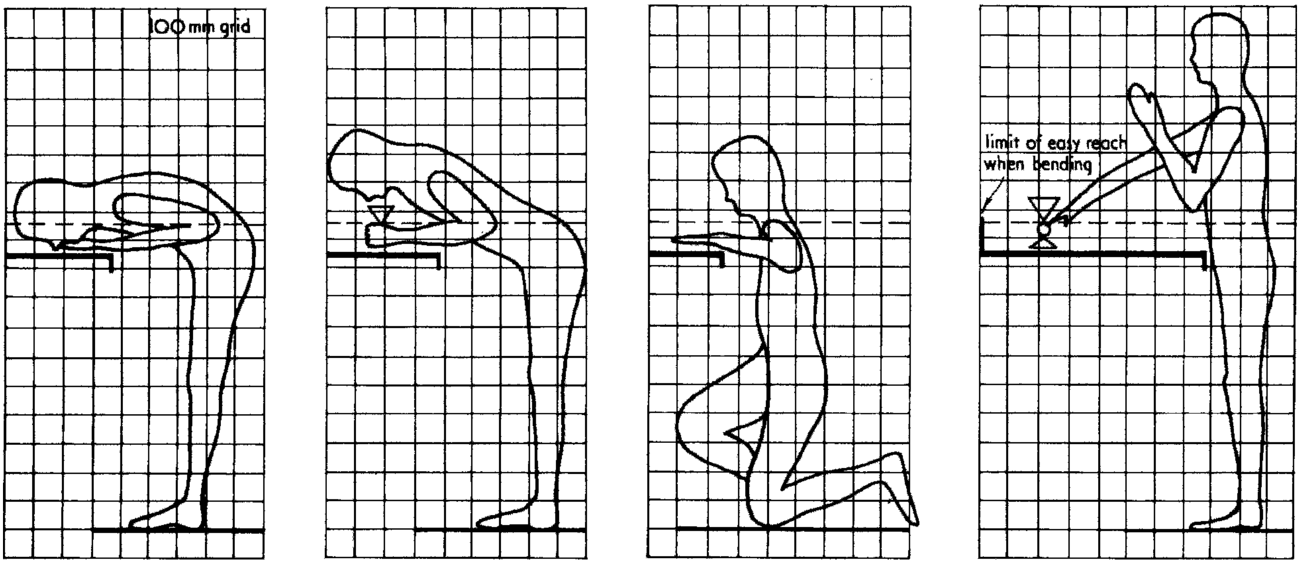
10.08 Communion table

A communion table with table lectern as used in Presbyterian churches is shown in **34.20**.

11 SANCTUARY FURNITURE AND PULPIT

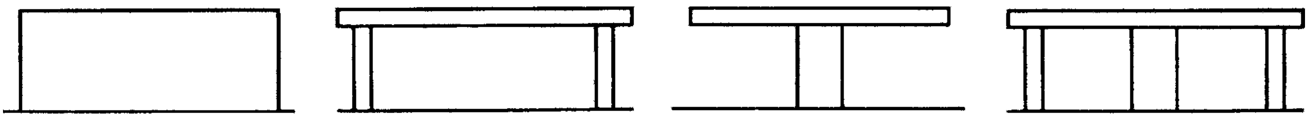
11.01 Lectern

This should be in or near the sanctuary but sufficiently apart from the altar to constitute a separate focus, and conveniently sited to be accessible to the congregation to read from, **34.21**. Occasionally two lecterns may be asked for, one each side. The lectern must be in a position where everybody can see the reader's face including those within the sanctuary. It may be fixed or movable, and it may also serve as a pulpit. Dimensions are shown in **34.22**.



a b c d

34.13 *'Critical actions of priest when standing at the altar. The horizontal dotted lines represents the eye level of the average adult member of the congregation when kneeling. This should preferably not be less than 75 mm above the top of the altar, emphasising the importance of keeping that low. This represents some sacrifice to the priest, since actions* **a** *and* **b** *are easier if the top is at the traditional height of just over 1 m.* **a** *Kissing the surface of the altar.* **b** *Saying the words of consecration.* **c** *Genuflecting. This position emphasises the value of recessing the altar supports at least on the priest's side, to prevent him bumping his knee.* **d** *Reaching forward when standing upright, illustrating the extent of reach*



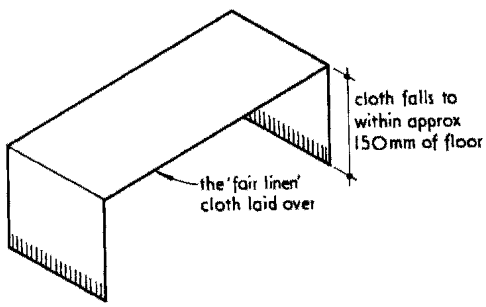
a *Monolith*

b *Support at four corners*

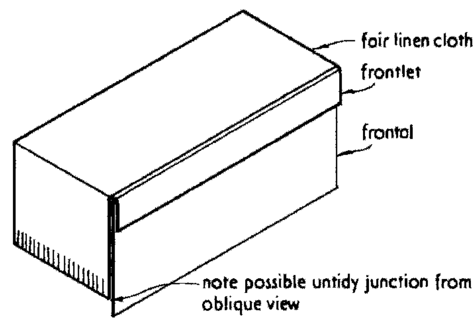
c *Centre support*

d *Centre support plus short end walls*

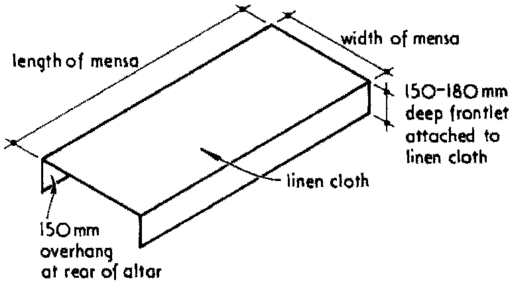
34.14 *Supporting the mensa (altar top). Note that RC altars should not oversail their supports by more than 150 mm, so that the bishop can pass his thumb over the joints at the Consecration*



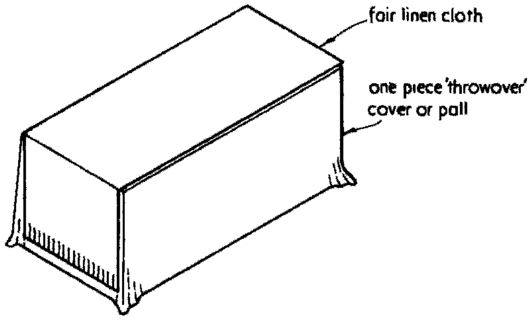
a *Second cloth*



c *Final appearance*

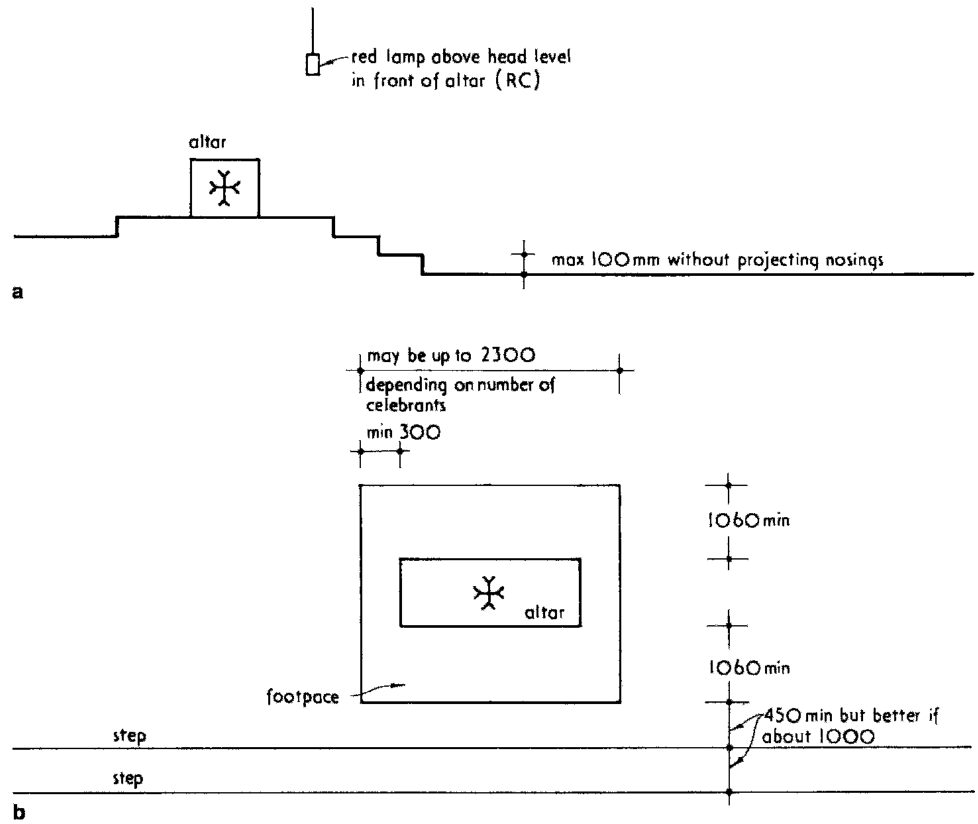


b *First cloth*

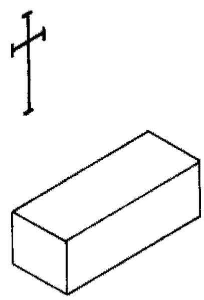


d *One-piece throwover altar cover. This may have loose draped corners as shown, or tight-fitted corners*

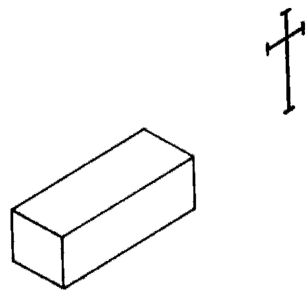
34.15 *Clothing the altar*



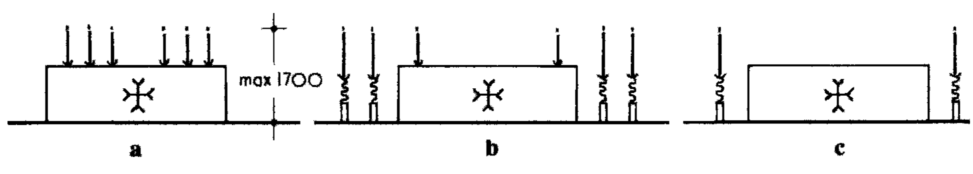
34.16 *Space around the altar. Keep altar as low as possible, usual maximum three steps. Position of the altar can also be defined by use of a canopy, structure, lighting, floor pattterns, etc.* **a** *Section.* **b** *Plan*



34.17 *The cross behind the altar at a height where it will not be obscured by the priest. Crosses are not usually placed on the altar in 'facing the people' churches*



34.18 *The cross forward of the altar to one side or suspended above*



34.19 *Arrangement of candles.* **a**, **b** *Six candles.* **c** *Two candles only. Candles may also be placed on a step lower than the altar to reduce height and obstruction to view*

11.02 Altar rail

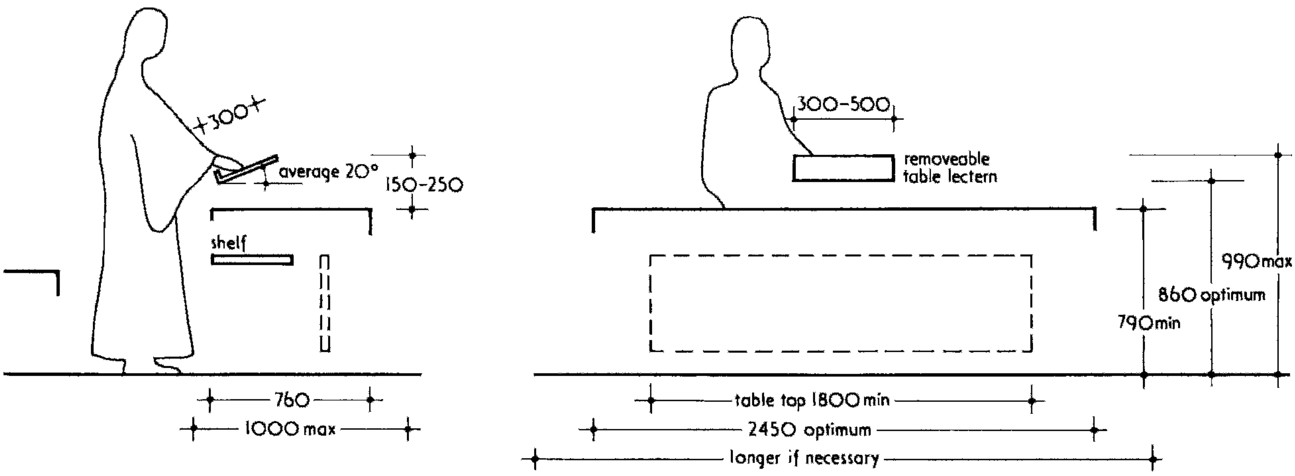
A rail may be dispensed with in some churches, but most will still provide lengths of rail for kneeling to receive communion. It need not be continuous, but must be rigid and firm. Minimum dimensions are given in **34.23** and **34.24**.

11.03 Credence table

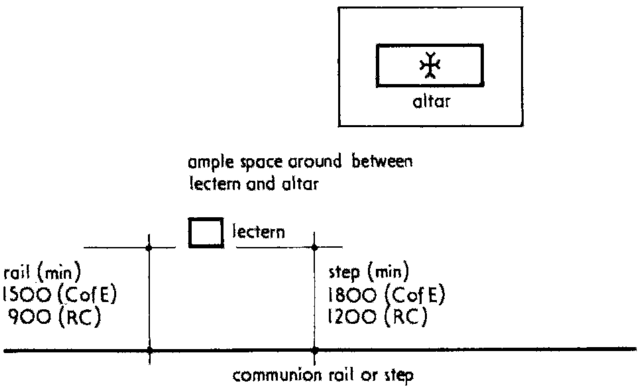
This serves as a sort of sideboard for water and wine, but check if anything else is to be placed on it (e.g. offertory money, service books, etc.) in which case a shelf below the table may be needed. It should be to the right of the celebrant within the sanctuary but not where it might cause a visual obstruction. It could be a shelf instead of a freestanding table. Dimensions will vary from about 610 × 760 mm to 1200 × 460 mm, with a minimum height of 820 mm.

11.04 Seating for officiants

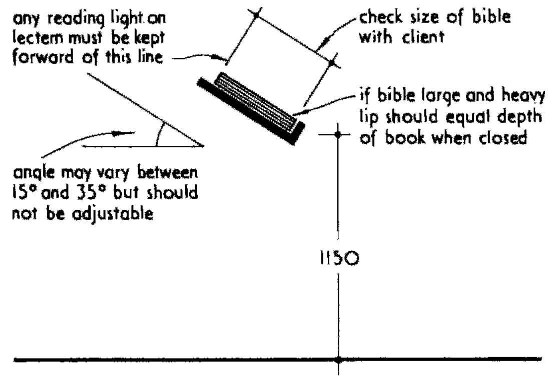
These will vary considerably and requirements must be established with the local community. Ceremonial seats for priests. In Roman Catholic churches the 'president's seat' will be on the centre line



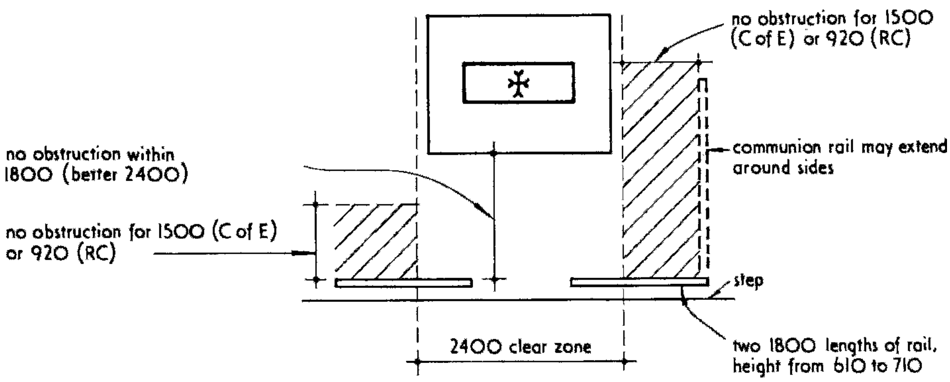
34.20 *Communion table with table lectern for use in Presbyterian churches instead of the altars described above*



34.21 *Minimum dimensions around lectern depending on whether communion rail or only a communion step is provided*



34.22 *Minimum requirements for lectern*



34.23 *Clear space requirements around communion rail*

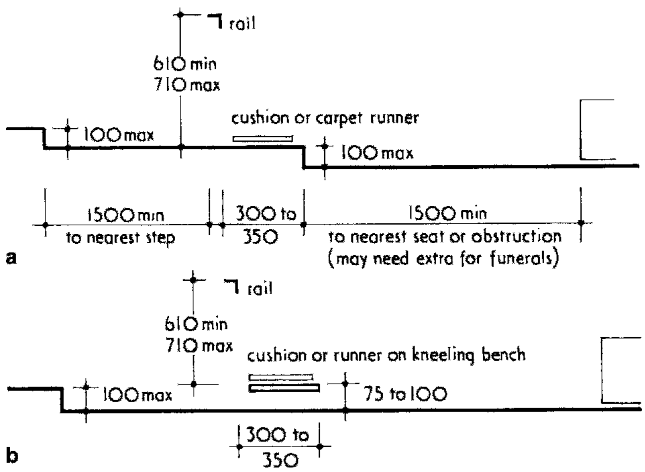
behind the altar, raised up on one or two steps, **34.25**. The seat, which is used by the priest, must not look like a bishop's throne and will usually not have a back to it. The bishop's throne is portable, and placed in front of the altar whenever he visits the church. In Church of England churches it is often better to have the ceremonial seat (which is used by the bishop) at the side of the sanctuary facing the altar.

Incidental seating should be kept to a minimum. It will be needed for additional priests, servers, and lay people on special occasions. It will usually be in the form of benches at the side of the sanctuary.

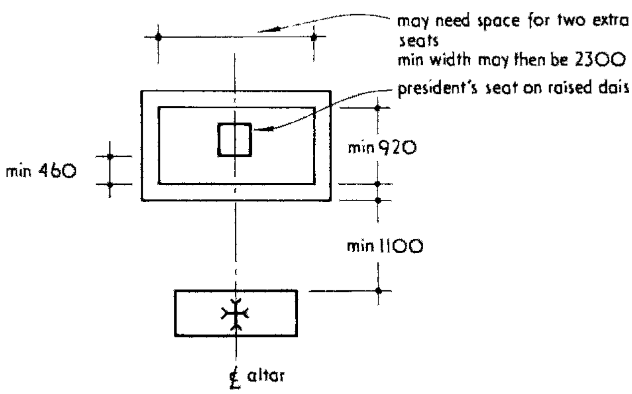
Stalls will be needed (especially in Church of England churches) for priests at matins and evensong at the side of the sanctuary. Dimensions are similar to those for congregational seating (see paragraph **14**) except that as priests are vested they will need more room to move in and out. Surface for resting a book should be deeper (say, 300 mm) and almost horizontal – not sloping – with a shelf below.

11.05 Pulpit

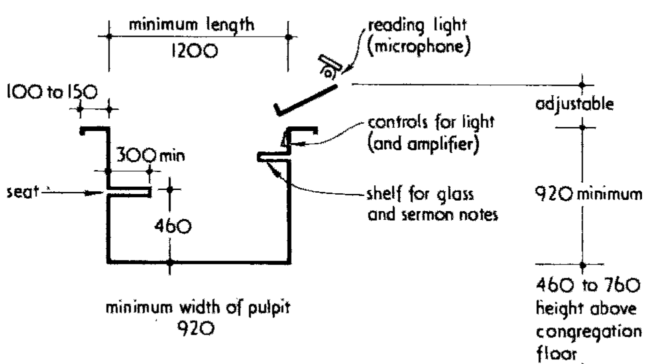
This should be sited outside but close to the sanctuary. No particular location is now insisted on apart from functional reasons of good sight and sound. Minimum internal area is about 1–2 m^2. Access should desirably be from the side (if from back, fit a door). Other details are shown in **34.26**. A Presbyterian pulpit may be behind the altar or at either side.



34.24 *Dimensions for altar rail (i.e. outside central zone of sanctuary). In a new Roman Catholic church there is unlikely to be a second step in the sanctuary, and the minimum unobstructed distance on the sanctuary side of the rail is 920 mm. It is also normal for the whole of the sanctuary to be one step above the nave, but too many steps should be avoided.* **a** *With stepped floor.* **b** *With flat floor*



34.25 *Dimensions around the President's seat*

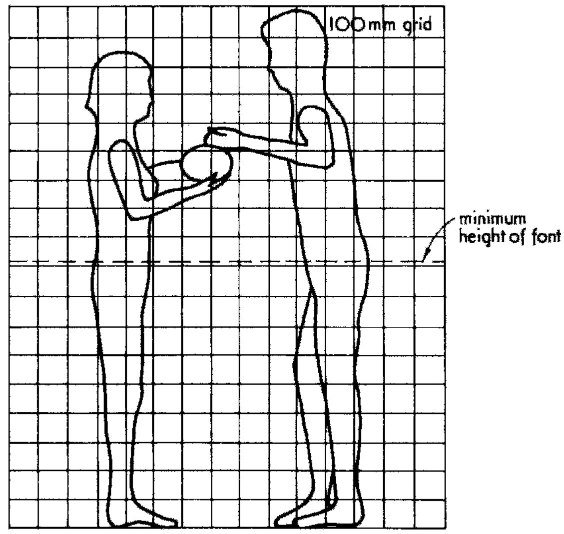


34.26 *Pulpit dimensions*

12 FONT

12.01 Description

In Roman Catholic churches movable fonts are not permitted and they are not generally approved of in the Anglican communion. They can be used in Presbyterian and Methodist churches.



34.27 *Anthropometric diagram showing the critical action at the font*

In Church of England churches fresh water is used for each baptism drained to a separate soakaway. In Roman Catholic churches water is blessed once a year and the baptismal water is stored in the font which has two compartments.

12.02 Dimensions and shape

Anthropometric requirements are shown in **34.27**. Shape is governed by the needs of the priest (space for service book and other small objects); the comfort of the priest in holding the baby; and the safety of the baby (the priest should not have to lean too far over).

12.03 Position of font

Various alternative positions are shown in **34.28**. The font must be approached from the church (congregation) side but be divided from it in some way (e.g. by difference in floor or ceiling levels). It must be in a prominent position and be seen by the congregation when seated, or space provided for most of the congregation to stand around. It should be a separate focus from the altar and therefore possibly not in the sanctuary.

13 RESERVATION OF THE SACRAMENT

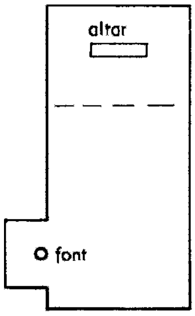
13.01 Siting

The reserved sacrament in Roman Catholic churches (the consecrated bread of the Eucharist) is not now normally kept in a tabernacle on the altar. It is normally kept:

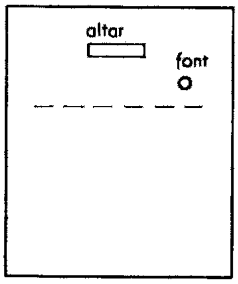
- In a separate chapel outside the sanctuary
- In a position which is architecturally important
- Where its location will be easily recognised by the congregation.

The requirements are complex and the practice of the local church community must be established and agreed with the Diocesan Advisory Committee. **34.29** and **34.30** show height limitations.

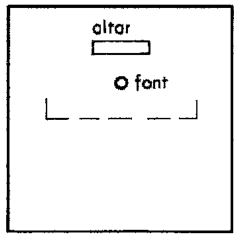
The reserved sacrament is occasionally found also in the Church of England, but is more rare and many methods of reservation are practised. For more explanation see the AJ information sheet 1529 contained in *Church buildings.*



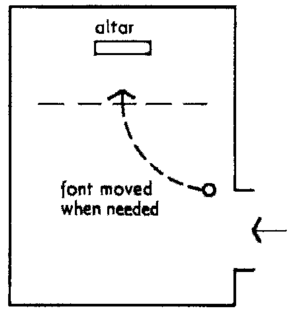
a *In separate baptistery. Acceptable if only baptism proper is performed here with the rest of the service is in the main body of the church*



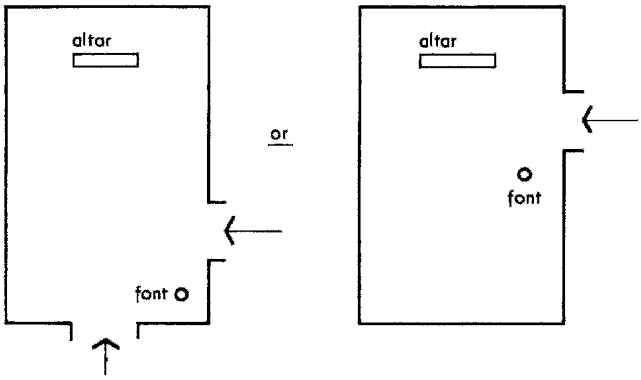
b *Font in sanctuary. It may compete with altar, or be made insignificant by it. But in a Presbyterian church, the font is often in this position although lower than the table and possibly on a side extension of the lowest sanctuary step*



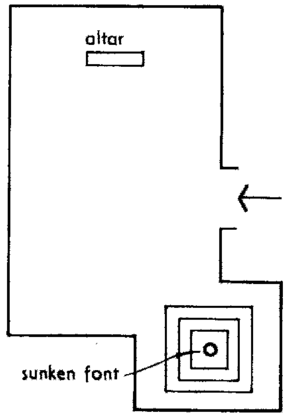
c *As for* **b**, *but the font is also an obstruction to sight*



d *Care is needed with a moveable font to retain the dignity of one of the church's great sacraments*

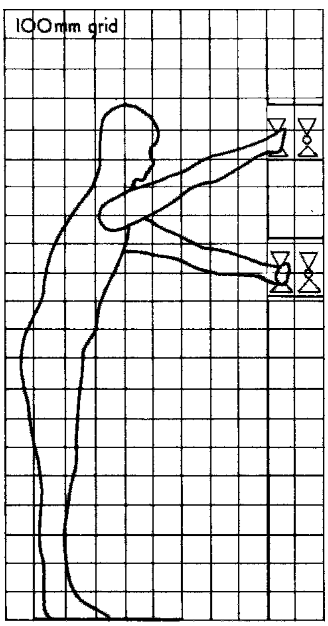


e *and* **f** *When font is placed near the entrance it is important to have the entrance near the font and not the font near the entrance! This may mean that the main entrance is in front of the people's seats and not behind*

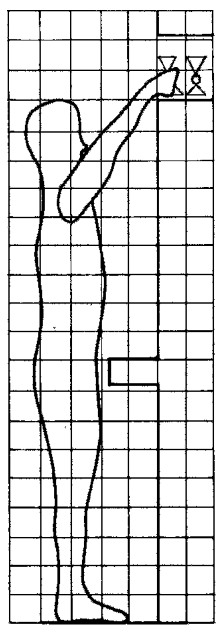


g *The font is sunk into a 'dry pool' with a 'drowning' symbolism*

34.28 *Variations on font positioning*



34.29 *Removing ciborium from tabernacle and putting on lower shelf*



34.30 *Maximum height to give view of back of tabernacle*

14 GENERAL ARRANGEMENTS

14.01 Entrance requirements

- Provide wind lobbies outside entrance doors;
- minimum clear door width (for processions and funerals) should be 1.7 m (1.1 m in a small church); minimum clear height (for processional cross) 2.3 m, otherwise 2.05 m is sufficient;
- provide proper access for disabled people (see Designing for the disabled);
- provide secondary exit door, especially for weddings;
- provide gathering spaces inside and outside the church as part of the normal exit route where people can naturally gather to talk;
- where needed (especially in RC churches) place a holy water stoup on the entrance side of each doorway leading into the church. Rims should be 710 to 760 mm above the floor;
- provide considerable space for notices of all types in a conspicuous position;
- allow space, where required, for one or two small credence tables just inside the entrance;
- provide facilities for selling of publications, etc.;
- where possible provide access from the entrance area to the WC and to the sacristy or vestry;
- as a general rule try to keep the purely *secular* activities more in view when the congregation is *leaving* than when entering for a service.

14.02 Arrangement of seating

The congregation should be continuous with the minister with no strong dividing line between them. Equally, the congregation must be united with one another and all must have good access to circulation and to the sanctuary. Seats facing each other around an altar should not be closer than about 6 m, and nobody should look sideways on to anybody else closer than 1.5 to 3.0 m.

14.03 Spacing and dimensioning of seats

Anthropometric details are given in **34.31**. Note also:

- minimum dimension of seat plus kneeling space front and back is 920 mm. Where congregations do not kneel (e.g. Methodists, Presbyterians), the dimension can be reduced to 760 mm;
- leave a space of about 280 mm between front edge of seat and back edge of kneeler;
- allow minimum width of 510 mm per person;
- maximum length of row is 10 persons (5.1 m) with access from both ends, or 6 persons (3.06 m) with access from one end;
- the ledge for hymn books should be about 150 mm wide; (300 mm for the choir).

14.04 Circulation

Basic dimensions are shown in **34.32**. Space must be allowed for invalid chairs during the service where the occupant can participate but not block circulation.

14.05 Sound reinforcement

Many churches now use systems of sound amplification of speech, singing and instrumental music. This is particularly important in connection with ‘loop’ systems for people who are hard of hearing. This is not of course confined to Christian buildings; it applies equally to other religious buildings (e.g. see para **18.03**).

Further, the increasing use of miniature and lapel microphones with radio transmitter/receivers linked to such a system enables the person leading the worship to move around when speaking. He or she is no longer tied to the pulpit and lectern. These traditional locations were determined largely by audibility and visibility requirements and the changed circumstances are now affecting their design and location; indeed some question whether they are needed at all. This can greatly increase the flexibility available, particularly where the worship function shares in a multi-use space.

15 VESTRIES AND SACRISTIES

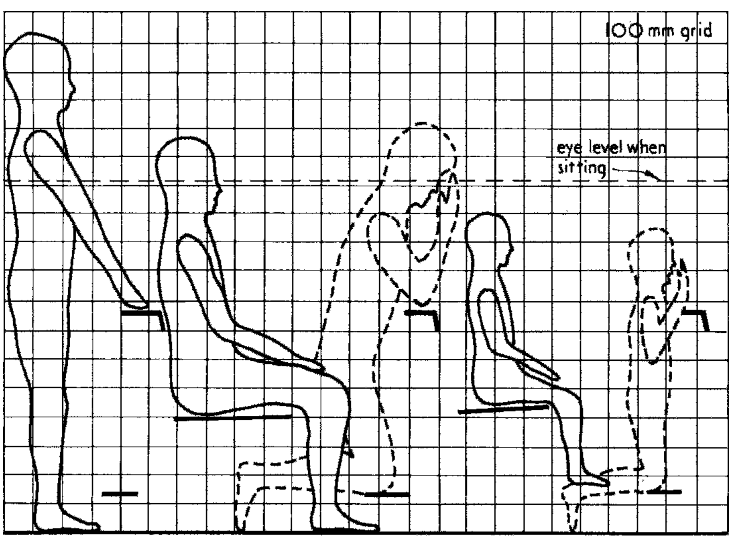
15.01 Accommodation

Accommodation requirements will vary considerably. The most lavish could include:

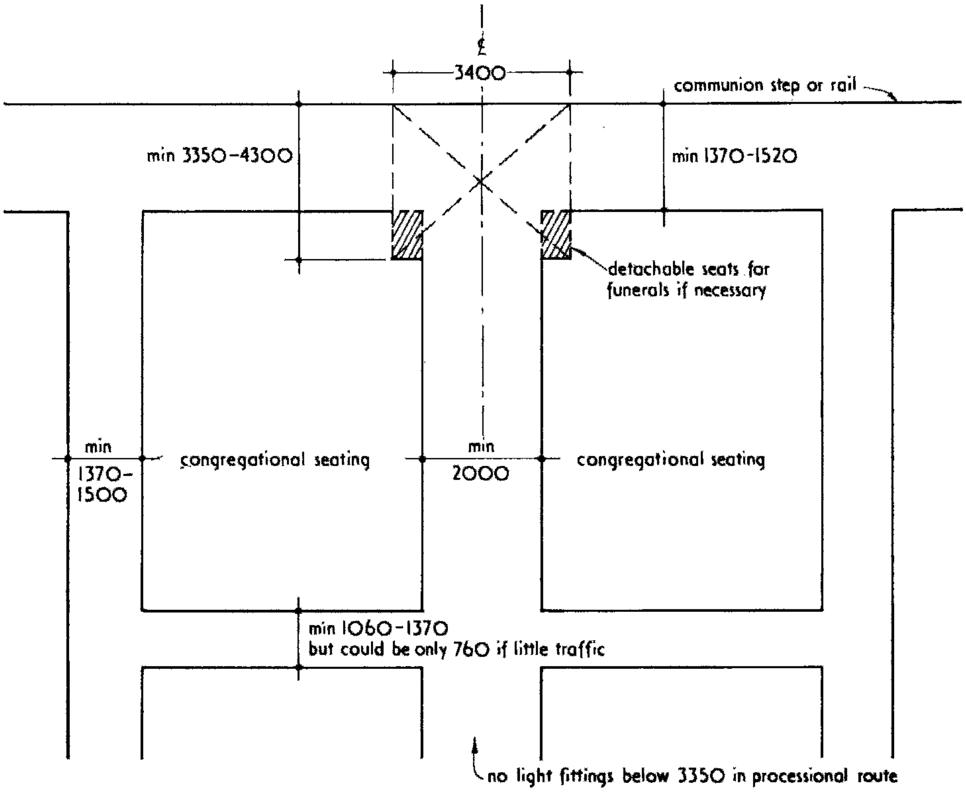
- Priest’s sacristy (sometimes called priest’s vestry)
- Server’s vestry
- Choir vestry and practice/committee room
- Women’s choir vestry
- Churchwardens’/interview room
- Cleaners’ room } sometimes placed together
- Flower arrangers’ room } and called working sacristy
- Priest’s WC
- Men’s and women’s WCs
- General storage
- Small kitchen.

15.02 Planning relationships

The tradition of the vestry/sacristy complex opening directly onto the sanctuary has disadvantages: it emphasises the separation of priest from the congregation and makes sharing of toilet facilities difficult. The vestry could be near the entrance (but ensure security) so that priest and procession go through the congregation



34.31 *Critical dimensions for seating. Black lines indicate one particular solution found very satisfactory in practice. The dotted line indicates ‘eye’ level when sitting, and concerns the relationship with the altar top*



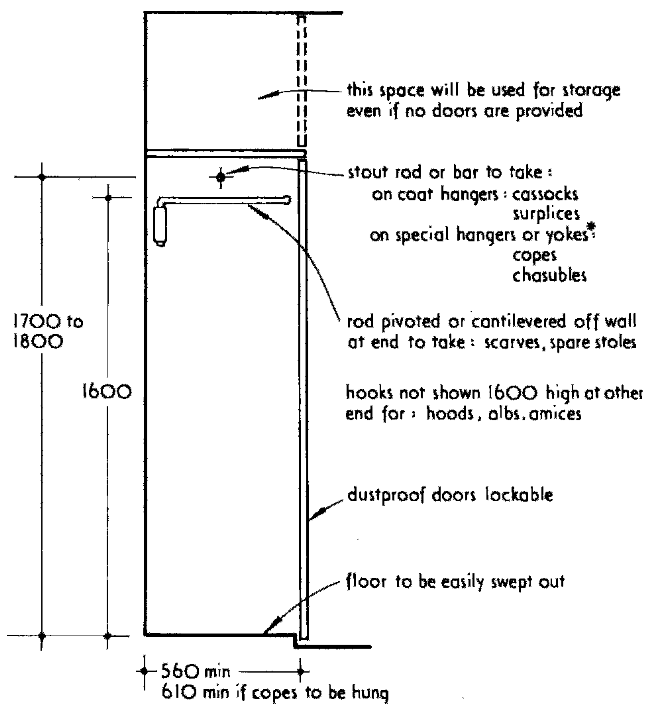
34.32 *Aisle widths. Size and pattern will depend on overall plan and liturgical considerations. Seating may be fan shaped or in blocks around the sanctuary*

to their place in the sanctuary. Since children often participate in adult worship for only part of its duration, movement between the main worship space and ancillary rooms should be considered.

There should be a lobby with double doors between the choir vestry and the worship room, and a space out of sight of the congregation for processions to form up. A door direct to the outside is essential as priests and choir should not have to go through the worship room to reach their vestries.

15.03 Detailed design

There is a very wide range of objects and vestments to be stored and the precise requirements must be ascertained. A vestment storage cupboard is shown in **34.33**. Doorways should be 1700 mm wide × 2300 mm high.



34.33 *Section through vestment cupboard*
Notes:
* *These to be fitted with 'trouser bar' under to take stole and maniple of each set of vestments*
† *Choir vestry: part of bar at 1320 if there are children in the choir*

16 CONFESSIONAL

16.01 Design requirements

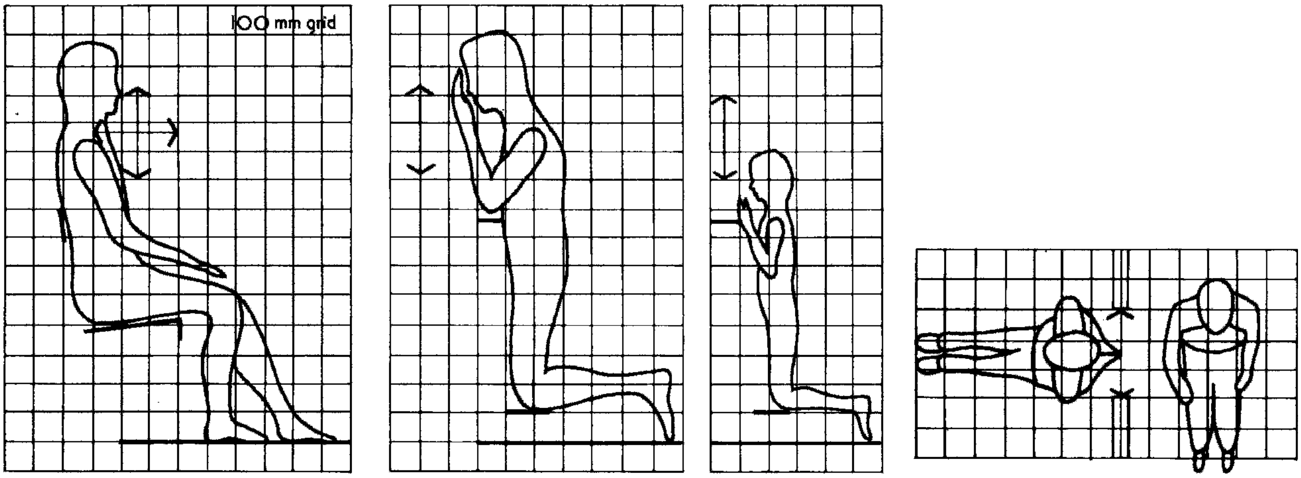
Priest and penitent must be able to hear what each other has to say without being overheard by others. The bishop's requirements must be established, and the psychological expectations of the parish.

Either priest and penitent may be enclosed in an acoustically isolated box or, more desirably, they may be visible but placed far enough away from other people to make a physical acoustic barrier unnecessary. Basic dimensions are shown in **34.34**.

17 ORGAN AND CHOIR

17.01 Music in church

Use of music in worship can be a highly emotive subject with the type of organ and the placing of the choir two of the most difficult problems. For new churches organs based on the 'werk prinzip' (sometimes called 'neo-classic') should be considered rather than the more traditional Victorian organs with high wind pressures and powerful but muffled tone. The organ builder should be brought in at an early stage of the discussions.



a *Relationship of grille to seated priest*

b *and* **c** *Kneeling penitents showing positioning of grille where it will serve both adult and child*

d *Plan view of priest and penitent*

34.34 *Anthropometric study of confessional*

17.02 Relationship of musical elements

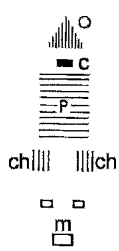
A few basic principles must be observed:

- The player must be with his or her instrument (i.e. the organ console must be near the pipes), **34.35**
- The choir should be as near as possible to the organ, **34.36**
- Ministers should not be separated from either people or organ, **34.37**
- People should not be placed between the choir and ranks of pipes, **34.36** and **34.37**
- The organ must be in the main volume of the building and raised above the floor so that the pipes are above the heads of the listeners.

Different possible locations of choir, organ and congregation are shown in **34.38**.

34.35 *Bad organ arrangement. Key: o organ, c organ console, p people, ch choir, m minister, a altar*

34.36 *Bad position of choir and people, key as for* **34.35**



34.37 *Bad position of choir, minister and people, key as for* **34.35**

Part C Non-Christian places of worship

18 SYNAGOGUES

18.01 History

The original churches evolved from the synagogues set up to supplement and eventually to supplant the Holy Temple in Jerusalem. It is therefore not surprising that they have many elements in common.

There are two main strands of Judaism: orthodox and progressive. As far as the design of the synagogue is concerned the only difference between them is that in the orthodox tradition men and women are rigidly segregated, and women take no direct part in the service.

18.02 The sanctuary

Holy Ark

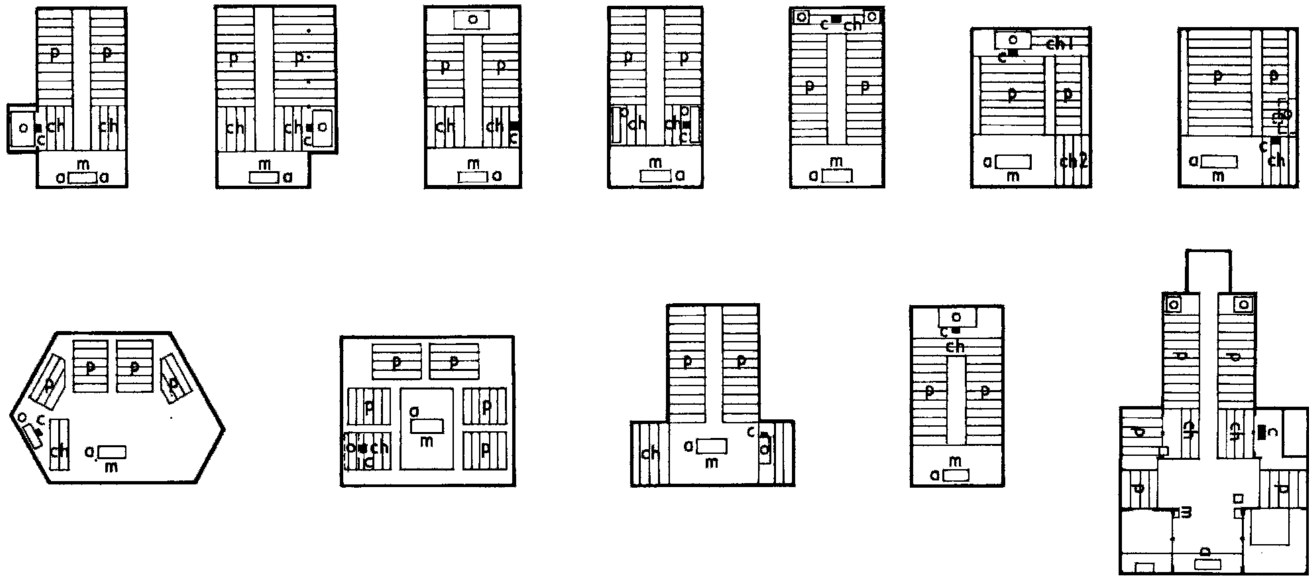
The principal architectural feature of the synagogue is the *Aron Kodesh* or Holy Ark, **34.39** which contains the Scrolls of the Law. These scrolls, **34.40**, are hand written on a very long strip of parchment, and are the first five books of the Old Testament, called the *Torah.* Each end of the parchment is fixed to a stave, and the parchment is rolled around the staves. Because the portion to be read is not immediately accessible, as in a conventional book, it is usual to have several scrolls in the Ark, so that the correct place is not having to be found during the service.

Scrolls, when not being read from, are bound, covered with a mantle, and usually adorned with a silver shield, a pointer and *rimonim.* The latter are detachable silver finials, often decorated with small bells, for the top ends of the staves on which the parchment is rolled. The Ark itself is raised and approached up steps from the floor of the synagogue. It should preferably, but not necessarily, be on the eastern wall of the synagogue. It has both doors and a curtain. It should be able to accommodate at least four scrolls, and may well be large enough for many more. It needs internal lighting, *not* operated by a door switch.

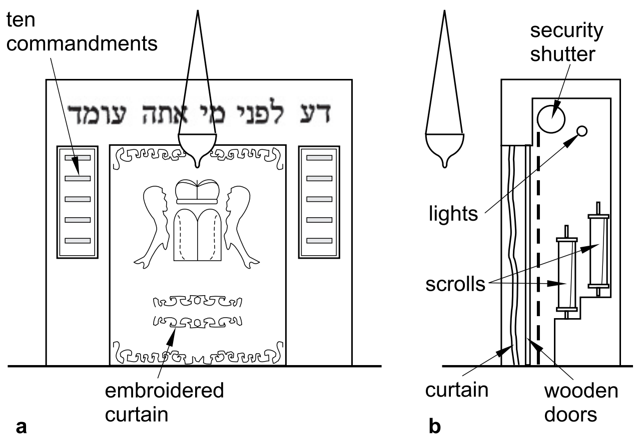
Traditionally the Ark is decorated with particular Hebrew texts, by representations of the Tablets of the Ten Commandments, and often by heraldic beasts.

Bima

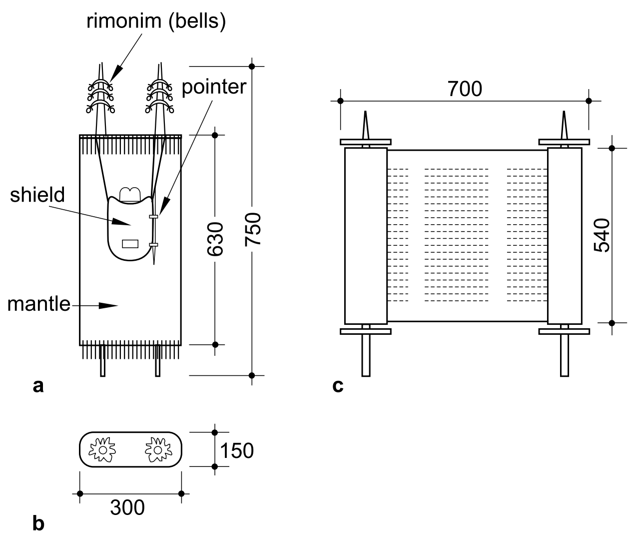
The service is conducted from a reading desk raised above the floor of the synagogue. Traditionally this should be in the centre of the space, as in the plan of a synagogue in **34.41**; but some synagogues have been designed with the Bima integrated with



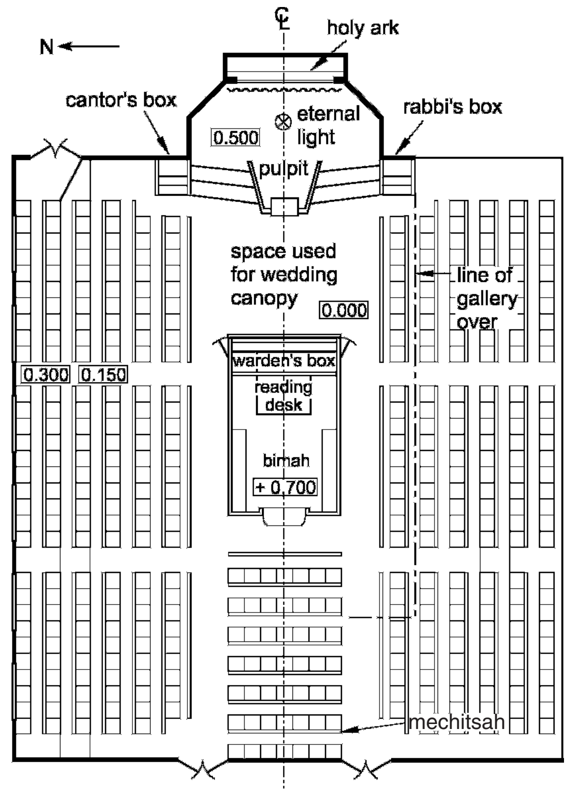
34.38 *Good relationships of organ, choir, congregation and minister/priest. Key as for* **34.35**



34.39 *Holy Ark.* **a** *Elevation, inscription means 'Know before whom you stand',* **b** *Section*



34.40 *Torah scroll,* **a** *Elevation,* **b** *Plan.* **c** *Scroll when open, on reading desk or when elevated*



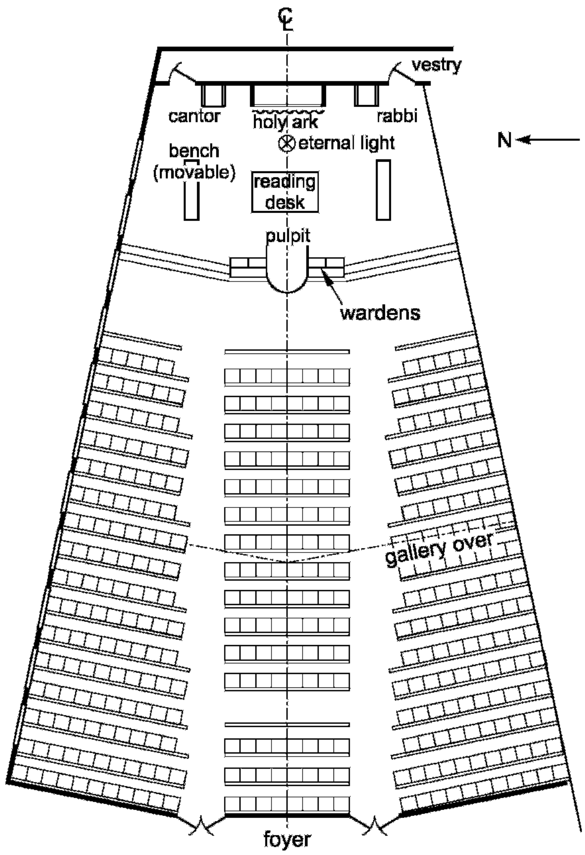
34.41 *Plan of synagogue with central Bima. This would seat 396 men downstairs, 7 women downstairs and 275 women in the gallery*

the Holy Ark, **34.42**. There is a custom that the Bima should be three steps above the floor.

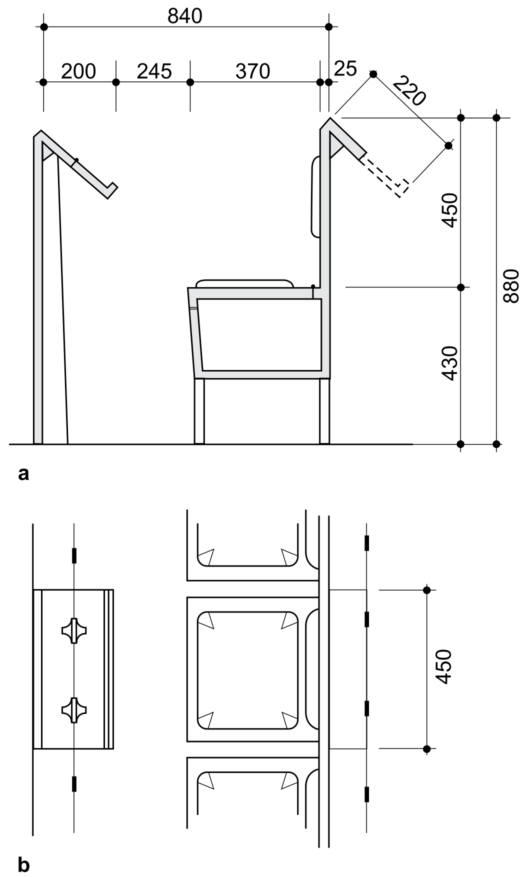
The Bima contains a reading desk large enough to hold an open Scroll, with at least five people around three sides of it. The Bima should also be able to accommodate two people holding unused scrolls, with sufficient space for dressing them (separately). Facilities are provided for scroll vestments to be kept while that scroll is being read, including pairs of 'spikes' for the rimonim.

Pulpit

A pulpit is provided for the minister or rabbi from which to deliver a sermon. It is usually placed on the longitudinal axis of the synagogue immediately in front of the Holy Ark, and is not raised above the Ark's level. It does not have a door.



34.42 *Plan of synagogue with Bima before the Holy Ark, seating 376 downstairs and 234 upstairs. For weddings the reading desk and benches are moved aside to accommodate the canopy on the Bima*



34.43 *Seat and bookrest.* **a** *Section. The bookrest folds up to make more clearance. The seat lifts to reveal a locker for prayer book, bible and prayer shawl.* **b** *Plan*

Congregational seating

The congregational seating surrounds the Bima. Since services can be very long (on *Yom Kippur* they take the whole day), the seats have to be comfortable. It is common for them to have lockable boxes beneath, as on the Sabbath orthodox people do not carry their prayer books, prayer shawls, etc. In larger synagogues the seating is banked to enable a good view for all.

The reading of the scroll is followed by the congregation from Hebrew bibles which are quite large. Each seat, therefore, needs a bookrest, **34.43**. However, some prayers have to be said facing the Holy Ark; this means turning sideways in many seats. It is normal for the bookrests to be hinged to increase the clearance. Prayers are said either standing or sitting. Congregants *never* kneel in a synagogue.

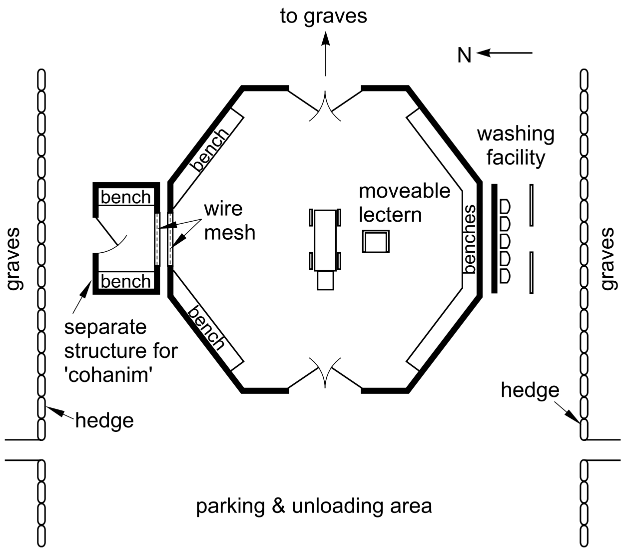
Most larger synagogues have galleries and in orthodox synagogues the women sit here. Since the use of a lift is forbidden on the Sabbath and Holydays, they are not usually provided in orthodox synagogues. Women unable to climb stairs are accommodated in a section of the downstairs behind a curtain *(mechitsah)*.

Processions

These are a feature of synagogue servces. At services where readings are given from the Torah, the scroll or scrolls are taken from the Holy Ark and processed to the Bima before the reading, and processed back afterwards. On the Feast of Tabernacles most of the men will process behind the scrolls carrying palm branches and citrons. On the Rejoicing of the Law, all the scrolls that the congregation owns will be processed around the synagogue many times. The aisles must be wide enough for these processions.

Other features

- A *Ner Tamid*, eternal light, hangs before the Holy Ark.
- The rabbi or minister has a ‘box’ normally placed to one side of the Ark, with a seat facing the congregation.
- The *chazan*, or cantor, has a matching box on the other side of the Ark.
- The wardens have a box usually placed just forward of the Bima facing the Ark. It should have room for four wardens.
- Where there is a choir it may be accommodated in a normal seating area, or in a special place such as above the Holy Ark.
- Storage near the entrance should be provided for prayer books, bibles and prayer shawls.
- A display board similar to a hymn board is provided for service details.
- Progressive congregations need an organ. Some orthodox synagogues have a limited musical facility for weddings.
- For weddings, a *chupah* (canopy) is erected on the Bima if there is room, or forward of it on the floor of the synagogue. The couple and the rabbi are accommodated under the chupah, with as many others of the family and witnesses as there are room for.
- Funerals only take place in synagogues on rare, very special occasions. A special prayer hall, **34.44** is provided at Jewish cemeteries. This is a covered open space with a few benches around the walls for infirm people. The floor is at ground level: the coffin is not carried by bearers but pushed on a wheeled cart. There are doors at both ends to signify the progress of man from birth to death. A small detached building on one side with open windows is provided for *cohanim* who are not permitted to enter any building containing a corpse.
- Purification using water, analagous to Christian baptism, takes place by total immersion not in a synagogue but in a separate facility called a *mikvah.* The design of this can be similar to a hydrotherapy pool. Such purification is not for infants, but is used by the orthodox at adult conversions, on certain occasions by women and by some men on a weekly basis.



34.44 *Plan of cemetery prayer hall*

18.03 Building services

Lighting
Lighting levels should be high as many services take place after dark. It is traditional for all available sources to be used even in daylight. Some may be symbolic, such as a *menorah* near the Holy Ark.

Heating
As services can be long, an efficient heating system is essential. Commonly this comprises hot water radiators; radiant sources such as used in churches are not popular.

Ventilation
This must be efficient as on occasion the synagogue will be packed. Control should preferably be automatic. It should not produce draughts or noise.

Speech reinforcement
This may be required in progressive synagogues, but is not permitted by the orthodox on Sabbaths and Holydays. However, nearly all synagogues are now allowed to use 'loop' systems for deaf people, and this will require microphones to be placed very discreetly on the Bima, pulpit and the Holy Ark controlled automatically.

Large Orthodox synagogues need to be carefully designed for excellent acoustics in view of the lack of any reinforcement system. Even so, this implies a maximum capacity of about 1500.

18.04 Outside the sanctuary

Since services are long, synagogues need adequate cloakroom and lavatory accommodation. A vestry for the rabbi and chazan is often provided at the Ark end of the building with a direct entrance into the sanctuary close to the rabbi's box.

There is a foyer between the street entrance and the sanctuary and there are stairs from this to the ladies' gallery. The foyer should have notice boards to publicise the many activities in conjunction with the congregation. There may also be one or more built-in charity boxes (used only on weekdays). Immediately outside there will be a board giving the times of services, etc.

Most synagogues have additional halls, classrooms for religion school, kitchens, etc. Orthodox synagogues provide no car parking, as driving on the Sabbath and Holydays is forbidden. However, a very few parking spaces may be provided where land is available for the minister and for weekday use.

18.04 Holydays

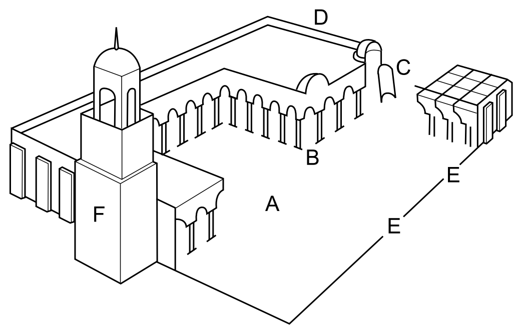
The High Holydays occur around September and congregations are much larger than on a normal Sabbath. Some buildings are designed to open up hall and classroom areas to the main sanctuary at this time; alternatively, one or more additional services are provided in detached halls. As Orthodox synagogues use no electrical speech reinforcement, additional services are separately conducted. This usually involves using a mobile Holy Ark with the reading desk on the floors of the hall used; thus special provision in the building design for these occasions need not be made.

19 MOSQUES

19.01 Elements

Muslims actually need no special place to pray – praying can and does take place in the street. Where a purpose-built mosque is provided, it should comprise and conform to particular rules.

Every mosque has four basic elements, **34.45**. These are the *Mihrab, Bab Al-Sadir*, dome and minaret. Both the dome and minaret have a symbolic rather than a utilitarian function in contemporary mosque design. (Terms in *italics* are listed in the Glossary section **19.10**).

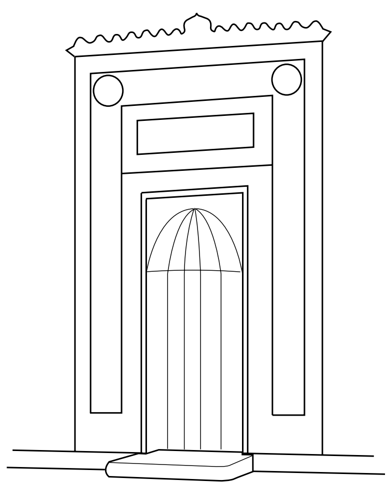


34.45 *Main features of a mosque. Key: A Fountain, B Worship hall, C Mihrab, D Qibla wall, E Entrances, F Minaret*

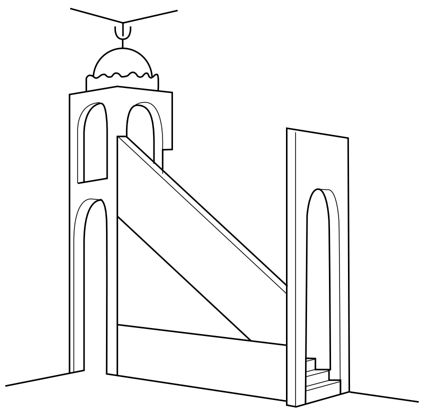
19.02 The Mihrab

The Mihrab, **34.46**, is indispensable, as it indicates the direction to the *Kaaba* in Mecca, Saudi Arabia. The direction to Kaaba is also known as *Qibla.* In symbolic terms, it is the most important element of the modern mosque.

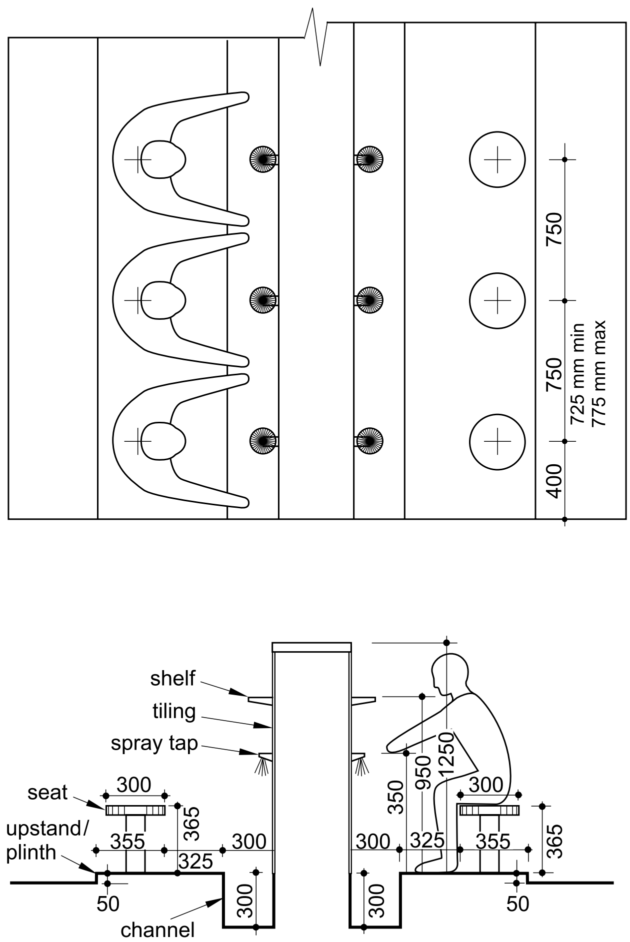
It is essential that this direction is accurately established. The Ordnance Survey office on application can give the precise bearing and distance to Mecca, Saudi Arabia from anywhere in the UK. Generally it is in a south-easterly direction with a bearing of approximately 118° from the north.



34.46 *Mihrab*



34.47 *Minbar*



34.48 *Plan and section of ablution*

The Mihrab is where the Imam leads the congregation for prayer and also houses the *Minbar*, **34.47**, a pulpit from which the *Imam* will address the congregation, particularly on Friday. The Minbar might be a low platform, or be at the head of a flight of stairs.

19.03 Bab Al-Sadir

Bab Al-Sadir is the grand entrance. In Arabic, 'Bab' means a gate or door and Al-Sadir meaning the frontal. Traditionally it symbolises the importance of the mosque in the life of the city.

19.04 The dome

The dome is generally centrally located over the main prayer hall and there may be more than one dome to a mosque. It is first and foremost a landmark, indicating the importance of the mosque to the life of the community. In addition, it has two practical functions; one is to echo the words of the Imam inside the mosque and the other is to cool the hot air when it rises upwards and draws in cooler air from outside. Modern technology compensates for the two functions above.

19.05 The minaret

The minaret is used to call the faithful to prayer. It is usually in the form of a circular, octagonal or square tower which projects above the mosque with at least one balcony along its length. It is possible to provide more than one minaret in a mosque and more than one balcony for each minaret.

Traditionally the minaret has an internal staircase leading up to the uppermost balcony, but these days it usually only carries a speaker system so that the Muezzin stays at ground level (sometimes a recording is used).

19.06 Prayers

Prayers are said standing, kneeling and prostrate. There are therefore no seats, but the prayer hall is carpeted and the carpet is marked with imprinted prayer mats pointing to Qibla. Allow at least 0.75 m^2 per person for praying.

No shoes are allowed past the main entrance, and there are places to leave them, usually in racks, to one or both sides of the entrance.

19.07 Other essentials

Other essentials to be provided are the *Wuzu, Wudu* or ablution area, the *Janaza* or morgue, and *Kutub Khana* or library.

19.08 Ablution area

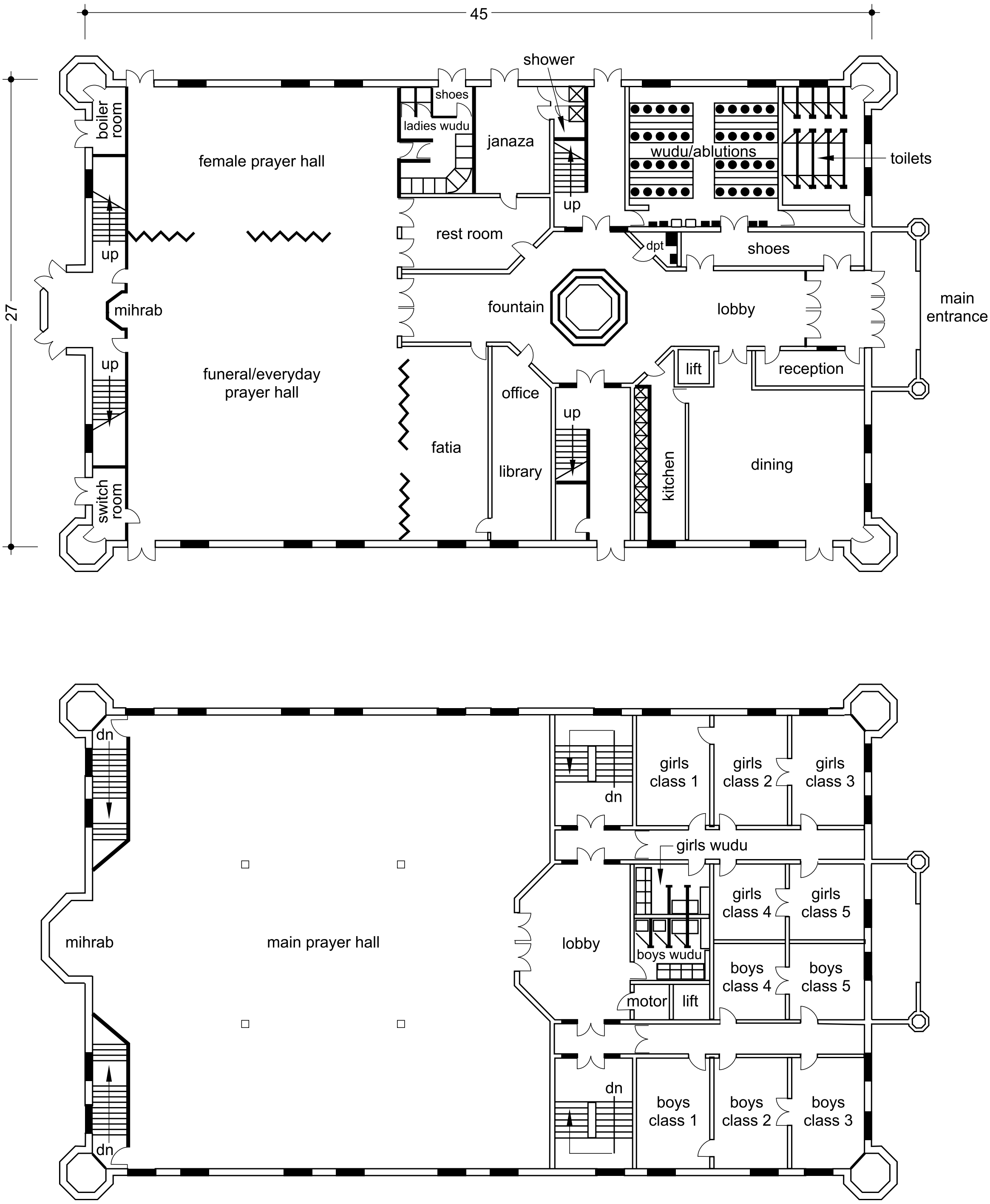
The ablution, **34.48**, is where the faithful wash their hands, elbows, faces, behind the ears and their feet in preparation for praying. This is performed under running water. The ablution area also houses the toilets and showers. The number of ablution seats, toilets and showers is governed by the size of the prayer hall.

19.09 Design

Mosque design must conform to particular detail rules, some of which are:

- Male and female entrance/exit, prayer hall and ablution must be separate
- Toilets should be in compartments not cubicles: i.e. must be of solid wall construction not thin partitions or gaps at floor level
- Their orientation is of paramount importance. Compartments must not face or back in the direction of Mecca
- Toilets to be of squatting type (see chapter 5) and have a water tap
- No other habitable enclosure or space should be behind the Mihrab within the confines of the site
- Toilets may not be situated under or over the prayer hall, and no drainage pipes whatsoever should pass under or over it.

It is important for the fulfilling of the client brief that the designer combine the four elements in proportion to each other. **34.49** shows plans of the two levels of a typical mosque.



34.49 *Plan of a mosque, ground and first floor*

19.10 Glossary

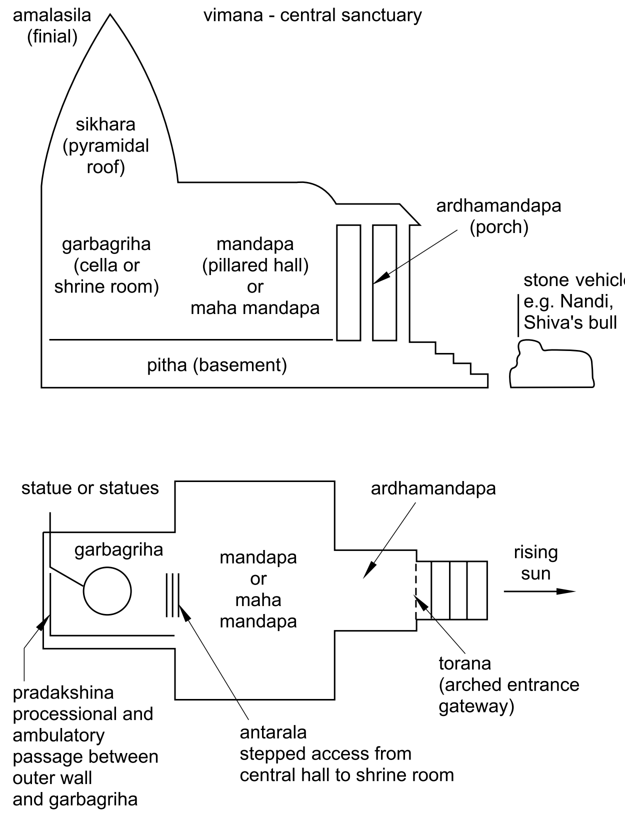
Bab	*Al-Sadir* main or grand entrance/gate
Imam	the holy man/preacher/leader of the prayer
Jami or Jame	Friday or congregational mosque
Janaza	morgue
Kaaba	the holy shrine in Mecca
Kutub Khana	library
Madrasa	school
Masjid	mosque
Mihrab	a niche in the Qibla wall indicating the direction to Kaaba
Minor or Minara	minaret
Minbar	pulpit or seat used by the Imam for Friday speech
Muezzin	person calling faithful for prayer
Qibla or Kibla	the direction of prayer oriented towards Kaaba in Mecca
Wuzu or Wudu	ablution

20 HINDU TEMPLE

20.01 Design

There are three main sections to a Hindu temple, **34.50**:

- The *garbagriha* or shrine room
- The *mandapa* or pillared hall and
- The *ardhamandapa* or porch.



34.50 *Hindu temple, longitudinal section and plan*

20.02 The garbagriha

This contains the object representing the deity, usually a statue. It may be covered by a canopy, or the roof of the garbagriha itself may be in the form of a pyramid. There should be an ambulatory called the *pradakshina* between the statue and the outer wall.

20.03 The mandapa

This is the central hall where the worshippers assemble. They approach the garbagriha through the *antarala* which steps up. Prayers are said here, seated upon the floor. A portable fire altar is brought into the room at the time of worship. Some of the worshippers play musical instruments, others assist the priest.

20.04 The ardhamandapa

This is traditionally orientated towards the rising sun, and also is raised above the ground by steps.

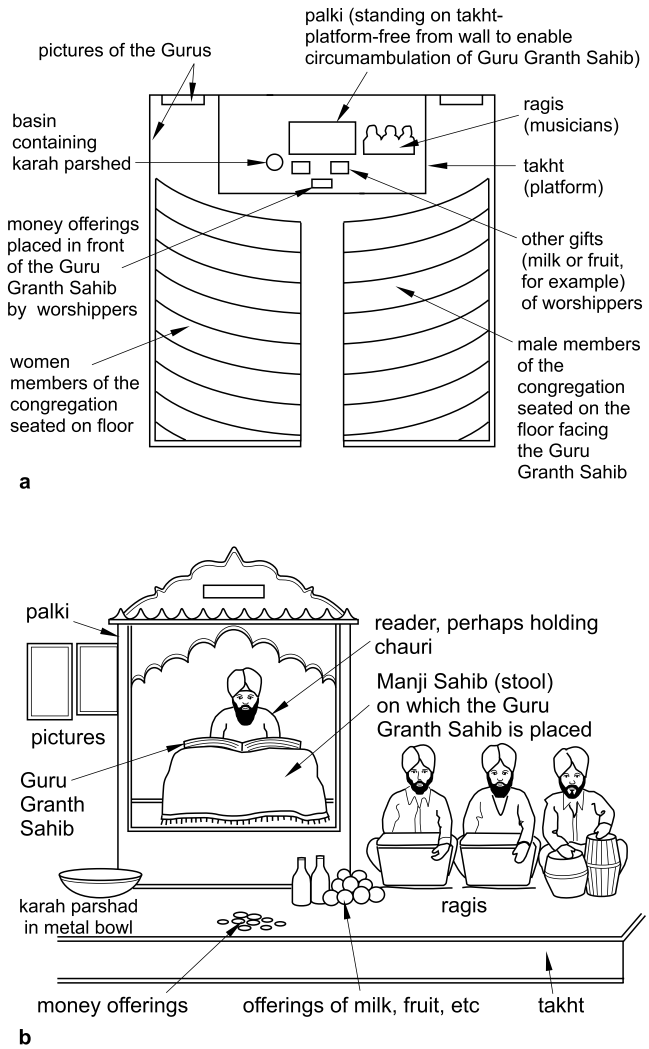
21 SIKH GURDWARA

21.01 Design

The gurdwara, **34.51**, consists of a single large room with the *takht* platform at the end furthest from the entrance. There are no special requirements for orientation. On the takht stands the *palki*, a canopy over the *Guru Granth Sahib* which is the focal point of the gurdwara. The Guru Granth Sahib is the Sikh scripture, and is kept on the *Manji Sahib*, a low reading desk. The palki is free of the wall behind to permit circumambulation.

21.02 Services

Worshippers enter the gurdwara at random times, go directly to the takht and prostrate themselves before the Guru Granth Sahib. They leave offerings of money or of kind on the takht in front of it. They then sit on the floor, men on one side and women on the other, leaving the central aisle for later comers. During the service, verses



34.51 *Sikh Gurdwara.* **a** *Plan. There is no standard shape but the Guru Granth Sahib must be the focus of attention always visible from all points of the room. The aisle is left free for worshippers to pay their respects to the Guru Granth Sahib before sitting in the congregation. Sometimes separate entrances are required for men and women.* **b** *Elevation of the Takht*

are read from the Guru Granth Sahib; hymns are sung, music is played by the *ragis*, musicians seated on the takht. The distinguishing feature of a gurdwara externally is the Sikh flag. A tall flagpole is therefore necessary.

Part D

22 CREMATORIA

22.01 Introduction

More people are cremated than buried now due mainly to the scarcity of land for cemeteries and the consequent high cost of grave space. However, some religions such as strict Catholicism and orthodox Judaism do not permit cremation.

In most cases of cremation a ceremony precedes the disposal. This may be religious or it may be a purely secular occasion. After the body has been cremated (which may not be immediately after the ceremony) the ashes may be:

- Deposited in a columbarium associated with the crematorium
- Scattered in a Garden of Remembrance also at the crematorium or
- Taken away for deposition or disposal elsewhere.

Crematoria may be municipal or commercial. In the former case they are usually situated in or next to a municipal cemetery.

Columbaria and Gardens of Remembrance can be provided on the cemetery land. Private crematoria will also provide these facilities, as they can be financially rewarding. The designer must establish a clear brief from a client in these respects.

22.02 Siting

The crematory (i.e. where the furnaces are housed) should not be sited near existing buildings because the effluent from the flue can be unpleasant under certain climatic conditions. The statutory situation requires that crematoria may not be sited closer than 183 m (92 m in inner London) to domestic property. Ideally, crematoria should be located in quiet surroundings, with as much natural landscape as possible.

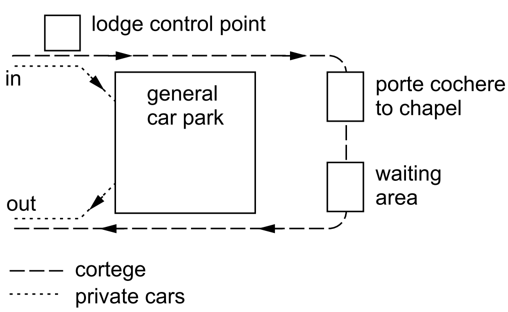
A minimum site of 1 hectare is required for the crematorium buildings themselves. Further space requirements will depend on whether a Garden of Remembrance is required, when a further hectare at least will be necessary, and more if commercial aspects are to be developed to the full. These areas include the space needed for traffic circulation, parking, a modest amount of room around the building, and the crematorium itself.

Vehicular access to the site should be simple and dignified and free from traffic hazards. The entrance should preferably not be immediately off a principal traffic route. If this is unavoidable, then it should be off a roundabout or where there is space in the central reservation of a dual carriageway for the hearse and mourners' cars to wait in a dignified manner.

22.03 On-site circulation

Clear routes should be provided within the site for vehicular and pedestrian traffic, **34.52**. Only the hearse, principal mourners' and disabled people's vehicles should be allowed beyond the car parking area. These vehicles should arrive at the building under a porte-cochère. The coffin will be transferred to the chapel and then the hearse and other vehicles routed to a waiting area, ready to pick up the principal mourners after the service. One or two parking bays should be provided close to the chapel for disabled people. All other mourners should park their cars in a car park away from the main building.

The entrances to and exits from the building should be located as far as possible from the furnace room so that mourners are not aware of the mechanics of disposal. The pedestrian traffic flow should follow that of the coffin into the chapel. Mourners arriving at the chapel should not meet mourners leaving the previous service. After the service, the people walk from the chapel to a covered way, where floral tributes are displayed, through to the chapel of remembrance (if provided) and then back to the car park via the garden.

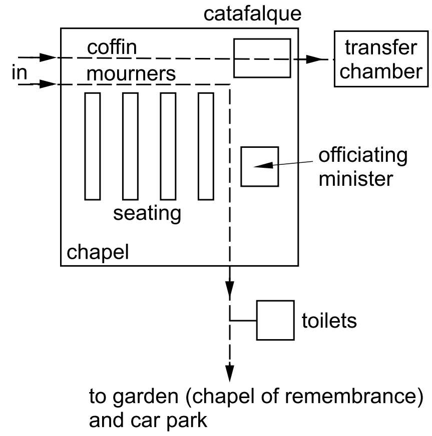


34.52 *Crematorium vehicular flow diagram*

22.04 Chapels

Chapels should take into account Christian, non-Christian and secular usage – perhaps separate chapels for Christian and other users; or if the same space is used for all, a system of easily changed symbols installed. Where more than one chapel is provided, one may be small (20 seats) and the other larger (110 seats). Organs are rarely used, but good facilities for playing recorded music are essential.

The chapel should be designed to reduce emotional disturbance caused by the proceedings, **34.53**. The event can be 'softened' in a number of ways. For example, windows can be provided at a number of levels to enable the mourners to look through the chapel into a restful and attractive external landscape; the designer should avoid a totally introspective environment. Again, the catafalque can be offset from a central position so that the mourners tend to concentrate on the minister conducting the service and not solely on the presence of the coffin.



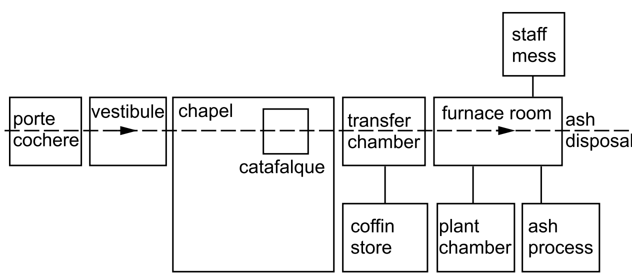
34.53 *Chapel arrangement*

22.05 Toilets

Many people become emotionally disturbed either before or during the service. The toilets should be easily accessible before the service, immediately after the service and at the point where relatives disperse after the ceremony. At least three groups of toilet facilities are required.

22.06 Coffin circulation

A diagram of the coffin circulation is given in **34.54**.



34.54 *Coffin circulation pattern*

22.07 The furnace room

The finishes in the furnace room should be impervious and easily maintained. Blow-back on ignition may occur occasionally, and soot deposits can accumulate on walls and ceiling.

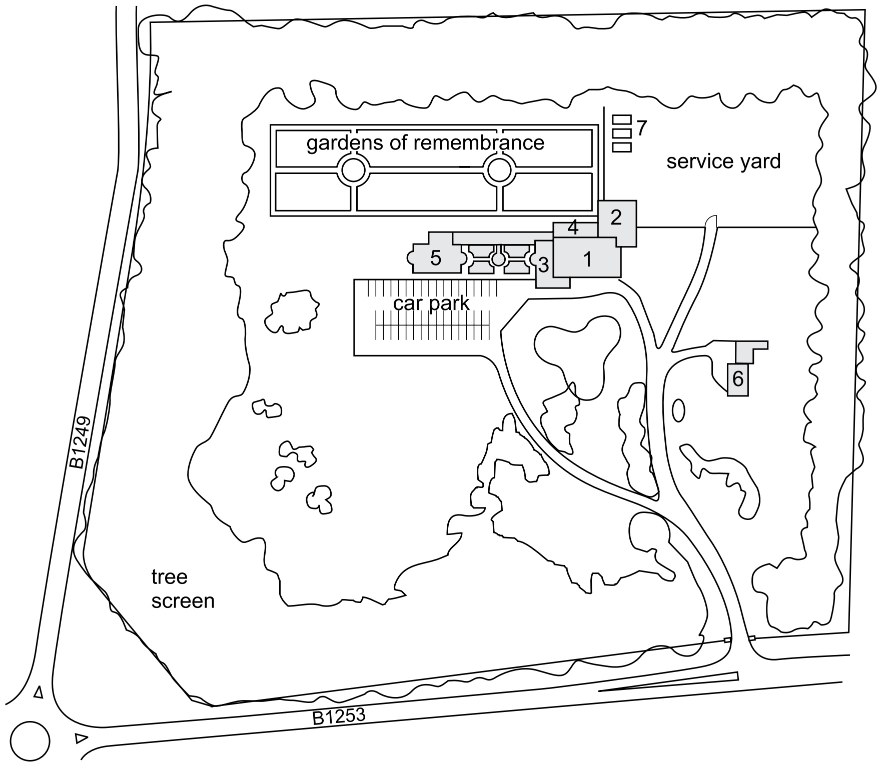
22.08 Ancillary accommodation

All or some of the following will be required depending on circumstances:

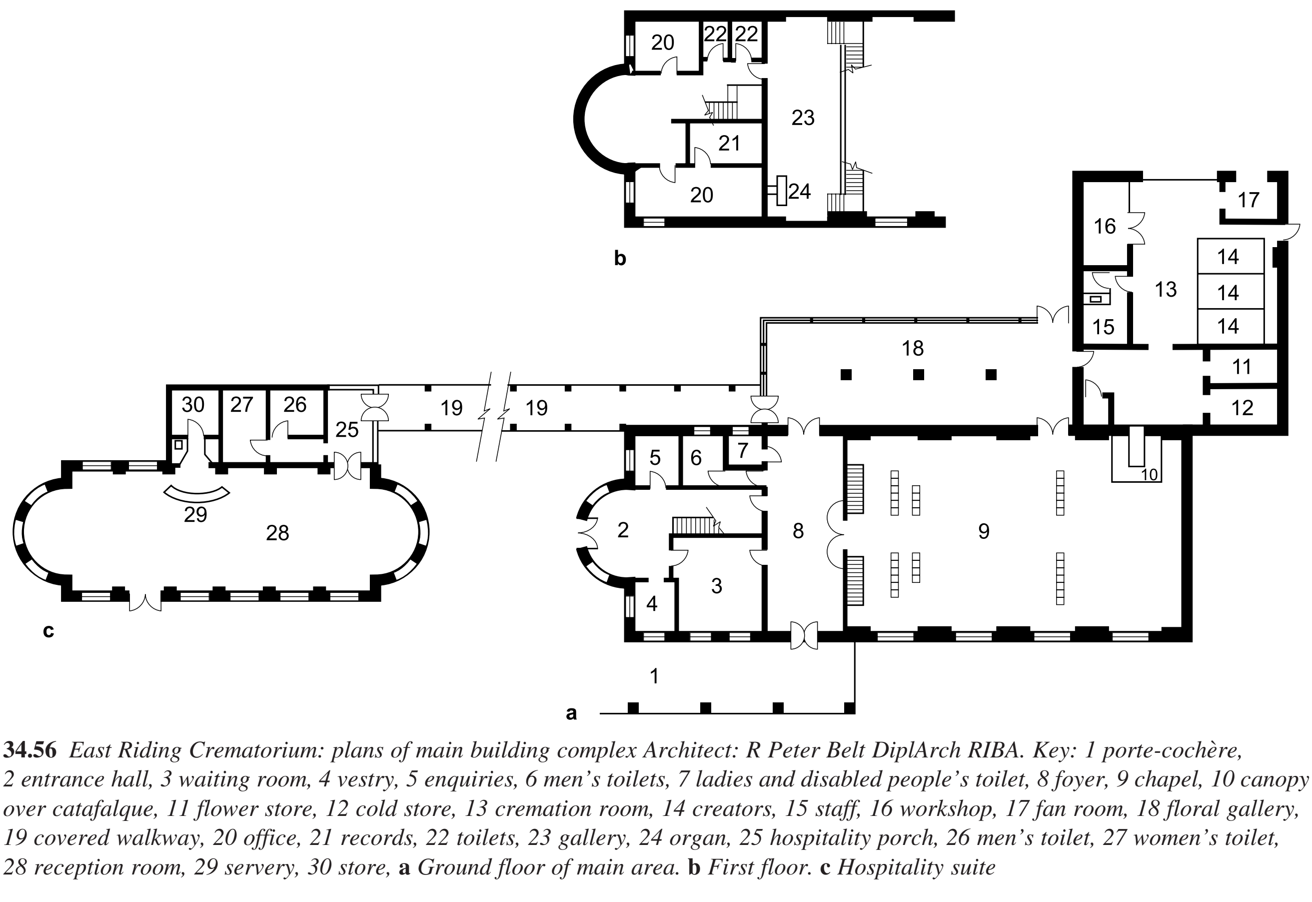
- Administrative suite
- Manager's office
- Waiting rooms
- Resting place with catafalque

- Vestry for clergy
- Flower room
- Transfer chamber and coffin storage
- Viewing room
- Furnace operator's room and storage
- Attendant's room
- Public toilets
- Gardener's store and porter's lodge.

The site plan of a recently constructed crematorium complex is shown in **34.55**. Plans of the main building are given in **34.56**.



34.55 *Site plan of East Riding Crematorium Architect: R Peter Belt DiplArch RIBA. Key: 1 chapel, 2 cremators, 3 porte-cochère, 4 floral gallery, 5 hospitality suite, 6 superintendant's house, 7 gas tanks*



34.56 *East Riding Crematorium: plans of main building complex Architect: R Peter Belt DiplArch RIBA. Key: 1 porte-cochère, 2 entrance hall, 3 waiting room, 4 vestry, 5 enquiries, 6 men's toilets, 7 ladies and disabled people's toilet, 8 foyer, 9 chapel, 10 canopy over catafalque, 11 flower store, 12 cold store, 13 cremation room, 14 creators, 15 staff, 16 workshop, 17 fan room, 18 floral gallery, 19 covered walkway, 20 office, 21 records, 22 toilets, 23 gallery, 24 organ, 25 hospitality porch, 26 men's toilet, 27 women's toilet, 28 reception room, 29 servery, 30 store,* **a** *Ground floor of main area.* **b** *First floor.* **c** *Hospitality suite*

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35 Tropical design

Patricia Tutt

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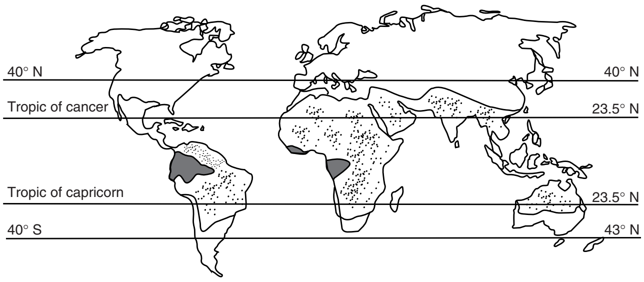
KEY POINTS:
- *Study existing buildings that work, and learn from them*
- *Apply normal good design and environmental practice, being sensitive to site, climate, culture and construction industry practices*
- *Review and revalidate all design assumptions*
- *Use local information and expertise*
- *Carry out a thorough desk study*
- *Anticipate extremes of climate change*

Contents

1 INTRODUCTION

1.01 'The Tropics'

'The tropics' are, technically, the low latitudes contained in the 'Torrid Zone' between the Tropics of Cancer and Capricorn, **35.1**, but the term is most typically applied to the world's hot, humid, equatorial coastal regions which have high rainfall, lush vegetation and, almost invariably, a colonial past. For our purposes here, however, the term can be applied to all climates in which the cooling load in buildings significantly exceeds the heating load **35.2**. This extends into the hot dry areas, the composite climates in the centre of large continental land masses, and some areas tempered by warm seas or prevailing winds that are as far away from the equator as latitudes 45° north and south. This section provides an introductory design guide for architects undertaking work in unfamiliar environments and climates. All guidance must be substantiated by site-specific data.



35.1 *The 'Torrid Zone' lies between the Tropics of Cancer and Capricorn. Toned areas have a mean annual temperature of 20°C or above; black areas have persistent overcast skies with less than 1600 h sunshine per annum*

1.02 Current agendas

Within the last 20 years, there has been a major shift in design agendas worldwide, with increasing awareness of global warming, climate change and the need for responsible, sustainable design. Environmental design has become an essential component of building design. There has been widespread high-tech adaptation of traditional third world technologies by architects working in temperate climates, **35.3**. There is increasing awareness of the limitations of globalisation when compared to the merits of regionalism. Increasing sophistication in building design has become apparent in many tropical countries, especially those around the Pacific Rim; and web-based documentation, communication and transfer of knowledge have revolutionised design methodologies in all climates, whilst research has revalidated many traditional tropical design technologies.

Many governments are dependent on external funding to enable them to execute major development programmes and government agendas may, therefore, be diverted or constrained by the policies of the donor agencies which may be single governments (USAID, CIDA), regional organisations (EC, ADB, AfDB), international agencies (UN, World Bank, WHO) or charities (Oxfam, Red Cross, Red Crescent). *(The acronyms stand for the United States Agency for International Development, Canadian International Development Agency, the European Community, Asian Development Bank, African Development Bank, the United Nations and the World Health Organisation.)*

1.03 Tropical design

Tropical design is no longer seen as a separate entity, but as good design that is attuned to specific variations in climate, construction industry structure, culture and socio-economic conditions, **35.4** and **35.5**. A high-tech, expensive building can disregard context and be built anywhere if funding is available; the harder task is to design a sensitive, sustainable, lower-tech, climate-responsive building that will serve its intended community well and need little maintenance. Ideally, this building should embody cultural memory without being a pastiche of the vernacular or colonial model, using valid older principles in ways that suit a modern, urban and, in many cases, industrial society. Whilst many third world clients understandably aspire to the twentieth century, high-tech Western model for their new buildings, it is the responsibility of their architect to ensure that they are aware of this twenty-first century shift in thinking towards sustainable models, and to understand the options available to them and the potential long-term consequences of their choice.

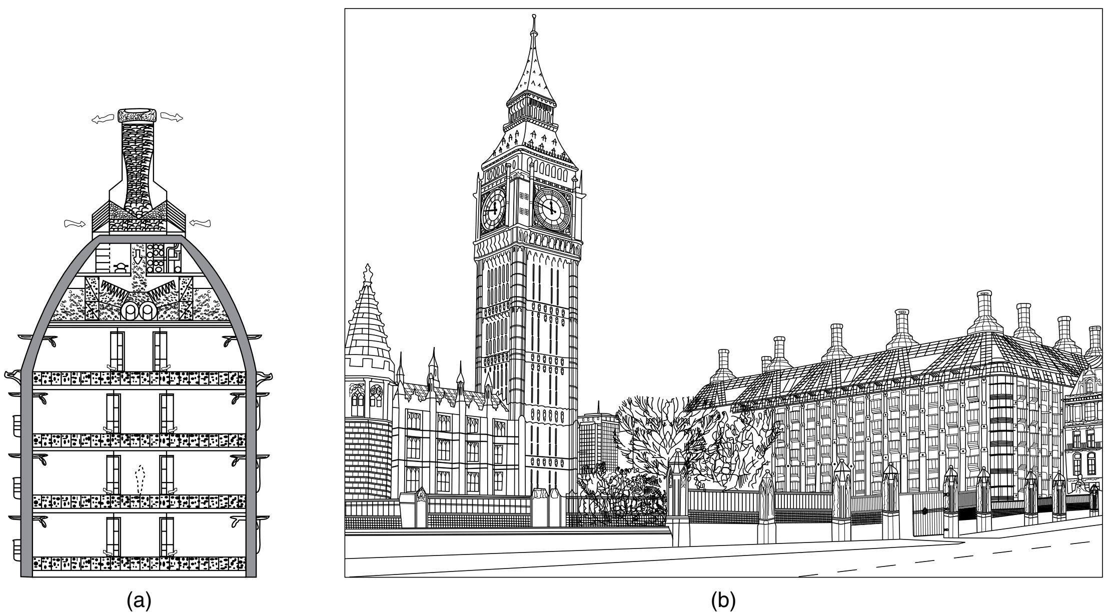
The purpose of this chapter is to provide prompts and checklists to enable the building designer working in an unfamiliar region to carry out a detailed desk study, having first identified those issues that require detailed research. Many of these prompts would be relevant in any climate, but the details given here highlight tropical contexts.

2 DESK STUDY – FACTORS AFFECTING DESIGN

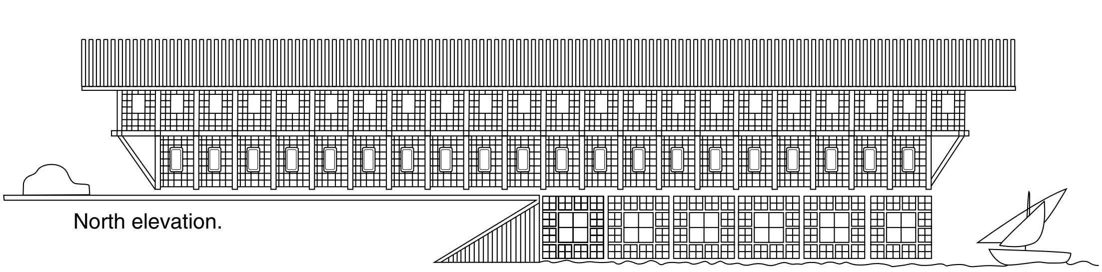
2.01

Whenever a building is being designed for an unfamiliar environment, the architect must check and revalidate even the most

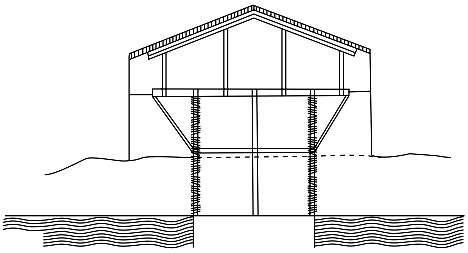
35.2 *Colonial bungalow, Zomba, Malawi, with clerestory windows, high ceilings and deep shaded verandas, including one for the car. Drawing by the Rev'd D Brian Roy, RIBA*



35.3 *Many of the traditional environmental strategies used throughout the Middle East have been co-opted into current mainstream architectural design. Portcullis House, the new offices for MPs alongside the Houses of Parliament, in London, updates the wind-catcher and wind-venting tower by incorporating heat recovery and mechanical back-up systems (Smith, 2001)*



35.4 *The work of the Singhalese architect, Geoffrey Bawa, ranges between a restrained aesthetic using modern materials, and a sophisticated and heightened reinterpretation of the vernacular in private houses and tourist hotels, and, as can be seen in his exquisite drawings. Steel Corporation Offices, Oruwela, Sri Lanka, 1968 – set half in the large pool (steel production holding tank) and in reinforced concrete throughout, with precast perforated and windowed walls (elevation and section)*



35.5 *Bawa's Ena De Silva house, Colombo, 1962 – the courtyards for secure outdoor living are kept cool by through ventilation, deep overhangs and shade trees. All materials except a small amount of glass and some steel reinforcement are local. One of the large trees was brought onto the site by elephant; the other was already on site and influenced the design*

basic design assumption, as it might be invalid in the new context. This section highlights some areas where research may be necessary. Relevant building science data is given in section 7.

2.02 Climate and microclimate

Confirm the climate type, Table I, and obtain as much site-specific data as possible, Tables II and III. Make sure you understand the terms used and are comparing like with like when evaluating data from differing sources. (Annual average temperature is the average of the mean monthly maximum and minimum temperatures. The average of the highest mean monthly maximum and lowest mean monthly minimum gives a close approximation.)

It is particularly important to ensure that data has nor been distorted by periodic aberrations, especially if based on short-term records. A comparison of annual rainfall records will show if any cyclical pattern occurs. The great lakes of east Africa had a pattern of rising and falling over a 7-year cycle in the first half of the twentieth century – believed to be related not only to rainfall but also to activity in the Great Rift through which the lakes seem to be interlinked. The continuation of this pattern will have been distorted by deforestation, the change from subsistence to cash crop agricultural practices that have allowed extensive run-off of topsoil and fertiliser into the lakes, and the construction of dams, barrages and other features that alter natural hydrological cycles.

A lot of the current and historical weather data will be available on the Web, as will definitions of the terms used, but as weather bureaux are often located at airports, which tend to have distinctive microclimates, this data need confirmation on site. Where rainfall is dependent on prevailing winds from one direction, a hillside site may be in the rain shadow and very much drier that the records suggest. On large projects, it may be advisable to establish a weather station on site to verify data and study microclimate. If climate change (see para. **2.02**) accelerates as expected, more extreme weather will occur, causing catastrophes of increasing magnitude. In particular, extreme storms, wind, rainfall or drought may get worse as well as occurring more frequently. Building design and site selection need to take account of this.

Table I Occurrence and characteristics of main climatic zones

Zone	Approximate latitude range	Natural vegetation	Typical cultivation	Climate	Problems	Requirements
Warm humid equatorial	7½N–7½S	Tropical rain forest	Banana, palm oil	Warm with high humidity and rainfall	Humidity prevents sweat evaporation; hot nights make sleep difficult; high rainfall and glare from overcast sky, sun on east and west facades	Air movement from fans or cross ventilation, low thermal capacity construction, sloping roofs and large overhangs, windows facing north and south
Tropical island	5–30°N 5–30°S	Rain forest	Sugar cane	Warm, humid but less cloud than warm humid zone	Similar to warm humid equatorial, but clear skies and bright sun more frequent	Similar to warm humid but with additional care in the design of shading the south facing windows in the northern hemisphere (vice versa in the southern)
Hot dry tropical	15–32°N 15–32°S	Desert, steppe	Palms, grazing (nomadic)	Hot and dry with high annual and daily variation of temperature	High diurnal range, very hot days in summer, cool winter days, low rainfall, very strong solar radiation and ground glare, sandy and dusty environment	High heat capacity construction, shading devices which allow solar heating in winter, small windows, flat roofs (often used for sleeping), small courtyards to give shade and protection
Maritime desert	15–30°N 15–30°S	Desert	Palms, grazing	Hot, humid with low rainfall	Similar to hot dry climates but with high humidity causing discomfort by preventing sweat evaporation	Similar to hot dry but air movement is desirable at times
Intermediate composite or monsoon	5–20°N 5–20°S	Monsoon forest, dry tropical forest or scrub, savannah	Paddy rice, sugar cane, millet	Warm humid and hot dry seasons often with cool season	Combines the problems of warm humid and hot dry climate	Compromise between the requirements of warm humid and hot dry climate or ideally (but more expensively) two buildings or parts of buildings for use at different times of the year
Equatorial upland	10°N–10°S	Broadleaf forest, mountain vegetation	Millet	Temperate to cool depending on altitude	Combine the problems of warm humid and hot dry climates with those of a temperate or cold climate for all or part of the year	Design to take advantage of solar radiation when cool or cold. Heating and additional insulation may be required
Tropical upland	10–30°N 10–30°S	Steppe, cedars	Wheat	Hot summers, cold winters	Do	Do
Mediterranean	32–45°N 32–45°S	Mediterranean scrub	Vines, olives, citrus fruits	Hot dry summers, cold wet winters	Summers have some of the problems of a hot dry climate while winters are cold and humid with moderate rainfall	Design with high thermal capacity, medium to small opening, and courtyards to give shade and protection

Table II Climatic data

Data required	Units	Relevance
Monthly mean maximum temperature	°C	thermal comfort analysis
Monthly mean minimum temperature	°C	
Monthly mean maximum humidity	%	
Monthly mean minimum humidity	%	
Monthly mean rainfall	mm	vegetation
Peak rainfall intensity and duration	mm/unit of time	storm damage
(Daily or hourly rainfall may be the only data available)	mm	rainwater drainage
Sunlight	hours	natural lighting
Cloud cover	oktas* or %	
Absolute maximum temperature	°C	thermal expansion
Absolute minimum temperature	°C	and effect on building materials
Frequency distribution of wind for different speeds and directions	% m/s	siting and orientation
Frequently of special phenomena, i.e. sandstorms, fog, hail, thunder	days per year	provision of special precautions

* 1 okta = 1 eighth of the sky.

Thermal comfort

Thermal comfort is dependent on temperature, humidity, radiation and air movement as well as type of activity, clothing and degree of acclimatisation. No two people will perceive and describe comfort equally. In a hot dry climate, perspiration evaporates quickly, enabling rapid cooling of the body; humid conditions prevent this, leading to heat gain and discomfort. Table IV indicates the range of bulb temperatures that are likely to be perceived as comfortable at particular levels of relative humidity.

These thermal comfort limits assume that there has been no heat loss or gain due to ventilation or insolation. Comparing monthly mean maximum and minimum temperatures for known levels of relative humidity will indicate whether that particular month will have days and nights that are comfortable or uncomfortable due to either heat, cold or humidity, Table V.

Various formulae for relating these indicators to design solutions have been developed. The most successful of these are the 'Mahoney tables' developed for the UN by Carl Mahoney and reproduced in Manual of *Tropical Building and Housing: Part 1 – Climatic Design* Koenigsberger et al. (1974). This remains an important text.

Table IV Thermal comfort limits (°C)

Monthly average relative humidity (RH)%	Annual average temperature					
	Over 20°C		15–20°C		Under 15°C	
	Day	Night	Day	Night	Day	Night
0–30	26–34	17–25	23–32	15–23	21–30	14–21
30–50	25–31	17–24	22–30	15–22	21–27	14–20
50–70	23–29	17–23	21–28	15–21	19–26	14–19
70–100	22–27	17–21	20–25	15–20	18–24	14–18

Table V Indicators of requirements for comfort for each month

Humid indicators		
H1	Air movement essential	mean monthly maximum temperature above the day comfort limits combined with humidity over 70% or humidity between 30–70% and a diurnal range of less than 10°C
H2	Air movement desirable	mean monthly maximum temperatures within the comfort limits combined with humidities over 70%
Arid indicators		
A1	Thermal storage required	diurnal range of temperatures over 10°C and humidity less than 70%
A2	Space required for outdoor sleeping	mean monthly minimum temperatures above the night comfort limits and humidity below 50%. Outdoor sleeping may also be indicated where maximum temperatures are above the day comfort limits and diurnal range is above 10°C with humidities less than 50%.
Cold indicators		
C1	Solar radiation desirable	mean monthly maximum temperatures below day comfort limits
C2	Additional heating required	mean monthly maximum temperature below 15°C

Meteorological data

Geographers and meteorologists distinguish a wide range of climate types in hot and warm climates and disagree over what to call them, but:

- The wet climates can be broadly distinguished by intensity and pattern of rainfall, humidity and cloud cover
- The dry climates by how dry they are, how cold they get in the cold season (for simplicity, referred to hereafter as 'winter') and whether what little rain they do get falls in summer or winter
- The composite climates by the degree of seasonal fluctuation in all climatic indicators; and whether it gets really cold in winter.

Table III Action points for weather data collection

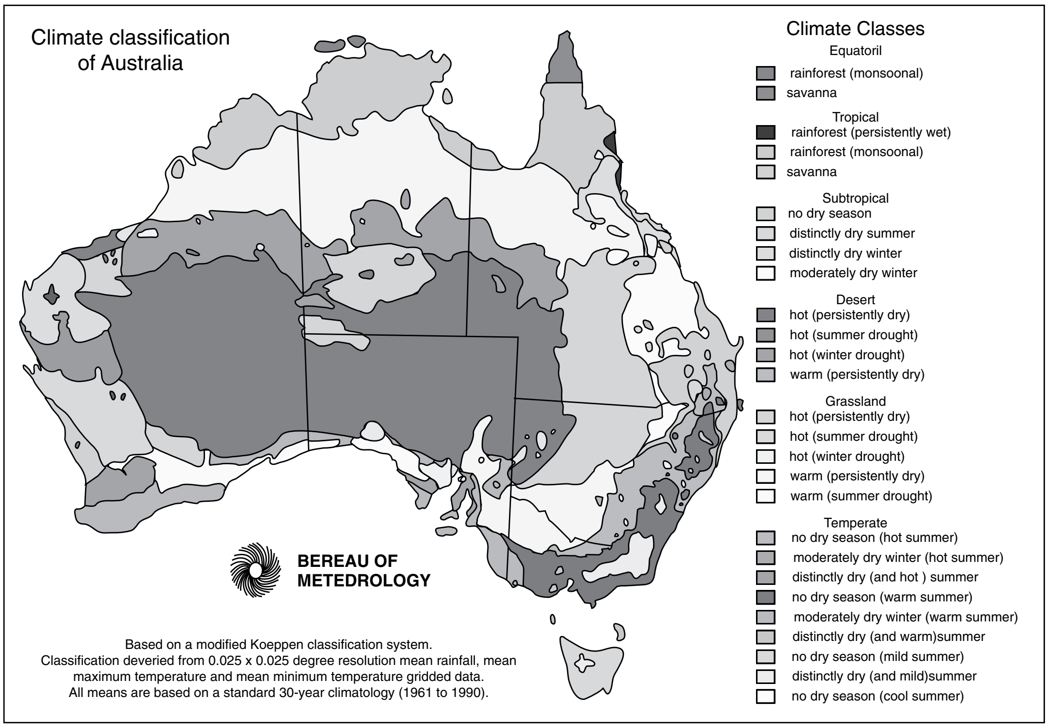
Historical data	• Check local weather bureaux, starting with the airport, making sure the data is relevant for the specific site. Even small countries can manifest several different climate types. Note changing patterns and periodic cycles that have recurred since record keeping began.
Now	• As a priority, collect weather data on site, as soon as the site is identified
Rainfall	• Establish the rainfall pattern – peaks, daily patterns (monsoon or 'main' rains often recur at the same time every day; some areas have a week or two of 'planting rains' a month or so before the main rains appear) • In areas with distinct seasonal variations, are there two (or more) 'rainy' seasons (as in Kenya) • Are the rains reliable or is there evidence of climate change? • Is there a known periodic cycle, such as El Niño? • Does the rain come from one direction and, if so, does this affect micro-climate on the site? • How heavy is the rainfall – does it drizzle for months or all come at once in a torrential cloudburst?
Other precipitation	• Is there a risk of hail or snow – not unknown in the tropics?
Storms, sandstorms, gales, hurricanes, tsunami, tornadoes, earthquakes, flash floods, landslides and other extreme weather events	• There are two aspects to these risks – how extreme are these events, and how often do they occur? • How often are two or more of these events inter-related or dependent on other, predictable or observable climatic events (tornadoes and changes in atmospheric pressure, earthquakes and tsunami, hurricanes and landslides)?
Sunlight and cloud cover	• Are there clear skies all year, or does the sky stay overcast during the rains for weeks on end? • How predictable is the cloud cover?
Relative humidity	• Records, seasonal variation • Is there a risk of mould growth in cupboards? • Does high humidity affect normal tasks or construction materials?
Temperature	• Yearly graph • Seasonal variations • Diurnal maximum and minimum

All these variables are moderated by latitude, altitude, prevailing winds, and whether they are at the centre of large landmasses. They can be covered by short lists of three or four types, based on data critical to particular groups (farmers concerned about rain, tourists concerned about humidity and clear skies, skiers wanting snow) or broken down into a longer definitive list. The Bureau of Meteorology, Australia, produces a range of maps showing different criteria, **35.6–35.9**.

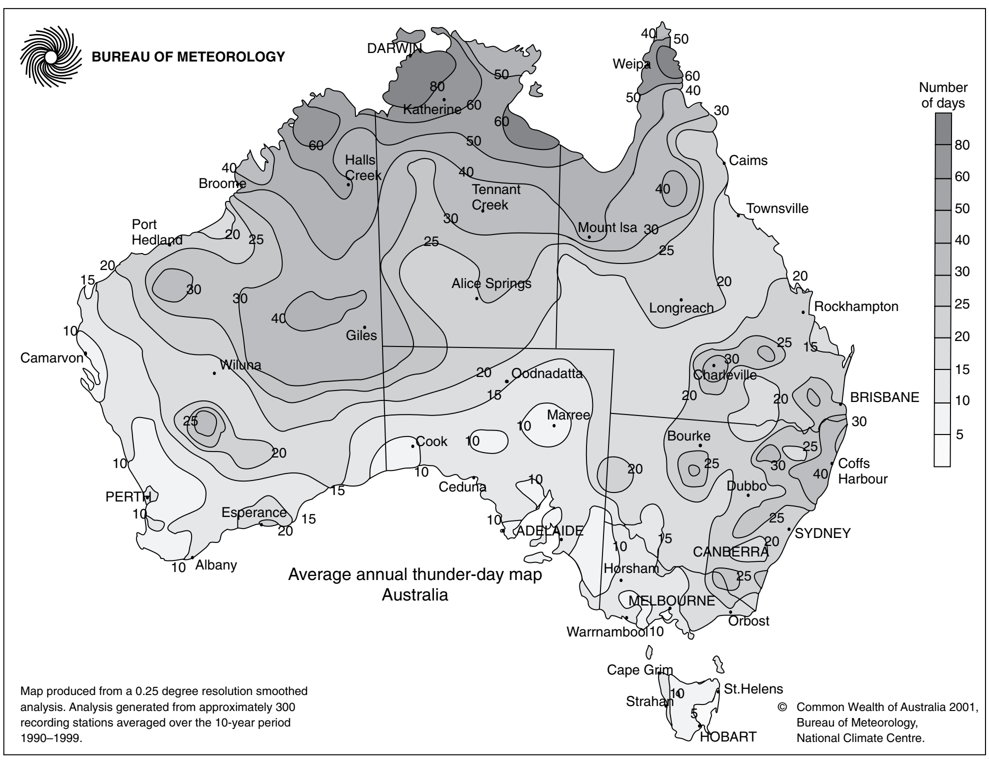
2.03 Climate change

Climate Change 2007, the Fourth Assessment Report (AR4) of the United Nations Intergovernmental Panel on Climate Change (IPCC), offers authoritative assessment of climate change implications for the tropics:

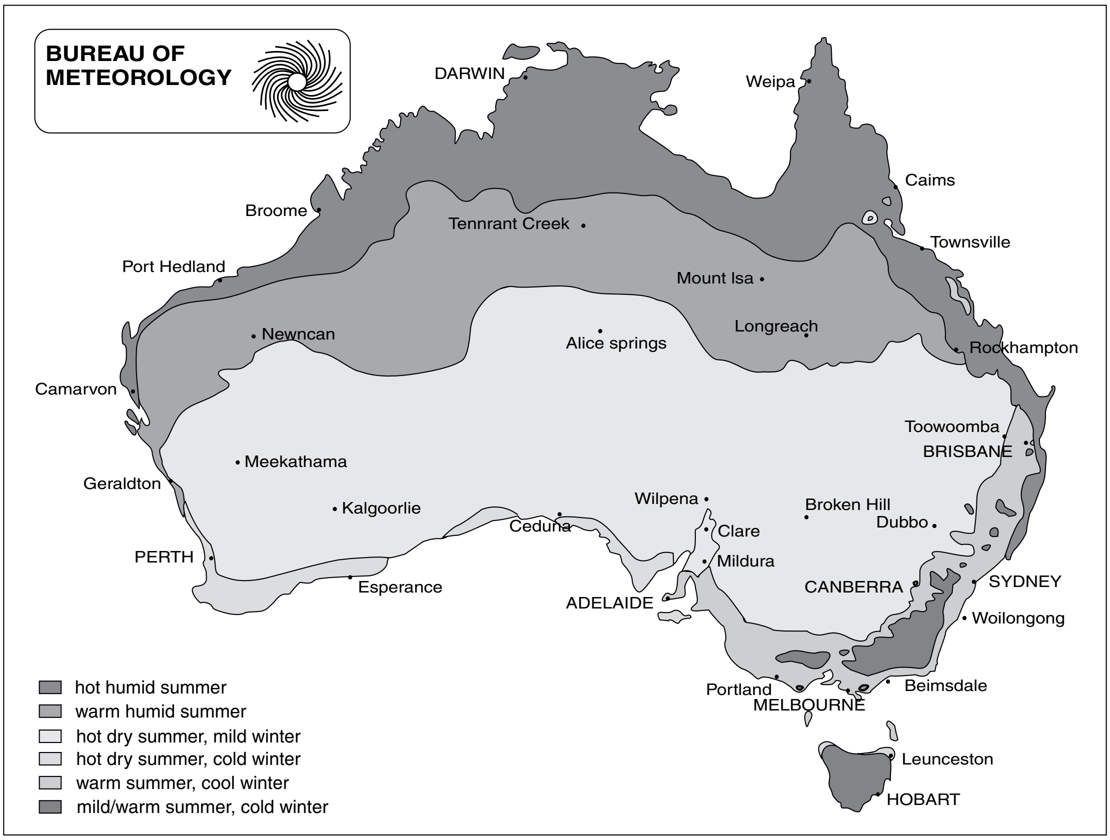
- Low-lying island nations may be overcome by rising sea levels
- Future tropical cyclones (typhoons and hurricanes) are expected to become more intense, with larger peak wind speeds and more heavy precipitation, but the number cyclone events may decrease overall
- Increase in drought in the centre of large continental land masses
- Increases in temperature
- Increasing unpredictabilty of weather patterns.



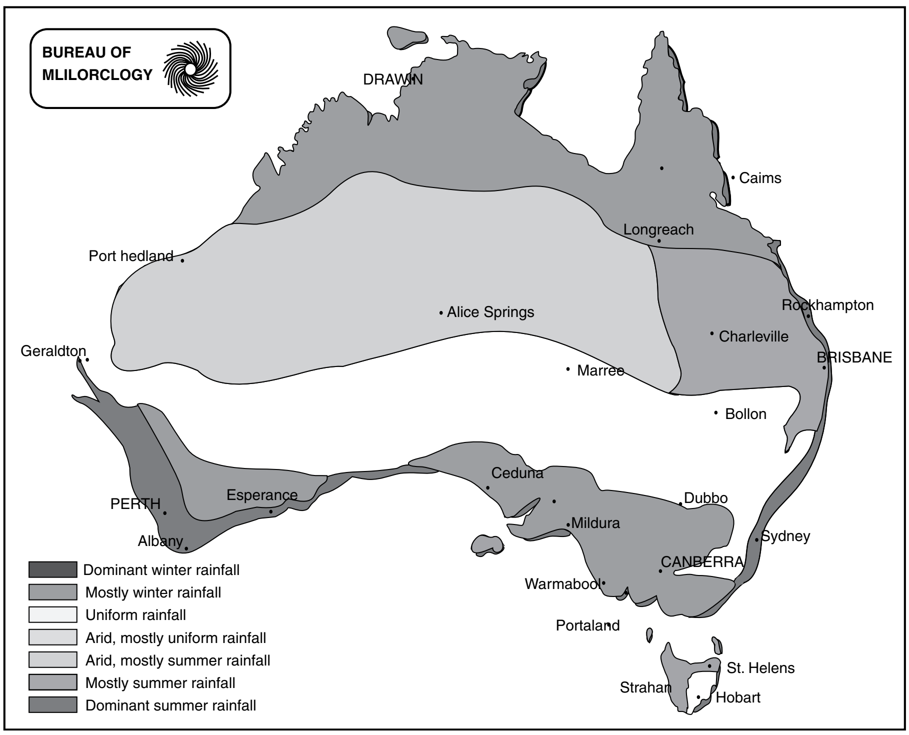
35.6 *Range of Tropical and subtropical climates found in Australia*



35.7 *Average annual thunder days in Australia*



35.8 *Map based on temperature and humidity only*



35.9 *Map based on rainfall only*

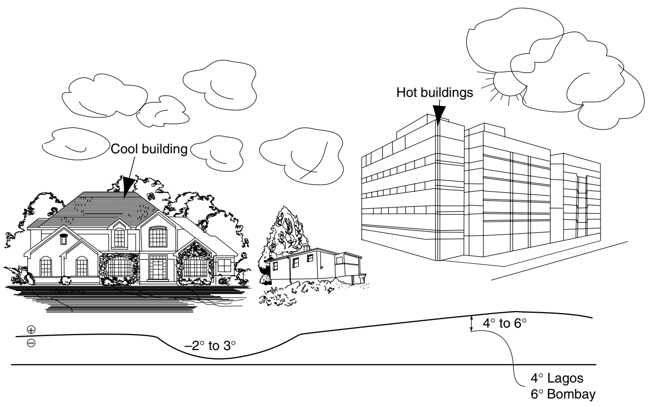
The report also anticipates 'substantial reduction in regional differences in per capita income' which will drive an expanding construction programme needing more resources and technological input.

2.04 Site selection

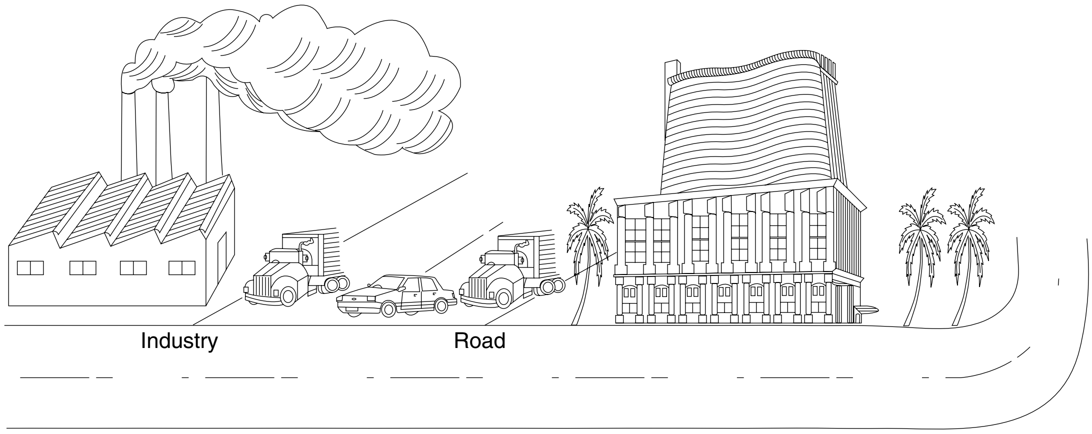
Sites and the detailed siting of individual buildings should primarily be chosen to maximise human comfort. Efficient performance of the building should follow from this.

Buildings should be sited:

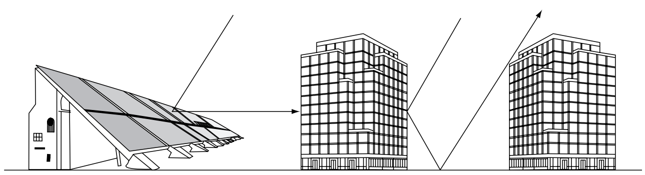
- close to, and downwind of, large heat sinks such as forests, rivers or lakes, which lower temperature and screen the site from airborne dust and noise, **35.10**
- remote from major traffic routes and those industries which generate heat, noise, pollution and smells, **35.11**
- where they will be shaded by trees or other buildings during the hottest part of the day and/or the hottest times of the year



35.10 *Site buildings downwind of heat sinks*



35.11 *Site buildings well away from busy roads and industry*



35.12 *Solar dazzle off sloping glazed facades is more likely to be reflected horizontally into adjacent buildings or into the eyes of approaching drivers. Similarly, it is an offence in some countries to use uncoated metal sheeting on roofs, as it can temporarily blind airline pilots*

- where they will take advantage of the prevailing breezes (wet and humid climates)
- where they will be screened from dust-landen winds and glare (hot arid climates)
- where they will not be subjected to solar dazzle from other buildings, **35.12**
- where they will not maximise heat gain and glare reflected from bright external paving or adjacent buildings with pale reflective surfaces (high albedo – see **7.02**).

2.05 Site characteristics

Altitude, aspect, insolation, gradient, prevailing wind, shelter, soil, geology, water table, vegetation, existing structures, archaeology and ecology may all be important. Traditional uses of the site, for grazing, footpaths or cultivation may all need negotiation. Crops on a site may need to be reimbursed to their full value if destroyed, or allowed time to be harvested.

Pollution

Pollution and smells from tanneries and other industries, saltpans, open storm drains and sewers, contaminated water supplies and aerobic sewage treatment works may present serious problems in countries without environmental legislation.

Environmental impact

Even small projects may affect water supply, soil stabilisation, fragile flora and fauna, and local inhabitants and their patterns of agriculture. An environmental impact assessment may be required and should always be considered.

2.06 Site investigations and geotechnics

Soils and geotechnics

The site may present unfamiliar soil and ground conditions and behaviours. In southern Africa, for example, there are no glacial soils, there is much more igneous rock than elsewhere and the weathering of the ancient landmass has produced a much higher percentage of residual soils. Most of these soils are non-saturated and many are either of expansive or collapsing types where smaller structures need to be lightweight and flexible rather than heavy and rigid. Larger structures may need piled foundations. The absence of ground frost frees foundation design from some of the constraints that operate in cold climates, but other factors, such as soil type and seasonal cycles of saturation and desiccation may present other problems. In many areas, tropical soils are thin and vulnerable to rapid erosion once tree-cover is removed or the surface exposed or cultivated. Soil stabilisation may be necessary, using planting, geo-membranes or gabions. It is rare to be working in a country that has not been extensively mapped geologically, however, and knowledge and expertise should be available.

Water supply
It may be impossible to ensure an adequate water supply throughout the year in dry or seasonally dry climates. There may be aquifers that can be tapped using wind pumps, but if water has to be piped over long distances or brought in by tanker, a scheme may become uneconomic. Ground water must be thoroughly tested by Government or independent analysts to ensure that it is potable and free from contamination. (The widespread arsenic poisoning in Bangladesh is the worst of many examples of unforeseen contamination. This disaster arose from well- intentioned international aid intended to improve health by stopping people drinking contaminated surface water. Four million tubewells were sunk – into contaminated ground.)

Water table and flooding
The water table may fluctuate seasonally or be altered by other constructional or civil engineering work in the vicinity. Flash flooding may be a risk in any dried out riverbed or low-lying area and roads may become impassable very quickly. Take advice, have up-to-date weather information and be alert to distant thunder.

Earthquakes and hot springs
World seismic data and geothermal activity are well recorded by the British Geological Survey and the US Geological Survey. Their web-based information is excellent.

Burial sites
Traditional burial sites may be unearthed in unexpected places, especially where the population is nomadic and the written record recent. All graves and religious sites must be treated with respect and local advice heeded. Burial sites may be indicated by the presence of particular tree species, or some other environmental marker.

Archaeological finds
Archaeological finds should be reported to local museum authorities. It may be wise when excavating a virgin site to take advice as to what to be looking out for, as remains or other finds may take unfamiliar forms, ranging from dinosaur eggs, through gemstones to rock paintings.

2.07 Culture and religion

Cultural and religious criteria
Many questions must be asked if they are germane to building design:

- Is the society homogeneous or divided on ethnic, political, religious or economic lines?
- Are there minority demands which have to be met?
- Are there strict gender-based criteria?
- Are there strict taboos with regard to personal hygiene and the butchering and eating of meat?
- Are some castes isolated?
- Do holy days vary?
- Does the workplace have to make provision for specific religious or social practices?
- Will shrines be required?
- Is Feng Shui practiced?

Historical factors
Colonial procedures can be very persistent in former colonies including the former and present members of the (British) Commonwealth and in Francophone Africa, and the former American, Portuguese, Dutch and German colonies. Government and legal processes, the police, the army and a wide variety of social practices will all reflect the past administrators to a greater or lesser degree – as will the past and, sometimes, the present architecture.

Social and ethical criteria
Limited literacy or the absence of a common language may necessitate a different approach to building signage. If labour is cheap, buildings may need to accommodate the proliferation of servants, messengers and other service personnel that this permits. In some countries, they will be provided with residential accommodation on-site and will be able to keep their extended families there – with implications for power, water and sanitation provision.

2.08 Politics and economics

Business practices
Are people taking a siesta at midday, when the sun is overhead, but working later in the afternoons, when glare from low sun and solar gain are most difficult to keep out of buildings? Do meetings and other interactions require special facilities? Are there regular group activities (Tai Chi, mid-morning coffee, emergency drills) that need special spaces?

Political factors
Political instability and conflicting political, ethnic, religious or tribal agendas may influence design and affect the buoyancy of the construction industry.

External aid and funding
International debt repayment agreements may skew local economies and suppress regeneration; purchases of military hardware from the more aggressive vendors in this field have been particularly bruising. In the recent past, newly independent countries received large amounts of unconditional project funding as donor governments sought to keep undesirable influences from the Communist bloc, Cuba or China out of vulnerable and potentially unstable areas. Much of this aid was designed to provide employment in the donor country (. . . you will use our architects, our materials, our equipment . . .) with little regard for local expertise, culture or long-term viability. Funding provided vehicles, but not the means of servicing them; hospitals, but not the staff to run them.

More recently, the more enlightened donors have started to move out of providing buildings and into support for sustainable, self-help projects that are intended to support local industries and generate wealth. Things still go wrong however – the never-ending stream of cheap second-hand clothing that charities are sending into Africa has destroyed the textile industry in several countries and stripped thousands of self-employed tailors of custom.

2.09 Construction industry, job management and professional expertise

Labour skills and costs
International price guides are now available for most countries and provide a good guide as to good local materials, cost peculiarities, materials that are difficult to source, labour rates and other cost indicators. It is important for architects to be familiar with local skills and use them, rather than to impose imported techniques that they are familiar with but local craftsmen are not.

Transport, accessibility and infrastructure
Transport can present many unforeseen problems on construction projects: vehicle availability, spares, maintenance, drivers, insurance, risks, road safety, road conditions, bad weather, roadblocks (official and unofficial) and drivers using official vehicles as unofficial, uninsured taxis.

Access and travelling
Is the country easy to get into and out of? Are permits, interpreters, guides, cost of flights, taxis, trains, buses or car hire required? It is important to develop local contacts and networks, using embassies, professional bodies and other agencies.

Project management strategies
Will these be local, international, co-partnership; via phone, fax or online?

Planning applications
Planning and other statutory procedures may be Anglophone, Francophone . . . or Byzantine. Local guidance is essential. Professional accreditation may be instantly available or complex and lengthy to obtain.

Cost
Costs will be unfamiliar and cost advice from resident consultants will be essential.

2.10 Resources and technologies

Utilities and services
Incoming services may include water (potable and recycled 'grey water'), electricity, telecommunications (including satellite and data services) oil and gas. Availability, reliability, method of reticulation and system type all need to be determined. In many countries, the very low density of new urban development imposes great strain on current and future services reticulation. Outgoing services – sewerage (mains and septic tank), storm drains and refuse – may also require non-standard design solutions. In areas without supply, alternatives must be considered.

Construction industry resources
Availability and reliability of materials, tools, plant, water supplies, resources, labour, skills, crafts, expertise, organisational structures, technologies and reliability of utility supplies will all affect the construction process, as will seasonal or climate events that affect employment, restrict transport movement or materials production, or stop construction (groundwork may not be possible during the rainy season). Local craftsmen may be adept in special applications of trades such as plastering and rendering, which have been lost in much of Europe or the USA. Scaffolding might use bamboo – a material worth exploring for a wide range of applications.

Alternative power sources
Water (hydro and wave), wind or solar power may be feasible. Grid-connected building-integrated photovoltaics (BIPV) are becoming more efficient and better documented.

Sustainability
The terms may differ – sustainable, ecological, 'green' – but the principles remain.

Good building design:

- should 'touch the earth lightly' by minimising use of non-renewable fossil fuels in collecting, manufacturing, transporting or using building materials;
- should reduce the need for the power derived from these fossil fuels in heating, lighting, ventilation and cooking by using passive design strategies in buildings and
- lifestyle and working practices should reduce the need to consume excessive energy in transport, workplace, leisure or entertainment.
- In the longer view, this should affect urban planning, the nature of residential development, the reticulation of services and the policies of central governments.

Sustainable strategies to consider include:

- use local materials – but don't consume beyond the capacity to regenerate
- make use of local waste products
- use passive design
- recycle energy
- restrict water consumption.

Appropriate technology
It is dangerous to make assumptions about suitable solutions: two neighbouring countries may appear similar in terms of climate, environment and socio-political culture, but may have very different construction industries. One may have good labour, traditional brick-making skills, popular decorative traditions, and use steel extensively, whilst its neighbour has no masonry construction, but builds in cement block and reinforced concrete. One may welcome low-tech solutions; another might be insulted by them. Clay ovens, sisal-reinforced roofing sheets and modern pit-latrines may work wonderfully but are unlikely to satisfy people wanting to come up to speed in the modern world. Indeed, these solutions are most effective when offered to refugees from that modern world, who wish to experience the 'bush' for a week or two. A technology is only appropriate if people want it.

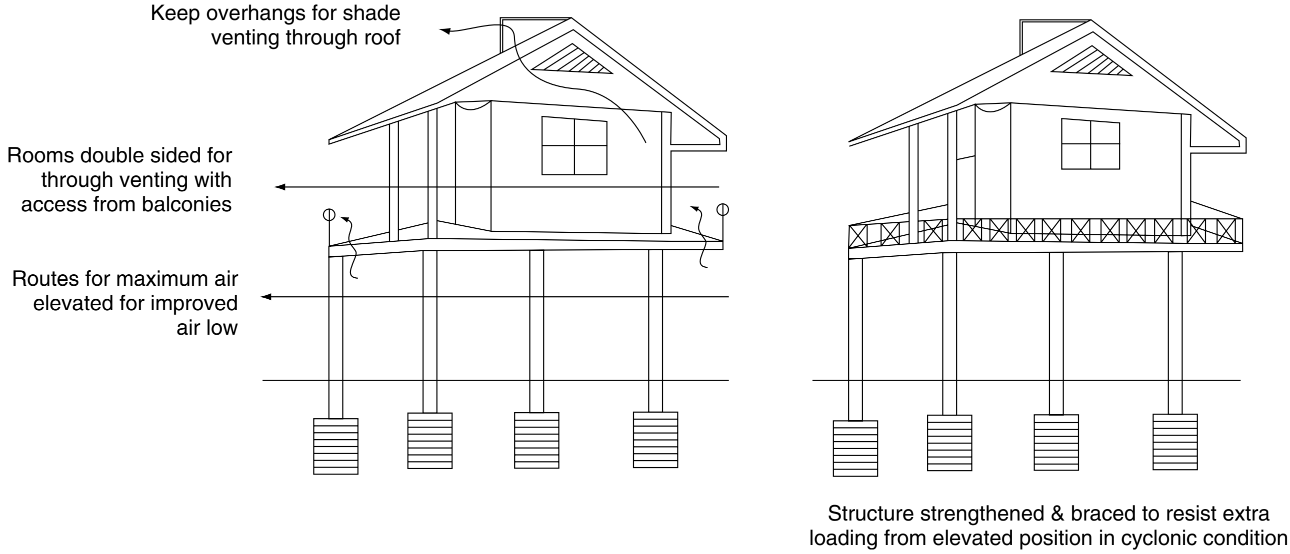
Transferable technologies
High-tech buildings in temperate climates now use design strategies that originated in the tropics (cooling towers, vented ridges, brises soleil). These sometimes perform less well than expected, as temperature variation is not sufficiently extreme to generate air movement, but when updated and reinterpreted in the tropics, they should work more efficiently. Conversely, temperate climate details (such as thermal insulation) can benefit tropical design, especially in composite climates at higher altitudes.

2.11 Environmental design

Environmental comfort within the building
Comfort depends on responding to climate specifics – humidity, seasonal variations that relate to altitude, prevailing winds and rainfall patterns, and the site and its environs. Do not forget that higher altitudes inland can get very cold overnight in the cold season – some areas have snow and frost; houses in the centres of large land masses and at altitudes over 1000 m often need room-heating fires in the sitting rooms and to take advantage of solar gain in winter. Effective passive solar design is an essential component of good design.

Environmental design around the building
Shading, restriction or enhancement of air movement, placement and type of landscaping, the use of water, reflectivity of surfaces, glare, screening against noise or dust and seasonal storm protection may all be important. Adjacent buildings may produce solar dazzle, block air movement or cast shade when it is most wanted. Public and private spaces, including car parking, may influence light levels, glare and general amenity.

Performance of the building envelope in the context of the local climate
Buildings may have to withstand torrential driving rain, lightning, cyclones, hurricanes, sandstorms, very high temperatures, extreme diurnal temperature variations with associated extremes of thermal movement, persistent high humidity, extended dry periods or



35.13 *Structures that are raised on platforms or pilotis may need strengthening to withstand strong winds*

salt-laden atmospheres, **35.13**. Structures that are elevated to catch the breeze will need additional structural measures to withstand high winds.

2.12 Flora, fauna and biohazards

Tropical diseases and infections
With climate change, global public health is declining as tropical diseases and their carriers spread into new areas where populations do not have natural immunities. The World Health Organisation offers current information on the following diseases on its website: Leishmaniasis, Onchocerciasis, Chaga's disease, Leprosy, Tuberculosis, Schistosomiasis (Bilharzia), Lymphatic filiariasis, Malaria, African trypanosomiasis (Sleeping sickness) and Dengue.

Snakes, spiders and flying insects
Find out whether the habitat offered by the site suits any venomous snakes and spiders. If it does, make personnel aware of the appropriate remedial treatment for bites. Be aware of any risks of diseases, including water-borne diseases and of diseases transmitted by insects. Any stagnant or still standing water may carry diseases or their mechanisms of transmission (such as bilharzia in Africa). Bees and wasps may be very aggressive and inclined to swarm in roof voids. Cockroaches can be difficult to eradicate.

Mosquitoes
Mosquitoes are endemic in the tropics, and several species are capable of transmitting a range of diseases (malaria is the most widespread) by transferring infected blood from one person they have bitten to the next. Recently, the increased incidence of the more extreme forms of malaria (Blackwater fever, cerebral malaria) has been accompanied by hardening resistance to the known treatments; so prophylactic medication regimes and technical solutions need greater vigilance. Government health departments, tropical disease hospitals (most countries with a colonial past or significant immigration from the tropics will have tropical expertise) and national airlines can advise on precautions. See **6.08** for guidance on design strategies to keep mosquitoes at bay.

Many tropical climates have cyclical patterns of temperature and rainfall variation, such as El Niño, that recur over a number of years. These cycles will affect the water table and extent of open water created and, when wet phases are linked to high temperatures, there will be epidemics of diseases linked to mosquitoes and other water-breeding insects. In Australia, outbreaks of Murray Valley encephalitis occur at the peaks in the Southern Oscillation Index, which coincides with El Niño years.

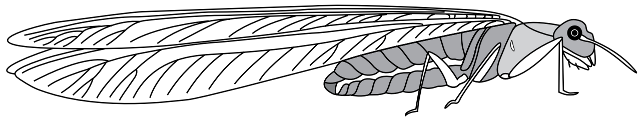
Larger mammals
In rural areas, wild animals can cause problems, as can free-ranging livestock. Hippos leave the water to go night-grazing, elephants strip bark from trees and feeding monkeys cause a lot of willful damage.

Wood-boring insects
Structural timber and timber furniture may be at risk of disfiguring borer attack.

Termites
The presence of termites, **35.14**, may only be apparent if they are of the type that constructs mounds or 'anthills'. Termites can penetrate small spaces and destroy constructional timbers very quickly. They will also destroy landscaping, stripping trees and shrubs of bark. Where they are prevalent, allowance should be made for the need to replace a percentage of all landscaping due to termite damage. Termites may affect the soil profile, leaving a distinctive line of stones at the lower limit of their activity.

There are three main types of termites:

- *Dampwood termites* inhabit damp rotting logs or pockets of rot in dead or living trees. They obtain all the water they need from their habitat and do not need contact with the ground.
- *Drywood termites* are similar to wood-boring beetles found in temperate climates. They can fly into buildings or be introduced in previously infested timber. They can be deterred by the use of (expensive) naturally resistant timbers, by pre-treatment of



Light shelves
Fins
Screens
Overhangs
Egg-crates

35.14 *Winged termite. Drawing copyright D G Mackean* timber with a wood preservative and by including physical barriers in the design, especially at roof level.

- *Subterranean termites* need to maintain contact with the ground and can survive in drier conditions than the drywood termites. They present the greatest risk to buildings. They can pass through fine cracks in slabs and mortar and construct mud galleries, linking their nest and a source of moisture underground with the cellulose food source within the building. Poorly ventilated, damp and dark spaces below floors and around the perimeter of the building will increase the risk of infestation. Landscaping can conceal activity, whilst disturbed soil or materials stored beneath the floor will facilitate it. Naturally resistant timber species are in short supply.

The options are to destroy the nest, and to use physical or chemical barriers. Low-pressure spraying of the ground with poison (usually the organophosphate chlorpyrifos or the pyrethroid bifenthrin) is generally considered the most effective treatment, but it must be continuous and not be compromised by later alterations or additions to the structure. In Australia, a fine-gauge stainless steel mesh is used as a barrier in any location, including below the floor slab. Smooth exposed faces of ground floor slabs (minimum 75 mm) assist detection and if constructed with sharp exposed corners, can deter termites, **35.15**.

Materials used in the floor slab and lower courses of walls, including hardcore, building sand, mortar and render are also usually poisoned with a pitch-based sealing compound and effective sealing of all cracks, joints and holes is essential. Termite shields are also used, but can be bridged and will become corroded, needing replacement. Chemical use should be by licensed who can also destroy nests by blowing arsenic trioxide into the colony using a hand blower. Regular inspection is essential.

2.13 Other essential design data

Design philosophy and practice

Be sensitive to local and regional practices and procedures, without producing a pastiche of the vernacular tradition.

Anthropometrics and ergonomics

European anthropometrics data tends to be out of date (we have got taller and bigger); elsewhere, particular tribal and ethnic groups may have distinctly different characteristics, especially with regard to height and reach. If there is no data available, arrange for a local agency to obtain it, rather than trying to do it yourself – you might unwittingly cause offence.

Disabled access

Policies will vary, as will the numbers of disabled, especially in current and former war zones. Polio may also have left its mark.

Special factors in the design of the spaces around the building

National attitudes to land ownership, landscaping, public access, vehicular access and the use of public art can vary greatly. In some areas where there are no public facilities, indeterminate public spaces and open drains may be used as latrines.

Security

Abductions, muggings, desecrations or petty thefts may be problems that constrain design. Diplomats, and some nationals in particular, can feel extremely vulnerable and demand extreme measures, including 'safe rooms'. Burglar bars and other security measures may restrict means of escape in case of fire, boundaries may be marked by high walls topped with razor-wire enclosing a patrolled *cordon sanitaire,* and gates may be protected by armed guards.

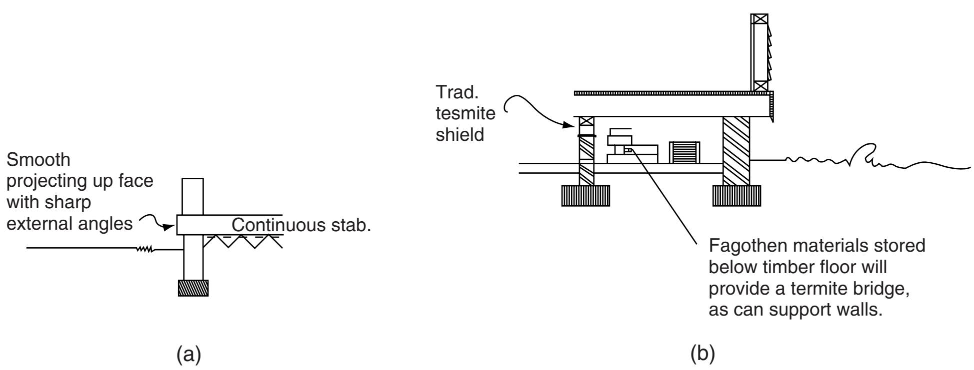
Landscape design

Plant availability, local knowledge and expertise vary from country to country – look at the landscaping of public buildings to gauge attitudes and possibilities. There may be some protection of indigenous flora and restrictions on exotic (imported) species. Throughout most of the tropics, previous colonial administrators and later horticulturalist and landscape architects have imported species from all parts of the world. These can homogenise tropical landscaping and there is a move towards using indigenous species.

Irrigation may be a problem, in which case species that are drought-resistant must be used in dry or seasonally dry climates, where plantings needing irrigation should be restricted to designated 'watered' beds. Landscaping should support the environmental agenda of the building design – shade, air-flow, cooling, etc.; soft landscaping can harbour insects, snakes, and vermin and, as a consequence, some clients may insist there is no planting close to the building. Irrigation will cool the air but raise humidity.

Rainwater dispersal

In any climate where there are frequent heavy rains, it is inappropriate to fit the small gutters and down-pipes that are normally used in temperate climates. A short rainstorm may well cause a flash flood and the conventional solution in some countries is to discharge water from overhanging eaves into open dish drains which convey the water to large open storm drains which increase rapidly in width and depth as more inlets are added. It is imperative that these all drain effectively, without leaving standing water in which mosquitoes, bilhartzia (*schistosomiasis*) and other diseases and bacteria can flourish. In public buildings and cities, where gutters normally will be used, they must be able to carry the heaviest rainfall or be able to overflow without causing damage or nuisance.



35.15 *Ground floor design can deter or encourage termites:* **a** *ground-bearing concrete floors;* **b** *suspended timber floor*

2.14 Desk study

It is essential that all these issues be investigated in a thorough desk study before detailed design work begins. Additionally, there will be an enormous range of built and documentary evidence, knowledge, expertise and experience within the country that can be invaluable in ensuring that an appropriate design solution is found. The architect who ignores this will compound the resentment of skilled local architects who have been overlooked when the commission to design the building was awarded. By including local expertise within the team, a whole range of subtle local factors may emerge, greatly enhancing the outcome.

3 CLIMATE-RESPONSIVE DESIGN: CLIMATE TYPES

3.01 Bioclimatic design

A careful evaluation of traditional and current aesthetic and technological local solutions will help to define the important design issues. In particular, if there is a highly evolved, almost iconic traditional building form, a detailed analysis of this form may prove particularly rewarding. Modern buildings and urban planning have usually derived from Western models and have not always been successful in resolving environmental problems or addressing social needs. The intention should be to reinterpret and add value to proven successful solutions, or to come up with different solutions that respond more effectively to changes in conditions or scale. A clear understanding of the issues and options is essential.

The international style of architecture seen around the world today is based on temperate-climate models and, like vernacular dry and arid climate architectures, it is enclosed, contained and defensive – based on solid geometry. Architecture in humid and composite climates, however, is often a fluid, unconstrained space under a canopy where people move in and out – through voids defined only by their upper surface. There is little physiological differentiation between being 'inside' and being 'outside' under a shady tree. In wall-less spaces, dramatic roof forms can make a much stronger statement.

In climates where much of daily life is conducted outside, it is common for buildings to take the form of a series of pavilions set in parkland and linked by covered walkways. In more congested sites, and where security is important, links between buildings may be semi-enclosed breeze-ways, walled with *brises-soleil* or some other form of defensive trelliswork.

Generically, designers recognise three main climatic types: hot dry, hot wet and composite (with seasonal variation). In reality, most locations will have some seasonal variation and overlap with other types. Tables VI–VIII summarise the main indicators and design responses.

3.02 Design in hot dry and arid climates

The hot dry climate building needs to be ventilated whilst keeping out sand and dust, have a slow thermal response – achieved by high mass outer walls and should have small windows at high level, to cut down glare and solar gain, **35.16**. Traditional solutions achieve high mass by using thick walls of stone, air-dried mud bricks or rammed earth (*pisé de terre*). The unfired clay usually has a protective render or coating that will withstand occasional rain,

Table VI Climate responsive design strategies – hot dry desert climates
(Baghdad, Alice Springs, Phoenix)

Indicators	Measurements	Design response
Latitudes	Between 15° and 30°N and S	Establish sunpath data; use to determine position of windows and other features
Location – within continental land mass	Altitude	
High daytime temperatures (up to 50°C), and cold nights (clear skies permit re-radiation of daytime solar gain) High diurnal range	Monthly mean maximum and minimum temperatures	Deep shade and high thermal mass with time lag to release warmth during cold night Stone and tiled floors will stay cool if fully shaded Use sound and sight of water for psychological cooling during the day
Low humidity, dry air	Average monthly relative humidity (RH) (from monthly mean maximum and monthly mean minimum) 10–55%	Use water for evaporative cooling
Low rainfall (precipitation)	Annual rainfall (range 50–155 mm)	Flat roofs, no gutters Provide for cleaning dust off the building envelope, especially windows
Two seasons, one hot, one cooler or cold	Monthly mean maximum and minimum temperatures	Use reduced solar altitude in winter to capture and store solar energy in trombe walls and on high mass paved floors. Reduce shading to permit solar gain in structure. Stabilise temperature with ground storage of water or energy.
Deep blue sky; glare from horizon worsens at end of dry season as dust in the atmosphere creates a haze	Solar radiation, luminance (1700–2500 cd/m^2, haze up to 10 000 cd/m^2)	Small windows placed at high level with view of deep blue sky (not facing into the sun's path) Use screens to cut glare (jail, mesh, masrabiya) with smaller apertures at lower levels to cut glare from horizon.
Air movement will contain dust and sand; whirlwinds will occur	Wind speed	Ventilation strategies depend on cooling and filtering air
Arid landscape with drought-tolerant species or desert conditions	Rainfall	Landscaping will depend on drought-resistant species or irrigation – but water use may be costly or restricted. Low humidity will affect growth.
Sandstorms	Wind speed	Defensive land-forming and building envelope with tight-fitting infill of openings (windows, doors, shutters, storm guards) Air vents and filters will require regular cleaning.
Variation – hot dry maritime desert climate (Kuwait, Karachi) Temperature – not as hot but with less seasonal variation		
Relative humidity	50–90%	A particularly uncomfortable climate – encourage air movement with overhead fans. Air-conditioning may be needed.
Cloud cover – there may be a thin haze, causing glare	Sunshine hours per annum	
Local breezes, off the sea during the day, from the land at night	Wind speed	Orient openings to take advantage of daytime breezes.
Salty atmosphere – risk of corrosion	Distance from sea	Specify appropriate materials

Table VI (Continued)

Indicators	Measurements	Design response
Design solutions		
Individual buildings	Buildings are inward looking and defensive with thick walls and small high windows. Building mass should be efficient with as little of the envelope exposed to the sun as possible, especially on the west where the afternoon sun is the hottest. Internal courtyards are widely used, with the use of water for evaporative cooling and decorative screens to cut down glare. Roofs, walls, windows, terraces and courtyards can be shaded with canopies or secondary structures.	
Urban development	Buildings are packed close together – in particular, east and west facing party walls should be protected from the sun. This reduces travel distances – to markets, shops and services. Adopt strategies that reduce physical effort. Narrow streets running north–south will receive least sun. Wind towers catch the breezes and cool the air, drawing it over water into shaded courtyards.	
Landscaping	Create an artificial oasis by contouring land and planting shelterbelts with drought-resistant species. If irrigation is possible, other species may be grown. Soil may have to be imported. If so, it will need stabilising and protection or the wind will take it away. Use water for functional, decorative and psychological benefits. Shade paved areas to cut down glare.	

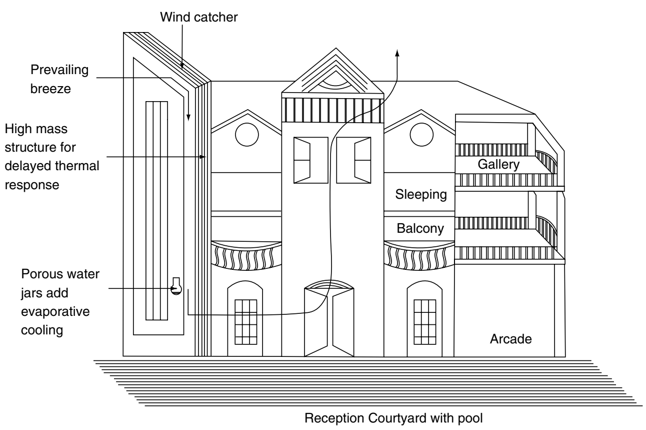
Table VII Climate responsive design strategies – warm humid equatorial climates
(Lagos, Dar-es-Salaam, Colombo, Singapore, Djakarta, Quito)

Indicators	Measurements	Design response
Latitudes	Between 15°N and 15°S	High solar altitude with small seasonal variation enables specific shading solutions to be accurately designed; principal elevations should face north and south
Typical mean maximum daytime temperature 27–32°C and mean minimum at night 21–27°C; low diurnal range	Monthly mean maximum and minimum temperatures	Temperatures exacerbated by humidity – use thin-skinned structures to speed cooling and ventilation Design should include covered and fly-screened verandas, etc.
High humidity all year, around 75% but may range from 50 to close to 100%	Average monthly relative humidity (RH)	High humidity may necessitate the use of air-conditioners at night
High rainfall which may get heavier for a few months	Annual rainfall (range 2000–5000 mm)	Pitched roofs with deep overhangs; no gutters or wide gutters. Verandas, colonnades and covered walkways will provide protection from the rain.
Rainfall will increase insect nuisance (mosquitoes, etc.)		Verandas should be fly-screened Eliminate stagnant standing water and take other precautionary measures.
Little seasonal variation, with perhaps some increase in rainfall, wind or storm conditions from time to time	Precipitation, monthly mean maximum and minimum temperatures	Little need for seasonal variation in design use
Overcast sky persists; cloud cover varies between 60 and 90%. Glare is intensified by reflection off cloud and can be intense. Cloud traps warm air, preventing night radiation to sky.	Sky cover and sunlight hours. Luminance range between heavy and bright overcast skies 850–7000 cd/m^2	Fly-screens, *brises soleil* and other screening devices will cut down glare, as will deep overhangs and verandas.
There is little wind movement, but gusts are occasionally recorded	Wind speed	Elevate buildings to maximise air movement; use louvre windows for maximum ventilation; rooms must have through ventilation.
Lush landscape with tropical forests, buttressed trees and vines. Impoverished laterite soils produce vegetables with little mineral content.	Rainfall, albedo	Landscaping will need to be controlled or will become overgrown. Waterlogged sites may need draining or planting with appropriate species.
Variation – warm humid island climate (Caribbean, Philippines, Hawaii)		
Daytime mean maximum 29–32°C and mean minimum at night 18–24°C. Small diurnal and annual temperature ranges.	Monthly mean maximum and minimum temperatures	
Relative humidity	55%–almost 100%	Assist ventilation with design
High rainfall; storms may be heavy; sea spray may be a nuisance	Annual rainfall 1250–1800 mm	Roofs must be well constructed
Skies are clear or with broken cloud except during storms.	Clear sky luminance 1700–2500 cd/m^2	
Trade winds are regular; cyclones may be severe	Wind speed	Design for high winds
Salty atmosphere – risk of corrosion	Distance from sea	Specify appropriate materials
Design solutions		
Individual buildings	Roofs must be robust to withstand heavy rain, and usually have deep overhangs to shed the rain; thin-walled structures with rapid thermal response (cooling) and cross-ventilation (avoid back-to-back rooms and central corridors – circulation can be via perimeter verandas); habitable verandas, some fly-screened; main axis east–west; windows face north and south; use clerestory windows, vented ridges and wind towers to improve ventilation; shade trees should have high canopy but not block ventilation below the eaves; position structures to catch the breeze; anticipate damp and mould, insects and vermin.	
Urban development	Buildings should be positioned to obtain maximum ventilation; line buildings with verandas, colonnades and covered walkways.	
Landscaping	Dramatic landscaping is possible, but beware of wind rock in trees close to buildings.	

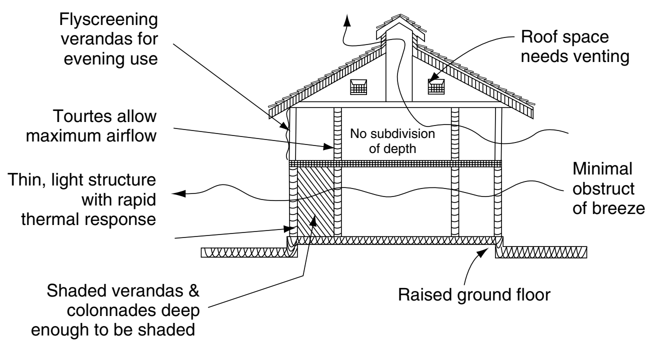
provided it is repaired from time-to-time. Regional variations using the same materials can be quite distinctive – adobe in New Mexico, barrel vaults as used by Hassan Fathy in Egypt or tower houses in Iran. The same unfired materials recur in composite climates, but are protected from heavier, more persistent rain by deep overhangs, being placed on raised floor platforms and being repaired every year. In the dry tropics, there is a flat roof, often used for sleeping in the hottest weather. Any dense material may be used for the thick outer wall. Choice of material and wall thickness will depend on the desired time lag of the thermal response.

Table VIII Climate responsive design strategies – composite or monsoon climates
(New Delhi, Kano)

Indicators	Measurements	Design response
In large continental landmasses, close to the Tropics (23.5°N and S)	Latitude, altitude	Distance from equator results in seasonal variation and compromises in design
High daytime temperatures (up to 50°C), and cold nights (clear skies permit re-radiation of daytime solar gain) High diurnal range	Maximum and minimum temperatures	Design for different lifestyle, adjusted to suit climate; ensure daytime shade, night-time heat retention
Dry season humidity 20–55%; wet season humidity 55–95%	Average monthly relative humidity (RH)	If high humidity is short-lived, prioritise longer-term conditions, and use mechanical fans, etc.
Seasonal rainfall (monsoon) can be heavy and prolonged – up to 38 mm/h	Annual rainfall (range 500 – 1300 mm)	Pitched roofs with overhangs
Two seasons – hot-dry and warm-humid (21–43°C); further from equator, third season – cool-dry (4–27°C). Diurnal range up to 22°C	Monthly mean maximum and minimum	Include adjustable building elements; different spaces to suit different conditions; create micro-climate
Sky overcast during rains, clear deep blue during dry season, becoming dust-laden and hazy towards end of dry season	Solar radiation, luminance, cloud cover, sunshine days	Placement of windows; screening of windows
Monsoon winds strong and may come from different direction than winds at other times of the year; winds carry dust in dry season		Variable features; shutters and screens
Landscape changes appearance seasonally – lush in rains, becoming parched in dry season	Rainfall	Use drought-resistant species or irrigation
Termites are common	Anthills, nests	Use barriers, poison, appropriate design measures; expect high wastage.
Variation – Tropical upland climate (Bogota, Nairobi)		
Upland zones	Altitude 900–1200 m	
Distance from the equator increases seasonal variation	Latitude	Design will need to meet winter conditions, as well as summer.
Temperature reduces with altitude; diurnal range large, ground frost may occur	Weather data	Open fires, winter solar gain
Rainfall often heavy – up to 80 mm/h	Precipitation + 1000 mm	Pitched roofs, deep overhangs, storm drains
Heavy dew at night; radiation heat loss at night may cause radiation fog; hail; thunder and lightning	Weather data	Lightning protection, thermal insulation
Design solutions		
Individual buildings	Design depends on winter temperatures, duration of high humidity and duration of rains.	
Urban development	Colonnades and arcades provide shelter from rain.	
Landscaping	Many species will tolerate these climates, but may need irrigation unless resistant to seasonal drought. Risk of frost needs to be determined. Termite damage can be considerable.	



35.16 *The hot arid climate building is cool, shaded, and heat retaining. Its form prevents normal ventilation flows, so these must be induced by the use of wind-catching towers and wind vents, water placed strategically to provide evaporative cooling and the creation of temperature differentials within the central spaces to drive air movement*



35.17 *The hot humid climate building is airy, shaded and thin-skinned with a roof that can disperse torrential rain. All habitable rooms should have cross-ventilation*

3.03 Design for hot wet and humid climates

The main requirements here are to maximise ventilation, shade and protection from rain, and to have a thin-skinned rapid thermal response building envelope, **35.17**. The maritime equatorial climate exhibits little variation over the year.

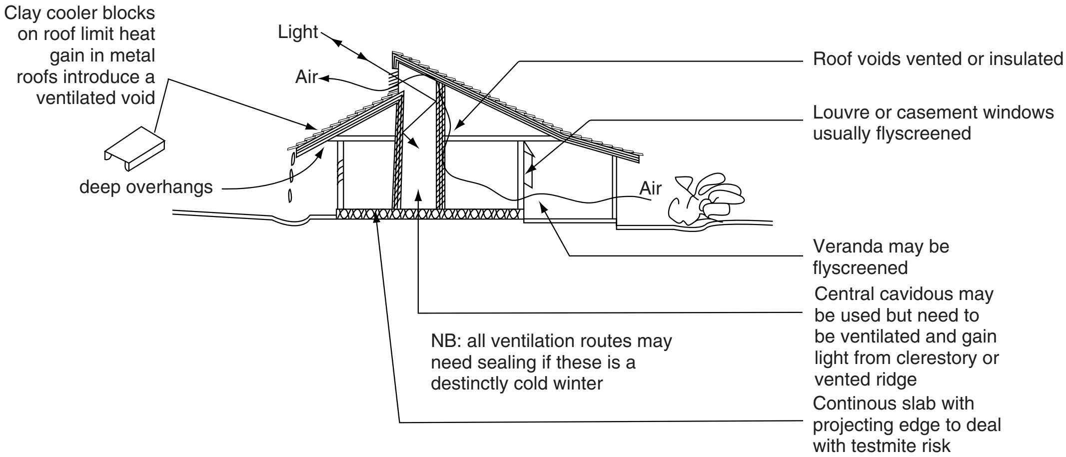
3.04 Design for composite climates

A composite climate has distinct seasonal variation. A decision needs to be made as to priorities in terms of climate-response, **35.18**. The seasonal variation in sunpath can be used to vary building response to the different climatic conditions, supplemented by movable elements, insulation and mechanical heating or cooling systems.

4 ENVIRONMENTAL DESIGN STRATEGIES: PASSIVE DESIGN

4.01

There are two approaches to the provision of climate-responsive design – passive or active. Passive design is architect-driven and architectonic; it suits smaller, individual buildings, especially the



35.18 *The composite climate: different regions have different solutions depending on climate variables. This example is based on typical housing in Malawi at altitudes of 1000 m. These houses are provided with a open fire in the sitting room. Cooler blocks are fired clay U-profile blocks loose-laid over profiled aluminium metal sheeting. They keep the worst of the solar radiation off the aluminium and create a ventilated space between the block and the roof-covering. Pitch is usually no more than 27.5°*

one-off house; and it does not usually attract large research grants. Active design is the domain of the scientist and engineer: it is mathematical and appears more measurable; and it tends to attract government grants, the support of industry (there is a marketable product) and is used on prestige projects. In the 1980s, these two stances tended to polarise the specialists in this field, but today, there is more recognition that a mix of both is needed to get the best outcome. Design is becoming more integrated – and more pragmatic.

Passive design is the careful siting, orientation, design and detailing of buildings to ensure that maximum advantage is taken of aspect, sunlight, wind, contour and shelter to minimise dependency on fossil fuels and externally generated power, heat or artificial light, **35.19**. Passive solar design uses fixed elements of the building fabric and its environs to manage solar radiation and optimise natural heating or cooling. The benefits of passive design are a more comfortable natural environment, reduced energy consumption, reduced costs, lower maintenance and long-term viability as a building which will meet future higher energy regulations and which will remain economic to run as fuel prices increase. This topic is covered extensively in academic websites worldwide. Many of these are illustrated with regional design solutions.

4.02 Shading

The best way to control solar radiation is to use external shading. This must be designed with a thorough understanding of sunpath data, obtained with the aid of a sun path diagrams and a shadow angle protractor (para **7.01** and Chapter 40). Shading of buildings, windows and internal courtyards can reduce the cooling load on buildings and alter ventilation, glare and daylight levels. It may affect views out of the building.
Passive shading, **35.20, 35.21**, may be achieved using:

- Landscaping
- Free-standing structures
- Pergolas, porches, verandas and colonnades (section 3.07)
- Structural elements
- Non-structural elements of the building envelope.

Passive shading elements, **35.22**, include:

- Light shelves
- Egg-crates
- Screens (jail, mashrabiỹa, metal grillages, cascading planting on wire framing)
- Overhangs
- Fins

Active shading, **35.23**, may be provided by:

- Manually controlled awnings and blinds
- Automatically controlled awnings and blinds
- Shutters – which may be removable
- Independent and temporary canopies.

A recent project at Valletta in Malta has a sealed glazed roof that opens in hotter weather, **35.24**.

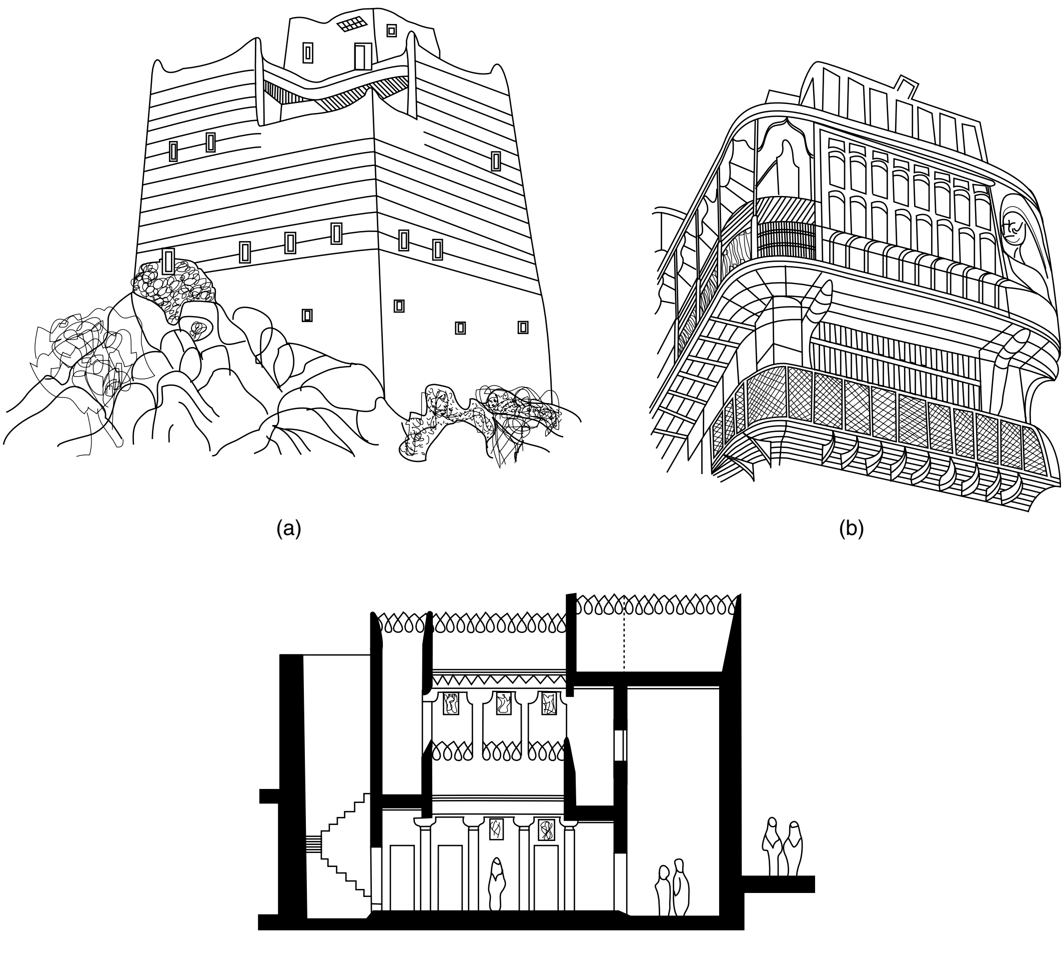
4.03 Porches, pergolas, balconies, verandas and colonnades

Any shaded or covered space around the edges of buildings or around internal courtyards will act as a transitional space which, depending on its particular function, can be seen as an extension of habitable space or as a barrier or a bridge between public and private space. In all cases, this shaded space will moderate temperature, keeping the sun off the main structure and maintaining a more consistent temperature in the interior. This interior will be glare-free and relatively dark, unless lit by clerestory windows, a split ridge, light scoops or light pipes, **35.25**. (Light pipes are highly polished metal tubes that reflect light gathered via a Perspex dome at roof level and discharged via a similar inverted dome diffuser into a dark interior space **35.26**. They are economical, efficient and effective.)

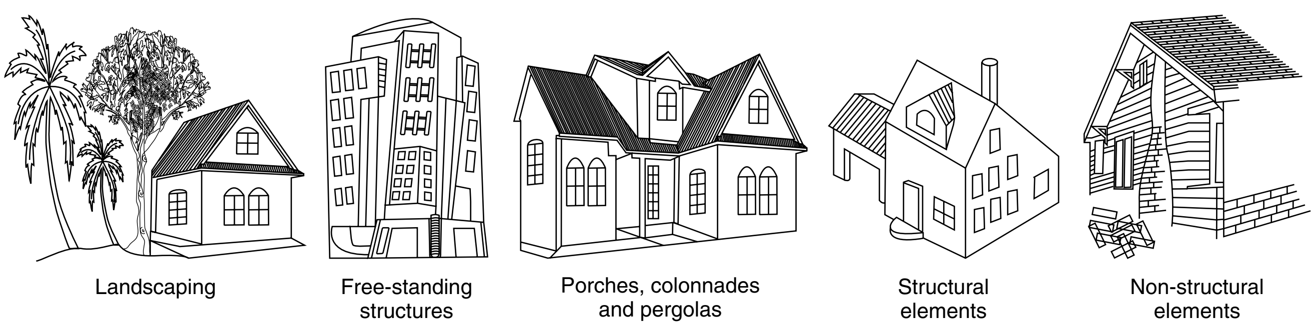
The dark interior may be gloomy in cold weather, except when low winter sun penetrates to the inner walls, but this darkness is psychologically cooling and pleasant, provided that it does not necessitate the use of artificial light during the day.

The effectiveness of these shade-giving spaces will depend on orientation, latitude, depth, prevailing breezes, and width/height ratio, **35.27**. In all hot climates, verandas may become the main living spaces for most of the year, and any building design should recognise the social and environmental importance of these spaces. Except in balconies to individual bedrooms, the covered space should have sufficient depth to allow a group of people to sit around a small table (private houses) or to allow people to work or promenade in comfort (public colonnades). The depth of shade should be sufficient to enable the anticipated activity to be carried out in comfort, **35.28**.

The iconic colonial bungalow has a veranda on all four elevations, with each one being used at different times of the day or year, **35.29**. In all climates with a marked seasonal variation in temperature, the main shaded space should be on the elevation facing the equator so that when the sun is overhead in the hot season, it barely penetrates into the space, but in the cold season, when the sun is lower, it shines into the recess, providing warmth, **35.30**.



35.19 *Passive design in the hot arid tropics:* **a** *thick-walled defensive structures with small, high-level window apertures keep out heat, glare and dust;* **b** *traditional timber mashrabiỹa provide shaded and screened views into urban streets;* **c** *interiors are shaded and arcaded, with inner courtyards*



35.20 *Passive shading options*

In hot humid climates, conditions may be too unpleasant indoors, during both the day and the night. In the humid evening and night, flying insects are a particular nuisance, and one or more of the verandas will be fly-screened. This cuts down air movement but is essential. In two-storey houses, a secure screened upper veranda may be used for sleeping on the hottest nights, **35.31**. In these climates, it is common practice to raise the house, sleeping areas and verandas as high as possible above the ground, to catch the night breezes. On cooler days, the dappled shade under a pergola supporting a vine or other climbing plant may be more pleasant than deep shade.

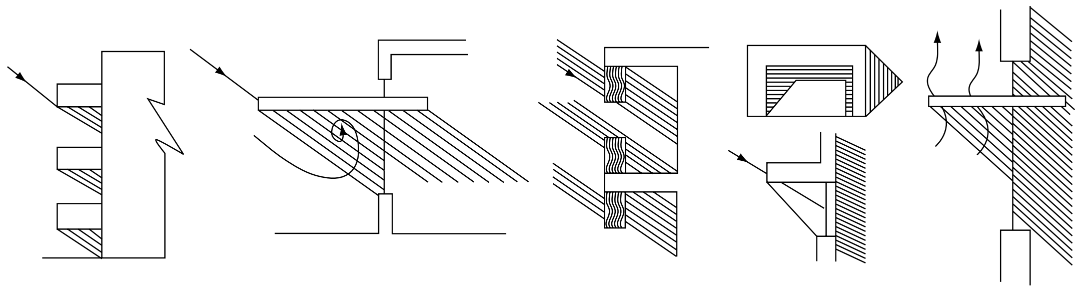
Security will be a consideration in the design of most external spaces.

4.03 Courtyards, patios and atria

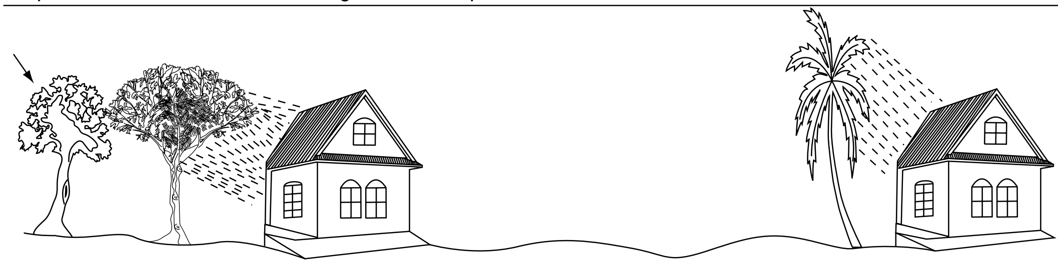
Courtyards or patios, **35.32**, are traditional features in most hot climates and serve several purposes:

- they defend the occupants from the busy, noisy, smelly street
- they ensure privacy
- they reduce built depth and should increase through-ventilation, Table IX.

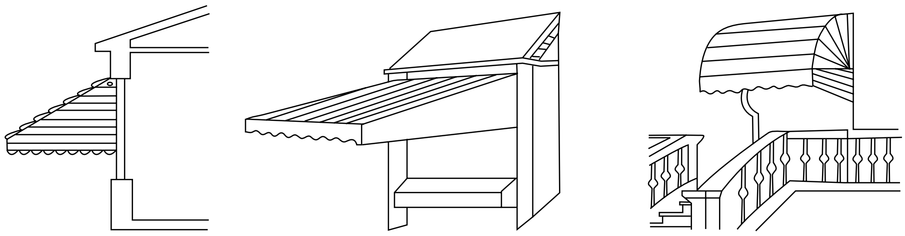
External devices to protect buildings from direct sunlight



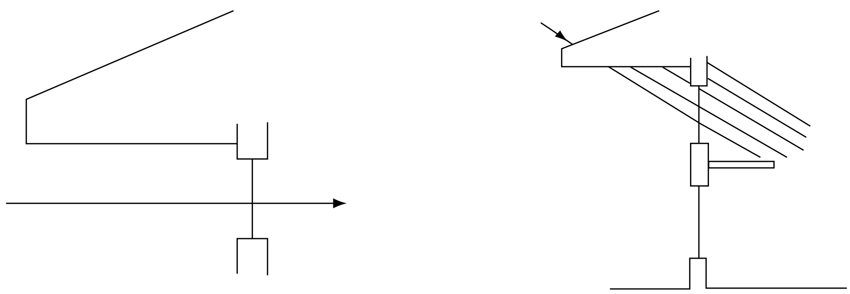
External shading: Balconies, light shelves, screening walls, window hoods, brises soleil, and other structural devices will provide shade, but should be designed not to trap heat.



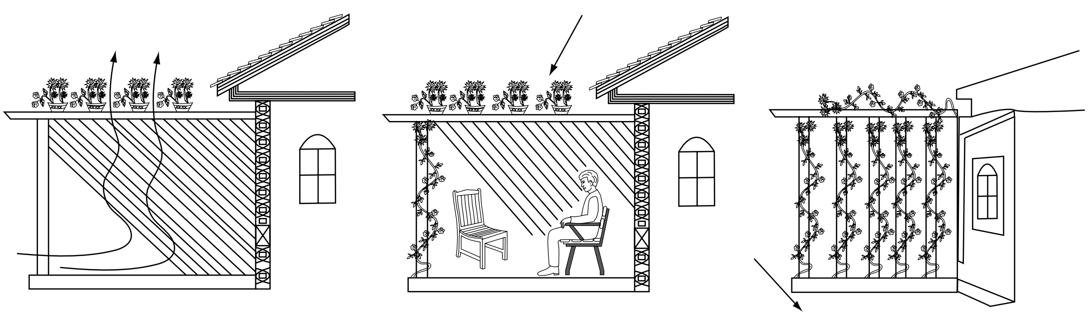
Soft landscaping: Trees may shade the roof, driveways, patios - the larger the better. Transpiration is evaporative cooling. All trees with forige at high level permit low air movement.



Awnings: Awnings are decorative, relatively cheap and adjustable. They block part of the view, can trap air and may suffer mechanical damage.

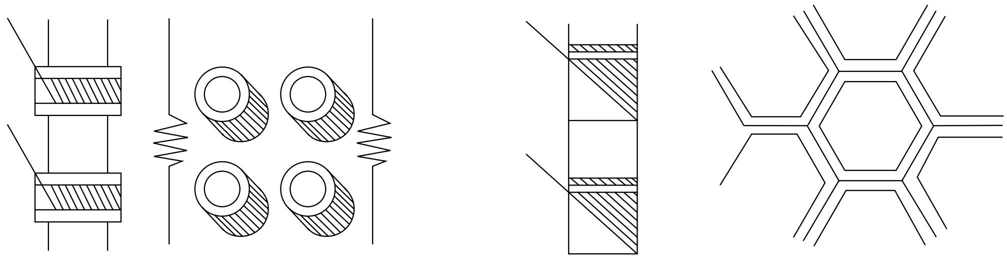


Deep overhangs: Overhangs do not provide relief for east and west-facing windows that face low sun. They will not shade the ground floor windows on a two-storey building.

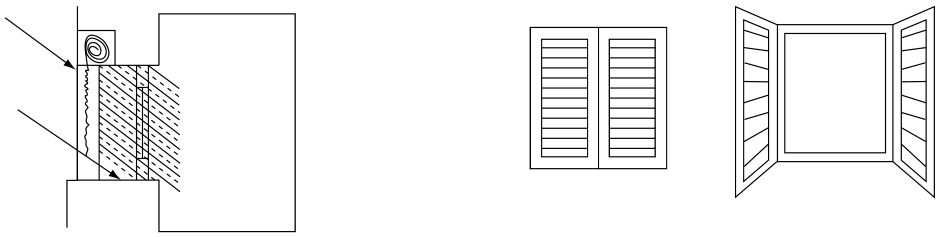


Pergolas and trellises: These permanent structures provide shade; climbing plants add evaporative cooling. If air conditioners and other electrical equipment are shaded, it improves their performance.

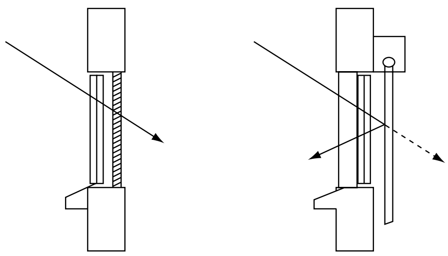
35.21 *Passive shading devices (continued over)*



Screen walling and ‘egg crates’: Perforated screen walling can admit light and breezes whilst keeping out the sun and ensuring security.
Devices at or within the window to protect from direct sunlight.

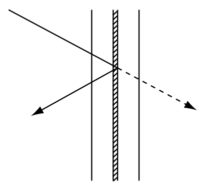


Louvres and shutters: External louvres and shutters will be more effective than internal ones. Metal shutters will become very hot and radiate heat into the building. The louvres on American shutters can be adjusted to retain some view and admit light whilst completely blocking the sun.

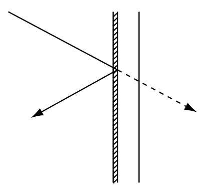


Venetian blinds, etc: Internal Venetian or roller blinds, or curtains (sheer or heavy drapes) should have a pale lining facing out to reflect heat back out of the window, fit tightly to prevent heat dispersing into the room, cover the whole window, and, for maximum effect, be made in a insulating material.

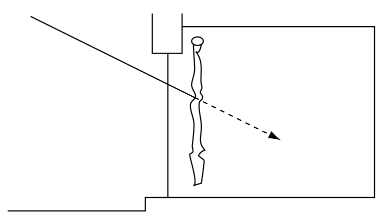
Special glass: A wide range of solar control glass is available, in grey, gold, green, blue and pink tints, usually aplied as the filling in a laminated sandwich. Outlook will be affected by the colour of the tint and degree of light reduction.



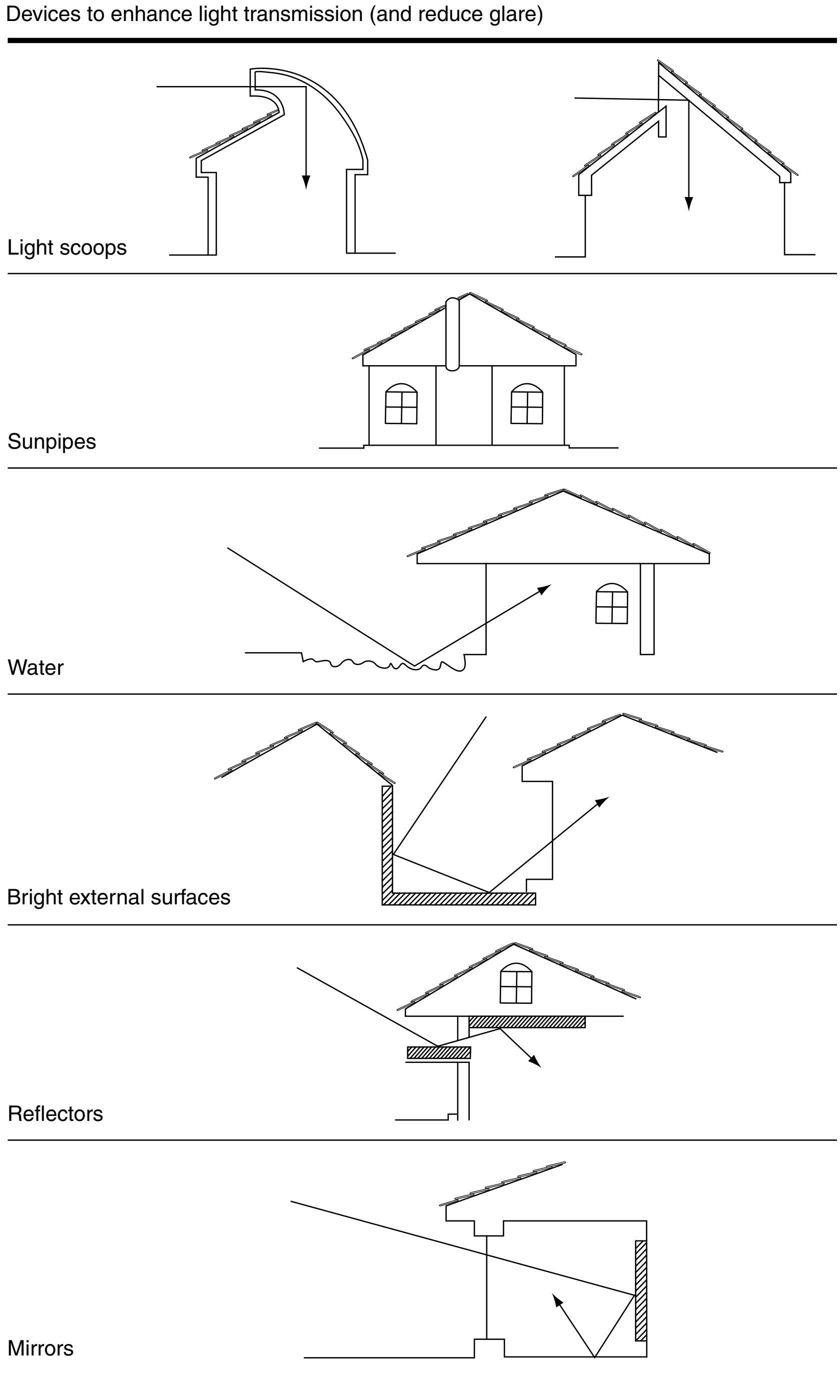
Special films applied to the glass: Plastic films containing gold and other minerals can be applied to achieve a wide range of effects. They are comparatively expensive and affect the outlook from the building.



Curtains – sheers: Sheers will reduce glare, but wil not significantly reduce solar gain.



35.21 *Continued*



35.21 *Continued*

Courtyards may be lined with verandas or colonnades (as was the monastic cloister). The surrounding walls and roof will cast shade into the courtyard from the east in the early morning and from the West in the early evening. The courtyard itself may be shaded by tall trees, awnings or retractable canopies.

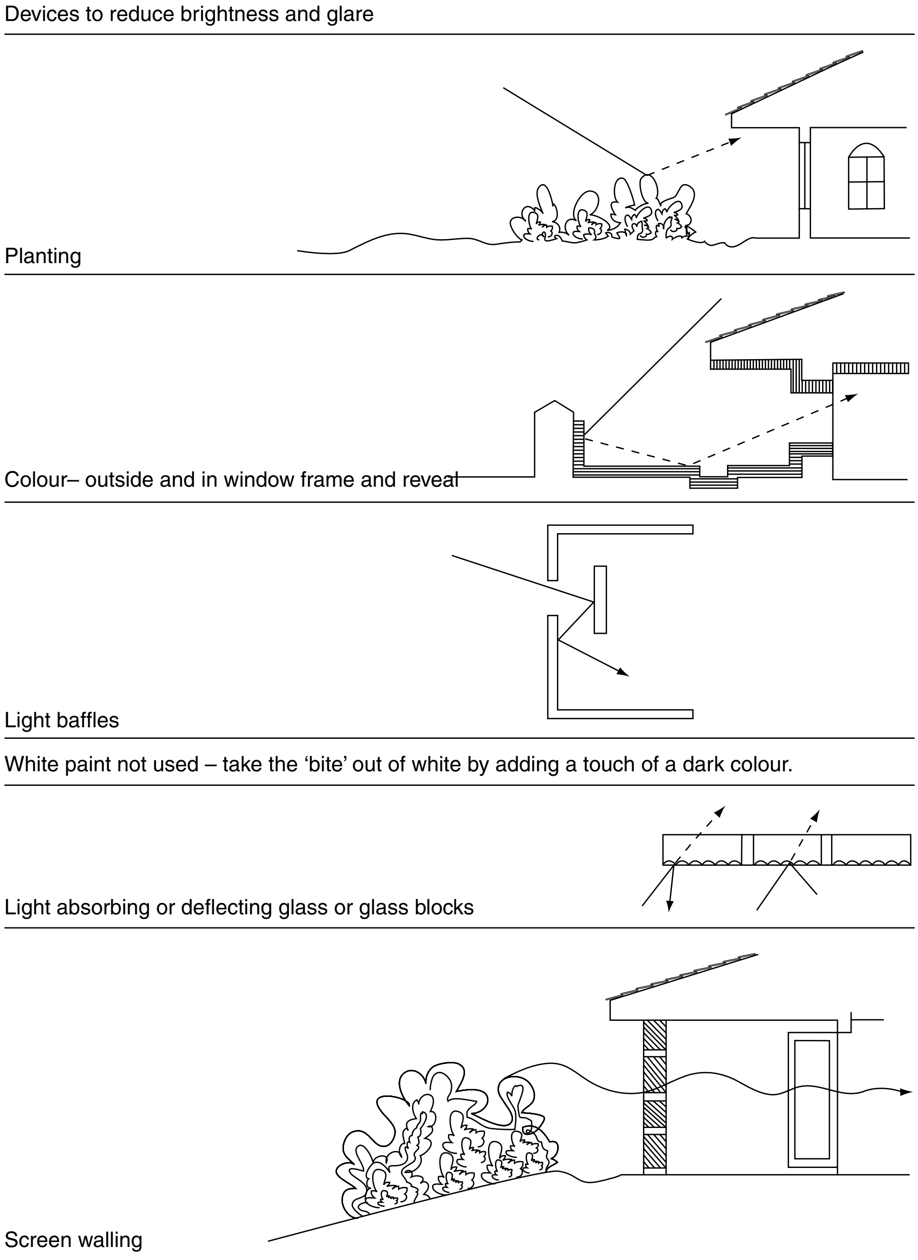
The aspect ratio, **35.33**, of courtyards is critical to their effectiveness.

Where H = height and W = width
a low aspect ratio has $H/W < 0.3$
a medium aspect ratio has H/W between 0.3 and 1
a high aspect ratio has $H/W > 1$.

An atrium (a Roman open courtyard, but today the term usually means an inner courtyard roofed over with glass) may overheat in hot climates unless carefully designed. It will provide an attractive large space within a building that acts as a focus point and, like any lightwell, it will admit and reflect light into spaces that would otherwise have been dark. The fall-off in lighting levels will be quite rapid at lower levels, as the no-sky line is passed, **35.34**. It has the potential to act as a solar flue if adequately ventilated (naturally or mechanically), drawing stale air out of the surrounding spaces. In climates with regular rainfall, atria can provide considerable amenity as meeting, eating and sheltering spaces. Their height means that landscaping can include tall trees. Glare and brightness can be reduced by using blinds below the glazing, or temporary tented canopies above it.

4.04 Wind towers, wind scoops and wind catchers

Wind towers are air extract or inlet flues, used to ventilate and cool buildings. The origin of these towers is in the arid tropical climate of the Middle East, where they are used to ventilate and cool the lowest floors of town houses. Houses in these climates are enclosed, with few external openings, to keep out sand and dust, as well as to minimise solar gain. They have a high thermal mass, which maintains some warmth in the cold winters.



35.21 *Continued*

The prevailing breeze is caught and funnelled down into the base of the house through a duct or flue in a party wall. This flue does not receive any solar radiation, so it remains cooler than the rest of the house during the day. Incoming air is cooled by conduction during its contact with the cool walls of the flue and relative humidity is increased when it passes over porous water jugs, **35.35**.

In Iraq, the cool breeze is discharged into a basement, used for the afternoon siesta. During the hottest months, the roof terrace is used for sleeping at night. The top of the wind-catcher is capped to keep rain out, and usually can be closed in winter, when it will have the reverse benefit of keeping the house warmer. Screens keep birds and insects out of the flue, **35.36**.

Urban wind towers

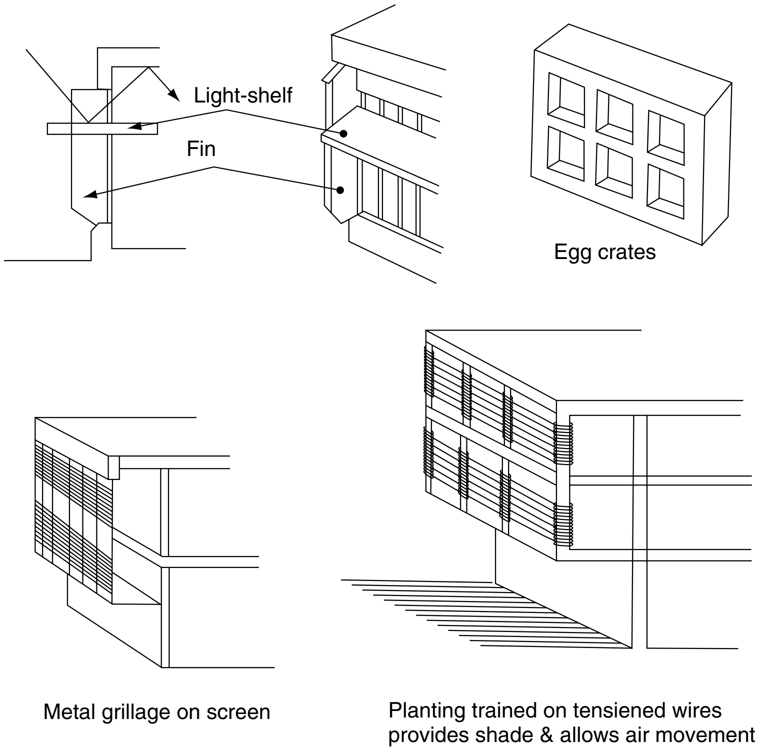
Air at street level in cities can be laden with toxic particulate matter and noxious gases. Air drawn from this environment will be polluted and will also introduce noise pollution. If we wish to use natural ventilation in city buildings, the cleanest air will be obtained from high level. Current UK Government sponsored research focuses on the 'top-down' ventilation of urban buildings.

In cities, the maze of streets, differing heights of buildings, levels of pollution, vortices, pressure differentials, etc. create local air movement patterns. Fixed wind-catchers can be ineffective in these situations, and scoops that can rotate with the wind become essential. The Bluewater development at Dartford, England uses large revolving scoops, **35.37**. Air inlets serving the flues may be windows, open courtyards, grilles, under-floor ducts (which can pre-cool the air) or wind scoops.

The use of wind towers reduces reliance on mechanical ventilation, chilling and air conditioning. Devices may also be used to accelerate air movement, and thereby improve ventilation, using aoerofoils which catch the wind, **35.38**.

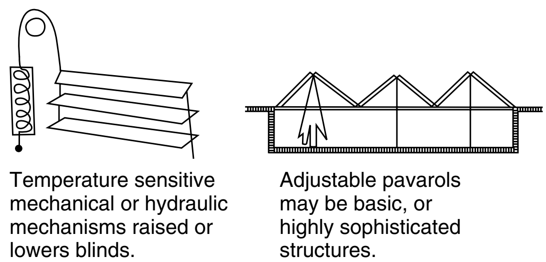
4.05 Solar flues

Solar flues are wind towers where air movement is achieved by heating the air in the tower or flue by intensifying solar radiation on the walls of the flue, as demonstrated by the Environmental Building at the BRE, **35.39**.

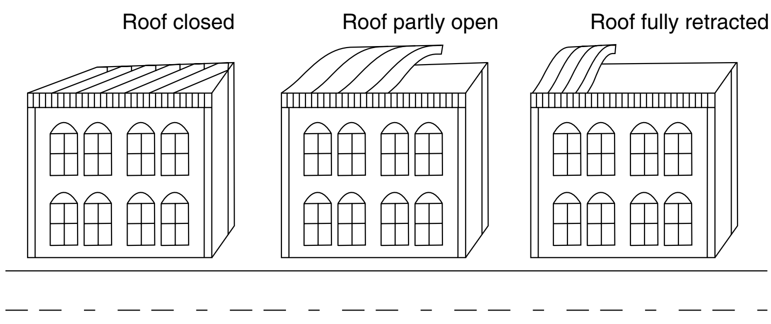


35.22 *Passive shading at windows must be designed to suit the sun path:*

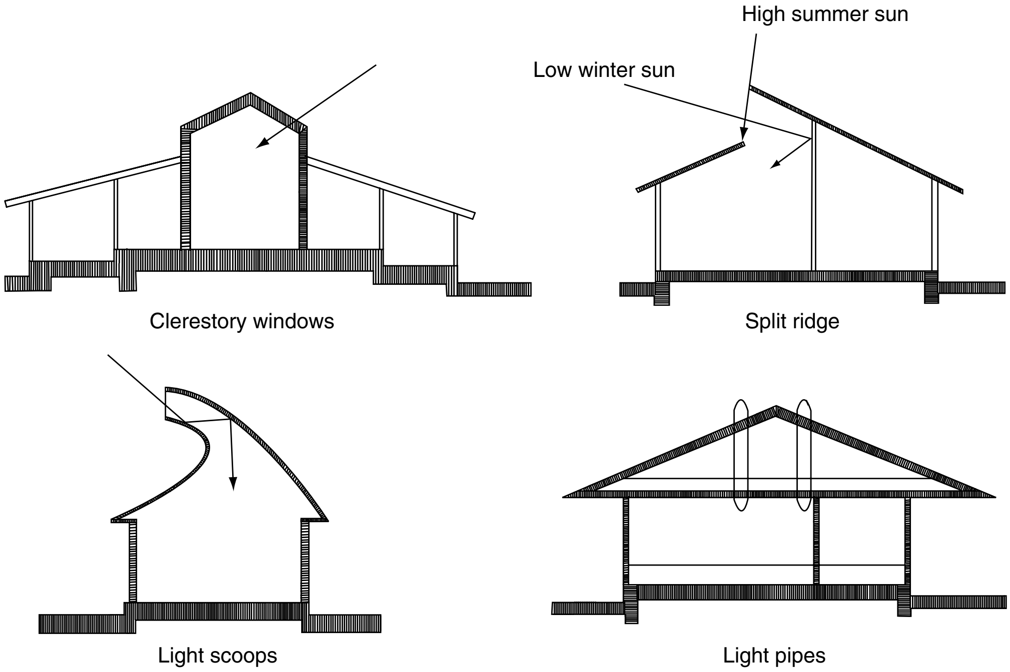
- *the combination of the light-shelf and vertical fin will provide protection from lateral as well as overhead angles, but will trap hot air unless partially slatted to allow air movement;*
- *egg crates, or some other form of brises soleil can create a striking design which may also serve as a security screen, but keep horizontal elements away from eye level in habitable rooms as they can be visually disturbing;*
- *recent buildings in Europe have used metal screens suspended up to a metre away from the window. These can be visually striking and functionally effective. They may also have the effect of acting as a 'rainscreen';*
- *another recent development is the use of sophisticated tensioned wire 'rigging' which may be suspended over facades to provide a support for climbing plants. Plants may grow up from the ground or down from high level irrigated containers. They will provide an attractive dappled shade but will need maintenance*



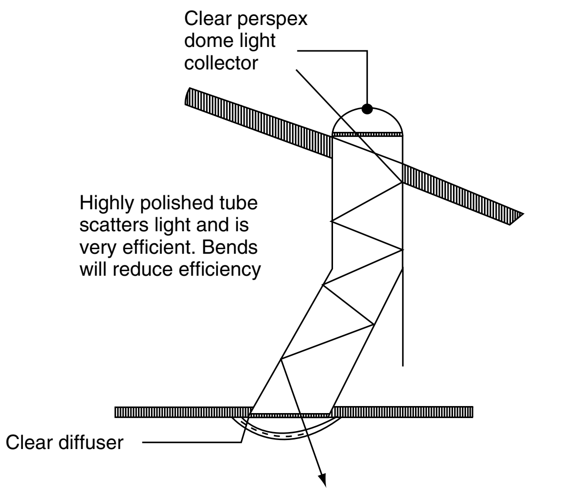
35.23 *Active shading devices are movable or adjustable, using techniques ranging from simple manual actions to very sophisticated computer controlled mechanisms that respond to changes in temperature or light intensity*



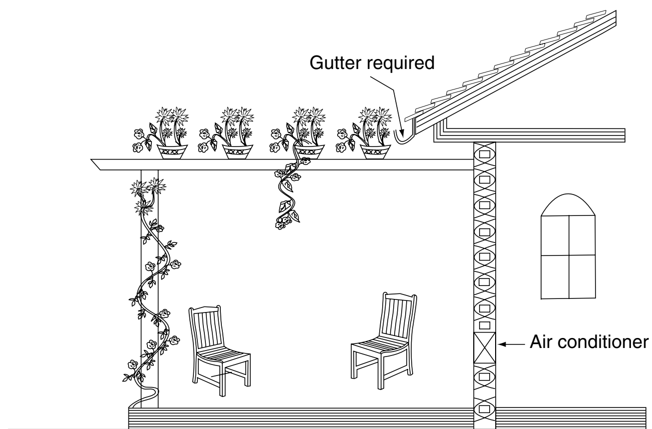
35.24 *The Manoel theatre, Valetta, Malta by Architecture Project has a retractable sealed, glazed roof over an inner courtyard that folds back in hot weather*



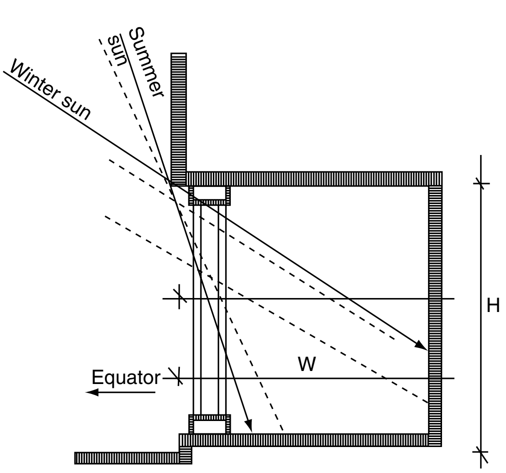
35.25 *Light-gathering strategies for dark interiors, all of which can be vented: clerestory windows, split ridge, light scoops and light pipes*



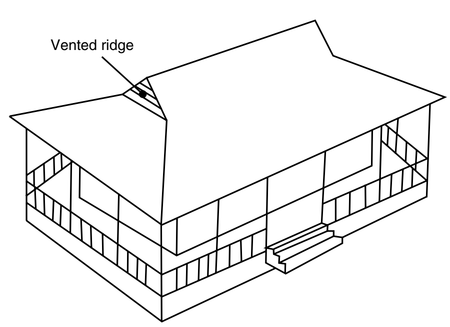
35.26 *The light pipe (which can also be enclosed in a vented duct with the clear domed toplight set within a louvred venting frame)*



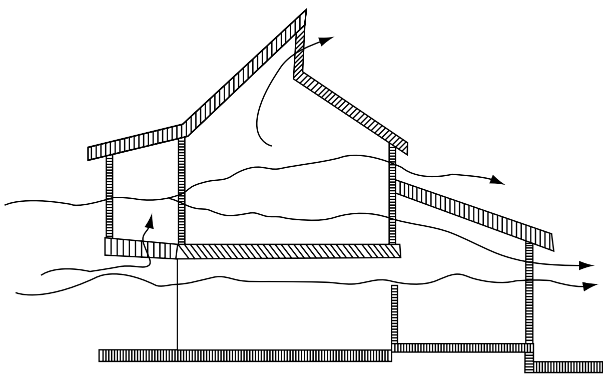
35.28 *Pergolas provide an attractive dappled shade. If used where they shade air conditioners, they will reduce intake temperatures and thereby reduce cooling load*



35.27 *The critical height/width ratio of a colonnade will depend on orientation, latitude and the particular use the space will be put to*



35.29 *The colonial bungalow with a veranda on all sides – the archetypical Australian farmhouse. Note the vented ridge, extending over the hip – a lesson learnt from the Indonesian lodge house*



35.30 *In summer, the overhead sun is kept out of the veranda, but in winter, the sun is lower and warms the spaces under the roof on cold mornings and evenings*

4.06 Trombe walls

The trombe wall is a thick dense wall within a building that receives and stores solar radiation (usually through the intensifying medium of glass) during daylight hours, and then radiates the heat into internal spaces during the evening. The wall is designed (material, thickness, location) to provide the desired time lag to provide the heat when it is most needed, **35.40**.

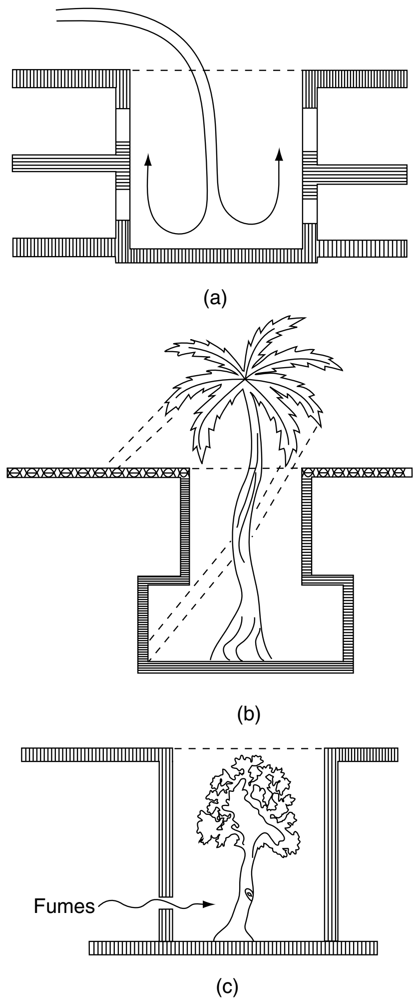
4.07 Site

Time and time again, in low and medium cost housing, the site layout is entrusted to a junior technician who has no concept of the importance of orientation or aspect. A house carefully designed to have principle elevations facing north or south is swung through 90° and meticulously lined up parallel to the next house so that there will be no breeze – and discomfort and dissatisfaction are assured. Orientation (and design to suit that orientation) are paramount, even if this conflicts with the normal good advice to follow the contour and keep substructure costs down. Building across the contour provides an opportunity to use a split-level plan, with associated discontinuities in the roofline to admit light and allow air movement.

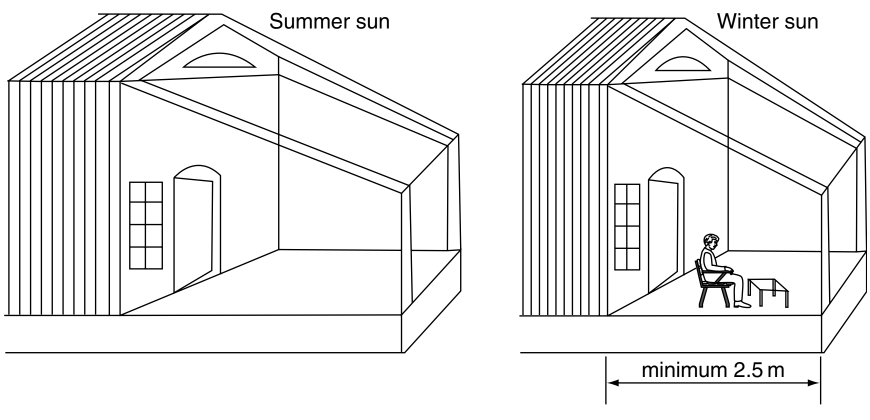
4.08 Landscaping

Trees and lush landscaping, together with lakes, fountains, pools and other open bodies of water, are visually attractive and will induce cooling. Strategic planting of trees and shrubs can shade buildings and lower temperature, reducing energy costs in mechanical cooling by up to 40%. This is achieved directly, by shading, and indirectly, through evaporative cooling induced by transpiration.

Plants grow quickly in the tropics and schemes can be established very quickly, but may require the establishment of on-site nurseries. Nurseries consume a lot of water and will require the construction of shade houses, **35.41**. The use of any hard or soft landscaping implies a commitment to irrigate, maintain, restock and clear leaf litter and rubbish from these areas, and to employ staff who will carry out these tasks. If sites such as roundabouts and the central strip of dual carriageways are to be landscaped, these will need a water supply, unless the landscaping is intended to be long-term and self-sufficient.



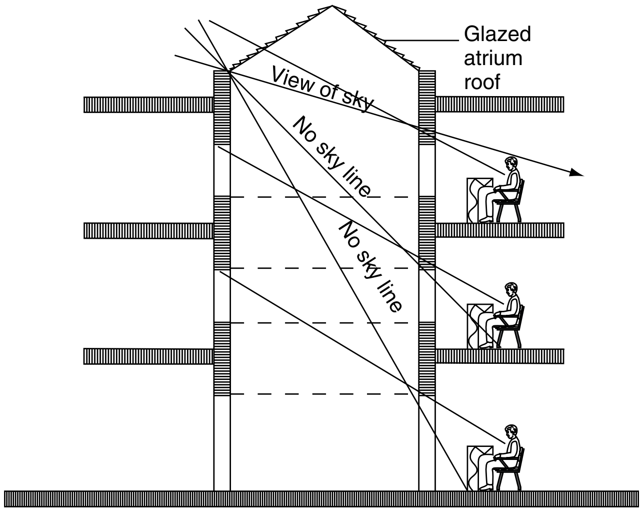
35.32 *In courtyards,* **a** *at night, cool night air sinks into the centre, whilst warmer air trapped in the courtyard rises around the perimeter, warming the rooms alongside;* **b** *tall trees with canopies above the yard will give effective shading whilst allowing air movement;* **c** *trees with their canopy below the courtyard roofline may trap air and fumes from appliances. Trees and retractable awnings can improve the performance of the courtyard*



35.31 *In hot humid tropical conditions, ventilated sleeping verandas may be essential for a comfortable night*

Table IX Courtyards

Benefits	Deficits
Courtyards:	Courtyards:
– will increase privacy from the street	– may reduce privacy for rooms facing one another across small courtyards
– will reduce noise from street	– may make sound may ricochet around the space
– will reduce building depth	– will increase footprint and cost
– should have increased air flow through rooms as a result of reduced depth	– may trap air and restrict air movement
– may cool the building at night by drawing in cool night air and accelerating dispersal of warm air	– may accumulate pollutants dispersed into the courtyard
– with trees will be shaded and the trees will transpire in the evening to accelerate cooling (deciduous trees will admit sun in winter)	– with deciduous trees will need clearing of leaf litter
– can use water effectively to modify temperature	
– will effectively enlarge the habitable space, as they can be used for many social and working activities, and may have temporary or retractable coverings for weather protection, decorative effect or additional privacy.	– will have an enlarged and more complex building footprint and the more complex design will incur extra costs – to be offset against the many gains.



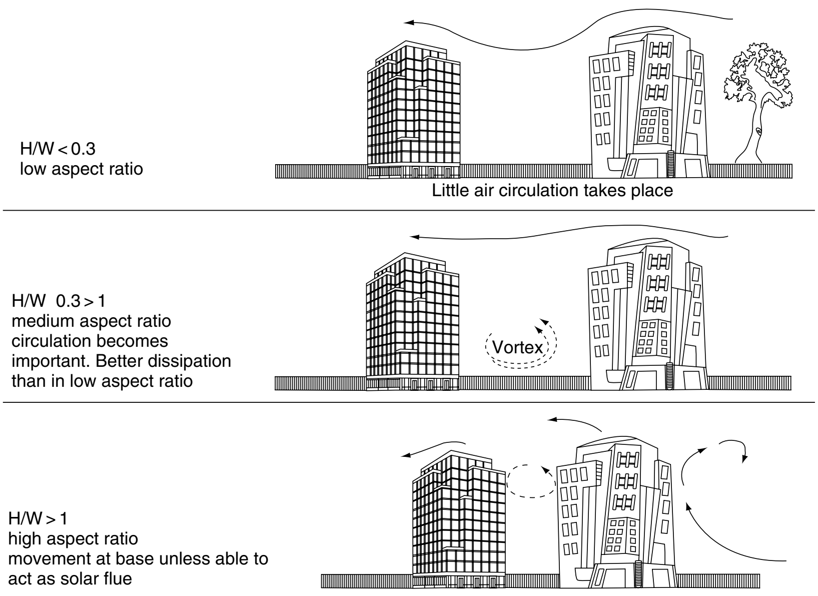
35.34 *The 'no-sky line' is the point at which the occupant is unable to see the sky: it is the point at which internal light levels drop off sharply*

In some countries, landscaping is highly valued, state-supported and recognised as providing valuable employment; in others it is politically frowned upon, being seen as diverting funding from schools, hospital and other socially important programmes. In either scenario, there may be a thriving agricultural industry that may include the cultivation of exotic species for exporting to distant world markets.

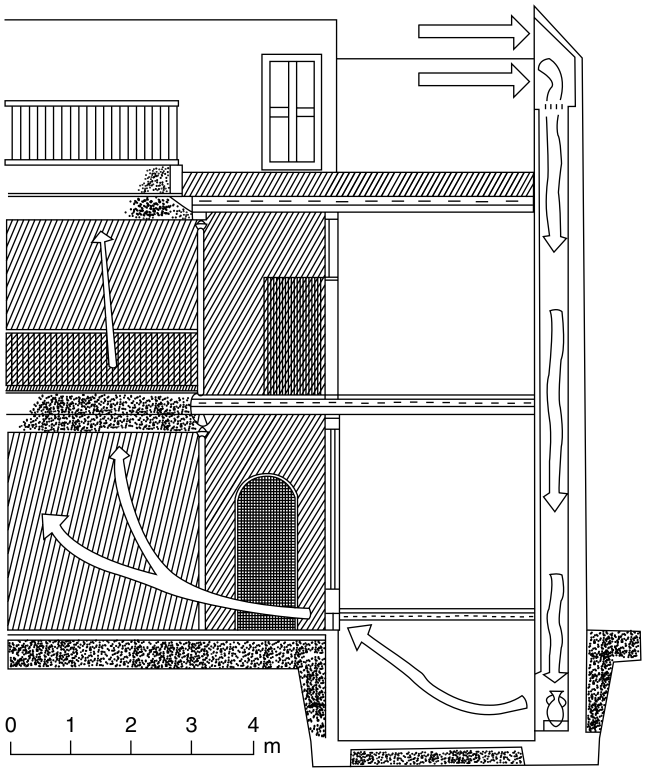
Soft landscaping that uses or integrates indigenous species will help to contextualise planting schemes and encourage use by wildlife. Whereas the mono-specific planting that is currently fashionable in Europe will not.

Hard landscaping strategies should take advantage of local materials and resources (such as local stone and specialised schools of carving and sculpting) and provide facilities for local cultural practices and acceptable activities (such as pavement cafes, street theatre, public exercise sessions, street traders and curio sellers). Public and company space may be required for sports (basketball, bowling, chess, football . . .). Some of these may need to be shaded. Sitting areas may need to be in the shade, rather than the sun, and drinking fountains may be required. Many activities, including produce markets, can be accommodated under shade structures, which lend themselves to simple but dramatic structural forms, such as shells or tents. Pergolas and shade trees, whether used for shading people or vehicles, should use species that give good dappled or deeper shade, have a root system that stays below paved surfaces, and that do not drop leaves, flowers, pods or fruit that will cause nuisance or damage.

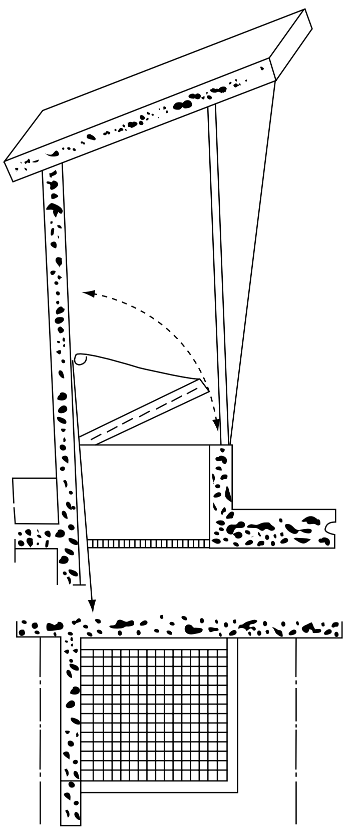
An indicative list of tree and shrub species used in landscaping schemes is given in Table X. Unless listed as drought-resistant, most species will require irrigation in climates with a marked dry season.



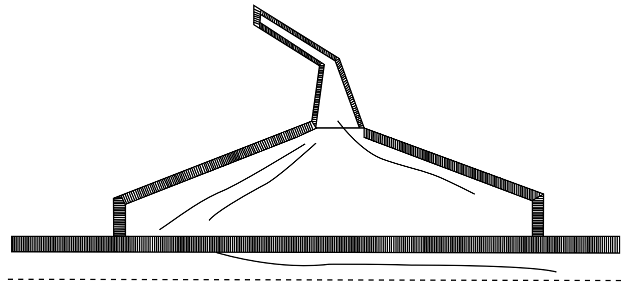
35.33 *Aspect ration of courtyards:* **a** *the low aspect ratio courtyard (H/W <0.3): access to external air is good, but there is little recirculation;* **b** *the medium aspect ratio courtyard (H/W 0.3–1): re-circulation becomes important; heat dissipation is better than in the low aspect ratio courtyard;* **c** *the high aspect ratio courtyard (H/W > 1): unless the courtyard acts as a solar flue, there will be turbulence at the top, but no air movement at the bottom*



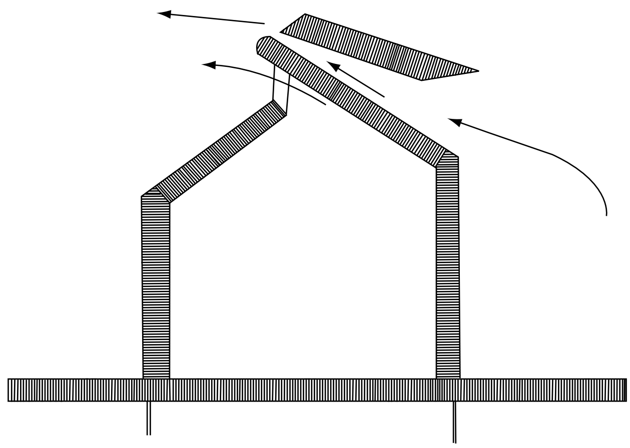
35.35 *A wind-catcher bringing fresh air into a basement. The air passes over the cool walls of the flue (shaded by neighbouring houses) and a porous jug containing water. Evaporative and contact cooling is effected*



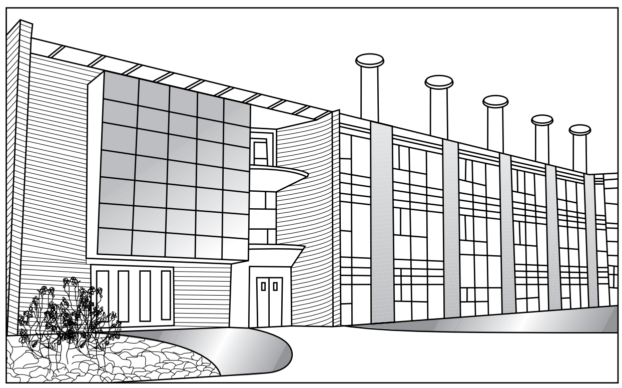
35.36 *The trap on the wind-catcher can be closed and screens can be fitted to filter dust and leaves*



35.37 *The Bluewater Shopping Centre in Dartford, England uses giant revolving wind scoops, reminiscent of Kentish oast house*



35.38 *Aerofoil shapes in conjunction with narrowing spaces act like aeroplane wings, creating pressure differentials that will draw air out of buildings*



35.39 *The Environmental Building at BRE, by Fielden Clegg Architects, is a demonstration/experimental building that makes use of solar flues*

4.09 Urban centres and street layouts

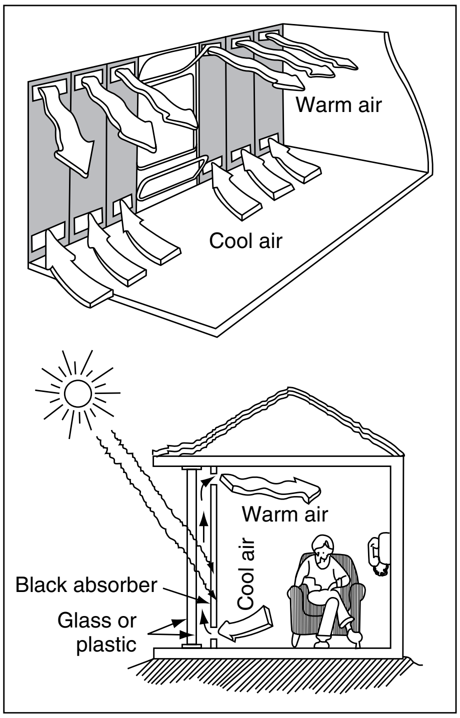
Temperature in cities

All large urban areas are hotter than the surrounding rural areas: people, industry, machines, vehicles, buildings – all generate heat, pollution and gases including CO_2. In hot climates, it is particularly important to incorporate heat sinks (lakes, parks, woodland) that can lower air and ground temperature.

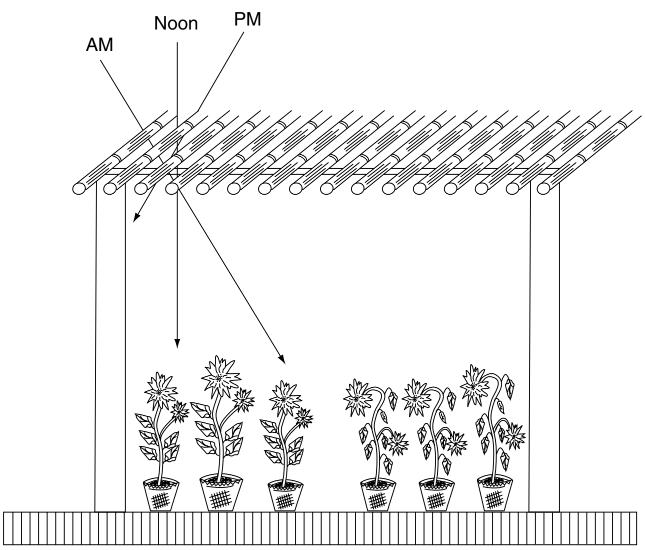
Urban streets

Narrow streets are cooler than wide boulevards, unless these are planted with large street trees, **35.42**.

On streets running north–south, the higher the height to width ratio (*H*/*W* ratio), the less time the sun has on the street surface and



35.40 *The Trombe wall: storing heat at the times of the year when it is needed The Trombe wall (like the stone floor, in this instance) acts as a heat store, with the hot sun passing through glass onto both surfaces. The dense mass of these materials retain the heat and, after a time lag, release the stored warmth into the room during the cold night (Bruce Anderson – The Solar House Book)*



35.41 *The shade house, roofed and walled with an open-woven split bamboo mat. Many tropical plants used in landscaping are forest species used to lower levels of light: using a slatted baffle allows a continual hit-miss pattern of daylight to pass over the plant as the sun moves across the sky, ensuring that the plants get adequate light on all sides, whilst being tricked into accelerating growth by the on–off daylight*

on facades facing the street, **35.43**. The street will be cool in the morning and evening.

On streets running east-west, latitude becomes more important than *H*/*W* ratio, **35.44**. On or near the equator, the sun will be overhead or rising and setting on the street alignment. As distance from the equator increases, there is greater likelihood that in the hot season most of the street surface and the elevation facing the equator will receive solar radiation all day, whilst in the cold season, narrower streets and one elevation may be in shade all day, with the elevation facing the equator only receiving significant solar radiation when the sun is above the roof level of the buildings on the other side of the street.

Vehicles

Vehicles parked in open sunlight will become unbearably hot and petrol will evaporate. Car parking that is not inside or under buildings must be shaded by freestanding canopies, shade trees or pergolas. Parking areas and street layouts may need to take account of specialised vehicles (bicycle-rickshaws, horse-drawn cabs, articulated buses) and differing percentages of pedestrians, public transport, car ownership or bicycle use in cities.

Litter

Some people generate more litter; some city administrations administer severe penalties for littering the streets (especially for dropping chewing gum or sugar cane waste).

5 ENVIRONMENTAL CONTROL STRATEGIES: ACTIVE MEASURES

5.01 Alternative energy

Energy supplies may be unreliable or non-existent on remote sites. Power may need to be supplied by a diesel generator, or some other means that capitalises on latent potential in or near the site, such as:

- *Biomass* – using crop and forestry wastes, slurries and rapid cropping trees and herbaceous plants which are dried, prepared and burnt, usually in a combination with gas, to produce energy
- *Geothermal* – naturally occurring subterranean hot water and gas
- *Biodieisel and biofuels* – ethanol may be a by-product of agro-industry (as in the conversion of sugar cane to granular sugar or cane spirit)
- *Solar power* – photovoltaics, water heating
- *Water* – micro-hydro, estuarine and tidal mini turbines
- *Wind* – free-standing wind pumps or building-integrated turbines, **34.45**.

5.02 Photovoltaics

Grid-connected BIPV are flat solar cells fixed to parts of the building envelope in an array that faces into the sun. They generate direct current (DC) which must be converted into alternating current (AC) and, although expensive and offering poor efficiency at present, can bring cost savings by downloading power to the national grid during the day, thereby reducing the cost of upload from the grid at night. These savings depend on an equitable arrangement with the national generating company, and on associated passive measures that use the building envelope efficiently. All photovoltaic cells use silicone, in various forms, and are either black or blue in appearance. The electrified arrays are dangerous, and must be installed, maintained and supervised by electricians with specialist expertise.

Photovoltaic slates have recently become available in the UK that appear no different to regular natural slates and which are claimed to achieve savings of up to 25% on domestic energy consumption.

5.02 Wind turbines

If these are attached to buildings, the design must accommodate the swing of the turbine blades and the additional structural loading from vibration. Risk of damage and injury from broken blades must be assessed.

Table X Species used in tropical landscaping schemes

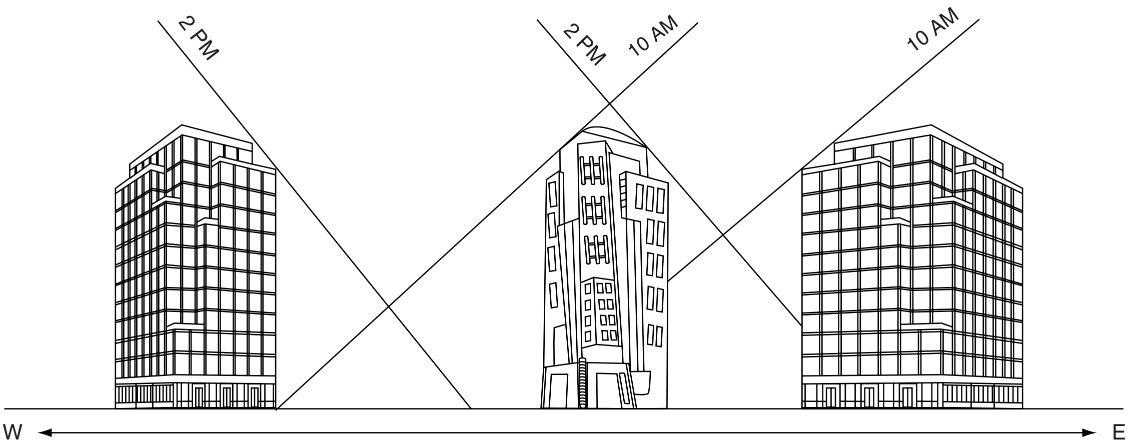
PLANT CHARACTERISTICS, REQUIREMENTS AND ORIGIN														**SPECIES**		
Plant species				**Habitat criteria**				**Continent of origin**								
Tree – **L**arge, **M**edium or **S**mall	Shrub – **L**arge, **M**edium or **S**mall	**C**limber	**H**erbaceous and other plants	Significant **F**lowers or foliage	Frost tolerant	Drought tolerant – **A**rid, **S**easonal	Altitude tolerant – Low, Med, High	Africa	Asia and Pacific	Australasia	Mediterranean Europe	North America	South and Central America and West Indies	Almost anything will grow in the tropics if it gets the right amount of water and humidity.		
														Species	**Description**	**Suggestions**
	M			G			H		✓					Acalypha wilkesiana (*Beefsteak plant, Jacob's coat*)	Medium sized shrubs with dramatic variegated foliage – predominantly green or brown with every leaf different – green/ yellow/cream/pink/red/brown. Leaves are large and obovate or narrow and dissected.	They are dramatic and reliable. It is easy to over-use them.
			H			A S							✓	Agave americana (*Century plant*)	Large rosette-forming succulent with a sharp spine on the leaf tips, and a spiny cream margin. The flower spikes are up to 8 m tall.	Agave species are used in mass planting, as specimens and as impenetrable hedges (traditionally around prisons).
			H					✓						Aloe sp.	Tall spikes of massed small bell-shaped flowers rising from rosettes of agave-like fleshy leaves with spiny margins.	
S				F		S			✓					Bauhinia purpurea (Orchid tree)	Elegant fragrant purple, pink or white flowers. Erect tree, some varieties are more lax and have softer less waxy flowers. Pods long, thin and some split and spiral explosively.	Attractive small street or garden tree with beautiful flowers. Lax varieties wider spreading. Pods are noisy when they explode open.
		C				S							✓	Bougainvillea glabra	Vigourous spiny scrambler smothered in distinctive magenta bracts. Cultivars include white, orange, pink, yellow of varying vigour.	Can be trained to form mounds, will scramble up trees and over walls. Can damage foundations and roofs if planted too close to houses and not controlled.
						S			✓					Brugmansia × candida [Datura] (*Moonflower*)	Reliable shrub with powerful scent and pendulous trumpet-shaped flowers, usually white or cream, but occasionally pink or peach. There are double forms. Narcotic.	
														Caesalpinia pulcherrima (Pride of Barbados)		
S	S M									✓				Callistemon sp. (Bottle brush)	Evergreen small trees or shrubs. Upright or weeping forms. Lanceolate leaves and red bottle brush flowers of varying sizes.	

Table X (Continued)

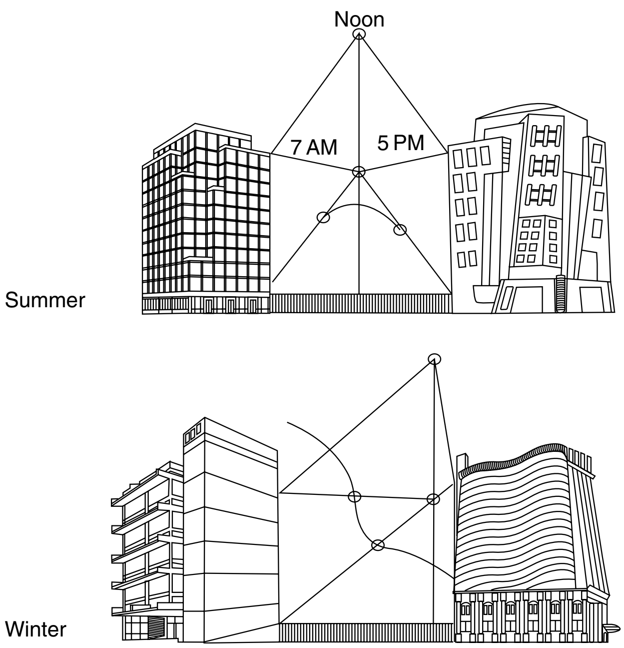
PLANT CHARACTERISTICS, REQUIREMENTS AND ORIGIN														SPECIES		
Plant species				Habitat criteria				Continent of origin								
Tree – **L**arge, **M**edium or **S**mall	Shrub – **L**arge, **M**edium or **S**mall	**C**limber	**H**erbaceous and other plants	Significant **F**lowers or folia**g**e	Frost tolerant	Drought tolerant – **A**rid, **S**easonal	Altitude tolerant – Low, Med, High	Africa	Asia and Pacific	Australasia	Mediterranean Europe	North America	South and Central America and West Indies	Almost anything will grow in the tropics if it gets the right amount of water and humidity.		
														Species	**Description**	**Suggestions**
M				F			L M		✓					Cassia spectabilis	Fast-growing tree with dense umbrella shaped canopy and large pinnate leaves. Large upright panicles of sweet-scented bright yellow flowers.	So fast growing and spectacular, it will occasionally collapse under its own weight. Stunning as a street tree, where the regularity of size and form is exceptional.
M				G			L M			✓				Casuarina equisetifolia	Delicate foliage resembling a pine tree with ling needles. Tolerates waterlogged ground and salt atmosphere.	Often planted on beaches as windbreaks and to stabilise the ground.
													✓	Cestrum nocturnum (*Queen of the night*)	Unexceptional shrub with sprays of narrowoff-white tubular flowers that open at night with a very powerful scent.	Often planted too close to bedrooms. The scent can be overwhelming at close range.
				G					✓					Coedaium variegatum	Like Acalypha, but more upright, with smaller, thicker and glossier leaves and preferring a hot humid climate.	Attractive and reliable.
									✓					Congea tomentosa	A scrambling shrub with sprays of downy white to pinky-lilac bracts.	Looks spectacular on trellises or climbing up trees. The colour is subtle. Sprays can be dried.
L						S	L M H						✓	Delonix regia (*Flamboyant, flame tree*)	Elegant spreading tree with masses of bright red orchid-like flowers on leafless branches. Leaves are bi-pinnate, similar to the jacaranda, which it follows into flower. Wide range of climates and altitudes.	This stunning tree needs space to show off in and to be allowed to retain its carpet of fallen flowers. Surface roots prevent planting or development under the canopy.
								✓						Erythrina abyssinica	This large tree has distinctive red flowers and flat pods with decorative red seeds. Other Erythrina species are also used.	Occasionally used as a street tree, or in larger gardens.
										✓				Eucalyptus sp.		
	M			F		S							✓	Euphorbia leucocephala (*snow bush*)	Medium sized shrub which is covered with spectacular rosettes of white bracts.	Spectacular in massed planting. Usually cut back hard each year to create a rounded bush about 1.5–2 m high.
									✓					Hibiscus rosa-sinensis	Shrub or small tree with showy red flowers. White, yellow, orange and pink varieties available.	Widely planted in the tropics. Best in humid lower altitudes.

L				F		S	M H						✓	Jacaranda mimosafolia	Stunning pale blue-violet flowers in clusters on leafless canopy in late dry season; large, airy bi-pinnate leaves with tiny leaflets.	Widely used as a street tree and in gardens; gives light dappled shade; surface rooter; grown at sea level and at high altitude in composite climates
	B					A			✓	✓			✓	Kalanchoe sp.	Large family of decorative flesh-leaved plants that put up a spike of bell-shaped flowers. Foliage is mostly grey, flowers mostly pink/orange.	Used for mass bedding without irrigation.
									✓					Melia azedarach (*Neem tree*)	Large fast-growing tree with attractive but not spectacular racemes of pale lilac flowers.	Widely used as a street tree with lightly dappled shade. Found in any country with Indian (Asian) residents.
											✓			Nerium oleander (Oleander)	Pretty fragrant flowers on a shrub with lanceolate leaves.	All parts of the plant are poisonous.
		C											✓	Petrea volubilis	Evergreen climber with pendulous racemes of beautiful star shaped lilac-purple flowers.	Covers walls, trellises and fences. Colour like the Jacaranda, which flowers at the same time, but more intense.
	L			F		S							✓	Poinsettia pucherrima	Large shrub with decorative bright red bracts. Many other species with a range of colours and forms. All are euphorbiacae – with latex sap.	Usually cut back hard after 'flowering'. Avoid contact with latex. Needs 12 h of darkness to produce bracts.
		C											✓	Pyrostegia venusta	Vigourous evergreen climber with long flowering season. Clusters of bright orange tubular bell-shaped flowers.	Climbs tall trees, covers walls and looks spectacular as raised ground cover, trained over a wire framework.
													✓	Roystonea regia (Royal Palm)		
													✓	Russelia equisetiformis	Small tubular red flowers are set along the drooping rush-like stems.	Planted in raised beds, to allow it to droop.
S													✓	Solanum (*Potato tree*)		A decorative small tree.
		C											✓	Solanum jasminoides (*Potato creeper*)	Papery blue or white flowers on a shrubby climber to 5 m.	
L								✓						Spathodea africana (African tulip tree)	This large tree has erect terminal racemes of orange-red flowers emerging from hairy liquid-filled buds.	Street or specimen tree.
														Tecoma stans	Shrub with bright yellow bell-shaped flowers.	Widely used as a hedging plant. Withstands cutting well.
									✓					Thunbergia grandiflora (*Heavenly blue*)	A large climber. The flowers have five lilac-blue petals around a yellow tube.	Climbs over walls, fences and verandas.

35.42 *The width of the spaces between buildings (in addition to their orientation) and the placement of large trees are critical to the amount of direct insolation they will receive*



35.43 *When streets run north–south, a narrow street near to the equator will only receive direct sunlight for a relatively short time – the principle used in the North African trading street – the souk*



35.44 *When streets near the equator run east–west, the sun will be shining into the street all day unless blocked by structures across the street*

Turbines may be 500 mm or 50 m in diameter. Siting is critical. The Danish Wind Industry Association website gives extensive design guidance (www.windpower.org/en/tour/design/index.htm).

5.03 Ventilation and air conditioning

The need for mechanical aids and the costs in running and maintaining them will be reduced by passive design strategies that offer improved ventilation, shading and temperature management. Wherever possible, design out the need for mechanical solutions. Designers are increasingly using wind towers and solar flues to drive ventilation.

Ceiling fans

Allow adequate headroom below the blades of the fan. Ceiling fans give a wide distribution of blown air. Since the diameter of the fan is large, the fan can have a relatively low speed, reducing noise.

Typical installation:

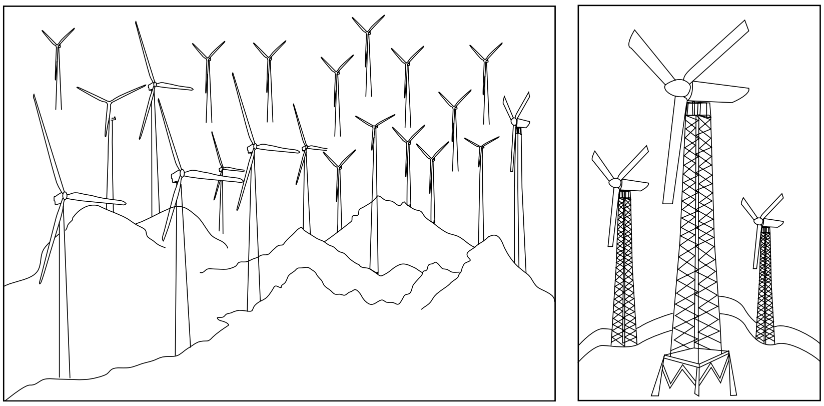
- ceiling height 3.0 m minimum
- minimum blade height above floor 2.5 m
- fan diameter 1.0 m

Wall and floor-mounted fans: Because the blades are set within a cage, these can give higher air speeds and a more concentrated air stream. They may be fixed or can oscillate.

Typical data:

- mounting height 1.5–2.0 m
- angle of oscillation up to 60°
- 'reach' of blown air 3–4 m

Roof extract fans and passive stack vents: With light roof constructions, extract fans are used to remove hot air from the ceiling void and internal rooms. Internal air temperatures may be reduced by 3–5°C in climates where high solar radiation is combined with moderate air



35.45 *Wind turbines*

temperatures. The extract fan does not give perceptible air movement within the building.

Unit air conditioners: Room air conditioners are available with a cooling capacity in the range from 1.5 to 7 kW (Btus/h are commonly used to measure capacity as many manufacturers and designs originate in the USA). Specifications vary considerably and may include heaters and fan-only options, as well as chillers. They are usually accommodated in walls or under windows (often as afterthoughts). Unit air conditioners require external air for removing excess heat, a fresh air inlet and drainage for water removed from the air during cooling.

Split air conditioning units: Split air conditioning units have the following advantages over unit (or 'room') air conditioners:

- Minimal structural alterations if installed in an existing building or minimal requirements for new buildings: the two pipes connecting the condenser to the air handler will fit through a 100 mm hole
- Greater security; important for banks, shops, etc.
- Reduced noise within the room, due to external position of condenser
- Greater flexibility internally as air handler may be placed on internal wall or even ceiling
- Improved external appearance as condenser may be placed on the roof, reducing problems of dripping condensate.

The disadvantage is:

- the condenser unit is unsightly and noisy and a space needs to be found for it: it may annoy the neighbours, rather than the room occupant.

6 STRUCTURE, SERVICES AND ENVIRONMENTAL DESIGN

6.01 Structural design

The structural form must be a viable economic choice and must facilitate the appropriate design response to climate. Hot arid climates suit dense masonry construction; hot humid climates suit a lightweight frame with a low mass ventilated infill. Composite climates require a mix – perhaps solid heat-storing floors with a lighter superstructure and adjustable shading. All structures must be able to withstand predicted climatic extremes that affect stability and structural integrity. There is less need for enclosure in all but the arid tropics and many structures will consist of a dramatic roof on exposed supports, with no permanent walls.

Concrete

Concrete is widely used in the tropics, where steel and other imported materials may be costly. Low-labour costs may have permitted the adventurous use of the plastic properties of concrete, in hypar, shell and other one-off forms (*see the structures section*). Use of concrete will depend on availability of cement and adequate water supplies. Taller buildings will need pumping capabilities. Hot climates may necessitate chilling of concrete (ice in tankers), the use of retarding agents and the shading and repeated wetting of poured concrete during the curing stage. Suitable formwork may be difficult to obtain.

Steel

Transportation costs may make steel structures uneconomic. Humid environments may necessitate special treatments. Steel doorframes and windows may be used in preference to timber, to reduce termite damage.

Timber

Timber should be from sustainable forests and must withstand termites, heat and desiccation or humidity, where applicable. Drying shrinkage and warping may be unacceptable. Seasoning may be required before timber can be used. The performance capabilities of each particular species must be known, especially for structural timbers. If large sections of structural timber are not available, glulam may be good alternatives (glulam – thin strips of timber built up in laminations to produce an attractive, consistent material with excellent structural properties). In some areas, profligate consumption of forest timber, in construction and as fuelwood, has lest some forest species critically depleted. Converted timber, as plywood and other board products, may be available to locally established specifications.

Structural form

Design issues are highlighted in Table XI: Design of building elements.

6.02 Design in earthquake zones

Earthquakes may occur anywhere on the globe, but are more common in the hotter regions. In earthquake zones, it is generally accepted that choosing the right type of structure is more important than minor variations in detail. Failures occur due to inelasticity – and these failures are difficult to model, especially in complex structures. Chilean good practice provides a good model: provide reliable strength, structural continuity and redundancy. Always work with a structural engineer. Always consider the impact of siting and landscaping and potential damage from surrounding structures and trees.

Table XI Design of building elements

Element	Type	Advantages or purposes	Disadvantages or problems	Details
Structure	*Generally*	• Absence of freezing conditions • Regulatory controls may permit more imaginative solutions • Local expertise in alternative technologies may offer new design potential	• Climate extremes, including diurnal temperature range, wind and rainfall • Limited skills or technical knowledge in some places • Limited performance data on local materials (Are there local materials testing labs?) • Season restrictions on working (dust storm, monsoon, etc.)	• Check if in earthquake zone • Check windloading from cyclones, etc. • Obtain rainfall data for short-term loading on roofs, gutters, etc. • Consider sustainability of all aspects of design (embodied energy, consumption of non-renewable resources, environmental contamination and depletion, especially of water supplies)
	Loadbearing masonry	• Are bricks and stone local materials? • Is brickwork a local skill? • Is masonry part of the vernacular style? • Thermal mass • Able to accommodate small fittings and accommodate alterations	• Limited availability, quality and consistency of materials and accessories • Traditional clamp-firing may consume huge quantities of non-renewable forest timber	• Check local practice • Is cavity wall construction used? • Establish strength and consistency of locally produced materials and materials testing regime
	Concrete frameand in-situ concrete work	• Is cement manufactured locally? • Is concrete construction a locally familiar technology? • Lower labour and formwork costs may facilitate one-off designs (hypars, etc.)	• Limited availability, quality and consistency of materials, plant and resources • Extreme care needed during curing	• Is/are formwork, reinforcement, mixing and transporting plant available? • Is there sufficient water for mixing, cooling, cleaning of plant?
	Steel frame	• Reusable material	• Limited availability, quality and consistency of materials and resources including skilled labour • Humidity	• What is the distance from foundry, workshop or supplier to site?
	Timber frame	• Timber produced locally? • From renewable forests?	• Resistance to humidity and termites • Effect of climate on lifespan	• Check windloading from cyclones, etc. • Strapping and bracing of timber elements
Floors	*Ground-supported floors*	• Use the delayed thermal flywheel effect of ground and/or floor mass to stabilise floor temperature and keep it cool (concrete, stone and ceramic floors always feel cooler and in some circumstances can be wetted to produce evaporative cooling – but this will increase humidity) • Reduce costs • Provide disabled access • Concrete floors are easy to clean – they are often waxed polished in the tropics	• Seasonal flooding risk • Risk of rain splashback • Termites, vermin, snakes, etc. • Restricted structural option – concrete? • Suitability of ground conditions for foundation type • Risk of damp and mould growth • Concrete, stone and ceramic floors, if polished, can be very slippery and cause accidents • Snakes may breed in poorly compacted hardcore under the slab	• Take precautions against termites and vermin penetrating the slab at junctions, changes of level, and points where the slab is penetrated by services or structure • The slab must be continuous (not split into bays separated by internal walls) • Keep termites out by poisoning soil (but avoid organophospates such as Aldrin or Dieldrin) or by using a special oversite steel mesh with a gauge too small for insects to penetrate (Australian solution) • Project slabs beyond foundations, with sharp external 90° angles which termites dislike • Floors with a high thermal mass should be kept shaded in hot weather, but can be allowed to absorb some solar radiation in the cold season to warm up the building (passive design).
	Suspended floors	• Keeps floor clear of seasonal flooding and splash-back from heavy rain • Keeps the floor away from termites and vermin • Use materials other than concrete, including open deck vented floors to improve air movement	• Floors should remain dry and free from damp • Security risk from below • Accessible soffit may be colonised by bats, snakes, etc. • Voids within the floor structure may be used by insects and small mammals (wasps, ants, etc.) • Termites may find timber and destroy it • In humid climates, damp and mould growth may accumulate unseen in sealed voids	• Low mass floors will maintain temperature closer to air temperature – an advantage in winter • All voids must be protected on the external faces by mesh strong enough to deter gnawing by rodents and of a gauge fine enough to keep out ants – except where bats, etc. are tolerated • Check timber floors (and structures) for fire risk from bush fires • Suspended floors may permit the introduction or seasonal use of vent stack/solar chimneys drawing cool air from shaded ground. • Leave underside of floor visible for inspection • Allow airflow and ventilation below the floor
	Raised access floors	• May be used to duct cooling air through a structure, or to recycle or remove heated air	• Do not contribute thermal mass • May be difficult to maintain • Insects and vermin may infest voids	• Failure of a raised access floor in an earthquake may critically affect escape from office buildings
	Intermediate floors and mezzanines	• Discontinuities in the building section, with mezzanine floors and variation in storey height, permit air movement	• Continuous floor slabs restrict vertical air movement • Structural continuity may be essential to maintain rigidity in earthquake zones	• Sound transmission • Spread of fire

Table XI (Continued)

Element	Type	Advantages or purposes	Disadvantages or problems	Details
	External floors, decks, platforms, balconies and terraces	• Can shade lower floors and walls • If in low mass materials (timber) and perforated, will reduce temperature and allow air movement	• May reflect light, glare and heat into buildings if light coloured and reflective, but if used as a light shelf, can shade windows whilst reflecting light off ceilings	• Outdoor living and sleeping in sun, shade or breeze should utilise roof spaces, courtyards, atria and the periphery of the building in a range of climate-responsive ways.
Ceilings	*Suspended ceilings*	• Ceiling void may be used to duct air • Ceiling may be used to deflect or reflect light • May contain heat or light sensors to adjust temperature, or the position of external or internal blinds	• Void may harbour insects and vermin – must be accessible • Void may trap hot air if poorly designed • Materials used for acoustic insulation in ceilings may be attractive to insects – avoid any containing cellulose	• Use wire or plastic mesh of appropriate gauge to keep out bats, birds, vermin whilst maintaining ventilation
	Exposed soffits; integrated ceilings	• Reduce costs	• Reduce options in servicing and air movement	
Wall features	*Flyscreens*	• Essential in food preparation, kitchen and sleeping areas where any flying insect is a nuisance • In mosquito infected areas, *all* rooms should be fly-screened.	• Impede air circulation	• Usually green or black plastic or coated wire gauze – must be robust • Fix with timber bead or metal cramp
	Shutters	• Personal security • Protection from severe weather • Adjustable (American) shutters cut down glare • Cut down extraneous noise	• Trap heat	• Consider fixing and maintenance
Cladding	*Rainscreen*	• Allows use of rough finish to structure concealed behind rainscreen • Can be used over pisé/adobe	• Voids can harbour vermin and conceal defects and deterioration	• Consider fixing and maintenance
Roof	*pitched roof*	• Essential in wet climates • Void can be used to vent inner rooms	• Can trap heat if not vented • Voids can harbour vermin and conceal defects and deterioration	• Large overhangs in wet tropics • Roof pitch, valleys, etc. must cope with intense rainfall
	flat roof	• Can be used as sleeping platform	• Difficult to weatherproof against rainstorms • Climate change may cause unpredictable weather	• Security is increasingly an issue
	double roof including aerofoil roof	• This structure places an open ventilated space between the weather-protection of the upper roof and the shaded element of the inner and lower roof, which may serve as a sleeping platform in hot weather • The aerofoil uses two converging and aerodynamically designed profiles to accelerate air movement over the roof	• May be vulnerable to storm damage in severe weather • There may be loss of security or privacy • Extra height • Extra cost • Aerofoil may need extensive modelling and testing to prove	• See Le Corbusier's houses in India and more recent European buildings

When designing buildings in earthquake zones, the following points should be noted:

Structural form

Use:

- simple, compact structural forms with continuous lines of structural force and inbuilt redundancies
- compact symmetrical plans with maximum resistance to torsional stresses
- symmetry in loading, fenestration, stair placement, cladding patterns and infilling.

Avoid:

- complex forms with irregular and diverted lines of structural force – H, L, T, U, X and E plan forms are particularly vulnerable, as vibration may differ along each axis
- discontinuities in form, mass, storey height, materials, setbacks, overhangs, or in infilling, which may create a 'soft storey' at any level and precipitate failure
- breaks in columns and shear walls – failure to continue upper floor columns and shear walls through the ground floor (creating a 'soft storey') have contributed to loss of structural integrity or serious progressive collapses in earthquakes (and terrorist bombings)
- windows within 600 mm of external corners.

Structural detail

- engineers may adopt a weak beam/strong column philosophy to allow beams to flex more than columns
- corner columns are more at risk: elevations may act as plates and twist corners
- the continuity, linking and placement of reinforcement can be crucial
- floor slab-to-column connections must resist punching shear
- continuous bottom reinforcement through slabs and beams will act as catenaries and resist collapse
- partial restraint of columns by partial height infilling can expose the remaining unrestrained section of the column to excessive shear at the expense of flexural yield, leading to failure.

Damage and injury

- some earthquake damage to the fabric will appear and must be accepted, but loss of structural integrity or collapse of inhabited buildings is never acceptable
- all significant structural and non-structural elements (cladding, parapets, staircases, etc.) must be securely tied to the structural system
- protect escape routes from falling glass or cladding.

Non-structural elements

- structural damage, gas explosions and fire can be caused by movement and failure of non-structural elements
- incoming gas services should have automatic safety shut off valves
- performance of structural elements can be compromised or altered by the action of non-structural elements
- injury and death can be caused by falling non-structural elements
- cost of repair of non-structural elements can render a building unviable
- all large appliances, cylinders and tall furniture should be bolted or strapped in place and loose items such as crockery or books that could fall and cause injury should be stored at low level.

Concrete structures

- concrete fill and landscaping soil on top of concrete slabs have no cohesion, no benefit and may cause excessive loads which contribute to collapse
- concrete structures shaken by successive earthquakes may suffer unseen and cumulatively worsening damage.

Steel framed structures

Assumptions that welded steel frames will have sufficient ductility to perform well during tremors has not been borne out by recent events in Kobe and California. Beam-to-column connections have cracked due to construction, material and bonding failures. Standards and codes have been revised in these areas.

Timber framed buildings

It is essential to create rigidity by using shear walls (studs stiffened by rigid ply panels) and to maintain continuity through the structure. Cripple walls, especially as aboveground substructure, form a 'soft storey' and are a regular point of failure, **35.46**. Structures built on top of piers must be securely restrained. Masonry chimneys set into timber framed buildings may collapse and upper floors with structural panels in the floor around the chimney will reduce the risk of injury.

6.03 Power

Mains power supply may be unreliable or only available in larger urban areas; however, many tropical countries have modern reliable utilities. Standards for voltage vary. The design of the distribution system is as for temperate climates except that high soil temperatures may lead to a requirement for cable sizes to be larger to avoid overheating and cable might need protection against termites and other hungry fauna.

6.04 Solar heating

At it simplest, a solar heater is a coil of hosepipe drawing water from the mains water supply which is set into a flat framed box set at an angle, usually on a roof, that will enable it to absorbs the maximum amount of sunlight. In the box, the hosepipe is laid on a reflective surface, and covered with a sheet of heat-absorbing glass, both of which are designed to heat up the water in the hosepipe as quickly as possible. The heated water is drawn off as needed using separate taps, or is stored once a predetermined temperature is reached. These water heaters are simple and effective, but do not raise water temperature significantly on cold or heavily overcast days, when hot water is most needed. They also need maintaining, as the hose is subjected to extreme heat and has a relatively short life. Ready-made solar heaters use more sophisticated materials. The heated water is usually stored in a tank and drawn off as needed.

6.05 Water supply

Table XII gives standards that have been recommended by international organisations. However, the standards actually adopted must be related to local resources and conditions. In some countries, brackish water for irrigation is supplied by an independent

35.46 *Braced timber-framed structures are likely to fail at their weakest point – usually where they are un-braced in their supporting storey of extended timber piles*

Table XII Daily domestic water standards (litres per capita)

Distribution	Minimum (or reduced or temporary supply)	Normal	With wastage allowances
Standpipe for up to 100 persons	120	40	60
Single tap connections	120	160	180
Multiple tap connections	160	200	240
Multiple tap connections in areas of water shortage	100	150	–

Source: WHO, World Bank.

Table XIII Water supply for irrigation in hot dry climates

Type of vegetation	Water supply requirement	litres/hectare/day
Private gardens	Maximum	350 000
Private gardens	Average	225 000
Private gardens without grass		170 000
Irrigated vegetables	Average	80 000
Public parks		60–140 000
Tree plantations		2–7000

system to conserve drinking water. Table XIII shows the large amounts of water required to maintain lawns and Western style gardens.

Where water supplies are erratic, scarce or costly, measures that reduce water consumption should be considered. These include using low-flush or dry toilets, showers in lieu of baths and the use of 'grey water'. Grey water is water that has already been used, in domestic washing, in chilling plant or in industry, and it is used to flush toilets and for uses other than drinking and cooking.

Design of a rainwater collection and storage system may be part of the building designer or services engineer's task. Water may be collected off expanses of sloping smooth surfaces, in seepage dams or in open tanks. Bacteria multiply at an astonishing rate in open water exposed to the sun.

6.06 Sanitary installations and waste disposal

Sanitary appliances

Customary and religious practices vary. Some societies prefer the more ergonomically correct squat pan to the Western WC. Muslims wash in running water, so prefer the shower to the bath, and wash hand basins should have a mixer rather than separate hot and cold taps.

Foul sewerage

The capacity of piped systems will be related to the water supply standard. Where sewers are laid with low falls and where high soil temperatures exist, sewage may become septic and attack asbestos cement and cement pipes. Sewage disposal may be by pit latrine, aqua privy or septic tank in low-density development. Pit latrines require adequate space for replacements after the average life of five years, although this depends on soil conditions, etc. They should be stack vented. European toilets and septic tanks sized in accordance with Western data will not be able to cope with the bulky stools produced by a high-bulk cereal diet based on maize and similar cereals. Standard design data for septic tanks will be available. The length of tail drains depends on the soil type.

6.07 Storm and surface water drainage

Design rainfall intensities may not have been measured, making it difficult to calculate the size of gutters but indicative data could be collected on site. Tropical storms can have brief periods with rainfall intensities of 100 mm/h. Frequently, very heavy rain follows a long dry period during which drainage channels become blocked with sand and soil. In these zones, open or openable monsoon or storm drains are used to provide adequate capacity and ease of cleansing. Where piped systems are employed large sand traps are needed at each gully, and a minimum pipe size of 150 mm is necessary (200 mm is sometimes mandatory). Gradients should give a minimum self-cleansing velocity of 1 m/s. Roof gutters may not be provided at the eaves where torrential rains are experienced, as they cannot cope with the volume of water. Water discharges straight off the roof into open dish drains, or onto a wide concrete apron with a fall away from the building to prevent any splashback onto walls which may be single skin. Porches that redirect the water are needed at entrances. Mosquitoes would breed in shallow water lying in gutters with low falls. On larger building where gutters are provided, these may be in the form of heavy and costly concrete features, but large section gutters are becoming available in a range of materials, including aluminium and steel. Large gutters in GRP or other more flexible materials would need to tested for strength to withstand the full water load if not fully supported.

6.08 Controlling mosquitoes and other flying insects

Mosquitoes (and other insects, including moths) are attracted to bright lights, still air and water. Geckoes and chameleons eat them.

The normal means of deterring mosquitoes have been to:

- prevent insects from entering buildings at all times;
- attract insects away from buildings;
- protect the body at night, especially early evening – when mosquitoes are most prevalent;
- take measures to kill any insects that have entered buildings;
- increase air movement in and around buildings (mosquitoes like still air);
- eliminate breeding sites around buildings; and
- undertake mass spraying programmes over larger areas.

Design solutions include:

- fly-screening all windows and open doorways
- using mosquito nets over beds
- increasing air movement using fans, stack venting and wind funnelling devices
- avoiding bright lights, especially in open sitting or dining areas
- using exterior lighting to draw them away from occupied buildings
- using electronic devices that use bright light or smell to attract and kill insects
- eliminating all existing or potential areas of standing water where mosquitoes breed, which will include cutting back undergrowth and controlling landscaping.

Mosquito nets are essential, but they restrict ventilation. The net may be suspended from a timber or metal frame, like a lightweight four-poster, or from the ceiling on a frame or circular ring (a hospital net). The net should be long enough to tuck securely around and under the mattress.

The use of sprayed insecticides within buildings at night has traditionally included organo-phosphates and other cumulative poisons. Long-term use of these substances is harmful. All chemicals need to be treated with caution. In the tropics, spraying, on either the domestic or mass scale, may still be carried out using chemicals such as DDT, which are banned in the developed world.

Elimination of standing water is very important, and extends beyond the careful design of open gutters and drains to ensure that the fall is sufficient to take water away from inhabited areas. Some local authorities will have strictly enforced byelaws banning the planting of maize and other plants where the leaf forms a sheath around the stem, trapping water. Water used in landscaping should be agitated by fountains or the recycling mechanism and not allowed to become stagnant. Swimming pools and their overspill areas will need similar care, especially if not treating with the type of chemicals that keep insects at bay. Other breeding sites can include sedimentation ponds on sewage farms, agriculturally dammed fields (paddy fields) and the large lagoons that linger in low-lying areas after heavy rains or coastal storms.

7 BUILDING SCIENCE DATA

7.01 Sun path diagrams

The use of sunpath diagrams and shadow angle protractors is fully detailed in the texts listed in the Bibliography. When the sunpath diagrams for the northern hemisphere are used for the southern hemisphere, changes should be made to the time, month, azimuth, direction as shown in Table XIV. Shading coefficients are given in Table XV. Online sunpath calculation tools are available.

7.02 Albedo (also known as solar reflectance or ground reflectance)

Albedo is the percentage of solar radiation reflected from a surface, compared to the incoming (incident) solar radiation that the surface receives. The term signifies 'Whiteness' and therefore reflectance within the visible spectrum, but is usually taken to mean total

Table XIV Changes for sunpath diagrams in southern latitudes

Time (solar time)		Date		Azimuth degrees clockwise		Direction
North→South		North→South		North→South		North→South
4	20	28 Jan	30 July	0	180	
5	19	28 Feb	30 Aug	30	210	
6	18	21 Mar	23 Sept	60	240	North–South
7	17	15 April	15 Oct	90	270	
7	17	15 May	15 Nov	120	300	
11	13	22 June	22 Dec	150	330	East–West
12	12	30 July	28 Jan	180	360	
13	11	30 Aug	28 Feb	210	30	
13	11	23 Sept	21 Mar	240	60	South–North
17	7	15 Oct	15 April	270	90	
18	6	15 Nov	15 May	300	120	
19	5	22 Dec	22 June	330	150	West–East
20	4			360	180	

Table XV Shading coefficients: the quantity of solar radiation transmitted as a proportion of that transmitted through clear glass

Fenestration	Shading coefficient
Clear 6 mm glass	1.00
Glass with internal dark roller blind	0.70–0.80
Glass with internal dark venetian blind	0.75
Glass with internal medium venetian blind	0.55–0.65
Glass with internal white venetian blind	0.45–0.55
Glass with external miniature louvres	0.50–0.10 (depends on angle of incidence)
Glass with dark canvas external awning	0.20–0.28
Glass with dense trees providing shade	0.20–0.30
Glass with movable louvres	0.10–0.20
Heat absorbing glasses	0.45–0.80

Table XVI Albedo of surfaces on and around buildings*

Category	Type	Albedo (%)
Soil	White sand	34–40
	Light clay	30–31
	Grey earth – dry	35–30
	Grey earth – moist	10–12
Natural vegetation and ground cover	Fresh snow	75–95
	Rock	12–15
	Tall grass	18–20
	Deciduous woodland	18
	Short grass – lawn	23–25
	Water – lakes, sea	3–10
Building materials	Weathered concrete	22
	Red cement tile	18
	White concrete tile – new	77
	Asphalt shingle – black	3.4
	Asphalt shingle – white	26
	Coated metal roofing – white	59
	Coated metal roof – slate blue	19
	Coated metal roof – various greens	8–24
	EPDM – grey	23
	Aluminium roofing – untreated	71

* *Sources*: Muneer (1997) [soil and vegetation] and Parker et al. of FSEC (2000) [building materials, except 'weathered concrete'].

short-wave energy. Albedo varies according to the colour, seasonal variations in ground cover (snow, deciduous trees, crops) and, to a lesser extent, humidity of the surface covering. To avoid overheating, surfaces exposed to solar radiation will have low absorptivities and high emissivities (high albedo) and, to accumulate heat gains and act as heat stores, will have high absorptivities and low emissivities (low albedo). Table XVI gives the Albedo for a range of surfaces.

For all materials:

$$\text{Reflectivity} = 1 - \text{absorptivity}$$

(for radiation of a given wavelength)

$$\text{Absorptivity} = \text{emissivity (for radiation of a given wavelength)}$$

$$\text{Albedo} = \frac{\text{reflected solar radiation}}{\text{incident solar radiation}}$$

Pale surfaces reflect the greatest percentage of incident radiation, thereby reflecting the associated heat away from the surfaces of the building or paving. This may make glare and heat gain worse in the adjacent building. The impact of albedo on the heat island effect in cities is an area of current research in many centres. Trees, with a low albedo, will lower temperature through different mechanisms – including metabolism and transpiration; bright surfaces reduce temperature by reflection. In the city, surfaces tend to be dark and with a low albedo (brick, asphalt, slate) so they absorb and store heat that can not easily be radiated back into the sky due to the canyon effect of city streets. These raised temperatures accelerate decay of the urban fabric, exacerbate pollution and worsen ozone concentration. Smog in the atmosphere above cities traps the hot air beneath it. It would appear that tree-planting in cities has greater benefits than high albedo of surfaces, especially as we know that raising albedo outside the city, by stripping tree cover and replacing it with cultivation, has the effect of lowering rainfall and increasing the risk of drought.

7.03 Sol air temperature

Sol air temperature is the temperature of the outside air that would give the same rate of heat transfer and the same distribution of temperature through a construction as the combined effects of solar radiation and air temperature. Sol air temperature will be higher than air temperature when a surface is subject to solar radiation:

$$\theta_{sa} = \frac{\alpha I}{f_o} + \theta_o$$

where θ_{sa} = sol air temperature (°C)
α = absorptivity of surface to solar radiation
f_o = outside surface conductance (W/m^{2}K)
I = intensity of solar radiation (W/m^2)
θ_o = outside air temperature (°C).

The solar heat factor is the heat flow through the construction due to solar radiation, expressed as a proportion of the total solar radiation incident on the surface of the construction. When a building has large openings and is well ventilated to the exterior (as is often the case in the tropics), the solar heat factor is dependent on the *U*-value and absorptivity the external surface conductance ('f_o' can be taken as a constant):

$$\frac{q}{I} = \frac{U\alpha}{f_o}$$

Surfaces will be hottest when wind velocities are low; therefore, external surface resistances for cold conditions should not be used. In hot conditions with low wind speeds, a recommended value for f_o is 20 W/(m^{2}K). If the solar heat factor is expressed as a percentage then:

$$\frac{q}{I} = \frac{U\alpha}{20} \times 100 = 5U\alpha$$

U-values may be increased if absorptivities are proportionately reduced, while still maintaining a constant solar heat factor. Most reflective surfaces require regular maintenance to remain effective, so if maintenance or repainting of surfaces cannot be assured, *U*-values should be decreased to obtain realistic standards.

A solar heat factor of less than 4% will ensure that ceiling temperatures will not be more than 5°C above air temperatures and will not add to discomfort.

The approximate absorptivity of solar radiation of paints can be calculated if the Munsell value is known (as it is for colours in the BS range of paints for building purposes). The 'value' of the colour is given by the number which appears after the 'hue' letter in the Munsell number. This should be substituted for V in the formula:

Absorptivity $= 100 - [V(V-1)]$ (for solar radiation)

Example: Munsell number 6.25Y8.5/13 (Yellow)
$V = 8.5$, Absorptivity $= 36\%$ (at low temperatures most paints have an emissivity of 80–90%).

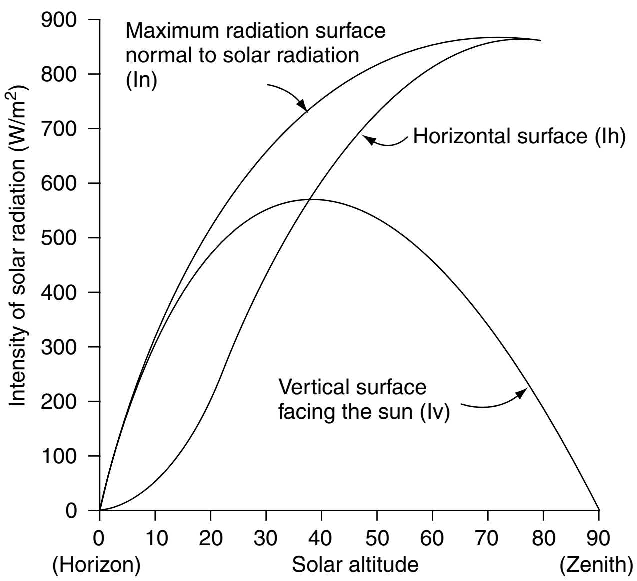
7.04 Solar radiation

The intensity of solar radiation on a surface depends on the altitude of the sun, the orientation of the surface in relation to the sun and the absorption of solar radiation by the atmosphere, pollution, cloud, etc., **35.47**.

Calculation: For vertical surfaces inclined at an angle θ to the azimuth (horizontal angle of sun on plan), the intensity of radiation on surface I will be:

$I_{v\theta} = I_v \times \cos\theta$, where I_v is taken from illustration **35.47**.

The altitude and azimuth of the sun can be found from sunpath diagrams or online calculation tools. The radiation from **35.47** should be multiplied by the values from Tables XVII and XVIII to give total radiation at the appropriate altitude and/or for appropriate atmospheric conditions.



35.47 *Intensity of solar radiation*

Table XVII Increase in solar radiation with altitude

Height above sea level	Altitude of sun in degrees				
	20°	30°	40°	60°	80°
900	1.14	1.12	1.10	1.08	1.08
1500	1.26	1.20	1.17	1.15	1.15
3000	1.30	1.31	1.28	1.25	1.23

Table XVIII Effect of cloud and atmospheric pollution on radiation*

Very low humidities and clear skies	1.1 (increase)
High humidities and pollution 'clear sky'	0.9 (decrease)
Overcast sky	0.1–0.3 (decrease)

* Varies greatly with cloud and solar altitude.

7.05 Illumination from sun and sky in the tropics

Illumination at work surfaces

The illumination required at the work surface for a given task is the same regardless of latitude. However, since light is associated with heat (both physically and psychologically), there is a case in the tropics for adopting slightly lower lighting standards to achieve higher levels of thermal comfort. In some countries, the cost of achieving high lighting standards may also be a factor.

The illumination from the sky is greater in tropical and sub-tropical regions so that a lower daylight factor can be used to achieve the same illumination at the work surface. The illumination from an overcast sky varies with latitude, altitude, degree of cloudiness and pollution. A guide is given in Table XIX.

Table XIX Illumination from a design sky

Latitude (N or S)	Design sky illumination
0°	17 000 lux
10°	15 000 lux
20°	13 000 lux
30°	9 000 lux
40°	6 000 lux
50°	5 000 lux

Position of windows – overcast skies

An overcast sky can be extremely bright and cause unacceptable glare from higher angular altitudes above 35°. Windows that offer a view below the 35° angle will increase comfort. In the warm humid equatorial regions, however, the luminance of the constant overcast sky may drop to 10 000 lux or below.

Position of windows – clear skies

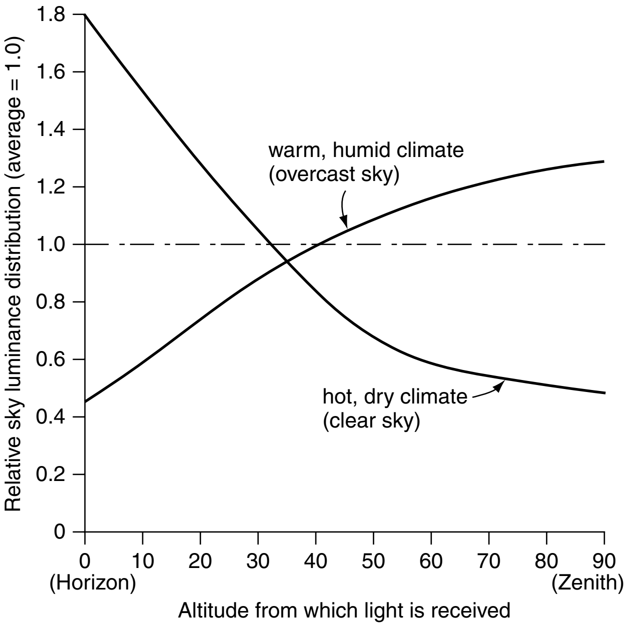
Hot dry desert regions receive light mainly from direct sunlight and considerably less from the (usually) deep blue sky, so windows should allow a view of this high altitude deep blue sky rather than along the horizon, which can reflect glare from distant haze and the sunlit ground. The window must be protected from direct solar radiation, if facing into the sun's path.

Incidence of light

Table XX gives a very rough comparison of the relative amount of light from different sources. **35.48** shows the relative sky luminance distribution in hot dry desert climates with a clear sky, and for warm humid climates with an overcast sky. (It is assumed that the warm, humid climate has a similar distribution to the CIE standard overcast sky.)

Table XX Sun, sky and ground brightness

Hot dry desert conditions	Sky (away from sun)	3 000 lux
	Sun	50 000 lux
	Ground (20% reflectivity)	11 000 lux
Warm humid equatorial conditions	Sky (overcast)	10 000 lux
	Ground (20% reflectivity)	2 000 lux



35.48 *Sky luminance distribution*

7.06 Glazing used in solar control

The best way to reduce solar radiation heat gain is to reduce window size (or provide external shading). Special solar control glass absorbs heat and this will cause thermal expansion, Table XXI. The high temperature of the glass may also cause physical discomfort. For comparison, a sheet of aluminium or an uninsulated concrete slab has been included in the table. Most special glasses will match these temperatures.

Body-tinted glass

Oxides are added to clear glass to change the colour and vary light and solar radiant heat transmission: iron oxide (green), cobalt oxide (grey and blue) and selenium oxide (bronze). Increased thickness darkens the colour and reduces light and heat transmission.

Coated and surface modified glasses

A film of microscopically thin metallic oxides is laid on the surface of clear or body-tinted glass and is usually protected or sealed within a sandwich of two or more layers of glass. Film performance is independent of glass thickness. Coated glasses receive their coating in a vacuum chamber; surface modified glasses are produced during the float process, using clear glass.

These coated and surface-modified glasses may modify:

- Light transmission
- Solar radiation properties
- Thermal insulation characteristics (by modifying surface emissivities).

Glass blocks

Glass blocks are available with different surface finishes that can diffuse, reduce or deflect light transmission. The mortar joint reduces thermal performance when compared to double-glazing, but they can also serve structural or fire protection functions. Most manufacturers recommend that glass blocks be used in shaded locations as the blocks can overheat or, in some cases, act as prisms with consequent risk of fire.

7.07 Wind

The Beaufort wind scale was initially developed for use at sea. It does not indicate wind speed and is usually replaced today by wind speed, measured 10 m above ground, in knots. Table XXII provides a conversion chart.

Wind loading on buildings varies with height, as friction with the ground slows down the wind at lower levels. This wind gradient is complex, but may be calculated. The American (USA) Building Codes give gradients levels of 300 m for cities, 400 m for suburbs, and 500 m for flat open terrain. Structural engineers may use the power law wind speed profile given below:

$$\nu_z = \nu_g \cdot \left(\frac{z}{z_g}\right)^{\frac{1}{\alpha}}, \ 0 < z < z_g$$

where:

ν_z = speed of the wind at height z
ν_g = gradient wind at gradient height z_g
α = exponential coefficient

Effect of internal wind speeds in warm humid climates

We can measure the effect of air movement within buildings, Table XXIII.

Hurricanes, typhoons, tsunami and tornadoes

Terminology varies from region to region. In addition to generating abnormally high wind loads, hurricanes, typhoons and tornadoes also cause extreme pressure differentials. Structural detailing and the

Table XXI Solar heat gains through glass*

Fenestration	Visible radiation transmitted %	Direct solar radiation transmitted %	Total solar radiation transmitted %	Index of increase of surface temp. above air temp (clear glass = 1)
Clear float glass	85	80	84	1
Glass with reflective polyester film	18	17	25	2
	33	31	39	2
Solar energy reflecting glass	42	47	52	2.5
	58	59	62	4
Surface modified heat absorbing glass	50	56	67	3
	50	48	62	4
Tinted solar control glass grey	42	45	62	4
	42	40	58	4
	24	22	47	4
	19	16	43	4.5
green	76	52	66	4
	74	45	61	4
	62	30	51	4
Clear glass with open weave curtain internally	40	70	82	1
Corrugated aluminium (new)	0	0	9	2
100 mm concrete	0	0	15	4

Sources: *Manufacturers' data; heat gains through fenestration*. F. J. Lotz and J. F. van Straaten, CSIR: R/Bov 223.
* Ranges of products are given. Consult manufacturers for specific data.

Table XXII Beaufort scale: descriptors and equivalent speeds for use on land. Separate descriptors apply at sea

Force	Description	Miles/hour	Kilometre/hour	Knots	Specification on land
0	Calm	0–1	0–1.6	0–1	Smoke rises vertically
1	Light air movement	1–3	1.6–5	1–3	Direction shown by smoke but not wind vanes
2	Light breeze	4–7	6–11	4–6	Wind felt on face, leaves rustle
3	Gentle breeze	8–12	13–19	7–10	Wind extends light flags, leaves in constant motion
4	Moderate breeze	13–18	21–29	11–16	Raises dust and loose paper, small branches are moved, onset of mechanical discomfort
5	Fresh breeze	19–24	31–39	17–21	Small trees in leaf begin to sway, uncomfortable in urban areas
6	Strong breeze	25–31	40–50	22–27	Large branches in motion, telegraph wires whistle, umbrellas difficult to use
7	Near gale	32–38	31–61	28–33	Whole trees in motion, difficult to walk against wind
8	Gale	39–46	63–74	34–40	Breaks twigs off trees, generally slows down walking
9	Strong gale	47–54	76–87	41–47	Slight structural damage occurs, tiles and slates dislodged
10	Storm	55–63	89–101	48–55	Seldom experienced inland
11	Violent storm	64–72	103–121	56–63	Trees uprooted
12	Hurricane	73–83	122+	64–71	Rarely experienced, accompanied by widespread damage
13–17	Beaufort numbers from force 13 to force 17 were added in 1955 by the United States Weather Bureau in 1955 to accommodate the exceptional winds experienced during a hurricane.				

Table XXIII Effect of internal wind speed in warm humid climates

Windspeed M/minimum	Effect
0–15	Not noticeable, less that 1°C of apparent cooling to the body
15–30	Cooling just noticeable – effect equal to a drop of temperature of 1–2°C
30–60	Effective and pleasant cooling
60–100	Maximum windspeed for cooling without undesirable side effects
100–200	Too fast for desk work; papers start to blow around
+200	Too fast and uncomfortable for internal conditions

fixing of non-structural elements must withstand the forces caused by the negative and positive pressure generated in these storms. Most countries experiencing these climatic events have appropriate building regulations concerning fixing and bracing for roofs, windows and structural design loadings. The risk of lightning strikes must also be considered. Electrical storms can be frequent and dramatic.

Sandstorms

Table XXIV shows the effect of wind on sand movements. This may vary with building height, sometimes becoming more severe at greater heights. Tight closing of all openings is required to reduce nuisance from blown sand. Finishes may need to withstand scouring and abrasion. Complete protection is not usually practical.

Table XXIV Effect of wind on sand

Windspeed M/minimum	Effect*
200	Sweeping sand. Visibility not impaired. Sand blown along the surface or up to 1 m above the ground.
300	Driving sand. Visibility impaired. Sand rises up to 2 m above the ground.
600	Sandstorm. Particles of sand remain suspended in the air.

* Depends on size of sand grain and on sand humidity.

7.08 Ventilation

Data on ventilation requirements and on mechanical ventilation is now widely available from CIBSE and other professional engineering institutions.

7.09 Lag

Time lag is the phase difference (delay) between external periodic variations in temperatures and the resulting internal temperature variations. The period of variations is 24 h and the lag is measured in hours. Table XXV gives time lag for homogeneous materials. For composite construction, the order in which different layers are placed can change the time lag considerably. If insulation is placed on the external surface of a dense material, the time lag is considerably increased. Table XXVI gives the time lag of a range of

Table XXV Time lag for homogeneous materials (in hours)

Materials		Thickness of material (mm)					
		25	50	100	150	200	300
Dense concrete	minimum	–	1.5	3.0	4.4	6.1	9.2
	maximum	–	1.1	2.5	3.8	4.9	7.6
Brick	minimum	–	–	2.3	–	5.5	8.5
	maximum	–	–	3.2	–	6.6	10
Wood	minimum	0.4	1.3	3.0	–	–	–
	maximum	0.5	1.7	3.5	–	–	–
Fibre insulating board	ave	0.27	0.77	2.7	5.0	–	–
Concrete with foamed slag aggregate	ave	–	–	3.25	–	8	–
Stone	ave	–	–	–	–	5.5	8.0
Stabilised soil	ave	–	–	2.4	4.0	5.2	8.1

Table XXVI Time lag for composite roof constructions

Construction (described from the external surface inwards)		Time lag (hours)
40 mm	Mineral wool	
100 mm	Concrete	11.8
100 mm	Concrete	3
40 mm	Mineral wool	(same as concrete alone)
14 mm	Cement plaster	
165 mm	Concrete	
14 mm	Cement plaster	3.8
14 mm	Cement plaster	
50 mm	Vermiculite concrete	
115 mm	Concrete	
14 mm	Cement plaster	13
Any finish		
25 mm	Expand polystyrene any structural concrete slab	over 8
Any finish		
75 mm	Lightweight concrete screed	
100 mm	Concrete slab	over 8
30 mm	Concrete tiles	
20 mm	Motor bed waterproof membrane	
60 mm	Screed	
240 mm	Hollow pot slab	
14 mm	Render	12

constructions. Although the time lag indicates when the thermal impact of outside temperature swings will affect the interior, the actual internal conditions can only be calculated when the heat flow into rooms and onto all room surfaces is considered.

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Regional Building Research Institutes
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Professional bodies
Centres with expertise, including aid agencies
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National Archives

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36 Structure

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KEY POINTS:

- *Current Codes of Practice require experts for the analysis and design of the specific type of structure and material*
- *Simplified approximate analysis and design methods do exist, but should not replace a rigorous final approach.*

Contents

1 INTRODUCTION

1.01

Structural engineering ensures that the loads of the building and its contents are transmitted safely and economically to the ground, allowing for considerations of function, aesthetics, internal and external environment and incorporating restraints imposed by other members of the building team, legislation, etc.

Structural engineering requires the use of mathematics to determine the forces in the framing elements of a structure (structural analysis). Sizing of these elements is then carried out based on interpretation of guidance provided in Codes of Practice relevant to the material being used (structural design). A competent structural engineer will have suitable training and be experienced in the required analysis and design techniques. Innovative and non-standard structures may require special consideration with the use of model testing to confirm analytical assumptions and member sizing.

1.02

In recent years, mathematical methods prescribed in new Codes of Practice, particularly the Eurocodes, have become more complex, making the use of computer programs essential.

1.03

The treatment of the subject in this chapter is necessarily brief. It will be even less comprehensive than in previous editions, but will still try to give the architect something of a feel for structure, and help him or her in discussions with a structural engineer. Because of the complexity of the methods now used, Local Authorities are increasingly insisting on the submission of calculations prepared by a Chartered Engineer from the recognized qualifying bodies, the Institution of Structural Engineers and the Institution of Civil Engineers who are entitled to use the designations CEng. MIStructE or CEng MICE, respectively.

1.04

There are three important factors in structural analysis and design:

- accurate assessment of the behaviour of the structural form
- accurate identification and calculation of all the forces acting
- full knowledge of the properties of the structural materials.

An outline of the methods used is given below.

2 BASIC STRUCTURAL THEORY

2.01

This section will summarise basic structural concepts and the terms that might be met in dealing with structural matters. Examination in greater depth may be found in the references given at the end of the chapter.

2.02 Limit state

Current techniques in the majority of structural engineering Codes of Practice are based on the concept of limit state design. Traditionally, design involved calculating the maximum stress and deflection in a member under working load. That stress was compared with the stress in that material known, through experiment, to lead to failure. Safe design included a margin, called the *factor of safety,* between the working and failure stress values. This traditional method was generally referred to as *permissible stress* design.

It is however important to anticipate how the form of the structure will behave under increasing load as factors other than excessive stress can cause building failure. These are known as *limit states* and must all be considered for satisfactory design. Apart from collapsing completely (*limit state of collapse* or *ultimate limit state*), a building may crack locally so badly as to let in the weather, it may deflect until the users feel unsafe (*limit state of deflection* or *serviceability limit state*). The task of the structural designer is to ensure that none of the possible limit states is ever reached.

In the case of the ultimate limit state, this is done by making sure that ultimate material stresses are not exceeded under critical ultimate load combinations. Ultimate stresses are derived by dividing the material failure stress by a prescribed material safety factor and ultimate loads are calculated by multiplying the loads (see para. **2.03**) by prescribed load factors. Both material and load factors are listed in the Codes of Practice relevant to the material being used.

The serviceability limit states of cracking and deflection are checked using working loads rather than ultimate loads, as the actual crack width and deflection in service is of interest.

2.03 Loads

In paragraph **2.02**, reference was made to loads. A load is an example of a force, and the term is usually used to describe those outside forces that act on a building structure. In Eurocodes, all loads and factors producing stress or deflection are called *actions.* Actions are of four types:

- Dead loads: from the weight of the structure itself and that of other fixed parts of the building such as cladding, finishes, partitions, etc.
- Imposed loads: from the weight of people, furniture and of materials stored in the building.

- Dynamic loads: these are of many origins. The most common dynamic load on a building is that caused by wind, which can produce horizontal and vertical pressures and suctions. Other dynamic loads are produced by moving machinery such as overhead cranes in large workshops and by earthquakes. For the purposes of design, dynamic loads were often transformed into approximate equivalent static loadings. The widespread availability of sophisticated analytical software now allows more accurate dynamic analysis to be carried out.
- The fourth type of action is one that is not produced by an outside force, but by internal factors such as thermal expansion.

2.04 Force units

Forces, including loads, are measured in Newtons (N). One Newton is the force required to give a mass of 1 kg an acceleration of 1 m/s^2. A tip to remember is that a Newton is about the weight of an apple. Most forces in structural engineering are expressed in kN (kilonewtons). Table I gives conversions from and to SI, MT and FPS (Imperial) units for loadings of all types.

2.05 Mass and weight

Confusion often arises between the terms *mass* and *weight.* Outside nuclear physics, the *mass* of an object is a fixed quantity which is a basic property of that object. Its *weight* will depend on the mass, but also on the value of the gravitational effect on the object. This is not a constant, but can vary, not only in extra-terrestrial conditions but even very slightly on different places on earth. However, for all practical purposes the acceleration of gravity is taken as 9.81 m/s^2, so that the weight of a kilogram mass is 9.81 N. This figure is invariably rounded up to 10 for ease of computation.

2.06 Loading assessment

Perhaps, the most important calculation the structural engineer carries out relates to the accurate assessment of loading. Table II below shows the loads of various materials which may comprise the fabric of a building that may be included in the dead load computation. It also gives the densities of materials that may be stored within it: part of the imposed loads. The figures are given both in the usual mass density form: kg/m^3, and also in the more convenient weight density kN/m^3. Some loadings are more conveniently calculated from superficial or linear unit weights, and a few are given in Table III. For a comprehensive list of weights of building materials, reference should be mad to BS648 *Schedule of weights of building materials*.

Table I Various conversions for loadings

Point loads
1 N = 0.102 kgf = 0.225 lbf
1 kN = 101.972 kgf = 224.81 lbf = 0.1004 tonf
1 MN = 101.972 tf = 224.81 kipf = 100.36 tonf
1 kgf = 9.807 N = 2.205 lbf
1 tf = 9.807 kN = 2.205 kipf = 0.9842 tonf
1 lbf = 4.448 N = 0.4536 kgf
1 kipf = 4.448 kN = 453.59 kgf = 0.4536 tf
1 tonf = 9.964 kN = 1.016 tf

Linearly distributed loads
1 N/m = 0.0685 lbf/ft = 0.206 lbf/yd
1 kN/m = 68.5 lbf/ft = 0.0306 tonf/ft
1 kgf/m = 9.807 N/m = 0.672 lbf/ft = 2.016 lbf/yd
1 tf/m = 9.807 kN/m = 0.672 kipf/ft = 2.016 kipf/yd = 0.3 tonf/ft = 0.9 tonf/yd
1 lbf/ft = 14.59 N/m = 1.488 kgf/m
1 kipf/ft = 14.58 kN/m = 1.488 tf/m
1 ton/ft = 32.69 kN/m = 3.33 tf/m
1 tonf/yd = 10.90 kN/m = 1.11 tf/m

Superficially distributed loads
1 N/m^2 = 0.0209 lb/ft^2
1 kN/m^2 = 20.89 lb/ft^2
1 MN/m^2 = 9.324 tonf/ft^2
1 kgf/m^2 = 9.80665 N/m^2 = 0.2048 lbf/ft^2 = 1.843 lbf/yd^2
1 tf/m^2 = 9.80665 kN/m^2 = 0.2048 kipf/ft^2 = 0.0914 tonf/ft^2 = 0.823 tonf/yd^2
1 lb/ft^2 = 47.88 N/m^2 = 4.88 kgf/m^2
1 kipf/ft^2 = 47.88 kN/m^2 = 4.88 tf/m^2
1 tonf/ft^2 = 107.25 kN/m^2 = 10.93 tf/m^2
1 tonf/yd^2 = 11.92 kN/m^2 = 1.215 tf/m^2

Densities
1 N/m^3 = 0.00637 lbf/ft^3
1 kN/m^3 = 6.37 lbf/ft^3
1 MN/m^3 = 2.844 tonf/ft^3
1 kg/m^3 = 0.0624 lb/ft^3 (mass density)
1 t/m^3 = 62.4 lb/ft^3
1 lb/ft^3 = 16.02 kg/m^3 1 lbf/ft^3 = 157 N/m^3
1 ton/ft^3 = 35.88 t/m^3 1 ton/ft^3 = 351.9 kN/m^3
1 ton/yd^3 = 1.33 t/m^3

Table II Densities of bulk materials

	kg/m^3	kN/m^3
Aggregates		
Coarse		
Normal weight, e.g. natural aggregates	1600	15.7
Fine		
Normal weight, e.g. sand	1760	17.3
Bricks (common burnt clay)		
Stacked	1602–1920	15.7–18.8
Cement		
Bags	1281	12.6
Concrete, plain		
Aerated	480–1600	
brick aggregate	1840–2160	
Clinker	1440	14.1
stone ballast	2240	22.0
natural aggregates	2307	
Concrete, reinforced		
2% steel	2420	23.7
Glass		
Plate	2787	27.3
Gypsum		
Plaster	737	7.2
Metals:		
Aluminium cast	2771	27.2
Iron		
Cast	7208	70.7
Wrought	7689	75.4
Lead:		
cast or rolled	11 325	111.1
Stone		
Bath	2082	20.4
masonry, dressed	2403	23.6
Granite	2643	25.9
Marble	2595–2835	25.4–27.8
Slate:		
Welsh	2803	27.5
Timbers:		
Ash (Canadian)	737	7.2
Balsawood	112	1.1
Beech	769	6.9
Birch	641	6.3
Cedar, western red	384	3.8
Deal, yellow	432	4.2
Ebony	1185–1330	11.6–13.1
Elm		
English	577	5.6
Fir:		
Douglas	529	5.2
Silver	481	4.7
Hemlock, western	497	4.9
Iroko	657	6.4
Larch	593	5.8
Mahogany: (African)	561	5.5
Maple:	737	7.2
Oak: English	801–881	7.8–8.6
Pine: New Zealand	609	6.0
Plywood	481–641	4.7–6.3
Plastic bonded	721–1442	7.0–14.2
Resin bonded	721–1362	7.0–13.4
Poplar	449	4.4
Spruce Canadian	465	4.6
Sycamore	609	6.0
Teak, Burma or African	657	6.4
Walnut	657	6.4
Whitewood	465	4.6
Water	1001	9.8

Table III Superficial masses of materials in kg/m^3 and weights in N/m^2. This is based on figures in BS 648:1964, and should be taken as approximate

	kg/m^2	N/m^2
Aluminium sheet		
Corrugated (BS 2855) (including 20% added weight for laps 'as laid') 0.71 mm	2.9	28
Battens		
Slating and tiling, 40 × 20 mm softwood 100 mm gauge	3.4	33
Blockwork, walling (per 25 mm thickness)		
Clay		
Hollow	25.5	250
Concrete		
Stone aggregate		
Cellular	40.0	392
Hollow	34.2	335
Solid	53.8	528
Lightweight aggregate		
Cellular	28.3	278
Hollow	25.5	250
Solid	31.7	311
Aerated		
Based on 560 kg/m^3	14.4	141
Based on 800 kg/m^3	19.2	188
100 mm thick	52.4	514
115 mm thick	56.9	558
Brickwork (all per 25 mm thick)		
Clay		
Solid		
Low density	50.0	490
Medium density	53.8	528
High density	58.2	571
Perforated		
Low density, 25% voids	38.0	373
Low density, 15% voids	42.3	415
Medium density, 25% voids	39.9	391
Medium density, 15% voids	46.2	453
High density, 25% voids	44.2	433
High density, 15% voids	48.0	471
Concrete	57.7	566
Flagstones		
Concrete 50 mm thick	115	1130
Natural stone 50 mm thick	56	549
Floors		
Hollow concrete units (including any concrete topping necessary for constructional purposes)		
100 mm	168	1650
150 mm	217	2130
200 mm	285	2800
Glass		
Float 6 mm	16.7	164
Gypsum panels and partitions		
Dry partition		
65 mm thick	26.5	260
Lathing		
Wood	6.3	62
Lead sheet (BS 1178)		
0.118 in (3.0 mm)	34.2	335
Plaster		
Gypsum		
Two coat, 12 mm thick		
Normal sanded undercoat and neat finishing	20.8	204
One coat, 5 mm thick, neat gypsum	6.7	66
Lime (non-hydraulic and hydraulic) 12 mm thick	23.1	227
Lightweight		
Vermiculite aggregate, two coat, ditto	10.5	103
Plasterboard, gypsum		
Solid core		
9.5 mm	8.3	81
12 mm	10.6	104
18 mm	16.1	158
Plywood		
Per mm thick	0.6 ± 0.1	6 ± 1
Rendering		
Portland cement: sand (1:3) 12 mm thick	27.7	272
Screeding		
Portland cement: sand (1:3) 12 mm thick	27.7	272
Slate		
Welsh		
Thin	24.4	239
Thick	48.8	479
Steel		
Mild, sheet Corrugated (1 mm)	15.6	153
Stonework, natural		
Note: For cramps add 80 kg/m^3 (5 Ib/ft^3)		
Limestone		
Light, e.g. Bathstone		
100 mm thick	206.6	2026
Medium, e.g. Portland stone		
100 mm thick	225.9	2215
Heavy, e.g. marble		
20 mm thick	53.7	527
Sandstone		
Light, e.g. Woolton		
100 mm thick	221.1	2168
Medium, e.g. Darley Dale		
100 mm thick	230.7	2262
Heavy, e.g. Mansfield Red		
100 mm thick	240.3	2357
Granite		
Light, e.g. Peterhead		
50 mm thick	129.7	1272
Medium, e.g. Cornish		
50 mm thick	134.5	1319
Heavy, e.g. Guernsey		
50 mm thick	144.2	1414
Thatching		
Reed (including battens) 300 mm thick	41.5	407
Tiling, roof		
Clay		
Plain Machine made, 100 mm gauge	63.5	623
Concrete		
Stone aggregate		
Plain		
75 mm gauge	92.8	910
100 mm gauge	68.4	671
115 mm gauge	61.0	598
Interlocking (single lap)	48.8 ± 7.3	479 ± 72

Table IV indicates minimum imposed loads that should be allowed for in designing buildings for various purposes. These figures are intended to allow for the people in the building, and the kind of material normally stored. However, these loads sometimes need to be checked against the figures in Tables II and III for more unusual circumstances.

2.07 Structural elements

For convenience of design, large structures are broken up into elements. These are of different types according to the function they perform in the building. Before describing each type, it will be necessary to explore the forces that are found internally in the materials of the structure.

2.08 Stress and strain

If a bar of uniform cross-section has a force applied at each end, **36.1**, it will stretch slightly. This stretch is called the *strain* in the bar, and is defined as the extension divided by the original length.

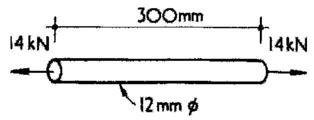
The *stress* on this bar is the force on the cross-section divided by its area. The relationship between the strain and the stress is an important factor in structural engineering. **36.2** shows a graph of this relationship for steel. The length OA is a straight line and is called the *elastic* zone. In the elastic zone, the ratio of stress to strain is a constant called *Young's Modulus*. At A, there is a sudden change called the *yield point. Hooke's Law*, which says that stress and strain are proportionate, only applies in the elastic zone. Beyond this point along the curve AB there is no constant relationship between the stress and the strain. In fact, even if there is no increase in stress, the strain can increase over time until the bar breaks at B. This length of curve is known as the *plastic zone.*

In **36.3**, OAB shows the actual stress/strain relationship for a typical concrete. This, for many practical purposes can be substituted by OCD. OC is the elastic and CD the plastic zone.

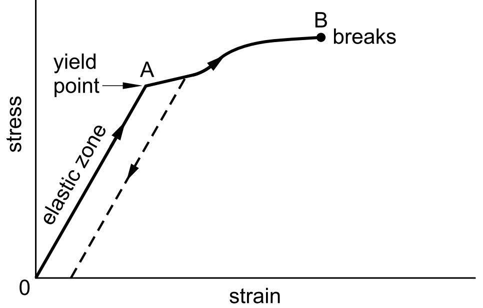
Table IV Typical minimum imposed floor loads extracted from BS 6399 – 1 Loading for buildings: Code of practice for dead and imposed loads

Type of activity/or occupancy for part of the building or structure	Examples of specific use		Uniformly distributed load (kN/m^2)	Concentrated load (kN)
A Domestic and residential activities (also see category C)	All usages within self-contained single family dwelling units. Communal areas (including kitchens) in blocks of flats with limited use (see note 1) (for communal areas in other blocks of flats see C3 and below)		1.5	1.4
	Bedrooms and dormitories except those in single family dwelling units and hotels and motels		1.5	1.8
	Bedrooms in hotels and motels Hospital wards Toilet areas		2.0	1.8
	Communal kitchens except in flats covered by note 1		3.0	4.5
	Balconies	Single family dwelling units and communal areas in blocks of flats with limited use (see note 1)	1.5	1.4
		Guest houses, residential clubs and communal areas in blocks of flats except as covered by note 1	Same as rooms to which they give access but with a minimum of 3.0	1.5/m run concentrated at the outer edge
		Hotels and motels	Same as rooms to which they give access but with a minimum of 4.0	1.5/m run concentrated at the outer edge
B Offices and work areas not covered elsewhere	Operating theatres, X-ray rooms, utility rooms		2.0	4.5
	Work rooms (light industrial) without storage		2.5	1.8
	Offices for general use		2.5	2.7
	Kitchens, laundries, laboratories		3.0	4.5
	Rooms with mainframe computers or similar equipment		3.5	4.5
	Factories, workshops and similar buildings (general industrial)		5.0	4.5
	Balconies		Same as rooms to which they give access but with a minimum of 4.0	1.5/m run concentrated at the outer edge
C Areas where people may congregate	Public, institutional and communal dining rooms and lounges, cafes and restaurants (see note 2)		2.0	2.7
C1 Areas with tables	Reading rooms with no book storage Classrooms		2.5 3.0	4.5 2.7
C2 Areas with fixed seats	Assembly areas with fixed seating (see note 3) Places of worship		4.0 3.0	3.6 2.7
C3 Areas without obstacles for moving people	Corridors, hallways, aisles, stairs, landings, etc. in institutional type buildings (not subject to crowds or wheeled vehicles), hostels, guest houses, residential clubs, and communal areas in blocks of flats not covered by note 1. (For communal areas in blocks of flats covered by note 1, see A.)	Corridors, hallways, aisles, etc. (traffic foot only)	3.0	4.5
		Stairs and landings (foot traffic only)	3.0	4.0
	Corridors, hallways, aisles, stairs, landings, etc. in all other buildings including hotels and motels and institutional buildings	Corridors, hallways, aisles, etc. (foot traffic only)	4.0	4.5
		Corridors, hallways, aisles, etc. subject to wheeled vehicles, trolleys, etc.	5.0	4.5
		Stairs and landings (foot traffic only)	4.0	4.0
	Balconies (except as specified in A)		Same as rooms to which they give access but with a minimum of 4.0	1.5/m run concentrated at the outer edge
C4 Areas with possible physical activities (see clause 9)	Dance halls and studios, gymnasia, stages		5.0	3.6
C5 Areas susceptible to overcrowding (see clause 9)	Assembly areas without fixed seating, concert halls, bars, places of worship and grandstands		5.0	3.6
	Stages in public assembly areas		7.5	4.5
D Shopping areas	Shop floors for the sale and display of merchandise		4.0	3.6
E Warehousing and storage areas. Areas subject to accumulation of goods. Areas for equipment and plant	General areas for static equipment not specified elsewhere (institutional and public buildings)		2.0	1.8
	Reading rooms with book storage, e.g. libraries		4.0	4.5
	General storage other than those specified		2.4 for each metre of storage height	7.0
	File rooms, filing and storage space (offices)		5.0	4.5
	Stack rooms (books)		2.4 for each metre in storage height but with a minimum of 6.5	7.0
	Dense mobile stacking (books) on mobile trolleys, in public and institutional buildings		4.8 for each metre of storage height but with a minimum of 9.6	7.0
	Plant rooms, boiler rooms, fan rooms, etc. including weight of machinery		7.5	4.5
F	Parking for cars, light vans, etc. not exceeding 2500 kg gross mass, including garages, driveways and ramps		2.5	9.0

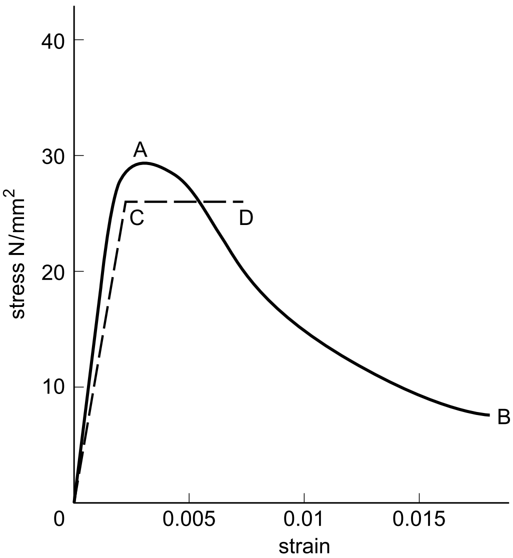
Note 1. Communal areas in blocks of flats with limited use refers to blocks of flats not more than three storeys in height and with not more than four self-contained single family dwelling units per floor accessible from one staircase.
Note 2. Where these same areas may be subjected to loads due to physical activities or overcrowding, e.g. a hotel dining room used as a dance floor, imposed loads should be based on occupancy C4 or C5 as appropriate. Reference should also be made to clause 9.
Note 3. Fixed seating is seating where its removal and the use of the space for other purposes is improbable.



36.1 *A bar of uniform cross-section under a tensile force*



36.2 *Stress–strain diagram for steel showing the yield point where Hooke's Law (stress is proportional to strain) no longer operates. Dotted line shows deformation caused when stress is reduced after the yield point, material does not return to its original form*



36.3 *Stress–strain diagram for a typical concrete*

2.09 Units of stress

The basic SI unit of stress is the N/m^2 (which is also called the Pascal, Pa), but this is too small a unit for practical purposes. The correct form for the normal unit is the mega Pascal, MPa or mega Newton MN/m^2 but this is expressed by engineers in units of N/mm^2.

2.10 Tension members

If the stress in a member tends to lengthen it, it is said to be in *tension.* Elements in tension are called *ties.* In many ways, this is the simplest kind of stress. Some materials, steel members in particular are ideal for resisting it. Cables, wires and chains can be used to carry tension. Materials such as stone, cast iron and unreinforced concrete have little or no resistance to tension.

2.11 Compression members

If the stress a member tends to shorten it, it is in *compression.* Elements in compression are called *struts, columns, piers* or *stanchions.* The term used depends on their location and the material of which they are made.

Most materials other than cables, wires and chains can be used to carry compression. However, there is an instability phenomenon that occurs in compression members called *buckling.* For some members, particularly those that are slender in comparison with their length, increase in compressive load will cause bending until failure occurs in tension on one side. It is this buckling effect that can be the cause of the collapse of slender towers and high walls of masonry construction.

2.12 Pin-jointed frames

Some structures are designed and constructed of members that act as struts and ties. Analysis methods assume that the members are pin jointed at their ends, which allows only the development of compressive or tensile forces in each member. A roof truss is typical of this type; the general term for which is *pin-jointed frame.* In practice, very few such structures are actually physically pin-jointed (although some have been built), but the use of flexible bolted connector plates adequately approximates the theoretical assumption of a pin at member ends.

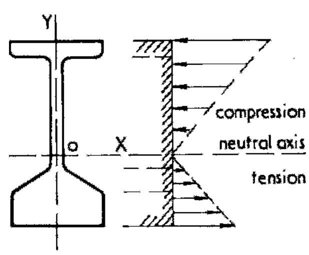
2.13 Bending

Unlike struts and ties which transmit only compressive and tensile forces along their length, beam members support loads by bending action. Internal forces known as bending moments are developed within the beam allowing it to support loads acting at right angles to its length. An example of beam action is that of a lintol spanning an opening and carrying the applied loads from floor and walls above safely around the opening.

Bending is the phenomenon by which a single member of significant depth develops both compression and tension across its section. Consider the case of a beam supported at each end with a load in the centre of the span, the deflected shape is a downward sag resulting in maximum compression in the top layers of the beam, and maximum tension in the bottom layers. Somewhere in the middle of the beam will be layer with no stress at all. This layer is known as the *neutral axis*, **36.4**. The externally applied bending moment is resisted by an internal moment in the beam which is a function of the product of the compressive and tensile forces and the distance between their lines of action.

2.14 Materials in bending

Since the internal moment of resistance of a beam depends upon the development of both compressive and tensile forces, only materials that are strong in both compression and tension are generally suitable for beams. Steel and timber are good examples of such materials. Stone, being weak in tension, makes poor bending members. The ancient Greeks had to construct buildings with closely spaced columns, as stone lintols would not span very far. Only when the arch had been invented could the spans be increased, because the arch is wholly in compression. Cast iron is weak in tension, although not as weak as stone. The bottom flanges of cast iron beams were often larger than the top flanges to allow for this inequality in strength. Concrete is also poor under tensile force, so steel is used in the tension zone (which is usually at the bottom, except for cantilevered and continuous beams – see below), to reinforce concrete beams.



36.4 *Structural member under pure bending*

2.15 Beams

Beams can be categorised as follows:

- *Simply supported*, **36.5**. The beam ends are assumed to be completely free to move rotationally resulting in zero moment at each end. In addition, one end is assumed to be supported on a roller bearing allowing freedom of movement in the direction of the beam length resulting in zero horizontal reaction at the roller bearing end. If the loading is uniformly distributed along the length of the beam then the bending moment will be a maximum at mid-span. This type of beam is known as statically determinate as the support reactions and bending moments can be calculated using the basic equations of equilibrium.
- *Cantilever*, **36.6**. This beam type is supported only at one end where it is fixed in both position and rotationally. The bending moment will be zero at the free end and a maximum at the support causing tension in the top of the beam.
- *Encastré or fixed end*, **36.7**. This beam is built-in at both ends. This type of beam is *statically indeterminate* as the values of the bending moments are not calculable by normal statistical methods. These values actually depend on a number of imponderables, such as how much fixity exists at each support. Maximum moments will occur in encastré beams either at mid-span or at one, other or both ends, depending upon the disposition of the loads.
- *Continuous*, **36.8**. A beam on several supports is known as a continuous beam. Generally, the maximum moments occur over the supports. Tension in the beam section over the supports occurs at the top but occurs at the bottom at midspan. Continuous concrete beams have to be reinforced accordingly.
- *Lintols*, **36.9**. Beams that are supported on brickwork, such as lintols over doorways and windows, are not considered structurally encastré, and are normally designed as simply supported.

2.16 Bending moments

In order to design a beam, an engineer first calculates the bending moments at critical sections generated by the worst case loading combination. Maximum internal stresses are then computed at those sections. For anything other than the simplest structure, this can be a time-consuming and complicated matter. For a large number of the simpler cases, the moment at midspan of an assumed simply supported beam will suffice to give a safe answer, if not perhaps the most economical. Table V gives maximum bending moments and deflections for the common cases likely to be met.

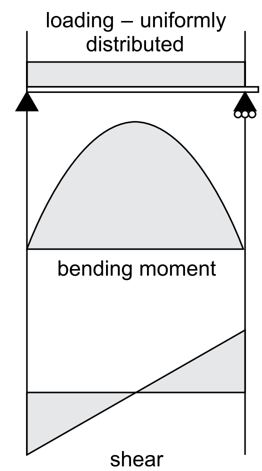
2.17 Bending stresses

Once the bending moment M is known, the stress f at any layer at distance y from the neutral axis can be found from elastic or plastic theory relationships. The choice of elastic or plastic design theory is dictated by the code of practice for the material being considered.

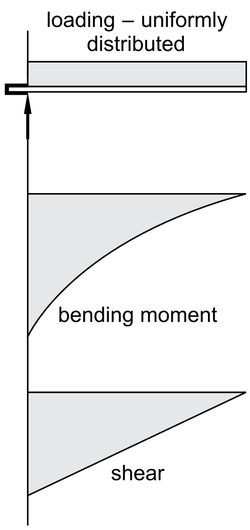
For elastic design, the relationship is:

$$\frac{M}{y} = \frac{f}{I}$$

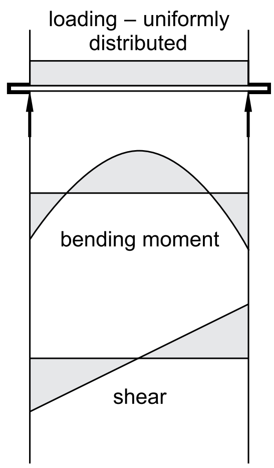
The stress in the extreme fibre of a beam therefore depends on the *second moment of area (I)* of the cross-section. While a full exposition of this parameter is beyond the scope of this chapter, values for a number of common cross-sectional shapes can be found in Table VI. Note that in most cases the I value is directly



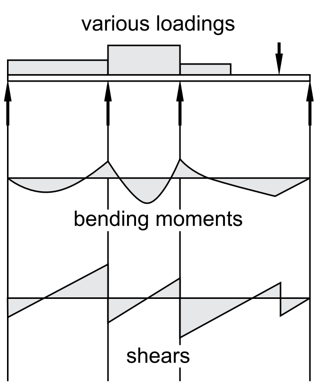
36.5 *Simply supported beam under uniform loading*



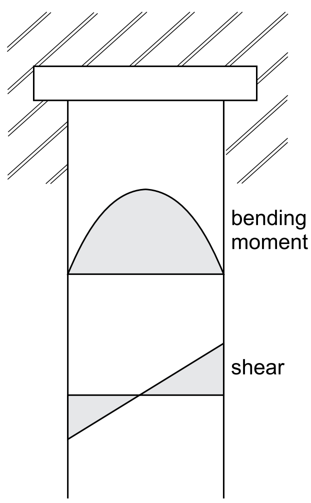
36.6 *Cantilever beam*



36.7 *Encastré beam*



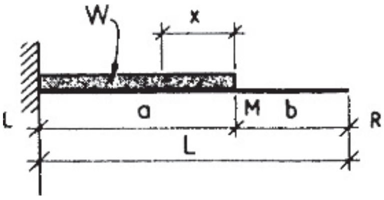
36.8 *Continuous beams*



36.9 *Lintol*

Table V Standard Beam conditions

1 Cantilevers

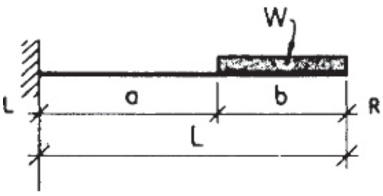


$M_X = \frac{Wx^2}{2a}$ $M_{max} = \frac{Wa}{2}$

$S_{max} = R_L = W$

$\delta_M = \frac{Wa^3}{8EI}$

$\delta_{max} = \delta_R = \frac{Wa^3}{8EI} \times \left(1 + \frac{4b}{3a}\right)$

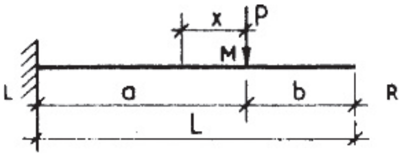


$M_{max} = W\left(a + \frac{b}{2}\right)$

$S_{max} = R_L = W$

$\delta_{max} = \delta_R$

$= \frac{W}{24EI}(8a^3 + 18a^2b + 12ab^2 + 3b^3)$



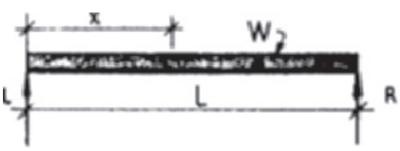
$M_X = P_x$ $M_{max} = Pa$

$S_{max} = R_L = P$

$\delta_M = \frac{Pa^3}{3EI}$

$\delta_{max} = \delta_R = \frac{Pa^3}{3EI} \times \left(1 + \frac{3b}{2a}\right)$

2 Simply supported beams

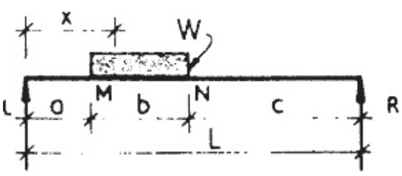


$M_X = \frac{Wx}{2}\left(1 - \frac{x}{L}\right)$

$M_{max} = \frac{WL}{8}$

$R_L = R_R = \frac{W}{2}$

δ_{max} at center $= \frac{5}{384} \times \frac{WL^3}{EI}$



$M_{max} = \frac{W}{b}\left(\frac{x^2 - a^2}{2}\right)$

when

$x = a + R_L \times \frac{b}{W}$

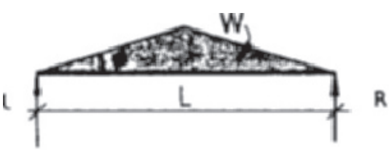
$R_L = \frac{W}{L}\left(\frac{b}{2} + c\right)$

$R_R = \frac{W}{L}\left(\frac{b}{2} + a\right)$

if $a = c$

$M = \frac{W}{8}(L + 2a)$

$\delta_{max} = \frac{W}{384EI} \times (8L^3 - 4Lb^2 + b^3)$



$M_X = W_X\left(\frac{1}{2} - \frac{2X^2}{3L^2}\right)$

$M_{max} = \frac{WL}{6}$

$R_L = R_R = \frac{W}{2}$

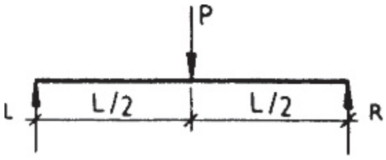
$\delta_{max} = \frac{WL^3}{60EI}$

If $\phi = 60°$ $M = 0.0725\ wL^3$

$R = 0.217\ wL^2$

Table V (Continued)

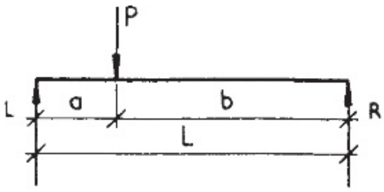
2 Simply supported beams, *continued*



$$M_{max} = \frac{PL}{4}$$

$$R_L = R_R = \frac{P}{2}$$

$$\delta_{max} = \frac{PL^3}{48EI}$$



$$M_{max} = P\frac{ab}{L} = M_p$$

$$R_L = \frac{Pb}{L} \; R_R = \frac{Pa}{L}$$

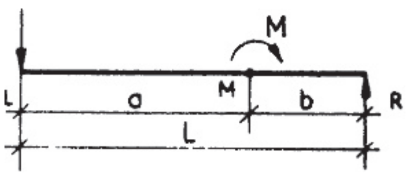
δ_{max} always occurs within 0.0774L of the center of the beam.

When b > a

$$\delta_{center} = \frac{PL^3}{48EI} \times \left[3\frac{a}{L} - 4\left(\frac{a}{L}\right)^3\right]$$

This value is always within 2.5% of the maximum value.

$$\delta_p + \frac{PL^3}{3EI}\left(\frac{a}{L}\right)^2\left(1 - \frac{a^2}{L}\right)^2$$

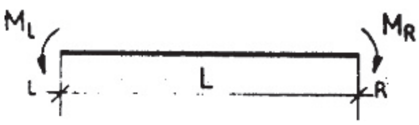


$$M_{ML} = M\frac{a}{L} \; M_{MR} = M\frac{b}{L}$$

$$R_A = R_B = \frac{M}{L}$$

when a > b

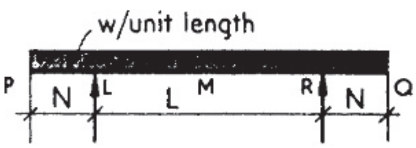
$$\delta_M = -\frac{Mab}{3EI}\left(\frac{a}{L} - \frac{b}{L}\right)$$



$$R_L = -R_R = \frac{M_L - M_R}{L}$$

when $M_L = M_R$,

$$\delta_{max} = -\frac{ML^2}{8EI}$$



$$M_L = M_R = -\frac{wN^2}{2}$$

$$M_{max} = \frac{WL^2}{8} + M_L$$

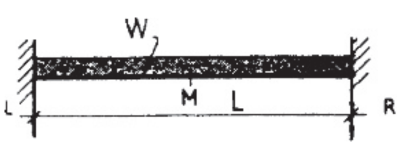
$$R_L = R_R = w\left(N + \frac{L}{2}\right)$$

$$\delta_p = \delta_q = \frac{wL^3N}{24EI} \times (1 - 6n^2 - 3n^3)$$

$$\delta_{max} = \frac{wL^4}{384EI}(5 - 24n^2)$$

$$n = \frac{N}{L}$$

3 Fixed end beams



$$M_L = M_R = -\frac{WL}{12}$$

$$M_M = \frac{WL}{24}$$

$$R_L = R_R = \frac{W}{2}$$

Points of contraflexure 0.21L from each end

$$\delta_{max} = \frac{WL^3}{384EI}$$

Table V (Continued)

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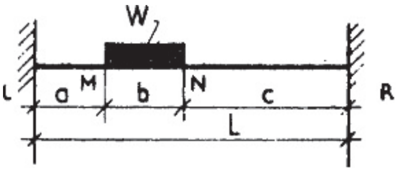
3 Fixed end beams, *continued*



$$M_L = -\frac{W}{12L^2b}$$

$$[c^3(4L - 3c) - c^2\,(4L - 3C)]$$

$$M_R = -\frac{W}{12L^2b}$$

$$[d^3(4L - 3d) - a^3(4L - 3a)]$$

$$a + b = d$$

$$b + c = e$$

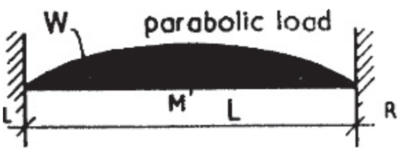
When r = reaction if the beam were simply supported.

$$R_L = r_L + \frac{M_L - M_R}{L}$$

$$R_R = r_R + \frac{M_R - M_L}{L}$$

When $a = c$,

$$\delta_{max} = \frac{W}{384EI} \times (L^3 + 2L^2a + 4La^2 - 8a^3)$$

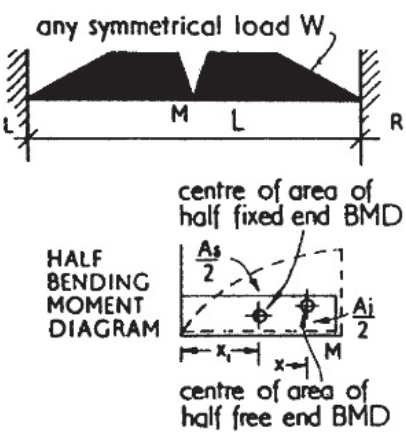


$$M_L = M_R = -\frac{WL}{10}$$

$$M_M = \frac{5WL}{32} - \frac{WL}{10} = \frac{9WL}{160}$$

$$R_L = R_B = \frac{W}{2}$$

$$\delta_{max} = \frac{1.3WL^3}{384EI}$$

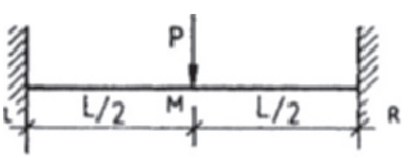


$$M_L = M_R = -\frac{A_s}{L}$$

where A_S is the area of the free bending moment diagram

$$R_L = R_R = \frac{W}{2}$$

$$\delta_{max} = \frac{A_Sx - A_1x_1}{2EI}$$



$$M_L = M_R = -\frac{PL}{8}$$

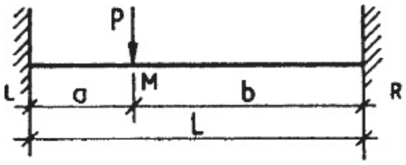
$$M_M = \frac{PL}{8}$$

$$R_L = R_R = \frac{P}{2}$$

$$\delta_{max} = \frac{PL^3}{192EI}$$

Table V (Continued)

3 Fixed end beams, *continued*



$$M_L = -\frac{Pab^2}{L^2}$$

$$M_R = -\frac{Pba^2}{L^2}$$

$$M_M = \frac{2Pa^2b^2}{L^3}$$

$$R_L = P\frac{b^2}{L^2}\left(1 + 2\frac{a}{L}\right)$$

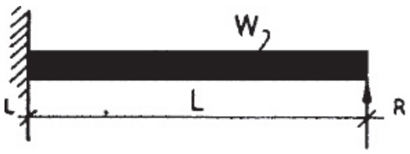
$$R_R = P\frac{a^2}{L^2}\left(1 + 2\frac{b}{L}\right)$$

$$\delta_m = \frac{Pa^3b^3}{3EIL^3}$$

$$\delta_{max} = \frac{2Pa^2b^3}{3EI(3L - 2a)^2}$$

$$\text{at } x = \frac{L^2}{3L - 2a}$$

4 Propped cantilevers



$$M_L = -\frac{WL}{8}$$

$$M_{max} = \frac{9WL}{128} \text{ at } x' = 5/8$$

$$M = 0 \text{ at } x' = 1/4$$

$$R_L = 5/8\,W$$

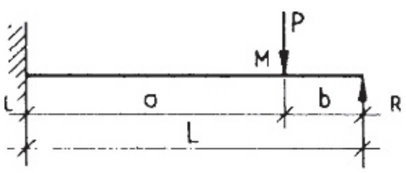
$$R_R = 3/8\,W$$

$$\text{if } m = 1 - X'$$

$$\delta = \frac{WL^3}{48EI} \times (m - 3m^3 + 2m^4)$$

$$\delta_{max} = \frac{WL^3}{185EI}$$

$$\text{at } X' = 0.5785$$



$$M_L = -\frac{Pb}{2}(1 - b^{12})$$

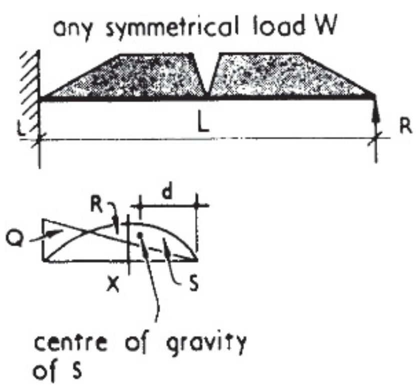
(maximum 0.193PL if $b' = 0.577$)

$$M_M = \frac{Pb}{2}(2 - 3b' + b^{13})$$

(maximum 0.174PL if $b' = 0.366$)

$$R_R = \tfrac{1}{2}Pa^{12}\,(b' + 2)$$

$$\delta_m = \frac{Pa^3b^2}{12EIL^3} - (4L - a)$$



If A_s = area of free bending moment diagram

$$M_L = \frac{3A_s}{2L}$$

$$R_L = \frac{W}{2} + \frac{M_L}{L}$$

$$R_R = \frac{W}{2} - \frac{M_L}{L}$$

δ_{max} at X where area Q = area R

$$\delta_{max} = \frac{\text{area } S \times X \times d}{EI}$$

Table VI Properties of sections

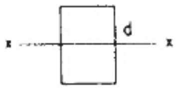
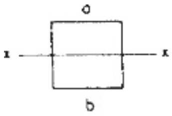
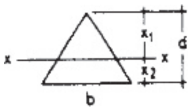
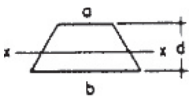
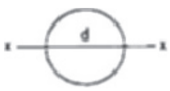
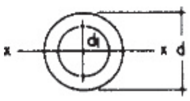
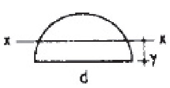
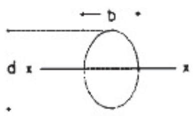
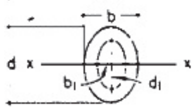
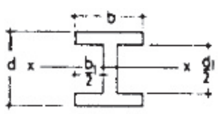
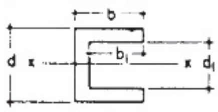
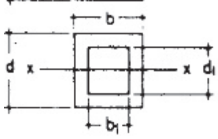
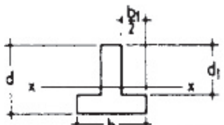
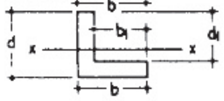
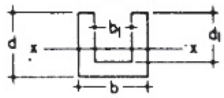
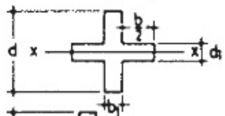
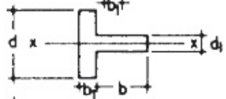
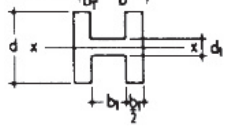
Section shape	Area of section A	Distance (y_1) of extremity of section from neutral axis	Moment of inertia about neutral axis X × (I_x)	Modulus $Z_x = \left(\frac{I_x}{Y_1}\right)$	Radius of gyration $k = \sqrt{\frac{I_x}{A}}$
	a^2	$\frac{a}{2}$	$\frac{a^4}{12}$	$\frac{a^3}{6}$	$\frac{a}{\sqrt{12}} = 0.289a$
	bd	$\frac{d}{2}$	$\frac{1}{12}bd^3$	$\frac{1}{6}bd^2$	$\frac{d}{\sqrt{12}} = 0.289d$
	a^2	$\frac{a}{\sqrt{2}} = 0.707a$	$\frac{a^4}{12}$	$\frac{\sqrt{2}}{12}a^3 = 0.118a^3$	$\frac{a}{\sqrt{12}} = 0.289a$
	$\frac{bd}{2}$	$\frac{d}{3}$	$\frac{bd^3}{36}$	$\frac{bd^2}{24}$	$\frac{d}{\sqrt{18}} = 0.236d$
	$\frac{a+b}{2}d$	$\frac{a+2b}{a+b}\frac{d}{3}$	$\frac{a^2+4ab+b^2}{36(a+b)}d^3$	$\frac{a^2+4ab+b^2}{12(a+2b)}d^2$	$d\sqrt{\frac{a^2+4ab+b^2}{18(a+b)^2}}$
	$\frac{\pi d^2}{4} = 0.7854d^2$	$\frac{d}{2}$	$\frac{\pi d^4}{64} = 0.0491d^4$	$\frac{\pi d^3}{32} = 0.0982d^3$	$\frac{d}{4}$
	$\frac{\pi}{4}(d^2 - d_1^2)$	$\frac{d}{2}$	$\frac{\pi}{64}(d^4 - d_1^4)$	$\frac{\pi}{32}\frac{d^4 - d_1^4}{d}$	$\frac{\sqrt{d^2 + d_1^2}}{4}$
	$\frac{\pi d^2}{8} = 0.3927d^2$	$\frac{2d}{3\pi} = 0.212d$	$\frac{9\pi^2 - 64}{1152\pi} = d^4 = 0.007d^4$	$\frac{(9\pi^2 - 64)d^3}{192(3\pi - 4)} = 0.024d^3$	$\frac{\sqrt{9\pi^2 - 64d}}{12\pi} = 0.132d$
	$\frac{\pi bd}{4} = 0.7854bd$	$\frac{d}{2}$	$\frac{\pi bd^3}{64} = 0.0491bd^3$	$\frac{\pi bd^2}{32} = 0.0982bd^2$	$\frac{d}{4}$
	$\frac{\pi}{4}(bd - b_1d_1)$	$\frac{d}{2}$	$\frac{\pi}{64}(bd^3 - b_1d_1^3)$	$\frac{\pi}{32}\frac{bd^3 - b_1d_1^3}{d}$	$\frac{1}{4}\sqrt{\frac{bd^3 - b_1d_1^3}{bd - b_1d_1}}$
	$(bd - b_1d_1)$	$\frac{d}{2}$	$\frac{1}{12}(bd^3 - b_1d_1^3)$	$\frac{bd^3 - b_1d_1^3}{6d}$	$\sqrt{\frac{bd^3 - b_1d_1^3}{12(bd - b_1d_1)}}$
	$(bd - b_1d_1)$	$\frac{d}{2}$	$\frac{1}{12}(bd^3 - b_1d_1^3)$	$\frac{bd^3 - b_1d_1^3}{6d}$	$\sqrt{\frac{bd^3 - b_1d_1^3}{12(bd - b_1d_1)}}$
	$(bd - b_1d_1)$	$\frac{d}{2}$	$\frac{1}{12}(bd^3 - b_1d_1^3)$	$\frac{bd^3 - b_1d_1^3}{6d}$	$\sqrt{\frac{bd^3 - b_1d_1^3}{12(bd - b_1d_1)}}$

Table VI (Continued)

Section shape	Area of section A	Distance (y_1) of extremity of section from neutral axis	Moment of inertia about neutral axis $X \times (I_x)$	Modulus $Z_x = \left(\frac{I_x}{Y_1}\right)$	Radius of gyration $k = \sqrt{\frac{I_x}{A}}$
	$(bd - b_1d_1)$	$\frac{bd^2 - 2b_1d_1d + b_1d_1^2}{2(bd - b_1d_1)}$	$\frac{(bd^2 - b_1d_1^2)^2 - 4bdb_1d_1(d - d_1)^2}{12(bd - b_1d_1)}$	$\frac{(bd^2 - b_1d_1^2)^2 - 4bdb_1d_1(d - d_1)^2}{6(bd^2 - 2bdd_1 + b_1d_1^2)}$	–
	$(bd - b_1d_1)$	$\frac{bd^2 - 2b_1d_1d + b_1d_1^2}{2(bd - b_1d_1)}$	$\frac{(bd^2 - b_1d_1^2)^2 - 4bdb_1d_1(d - d_1)^2}{12(bd - b_1d_1)}$	$\frac{(bd^2 - b_1d_1^2)^2) - 4bdb_1d_1(d - d_1)^2}{6(bd^2 - 2bdb_1 + b_1d_1^2)}$	–
	$(bd - b_1d_1)$	$\frac{bd^2 - 2b_1d_1d + b_1d_1^2}{2(bd - b_1d_1)}$	$\frac{(bd^2 - b_1d_1^2)^2 - 4bdb_1d_1(d - d_1)^2}{12(bd - b_1d_1)}$	$\frac{(bd^2 - b_1d_1^2)^2) - 4bdb_1d_1(d - d_1)^2}{6(bd^2 - 2bdb_1 + b_1d_1^2)}$	–
	$(bd_1 + b_1d)$	$\frac{d}{2}$	$\frac{1}{12}(bd_1^3 + b_1d^3)$	$\frac{b_1d^3 + bd_1^3}{6d}$	$\sqrt{\frac{bd_1^3 + b_1d^3}{12(bd_1 + b_1d)}}$
	$(bd_1 + b_1d)$	$\frac{d}{2}$	$\frac{1}{12}(bd_1^3 + b_1d^3)$	$\frac{b_1d^3 + bd_1^3}{6d}$	$\sqrt{\frac{bd_1^3 + b_1d^3}{12(bd_1 - b_1d)}}$
	$(bd_1 + b_1d)$	$\frac{d}{2}$	$\frac{1}{12}(bd_1^3 + b_1d^3)$	$\frac{b_1d^3 + bd_1^3}{6d}$	$\sqrt{\frac{bd_1^3 + bd_1d^3}{12(bd_1 + b_1d)}}$

proportional to the cube of the depth of the section. Suffice it to say that the larger the depth of the section, the smaller will be the maximum stress. It is therefore beneficial to choose cross-section shapes that have large *I*-values for the given area of material. For this reason, the most common shape of cross-section for a steel beam is an *I*, a greater distance between the flanges results in a reduction of material for the required second moment of area.

There is a limit to this, however. Since the top flange is in compression, if it becomes too slender it can buckle. This is particularly significant in the design of steelwork and is the reason that beams have to be checked for lateral torsional buckling when the compression flange is not fully restrained.

2.18 Shear

In addition to internal forces generated by bending moments, most beam cross-sections will also have to carry a force in the plane of the section, called a *shear force*. Generally, the shear will be greatest at the supports of a beam, and least at midspan.

In the case of an *I*-section, the shear force acts mainly within the web connecting together the two flanges that are in compression and tension. If the web becomes too slender it can buckle under the influence of the shear force.

2.19 Deflection

Since the top of a loaded beam is in compression, it must reduce in length; the bottom, in tension, must stretch. This will lead to the beam taking up a curved form: in the case of a simply supported beam with vertical loading, it will sag. Excessive sagging is not only unsightly, but also may cause damage to finishes such as plaster ceilings, or cause load to be transferred onto partitions that are not designed to carry such load. Formulae are published in many texts giving the deflections of various kinds of beams under different loadings (some are included in Table V).

As a guide to probable deflection characteristics, rule-of-thumb span-to-depth ratios are often used. Provided the use is confined to preliminary design and the actual deflections are later checked, the ratios in Table VII will be found of value.

Table VII Maximum span/depth ratios (rule-of thumb) for preliminary sizing

Concrete beams	20
Concrete slabs	30
Steel beams (I-section)	25
Timber joists	20

3 STRUCTURAL MATERIALS

3.01

The third major factor in structural design is an adequate knowledge of the behaviour of the materials used. The basic palette of materials consists of masonry (stone, brick and block), timber, steel and reinforced concrete. Design in new materials such as plastics, fabric and glass are becoming more widespread Table VIII compares some properties of structural interest for these materials.

4 MASONRY

4.01

Masonry is the general term used for loadbearing construction in brick, block and stone; these are materials of interest to architects. Since they and the mortar that is used to fill the gaps between their elements are all weak in tension, such construction is normally used to carry only simple compressive forces in vertical elements such as walls and piers, sometimes in arches. Masonry can also be used to resist lateral loads from soil and water pressures in retaining walls and wind loads when used in loadbearing masonry or when used as a cladding to a framed building structure. Masonry can be reinforced with steel bars and or mesh to increase its tensile resistance and hence overall strength.

4.02 Design

Design of masonry should be carried out in accordance with BS5268 – 1 Code of practice for the use of masonry. Structural

Table VIII Comparison of material properties

Property	Masonry (clay brickwork)	Reinforced concrete (with 4% reinforcement)	Steel (mild steel)	Wood (whitewood)	Glass reinforced plastic (polyester)	Annealed glass	Fabric (polyester yarn with pvc coating)
Type of material	Ceramic	Cementitious with metal	Metal	Natural Composite	Synthetic Composite	Glass	Polymer
Weight (p) kN/mm^3	22	24	78	4.5	18	25	14
Tensile strength (σ_{TS}) N/mm^2	1	18	400	75	250	5000 but fracture governed	1000
Compressive strength (σ_c) N/mm^2	15	45	400	25	150	1000 but complimentary tensile strength will govern	none
Flexural strength – modulus of rupture (σ_b) N/mm^2	1.5	18	400	50	300	–	none
Elastic modulus (E) kN/mm^2	20	35	210	10	15	70–74	14
Reversible moisture	0.02	0.02	none	1.50	small	–	small
Movement % initial expansion (+) or shrinkage (–) %	+0.05	−0.02	none	...	small	–	
Coefficient of thermal expansion (α) × 10^{-6}/°C	6	12	12	4	14	7.7–8.8	...

Table IX Properties of masonry as built

Property	Clay brickwork	Calcium silicate brickwork	Dense concrete blockwork	Aerated concrete blockwork	Natural limestone
Weight kN/m^3	22	20	21	9	22
Compressive strength N/mm^2	3–24	3–8	3–24	6	10
Flexural strength N/mm^2					
– Parallel to bed joints	2.0	1.2	1.0	0.5	...
– Perpendicular to bed joints	0.8	0.4	0.4	0.3	
Elastic modulus kN/mm^2	5–25	14–18	5–25	2–8	15
Reversible moisture Movement %	0.02	0.01–0.05	0.02–0.04	0.02–0.03	0.01
Initial moisture expansion (+) or Drying shrinkage (–)%	+0.02 to +0.08	−0.01 to −0.05	−0.02 to −0.06	−0.05 to −0.09	+0.01
Coefficient of thermal expansion × 10^{-6}/°C	5–8	8–14	6–12	8	4

use of unreinforced masonry, a limit state code based upon plastic design theory. The Eurocode for masonry, BS EN 1996-3:2006, *Eurocode 6; Design of masonry structures. Simplified calculation methods for unreinforced masonry structures* will replace BS5628 on its withdrawal.

The Institution of Structural Engineers *Manual for the design of plain masonry in building structures* (the Red Book) offers design guidance for simple structural masonry.

4.03

Table IX gives properties of common masonry materials.

4.04 Vertical loadbearing elements

A *wall* is a vertical load-carrying element whose length in plan is at least four times its width, otherwise it is a *column. A pier* is a column integral with a wall. References to walls apply also to columns and piers unless stated otherwise.

The load-carrying capacity of a wall depends on:

- The crushing strength of the masonry unit
- The composition of the mortar
- The size and shape of the masonry unit
- The height of the wall relative to its width – its slenderness ratio
- The eccentricity of the loading

Details of design methods will be found in the publications listed in the Bibliography.

Tables X–XIV give information on typical masonry designs. Although popular in the past, masonry is rarely used for floors nowadays. However, vaults and domed roofs continue to be built in traditional types of buildings such as churches.

5 TIMBER

5.01 Structure of timber

Timber is probably the oldest building material used. Wood is composed of hollow tubular fibres of cellulose impregnated with the resin lignin, packed closely together not unlike a bundle of drinking straws. The result is that the material is strong in the longitudinal direction – in tension and compression – but weak along the interface between the fibres.

5.02 Advantages of timber

Consequently, timber has the supreme virtue of ‘toughness’. It usually gives a forewarning of imminent failure, as the weakness between the fibres inhibits the progress of transverse cracks. Even when failure has occurred, there is often enough residual strength to carry a substantial load. Its principal drawbacks are susceptibility to insect and fungal attack and vulnerability to fire. Biological resistance can be fortified by treatment and a constant charring rate allows fire resistance to be designed in by over sizing members for the required period.

Table X Masonry – vertical support elements

Element	Horizontal and vertical section	Typical heights (h) (m)	h/d between lateral supports	Critical factors for sizing	Remarks
Masonry column		1–4	15–20	Buckling and crushing ($h/d > 6$) Crushing ($h/d < 6$) Bending	h is vertical distance between lateral supports and d is thickness of column
Masonry wall		1–5	18–22	Buckling and crushing ($h/d > 6$) Crushing ($h/d < 6$) Bending	h is vertical distance between horizontal lateral supports; wall may also have vertical lateral supports
Reinforced and prestressed masonry columns and walls		2–7	20–35	Bending	h is vertical distance between horizontal lateral supports; wall may also have vertical lateral supports

Table XI Masonry – floors

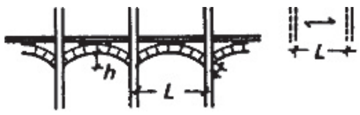
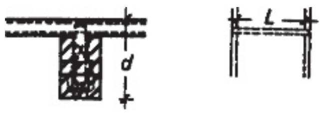
Element	Section and plan	Typical depths (d) (mm)	Typical spans (L) (mm)	Typical L/d	Critical factors for sizing/remarks
Masonry arch and fill		50–225	2–5	20–30	Bending or cracking from loads at quarter points Fill above arch crown helps to prestress arch L/H ratio about 10–20
Reinforced brick beam		300–600	4–12	10–16	Deflection and splitting of brick joints. Bending

Table XII Masonry – roofs

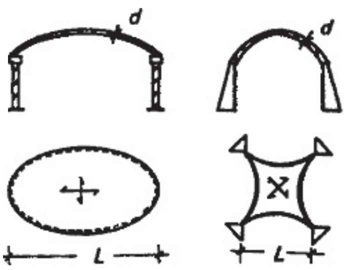
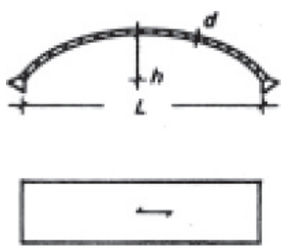
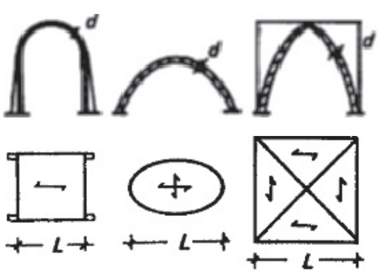
Element	Section and plan	Typical depths (d) (mm)	Typical spans (L) (m)	Typical L/d	Critical factors for sizing/remarks
Masonry shells		75–125	6–15	80–120	Bending at edge of shell Shell has funicular shape for major load so as to reduce tension and shear stresses Reinforcement may be necessary for larger spans
Masonry arch		70–600	8–50	30–60	Bending or cracking Arch requires funicular shape for load due to self-weight Flat arches cause high side thrust L/H ratio about 5
Vaults and domes		50–150	5–40	30–80	Domes have been built spanning up to 40 m and stone vaults up to 20 m Vaults built at high level require buttresses

Table XIII Masonry wall/roof systems

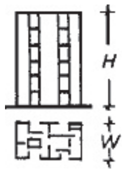
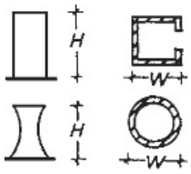
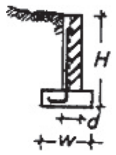
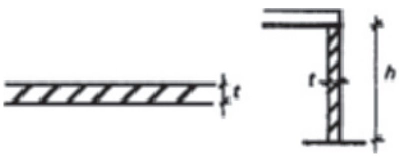
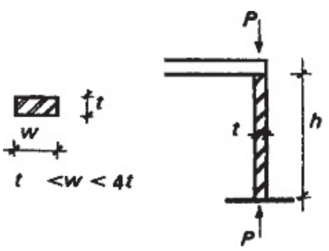
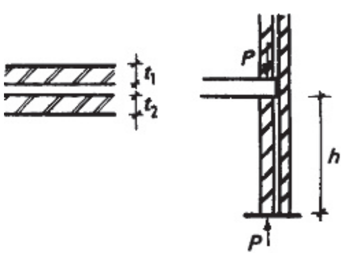
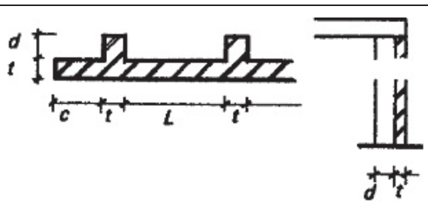
Element	Section and plan	Typical heights (H) (storeys)	Typical H/W	Remarks
Multi-storey cellular loadbearing walls with concrete slabs		5–25 storeys	1.5–3.5	Most economic for buildings with small room areas Lateral forces resisted by walls in plane of forces. Progressive collapse needs to be addressed
Masonry towers		5–25 storeys	3–6	Sections may require stiffening with rings or horizontal slabs at intervals. Lower heights permit higher values of H/W Progressive collapse needs to be addressed

Table XIV Masonry elements carrying gravity loads

Element	Section	Typical heights (H) (m)	Typical H/d	Remarks
Reinforced masonry retaining wall		1–6	10–15	Wall made of reinforced hollow blocks or units with reinforced concrete pockets w about $H/2$–$2H/3$
Masonry rubble in baskets (gabions)		1–3	1–2	Rubble masonry gabion walls usually more economic than thick mass concrete retaining wall

Plan/on element	Vertical section	Formulae for preliminary sizing only – elastic theory	Remarks
Single wall		$\frac{h}{t} < 20$	Formula valid when lateral movement is prevented at top and bottom of wall, at right angles to wall; such restraint usually provided by floor and roof construction Wall has greater bending strength in the horizontal direction so that vertical supports would be preferred to horizontal supports Walls fail by crushing if $h/t < 10$ or by buckling and crushing if $h/t > 10$
Column		$\frac{h}{t}$ and $\frac{2h}{w} < 20$ $p < \frac{t.w.u}{5}$ where u is ultimate compressive strength of small masonry sample	Column illustrated given lateral restraint at top in one direction only and effective height of column in that direction taken as actual height; effective height in direction at right angles taken as twice actual height Columns fail by crushing if slenderness ratio, $h_{cf}/t < 10$ where h_{cf} is effective height and t is thickness of column P is unfactored value of load applied near centre of column t_1 and t_2 are thicknesses of leaves of cavity wall which are tied together Wall illustrated has vertical load from floor taken by inner leaf only
Cavity wall		$\frac{h}{t_{cf}} < 20$ where t_{cf} is greater of t_1, t_2 or $2/3(t_1 + t_2)$	
Single wall with piers or intersecting walls		$\frac{L}{t} < 20$ $\frac{2.5c}{t} < 20$	Vertical piers or intersecting walls used to restrain walls as alternative to horizontal supports at top and bottom of wall. Dimension c is distance of outhang from last vertical support d is depth of pier of intersecting wall which should be greater than 500 mm

Timber is one of that minority of materials that is almost equally strong in tension and compression. This strength is such that buckling of the compression flange of bending members is rarely a problem. Rectangular sections are easily formed and used for this purpose. Timber is easily worked by hand and machine tools and it is simple to connect with other members, both other timber members and those of steel, masonry and concrete. However, even moderately stressed connections require plenty of room to accommodate the required number of fixings.

5.03 Design

Advances in the technology of timber started in the railway era when it was used for elaborate viaducts and bridges. These were generally constructed by trial and error, calculation methods being developed later. In recent years, these methods of calculation have been taken to the point where it has become an extremely specialised field. The use of the current Codes of Practice by non-specialists is not recommended. In complicated timber structures, the sizes of the members tend to depend more on the design of the connections than on the internal stresses.

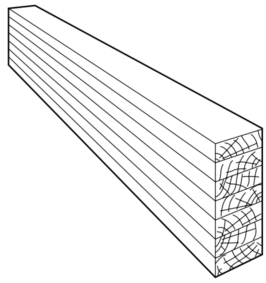
Design of timber should be carried out in accordance with BS 5268-2:2002 *Structural use of timber. Code of practice for permissible stress design, materials and workmanship*, a permissible stress design code based upon elastic design theory. The Eurocode for timber, BS EN 1995-1-1:2004, *Eurocode 5. Design of timber structures. General. Common rules and rules for buildings* will replace BS5268 on its withdrawal.

5.04 Timber sources and grades

Timber can be home-produced or imported from many places. There is a degree of standardisation, but the designer can encounter a wide variation in qualities. The structural properties of some common types are given in Table XV.

5.05 Large timber sections

Because of the shape and composition of the tree trunks from which timber comes, it is difficult to directly produce the larger size sections often required for modern construction, particularly for beams. For such larger sections, smaller timbers are glued together to form *laminated beams*, **36.10**. These are extremely useful for many purposes, and manufacturers produce handbooks giving comprehensive data for their use.



36.10 *A laminated timber beam*

5.06 Timber frame

Over 80% of the world's housing is composed of timber frame and it is becoming more common in the UK. Tables XVI–XXI give information relating to vertical support in timber and on frame and wall systems.

5.07 Roof trusses

The average UK architect meets timber in two common places: roof trusses and floor joists. Nowadays, most trusses are of the gang-nail type supplied to order for the required conditions. The manufacturer will supply calculations based on the Code of Practice for submission to the local building inspector. For preliminary design purposes, the data in Tables XXII and XXIII will be found of value for trusses of the shapes in **36.11** and **36.12**.

5.08 Floor joists

For the design of floor joists Table XXIV gives a guide to maximum spans of joists for timber of strength class C16, based on the TRADA publication 'Span tables for solid timber members in floors, ceilings and roofs (excluding trussed rafter roofs) for dwellings' alternatively, calculations should be prepared for final design by a qualified engineer in accordance with BS 5268.

6 REINFORCED CONCRETE

6.01 Composition

Reinforced concrete is one of the most prolific and versatile structural materials available to the designer. It is composed of two distinct materials: concrete and reinforcement, each of which can be varied in strength, disposition and quantity to fulfil almost any requirement.

Table XV Properties of wood

Property at 12% moisture content	Hem-fir softwood	Kapur hardwood	Hem-fir glulam timber	Douglas fir plywood	Wood chipboard
Weight kN/m^3	3.9	7.2	4.0	5.5	7.0
Mean 7-day tensile strength of good quality working size sample N/mm^2					
– Along grain	60	115	75	40	15
– Across grain	2	4	2		
Mean 7-day tensile strength of good quality working size sample N/mm^2					
– Along grain	24	45	30	25	
– Across grain	3	6	3	3	
Mean 7-day flexural strength of good quality working size sample – modulus of rupture N/mm^2	42	85	50	60 (face parallel to grain)	15
Elastic modulus in bending kn/mm^2	9–10	12–20	10	10–12	2–3
Reversible movement for 30% change in relative humidity %					
– Along grain	0.05	0.05	0.05	0.25 (in plane)	0.25 (in plane)
– Across grain	1.0–2.5	1.0–4.0	1.0–2.5	2.00 (across plane)	4.50 (across plane)
Coefficient of thermal expansion × 10^{-6}/°C					
– Along grain	3.5	4	3.5		
– Across grain	34	40	34		

Table XVI Wood – vertical support elements

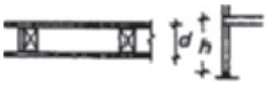
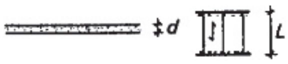
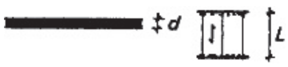
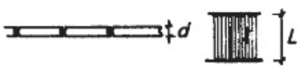
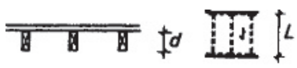
Element	Horizontal and vertical section	Typical heights (h) (m)	h/d between lateral supports	Critical factors for sizing	Remarks
Glued laminated timber column		2–4	15–30	Splitting and crushing ($h/d < 15$) Crushing and buckling ($h/d > 15$)	Ratio $w/d \approx 2–3$ Multi-storey columns may require lower h/d ratios than those given.
Stud frame wall panel		2–4	20–35	Crushing and buckling Thickness of insulation required	Studs usually at about 400 mm centres with plywood or other sheeting nailed to it.
Solid timber column		2–4	15–30	Warping or distortion of timber	Multi-storey columns may require lower h/d ratios than those given

Table XVII Wood – floors

Element	Section and plan	Typical depths (d) (mm)	Typical spans (L) (m)	Typical L/d	Critical factors for sizing/remarks
Particle boards		12–30	0.3–0.6	24	Strength Creep deflection
Plywood floor decking		12–30	0.3–0.9	30–40	Deflection Point loads Strength
Softwood floor boards		16–25	0.6–0.8	25–35	Deflection Strength
Joists with floor board					
– Softwood		200–300	2–6	12–20	Deflection
– Hardwood		100–250	2–7	22–28	Spacing of joists is about 450–600 mm
Glued laminated timber beam		180–1400	5–12	14–18	Deflection Ratio d/b about 3–5 to prevent instability of unrestrained section.

The concrete component is itself an amalgam of at least three constituents: aggregate, cement and water. These are mixed together into a homogeneous mass, placed in formwork and left for the chemical and physical changes to occur that result in a hard and durable material. The strength and durability will depend on the quality and quantity of each of the constituents; and whether any additives have been introduced to the wet mix. Onsite mixing of concrete for structural purposes is only carried out for larger jobs which merit the setting up of a batching plant. Concrete mixed offsite at the premises of the ready-mix supplier is a quality controlled product, designed to meet the requirements of the specifier. An indication of early concrete strength can be assessed by 7 or 14 day tests, but the specified strength can only be checked by crushing cubes of hardened concrete at 28 days. Cylinder tests are specified for strength comparison of mixes designed in accordance with Eurocodes. The crushing test will not necessarily indicate that sufficient cement has been included to fulfil the requirement for long-term durability. Sometimes additives are included in the mix to promote workability, early strength, frost resistance, etc. Deterioration in the material due to some of these factors may not become evident for some years, but may then be disastrous. The properties of various types of concrete are summarized in Table XXV.

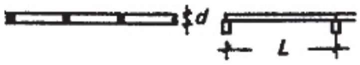
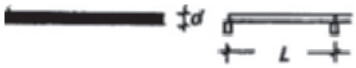
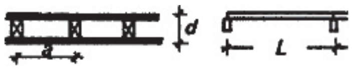
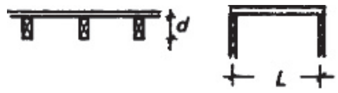
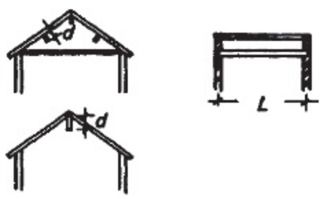
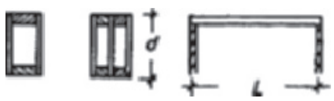
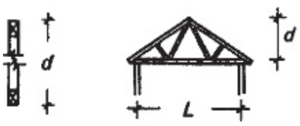
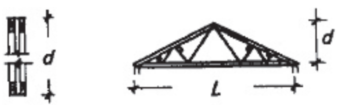
6.02 Specification

Provided a clear specification is prepared and concrete placement is checked by site staff, the concrete should fulfil its function indefinitely. This specification should be in accordance with BS 8500-1 Complementary British Standard to BS EN 206-1. Method of specifying and guidance for the specifier and BS EN 2006 – 2. Complementary British Standard to BS EN 206-1. Specification for constituent materials and concrete, which cover not only strength requirements but also minimum cement content, aggregate size, cement type and other relevant aspects.

6.03 Design

Design of reinforced concrete should be carried out in accordance with BS 8110-1:1997 *Structural use of concrete. Code of practice for design and construction,* the limit state code for the structural

Table XVIII Wood – roofs, beam and deck

Element	Section and elevation	Typical depths (d) (mm)	Typical spans (L) (m)	Typical L/d	Critical factors for sizing/remarks
Roof planks		25–75	2–6	45–60	Deflection Planks assumed to be simply supported
Plywood roof decking		10–20	0.3–1.2	50–70	Deflection Decking assumed to be continuous
Stressed skin plywood roof panels		100–450	3–7	30–35	Deflection Panel assumed to be simply supported Dimension *a* is about 300–500 mm
Joists with roof deck – Softwood – Hardwood		 100–225 100–250	 2–6 3–8	 20–25 30–35	 Deflection Joists assumed to be simply supported and spaced at 600 mm
Roof purlins – Softwood – Hardwood		 150 –300 200–400	 2–5 3–8	 10–14 15–20	 Available length and depth of wood Bending strength Purlin assumed to be vertical, simply supported and carrying about 2 m width of roof
Glued laminated timber beam with roof deck		180–1400	4–30	15–20	Deflection Beams assumed to be simply supported with spacing $L/3$–$L/5$ Ratio d/b about 5–8
Glued plywood box beam		200–2000	6–20	10–15	Deflection Bending strength Longitudinal shear Web buckling Beams assumed to be simply supported
Trussed rafter without purlins		1200–2000	6–10	4–6	Strength of joints Bending in rafter Assumed spacing 600 mm
Sloping trusses with purlins		1000–3000	6–20	5–7	Strength of joints Assumed spacing is 2–5 m
Flat top timber girders		1500–3000	12–25	8–10	Strength of joints Assumed spacing is 4–6 m

use of concrete in buildings and structures. The Eurocode for concrete BS EN 1992-1-1: 2004 *Eurocode 2. Design of concrete structures. General rules and rules for buildings* will replace BS8110 on its withdrawal. A succinct guide to the requirements of BS 8100 can be found in the *Manual for the Design of Reinforced Concrete Building Structures* (the Green Book), prepared by the Institution of Structural Engineers.

6.04 Reinforcement

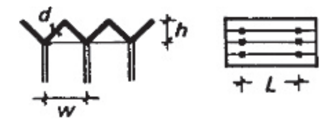
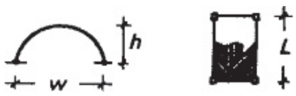
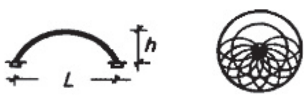
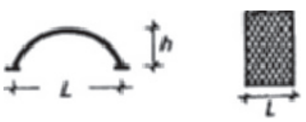
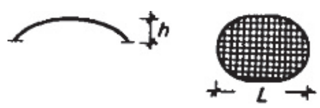
Reinforcement is generally steel rods, although other materials such as glass fibres and steel fibres have been tried in cladding units and steel and polypropylene fibres are now commonly used for crack control in floor slabs on ground. The reinforcing bars may be smooth round mild steel, in which case the bars are referred to as R25, etc. the letter R indicating mild steel and the numbers indicating the diameter in millimetres. Only those sizes in Table XXVIII are available.

The other type of bar reinforcement is a high-yield bar referred to as T25, etc. In this case, the letter indicates hot rolled or cold worked high-yield steel and the numbers refer to the plain bar diameter of equivalent cross-sectional area. The actual bar size will be about 10% greater than this due to the deformation.

6.05 Mesh reinforcement

For many structural elements, such as slabs and walls, it is convenient to use reinforcement in the form of a pre-welded mesh

Table XIX Wood – roofs, beam and surface

Element	Section and plan	Typical spans (*L*) (m)	Typical *L/d*	Remarks
Stressed skin panel folded plate roof		9–20	8–15	Panel has 2 skins with *w/d* ratio of 20–30 and thickness of about 75–200 mm
Three-layer stressed skin ply hyperbolic paraboloid		12–30	2–8	Shell has edge beams with *L/d* ratio of about 60–80
Three-layer stressed skin ply barrel vault		9–30	4–8	Shell has edge beams Ratio *w/h* about 2–4
Pyramid roof		12–35	2–6	Simple to construct Often used with steel tension members at base
Glued laminated timber dome		12–100	5–7	Typically, dome members have three-way grid, radial lines or lamellar curve patterns when projected on plan Connections semi-rigid or pinned
Lamellar arch roof		15–25	5–7	Typically, members on two intersecting parallel lamellar lines making diamond shapes when projected on plan
Warped rectangular grid (hyperbolic paraboloid)		12–80	5–10	Grid covered with ply panels Ratio *L/d* about 60–80
Domed grid shell		12–30	5–7	Grid members flexible to allow shaping to curve Shape reasonably close to funicular shape for dead load

consisting of bars in both directions. Care should be taken in specifying the correct mesh as they have different areas of bars in each direction depending upon their designation letter. An ‘A’ square mesh has the same area of bars in each direction. A ‘B’ structural mesh has larger bars in the main direction and the area of bars in the cross direction satisfies the minimum area of secondary reinforcement requirement of BS 8110. It is important therefore to ensure that a structural mesh is oriented correctly, as indicated on the reinforcement drawing in order that structural strength is not compromised. A ‘C’ long mesh is similar to a ‘B’ mesh except that the area of cross wires does not meet the requirements of BS 8110. These meshes are generally used for reinforcing slabs on ground. Table XXIX gives the standard sizes of available meshes.

6.06 Reinforcement position

Concrete is strong in compression, but weak in tension and reinforcement is used to compensate for this weakness. Adequate reinforcement must therefore be placed wherever any tension is likely to occur. Simply spanning beams are reinforced near the bottom, with most reinforcement at midspan. Shear forces also produce tensile stresses – links or stirrups are used to reinforce the concrete against the effects of these stresses. Sometimes the compressive strength of the concrete is insufficient for the loading. In this case, reinforcing bars can be used to help take the compression as well. Such use for reinforcement is expensive and is only used when increasing the size of the beam is not possible.

In cantilever beams, the tension occurs near the top. These beams have their heaviest reinforcement at the top, with most near the support.

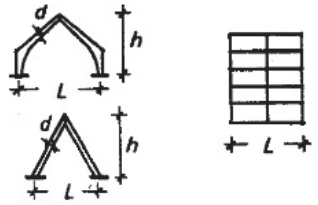
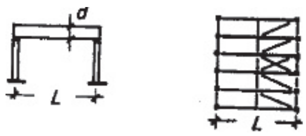
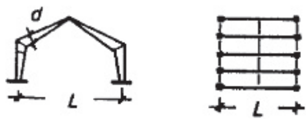
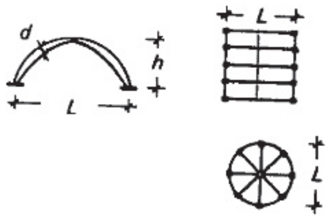
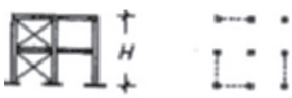
6.07 Effective depth

The effective depth of a beam is the distance from the top (or compression flange) to the centroid of area of the tensile steel reinforcement. It is indicated by the symbol d.

6.08 Minimum reinforcement

Stresses arise in concrete not only from the applied loads but also from a variety of other causes. For example, when concrete dries and sets it tends to shrink slightly. If it cannot move, it will tend to crack. Similar cracking will occur if movement induced by thermal expansion and contraction is inhibited. Consequently, to reduce the tendency to form large cracks, a modicum of reinforcement is used throughout, allowing the formation of a multitude of fine cracks which are invisible to the naked eye.

Table XX Wood – frame and wall systems

Element	Section and plan	Typical spans (*L*) (m)	Typical *L*/*d*	Remarks
Rigid glued laminated timber frame		12–35	30–50	Spacing of frames about 4–6 m Laminated frame may be curved and of varying depth but more expensive than uniform straight members Ratio *L*/*H* about 5–7
Glued laminated beam and post		4–30	18–22	Frame not rigid in its own plane so vertical bracing necessary, e.g. with rigid gables connected to roof plane
Plywood box portal frames		9–45	20–40	Box beams made of solid section timber flanges, glued and nailed to plywood side pieces, acting as webs Spacing of frames about 4–6 m
Glued laminated arch		15–100	30–50	Maximum convenient transportable lengths 15–25 m Arch shape is nearly funicular for important load case Arches may have rectangular or circular plan Ratio *L*/*H* about 5–7
Plywood floor and wall panels		Height, *H* 2–4 storeys		Enclosures usually built in platform construction in which vertical framing members are not continuous
Braced frame		2–4 storeys		Frame may be braced with diagonal steel rods or plywood panels acting as diaphragms

6.09 Deflection

In addition to limiting the stresses below the ultimate values, reinforced concrete must possess sufficient stiffness to prevent deflection or deformation which might impair the strength or efficiency of the structure, or produce unsightly cracks in finishes or partitions. For all normal cases, it may be assumed for preliminary design that the stiffness will be satisfactory if the ratio of span to overall depth does not exceed the appropriate guide value from Table XXX.

6.10 Concrete cover to reinforcement

In all cases, there must be sufficient concrete cover to reinforcement. This is:

- To preserve it from corrosion
- To ensure an adequate bond with the concrete and
- To ensure sufficient protection in case of fire.

Tables A.6, A.10, A.12 and A.13 of BS 8500-1 give limiting values for the nominal cover of concrete made with normal weight aggregates. In no case should the cover be less than the nominal maximum aggregate size, or, for the main reinforcement, the bar size.

6.11

Details of various kinds of concrete structure are given in Tables XXXI–XXXVI.

7 STRUCTURAL STEELWORK AND OTHER METALS

7.01 Metals

Steel is by far the metal most widely used for building structures, but other materials are used in ancillary elements. Table XXXVII gives properties of various steels and aluminium alloys.

7.02 Design

Design of steelwork should be carried out in accordance with BS 5950-1:2000; *Structural use of steelwork in building. Code of practice for design. Rolled and welded section,* a limit state code based upon plastic theory. Eurocode 3 BS EN 1993-1-1:2005. *Design of steel structures. General rules and rules for buildings,* should be used after withdrawal of BS 5950.

A book of tables published by the Steel Construction Institute, (the blue book) gives dimensions and section properties of currently manufactured steel sections. Tables XXXVIII–XL show the

Table XXI Softwood timber – elements carrying gravity load

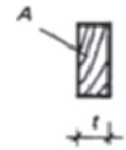
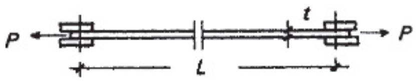
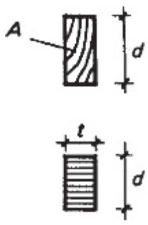
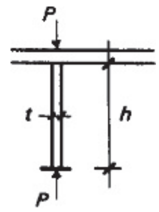
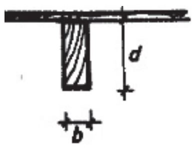
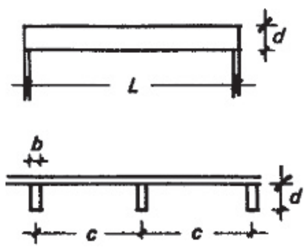
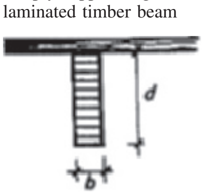
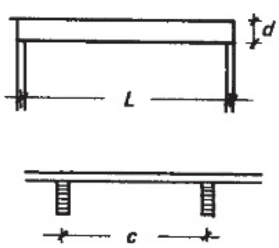
Element and horizontal section	Elevation and section on element	Formulae for preliminary sizing only	Remarks
Solid timber tie 		$\frac{p}{0.84A} < P_t$ where P is unfactored value of tie force A is gross area of tie P_t is allowable working stress of timber softwood in tension = 3.5 N/mm^2 $\frac{L}{t} < 70$ where t is least dimension of tie cross-section L is length of tie between supports	Area of tie at connection assumed to be 80% of gross area Given span to width ratio assumes tie may take small amount of compression Actual area of tie usually decided by type of connection detail; because of difficulty of tension connection steel rods often used in place of timber ties Given allowable stress is for long-term (2 month) load on construction grade softwood
Solid timber column 		$\frac{P}{A} < p_c$ where P is working value of compression in column P_c is allowable working stress of timber in compression which depends on slenderness ratio h_{cf}/t see below, where h_{cf} is effective height of column; slenderness ratio should not normally exceed 50 $\frac{h_{cf}}{t}$ = p_c = 10 9.0 N/mm^2 20 6.0 N/mm^2 30 2.8 N/mm^2 40 1.5 N/mm^2 50 1.0 N/mm^2	For buildings which are laterally braced for example by cross-bracing, effective height of columns h_{cf} is not greater than actual height h between floors Given formula valid for columns carrying axial load Given allowable stress is for long-term (2 month) load on construction grade softwood
Simply supported solid timber beam 		$\frac{M}{Z} < p_{bc}$ where M is unfactored value of bending moment on beam Z is the section modulus of the beam p_{bc} is allowable working stress of softwood in bending = 7 N/mm^2 $\Delta = \frac{5W.L^3}{384E.I} = \frac{5f_{bc}.L^2}{24E.d}$ where W is total u.d. load on beam L is span and d is depth of beam Δ is midspan deflection I is moment of inertia of beam E is elastic modulus of timber including effects of creep which depends on duration of load f_{bc} is actual bending stress in beam at midspan To prevent ponding on flat roofs $E.I > c.\rho_w L^4/50$ where I is moment of inertial of roof beams at spacing c E is short-term elastic modulus of softwood = 11 kN/mm^2 ρ_w is density of water = 10 kN/m^3 L is span of roof beams given camber > 2.5Δ_d where Δ_d is dead load deflection of beams at midspan	Formulae assume top of beam is laterally restrained or has ends held in position; in general $d/b < 7$ and if $d/b > 6$ beam requires bridging as well as lateral restraint where b is width of beam Given allowable stress is for long-term (2 month) load on construction grade softwood Typical spacing of beams in floors, c is 450–600 mm If total deflection limited to $L/330$ then $E.I > 4.34\,W.L^2$
Simply supported glued-laminated timber beam 		$\frac{M}{Z} < p_{bc}$ where P_{bc} is allowable – working stress in bending = 12.5 N/mm^2 To prevent ponding on flat roofs $E.I > c.\rho_w L^4/50$ where E is short-term elastic modulus of laminated softwood = 12 kN/mm^2	Notes and formula for deflection as for solid timber beams

Table XXII Maximum permissible spans for rafter members shown in Fig 36.11 (ref BS 5268-3 Table B2)

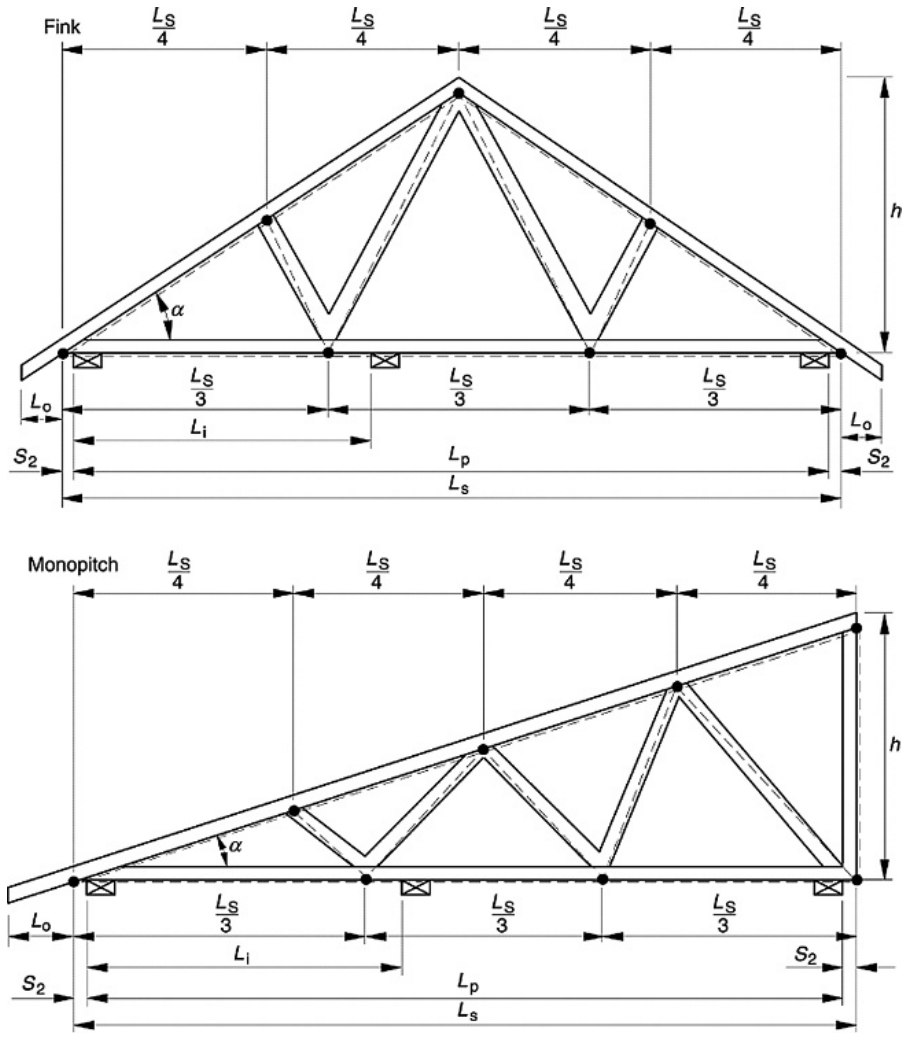
Strength class of timber[b]	Finished size[c]	Pitch								
		15°	17½°	20°	22½°	25°	27½°	30°	32½°	35°
	mm	m	m	m	m	m	m	m	m	m
C16	35 × 72	5.06	5.20	5.34	5.49	5.63	5.77	5.91	6.06	6.21
	35 × 97	6.35	6.53	6.70	6.87	7.05	7.22	7.40	7.57	7.75
	35 × 120	7.55	7.75	7.94	8.15	8.36	8.54	8.74	8.94	9.14
	35 × 145	8.83	9.07	9.29	9.53	9.74	9.97	10.21	10.43	10.67
	38 × 72	5.25	5.40	5.54	5.68	5.82	5.97	6.11	6.26	6.41
	38 × 89	6.16	6.33	6.50	6.66	6.83	7.00	7.16	7.33	7.50
	38 × 114	7.48	7.53	7.87	8.07	8.28	8.47	8.67	8.81	9.07
	38 × 140	8.73	8.98	9.25	9.49	9.71	9.95	10.18	10.41	10.65
	47 × 72	5.83	5.98	6.12	6.26	6.41	6.56	6.70	6.85	7.00
	47 × 97	7.32	7.50	7.69	7.88	8.06	8.25	8.44	8.63	8.81
	47 × 120	8.51	8.73	8.96	9.19	9.41	9.64	9.87	10.10	10.32
	47 × 145	9.63	9.90	10.16	10.43	10.71	10.99	11.25	11.53	11.79
C22	35 × 72	5.60	5.76	5.92	6.09	6.25	6.41	6.57	6.74	6.90
	35 × 97	7.03	7.23	7.42	7.62	7.82	8.02	8.22	8.41	8.61
	35 × 120	8.35	8.58	8.80	9.03	9.26	9.48	9.71	9.93	10.15
	35 × 145	9.76	10.04	10.29	10.56	10.80	11.00	11.00	11.00	11.00
	47 × 72	6.46	6.63	6.79	6.95	7.12	7.29	7.45	7.62	7.78
	47 × 97	8.10	8.31	8.53	8.74	8.95	9.16	9.38	9.59	9.80
	47 × 120	9.41	9.67	9.93	10.19	10.45	10.70	10.96	11.22	11.47
	47 × 145	10.65	10.96	11.26	11.57	11.88	12.00	12.00	12.00	12.00
C24	35 × 72	5.96	6.12	6.30	6.46	6.63	6.80	6.96	7.13	7.25
	35 × 97	7.50	7.71	7.92	8.12	8.33	8.54	8.74	8.94	9.00
	35 × 120	8.71	8.95	9.20	9.42	9.66	9.89	10.12	10.15	10.15
	35 × 145	10.25	10.54	10.80	11.00	11.00	11.00	11.00	11.00	11.00
	38 × 72	6.19	6.34	6.51	6.66	6.83	6.99	7.14	7.30	7.43
	38 × 89	7.27	7.46	7.65	7.83	8.02	8.21	8.39	8.57	8.74
	38 × 114	8.66	8.90	9.14	9.36	9.59	9.82	10.06	10.15	10.21
	38 × 140	10.16	10.45	10.72	10.99	11.25	11.25	11.25	11.25	11.25
	47 × 72	6.87	7.01	7.14	7.28	7.42	7.55	7.69	7.82	7.96
	47 × 97	8.64	8.81	8.99	9.17	9.35	9.52	9.70	9.87	10.05
	47 × 120	9.81	10.07	10.32	10.58	10.83	11.10	11.34	11.60	11.85
	47 × 145	11.10	11.41	11.73	12.00	12.00	12.00	12.00	12.00	12.00

[a] These maximum permissible spans are suitable for trussed rafters fabricated and used in accordance with the conditions given in Annex B.
[b] Subject to the visual grading criteria in 5.1.2.
[c] Measured at a moisture content of 20% and subject to the manufacturing tolerance in 5.1.3.

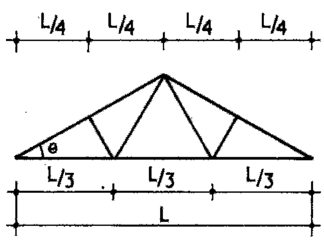
Table XXIII Maximum permissible spans for ceiling ties (ref BS 5268-3 Table)

Strength class of timber[b]	Finished size[c]	Pitch								
		15°	17½°	20°	22½°	25°	27½°	30°	32½°	35°
	mm	m	m	m	m	m	m	m	m	m
C16	35 × 72	3.70	3.97	4.24	4.50	4.77	5.02	5.29	5.55	5.82
	35 × 97	5.13	5.51	5.90	6.28	6.65	7.03	7.41	7.78	8.15
	35 × 120	6.29	6.79	7.29	7.78	8.24	8.72	9.20	9.69	10.14
	35 × 145	7.36	8.04	8.71	9.38	10.05	10.73	11.00	11.00	11.00
	38 × 72	3.85	4.14	4.42	4.69	4.97	5.24	5.52	5.79	6.07
	38 × 89	4.84	5.20	5.56	5.89	6.27	6.63	6.98	7.33	7.68
	38 × 114	6.15	6.64	7.13	7.60	8.07	8.55	9.02	9.49	9.95
	38 × 140	7.27	7.94	8.59	9.25	9.91	10.57	11.23	11.25	11.25
	47 × 72	4.31	4.63	4.95	5.26	5.58	5.89	6.20	6.51	6.82
	47 × 97	5.81	5.26	6.70	7.14	7.57	8.01	8.45	8.88	9.31
	47 × 120	6.91	7.50	8.09	8.67	9.25	9.82	10.37	10.94	11.50
	47 × 145	7.77	8.59	9.33	10.11	10.88	11.66	12.00	12.00	12.00

[a] These maximum permissible spans are suitable for trussed rafters fabricated and used in accordance with the conditions given in Annex B.
[b] Subject to the visual grading criteria in 5.1.2.
[c] Measured at a moisture content of 20% and subject to the manufacturing tolerance in 5.1.3.



36.11 *Typical trussed rafter layouts (ref BS 5268-3 Fig. 11)*



36.12 *Diagram of a fink or 'W' trussed rafter*

dimensions for universal beams, columns and joists. This book also contains capacity tables which may be used to quickly determine the suitability of a particular section for preliminary design. More rigorous calculations to BS 5950 are generally required for final design. The *Manual for the design of steelwork building structures* issued by the Institution of Structural Engineers provides guidance for design.

7.03 Grades of steel

Steel for structural purposes is available in the United Kingdom in three grades increasing in strength: S275, which corresponds to the previous description of 'mild steel', S355 and S460.

7.04

Details of various kinds of steel structure are given in Tables XLII–XLVIII.

8 GLASS

8.01

Glass is being used to create spectacular structures in modern architecture and it can be incorporated as a structural material in a number of ways.

8.02 Design

The structural use of glass requires an understanding of the behaviour of both the structure and the material. The inherent brittle nature of glass dictates consideration of the nature and consequences of any failure modes.

The choice of international standards for the design of edge supported glass panels is wide-ranging, but BS 6262-1:2005, *Glazing for buildings. General methodology for the selection of glazing*, is the current British Standard.

8.03 Types of glass

A number of processes are used to produce the main glass types used in structures.

Annealed float glass is made by melting the ingredients (Silicon, soda ash and recycle broken glass) together. The molten glass is then poured onto a float bath of molten tin were it undergoes controlled cooling after which it is further cooled in and an annealing oven. The resulting product exhibits elastic properties, but suffers brittle fracture under impact, bending and

Table XXIV Permissible clear spans for domestic floor joists (m) (Ref TRADA Technology Design Aid DA 1/2004)

Table 6 Permissible clear spans for domestic floor joists
Imposed load not exceeding 1.5 kN/m²
Strength Class C16 Service Class 1 or 2

Size of joist		Dead load (kN/m²) excluding self-weight of joist								
		Not more than 0.25			More than 0.25 but not more than 0.50			More than 0.50 but not more than 1.25		
		Spacing of joists (mm)								
Breadth (mm)	Depth (mm)	400	450	600	400	450	600	400	450	600
		Maximum clear span (m)								
38	97	1.84	1.70	1.31	1.73	1.56	1.22	1.43	1.31	1.04
38	120	2.45	2.34	1.88	2.33	2.17	1.72	1.91	1.76	1.42
38	145	2.96	2.84	2.49	2.83	2.69	2.30	2.43	2.26	1.84
38	170	3.46	3.33	2.89	3.30	3.12	2.70	2.82	2.66	2.28
38	195	3.96	3.78	3.28	3.75	3.54	3.07	3.21	3.03	2.62
38	220	4.46	4.23	3.67	4.20	3.96	3.44	3.59	3.39	2.93
44	97	1.97	1.86	1.50	1.87	1.77	1.39	1.59	1.46	1.17
44	120	2.58	2.47	2.14	2.46	2.36	1.94	2.12	1.95	1.58
44	145	3.11	2.99	2.68	2.97	2.85	2.51	2.62	2.47	2.05
44	170	3.63	3.49	3.11	3.48	3.34	2.91	3.03	2.86	2.48
44	195	4.16	4.00	3.53	3.98	3.81	3.30	3.45	3.25	2.82
44	220	4.68	4.51	3.95	4.48	4.26	3.70	3.86	3.64	3.16
47	97	2.03	1.92	1.59	1.93	1.82	1.47	1.67	1.53	1.23
47	120	2.63	2.53	2.26	2.52	2.42	2.05	2.22	2.05	1.66
47	145	3.17	3.05	2.77	3.04	2.92	2.59	2.70	2.55	2.15
47	170	3.71	3.57	3.21	3.55	3.42	3.00	3.14	2.96	2.56
47	195	4.25	4.09	3.64	4.07	3.91	3.41	3.56	3.36	2.91
47	220	4.75	4.61	4.08	4.58	4.39	3.82	3.99	3.76	3.26
50	97	2.10	1.98	1.68	1.98	1.88	1.55	1.75	1.61	1.29
50	120	2.69	2.58	2.33	2.57	2.47	2.15	2.29	2.14	1.74
50	145	3.24	3.12	2.83	3.10	2.98	2.67	2.78	2.63	2.24
50	170	3.79	3.65	3.31	3.63	3.49	3.10	3.23	3.05	2.64
50	195	4.34	4.17	3.76	4.15	3.99	3.52	3.67	3.47	3.01
50	220	4.82	4.69	4.20	4.67	4.50	3.94	4.11	3.88	3.36
63	97	2.33	2.21	1.93	2.20	2.09	1.83	1.94	1.85	1.54
63	120	2.90	2.79	2.54	2.78	2.67	2.42	2.50	2.40	2.05
63	145	3.50	3.36	3.06	3.35	3.22	2.92	3.01	2.89	2.56
63	170	4.09	3.93	3.58	3.91	3.77	3.42	3.52	3.39	2.97
63	195	4.67	4.50	4.10	4.48	4.31	3.92	4.03	3.88	3.37
63	220	5.10	4.96	4.61	4.94	4.80	4.41	4.54	4.34	3.77
75	120	3.07	2.96	2.69	2.94	2.83	2.57	2.65	2.54	2.29
75	145	3.70	3.56	3.24	3.54	3.41	3.10	3.19	3.07	2.78
75	170	4.32	4.16	3.79	4.14	3.99	3.63	3.73	3.59	3.23
75	195	4.87	4.73	4.34	4.72	4.56	4.15	4.27	4.11	3.67
75	220	5.32	5.17	4.82	5.15	5.01	4.67	4.77	4.63	4.11
	ALS/CLS									
38	140	2.86	2.74	2.41	2.73	2.60	2.18	2.34	2.16	1.76
38	184	3.74	3.58	3.11	3.56	3.36	2.91	3.04	2.87	2.48
38	235	4.73	4.50	3.91	4.46	4.21	3.66	3.82	3.60	3.12
89	184	4.86	4.73	4.33	4.71	4.55	4.15	4.27	4.11	3.73
89	235	5.80	5.65	5.28	5.63	5.47	5.11	5.22	5.07	4.72

(shaded) See Clause 4.1.4

C16

thermal loading. Typical properties of annealed glass are shown in Table VIII.

Toughened glass is produced by heating and then rapidly cooling annealed glass. This results in a glass core which is in tension, sandwiched between surface layers which are in compression. Toughened glass therefore has an ability to sustain higher stresses than annealed glass. Toughened glass is prone to sudden shattering due to nickel sulphide inclusions. Such failure will also be instigated if the compressive surface layers are breached by scratching.

Laminated glass is produced by bonding two layers of glass with a layer of acrylic resin. The resulting material does not shard on impact but remains intact, minimising the risk of injury on failure.

8.04 Structural uses

A number of structural uses are possible as summarised in Table XLIX.

9 OTHER MATERIALS

9.01 Plastics

Properties of some plastics materials are shown in Table L. The use of these in roofs is given in Table LI.

Table XXV Properties of concrete

Property	Structural concrete	Lightweight concrete	No-fines concrete	Autoclaved aerated concrete	Polymer concrete (Polyester mortar)	Glass-fibre reinforced cement (5% fibre)	Sprayed concrete without fibre reinforcement
Weight kN/m^3	24	4–20	15–19	6–9	24	25	23
Long-term compressive strength N/mm^2	20–100	5–60	4–9	3–6	50–100	30–100	30–60
Long-term flexural strength-modulus of rupture N/mm^2	3	3	1	1	10–40	15–20 (10 years)	3
Elastic modulus in compression kN/mm^2	15–40	5–25	15	1.5–9	3–15	20–30 (10 years)	20–30
Impact strength	very low	low	very low	very low	high	high but decreases	low
Tensile strain capacity % – elongation before cracking	0.004–0.012	–	–	–	1–5	0.05	–
Reversible moisture movement %	0.02–0.10	0.03–0.20	–	0.02–0.03	–	0.15–0.30	0.15–0.30
Initial drying shrinkage %	0.02–0.08	0.03–0.04	0.01–0.03	0.02–0.09	1.00	0.15–0.30	0.15–0.30
Coefficient of thermal expansion × 10^{-6}/°C	7–14	6–12	4–8	8–10	20–40	7–11	7–14

Table XXVI Mix proportions for standardized prescribed concretes (Ref BS EN 206 – part 2 table 10)

Standardized prescribed concrete	Constituent	Quantity or proportion of constituent					
		Maximum aggregate size 40 mm or 45 mm			Maximum aggregate size 20 mm or 22.4 mm		
		Slump class S1 or S2	Slump class S3	Slump class S4	Slump class S1 or S2	Slump class S3	Slump class S4
ST1[a]	Cement or combination	200 kg	220 kg	230 kg	230 kg	255 kg	265 kg
	Total aggregate	1 990 kg	1 930 kg	1 895 kg	1 925 kg	1 860 kg	1 825 kg
ST2[a]	Cement or combination	230 kg	255 kg	270 kg	265 kg	285 kg	300 kg
	Total aggregate	1 960 kg	1 905 kg	1 870 kg	1 895 kg	1 840 kg	1 805 kg
ST3[a]	Cement or combination	265 kg	285 kg	300 kg	295 kg	330 kg	345 kg
	Total aggregate	1 930 kg	1 875 kg	1 850 kg	1 865 kg	1 800 kg	1 865 kg
ST4	Cement or combination	310 kg	330 kg	340 kg	330 kg	365 kg	380 kg
	Total aggregate	1 900 kg	1 840 kg	1 815 kg	1 835 kg	1 775 kg	1 740 kg
ST5	Cement or combination	350 kg	375 kg	390 kg	375 kg	395 kg	415 kg
	Total aggregate	1 870 kg	1 805 kg	1 780 kg	1 800 kg	1 740 kg	1 705 kg
ST1 ST2 ST3	Fine aggregate[b] as a mass fraction of total aggregate	30 % to 45 %	30 % to 45 %	35 % to 50 %	35 % to 50 %	35 % to 50 %	40 % to 55 %
ST4 ST5	Fine aggregate[b, c] as a mass fraction of total aggregate						
	Grading limits 0/4 (CP)	30 % to 40 %			35 % to 45 %		
	Grading limits 0/4 (MP) or 0/2 (MP)	25 % to 35 %			30 % to 40 %		
	Grading limits 0/2 (FP) or 0/1 (FP)	25 % to 30 %			25 % to 35 %		

[a] The aggregates may be batched by volume (see Table 12).
[b] Lower proportions are generally applicable to finer gradings, smoother textures or rounded shapes. Higher proportions are generally applicable to coarser gradings, rougher textures or angular shapes. For all grades, small adjustments in the percentages of fine aggregates might be required depending on the properties of the particular aggregates used.
[c] The overlapping ranges reflect the overlapping grading limits CP, MP and FP in BS EN 12620. The higher proportions are applicable to the coarser end of each grading limit and to concretes of higher consistence.
Where the grading of the fine aggregate approaches the coarser end of grading limits CP or the finer end of grading limits FP, the proportion of fine aggregate shall be checked to verify that it produces satisfactory concrete.

Table XXVII Mix proportions for volume batching of ST1–ST3 (Ref BS EN 206 – part 2 table 12)

Standard strength class of cement	Standardized prescribed concrete	Slump class	Number of (25 kg) bags of cement	Fine aggregate litres	Coarse aggregate litres
42,5 or higher	ST1	S1, S2	1	60	90
	ST2	S1, S2	1	50	75
	ST2	S3	1	50	65[a]
	ST2	S4	1	45	60[a]
	ST3	S1, S2	1	45	65
	ST3	S3	1	40	55[a]
	ST3	S4	1	40	50[a]
32,5	ST1	S1, S2	1	50	80
	ST2	S1, S2	1	45	65
	ST2	S3	1	45	55[a]
	ST2	S4	1	45	50[a]
	ST3	S1, S2	1	40	55
	ST3	S3	1	35	50[a]
	ST3	S4	1	35	45[a]

[a] Fine aggregates MP and CP only.

Table XXVIII Cross-sectional areas in square millimetres of specific numbers of bars (mm^2)

Diam (mm)	Weight (kg/m)	Number of bars									
		1	2	3	4	5	6	7	8	9	10
8	0.395	50	100	151	201	251	302	352	402	452	503
10	0.617	79	157	236	314	393	471	550	628	707	785
12	0.888	113	226	339	452	566	679	792	905	1018	1131
16	1.58	201	402	603	804	1005	1206	1407	1608	1810	2011
20	2.47	314	628	942	1257	1571	1885	2199	2513	2827	3142
25	3.86	491	982	1473	1963	2454	2945	3436	3927	4418	4909
32	6.31	804	1608	2413	3217	4021	4825	5630	6434	7238	8042
40	9.87	1257	2513	3770	5026	6283	7540	8790	10 053	11 310	12 566

Diam (mm)	Areas in mm^2/m for spacings in mm								
	50	75	100	125	150	175	200	250	300
8	1066	670	503	402	335	287	251	201	168
10	1570	1047	786	628	524	449	393	314	262
12	2262	1508	1131	905	754	646	565	452	377
16	4022	2681	2011	1608	1340	1149	1005	801	670
20	–	4189	3142	2513	2094	1795	1571	1257	1047
25	–	6545	4909	3927	3272	2805	2454	1963	1636
32	–	–	8042	6434	6362	4596	4021	3217	2681
40	–	–	–	10 053	8378	7181	6283	5027	4189

Table XXIX Sizes of reinforcing meshes

BS reference	Mesh sizes Nominal pitch of wires (mm)		Size of wires (mm)		Cross-sectional area (mm^2) per metre width		Nominal mass kg per m^2
	Main	Cross	Main	Cross	Main	Cross	
Square mesh fabric							
A 393	200	200	10	10	393	393	6.16
A 252	200	200	8	8	252	252	3.95
A 193	200	200	7	7	193	193	3.02
A 142	200	200	6	6	142	142	2.22
A 98	200	200	5	5	98	98	1.54
Structural fabric							
B 1131	100	200	12	8	1131	252	10.90
B 785	100	200	10	8	785	252	8.14
B 503	100	200	8	8	503	252	5.93
B 385	100	200	7	7	385	193	4.53
B 283	100	200	6	7	283	193	3.73
B 196	100	200	5	7	196	193	3.05
Long mesh fabric*							
C 785	100	400	10	6	785	71	6.72
C 636	100	400	9	6	636	71	5.55
C 503	100	400	8	5	503	49	4.34
C 385	100	400	7	5	385	49	3.41
C 283	100	400	6	5	283	49	2.61
Wrapping fabric							
D 49	100	100	2.5	2.5	49.0	49.0	0.77

*Cross wires for all types of long mesh may be of plain hard drawn steel wire.

Table XXX Span to depth ratios for preliminary design

Beams	
Simply supported beams	20
Continuous beams	25
Cantilever beams	10
Slabs	
Slabs spanning in one direction, simply supported	30
Slabs spanning in one direction, continuous	35
Slabs spanning in two directions, simply supported	35
Slabs spanning in two directions, continuous	40
Cantilever slabs	12

9.02 Fabric

Plastics are used in the manufacture of many structural fabrics which are finding increasing uses. Table LII gives properties of some of these, and Table LIII covers their use in roofs.

10 FOUNDATIONS

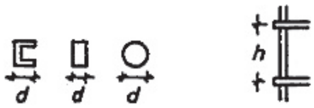
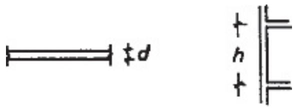
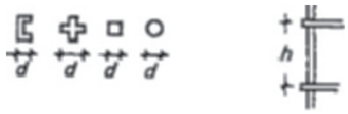
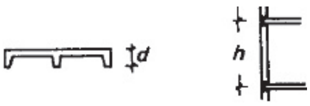
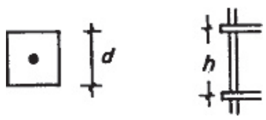
10.01 Nature

The purpose of a foundation is to transmit the dead and live loads from a building structure to the ground. The nature of the foundation will depend on:

- The characteristics of the soil
- The magnitude of the loads from the structure
- The nature of the loads from the structure.

In the majority of buildings, the loads transmitted to the ground will arrive either as point loads down columns or line loads down walls. For the type of building with which these notes deal, the magnitudes of these loads will not be so great as to significantly affect the choice of foundation system.

Table XXXI Concrete – vertical support elements

Element	Horizontal and vertical section	Typical heights (h) (m)	h/d between lateral supports	Critical factors for sizing	Remarks
Cast-in-place column – Single storey – Multi-storey		2–8 2–4	12–18 6–15	Buckling and crushing ($h/d > 10$) Crushing ($h/d < 10$) Bending	Columns rigidly connected to beams form frames which act as a vertical bracing system
Cast-in-place wall		2–4	18–25	Buckling Construction method	
Precast column – Single storey – Multi-storey		2–8 2–4	15–30 6–20	Buckling and crushing ($h/d > 10$) Crushing ($h/d < 10$) Bending Connections	Variety of high-quality finishes available with precast products
Precast loadbearing panel		2–3	20–25	Buckling Connections Handling stresses	
Precast tilt-up panel		4–8	15–25	Handling stresses	
Prestressed concrete columns – Single storey – Multi-storey		4–8 2–4	15–25 10–20	Buckling	Prestressing helps to eliminate tensile stresses due to bending
Prestressed concrete hangers		1–40	1–150	Variation in load	Stiffer and more resistant to corrosion than the steel tie

10.02 Soil

This will basically depend on the strength of the soil to carry the load. The term 'soil' in this context means not vegetable material suitable for growing crops (topsoil), but the material forming the surface of the earth to a depth of about 100 m, which is not so hard as to be classified as a 'rock'.

The technology of the physical properties of soil is called soil mechanics. It is not appropriate to deal in depth with this subject, but some simple principles are necessary to understand the design of foundations.

10.03 Bearing pressure

The bearing pressure that can be carried by the soil is the *additional* load that can be carried on a unit area. A soil stratum at a depth of, say, 3 m is already carrying the weight of that 3 m (overburden) of soil, **36.13**. In fact, the bearing capacity of many soils increases substantially with depth. This is because a common mode of failure under excessive load is sideways spillage of the soil, often accompanied by upward heave of the material around the area of application, **36.14**. Obviously this is much less likely where the load is carried at some depth, **36.15**.

Since the bearing capacity represents the additional load the soil can carry, the greater the depth, the smaller proportion of the total (or gross) pressure this will form. In fact, it is even possible to produce zero or negative net pressure by removing the overburden, and replacing it with something weighing much less, for example a hollow box. This is the principle by which loads can be carried on soft marshy soil; the analogy is that of a boat floating on water. In many cases, the architect will be told what the bearing capacity of the soil is at normal foundation depth – about 1 m. Table LIV gives figures for common soils but should be used with caution.

10.04 Pad and strip foundations

These are the types of foundation most commonly met by architects, and their design should only require the use of an engineer if there are complications. Care should however be taken in soft soils where settlement rather than bearing capacity is the critical criteria. Simple pad and strip foundation calculation is best shown from an example.

Example 1

A brick wall forming the outside of a house carries a load of 85 kN/m. What width of foundation will be required at a depth of 1.5 m, given an allowable bearing capacity on the soil at that depth of 60 kN/m^2? Ignore the weight of the foundation itself:

If B the width of the foundation in metres, the pressure transmitted to the soil will be

$$\frac{85}{B}\,\mathrm{kN/m^2}$$

Table XXXII Concrete – floors

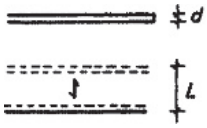
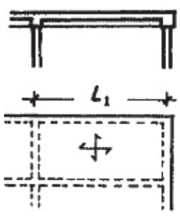
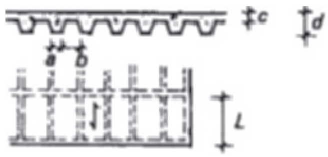
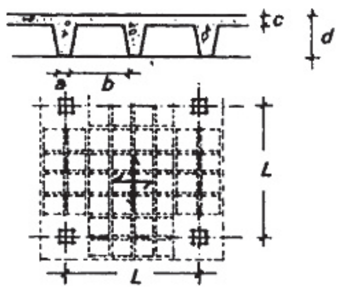
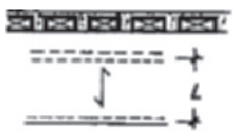
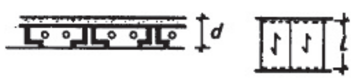
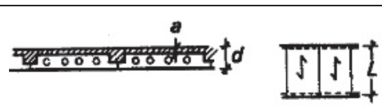
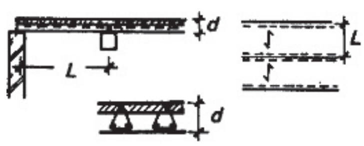
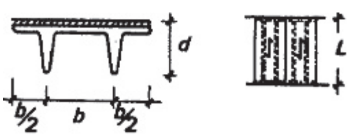
Element	Section and plan	Typical depths (d) (mm)	Typical spans (L) (m)	Typical L/d	Critical factors for sizing/remarks
One-way solid slab – Reinforced – Prestressed		 100–250 125–200	 2–7 5–9	 22–32 38–45	 Deflection Bending Simply supported slabs have the lower values of L/d in given range.
Reinforced two-way slab		100–250	6–11	28–35	Deflection Bending Suitable for heavy loading and concentrated loads $L < L_1 < 1.4L$
One-way ribbed slab (pan joist) – Reinforced – Prestressed		 225–600 300–450	 4–12 10–18	 18–26 30–38	 Deflection Bending Shear Most suitable for long spans with light loads Dimensions a, b and c as below
Two-way waffle slab – Reinforced – Prestressed		 350–650 450–650	 9–15 10–22	 18–24 25–32	 Deflection Bending Form moulds of standard size available More costly to form than ribbed slab Dimensions for a are 100–200 mm, b are 900–1800 mm, c are 60–100 mm approximately
Reinforced one-way joists with hollow blocks (filler blocks)		150–300	3–7	20–25	Bending Shear Small holes in the floor easily made for services
Block and joist floor (joists prestressed)		150–200	3–7	30–35	Bending Deflection Block and joist are precast but have cast-in-place topping 50–75 mm thick
Precast prestressed planks		100–200	6–9	35–45	Live load deflection Bending Slabs more than 175 mm deep often built with voids Topping depth, a, is 50–75 mm thick
Prestressed hollow core slab		100–350	6–10	35–40	Bending Joists are precast but have cast-in-place topping of depth, a, 35–50 mm thick
Widespan slab Bending – Reinforced – Prestressed		 100–300 100–225	 3–7 4–9	 26–32 35–45	 Bending Deflection Slabs are precast with cast-in-place topping Slab often propped during construction.
Precast prestressed double-T beams		350–800	9–18	20–30	Live load Bending Shear Handling stresses Beams have cast-in-place topping 50–75 mm thick

Table XXXII (Continued)

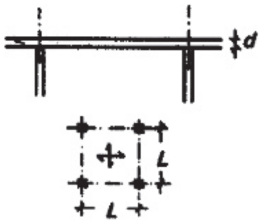
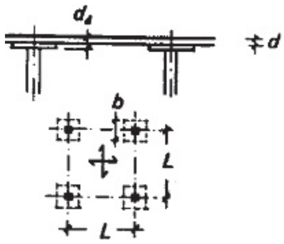
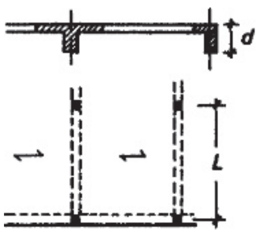
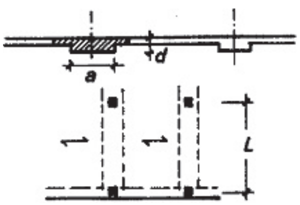
Element	Section and plan	Typical depths (*d*) (mm)	Typical spans (*L*) (m)	Typical *L*/*d*	Critical factors for sizing/remarks
Flat slab without drop panels (flat plates) – Reinforced – Prestressed		 125–200 200–225	 4–8 9–10	 28–36 40–48	 Shear round columns Deflection Bending Compared to beam and slab, flat slabs save depth and formwork costs but have lower resistance to lateral forces
Flat slab with drop panels – Reinforced – Prestressed		 125–300 200–225	 5–10 12–14	 28–36 40–48	 Shear at drops Deflection Bending Dimension d_d is about 1.25*d*–1.45*d*; *b* is about *L*/3
T or L Beam – Reinforced – Prestressed		 400–700 300–850	 5–15 9–24	 14–20 20–30	 Beams usually spaced at about 3–7 m giving slab depth between 100–175 mm Simply supported beams have the lower values of *L*/*d* in the given range
Wide beam – Reinforced – Prestressed		 350–650 300–500	 6–12 9–15	 16–22 22–32	 Deflection Bending Used where height is limited Simply supported beams have the lower values of *L*/*d* in the given range Dimension *a* is about 600–1200 mm

Table XXXIII Concrete – roofs

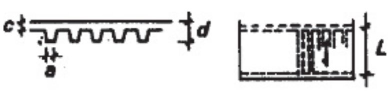
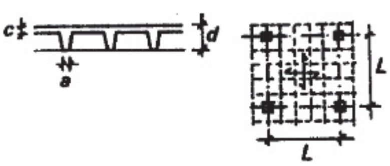
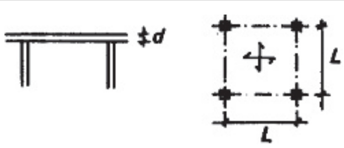
Element	Section and plan	Typical depths (*d*) (mm)	Typical spans (*L*) (m)	Typical *L*/*d*	Critical factors for sizing/remarks
Reinforced one-way solid slab		125–500	3–6	20–30	Deflection Bending
Reinforced one-way ribbed slab (pan joist)		500–1200	6–14	25–30	Deflection Shear Bending Dimensions for *a* are 100–150 mm; *c* are 50–100 mm
Reinforced two-way waffle slab		625–1500	9–16	20–25	Deflection Bending Dimensions as above
Reinforced flat slab without drop panels		400–900	4–8	32	Shear round columns Deflection Bending

Table XXXIII (Continued)

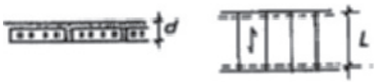
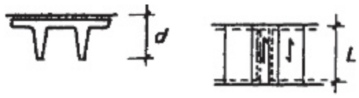
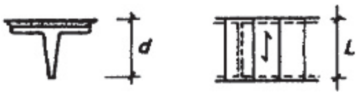
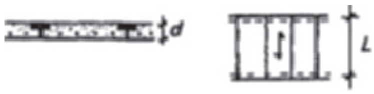
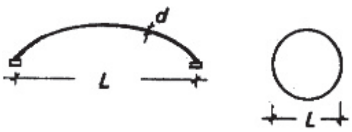
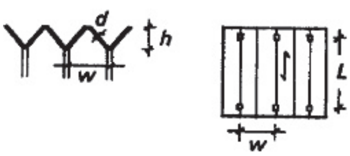
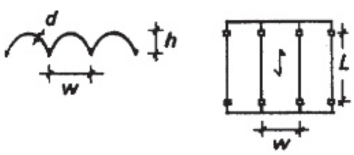
Element	Section and plan	Typical depths (*d*) (mm)	Typical spans (*L*) (m)	Typical *L*/*d*	Critical factors for sizing/remarks
Prestressed hollow core slabs		100–200	6–10	40–50	Compressive strength of unit Live load variation Slabs are precast but have 50–75 mm cast-in-place topping
Prestressed double-T beam		350–800	12–25	30–35	Bending Shear Handling stresses
Prestressed single-T beam		750–2500	15–25	30–35	Bending and shear Handling stresses Beams are precast but have 50–75 mm cast-in-place topping
Reinforced aerated concrete slabs		100–200	2–5	20–25	Bending Slabs connected by strip of cast-in-place concrete
Reinforced inverted hyperbolic paraboloids (umbrellas)		75–100	9–15	120–200	Cover to bars Tension reinforcement required at top of umbrella Umbrellas are independent and may be at different heights *L*/*H* ratio about 6–12.
Reinforced hyperbolic paraboloid shell		75–100	15–55	200–450	Deflection at tips Cover to bars Edge beams may be prestressed to overcome tensile stresses *L*/*H* ratio about 4–7
Domes		75–300	15–120	300–450	Shell buckling Cover to bars Minimum thickness, *d*, about 60 mm Tension ring at base often prestressed
Reinforced concrete folded plates		75–125	9–36	40–50 (*w*/*d*)	Bending in slab Tie force in valley Minimum thickness about 60 mm *L*/*H* ratio about 8–15
Reinforced long barrel shell		75–100	25–40	50–65 (*w*/*d*)	Cover to bars Minimum thickness about 60 mm Shell often prestressed to overcome tensile stresses *L*/*H* ratio about 10–15.
Reinforced skew grid		300–700	10–20	25–35	Deflection Bending Corners stiffer with skew grid than with grid parallel to sides thus allowing larger spans

Table XXXIV Concrete – wall and frame systems

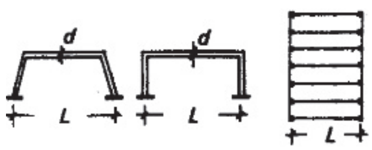
Element	Section and plan	Typical spans (*L*) (m)	Typical *L*/*d*	Remarks
Single storey precast frames		12–24	22–30	Joints in horizontal member usually at corner or about *L*/4 from corner if frame is large

Table XXXIV (Continued)

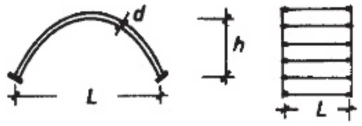
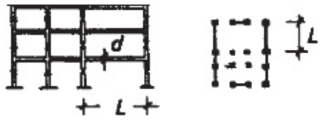
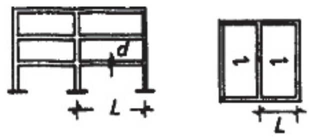
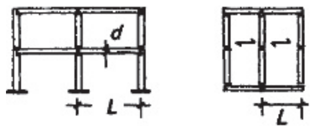
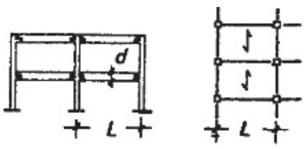
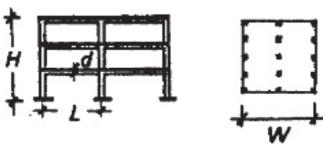
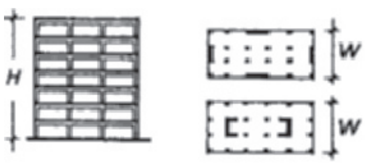
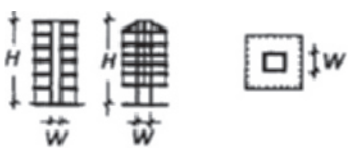
Element	Section and plan	Typical spans (*L*) (m)	Typical *L*/*d*	Remarks
Arches		15–60	28–40	Arches usually continuous and fully rigid between springing points *L*/*H* ratio about 4–12
Precast exterior frames with interiors cast-in-place		6–12	22–30	Connections between precast components done with cast-in-place concrete Interior frame may also use precast elements or be cast against precast permanent formwork System used for buildings up to about 20 storeys high Spans given indicative only
Cast-in-place floor and wall panel systems		6–12	25–30	This system usually uses a standard rapid formwork system System is inherently rigid and used for buildings up to about 20 storeys high
Precast floor and wall panel systems		6–12	22–25	Usually no rigid joint between floor and wall panels; hence system similar in many respects to load bearing masonry with floor slab System economic up to about 15 storeys
Precast beams and columns with precast floor units		6–12	14–16	With rigid connections, system can only go up to about two storeys without extra vertical bracing
Multi-storey cast-in-place frames		5–15 storeys	1–5	Cast-in-place frames without extra vertical bracing are economic up to about 15 storeys *L*/*d* ratio about 20–40
Shear walls or cores with rigid frame		10–55 storeys	4–5	Shear wall or core interacts with rigid frame to provide a vertical bracing system which is stiff over height of building Given values of height ratio (*H*/*W*) larger for buildings less than about 20 storeys high
Framed tubes and core		40–65 storeys	6–7	Also known as tube in tube system Framed tube interacts with core
Core structures with suspended floors or semi-rigid frame		10–30 storeys	8–12	Core provides all lateral stability Only limited plan areas with suspended floors

Table XXXV Concrete – below ground

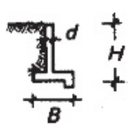
Element	Section	Typical heights (*H*) (m)	Typical *L*/*d*	Remarks
Retaining wall		2–6	10–12	Dimension *B* is about *H*/2–2*H*/3 Toe helps to prevent sliding
Shell and box enclosures		1–4	25–30	Used for subways, culverts etc. Loading depends on soil type and depth

Table XXXVI Concrete – elements carrying gravity load

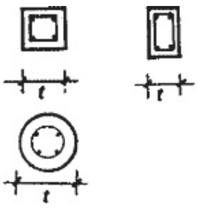
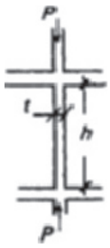
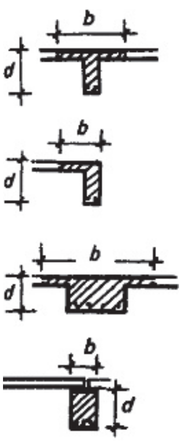
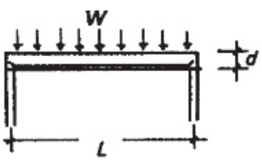
Horizontal section on element	Elevation on element	Formulae for preliminary sizing only – elastic theory	Remarks
Prestressed tie 		$P < \frac{A.u.}{3}$ where A is area of tie P is unfactored value of tie force u is ultimate compressive strength of concrete by standard cylinder test (= 0.8 × ultimate strength by standard cube test)	Minimum unfactored force in prestressing cables is at least equal to P
Reinforced column 		$P < \frac{A.u}{3}(1 + 0.14n)$ where A is area of column P is unfactored value of axial load n is percentage of mild steel longitudinal reinforcement $\frac{h}{t} < 15$ where t is least width of column and h is height between lateral supports	Concrete columns in buildings are usually 'short' $h_{cf}/t < 15$ formulae given for 'short' columns, axially loaded with longitudinal reinforcement and link bars With more reinforcement reduction in area possible e.g. with 4% reinforcement there is a possible 20% reduction in area compared to 2% reinforcement; typical percentages vary from 2–6% For building laterally braced, for example by stair or elevator shafts, the effective height of columns h_{cf}, is not greater than the actual height; for slender columns, those with h_{cf}/t >15, there is a decrease in load compared to that for 'short' columns e.g. for column with $h_{cf}/t = 30$ area required is double that for same load on 'short' column To take account of bending, if present, as well as the compression in columns, multiply vertical load on column by $\frac{s + x}{s + 1}$ and treat factored amount as axial vertical load where s is the number of storeys above the column considered and $x = 1.25$ for interior columns, $x = 2.00$ for corner columns and $x = 1.50$ for all other exterior columns For 1 h fire rating, minimum length of side of column = 200 mm and for 2 h rating length = 300 mm
Simply supported reinforced beam showing effective section at midspan 		$\frac{L}{d} = 18$ (rectangular beams) or $\frac{L}{d} = 15$ (T and L beams) giving $\Delta \approx L/240$ where d is overall depth of beam and L is span Economic value of d given when $\frac{M}{u.b.d^2} = 0.03$ to 0.05 with maximum value ≈ 0.09 where M is unfactored value of bending moment b is width of top of beam	Span to depth ratios given for beams with about 1% tension reinforcement at a stress 240 N/mm^2; higher values of L/d up to about 1.5 those given are possible for wide beams or those with heavier reinforcement; for long spans L/d should be reduced Span to depth ratios given are for rectangular and T and L beams having similar flange widths; T and L beams give considerable savings in concrete section and weight, compared to rectangular beams designed for same task, and can be assumed to have same L/d ratio as a narrow rectangular beam For T beams at midspan $b = L/5$ and for L beams $b = L/O$ Typical total percentages of reinforcement in beam are between 2.5 and 4.5% More efficient use of material is had with high values of L/d; however, to prevent lateral instability restraints required, usually by floor or roof construction, e.g. for a beam with $d/b = 4$ maximum span between lateral – restraints $60b$ Bending moment in middle of beam, $M = W.L/8$ where W is total u.d. load on beam and shear at supports = $W/2$ For 1 h fire rating minimum width of beam = 120 mm and for 2 h fire rating width = 200 mm

Table XXXVI (Continued)

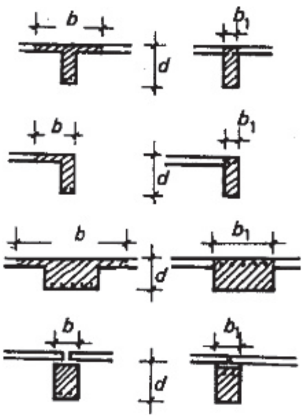
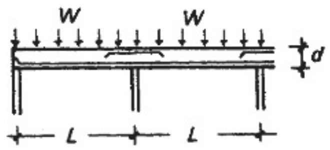
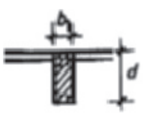
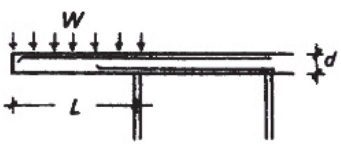
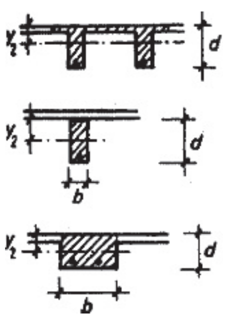
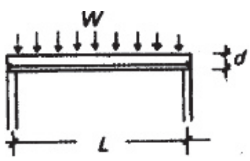
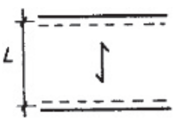
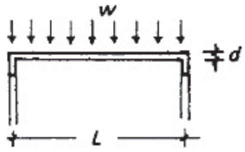
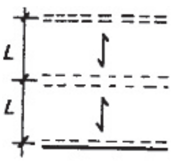
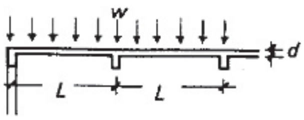
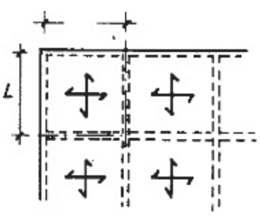
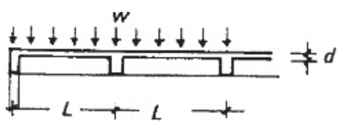
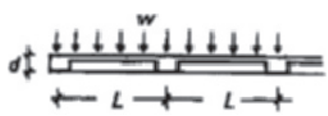
Horizontal section on element	Elevation on element	Formulae for preliminary sizing only – elastic theory	Remarks
Continuous reinforced beam showing effective section at midspan, left, and at support, right 		$\frac{L}{d} = 22$ (rectangular beams) or $\frac{L}{d} = 18$ (T and L beams) giving $\Delta \approx = L/240$ where d is overall depth of beam and L is span Economic value of d given when $\frac{M}{u.b.d^2}$ or $\frac{M}{u.b_1.d^2} = 0.03 - 0.05$ with maximum value ≈ 0.09 where M is unfactored value of bending moment b is width of top of beam at midspan and b_1 is width of beam web at support u is ultimate strength of concrete by standard cylinder test (= 0.8 × ultimate strength by standard cube test)	At support points T and L beams have an effective section which is rectangular For T-beam at midspan $b = L/7$ and for L-beams $b = L/14$ Bending moment at middle of end span = $W.L/11$ and at first interior support = $W.L/9$ where W is total unfactored u.d. load on span, all spans are equal and dead load is greater than live load Shear at supports = 0.6 W Notes on span to depth ratios as for simply supported beams For 1 h fire rating minimum width of beam = 120 mm and for 2 h fire rating width = 150 mm
Cantilevered reinforced beam showing effective at support 		$\frac{L}{d} = 8$ where d is overall depth of cantilever L is length of cantilever Economic value of d given when b_1 is width of web of beam $\frac{M}{u.b_1.d^2} = 0.03 - 0.05$ with maximum value ≈ 0.09 where M is unfactored value of bending moment	For cantilever beam with $d/b = 4$, maximum distance between end and last lateral restraint = 25 b Bending moment at support = $W.L./2$ where W is total u.d. load on cantilever and shear is W Notes on fire resistance and on span to depth ratio as for simply supported beams
Simply supported prestressed beam 		$\frac{L}{d} = 34$ (rectangular beams) or $\frac{L}{d} = 28$ (T and L beams) $Z = \frac{1}{y_2} = \frac{1.40M}{u}$ (rectangular section) or $Z_2 = \frac{1}{y_2} = \frac{1.45M}{u}$ (double T-section)	y_2 is the distance from the centroid to the top of the concrete section I is the moment of inertia of the section about the centroid Z is the section modulus, which, for rectangular sections, is equal to $b.d^2/6$ M is the unfactored value of the banding moment Depth of prestressed beams are about 65% of those required in reinforced concrete Minimum unfactored values of the prestressing sections or $M/0.6d$ for double T sections, where M, as above, is the maximum unfactored value of the bending moment in the beam

Table XXXVI (Continued)

Horizontal section on element	Elevation on element	Formulae for preliminary sizing only – elastic theory	Remarks
Simply supported one-way solid slab 		$\frac{L}{d} = 20$ giving $\Delta \approx L/240$ where d is overall depth of slab and L is span	Span to depth ratio given for slabs with about 0.5% tension steel reinforcement working at a stress of 240 N/mm^2. With effective depth of slab = 0.85d; higher values of L/d up to about 30 possible with more reinforcement. Typical percentages of reinforcement in one-way slabs ≈ 1% Bending moment at middle of slab = $w.L^2/8$ per unit width where W is load per unit area For cantilever slabs span to depth ratio L/d = 9 with bending moment = $w.L/2$ For 1 h fire rating minimum, depth of slab d = 95 mm and for 2 h fire rating d = 125 mm
Continuous one-way solid slab 		$\frac{L}{d} = 25$ giving $\Delta \approx L/240$	Span to depth ratio given for slabs with about 0.5% tension steel reinforcement working at a stress of 240 N/mm^2. With effective depth of slab = 0.85d; higher values of L/d up to about 35 possible with more reinforcement For 1 h fire rating minimum depth of slab d = 95 mm and for 2 h rating d = 125 mm Bending moment in middle of slab = $w.L^2/12$ per unit width and bending moment at interior supports = $w.L^2/9$ where w is total load per unit area and dead load is greater than live load
Continuous two-way solid slab 		$\frac{L}{d} = 32$ giving $\Delta \approx L/240$	Span to depth ratio given for square slabs supported along the edges with 0.25% tension steel reinforcement, in two directions, working at stress of 240 N/mm^2. With effective depth of slab = 0.8d; higher values of L/d up to about 40 possible with more reinforcement Typical percentages of reinforcement in two-way slabs ≈ 0.8% Bending moment at middle of slab = $w.L^2/24$ per unit width and bending moment at interior supports = $w.L^2/18$ where w is total load per unit area and dead load is greater than live load Notes on fire resistance as for one-way slabs
Continuous one-way ribbed slab		$\frac{L}{d} = 16$ giving $\Delta \approx L/240$ where d is overall depth of slab and L is span	Span to depth ratio given for slab with about 0.5% tension reinforcement, based on gross cross-sectional area including voids, working at a stress of 240 N/mm^2. With effective depth of slab = 0.85d; higher values of L/d up to about 30 possible with more reinforcement. Bending moment on each rib at centre of slab = $c.w.L^2/12$ and bending moment on each rib at support = $c.w.\ L^2/9$ with narrow support beam where c is spacing of ribs and w is load per unit area For 1 h fire rating minimum width of ribs and depth of slab between ribs = 90 mm and for 2 h rating these dimensions = 115 mm

Put this equal to the capacity to obtain the minimum allowable value of B:

$$85/B = 60, \quad \text{hence } B = 1.42\,\text{m}$$

The practical width of foundation is therefore 1.5 m, **36.16**.

Example 2

A column carries a load from a warehouse building of 1000 kN. The soil is poor in quality down to a depth of 2.5 m, where a gravel seam is capable of carrying 185 kN/m^2. A square concrete pier is to be constructed from the bearing layer up to ground level. What should be size of the pier be (**36.17**)?

The gravel will have to carry the weight of the concrete pier as well as the column load. The load imposed by any material will be

$$\text{Density} \times \text{height}$$

The density of reinforced concrete is assumed to be 24 kN/m^3 (Table II). The pressure on the gravel due to this concrete will therefore be

$$24 \times 2.5 = 60\,\text{kN/m}^2$$

Table XXXVI (Continued)

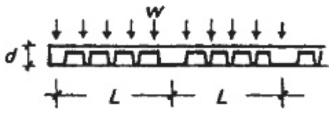
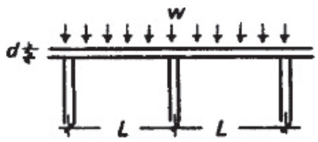
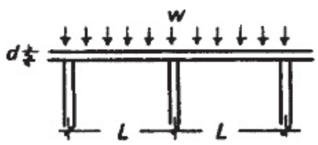
Horizontal sectionon element	Elevation on element	Formulae for preliminary sizing only – elastic theory	Remarks
Continuous two-way waffle slab		$\frac{L}{d} = 26$ giving $\Delta \approx L/240$	Span to depth ratio given for slab with 0.25% tension reinforcement in two directions, based on gross cross-sectional area including voids, working at a stress of 240 N/mm^2. With effective depth of slab = 0.80*d*; higher values of *L*/*d* up to about 35 possible with more reinforcement Bending moment on beams with the same depth as the slab are as for T-beams in two-way beam and slab systems M at midspan $= \frac{2w.L^2}{3} \cdot \frac{L}{12}$ and at support $= \frac{2w.L^2}{3} \cdot \frac{L}{9}$ where *w* is total load per unit area with dead load greater than live load Bending moment on each rib at centre of slab = $c.w.L^2/24$ and at support = $c.w.L^2/18$ where *c* is spacing of ribs of waffle slab
Flat slabs without drop panels		$\frac{L}{d} = 29$ $\frac{w.L^2}{u.d(4t + 12d)} < 0.014$ where *t is* diameter of round column or length of side of square column	Span to depth ratio given for square panels having three equal bays in each direction with 0.25% tension reinforcement in two directions working at stress of 240 N/mm^2 Higher values of *L*/*d* up to 32 possible with more reinforcement Bending moments on column strip at midspan = $w.L^2/8$ per unit width and over columns, without redistribution, = $w.L^2/6$ per unit width where *w* is full load per unit area and dead load is greater than live load; bending moments on middle strip as for two-way solid slabs
Flat slab with drop panels		$\frac{L}{d} = 32$ $\frac{w.L^2}{u.d_d(4t + 12d_d)} < 0.014$ where d_4 is depth of slab plus depth of drop panel	Span to depth ratio given for square panels having three equal bays in each direction with 0.25% reinforcement in two directions working at stress of 240 N/mm^2 Higher values of *L*/*d* up to 36 possible with more reinforcement Bending moments as for flat slabs without drop panels Typical value of length of side of drop panel, *m*, is between 0.3*L* and 0.5*L*

Table XXXVII Properties of steel and aluminium

Property	Prestressing strand	High strength low-alloy steel	Structural carbon steel	Cold formed steel	Casting steel	Wrought iron	Grey cast iron	Wrought aluminium Alloy
Carbon content %	0.60–0.90	0.10–0.28	0.10–0.25	0.20–0.25	0.15–0.50	0.05	2.50–4.50	..
Weight kN/m^3	77	77	77	77	77	75	71	27
Tensile strength N/mm^2	1200–1800	400–700	400–560	280–600	400–600	300–350 (in line of rolling)	150–350	200–550
Yield stress or 0.2% proof stress N/mm^2 – stress at or near which permanent deformation starts	1100–1700	340–480	240–300	200–500	200–400	180–200 (in line of rolling)		120–500
Elastic modulus kN/mm^2	165	210	210	210	210	190	210	70
Elongating % – ductility	4	15	15–25	12–25	15–20	8–25	2	8–20
Weldability	Not suitable for welding	Good with right alloys	Good if low-carbon steel	Generally good	Moderate	Generally poor	Poor	Good if right alloys
Coefficient of thermal expansion $\times 10^{-6}$/°C	12	12	12	12	12	12	12	24
Temperature at which metal has 50% of room temperature strength °C	350–500	500	500	500	500	500	can crack at high temperature	190
Corrosion resistance of untreated metal	Poor	Moderate to good	Poor	Poor to moderate	Moderate	Good	Good	Very good

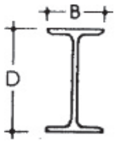
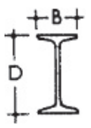


Table XXXVIII Universal beams

Dimensions

Section Designation	Mass per Metre kg/m	Depth of Section D mm	Width of Section B mm	Thickness Web t mm	Thickness Flange T mm	Root Radius r mm	Depth between Fillets d mm	Ratios for Local Buckling Flange b/T	Ratios for Local Buckling Web d/t	Dimensions for Detailing End Clearance C mm	Dimensions for Detailing Notch N mm	Dimensions for Detailing Notch n mm	Surface Area Per Metre m^2	Surface Area Per Tonne m^2
305x165x54	54.0	310.4	166.9	7.9	13.7	8.9	265.2	6.09	33.6	6	90	24	1.26	23.3
305x165x46	46.1	306.6	165.7	6.7	11.8	8.9	265.2	7.02	39.6	5	90	22	1.25	27.1
305x165x40	40.3	303.4	165.0	6.0	10.2	8.9	265.2	8.09	44.2	5	90	20	1.24	30.8
305x127x48	48.1	311.0	125.3	9.0	14.0	8.9	265.2	4.47	29.5	7	70	24	1.09	22.7
305x127x42	41.9	307.2	124.3	8.0	12.1	8.9	265.2	5.14	33.1	6	70	22	1.08	25.8
305x127x37	37.0	304.4	123.4	7.1	10.7	8.9	265.2	5.77	37.4	6	70	20	1.07	29.0
305x102x33	32.8	312.7	102.4	6.6	10.8	7.6	275.9	4.74	41.8	5	58	20	1.01	30.8
305x102x28	28.2	308.7	101.8	6.0	8.8	7.6	275.9	5.78	46.0	5	58	18	1.00	35.4
305x102x25	24.8	305.1	101.6	5.8	7.0	7.6	275.9	7.26	47.6	5	58	16	0.992	40.0
254x146x43	43.0	259.6	147.3	7.2	12.7	7.6	219.0	5.80	30.4	6	82	22	1.08	25.1
254x146x37	37.0	256.0	146.4	6.3	10.9	7.6	219.0	6.72	34.8	5	82	20	1.07	29.0
254x146x31	31.1	251.4	146.1	6.0	8.6	7.6	219.0	8.49	36.5	5	82	18	1.06	34.2
254x102x28	28.3	260.4	102.2	6.3	10.0	7.6	225.2	5.11	35.7	5	58	18	0.904	31.9
254x102x25	25.2	257.2	101.9	6.0	8.4	7.6	225.2	6.07	37.5	5	58	16	0.897	35.6
254x102x22	22.0	254.0	101.6	5.7	6.8	7.6	225.2	7.47	39.5	5	58	16	0.890	40.5
203x133x30	30.0	206.8	133.9	6.4	9.6	7.6	172.4	6.97	26.9	5	74	18	0.923	30.8
203x133x25	25.1	203.2	133.2	5.7	7.8	7.6	172.4	8.54	30.2	5	74	16	0.915	36.4
203x102x23	23.1	203.2	101.8	5.4	9.3	7.6	169.4	5.47	31.4	5	60	18	0.790	34.2
178x102x19	19.0	177.8	101.2	4.8	7.9	7.6	146.8	6.41	30.6	4	60	16	0.738	38.8
152x89x16	16.0	152.4	88.7	4.5	7.7	7.6	121.8	5.76	27.1	4	54	16	0.638	39.8
127x76x13	13.0	127.0	76.0	4.0	7.6	7.6	96.6	5.00	24.1	4	46	16	0.537	41.3



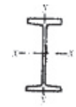


Table XXXIX Joists

Dimensions

Section Designation	Mass per Metre kg/m	Depth of Section D mm	Width of Section B mm	Thickness Web t mm	Thickness Flange T mm	Radii Root r_1 mm	Radii Toe r_2 mm	Depth between Fillets d mm	Ratios for Local Buckling Flange b/T	Ratios for Local Buckling Web d/t	Dimensions for Detailing End Clearance C mm	Dimensions for Detailing Notch N mm	Dimensions for Detailing Notch n mm	Surface Area Per Metre m^2	Surface Area Per Tonne m^2
254x203x82 #	82.0	254.0	203.2	10.2	19.9	19.6	9.7	166.6	5.11	16.3	7	104	44	1.21	14.8
254x114x37 ‡	37.2	254.0	114.3	7.6	12.8	12.4	6.1	199.3	4.46	26.2	6	60	28	0.899	24.2
203x152x52 #	52.3	203.2	152.4	8.9	16.5	15.5	7.6	133.2	4.62	15.0	6	78	36	0.932	17.8
152x127x37 #	37.3	152.4	127.0	10.4	13.2	13.5	6.6	94.3	4.81	9.07	7	66	30	0.737	19.8
127x114x29 #	29.3	127.0	114.3	10.2	11.5	9.9	4.8	79.5	4.97	7.79	7	60	24	0.646	22.0
127x114x27 #	26.9	127.0	114.3	7.4	11.4	9.9	5.0	79.5	5.01	10.7	6	60	24	0.650	24.2
127x76x16 ‡	16.5	127.0	76.2	5.6	9.6	9.4	4.6	86.5	3.97	15.4	5	42	22	0.512	31.0
114x114x27 ‡	27.1	114.3	114.3	9.5	10.7	14.2	3.2	60.8	5.34	6.40	7	60	28	0.618	22.8
102x102x23 #	23.0	101.6	101.6	9.5	10.3	11.1	3.2	55.2	4.93	5.81	7	54	24	0.549	23.9
102x44x7 #	7.5	101.6	44.5	4.3	6.1	6.9	3.3	74.6	3.65	17.3	4	28	14	0.350	46.6
89x89x19 #	19.5	88.9	88.9	9.5	9.9	11.1	3.2	44.2	4.49	4.65	7	46	24	0.476	24.4
76x76x15 ‡	15.0	76.2	80.0	8.9	8.4	9.4	4.6	38.1	4.76	4.28	6	42	20	0.419	27.9
76x76x13 #	12.8	76.2	76.2	5.1	8.4	9.4	4.6	38.1	4.54	7.47	5	42	20	0.411	32.1

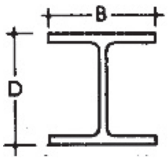


Table XL Universal columns

Dimensions

Section Designation	Mass per Metre	Depth of Section	Width of Section	Thickness		Root Radius	Depth between Fillets	Ratios for Local Buckling		Dimensions for Detailing			Surface Area	
				Web	Flange			Flange	Web	End Clearance	Notch		Per Metre	Per Tonne
		D	B	t	T	r	d	b/T	d/t	C	N	n		
	kg/m	mm	mm	mm	mm	mm	mm			mm	mm	mm	m^2	m^2
254x254x167	167.1	289.1	265.2	19.2	31.7	12.7	200.3	4.18	10.4	12	134	46	1.58	9.45
254x254x132	132.0	276.3	261.3	15.3	25.3	12.7	200.3	5.16	13.1	10	134	38	1.55	11.7
254x254x107	107.1	266.7	258.8	12.8	20.5	12.7	200.3	6.31	15.6	8	134	34	1.52	14.2
254x254x89	88.9	260.3	256.3	10.3	17.3	12.7	200.3	7.41	19.4	7	134	30	1.50	16.9
254x254x73	73.1	254.1	254.6	8.6	14.2	12.7	200.3	8.96	23.3	6	134	28	1.49	20.4
203x203x86	86.1	222.2	209.1	12.7	20.5	10.2	160.8	5.10	12.7	8	110	32	1.24	14.4
203x203x71	71.0	215.8	206.4	10.0	17.3	10.2	160.8	5.97	16.1	7	110	28	1.22	17.2
203x203x60	60.0	209.6	205.8	9.4	14.2	10.2	160.8	7.25	17.1	7	110	26	1.21	20.1
203x203x52	52.0	206.2	204.3	7.9	12.5	10.2	160.8	8.17	20.4	6	110	24	1.20	23.0
203x203x46	46.1	203.2	203.6	7.2	11.0	10.2	160.8	9.25	22.3	6	110	22	1.19	25.8
152x152x37	37.0	161.8	154.4	8.0	11.5	7.6	123.6	6.71	15.5	6	84	20	0.912	24.7
152x152x30	30.0	157.6	152.9	6.5	9.4	7.6	123.6	8.13	19.0	5	84	18	0.901	30.0
152x152x23	23.0	152.4	152.2	5.8	6.8	7.6	123.6	11.2	21.3	5	84	16	0.889	38.7

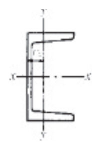


Table XLI Parallel flange channels

Dimensions

Section Designation	Mass per Metre	Depth of Section	Width of Section	Thickness		Root Radius	Depth between Fillets	Ratios for Local Buckling		Dimensions for Detailing			Surface Area	
				Web	Flange			Flange	Web	End Clearance	Notch		Per Metre	Per Tonne
		D	B	t	T	r	d	b/T	d/t	C	N	n		
	kg/m	mm	mm	mm	mm	mm	mm			mm	mm	mm	m^2	m^2
430x100x64	64.4	430	100	11.0	19.0	15	362	5.26	32.9	13	96	36	1.23	19.0
380x100x54	54.0	380	100	9.5	17.5	15	315	5.71	33.2	12	98	34	1.13	20.9
300x100x46	45.5	300	100	9.0	16.5	15	237	6.06	26.3	11	98	32	0.969	21.3
300x90x41	41.4	300	90	9.0	15.5	12	245	5.81	27.2	11	88	28	0.932	22.5
260x90x35	34.8	260	90	8.0	14.0	12	208	6.43	26.0	10	88	28	0.854	24.5
260x75x28	27.6	260	75	7.0	12.0	12	212	6.25	30.3	9	74	26	0.796	28.8
230x90x32	32.2	230	90	7.5	14.0	12	178	6.43	23.7	10	90	28	0.795	24.7
230x75x26	25.7	230	75	6.5	12.5	12	181	6.00	27.8	9	76	26	0.737	28.7
200x90x30	29.7	200	90	7.0	14.0	12	148	6.43	21.1	9	90	28	0.736	24.8
200x75x23	23.4	200	75	6.0	12.5	12	151	6.00	25.2	8	76	26	0.678	28.9
180x90x26	26.1	180	90	6.5	12.5	12	131	7.20	20.2	9	90	26	0.697	26.7
180x75x20	20.3	180	75	6.0	10.5	12	135	7.14	22.5	8	76	24	0.638	31.4
150x90x24	23.9	150	90	6.5	12.0	12	102	7.50	15.7	9	90	26	0.637	26.7
150x75x18	17.9	150	75	5.5	10.0	12	106	7.50	19.3	8	76	24	0.579	32.4
125x65x15 #	14.8	125	65	5.5	9.5	12	82.0	6.84	14.9	8	66	22	0.489	33.1
100x50x10 #	10.2	100	50	5.0	8.5	9	65.0	5.88	13.0	7	52	18	0.382	37.5

Table XLII Steel – vertical support elements

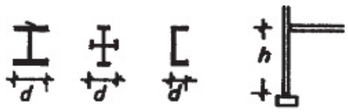
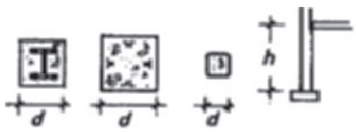
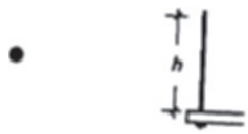
Element	Horizontal and vertical section	Typical heights (*h*) (m)	*h/d* between lateral supports	Critical factors for sizing	Remarks
Rolled steel of open section – single storey – multi-storey		2–8 2–4	20–25 7–18	Buckling (*h/d* > 14) Buckling and compression (*h/d* < 14)	Standard rolled sections usual but special shapes may be made by welding Connections easier with open rather than closed sections
Rolled steel of hollow section – single storey – multi-storey		2–8 2–4	20–35 7–28	Buckling (*h/d* < 20) Buckling and compression (*h/d* > 20)	Closed sections have smaller exposed surface and greater torsional stiffness than open sections of same weight.
Lattice column		4–10	20–25	Buckling	Lattice may be used if large column required
Steel and concrete composite column		2–4	6–15	Buckling and crushing (*h/d* > 10)	Concrete increases stiffness and fire resistance
Cold-formed steel studs with steel panels		2–8	15–50	Buckling	Steel studs can also be stiffeners for gypsum, GRC or plywood panels
High strength steel hangers		1–40	–	Axial stiffness	Hangers usually solid rods, strand or rope cables. Rods have less tensile strength but axially stiffer than cable

Table XLIII Steel – floors

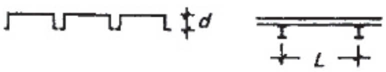
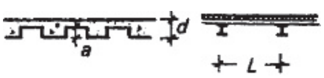
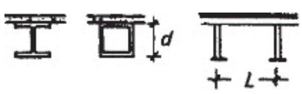
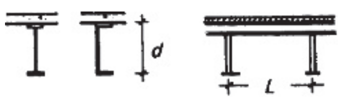
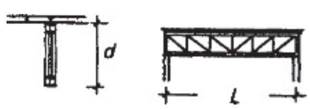
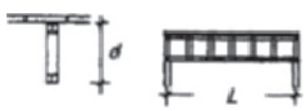
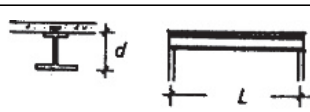
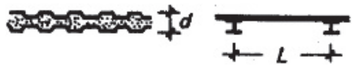
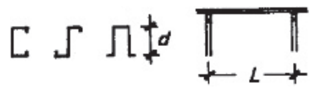
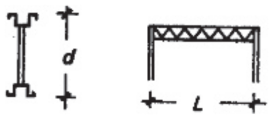
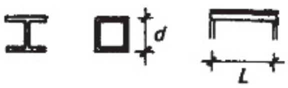
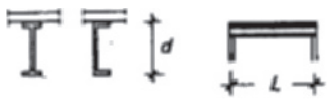
Element	Section and elevation	Typical depths (*d*) (mm)	Typical spans (*L*) (m)	Typical *L/d*	Critical factors for sizing/remarks
Steel decking		50–75	2–3	35–40	Deflection
Cold-formed steel deck with composite concrete topping		100–150	2–4	25–30	Deflection of deck when used as formwork Thickness of concrete for fire protection Dimension *a* = 40–80 mm
Wide flange rolled steel section		100–500	4–12	18–28	Deflection
Deep rolled steel section		200–500	6–30	15–20	Deflection Bending strength
Rolled steel truss		1000–4000	12–45	8–15	Axial compression of members Joints Deflection
Vierendeel girder		1000–3000	6–18	4–12	Bending strength of members near supports Deflection
Composite concrete steel girder		300–1000	7–15	20–25	Often used with secondary steel joists between girders Saving of about 25% in steel compared to non-composite section

Table XLIV Steel – roofs, beam and deck

Element	Section and elevation	Typical depths (*d*) (mm)	Typical spans (*L*) (m)	Typical *L/d*	Critical factors for sizing/remarks
Cold-formed steel deck		25–120	2–6	40–70	Deflection
Steel sandwich panel		75	2–3	25–30	Sheet has injected plastic foam insulation Good bond of insulation to steel sheet is important.
Cold-formed steel sections		120–300	3–12	25–35	Deflection Often very flexible about minor axis
Cold-formed open web steel joist		300–1000	5–20	15–25	Deflection Buckling
Wide flange rolled steel section		100–500	6–14	20–30	Deflection
Deep rolled steel section		200–1000	6–60	18–26	Deflection Bending strength Buckling of top flange

However, the same depth of soil will have been removed to construct the pier. The pressure this exerted on the gravel layer was $2.5 \times 16\,\text{kN/m}^2$ (assumed density of soil) $= 40\,\text{kN/m}^2$

Consequently, the pressure capacity available to carry the load of the column will be:

Bearing capacity + soil pressure – pier weight

$$185 + 40 - 60 = 165\,\text{kN/m}^2$$

The required pier area is hence

$$\frac{1000}{165} = 6.06\,\text{m}^2$$

The sides of the square pier will be $\sqrt{6.06} = 2.46$ m, say 2.5 m

10.05 Other foundation types

It is frequently found that the loads of the building are so large, or the bearing capacity of the soil is so poor, that suitable pad or strip foundations will be either very deep, or required to be so large that adjoining bases impinge on one another. The two common solutions to this problem are:

- Raft foundations, **36.18**, where the bases are combined together to form one large base. The raft has to be so reinforced to cater for the stresses induced by inequalities of loading and bearing capacity
- Piles, **36.19**, which are devices for carrying loads down to deeper levels than would otherwise be practical.

Raft foundations are beyond the scope of this section; however, useful guidance on raft design is given in the Structural Foundation Designers Manual (see Bibliography).

10.06 End-bearing piles

Piles can be divided into those that carry their loads into the soil mainly by end bearing, **36.20** and those that act by virtue of the shaft friction at the interface between the pile length and the soil, **36.21**. End-bearing piles normally sit on rock or gravel strata with high bearing capacities. They may consist of a precast concrete shaft, driven into place with a large mechanical hammer. Alternatively, a hollow shell is driven and afterwards filled with wet concrete to form the pile. In either of these cases, the amount of penetration achieved at each hammer blow is an indication of the load carrying capacity of the pile. A design method for simple end-bearing piles in the shape of the short-bored variety sometimes used in housing is illustrated in the following example.

Example 3

The brick wall in Example 1 above is to be carried on bored piles taken down to a gravel seam 4 m deep. The gravel has a safe bearing capacity of $500\,\text{kN/m}^2$, and the piles are 650 mm diameter. What is the required spacing of the piles (**36.22**)?

The area of the pile base is

$$\pi \times (½ \times 0.65)^2\,\text{m}^2 = 0.332\,\text{m}^2$$

The load that can be carried by each is therefore

$$500 \times 0.332 = 166\,\text{kN}$$

The length of wall loaded at 85 kN/m carried on one pile is hence

$$\frac{166}{85} = 1.95\,\text{m}$$

Therefore, piles should be at, say, 1.95 m centres.

As a rule of thumb, the minimum practicable spacing is taken as $3 \times$ pile diameter or 1.95 m in this case, a spacing of 1.95 m is therefore acceptable.

10.07 Skin-friction piles

Skin-friction piles, mostly appropriate for cohesive soils such as clays, are usually bored. In this method, a circular hole is excavated in the ground by a large auger or other methods. If necessary, the sides of the hole are temporarily sleeved. When the necessary

Table XLV Steel – roofs, beam and surface

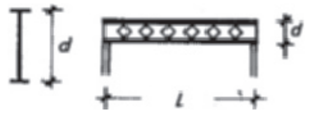
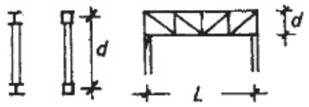
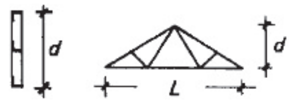
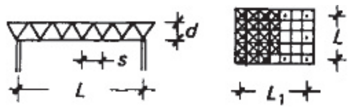
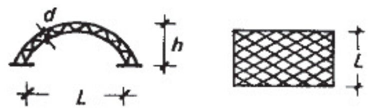
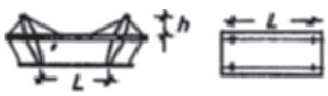
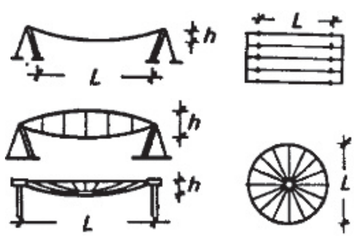
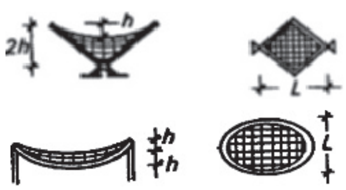
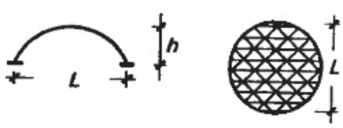
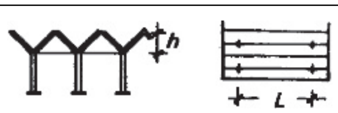
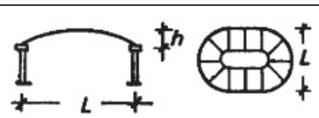
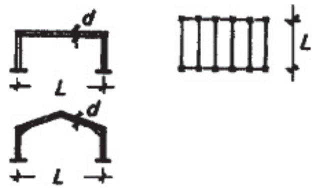
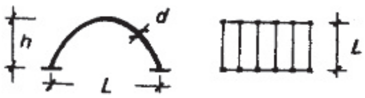
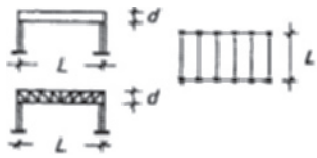
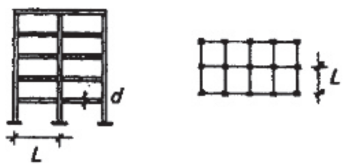
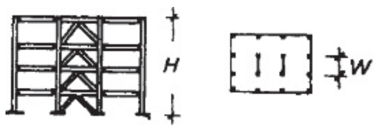
Element	Section and elevation or plan	Typical spans (L) (m)	Typical L/d or L/b	Remarks
Rolled steel castellated beam		6–18	10–18	Web buckling Shear
Flat rolled steel truss		12–75	10–18	Bending strength Deflection Typical spacings of trusses 6–12 m Truss cambered for spans > 25 m
Sloping rolled steel truss		8–20	5–10	Truss often bolted up from steel angle sections
Two-layer space frame		30–150	15–30	Space frame has pinned or semi-rigid joints and works as three-dimensional reticulated structure Plan geometry based on rectangular, triangular or hexagonal grids Size of grid, d, about 1.4 h and about 5–12% of span, L, $L < L_1 < 1.4\,L$
Braced barrel vault		20–100	55–60	Vaults may have single or double layer of steelwork L/H ratio about 5–6
Corrugated arch		30–45	4–5	Made with two layers of cold-formed corrugated sheet bolted together with insulation between
Cable-stayed roof beams		60–150	5–10	Cables serve to support horizontal beams and increase the span
Hanging cable roof		50–180	8–15	Roofs have single curvature (gutter) shape or synclastic double curvature (gutter) shape or synclastic double curvature (saucer) shape
Net roof with rigid covering		30–180	6–12	Roofs have anticlastic double curvature (saddle) shape
Single-layer domed grid		15–100	5–7	Double-layer domes also constructed spanning up to 200 m
Double-layer stressed skin folded plate		9–30	10–20	Single-layer skin construction possible spanning up to about 25 m Failure usually caused by connections or buckling
Double-layer stressed skin hyperbolic paraboloid shell		9–30	6–12	Steel sheets are laid along the straight line generators on the hp surface and slightly twisted across their width
Air supported stainless steel membrane		80–300	25–30	Low L/H ratio gives roof wind uplift and requires only small change in shape from flat plan shape

Table XLVI Steel – frame systems

Element	Section and plan	Typical spans (L) (m)	Typical L/d	Remarks
Single-storey rigid frame		9–60	35–40	Frame is rigid in its own plane Typical spacing of frames $L/4$–$L/6$
Arch		60–150	40–50	Buckling often critical Arch usually has pinned connections at base and sometimes at apex too Typical L/H ratio about 5–15
Single-storey beam and post		6–40	12–20	Frame not rigid in its own plane so vertical bracing necessary, e.g. with rigid gables connected to roof plane
Multi-storey rigid frame		6–20	20–35	Sidesway at top and between storeys often critical Rigid joints between beams and columns obtained by welding or welding and bolting System economic up to about 25 storeys With moment joints between beams and columns, obtained by bolting, building may go up to about 15 storeys without the use of extra vertical bracing
Shear truss and simple frame		typical height, H 5–20 storeys	H/W 6–8	Frame is not rigidly connected to shear truss Shear truss more efficient as vertical bracing than rigid frame

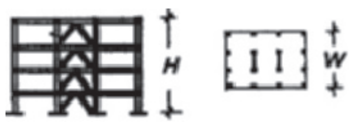
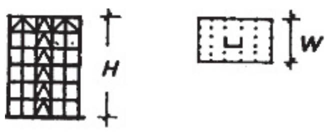
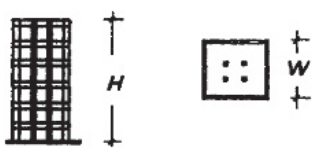
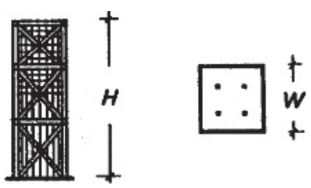
Element	Section and plan	Typical heights (H) (storeys)	Typical H/W	Remarks
Shear truss and rigid frame		10–40 storeys	3–4	Frame is rigidly connected and interacts with shear truss Frame provides ductile strength in earthquake areas
Shear truss and rigid frame with belt trusses		40–60 storeys	5–7	Horizontal belt trusses reduce sidesway
Framed tube		30–80 storeys	5–7	Deep column and beam sections stiffen frame so that it can behave like a perforated tube
Diagonal truss tube		60–110 storeys	5–7	Diagonals take horizontal and vertical loads and stiffen frame

Table XLVII Steel–below ground

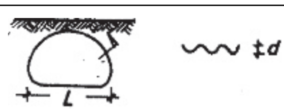
Element	Section	Typical spans (L) (m)	Typical L/d	Remarks
Steel corrugated shells		2–8	30–80	Pipe arches usually made from galvanised cold-formed steel sheets with corrugations about 50–100 mm deep and bolted together with high-strength bolts Compression in sheet depends on soil and depth of cover

Table XLVIII Steel – elements carrying gravity load

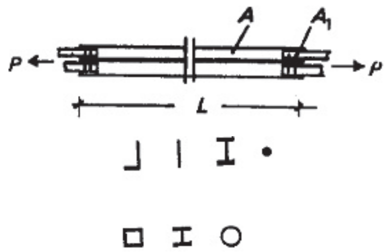
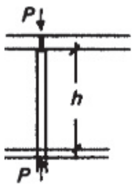
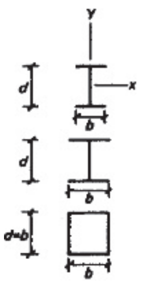
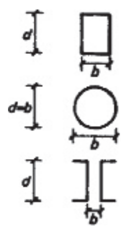
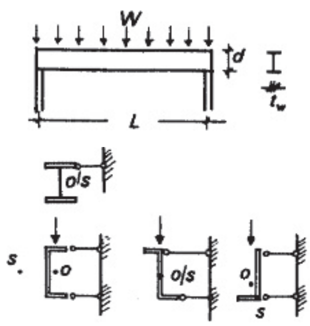
Element	Section and elevation on element or plan	Formulae for preliminary sizing only – elastic theory	Remarks
Tie		$\frac{P}{A_1} < p_1$ where P is unfactored value of tie force A_1 is net area of tie p_1 is allowable working stress of steel in tension = 110 N/mm^2 $\frac{L}{r_{min}} < 240$ where r_{min} is minimum radius of gyration of tie section L is length of tie between supports Extension $e = \frac{P.L}{A.E}$ should be checked where A is gross area of tie E is elastic modulus of steel = 2.1×10^5 N/mm^2	At bolted connections, area of tie is reduced by holes and this is the net area, A_1 Area of tie usually decided by connection detail and need to limit extension If connection points markedly eccentric to centroid of tie, area of tie may need to be increased Increasing the width of the joint, whether bolted or welded, increases strength more than increasing overlap of joint Joints subject to alternating tension and compression need special consideration to prevent fatigue
Column	 r_y/b = r_x/d = 0.22 0.38 0.25 0.42 0.38 0.38  r_y/b = r_x/d = 0.41 0.35 0.35 0.35 0.60 0.35 	$\frac{P}{A_1} < p_c$ where P is axial load in column A is area of column P_c is allowable working stress of steel in compression which depends on slenderness ratio h_{ef}/r_{min} see below, where h_{ef} is effective height of column; slenderness ratio must not exceed 200 and should normally be less than 180 $\frac{h_{ef}}{r_{min}}$ = p_c = 10 150 N/mm^2 50 120 N/mm^2 80 100 N/mm^2 150 40 N/mm^2 200 20 N/mm	Dimension b is width of column along x-axis, d is depth of column along y-axis and c is width of column at right angles to v-axis (axis of minimum moment of inertia and radius of gyration) For buildings which are laterally braced for example by cross-bracing or cores, effective height of columns, h_{ef} is not greater than actual height between floors h. Given formula valid for columns carrying axial load; for columns carrying bending moment as well as axial load Steel columns are usually slender and more efficient use of column material is had by collecting loads into one rather than several columns; an efficient section shape for each individual column is one with a low value of A/r_{min}^2, e.g. A/r_{min}^2 for square or circular sections varies from 0.8 to 2.5 and for 1-sections varies from 2 to 7
Simply supported rolled steel beam		$\frac{M}{Z} = f_{bc} < p_{bc}$ where M is unfactored value of bending moment on beam Z is the section modulus of the beam P_{bc} is allowable working stress of steel in bending = 165 N/mm^2 $\Delta = \frac{5W.L^3}{384E.I} = \frac{5f_{bc}.L^2}{24E.d}$ where W is u.d. load on beam L is span Δ is midspan deflection I is moment of inertia of beam E is elastic modulus of steel = 2.1×10^5 N/mm^2 f_{bc} is actual bending stress in beam at midspan Typical maximum span to depth ratios, L/d, are 28 for roof purlins 25 for roof beams in flat roofs 22 for floor beams giving total dead and live load deflections $\Delta = L/220$, $L/250$ and $L/280$, respectively, if beam fully stressed, from above formula If live load deflection limited to $L/360$ then $E.I > 3.98\,W_l.L^2$ where W_L is u.d. live load on beam $\frac{V}{d.t_w} < p_v$ where V is unfactored value of shear force on beam t_w is the thickness of web of beam P_v is allowable working stress of steel in shear = 105 N/mm^2	Given allowable stress in bending p_{bc} assumes top flange restrained against buckling, and horizontal forces if any, with maximum distance between lateral restraints = $85r_{min}$; if distance between restraints = $150r_{min}$ then P_{bc} = 100 N/mm^2, where r_{min} is minimum radius of gyration of top flange spanning between any lateral restraints Steel sections symmetrical about the y-axis have shear centre (O) in vertical line with centroid of section (S) for sections not symmetrical about y-axis, loading along vertical line through centroid requires lateral restraint to prevent twist and/or lateral deflection of the section e.g. channel sections twist, Z-sections deflect laterally and angle sections twist and deflect laterally without such restraints; normally restraints provided by floor or roof construction Bending moment in middle of beam, M, = $W.L/8$ and shear force at supports = $W/2$

Table XLVIII (Continued)

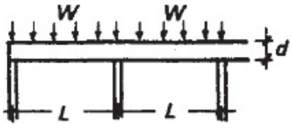
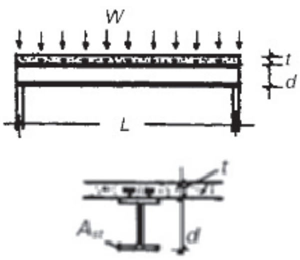
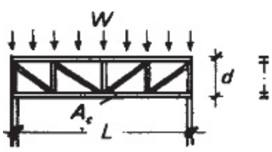
Element	Section and elevation on element or plan	Formulae for preliminary sizing only – elastic theory	Remarks
Continuous rolled steel beam		$\frac{M}{Z} = f_{bc} < p_{bc}$ where M is unfactored value of bending moment on beam Z is the section modulus of the beam p_{bc} is allowable working stress of steel in bending = 165 N/mm^2 $\Delta = \frac{5f_{bc}.L^2}{24E.d}$ or less where L is span of beam Δ is midspan deflection E is elastic modulus of steel = 2.1×10^5 N/mm^2 f_{bc} is actual bending stress in beam at midspan $\approx \frac{1}{Z}\left(M_S - \frac{M_A + M_B}{2}\right)$ where M_S is $W.L/8$, M_A and M_B are moments at supports, all at unfactored values, W is u.d. load on beam, Z is section modulus of beam $\frac{V}{d.t_w} < P_V$ where V is unfactored value of shear force on beam t_w is the thickness of web of beam p_v is the allowable working stress of steel in shear = 105 N/mm^2	Assuming W is total u.d. load on each span, all spans are equal and dead load is greater than live load, bending moment in span of beam, M_t, = $W.L/12$ and bending moment at interior supports = $W.L/9$ except first interior support for which bending moment = $W.L/8$ Shear at supports $V = 0.6\,W$ Notes on allowable stress and unsymmetrical sections as for simply supported beams
Simply supported composite steel and concrete beam		$\frac{M}{A_{st}\,(0.5\,d + 0.8\,t)} < p_t$ and $\frac{M_d}{Z_{st}} < P_{bc}$ where M is unfactored value of total bending moment on beam $\frac{M}{Z_{comp}} < P_{bc}$ where $\frac{Z_{comp}}{Z_{st}} < 1.35 + 0.35M_t/M_d$ and M_t is unfactored value of bending moment due to live load $\Delta_d = \frac{5W_d, L^3}{384E.l_{st}}$ and $\Delta_t \approx \frac{5r.W_t, L^3}{384E.l_{st}}$ where r has a value between 0.3 and 0.5	Typical values of $\frac{L}{t + d}$ are 24 or 20 for those with vibration Given formulae assume that steel beam is not propped during construction and carries dead load alone but the live load is carried by composite action M_d is unfactored value of bending moment due to dead load A_{st}, Z_{st} and d are area, section modulus and depth of steel beam and t is depth of concrete slab P_t and P_{bc} are allowable working stresses for steel in tension = 125 N/mm^2 and for steel in bending = 165 N/mm^2 Z_{comp} is section modulus of composite section Δ_d and Δ_t are deflection due to dead and live loads W_d and W_t are unfactored values of dead and live u.d. load on span l_{st} is the moment of inertia of the steel section
Simply supported truss		$\frac{M}{d.A_v} < p_c$ where M is unfactored value of bending moment on truss at midspan A_v is area of top or bottom chord of truss at midspan d is depth of truss between chord centre lines P_c is allowable working stress of steel in compression ≈ 150 N/mm^2 $\Delta \approx \frac{10W.L^3}{384E.l}$ where l is moment of inertia of top and bottom chords about centreline of truss = $A_c.d^2/2$ If live load deflection limited to $L/360$ then $E.l > 7.96\ W_t.L^2$ Economic value of L/d = 10–14	Given formulae apply to trusses with top chord restrained against buckling Forces in truss members largely axial and are checked under tension or compression Deflection in truss is greater than that of beam with same moment of inertia because of shear deflection in truss due to change in length of diagonal and vertical members

Table XLVIII (Continued)

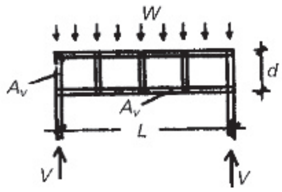
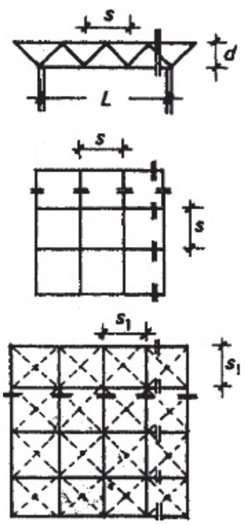
Element	Section and elevation on element or plan	Formulae for preliminary sizing only – elastic theory	Remarks
Simply supported vierendeel girder		$\frac{M}{d.A_v} < p_c$ where M is unfactored value of bending moment on girder at midspan A_v is area of top or bottom chord of girder at midspan d is height of girder between chord centre lines equal to horizontal panel dimension $\frac{V}{2A_v} + \frac{M}{Z} < P_c$ where A is area of vertical member above support and of adjacent top and bottom chord members M_v is unfactored value of bending moment on end chords and verticals = $V.d/4$ where V is equal to vertical reaction at each support Economic value of L/d = 6–10	Given formulae apply to gender with top chord restrained against buckling Members in vierendeel girder subject to shear forces, axial forces and bending moments; although vierendeel girder inefficient form becomes relatively more efficient with increase in size Estimate of deflection of truss established by frame analysis of girder taking account of flexibility of members in bending and shear
Double layer space frame		Economic value of $\frac{L}{d} < 15$ for space frame supported at corners or $\frac{L}{d} < 20$ for space frame supported around perimeter where L is span and d is depth of frame $s \approx \sqrt{2}d$ to $2d$ and $s \approx L/10$ for L up to 50 m or $s \approx L/10$ to $L/15$ for L above 5 m where s is module size of bottom layer of frame $s_1 = s$ to $\frac{s}{\sqrt{2}}$ where s_1 is module size of top layer of frame	Wide variations in span to depth ratios from those given are possible The number of joints and members in a space frame is proportional to the inverse of the square of the module size; therefore economy of space frame increased by larger number of supports, moderate span to depth ratio as well as by larger module size

Table XLIX Structural glass elements

Element	Typical spans	Typical thickness	Critical factors for sizing	Remarks
Floor panels Stairs	1–4 m		User sensitivity to deflections	Susceptible to flaws and surface scratching Use edge supported laminated glass
Balustrades	1.1 m cantilever	12–25 mm		Cantilevered with continuous or point fixings at support
Walls			Elastic stability Consider safety implications on failure	
Beams and fins	4–6 m		Deflections and elastic stability	Simply supported or cantilevered. Length of available glass sheet determines maximum span

depth has been reached, reinforcement is lowered into the hole and concrete is poured in. Some method of compacting the concrete is employed, so that all cavities in the ground are properly filled. The sleeve is withdrawn as the concrete goes in, to ensure intimate contact between pile and soil, **36.21**.

The capacity of this type of pile is not self-evident as in the case of driven piles. Calculation is used to determine the length of pile required, based on the shear strength of the clay at various depths below the ground. Parameters for soil properties are gained by carrying out a site investigation prior to the design.

While the calculations themselves are not particularly difficult, the subject is one where engineering judgment is required in their interpretation. It is recommended that this type of pile should be designed by the specialist piling contractor and checked by the consulting engineer, with adequate supervision and testing on site to ensure that the pile is suitable for the design loads.

10.08 Pile testing

In both driven and bored piles, it is usual to carry out one or more tests on the actual piles on each contract. On very large contracts, additional piles are tested to failure, but normally one of the working piles is loaded to 1.5 times the working load to prove the efficacy of the design. These maintained load static tests are

Table L Properties of structural plastic

Property	Polyester resin (thermoset.)	Polyester with chopped strand glass mat	Polyester with woven glass rovings	Polyester with glass unidirectional reinforced glass rovings epoxy		Polycarbonate (thermopl.)	Acrylic (thermopl.)
Glass content by weight %	nil	25–50	50	60	60		
Weight kN/m^3	12	15	18	19	21	12	12
Short-term tensile strength at 20°C N/mm^2	40–80	80–175	210–250	660	350–550	60	50–70
Short-term flexural strength at 20°C modulus of rupture (N/mm^2)	50–90	125–210	220–300	700	500–825	80	90–100
Short-term elastic modulus in bending in direction of fibres at 20°C(68°F)	2–5	6–10	15	30	35	2.6	3.2
Fracture toughness at 20°C MN/m$^{3/2}$	0.5	10–20	10–30	10–40	40–50	1–2	1–1.5
Long-term tensile strength (10 years) at 20°C put as proportion of short-term strength		0.5	0.5	0.5	0.5–0.65	0.20	0.25
Shrinkage %	0.004–0.080						
Water adsorption over 24 h %	0.15–0.60		0.20	0.15	0.30–0.40		
Coefficient of thermal expansion × 10^{-6}/°C	100–180	20–30	10–15	10–15	10–15	70	60–70
Softening temperature or maximum operating temperature °C	70	70	70	70	110	120	75
Visible effect of weathering	yellows	yellows	Yellows	yellows	no effect	yellows and becomes brittle	no effect

Table LI Plastics – roofs, surface

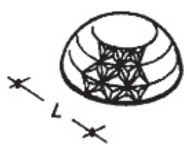
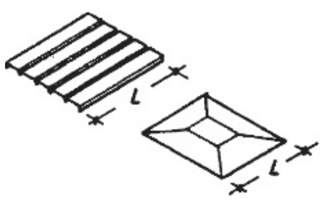
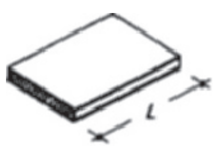
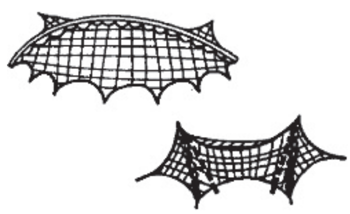
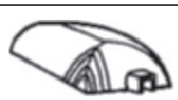
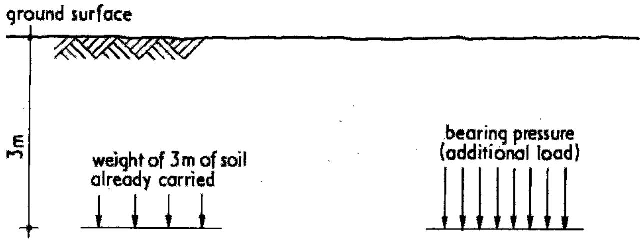
Element	Axonometric	Typical spans (L) (m)	Critical factors for sizing	Remarks
Domes using shaped panels		5–20	Thickness affected by size and shape of panel	Domes may have rectangular or circular base Made by bolting together shaped panels Plastic panels typically 2–6 mm thick but thicker than this at edges
Folded plate structures using shaped panels		5–20	Thickness affected by size and shape of panel	Made by bolting together two or three different types of shaped panel Panels may be double skin with insulation between
Shaped roof panels		1–5	Deflection	Panels must be shaped or have stiffeners to overcome flexibility
Laminated panel		4–6	Deflection	Made from good quality grp with 40–60 mm insulation between skins Used for roofs but also as load-bearing panels and for floors in two or three storey buildings of small plan area

Table LII Properties of fabric

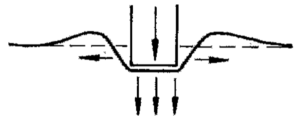
Property	PVC-coated polyester fabric	PTFE-coated glass fabric	Silicone-coated glass fabric	Neoprene-coated nylon fabric
Weight of fabric yarn kN/m^3	13.5	25.0	25.0	11.2
Short-term tensile strength of fabric yarn N/mm^2	1100	1500–2400	1500–2400	500–960
Tenacity N/tex short-term strength to linear density in tex of fabric yarn	0.90	1.10	1.10	0.95
Elastic modulus of fabric yarn kN/mm^2	14	65	65	6
Elastic modulus to linear density of fabric N/tex	12	30	30	5
(a tex is the mass in gm of 1 km of yarn)	12	30	30	5
Weight of a typical fabric N/m^2 – Warp direction – Weft (fill) direction	8 (0.7 mm thick) 1800 (0.7 mm thick) 1700	15 (1 mm thick) 6500 (1 mm thick) 5500	11 (0.9 mm thick) 6500 (0.9 mm thick) 6000	7 (0.8 mm thick) 2000 (0.8 mm thick) 1600
Long-term tensile strength of Coated Fabric (2 years) under	0.5	0.6	0.6	–
Tear strength of fabric N – Warp direction – Weft (fill) direction	 300 (0.7 mm thick) 350	 270 (1 mm thick) 350	 400 (0.9 mm thick) 450	 500 (0.8 mm thick) 700
Elongation of fabric % – Warp direction – Weft (fill) direction	 14 20	 6 7	 5 5	 25 30
Shear strength of fabric N/degree	small	450 (1 mm)	–	small
Combustibility of untreated fabric	flammable	hardly flammable	hardly flammable	flammable
Durability years	10–15	25	25	8–12

Table LIII Fabric – roofs

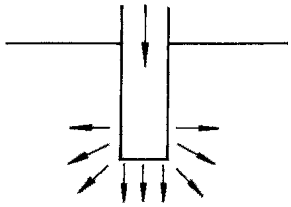
Element	Axonometric	Typical spans (L) (m)	Typical curvatures (m)	Critical factors for sizing	Remarks
Fabric tent		9–18	25–35	Radius of curvature Tear strength	Surface of tent has anticlastic (saddle) shape at each point and is prestressed Typical prestress in fabric 5–10 kN/m Prestress determined by loads and curvature.
Cable reinforced fabric tent		18–60	80–100	Tear strength of fabric, spacing of cables, radius of curvature and wind and snow loads	Surface of tent has anticlastic shape and is prestressed by pulling on cables Prestress in fabric and cables determined by loads and curvature.
Prestressed steel net with fabric covering		25–100	–	Radius of curvature Wind or snow load	Size of cable mesh about 500 × 500 mm Surface of net has anticlastic shape Typical average stress in net 40–60 kN/m High strength of net allows large radius of curvature
Air-supported membrane		15–45	–	Radius of curvature Tear strength Wind or snow loads	Inflation pressure low Surface of membrane has synclastic (dome shape at each point and is prestressed.
Cable stayed air supported membrane		90–180	80–100	Tear strength of fabric, spans, spacing of cables and snow loads	Cables anchored to ring beam that has funicular shape Low rise of roof gives wind uplift on it
Pneumatic frame (prestressed tube)		6–45	–	Tear strength Shape and diameter of tube Wind or snow loads	Tubes require large diameters and high pressures to achieved sufficient stiffness



36.13 *Bearing pressure on formation level of soil*



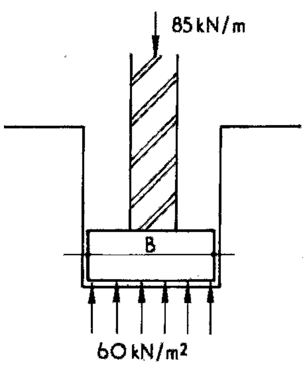
36.14 *Shallow foundation carrying excessive load can cause heave*



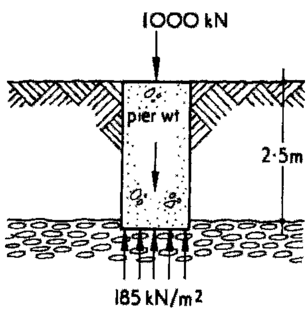
36.15 *A deeper foundation is restrained*

Table LIV Presumed allowable bearing values under static loading (Ref BS 8004 table 1)

Group	Types of rocks and soils	Presumed allowable bearing value kN/m^2	Remarks
Rocks	Strong igneous and gneissic rocks in sound condition	10 000	These values are based on the assumption that the foundations are carried down to unweathered rock
	Strong limestones and strong sandstones	4000	
	Schists and slates	3000	
	Strong shales, strong mudstones and strong siltstones	2000	
Non-cohesive soils	Dense gravel, or dense sand and gravel	> 600	Width of foundation (B) not less than 1 m
	Medium dense gravel, or medium dense sand and gravel	200–600	Ground-water level assumed to be a depth not less than B below the base of the foundation
	Loose gravel, or loose sand and gravel	< 200	
	Compact sand	> 300	
	Medium dense sand	100–300	
	Loose sand	< 100	
Cohesive soils	Very stiff boulder clays and hard clays	300–600	Susceptible to long-term consolidation settlement
	Stiff clays	150–300	
	Firm clays	75–150	
	Soft clays and silts	< 75	
	Very soft clays and silts	Not applicable	
Peat and organic soils		Not applicable	
Made ground or fill		Not applicable	



36.16 *Width of a strip foundation, section (Example 1)*

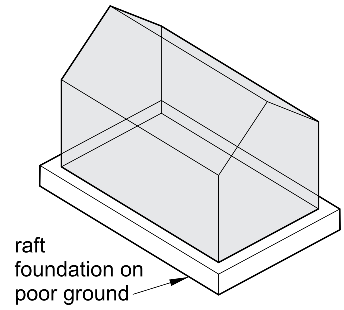


36.17 *Concrete pier of gravel layer (Example 2)*

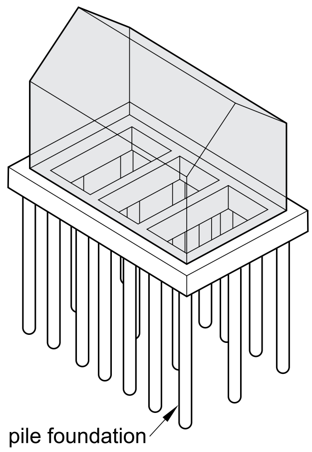
expensive and time consuming, requiring the use of large concrete blocks (kentledge) or the installation of tension piles against which a jacking load can be applied to the test pile. Other, more rapid methods of testing by measuring the dynamic response of the pile to a hammer strike at the pile head can be employed, but engineering judgement is required to determine the correct regime and method/methods of test required.

10.09 Under-reamed piles

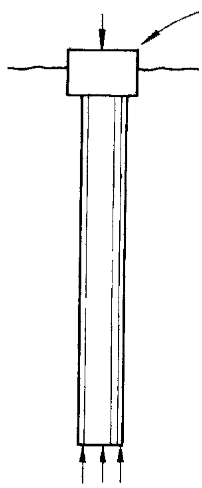
There is a third type of pile which is a bored end-bearing pile. The shaft is augured in the usual way, but when the required depth has been reached a special tool is used to enlarge the base to a bell-shape, **36.23**. These piles are substantial in size, and remote inspection of the base must be carried out to check the integrity of the soil on which the load will rest. It is not often possible to test this type of pile using static methods due to the magnitude of the loads carried.



36.18 *Raft foundation as used on poor ground*



36.19 *Alternative pile foundation*



36.20 *End-bearing pile*

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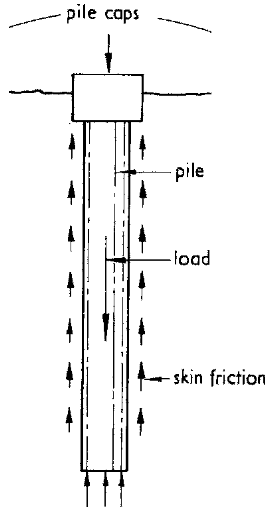
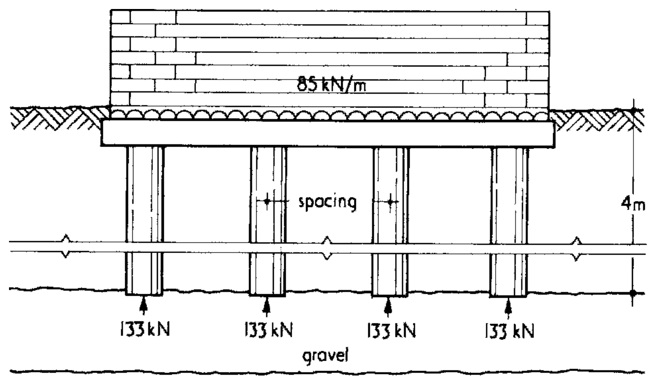
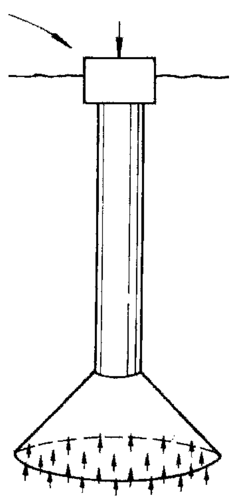


36.21 *Friction pile*



36.22 *Short-bored piles (Example 3)*



36.23 *Under-reamed pile*

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37 Materials

CI/Sfb: Ya

Arthur Lyons

Dr Arthur Lyons authors texts on building materials; he recently retired from the Leicester School of Architecture, Faculty of Art and Design, De Montfort University, Leicester, UK

KEY POINT:

- *Standards and specifications are constantly changing, always refer to current regulations and manufacturers' details.*

Contents

1 INTRODUCTION

The majority of construction materials are supplied to metric dimensions; however, a few materials still retain their imperial designations. Where appropriate, the listings are taken from British and European Standards or trade organizations and will therefore not necessarily correspond to the full ranges offered by individual suppliers. Inevitably, changes in published Standards and Building Regulations will occur, affecting availability of particular products. Specifiers are, therefore, always advised to check current availability and delivery times.

2 STEEL

2.01 General

BS 6722: 1986 defines the recommended dimensions for ferrous and non-ferrous metal wires, bars and flat products. These preferred dimensions are listed in Tables I and II.

Table I Recommended thicknesses (mm) for ferrous and non-ferrous metal bars and flat products (BS 6722: 1986)

0.10, *0.11*, 0.12, *0.14*, 0.16, *0.18*, 0.20, *0.22*, 0.25, *0.28*, 0.30, *0.35*, 0.40, *0.45*, 0.50, *0.55*, 0.60, *0.70*, 0.80, *0.90*, 1.0, *1.1*, 1.2, *1.4*, 1.6, *1.8*, 2.0, *2.2*, 2.5, *2.8*, 3.0, *3.5*, 4.0, *4.5*, 5.0, *5.5*, 6.0, *7.0*, 8.0, *9.0*, 10.0, *11.0*, 12.0, *14.0*, 16.0, *18.0*, 20.0, *22.0*, 25.0, *28.0*, 30.0, *35.0*, 40.0, *45.0*, 50.0, *55.0*, 60.0, *70.0*, 80.0, *90.0*, 100.0, *110.0*, 120.0, *140.0*, 160.0, *180.0*, 200.0, *220.0*, 250.0, *280.0*, 300.0

Note: First preference ordinary type, second preference italics.

Table II Recommended widths and lengths (mm) for ferrous and non-ferrous metal flat products (BS 6722: 1986)

400, 500, 600, 800, 1000, 1200, 1250, 1500, 2000, 2500, 3000, 4000, 5000, 6000, 8000, 10 000.

Table III Cold reduced mild steel sheet

Thickness (mm)	0.6	0.8	0.9	1.0	1.2	1.25	1.5	1.6	2.0	2.5	3.0
Mass (kg/m^2)	4.71	6.28	7.07	7.85	9.42	9.62	11.78	12.56	15.70	19.63	23.55

Note: Stock range from Corus
Standard sheet sizes are 2000 × 1000, 2500 × 1250 and 3000 × 1500 mm.

2.02 Steel sheet, plate and bars

Cold reduced mild steel sheet is produced with standard thickness ranging from 0.6 to 3.0 mm (Table III). Hot rolled sheet (< 3 mm) and plate ($\geq$ 3 mm) is produced with a range from 1.5 to 250 mm (Table IV). Standard sheet sizes are given in the tables.

Steel bars – flats, rounds, squares and hexagons: The standard sizes for flats, rounds and squares are given in Tables V–VII, respectively.

The standard BS EN 10061: 2003 gives the preferred dimensions for hot rolled hexagon bars (Table VIII); however, standard stock is in the range 7–75 mm.

2.03 Structural steel sections

Most steel sections of British origin are still based on the old imperial sizes although sized in metric dimensions and billed in kilograms or tonnes. Tables IX–XI summarise the standard dimensions, but it should be noted these are quoted as nominal sizes and that exact dimensions should be verified from manufacturers' data. Tolerances on nominal dimensions for joists and channels are given in BS 4-1: 2005, and for I and H sections in BS EN 10034: 1993. Some structural steel sections, listed in Table XII, are made in metric co-ordinated sizes, and these are also available from the continent.

Structural steel hollow sections: Structural hollow sections may be hot finished or cold formed. Hot finished structural steel hollow sections are manufactured in either 275 or 355 MPa minimum yield strength steel (S275J2H or S355J2H, respectively) to BS EN 10210: 2006. Cold formed sections, produced in both 235 and 355 MPa minimum yield strength steel, are limited to thicknesses of 8 and 16 mm, respectively. Hot finished hollow structural steel is available as square, rectangular, circular and oval sections. Cold formed hollow structural steel is available as square, rectangular and circular sections.

The standard BS EN 10210-2: 2006 covers hot finished sections to the following maximum sizes: circular – outside diameter 2500 mm, square – outside dimensions 800 × 800 mm, rectangular – outside dimensions 750 × 500 mm and elliptical – outside dimensions 500 × 250 mm, although not all section sizes are fully described in the standard.

2.04 Steel alloys

Weather-resistant steel: Weather-resistant steels (BS 7668: 2004) are structural steels alloyed with a small proportion of copper, which together with other alloying constituents has the effect of making the natural rust adhere tenaciously to the surface to prevent further loss by spalling. The design detailing of weathering steel (*Cor-Ten®*), must ensure that rainwater run-off does not cause staining to adjacent materials, particularly concrete and glass, during the first few years of exposure to rain. Also detailing should ensure no entrapment of pockets of water or damp debris to prevent continuing corrosion at these locations. Weather-resistant steel has been used for exposed structures in buildings, bridges and as a cladding material.

Stainless steel: Stainless steels are a range of alloys containing at least 10.5% chromium. The corrosion resistance of the material is due to the natural passive film of chromium oxide, which is naturally regenerated if the surface is scratched. The grades of stainless steel

Table IV Hot rolled steel sheet and plate

Thickness (mm)	1.6	2.0	2.5	3.0	4.0	5.0	6.0	8.0	10.0	12.5	15	20	25	30
Mass (kg/m^2)	12.6	15.7	19.6	23.6	31.4	39.6	47	63	79	98	118	157	196	236
Thickness (mm)	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Mass (kg/m^2)	275	314	353	393	432	471	510	550	589	628	667	707	746	785
Thickness (mm)	105	110	115	130	135	140	150	160	180	200	250			
Mass (kg/m^2)	864	903	942	1021	1060	1099	1178	1256	1413	1570	1963			

Note: Stock range from Corus.
Standard sheet sizes are 2000 × 1000, 2500 × 1250, 3000 × 1500, 4000 × 1750, 4000 × 1830, 4000 × 2000, 5000 × 2500, 6000 × 1500, 6000 × 2000, 6000 × 3000, 8000 × 2000, 9000 × 2000, 10 000 × 2500 and 12 000 × 2500 mm.
Tolerances on dimensions and shape for hot rolled narrow steel strip are given in BS EN 10048: 1997, for sheet, plate and strip in BS EN 10051: 1991 and for plate over 3 mm in BS EN 10029: 1991.

Table V Hot rolled flats

Width (mm)	**Thickness (mm)**																	
	3	**4**	**5**	**6**	**8**	**10**	**12**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**60**	**65**	**75**
10	×																	
12	×																	
13	×	×	×	×														
15	×	×	×															
16	×	×	×		×	×												
20	×	×	×	×	×	×	×											
22	×		×			×												
25	×	×	×	×	×	×	×	×	×									
30	×	×	×	×	×	×	×	×	×	×								
35	×	×	×	×	×	×	×	×										
40	×	×	×	×	×	×	×	×	×	×	×							
45	×	×	×	×	×	×	×	×	×	×	×							
50	×	×	×	×	×	×	×	×	×	×	×		×					
55			×	×	×	×	×	×	×	×	×							
60	×	×	×	×	×	×	×	×	×	×	×	×	×					
65	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			
70	×		×	×	×	×	×	×	×	×	×		×		×			
75	×	×	×	×	×	×	×	×	×	×	×		×		×	×	×	
80	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	
90	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			
100	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
110	×		×	×	×	×	×		×	×	×		×	×	×			
120			×	×	×	×	×	×	×	×	×							
130	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×		×
140				×	×	×	×	×	×	×	×							
150	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×	×	×
160						×	×		×	×								
180			×	×	×	×	×	×	×	×	×		×		×			
200		×		×	×	×	×	×	×	×	×		×	×	×			×
220			×	×	×	×	×	×	×	×	×		×		×			
250				×	×	×	×	×	×	×	×		×	×	×			
275				×	×	×	×											
300						×	×	×	×	×	×		×	×	×	×		
350						×	×	×	×	×	×		×					
375							×	×	×	×	×		×					
400						×	×	×	×	×	×		×					
450							×	×	×	×								

Note: Stock range from Corus.
Tolerances on dimensions and shape for flat steel bars are given in BS EN 10058: 2003.

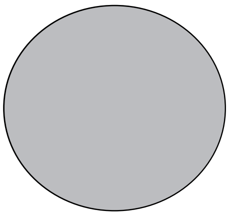
for construction are listed in Table XIII (BS EN 10088-1: 2005). Stainless steel is available in hollow and standard sections for structure and in sheet form for cladding, roofing and trim.

2.05 Coated steels

The range of metal-coated steels includes traditional hot-dip galvanized steel, aluminium–zinc alloy- and terne-coated steels. The durability of galvanized steel is dependent on the thickness of the coating and the environment, also the avoidance of contact with other metals particularly copper and the alkalis in wet mortar and plaster. Aluminium–zinc alloy coating is more durable than the equivalent thickness of pure zinc. Terne, an alloy of lead and tin, hot-dipped onto either steel or stainless steel, produces a durable cladding and roofing material. Lead–clad steel is a laminate of lead on terne-coated or stainless steel. It offers a durable, self-supporting roofing or cladding system in which joints can be soldered or lead burned.

The predominant organic coatings (*Colorcoat*®) to steel are polyvinyl chloride plastisol (PVC[P]), polyvinylidene fluoride (PVDF) and polyurethane on zinc–aluminium alloy or zinc-coated steel. PVC[P] has a leather grain finish, PVDF has a smooth finish with good colour stability and polyurethane offers colour and metallic gloss finishes. The products are available in a wide range of colours for use in roofing, cladding and interior finishes. Other organic finishes include polyester coating and patterned or textured polyvinyl chloride (PVC) film.

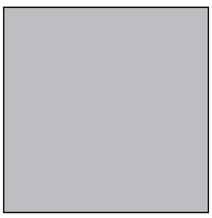
Table VI Rounds



Diameter (mm)	Mass/ length (kg/m)	Diameter (mm)	Mass/ length (kg/m)	Diameter (mm)	Mass/ length (kg/m)
6	0.22	75	34.70	160	158.0
8	0.39	80	38.50	165	168.0
10	0.62	85	44.50	170	178.0
12	0.89	90	49.90	180	200.0
13	1.04	95	55.60	185	211.0
15	1.39	100	61.70	190	223.0
16	1.58	105	68.00	195	234.0
20	2.47	110	74.60	200	247.0
22	2.98	115	81.50	210	272.0
25	3.85	120	88.00	220	298.0
30	5.55	125	96.30	230	326.0
35	7.55	130	104.0	240	356.0
40	9.86	135	112.0	250	385.0
45	12.50	140	121.0	260	417.0
50	15.41	145	130.0	270	448.0
60	22.20	145	130.0	275	466.0
65	26.00	150	139.0	280	483.0
70	30.20	155	148.0	300	555.0

Note: Stock range from Corus.
Tolerances on dimensions and shape for round steel bars are given in BS EN 10060: 2003.

Table VII Squares



Side length (mm)	Mass/length (kg/m)
8.0	0.50
10.0	0.79
12.0	1.13
15.0	1.77
16.0	2.01
20.0	3.14
25.0	4.91
30.0	7.07
35.0	9.62
40.0	12.6
45.0	15.9
50.0	19.6
60.0	28.3
65.0	33.2
75.0	44.2

Note: Stock range from Corus.
Tolerances on dimensions and shape for square steel bars are given in BS EN 10059: 2003.

2.06 Steel reinforcement for concrete

For details of sizes of these refer to Chapter 41, Structure.

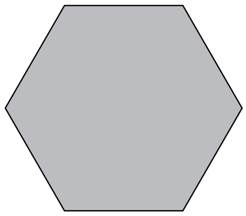
Concrete should be specified to BS EN 206-1: 2000, and steel reinforcement to BS 4449: 2005 (bar/coil and decoiled steel), BS 4482: 2005 (steel wire) and BS 4483: 2005 (steel fabric).

3 TIMBER

3.01

Timber used in building is either softwood or hardwood, depending on species; each may be supplied sawn or finished. Sizes are usually quoted 'ex', meaning the sawn size. Structural timber is

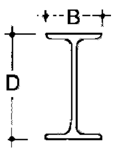
Table VIII Hexagons (BS EN 10061: 2003)



Width across flats (mm)	Mass/length (kg/m)	Width across flats (mm)	Mass/length (kg/m)
13	1.15	37.5	9.56
14	1.33	39.5	10.6
15	1.53	42.5	12.3
16	1.74	47.5	15.3
17	1.96	52	18.4
18	2.20	57	22.1
19	2.46	62	26.1
20.5	2.86	67	30.5
22.5	3.44	72	35.2
23.5	3.75	78	41.4
25.5	4.42	83	46.8
28.5	5.52	88	52.6
31.5	6.75	93	58.8
33.5	7.63	98	65.3
35.5	8.56	103	72.1

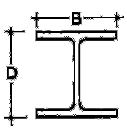
Note: Standard stock range is from 7 to 75 mm.
Tolerances on dimensions and shape for hexagon steel bars are given in BS EN 10061: 2003.

Table IX British Standard structural steel sections to BS4: Part 1: 2005



Universal beams (BS4: Part 1: 2005)

Nominal dimensions (mm)	Standard mass per unit length (kg/m)
914 × 419	388, 343
914 × 305	289, 253, 224, 201
838 × 292	226, 194, 176
762 × 267	197, 173, 147, 134
686 × 254	170, 152, 140, 125
610 × 305	238, 179, 149
610 × 229	140, 125, 113, 101
533 × 210	122, 109, 101, 92, 82
457 × 191	98, 89, 82, 74, 67
457 × 152	82, 74, 67, 60, 52
406 × 178	74, 67, 60, 54
406 × 140	46, 39
356 × 171	67, 57, 51, 45
356 × 127	39, 33
305 × 165	54, 46, 40
305 × 127	48, 42, 37
305 × 102	33, 28, 25
254 × 146	43, 37, 31
254 × 102	28, 25, 22
203 × 133	30, 25
203 × 102	23
178 × 102	19
152 × 89	16
127 × 76	13

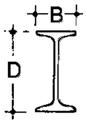


Universal columns (BS4: Part 1: 2005)

Nominal dimensions (mm)	Standard mass per unit length (kg/m)
356 × 406	634, 551, 467, 393, 340, 287, 235
356 × 368	202, 177, 153, 129
305 × 305	283, 240, 198, 158, 137, 118, 97
254 × 254	167, 132, 107, 89, 73
203 × 203	86, 71, 60, 52, 46
152 × 152	37, 30, 23

Table IX (Continued)

Nominal dimensions (mm)	Standard mass per unit length (kg/m)



Joists with taper flanges (BS4: Part 1:2005)

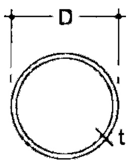
254 × 203	82
254 × 114	37
203 × 152	52
152 × 127	37
127 × 114	29, 27
127 × 76	16
114 × 114	27
102 × 102	23
102 × 44	7
89 × 89	19
76 × 76	15, 13

Universal bearing piles (BS4: Part 1: 2005)

356 × 368	174, 152, 133, 109
305 × 305	223, 186, 149, 126, 110, 95, 88, 79
254 × 254	85, 71, 63
203 × 203	54, 45

Tolerances on dimensions and shape for structural steel I and H sections are given in BS EN 10034: 1993 and for taper flange I sections in BS 10024: 1995.

Table X Structural hollow sections

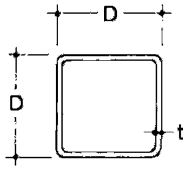


Circular structural hollow sections (BS EN 10210-2: 2006)

Nominal external diameter (mm)	Thickness (mm)
1219	*25, 20, 16, 14.2, 12.5, 10*
1168	*25, 20, 16, 14.2, 12.5, 10*
1067	*30, 25, 20, 16, 14.2, 12.5, 10*
1016	*30, 25, 20, 16, 14.2, 12.5, 10, 8*
914	*30, 25, 20, 16, 14.2, 12.5, 10, 8*
813	*30, 25, 20, 16, 14.2, 12.5, 10, 8*
762	*50, 40, 30, 25, 20, 16, 14.2, 12.5, 10, 8, 6.3*
711	*60, 50,* 40, 36, 32, *30,* 28, *25, 20, 16, 14.2, 12.5, 10, 8, 6.3*
660	40, 36, 32, 28
610	*50,* 40, 36, 32, *30,* 28, *25, 20, 16, 14.2, 12.5, 10, 8, 6.3*
508	*50,* 40, 36, 32, *30,* 28, 25, 22, *20,* **16**, 14.2, **12.5**, **10**, 8, 6.3
457	40, 36, 32, *30,* 28, 25, 22, *20,* **16**, 14.2, **12.5, 10, 8**, 6.3
406.4	*40, 30, 25, 20*, **16**, 14.2, **12.5, 10, 8**, 6.3
355.6	*25, 20*, 16, 14.2, 12.5, 10, 8, 6.3
323.9	*25, 20*, **16**, 14.2, **12.5, 10, 8, 6.3**, 5.0
273	*25, 20*, **16**, 14.2, **12.5, 10, 8, 6.3**, 5.0
244.5	*25, 20*, **16**, 14.2, 12.5, 10, 8, 6.3, 5.0
219.1	*20*, 16, 14.2, 12.5, **10, 8, 6.3, 5.0**
193.7	*16, 14.2*, 12.5, **10, 8, 6.3, 5.0**
177.8	*12.5, 10, 8, 6.3, 5.0*
168.3	12.5, **10, 8, 6.3, 5.0**, *4.0*
139.7	*12.5*, **10, 8, 6.3, 5.0**, 4.0, 3.6, 3.2
114.3	*10, 8,* **6.3, 5.0**, 4.0, **3.6, 3.2**
101.6	*10, 8, 6.3, 5.0, 4.0, 3.2*
88.9	6.3, **5.0, 4.0**, 3.6, **3.2**, 2.9
76.1	6.3, **5.0**, 4.0, 3.6, **3.2**, 2.9, *2.6*
60.3	**5.0**, 4.0, 3.6, 3.2, 2.9, *2.6*
48.3	**5.0**, 4.0, 3.6, 3.2, 2.9, *2.6*
42.4	5.0, 4.0, 3.6, 3.2, 2.9, 2.6
33.7	4.0, 3.6, 3.2, 2.9, 2.6
26.9	3.2, 2.9, 2.6, *2.3*
21.3	3.2, 2.9, 2.6, *2.3*

Note: Not all listed sizes are readily available. Regular production sections are in bold, non-regular production sizes are in normal type and other thicknesses quoted in the Standard are in italics. Some intermediate thicknesses (2.9, 3.6, 19, 22, 28, 32, 36 mm) and diameters (660 and 559 mm) are not listed within the limited range of the Standard BS EN 10210-2: 2006.

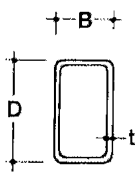
Table X (Continued)



Square structural hollow sections (BS EN 10210-2: 2006)

Nominal side dimensions (mm)	Thickness (mm)
800 × 800	60, 50, 45, 40, 36, 32, 28, 25, 22, 19, 16
750 × 750	60, 55, 50, 45, 40, 36, 32, 28, 25, 22, 19, 16
700 × 700	60, 55, 50, 45, 40, 36, 32, 28, 25, 22, 19, 16
650 × 650	60, 55, 50, 45, 40, 36, 32, 28, 25, 22, 19, 16
600 × 600	60, 55, 50, 45, 40, 36, 32, 28, 25, 22, 19, 16
550 × 550	55, 50, 45, 40, 36, 32, 28, 25, 22, 19, 16
500 × 500	50, 45, 40, 36, 32, 28, 25, 22, 19, 16, 12
450 × 450	40, 36, 32, 28, 25, 22, 19, 16, 12
400 × 400	40, 36, 32, 28, 25, 22, 20, **16**, 14.2, **12.5, 10**, 8.0
350 × 350	25, 22, 19, **16**, 14.2, **12.5, 10, 8.0**
300 × 300	**16**, 14.2, **12.5, 10, 8.0**, 6.3
260 × 260	16, 14.2, 12.5, 10, 8.0, 6.3
250 × 250	**16**, 14.2, **12.5, 10, 8.0, 6.3**, 5.0
220 × 220	*16, 14.2, 12.5, 10, 8.0, 6.3*
200 × 200	**16**, 14.2, **12.5, 10, 8.0, 6.3, 5.0**
180 × 180	**16**, 14.2, **12.5, 10, 8.0, 6.3**, 5.0
160 × 160	16, 14.2, 12.5, **10, 8.0, 6.3, 5.0**
150 × 150	16, *14.2*, **12.5, 10, 8.0, 6.3, 5.0**
140 × 140	**12.5, 10, 8.0, 6.3, 5.0**
120 × 120	**12.5, 10, 8.0, 6.3, 5.0**, 4.0
100 × 100	**10, 8, 6.3, 5.0, 4.0**, 3.6
90 × 90	**8.0, 6.3, 5.0, 4.0**, 3.6
80 × 80	**8.0, 6.3, 5.0**, 4.0, **3.6**, 3.2, 3.0
70 × 70	8.0, 6.3, **5.0**, 4.0, **3.6**, 3.2, 3.0
60 × 60	8.0, **6.3, 5.0, 4.0**, 3.6, 3.2, 3.0, *2.6*
50 × 50	**6.3, 5.0, 4.0**, 3.6, **3.2**, 3.0, *2.6*
40 × 40	**5.0, 4.0**, 3.6, 3.2, 3.0, *2.6*

Note: Regular production sections in S355J2H grade steel are in bold, non-regular production sizes are in normal type and other thicknesses quoted in BS EN 10210-2: 2006 are in italics. Some intermediate thicknesses (3.0, 3.6, 19 and >20 mm) are not listed within the limited range of the Standard BS EN 10210-2: 2006.



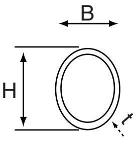
Rectangular structural hollow sections (BS EN 10210-2: 2006)

Nominal external dimensions (mm)	Thickness (mm)
700 × 500	40, 36, 32, 28, 25, 22, 19, 16
650 × 450	40, 36, 32, 28, 25, 22, 19, 16
600 × 400	40, 36, 32, 28, 25, 22, 19, 16
550 × 350	28, 25, 22, 19, 16, 12
500 × 300	20, **16**, 14.2, 12.5, **10**, 8.0
500 × 200	16, 14.2, 12.5, 10, 8.0
450 × 250	**16**, 14.2, **12.5, 10, 8.0**
400 × 300	16, 14.2, 12.5, 10, 8.0
400 × 200	**16**, 14.2, **12.5, 10, 8.0**, 6.3
400 × 150	16, 14.2, 12.5, 10, 8.0, 6.3
400 × 120	16, 14.2, 12.5, 10, 8.0, 6.3
350 × 250	16, 14.2, 12.5, 10, 8.0, 6.3
350 × 150	16, 14.2, 12.5, 10, 8.0, 6.3
300 × 250	16, 14.2, 12.5, 10, 8.0, 6.3
300 × 200	**16**, 14.2, **12.5, 10, 8.0, 6.3**, 5.0
300 × 150	16, 14.2, 12.5, 10, 8.0
300 × 100	16, 14.2, 12.5, **10, 8.0**, 6.3, 5.0
260 × 180	*16, 14.2, 12.5, 10, 8.0, 6.3*
260 × 140	16, 14.2, 12.5, 10, 8.0, 6.3, 5.0
250 × 200	14.2, 12.5, 10
250 × 150	16, 14.2, 12.5, 10, 8.0, 6.3, 5.0
250 × 100	16, 14.2, 12.5, 10, 8.0, 6.3, 5.0
200 × 150	16, 14.2, 12.5, **10, 8.0**, 6.3, 5.0
200 × 120	16, 14.2, 12.5, **10, 8.0, 6.3, 5.0**
200 × 100	16, **12.5, 10, 8.0, 6.3, 5.0**
180 × 100	*12.5, 10, 8.0, 6.3, 5.0, 4.0*
160 × 80	12.5, **10, 8.0, 6.3, 5.0, 4.0**
150 × 125	12.5, **10**, 8.0, 6.3, 5.0, 4.0
150 × 100	12.5, **10, 8.0, 6.3, 5.0**, 4.0
120 × 80	**10, 8.0, 6.3, 5.0**, 4.0, 3.6

Table X (Continued)

Nominal external dimensions (mm)	Thickness (mm)
Rectangular structural hollow sections (BS EN 10210-2: 2006) *continued*	
120 × 60	10, **8.0, 6.3, 5.0**, 4.0, **3.6**
100 × 60	**8.0, 6.3, 5.0**, 4.0, 3.6, 3.2, 3.0
100 × 50	10**, 8.0, 6.3, 5.0, 4.0**, 3.6, **3.2, 3.0**
90 × 50	8.0, 6.3, **5.0**, 4.0, 3.6, 3.2, 3.0
80 × 40	8.0, 6.3, 5.0, 4.0, 3.6, 3.2, 3.0
60 × 40	6.3, 5.0, 4.0, 3.6, 3.2, 3.0
50 × 30	5.0, 4.0, 3.6, 3.2, 3.0

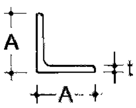
Note: Regular production sections in S355J2H grade steel are in bold, non-regular production sizes are in normal type and other thicknesses quoted in BS EN 10210-2: 2006 are in italics.



Elliptical structural hollow sections (Ovals) (BS EN 10210-2: 2006)

Nominal external dimensions (mm)	Thickness (mm)
500 × 250	**16, 12.5, 10**
480 × 240	*14, 12, 10*
400 × 200	14, **12.5**, 12, **10, 8**
320 × 160	*14, 12, 10, 8.0*
300 × 150	**16**, **12.5**, 12, **10, 8.0**
250 × 125	12.5, *12*, 10, 8, 6.3, *6.0*
220 × 110	*10, 8, 6.0*
200 × 100	12.5, **10, 8, 6.3, 5.0**
180 × 90	*10, 8, 6.0*
150 × 75	*10, 8*, **6.3**, *6.0,* **5.0, 4.0**
120 × 60	*8, 6.0, 5.9, 4.0, 3.2*

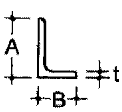
Table XI Channels and angles



Equal angles (BS EN 10056-1: 1999)

Nominal dimensions (mm)	Thickness (mm)
200 × 200	24, 20, 18, 16
150 × 150	18, 15, 12, 10
120 × 120	15, 12, 10, 8
100 × 100	15, 12, 10 8
90 × 90	12, 10, 8, 7, 6
80 × 80	10, 8, 6
70 × 70	10, 8, 6
60 × 60	10, 8, 6, 5
50 × 50	8, 6, 5, 4, 3
40 × 40	6, 5, 4, 3
30 × 30	5, 4, 3
25 × 25	5, 4, 3

Note: Stock range from Corus.
The standard BS EN 10056-1: 1999 refers to a wider range from 250 × 250 to 20 × 20 mm.
Tolerances on dimensions and shape for equal leg angles are given in BS EN 10056-2: 1993.



Unequal angles (BS EN 10056-1: 1999)

Table XI (Continued)

Nominal dimensions (mm)	Thickness (mm)
Unequal angles (BS EN 10056-1: 1999) *continued*	
200 × 150	18, 15, 12
200 × 100	15, 12, 10
150 × 90	15, 12, 10
150 × 75	15, 12, 10
125 × 75	12, 10, 8
100 × 75	12, 10, 8
100 × 65	10, 8, 7
80 × 60	8, 7, 6
75 × 50	8, 6
65 × 50	8, 6, 5
60 × 30	6, 5
40 × 25	4

Note: Stock range from Corus.
The standard BS EN 10056-1: 1999 refers to a wider range down to 30 × 20 mm.
Tolerances on dimensions and shape for unequal leg angles are given in BS EN 10056-2: 1993.

Parallel flange channels

Nominal dimensions (mm)	Standard mass per unit length (kg/m)
430 × 100	64
380 × 100	54
300 × 100	46
300 × 90	41
260 × 90	35
260 × 75	28
230 × 90	32
230 × 75	26
200 × 90	30
200 × 75	23
180 × 90	26
180 × 75	20
150 × 90	24
150 × 75	18
125 × 65	15
100 × 50	10

Note: Stock range from Corus.
Tolerances on dimensions and shape for hot rolled steel channels are given in BS EN 10279: 2000.

Tapered flange channels

Nominal dimensions (mm)	Standard mass per unit length (kg/m)
76 × 38	11
76 × 38	6.7

Note: Stock range from Corus. A range of sizes from 140 × 60 to 40 × 20 mm are also available.
Tolerances on dimensions and shape for hot rolled steel channels are given in BS EN 10279: 2000.

Metric steel structural sections

Sizes of beams may be slightly larger or smaller than listed, varying for the different masses given. For details see Corus Construction & Industrial publication: '*Structural Sections in accordance with European Specifications – 2006*.'

Table XII Metric structural sections

Beams with parallel flanges (Euronorm 19–57)

Nominal dimensions (mm)	Standard mass per unit length (kg/m)
750 × 265	222, 210, 196, 185, 173, 160, 147, 137
600 × 225	184, 154, 144, 122, 108
550 × 210	159, 134, 123, 106, 92
500 × 200	129, 111, 107, 91, 79
450 × 190	104, 95, 92, 78, 67
400 × 180	84, 82, 76, 66, 57
360 × 170	70, 66, 57, 50
330 × 160	60, 57, 49, 43
300 × 150	52, 49, 42, 37

Table XII (Continued)

Nominal dimensions (mm)	Standard mass per unit length (kg/m)
Beams with parallel flanges (Euronorm 19–57)	
270 × 135	44, 42, 36, 31
240 × 120	37, 34, 31, 26
220 × 110	32, 29, 26, 22
200 × 100	27, 25, 22, 18
180 × 90	22, 21, 19, 15
160 × 80	18, 16, 13
140 × 75	14, 13, 11
120 × 65	10, 8.7
100 × 55	8.1, 6.9
Parallel wide flange beams (Euronorm 53–62)	
Nominal dimensions (mm)	**Standard mass per unit length (kg/m)**
1000 × 300	349, 314, 272, 222
900 × 300	333, 291, 252, 198
800 × 300	317, 262, 224, 172
700 × 300	301, 241, 204, 166, 150
650 × 300	293, 225, 190, 138
600 × 300	285, 212, 178, 175, 151, 137, 129
550 × 300	278, 199, 166, 120
500 × 300	270, 187, 155, 107
450 × 300	263, 171, 140, 124, 100
400 × 300	256, 155, 125, 107, 92
360 × 300	250, 142, 112, 84
340 × 300	248, 134, 105, 79
320 × 300	245, 127, 98, 74
300 × 300	238, 117, 88, 70
280 × 280	189, 103, 76, 61
260 × 260	172, 93, 68, 54
240 × 240	157, 83, 60, 47
220 × 220	117, 72, 51, 40
200 × 200	103, 61, 42, 35
180 × 180	89, 51, 36, 29
160 × 160	76, 43, 30, 24
140 × 140	34, 25, 18
120 × 120	27, 20, 15
100 × 100	20, 17, 12
Equal angles (BS 10056-1: 1999)	
Nominal dimensions (mm)	**Thickness (mm)**
200 × 200	24, 20, 18, 16
150 × 150	18, 15, 12, 10
120 × 120	15, 12, 10, 8
100 × 100	15, 12, 10, 8
90 × 90	12, 10, 8, 6
Unequal angles (BS 10056-1: 1999)	
Nominal dimensions (mm)	**Thickness (mm)**
200 × 150	18, 15, 12
200 × 100	15, 12, 10
150 × 100	14, 12, 10
150 × 90	15, 12, 10
150 × 75	15, 12, 10
125 × 75	12, 10, 8
120 × 80	12, 10, 8
100 × 75	12, 10, 8
100 × 65	10, 8, 7

classified into strength classes (Table XIV) to BS EN 338: 2003 for both softwoods and hardwoods.

Table XIII Stainless steel grades for different environmental conditions (BS EN 10088-1: 2005)

Type	Metallic alloying components (%)	Number	Suitable environments
Austenitic	Chromium/nickel 18-10	1.4301	Rural and clean
	Chromium/nickel/ molybdenum 17-12-2	1.4401	Urban industrial and marine
Ferritic	Chromium 17	1.4406	Interior
Duplex	Chromium/nickel/ molybdenum 22-5-3	1.4462	Severe industrial and marine

3.02 Softwood

Preferred sizes for sawn softwood have been agreed within the European Union, but with provision for additional complementary sizes for individual member states. These are summarised in Table XV.

Permitted tolerances on structural timber are given in Table XVI, and reductions from sawn to planed softwood sizes are given in Table XVII. Customary lengths of sawn softwood are given in Table XVIII.

Joinery timber requires a high level of finish and straightness, and is classified into seven quality classes (BS EN 942: 2007) according to the number and size of visible natural defects, particularly knots.

A wide range of standard softwood profiles are available, of which tongue-and-groove boarding is the commonest. **37.1** gives the standard dimensions of softwood flooring to BS 1297: 1987.

Regularly available softwood species and their origin include Douglas Fir (North America and UK), Western Hemlock (North America), European larch (Europe), Japanese larch (Europe), Parana Pine (South America), Corsican Pine (Europe), Elliotis Pine (Brazil and Chile), Lodgepole Pine (North America), Maritime Pine (Europe), Pitch Pine (Southern USA), Radiata Pine (South Africa, South America, Australia and New Zealand), Scots Pine (UK), Southern Pine (Southern USA), Yellow Pine (North America), European Redwood (Scandinavia and Russia), Spruce (Canada), Sitka Spruce (North America and UK), Western Red Cedar (North America), European Whitewood (Europe and Russia).

3.03 Hardwood

Hardwood is normally supplied in planks of specified thickness but arbitrary width and length, depending on species and thickness. The preferred dimensions including complementary thicknesses are given in Table XIX. Maximum reductions for planing are listed in Table XX.

Regularly available hardwood species and their origin include American Ash (USA), European Ash (Europe), Beech (Europe), Birch (America), Iroko (West Africa), Jelutong (South East Asia), Keruing (South East Asia), Mahogany (West Africa), American Mahogany (Central and South America), Maple (North America), Meranti/Red Lauan (South East Asia), Meranti/White Lauan (South East Asia), American Red Oak (North America), American White Oak (North America), Obeche (West Africa), Sapele (West Africa), Teak (Burma and Thailand), Utile (West Africa).

3.04 Timber products

The wide range of products manufactured from wood includes laminated timber, laminated veneer lumber (LVL), plywood,

Table XIV Relationship between strength classes and physical properties for structural softwoods and hardwoods (BS EN 338: 2003)

Strength class	C14	C16	C18	C20	C22	C24	C27	C30	C35	C40	C45	C50	D30	D35	D40	D50	D60	D70
Bending strength (MPa)	14	16	18	20	22	24	27	30	35	40	45	50	30	35	40	50	60	70
Mean density (kg/m^3)	350	370	380	390	410	420	450	460	480	500	520	550	640	670	700	780	840	1080

Note: C refers to coniferous softwoods and D refers to deciduous hardwoods.

Table XV Standard sizes of softwood (BS EN 1313-1: 1997)

Thickness (mm)	Width (mm)																						
	50	60	63	75	80	90	100	115	120	125	138	140	150	160	175	180	200	220	225	240	250	260	275	300
35				e			e	e		e			e		e		e		e				e	
38	h		f	fu			*	fnu		*	u		*		fhinsuw		fhinuw		fhnuw		uw		hu	uw
40		g																						
44				eh			ehsw	e		ehsw			ehsw		ehw		ew		e					
47				uw			uw			uw			uw		uw		uw		uw		uw		w	uw
50	h		h	ehuw	a		* a	f	a	*		a	*	af	*	a	* a	a	*	a	uh	a		u
58													i		i		i		i					
60					g		a		ag			ag		ag		ag	g			g				
63				efhin		i	*			*			*	fh	*		ehinswu		ehiswu		h		h	
75				fhw		i	efhuw			ehiuw			*		*		*		*		hu		ehuw	uw
80					ag		ag		acg			acg		acg		acg	acg			g				
95							h			h			h											
100					a		acfghuw		acg	h		ac	huw	ac	fw	c	* acg	c	huw	a	huw		uw	uw
115								f																
120					a		a		acg					a		ac	acg	c		acg				
125										f														
140					a		a					ac				a		c		c		c		
150												f	u				u							u
160					a		a		a					acg			a			ag		cg		
200																	f							
225																			f					
250																					u			
300																								u

Key: * Eurostandard preferred sizes
Additional sizes in the following countries:
a Austria, c Switzerland, e Ireland, f France, g Germany, h Netherlands, i Italy, n Norway, s Finland, u United Kingdom and w Sweden.

Table XVI Permitted deviations on structural timber sizes (BS EN 336: 2003)

Maximum deviations from target sizes	Tolerance class T1	Tolerance class T2
Thicknesses and widths ≤ 100 mm	−1 to +3 mm	−1 to +1 mm
Thicknesses and widths > 100 mm	−2 to +4 mm	−1.5 to +1.5 mm

Table XVII Maximum reductions from sawn sizes of softwoods by planing two opposed faces (BS EN 1313-1: 1997)

Typical application	Reduction from sawn sizes of width or thickness (mm)			
	15–35	36–100	101–150	Over 150
Constructional timber	3	3	5	5
Matching and interlocking boards (not flooring)	4	4	6	6
Wood trim	5	7	7	9
Joinery and cabinet work	7	9	11	13

Table XVIII Customary lengths of structural timber (BS EN 1313-1: 1997)

Length (m)						
1.80	2.10	3.00	4.20	5.10	6.00	7.20
	2.40	3.30	4.50	5.40	6.30	
	2.70	3.60	4.80	5.70	6.60	
		3.90			6.90	

Note: Lengths over 5.70 m may not be readily available without finger jointing.

Table XIX Standard sizes of sawn hardwood (BS EN 1313-2: 1999)

Preferred thicknesses EU (mm)	20	27	32	40	50	60	65	70	80	100
Complementary thicknesses UK (mm)	19	26		38	52		63	75		

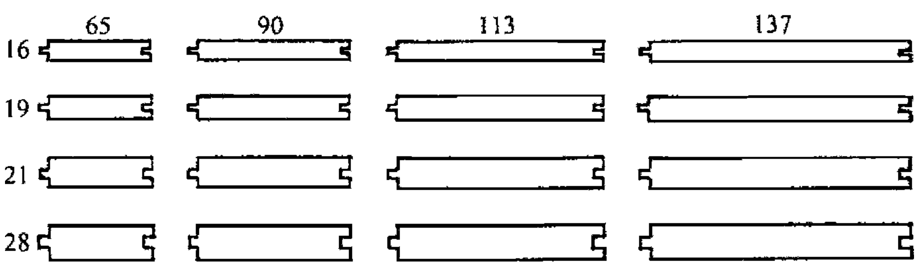
Preferred widths
EU 10 mm intervals for widths between 50 and 90 mm, 20 mm intervals for widths of 100 mm or more

Preferred lengths
EU 100 mm intervals for lengths between 2.0 and 6.0 m, 50 mm intervals for lengths less than 1.0 m

Table XX Maximum reductions from sawn sizes of hardwoods by planing two opposed faces (BS EN 1313-2: 1999)

Typical application	Reduction from sawn sizes of width or thickness (mm)				
	15–25	26–50	51–100	101–150	151–300
Flooring, matchings, interlocked boarding and planed all round	5	6	7	7	7
Trim	6	7	8	9	10
Joinery and cabinet work	7	9	10	12	14

particleboard, fibreboard and thermowood. All wood products are, to a greater or lesser degree, affected by moisture, and are therefore classified for use under specified environmental conditions to five use classes by BS EN 335-1: 2006 as in Table XXI.



37.1 *Standard floor board dimensions (mm) (BS 1297: 1987)*

Table XXI Use classes for wood and wood-based products (BS EN 335-1: 2006)

Use Class	Exposure to wetting in service	General service situation
Class 1	dry	interior, covered
Class 2	occasionally wet	interior or covered
Class 3	occasionally wet frequently wet	exterior, above ground, protected exterior, above ground, unprotected
Class 4	predominantly or permanently wet permanently wet	exterior, in ground contact and/or fresh water exterior in ground and/or fresh water
Class 5	permanently wet	in salt water

Plywood: Plywood is classified (BS EN 313-1: 1996) according to its construction and properties including durability, strength and surface condition. Bonding properties and durability for Classes 1–3 use are specified in BS EN 636: 2003. Softwood plywood (predominantly pine and spruce) is imported from North America and Scandinavia. Temperate hardwood products are imported from Finland (birch) and Germany (beech), while tropical hardwood sheets are imported from Indonesia, Malaysia, South America and Africa. The standard sheet sizes are 1220 mm × 2440, 3050 and 3660 mm but larger sizes to 3660 × 3050 mm are available especially for concrete formwork. Thicknesses range typically from 4 to 30 mm.

Laminated timber: Laminated timber sections can be manufactured to any transportable size, typically 30 m although spans of over 50 m are possible. Strength-graded timber sections, continuously glued with resin adhesive and the use of scarf or finger jointing within the laminates ensure a uniform structural product. Sections may be joined on site by finger jointing (BS EN 387: 2001), giving units to the appropriate overall strength class (BS EN 1194: 1999). Standard straight sections range from 180 × 65 to 1035 × 215 mm, with 315 × 65 and 90 mm, 405 × 90 and 115 mm and 450 × 115 mm being stock sizes. Arches, portal frames and other geometrical forms are made to design specification.

Laminated veneer lumber: LVL is manufactured by laminating timber strands with polyurethane resin followed by heat or microwave curing under pressure. It can be produced in sheets or billets up to 26 m long and subsequently machined as solid timber. It is frequently used in I-section joists for roof and floor construction. The three grades are listed in Table XXII.

Particleboards: Particleboards are manufactured from particles of wood, flax or hemp and a binder. Wood particleboard (BS EN 309: 2005) and cement-bonded particle board (BS EN 634-2: 2007) are bonded with resin and cement binder, respectively. Oriented strand board (OSB) is manufactured from larger wood flakes and binder to BS EN 300: 2006.

The standard sizes of wood particleboard (chipboard) are 2440 × 1220, 2750 × 1220, 3050 × 1220 and 3660 × 1220 mm, with the common thicknesses within the range 12–38 mm. Two generic manufacturing processes are used for the production of wood particleboard giving products with different properties. The pressed product is stronger, whereas the extruded board (BS EN 14755: 2005) may be solid or with void spaces. Standard grades of wood particleboard are hygroscopic and respond to changes in humidity, but humid-resistant grades are tolerant to occasional wetting. Grades of wood particleboard and extruded particleboard are listed in Tables XXIII and XXIV.

Cement-bonded particle board has good resistance to fire, water, fungal attack and frost. The Standard (BS EN 634-2: 2007) specifies only one grade as in Table XXV. Board sizes are typically 1200 × 2400, 2660 or 3050 mm with standard thickness of 12 and 18 mm, although sheets up to 40 mm thickness are manufactured. OSB is graded (Table XXVI) to its anticipated loading and environmental conditions (BS EN 300: 2006). It is available in sheet thicknesses from 6 to 38 mm, although the standard range is from 9 to 18 mm.

Fibreboards: Fibreboards are manufactured from wood or other plant fibres, and generally are bonded under pressure using the natural adhesive properties and felting of the fibres. In the case of medium density fibreboard (MDF) a resin bonding agent is used. Essentially differing degrees of compression give rise to the product range, although some products are impregnated with additives. Tables XXVII–XXX give the grades of MDF, hardboard, mediumboard and softboard, respectively.

Table XXII Grades of laminated veneer lumber (LVL) (BS EN 14279: 2004)

Type	Exposure class	Exposure	Purpose/loading
LVL/1	class 1	Dry	load-bearing
LVL/2	class 2	Humid	load-bearing
LVL/3	class 3	Exterior conditions (with appropriate finish)	load-bearing

Table XXIII Grades of wood particleboard (BS EN 312: 2003)

Type	Exposure	Colour coding		Purpose/loading
P1	Dry	White, white	blue	General purpose
P2	Dry	White	blue	Interior fitments
P3	Humid	White	green	Non-loadbearing
P4	Dry	Yellow, yellow	blue	Loadbearing
P5	Humid	Yellow, yellow	green	Loadbearing
P6	Dry	Yellow	blue	Heavy-duty loadbearing
P7	Humid	Yellow	green	Heavy-duty loadbearing

Table XXIV Grades of extruded wood particleboard (BS EN 14755: 2005)

Grade	Description
ES	Extruded Solid board with a minimum density of 550 kg/m^3
ET	Extruded Tube board with a minimum solid density of 550 kg/m^3
ESL	Extruded Solid Light board with a density of less than 550 kg/m^3
ETL	Extruded Tube Light board with a density of less than 550 kg/m^3

(Grade ET must have at least 5 mm of material over the void spaces)

Table XXV Grade of cement-bonded particleboard (BS EN 634-2: 2007)

Exposure	Colour coding		Purpose/loading
Dry, humid and exterior	White, white	brown	Non-loadbearing

Table XXVI Grades of oriented strand board (OSB) (BS EN 300: 2006)

Grade	Exposure	Colour coding		Purpose/loading
OSB 1	Dry	White	blue	General purpose Interior fitments
OSB 2	Dry	Yellow, yellow	blue	Loadbearing
OSB 3	Humid	Yellow, yellow	green	Loadbearing
OSB 4	Humid	Yellow	green	Heavy-duty loadbearing

Table XXVII Grades of medium density fibreboard (MDF) BS EN 622-5: 2006)

Grade	Exposure	Colour Coding		Purpose/loading
MDF	Dry	White, white	blue	General purpose Interior fitments
MDF.H	Humid	White, white	green	General purpose
MDF.LA	Dry	Yellow, yellow	blue	Loadbearing
MDF.HLS	Humid	Yellow, yellow	green	Loadbearing
L-MDF	Dry			
L-MDF.H	Humid			
UL1-MDF	Dry			Insulating panels with limited stiffening function
UL2-MDF	Dry			Insulating panels with a stiffening function
MDF-RWH				Rigid underlays in roofs and walls

Table XXVIII Grades of hardboard (BS EN 622-2: 2004)

Grade	Exposure	Colour coding		Purpose/loading
HB	Dry	White, white	blue	General purpose
HB.H	Humid	White, white	green	General purpose
HB.E	Exterior	White, white	brown	General purpose
HB.LA	Dry	Yellow, yellow	blue	Loadbearing
HB.LA1	Humid	Yellow, yellow	green	Loadbearing
HB.LA2	Humid	Yellow	green	Heavy-duty loadbearing

Table XXIX Grades of mediumboard (BS EN 622-3:2004)

Grade	Exposure	Colour coding		Purpose/loading
MB.L	Dry	White, white	blue	General purpose
MB.H	Dry	White, white	blue	General purpose
MBL.H	Humid	White, white	green	General purpose
MBH.H	Humid	White, white	green	General purpose
MBL.E	Exterior	White, white	brown	General purpose
MBH.E	Exterior	White, white	brown	General purpose
MBH.LA1	Dry	Yellow, yellow	blue	Loadbearing
MBH.LA2	Dry	Yellow	blue	Heavy-duty loadbearing
MBH.HLS1	Humid	Yellow, yellow	green	Loadbearing
MBH.HLS2	Humid	Yellow	green	Heavy-duty loadbearing

Table XXX Grades of softboard (BS EN 622-4: 1997)

Grade	Exposure	Colour coding		Purpose/loading
SB	Dry	White, white	blue	General purpose
SB.H	Humid	White, white	green	General purpose
SB.E	Exterior	White, white	brown	General purpose
SB.LS	Dry	Yellow, yellow	blue	Loadbearing
SB.HLS	Humid	Yellow, yellow	green	Loadbearing

4 BRICKS AND BLOCKS

4.01 Bricks

The standard work size of clay and calcium silicate bricks is 215 × 102.5 × 65 mm (coordinating size 225 × 112.5 × 75 mm). Clay brick is supplied in an enormous variety of face colours, textures (including glazed), strengths, frost resistance (Table XXXI) and other properties. Calcium silicate bricks are available in a wide range of colours from pastel to deep shades with a selection of textures. Manufactures usually offer specials from within the British Standard range (BS 4729: 2005). The standards illustrate the wide-ranging specifications required for clay bricks (BS EN 771-1: 2003) and calcium silicate bricks (BS EN 771-2: 2003). Only one size of modular brick (work size 190 × 90 × 65 mm, coordinating size 200 × 100 × 75 mm) is current within the standard (BS 6649: 1985).

Concrete bricks in standard and modular sizes are covered by BS EN 771-3: 2003 (Table XXXII) with other larger concrete masonry units.

Table XXXI Freeze/thaw resistance for clay bricks (BS EN 771-1: 2003)

Durability designation	Freeze/thaw resistance
F2	Masonry subjected to severe exposure
F1	Masonry exposed to moderate exposure
F0	Masonry subjected to passive exposure

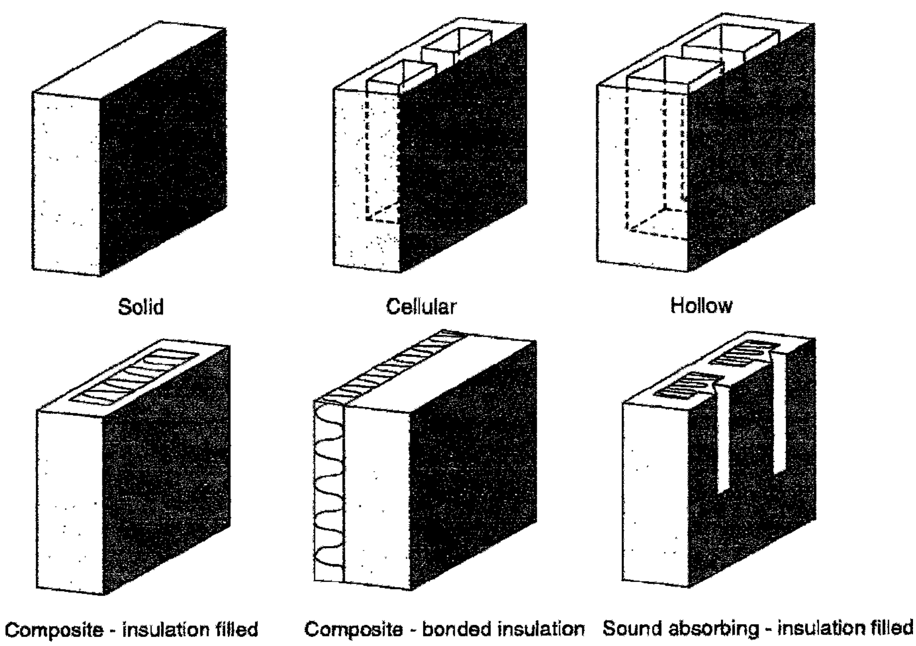
Table XXXII Standard and modular work sizes for concrete bricks (BS EN 771-3: 2003)

	Length (mm)	Width (mm)	Height (mm)
Standard	215	103	65
Modular	290	90	90
	190	90	90
	190	90	65

4.02 Building blocks

The standard BS EN 771-3: 2003 does not limit the sizes of dense and lightweight concrete blocks (masonry units), but it does refer to the fairly restricted range given in Table XXXIII. However, manufacturers offer a considerably wider range, both of face dimensions (including large format blocks) and of widths (thicknesses) between 50 and 350 mm. Types of block are illustrated in **37.2**.

Other available face sizes include 440 × 430, 610 × 215, 610 × 270, 620 × 215, 620 × 300 and 620 × 430 mm as wall blocks and further additional sizes for coursing, floors and foundations. Tolerances on block sizes for concrete and autoclaved aerated concrete blocks are given in Tables XXXIV and XXXV respectively.



37.2 *Types of concrete blocks*

Table XXXIII Common work sizes of concrete blocks (BS EN 771-3: 2003)

Length (mm)	Height (mm)	Width (mm)								
		75	90	100	140	150	190	200	215	225
390	190		*	*	*		*	*		
440	215	*	*	*	*	*	*	*	*	*

Table XXXIV Limit of tolerance on block sizes (BS EN 771-3: 2003)

Dimensions (mm)	Tolerance category			
	D1	D2	D3	D4
Length	+3 −5	+1 −3	+1 −3	+1 −3
Width	+3 −5	+1 −3	+1 −3	+1 −3
Height	+3 −5	+2 −2	+1.5 −1.5	+1 −1

Table XXXV Limit of tolerance on autoclaved aerated concrete block sizes (BS EN 771-4: 2003)

Dimensions (mm)	Standard mortar joints	Thin layer mortar joints TLMA	Thin layer mortar joints TLMB
Length	+3 to −5	±3	±1.5
Height	+3 to −5	±2	±1.0
Width	±3	±2	±1.5

Table XXXVI Sizes and types of paving flags (BS EN 1339: 2003)

Flag designation	Nominal size (mm)	Work size (mm)	Thickness (mm)
A	600 × 450	598 × 448	50 or 63
B	600 × 600	598 × 598	50 or 63
C	600 × 750	598 × 748	50 or 63
D	600 × 900	598 × 898	50 or 63
E	450 × 450	448 × 448	50 or 70
F	400 × 400	398 × 398	50 or 65
G	300 × 300	298 × 298	50 or 60

Table XXXVII Aluminium alloys in construction

Code number	Composition	Typical application
EN AW 1080A	99.8% pure	Flashings
EN AW 1050A	99.5% pure	Flashings
EN AW 1200	99% pure	Fully supported sheet roofing, insulating foils
EN AW 3103	Manganese alloy	Profiled roofing and cladding
EN AW 5083SPE	Superplastic alloy	Rainscreen cladding
EN AW 6063	Magnesium/silicon	Extruded sections – curtain walling, windows and doors
EN AW 6082	Structural aluminium	Loadbearing structures

An extensive range of fired clay blocks of low and high density other than bricks is illustrated in BS EN 771-1: 2003, but not all are readily available from suppliers.

5 PRECAST CONCRETE

5.01 Paving flags

Paving flags are manufactured to the requirements of BS EN 1339: 2003. The standard does not specify preferred dimensions, except a maximum length of 1 m. UK flags, however, are traditionally supplied in the dimensions given in Table XXXVI. Tactile flags are used in the pedestrian pavement adjacent to pedestrian crossings to indicate their presence to people who are visually impaired.

The standard (BS EN 1339: 2003) refers to four classes of flag related to ranges of strength and durability. Class 1 flags are appropriate for light domestic use (gardens/drives), Class 3 flags are suitable for normal public areas, but Class 4 are required for very heavy pedestrian and vehicular use. Class 1 products are not resistant to freeze/thaw effects, but Class 3 flags are resistant to repeated freezing and thawing and the regular use of deicing salts.

6 ALUMINIUM

Wrought aluminium and its alloys are each designated by the letters European Norm Wrought Aluminium (EN AW) followed by a unique four digit coding (BS EN 573-1: 2004). Table XXXVII gives examples of the standard construction alloys. Aluminium may also be cast into components. The range of aluminium finishes includes anodizing, texturing, metallic (zinc) and plastic (polyester or PVC) coatings.

6.01 Aluminium bars and flats

Aluminium bars are made to the dimensional requirements of BS 6722: 1986 (see Tables I and II, para. **2.01** above). Stock sizes for round section typically range from 3 to 200 mm diametre, for square section from 3 to 180 mm side and for flat sections from 3 to 70 mm × 10 to 250 mm depending upon the manufacturer.

6.02 Aluminium structural sections

Table XXXVIII based on BS 1161: 1977 gives the sizes of standard I, T and channel sections. Further details of the structural aluminium alloys used in construction are given in BS 8118-1: 1991.

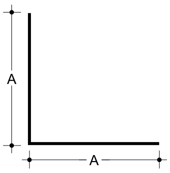
7 ROOFING AND CLADDING

Sheet metal for roofing and cladding is covered in the standards BS EN 14782: 2006 and BS EN14783: 2006 for self-supporting and fully supported sheet metal, respectively. The standards list minimum thicknesses for aluminium, steel, stainless steel, zinc and copper, also lead for fully supported systems. However, it is noted that European Union member states may require thicknesses greater than those described. The new standard BS 8747 relates to reinforced bitumen membranes for roofing and traditional mastic asphalt is covered by BS 6925: 1988.

7.01 Aluminium

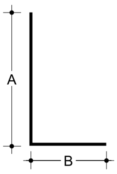
The Code of Practice for aluminium sheet roof and wall covering, CP143 Part 15: 1973, is still current. Sheeting comes to site in coils, and is passed continuously through a machine to form standing seams *in situ.* This long strip system removes the necessity to form joints transverse to the standing seams up to a maximum of 7 m. The standard thickness for long strip aluminium roofing is

Table XXXVIII Aluminium alloy structural sections (BS 1161: 1977)



Equal angles

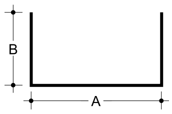
Nominal size (mm)	Thickness (mm)	Mass/length (kg/m)
120 × 120	10	6.47
	7	4.68
100 × 100	8	4.31
	6	3.34
80 × 80	6	2.59
	5	2.23
60 × 60	5	1.62
	3.5	1.17
50 × 50	4	1.08
	3	0.84
40 × 40	3	0.65
30 × 30	2.5	0.40



Unequal angles

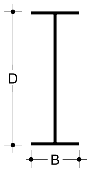
Nominal size (mm)	Thickness (mm)	Mass/length (kg/m)
140 × 105	11	7.26
	8.5	5.83
120 × 90	10	5.65
	7	4.11
100 × 75	8	3.77
	6	2.94
80 × 60	6	2.26
	5	1.96
60 × 45	5	1.41
	3.5	1.03
50 × 38	4	0.95
	3	0.74

Table XXXVIII (Continued)



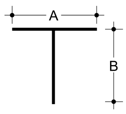
Channels

Nominal size (mm)	Thickness (mm)		Mass/length (kg/m)
	Web	Flange	
240 × 100	9	13	12.5
200 × 80	8	12	9.19
180 × 75	8	11	8.06
160 × 70	7	10	6.58
140 × 60	7	10	5.66
120 × 50	6	9	4.19
100 × 40	6	8	3.20
80 × 35	5	7	2.29
60 × 30	5	6	1.69



I-sections

Nominal size (mm)	Thickness (mm)		Mass/length (kg/m)
	Web	Flange	
160 × 80	7	11	7.64
140 × 70	7	10	6.33
120 × 60	6	9	4.77
100 × 50	6	8	3.72
80 × 40	5	7	2.54
60 × 30	4	6	1.59



Tees

Nominal size (mm)	Thickness (mm)	Mass/length (kg/m)
90 × 120	10	5.68
75 × 100	8	3.79
60 × 80	6	2.27
45 × 60	5	1.42
38 × 50	4	0.95

Table XXXIX Standard thicknesses and sizes of copper sheet for traditional roofing

Sheet thickness (mm)	Standard width of sheet to form bay (mm)	Bay width with standing seam (mm)	Bay width with batten roll (mm)	Length of each sheet (m)	Mass (kg/m^2)
0.60	600	525	500	1.8	5.4
0.70	750	675	650	1.8	6.3

Table XL Recommended widths of copper strip for the long strip system

Width of strip (mm)	400	450	500	600	670
Standing seam centres (mm)	325	375	425	525	595

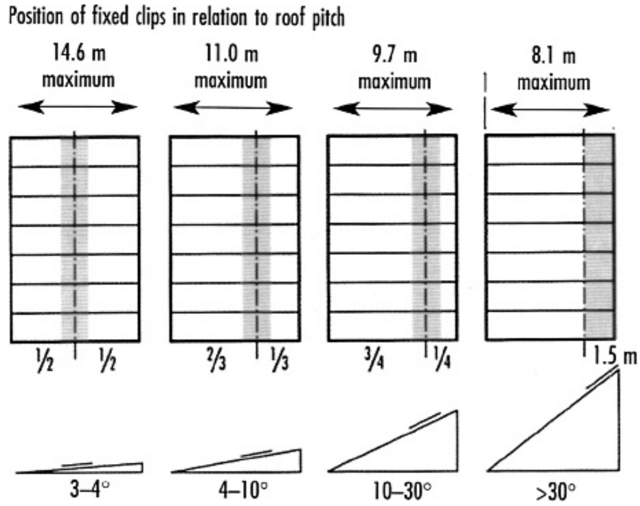
Note: using 0.6 or 0.7 mm copper strip at ¼ or ½ hard temper with a fixed zone of 1.5 m within a maximum 10 m length.

0.8 mm and the recommended maximum width of 450 mm produces standing seams at 375 mm centres. A minimum fall of 1.5° is recommended.

7.02 Copper

The standard grade of copper for fully supported and self-supported roofing is Cu-DHP (C106) (phosphorus deoxidized non-arsenical copper) to BS EN 1172: 1997. Sheet copper is available in a range of thicknesses from 0.5 to 1.0 mm (up to 3.0 mm for curtain walling) with 0.6 and 0.7 mm the standard thicknesses for roofing. Sheet widths range from 500 to 1000 mm with 600 mm standard for roofing.

The two methods of copper roofing available are traditional and long-strip. Fully annealed copper strip is normally used in traditional roofing as detailed in Table XXXIX. For long-strip roofing 1/8 to 1/4 hard temper copper strip is required to prevent buckling with thermal movement, **37.3**. Typical long strip dimensions are listed in Table XL. Prepatinised copper is available if the



37.3 *Long strip copper roofing*

immediate effect of green colouration is required, alternatively protective clear coatings may be applied to retain the original copper colour, although these will require regular maintenance. Copper sheet is also used for shingles, **37.4**.

7.03 Lead

Sizes of milled lead sheet and strip are specified in BS EN 12588: 2006, summarised in Table XLI. The traditional UK lead codes are not referenced in the European Standard; however, the current Code of Practice for fully supported lead sheet roof and wall coverings, BS 6915: 2001, does refer lead codes in addition to metric thicknesses.

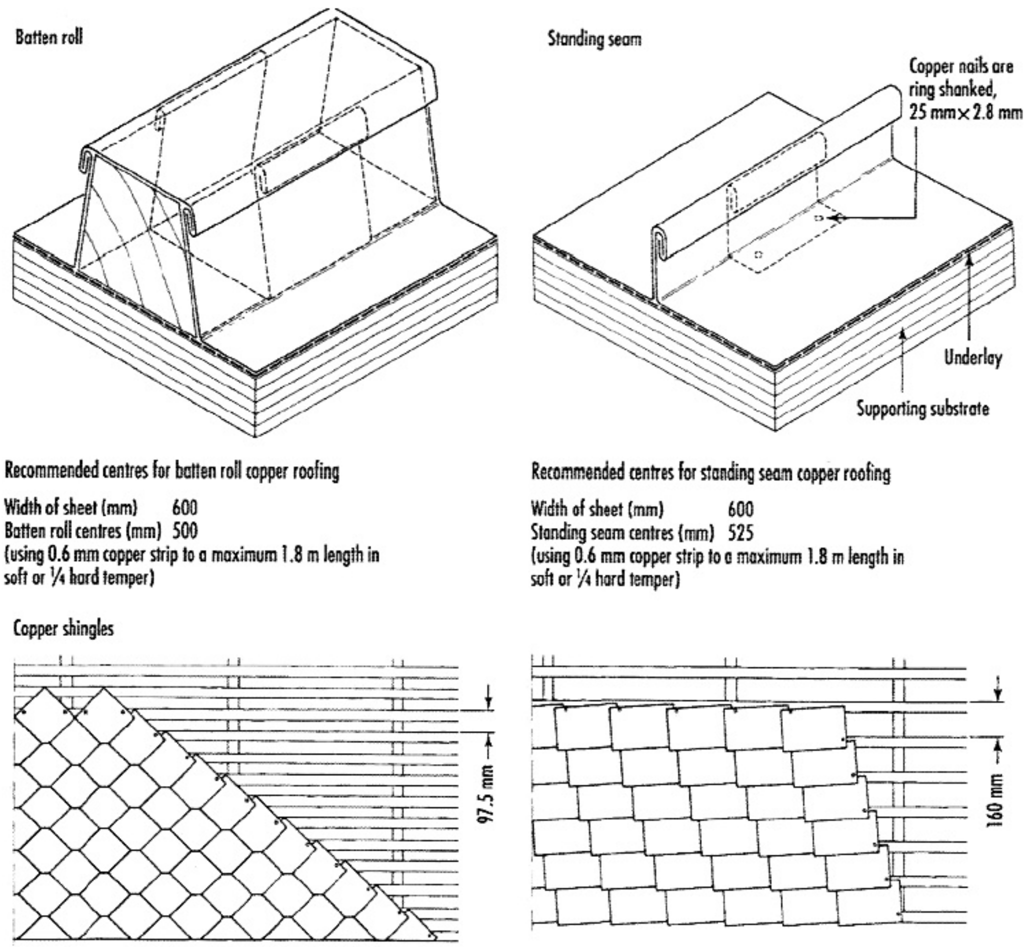
Table XLI Milled lead sheet and strip sizes (BS EN 12588: 2006 and BS 6915: 2001)

Lead code	Thickness (mm)	Average weight (kg/m^2) (based on larger thicknesses)	Colour marking
3	1.25 or 1.32	14.97	Green
	1.50 or 1.59	18.03	Yellow
4	1.75 or 1.80	20.41	Blue
5	2.00 or 2.24	25.40	Red
6	2.50 or 2.65	30.06	Black
7	3.00 or 3.15	35.72	White
8	3.50 or 3.55	40.26	Orange

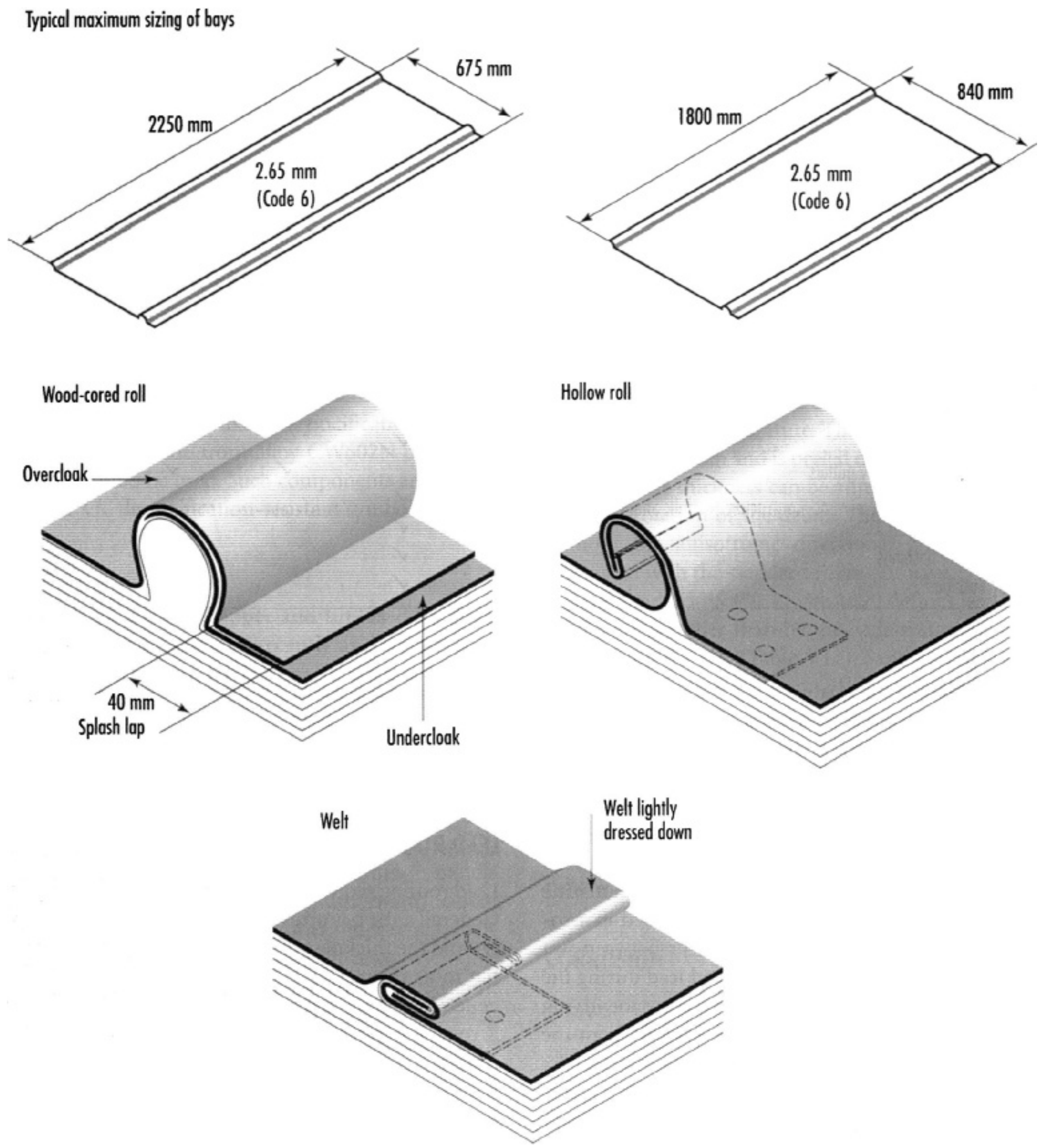
Sand-cast lead is manufactured for conservation work. Patination oil can be applied to new lead work to prevent the production of unsightly white lead carbonate staining. Typical lead roof details are shown in **37.5**.

7.04 Zinc

Zinc is covered by BS EN 988: 1997. The standard thicknesses are 0.6, 0.65, 0.7, 0.8 and 1.0 mm (Table XLII). Preferred lengths are 2.0 and 3.0 m, in a range of widths from 100 to 1000 mm. Pure zinc sheet roofing is no longer used, as it had a lifetime of approximately 40 years in urban conditions (CP 143-5: 1964). However, zinc–copper–titanium alloy is the standard product and may be used directly or coated. Organic coatings include acrylic, polyester and silicon-polyester paints, PVDF and PVC[P] coatings also chemical pre-weathering treatment. The minimum thickness to BS EN 501: 1994 for fully supported roofing is 0.6 mm. Either traditional or long-strip roofing may be used with titanium zinc. A minimum fall of 3° is recommended. Where bays are longer than 3 m, a fixed zone and sliding clips will be required to accommodate thermal movement.



37.4 *Traditional copper roofing and copper shingles*



37.5 *Traditional lead roofing*

Table XLII Zinc–copper–titanium alloy standard sheet thicknesses (BS EN 988: 1997)

Nominal thickness (mm)	Approximate mass (kg/m^2)
0.60	4.3
0.65	4.7
0.70	5.0
0.80	5.8
1.00	7.2

7.05 Stainless steel

Stainless steel as a sheet roofing material is covered by BS EN 508-3: 2000 for the self supporting material and by BS EN 502: 2000 for the fully supported product. Table XLIII gives the most commonly used grades of stainless steel sheeting with and without organic coatings. The appropriate grade and finish depends upon the local environment and durability requirements.

Table XLIII Stainless steel self supported and fully supported sheet

Steel grade	Steel designation	
	Steel name	Steel number
Ferritic with organic coating	X6Cr13	1.4000
Ferritic with or without organic coating	X6Cr17 X6CrMo17-1 X3CrTi17 X2CrMoTi18-2	1.4016 1.4113 1.4510 1.4521
Austenitic with or without organic coating	X5CrNi18-10	1.4301
Austenitic/molybdenum with or without organic coating	X5CrNiMo17-12-2	1.4401

Note: X is carbon content, Cr Chromium, Ni Nickel, Mo Molybdenum and Ti Titanium.

7.06 Titanium

Titanium sheet (0.3–0.4 mm) may be used as roofing or cladding. The 99% pure material used for construction work has a density (4510 kg/m^3) intermediate between that of steel and aluminium, and a low coefficient of expansion (8.9×10^{-6}°C). The natural oxide film can be thickened by anodizing to a range of colours between blue and cream, or a textured finish may be applied.

7.07 Reinforced bitumen membranes for roofing

A new standard (BS 8747) on reinforced bitumen membranes for roofing is imminent as a replacement for BS 747: 2000. Currently, bitumen roofing membranes are covered by the Code of Practice BS 8217: 2005, and the standard BS EN 13707: 2004. Standard membranes and their applications are listed in Table XLIV, but these do not include the high performance polymer-modified

Table XLIV Reinforced bitumen membranes for roofing

Class	Base material	Type	Use	Colour code
Class 1	Organic fibres and jute Hessian base	Type 1F	Underlays for discontinuous roofs	White
Class 3	Glass-fibre base	Type 3B Type 3E Type 3G	Fine granule surface Mineral surface Venting base layer	Red Red None
Class 4	Flax or jute fibre base	Type 4A black Type 4A brown	Underlay to mastic asphalt Underlay to mastic asphalt	None None
Class 5	Polyester base	Type 5B Type 5E Type 5U	Fine granule surface Mineral surface Fine granule underlayer	Blue Blue Blue

Table XLV Mastic asphalt grades (BS 6925: 1988)

Type	Composition
BS 988B	100% bitumen
BS 988T25	75% bitumen, 25% lake asphalt
BS 988T50	50% bitumen, 50% lake asphalt
Specified by manufacturers	Polymer-modified grades

bitumen membranes manufactured with atactic polypropylene (APP) or styrene–butadiene–styrene (SBS).

7.08 Mastic asphalt roofing

Mastic asphalt for roofing (also flooring and damp-proofing) is specified in BS 6925: 1988, to the grades listed in Table XLV. Polymer modified mastic asphalts containing SBS are more durable with enhanced flexibility.

7.09 Single-ply roofing systems

Single-ply roofing systems are described in the standard, BS EN 13956: 2005. They usually consist of a continuous membrane between 1 and 3 mm thick covering any form of flat or pitched roof with limited access. The membrane material is typically a thermoplastic, elastomeric or a modified bitumen system which may be glass-fibre or polyester reinforced. Joints between sheets are either heat or solvent welded or sealed with adhesives. The waterproofing sheet may be fixed to the substructure by mechanical fastening, full or partial adhesive bonding or by ballasting to prevent wind uplift **37.6**. Mechanically fixed sheets require the fastenings to be covered by a further layer of waterproofing material, usually at the joints between sheets. Many membranes are backed with a polyester fleece to smooth out any discontinuities in the substructure and where appropriate to assist adhesive bonding. Certain materials are available in a variety of colours or have mineral finishes.

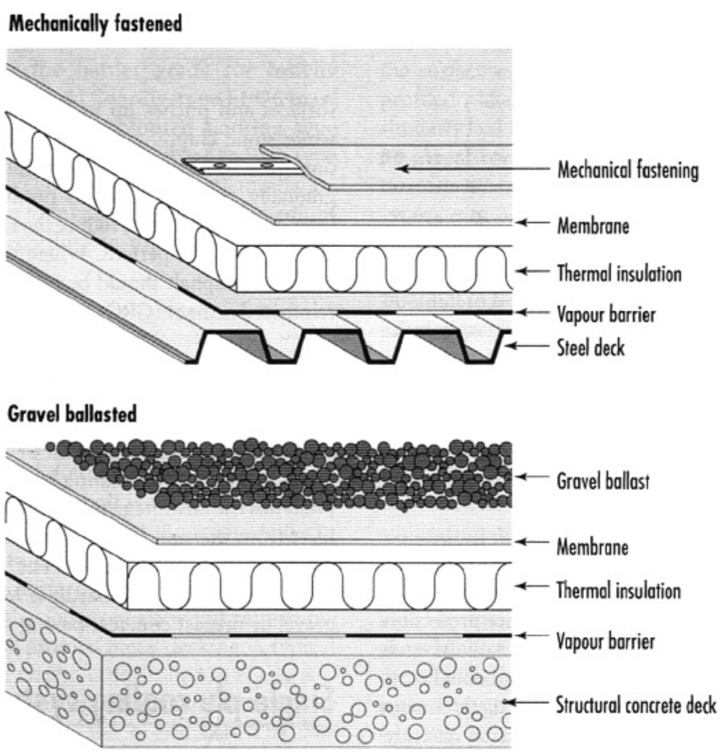
Within the range of thermoplastic systems PVC, flexible polyolefin (FPO), flexible polypropylene alloy (FPA), vinyl ethylene terpolymer (VET), chlorinated polythene (CPE), chlorosulphonated polyethylene (CSM) and polyisobutylene (PIB) are standard products. While ethylene propylene diene monomer (EPDM) and SBS or APP modified bitumen are the standard elastomeric and bitumen-based products, respectively. The modified bitumen products are usually up to 5 mm in thickness.

7.10 Tensile fabric structures

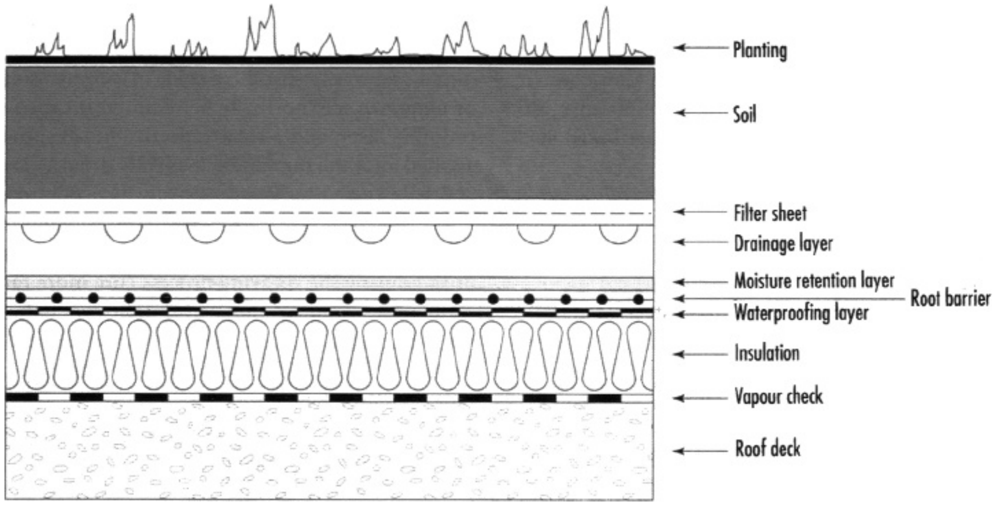
The two alternative materials for tensile roof structures are PVC-coated polyester fabric and PTFE-coated woven glass fibre. PVC-coated polyester is available in a variety of colours and has an anticipated lifespan of approximately 10–15 years. The more expensive white PTFE-coated glass fibre material is self-cleaning and non-combustible with an anticipated lifespan of 25 plus years. A range of standard design canopies and shelters are commercially available as alternatives to bespoke designs.

7.11 Green roofs

Green roofs are defined as either extensive or intensive according to the type of planting and the associated loading. Extensive roofs are not designed for general access, but are planted with low maintenance, drought and frost tolerant species such as sedums, herbs and grasses. Only occasional access will be required for weeding and the filling of any bare patches. Intensive roofs,



37.6 *Typical single-ply roofing system, mechanically fastened and gravel ballasted*



37.7 *Typical green roof system*

which support recreational activity with hard and soft landscaping, require depths of soil between 200 and 300 mm, giving additional structural loading. A typical green roof will require a multi-layer system **37.7** to support the planting and to ensure secure waterproofing of the substructure. Green roofs have the advantage of significantly reducing rapid rainwater run-off, whilst enhancing air quality and giving improved thermal and acoustic insulation to the roof.

8 GLASS

The selection of glazing for buildings is highly complex due the wide variety of design requirements that need full consideration. A suitable methodology to ensure appropriate attention to all significant factors is described in the British Standard BS 6262-1: 2005. The additional parts of the standard BS 6262 give more detailed information on the following aspects of glazing for buildings.

BS 6262	Glazing for buildings:
BS 6262-1: 2005	General methodology for the selection of glazing.
BS 6262-2: 2005	Code of practice for energy, light and sound.
BS 6262-3: 2005	Code of practice for fire, security and wind loading.
BS 6262-4: 2005	Code of practice for safety related to human impact.
BS 6262-5 (to be published in 2008)	Code of practice for frame design considerations.
BS 6262-6: 2005	Code of practice for special applications. (This relates mainly to structural fixings)
BS 6262-7: 2005	Code of practice for the provision of information.

The key design requirements from BS 6262-1: 2005 are listed in Table XLVI together with additional commentary. Types of glass fulfilling the functions are listed in Table XLVII.

Current Building Regulations with a focus on Dwelling (DER) and Building Emission Rates (BER) for energy conservation make the use of solar control and energy efficient glazing systems virtually mandatory in most situations. In addition, health and safety legislation and regulation requires the use of safety glasses in many locations.

Table XLVI Design requirements for glazing in buildings (BS 6262-1: 2005)

Design requirements	Additional considerations
Natural lighting	View in and out by day and night. Size and shape of glazing, aesthetic considerations. Appropriate natural and artificial task and amenity lighting levels. Legislative requirements. Glare from sun, sky, reflections/diffraction. Privacy – embossed, etched, sandblasted, and coloured glass; variable transmission glass. Clear white glass.
Thermal considerations	Energy balance of solar gains versus heat losses. Building Emission Rate. Double/triple glazing, low emissivity glass, inert gas fill, window energy ratings, *U*-values. Solar control glass – body tinted/reflective coated, glazing orientation, shading devices. Intelligent glass, condensation.
Sound	Acoustic control from inside/outside. Low, middle and high frequency band sounds. Glass thickness, laminated glass of differing thicknesses with interlayers, double glazing spacing with sound absorbing material, sealed systems.
Safety	Location of glass – impact damage, barriers, manifestation (BS 6262-4: 2005). Toughened glass, heat-strengthened glass, laminated glass, applied plastic films. Radiation protection.
Security	Protection of persons and property. Vandalism, use of firearms and explosives. Laminated anti-bandit glass, one-way observation glass, alarm glass, glass blocks.
Fire	Classification – integrity (E)/insulation (I)/radiation (R). Regulations. Georgian wired glass, toughened, laminated glass. Non-insulating, insulating, partially insulating glass.
Durability	Verify durability of glass or plastics glazing sheet materials.
Wind loading	Determine wind pressure (BS 6399-2: 1997).
Maintenance	Access, ease and cost of replacement, self-cleaning glass.

Note: In addition glass may be used as a structural material. Applications include walkways, stairs and all-glass structures constructed with laminated toughened glass joined with metal fixings or clear high-modulus structural adhesives.

Table XLVII Types of Glass and Glazing
It should be noted that glass fulfils many functions concurrently, and the following table should only be used as general guidance on specific key glazing functions

Function/Type	Description	Thickness (mm)	Maximum size (mm)
LIGHTING AND VISUAL LINK			
Float Glass	Standard annealed glass product (Type A breakage with sharp edges)	4–25 mm	3210 × 6000 mm
White glass	Reduced level of iron oxide impurities giving high light transmission, virtually colourless	4–19 mm	3210 × 6000 mm
Privacy			
Embossed	Range of decorative patterns with differing levels of privacy (obscuration factors)	3.2, 4, 6, 8 and 10 mm also 12 and 19 mm	2040 × 4350 mm 1800 × 2520 mm
Screen printed	White or coloured ceramic frit printed and fused onto clear or tinted float glass	6–19 mm	2130 × 3600 mm
Etched/sand blasted	Range of acid etched or sand blasted designs on clear or tinted glass Bespoke designs	4, 5, 6, 8, 10, 12, 15 and 19 mm	2000 × 3210 mm
Translucent finish	Diffusing frosted float glass	4, 6, 9.5 mm	2000 × 3300 mm
Electro-optic glass	Changes by electrical switching from transparent to translucent (liquid crystal film interlayer)	7 and 11 mm	1000 × 3000
Coloured glass	Through coloured glass, bevels and laminated plastic films. Standard and bespoke designs		
THERMAL CONSIDERATIONS			
Solar Control			
Heat reflecting	Heat reflecting off-line metal or metal oxide sputter coatings (clear, neutral, silver, blue, green, grey) Heat reflecting on-line pyrolytic coating (silver, grey, bronze, blue/green)	6, 8 and 10 mm 5, 6, 8 and 10 mm	3210 × 6000 mm 3210 × 6000 mm
Heat absorbing	Heat absorbing body-tinted glass (green, bronze, blue, grey)	4, 5, 6, 8, 10 and 12 mm	3210 × 6000 mm
Laminated glass	Tinted plastic interlayers		
Blinds	Insulating glass units with integral blinds		1000 × 2000 mm
Thermal Insulation			
Multiple glazing	Double/triple glazing systems with inert gas fill (argon – standard).		units 2600 × 5000 mm
Low emissivity glass	Soft off-line ultra- low emissivity coating (ε_n 0.04) Pyrolytic low emissivity hard coating on clear and tinted glass (ε_n 0.15)	4, 6, 8, 10 and 12 mm 4, 6 and 8 mm	3210 × 6000 mm 3210 × 6000 mm
SOUND			
Noise control	Laminated glass with PVB (polyvinyl butyral) interlayer Sealed units with large spacing and acoustic insulation around perimeter	Single leaf 6.8–16.8 mm Units up to 50 mm	3210 × 6000 mm
SAFETY			
Toughened	Five times stronger than annealed glass. Safety glass (Type C breakage into relatively harmless granules)	4, 5, 6, 8, 10, 12, 15 and 19 mm	2400 × 5850 mm
Heat soaked toughened glass	Reduces the risk of spontaneous breakage of toughened glass due to nickel sulfide inclusions		
Heat-Strengthened	Half the strength of toughened glass and breaks into pieces like annealed glass. Not a safety glass (Often used in laminated glass.) (Type A breakage with sharp edges)	4, 5, 6, 8 and 10 mm	
Laminated	Laminated glass gives protection from injury in case of breakage. PVB interlayer for flat glass – Resin interlayer for curved laminates. (Type B breakage – cracks but the fragments hold together)	6.4–8.4 mm for personal safety	3210 × 6000 mm
Plastic film	A range of thin plastic films to change the optical and/or thermal properties of glass Thick structural plastic interlayer – 1.52 or 2.28 mm (Appropriate plastics film coverage to annealed glass can give a Type B breakage as in laminated glass)		2000 × 3500 mm
SECURITY			
Laminated	Vandalism/anti-bandit/bullet or explosion resistant depending upon number and thickness of glass laminates. (PVB layers 0.4 or 0.8 mm) (Type B breakage – cracks but the fragments hold together)	6.8–87 mm according to required impact resistance	3210 × 6000 mm
One-way vision	Requires low level of lighting on the observers side (max 1/7 of lighting level)	4, 5, 6, 8 and 10 mm	2550 × 3650 mm

Table XLVII (Continued)

Function/Type	Description	Thickness (mm)	Maximum size (mm)
FIRE PROTECTION			
Non-insulating wired glass	Georgian wired glass – polished or cast 30, 60 min integrity only (E30 to E60) (Type B breakage – cracks but the fragments hold together) Heavier grade of wire to meet BS 6206: 1981 impact test		
Integrity	Restricts flame and hot gases only. (E30) – (E60)	7–13 mm	
Integrity and insulation	Laminated with interlayers. 30,60, 90, 120, 180 min insulation (in appropriate frame system) (EI 30, EI 60 single glazing(up to EI 180 double glazing units) (intumescent or gel interlayers)	15 to 60 mm (double glazing units) according to protection required	
Integrity with some radiation protection	Laminated with interlayers. Reduced heat radiation (E/EW)(EW 30 to EW 120)	Upwards from 13 mm	
MAINTENANCE			
Self-cleaning	Hydrophilic and photocatalytic on-line coating spreads water and oxidises dirt on the surface. Clear and blue	4, 6, 8 and 10 mm	3210 × 6000 mm
SPECIAL APPLICATIONS			
Spandrel glass	Range of colours and screen print designs. Enameled/opaque glass or insulated glazing units (IGUs)		
Curved glass	CIP (cast in place) if required laminated		
Mirror glass	Mirror	3, 4 and 6 mm	3210 × 6000 mm
Radiation protection	X-ray and gamma ray protection. Lead rich glass – amber colour. Lead and barium glass – neutral colour	6, 8.5, 11 and 13 mm 3.5 to 16 mm	1000 × 2000 mm 1300 × 2500 mm
GLASS SYSTEMS	Double and triple glazed systems. Fixings to BS 6262-6: 2005 – bolts, sealant, fins or tension wires. Triple glazing units $U = 0.8\ W/m^2K$	10, 12, 15 and 19 mm	double glazed max. unit size 2400 × 4800 mm triple glazed max. unit size 2400 × 4200 mm

Notes: Data supplied by Pilkington Building Products UK and Saint Gobain Glass UK Ltd.
Not all manufacturers supply the full range sizes and thicknesses of each product and in many cases the maximum sheet size is dependent on thickness.
Combinations of functions e.g. self-cleaning and pattered glass are available.
The descriptions of breakages are in accordance with BS EN 12600: 2002.
Critical locations for safety glass are illustrated in BS 6262-4: 2005.
Where there is a risk of human impact on glass in buildings, its manifestation is required in the form of lines, patterns or logos between 600 and 1500 mm above floor level (BS 6262-4: 2005).
Maximum sheet sizes are not necessarily safe sizes.

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BS 4482: 2005 Steel wire for the reinforcement of concrete products. Specification

BS 4483: 2005 Steel fabric for the reinforcement of concrete products. Specification

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38 Windows, doors, pipes and cables

CI/Sfb: Ya

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KEY POINT:

- *Standards and specifications are constantly changing, always refer to current regulations and manufacturers details.*

Contents

1 WINDOWS AND DOORS

1.01

Windows and door frames are generally available in four materials:

- Wood
- Steel
- Aluminium alloy
- Unplasticised polyvinyl chloride (PVC-U)

Additionally, frameless glass doors are manufactured from 8 to 19 mm toughened glass using stainless steel fittings. The maximum door size being dependent on the weight of glass and the type of glass fixing adopted.

As much work in the construction industry related to windows and doors is within the field of replacements, a significant proportion of products are based on imperial dimensions, although they may be expressed both in imperial and metric measures.

1.02 Windows

The typical range of window types (BS 644: 2003) is illustrated **38.1**.

The modular range of windows (BS 644: 2003) is based on increments of 150 mm in height and 300 mm in width. The equal divide range also has height increments of 150 mm, but the widths are related to standardization of components in the manufacturing process. The two standard ranges are listed in Table I.

The following standards relate to windows constructed from the standard materials; Timber (BS 644: 2003), Aluminium alloy (BS 4873: 2004), Steel (BS 6510: 2005) and PVC-U (BS 7412: 2002). The safety aspects of cleaning windows are specified in BS 8213-1: 2004. Where required by the Building Regulations Part B 2000 (2006 Edition), fire escape windows must be provided with a clear opening of greater than 0.33 m^2 and a minimum clear dimensions of 450 mm. (e.g. 450 × 735 mm). These windows must not be restricted or lockable with removable keys.

Safety considerations (BS 6180: 1999) dictate that any opening window less than 800 mm from the floor should be protected to 800 mm by a barrier or restricted to less than 100 mm opening. It is a requirement (BS 6262-4: 2005) that all glazing less than 800 mm above floor (or ground level) should be of safety glass. Large openings up to 1100 mm above floor level should be guarded to that level when there is a drop outside of more than 600 mm (BS 8213-1: 2004).

Window Energy Ratings (WERs) are an established measure of window energy efficiency. A formula combines the elements of solar heat transmittance, U-value and air infiltration to produce an overall rating on the A–G scale, with A the most energy efficient for the whole window unit. Best building practice incorporates windows with ratings of C or better. To date, only a small proportion of complete window units qualify for the maximum A rating.

1.02 Doors

The majority of doors are manufactured to imperial dimensions, but the imperial sizes are usually quoted in metric units. Standard metric sizes for internal doors are 2040 mm × 526, 626, 726, 826 and 926 mm with thicknesses of 40 or 44 mm. Fire doors are rated either to BS 476-22: 1987 (e.g. FD 30) or to the European Standard BS EN 13501-2: 2003 (e.g. E30) for integrity in minutes. The ratings are normally subject to the use of appropriate frames with intumescent strips and any glazing being factory-fitted. In certain locations, the Building Regulations Part E, related to the passage of sound, require minimum sound reduction criteria, and these can be achieved by the use of appropriately sealed doorsets.

The standard metric size for external doors is 2000 × 807 mm (1994 mm × 806 and 906 mm to BS 4787-1: 1980) with thicknesses of 40 or 44 mm. Metric external door frames for 2000 × 807 mm external doors are typically 2100 × 900 mm coordination size (work size 2095 × 890 mm) with hardwood threshold and coordinating size 2053 × 900 mm (work size 2043 × 890 mm) without threshold.

1.03 Access for disabled people

The Building Regulations Part M – 2004 edition, requires a wheelchair access into buildings with a threshold no higher than 15 mm. Normally, the minimum effective clear entrance width required is 800 mm in new buildings, but 1000 mm in buildings used by the general public. Visibilty zones are required in doors between 500 mm and 1500 mm from floor level.

Windows also need to be carefully designed so that a transom interrupting vision for a seated person should not be between 900 and 1200 mm from the floor. The height for window controls to be used by people in wheelchairs should be between 800 and 1000 mm from the floor.

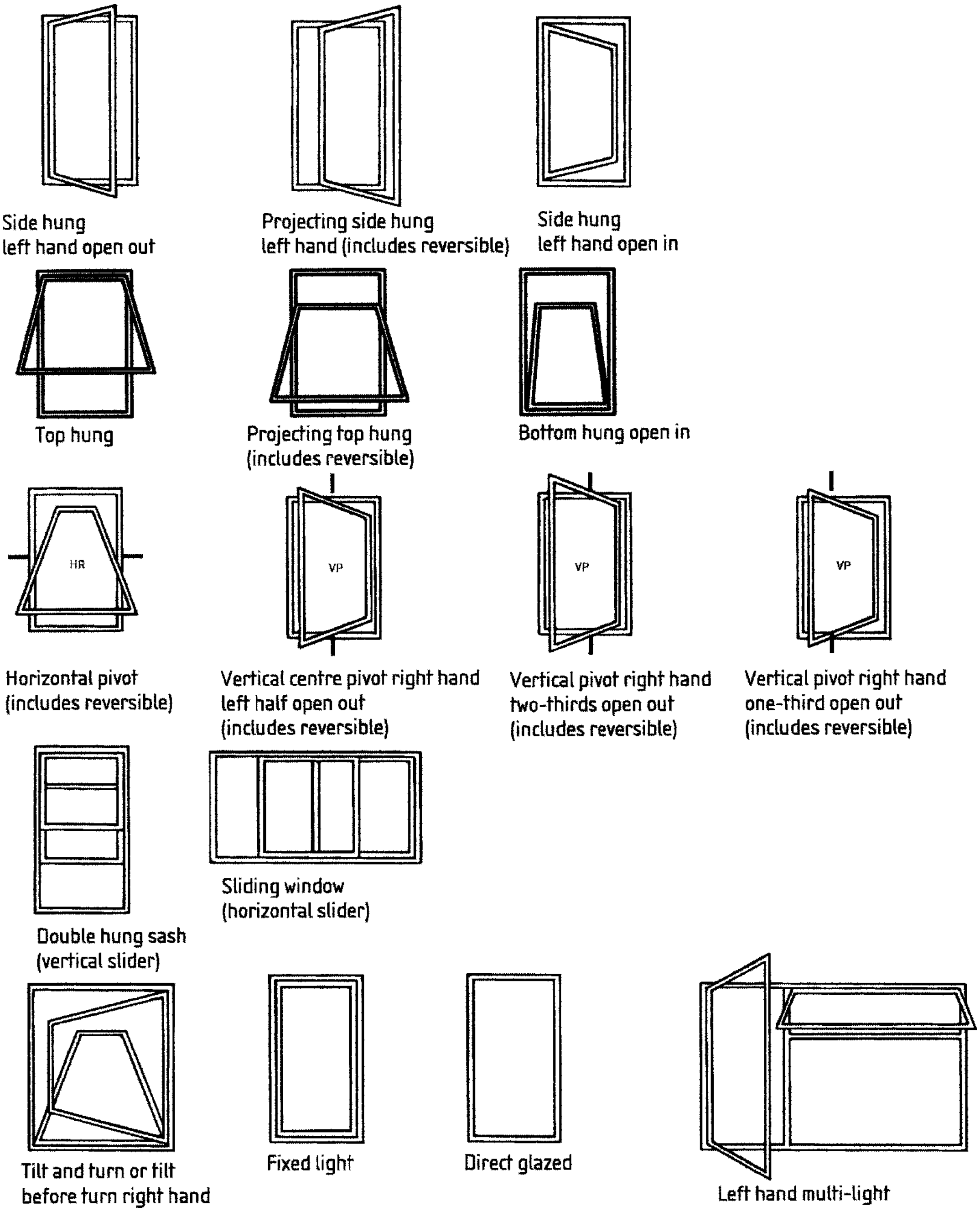
2 PIPES FOR PLUMBING AND DRAINAGE

2.01

Pipes for the conveyance of liquids and gases vary widely in material, quality, size and jointing methods. Many types are still based on inch measures and Whitworth screw threads, particularly as these were and are widely used not just in the United Kingdom but also in continental Europe. Even where pipe sizes are metricated, they do not always conform to the recommended series of dimensions. The standard (BS EN ISO 6708: 1996) recommends nominal sizes in millimeters (DN) for pipework systems. The DN designation may refer to either the bore or the outside diameter, which would then be referenced as DN/ID or DN/OD respectively. The nominal sizes do not relate to exact sizes, and many other size designations are also used.

The preferred DN values (BS EN ISO 6708: 1996) are: 10, 15, 20, 25, 32, 40, 50, 60, 65, 80, 100, 125, 150, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1400, 1500, 1600, 1800, 2000, 2200, 2400, 2600, 2800, 3000, 3200, 3400, 3600, 3800 and 4000.

The specifications for domestic water services in buildings are described in the standards BS 6700: 2006, BS EN 805: 2000 and



38.1 *Typical window types and handing. Note: When specifying handing, the window must be viewed from the outside*

Table I Standard metric window dimensions (BS 644: 2003)

Window height (mm)	Window width for modular range (mm)						Window width for equal divide range (mm)					
	300	600	900	1200	1800	2400	488	630	915	1200	1770	2339
450								*	*	*	*	*
600		*	*	*	*			*	*	*	*	*
750	*	*	*	*	*	*	*	*	*	*	*	*
900	*	*	*	*	*	*	*	*	*	*	*	*
1050	*	*	*	*	*	*	*	*	*	*	*	*
1200	*	*	*	*	*	*	*	*	*	*	*	*
1350	*	*	*	*	*	*	*	*	*	*	*	*
1500		*	*	*	*	*		*	*	*	*	*
2100			*	*	*	*			*	*	*	*

Note: The sizes given are co-ordinating sizes.
The work sizes are 5 mm less than the co-ordinating sizes.
Sizes not marked with an asterisk and certain larger sizes up to 3600 mm in width are standard products for some manufacturers.

BS EN 806-2: 2005. The standard BS 6700: 2006 also includes a comprehensive list of references relating to plumbing systems. Gravity drainage systems inside buildings are described in the series of standards BS EN 12056: 2000 Parts 1–5.

2.02 Pipe materials

Pipes are made of the following materials:

- Steel
- Copper
- Stainless steel
- Cast iron
- Plastics
- Vitrified clay
- Glass (for specialist laboratories, etc.).

2.03 Pipe joints

The methods in general use are:

- Screwed joints – steel and plastic
- Welding – steel
- Spigot and socket dry (push-fit)
- Spigot and socket with cementitious material – cast iron
- Spigot and socket with solvent cement – plastics
- Compression fittings – copper, stainless steel, light-gauge steel, plastics
- Capillary soldering – copper.

2.04 Insulation

Pipes carrying hot or chilled liquids, or in exposed conditions, will be insulated. The thickness of insulation will typically be between 25 and 75 mm depending on material used and the size of the pipe. After allowing for any such insulation, the space allowed for any pipe should be between two and three times its actual diameter which will allow for sockets, joints, bends and clearances. The standard BS 5970: 2001 as the Code of Practice, describes the types of insulating systems appropriate for various temperature ranges and BS 5422: 2001 indicates insulation thicknesses required under various conditions.

2.05 Steel pipes for screwed joints

Steel tubes are available in a range of gauges from light to heavy (BS EN 10220: 2002). Standard outside diameters for the range of nominal DN bore sizes are given in Table II based on BS EN 10241: 2000 and BS EN 10255: 2004.

2.06 Copper

Copper pipes are specified in accordance with BS EN 1057: 2006. Joints are made with compression fittings or by capillary soldering. There are three grades of delivery condition:

R220 (annealed)
R250 (half-hard)
R290 (hard)

Straight lengths are provided in hard or half-hard condition from 6 to 267 mm outside diameter and coils in annealed (soft) condition from 6 to 28 mm outside diameter.

Standard sizes and thicknesses are given in Table III. Tolerances are quoted in BS EN 12449: 1999.

2.07 Stainless steel

Stainless steel pipes are used as an alternative to copper piping – the appropriate alloys are listed in BS EN 10312: 2002. The standard dimensions for light gauge tubes are shown in Table IV to BS EN 10312: 2002, but a wider range of diameters and thicknesses are listed in BS EN ISO 1127: 1997. The standard BS 6362: 1990 gives a small range of thicknesses for use with pressure-tight threaded joints.

Table II Standard steel pipe sizes (BS EN 10241: 2000 and BS EN 10255: 2004)

Nominal size (DN)	Imperial dimension (inch)	Specified outside diameter (mm)
6	1/8	10.2
8	1/4	13.5
10	3/8	17.2
15	1/2	21.3
20	3/4	26.9
25	1	33.7
32	1 1/4	42.4
40	1 1/2	48.3
50	2	60.3
65	2 1/2	76.1
80	3	88.9
100	4	114.3
125	5	139.7

Table III Standard copper pipe sizes (BS EN 1057: 2006)

Nominal outside diameter (mm)	Nominal wall thickness (mm)
6	0.6, 0.8, 1.0
8	0.6, 0.8, 1.0
10	0.6, 0.7, 0.8, 1.0
12	0.6, 0.7, 0.8, 1.0
14	0.8, 1.0
15	0.7, 0.8, 1.0
16	1.0
18	0.8, 1.0
22	0.9, 1.0, 1.1, 1.2, 1.5
28	0.9, 1.0, 1.2, 1.5
35	1.0, 1.2, 1.5
40	1.0
42	1.0, 1.2, 1.5
54	1.0, 1.2, 1.5, 2.0
64	2.0
66.7	1.2, 2.0
76.1	1.5, 2.0
88.9	2.0
108	1.5, 2.5
133	1.5, 3.0
159	2.0, 3.0
219	3.0
267	3.0

Table IV Light gauge stainless steel pipe sizes (BS EN 10312: 2002)

Specified outside diameter (mm)	Maximum outside diameter (mm)	Specified wall thickness (mm)
6	6.04	0.6
8	8.04	0.6
10	10.04	0.6
12	12.04	0.6
15	15.04	0.6
18	18.04	0.7
22	22.05	0.7
28	28.05	0.8
35	35.07	1.0
42	42.07	1.1
54	54.07	1.2
66.7	66.75	1.2
76.1	76.3	1.5
108	108.3	1.5
133	133.5	1.5
159	159.5	2.0

2.08 Cast iron

Cast iron pipes are made to the following specifications:

- BS 460: 2002 Cast iron rainwater goods – specification.
- BS EN 877: 1999 Above and below ground pipes and fittings.
- BS 416 Part 1: 1990 Discharge and ventilating pipes – spigot and socket systems.
- BS 437: 1978 Underground spigot and socket drain pipes.

Nominal DN and maximum external pipe diameters are given in Table V.

Table V Cast iron pipe maximum external diameters

Nominal size (DN)	BS 460: 2002 (mm)	BS EN 877: 1999 (mm)	BS 416-1: 1990 (mm)	BS 437: 1978 (mm)
40		50		
50	56	60	63	65
65	69	80	76	
75	82	85	89	92
90			101	
100	108	112	114	119
125		137		
150	157	162	165	173
200		212.5		
225				256
250		276.5		
300		328.5		
400		431		
500		534		

2.09 Plastics

Both the types of plastic used for pipes and their uses are numerous. Consequently, there are a considerable number of British and European Standards governing this range of materials. BS 6700: 2006 has many useful references and lists the following plastics for domestic water services – polybutylene (PB), polyethylene (PE), cross-linked polyethylene (PE-X), unplasticised polyvinyl chloride (PVC-U), acrylonitrile butadiene styrene (ABS). In addition, chlorinated poly vinyl chloride (PVC-C), polypropylene copolymer (PP) and styrene copolymer (SAN+PVC) are used in soil and waste systems. Standards BS ISO 11922 Parts 1 and 2: 1997 give the nominal outside diameters for metric and inch series thermoplastic pipes respectively. These are given in Tables VI and VII, respectively.

The following table (Table VIII) lists the standards relating to the various types of plastic pipe.

BS EN 1451-1: 2000 describes polypropylene waste pipes and fittings for the series based on inch diameters. Table IX gives the dimensions of this limited range.

2.10 Pipes of vitrified clay

Vitrified clay pipes for drains and sewers are described in BS EN 295-1: 1991. The minimum bores are slightly less than the listed nominal sizes (DN); 100, 150, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000 and 1200.

Table VI Sizes of plastic pipes (BS ISO 11922-1: 1997) (metric series)

Nominal outside diameter (mm)			
10	50	160	355
12	63	180	400
16	75	200	450
20	90	225	500
25	110	250	560
32	125	280	630
40	140	315	710

Note: More larger sizes are also included in the standard.

Table VII Sizes of plastic pipes (BS ISO 11922-2: 1997) (inch-based series)

Nominal size (inches)	Mean external diameter (mm)	Nominal size (inches)	Mean external diameter (mm)
1/8	10.2	7	193.7
1/4	13.5	8	219.1
1/8	17.2	9	244.5
1/2	21.3	10	273.0
3/4	26.9	12	323.9
1	33.7	14	355.6
1 1/4	42.4	16	406.4
1 1/2	48.3	18	457.2
2	60.3	20	508.0
2 1/2	75.3	22	558.8
3	88.9	24	609.6
4	114.3	26	660.4
6	168.3	28	711.2

Note: More larger sizes are also included in the standard.

Table VIII Plastic pipe standards

Utility function	Standard	Plastic pipe type
Soil and waste	BS EN 1329-1: 2000	Unplasticised poly vinyl chloride (PVC-U)
	BS EN 1451-1: 2000	Polypropylene (PP)
	BS EN 1453-1: 2000	Unplasticised poly vinyl chloride (PVC-U)
	BS EN 1455-1: 2000	Acrylonitrile-butadiene-styrene (ABS)
	BS EN 1456-1: 2001	Unplasticised poly vinyl chloride (PVC-U)
	BS EN 1519-1: 2000	Polyethylene (PE)
	BS EN 1565-1: 2000	Styrene copolymer blends (SAN+PVC)
	BS EN 1566-1: 2000	Chlorinated polyvinyl chloride (PVC-C)
Water supply	BS EN 1452-1: 2000	Unplasticised poly vinyl chloride (PVC-U)
	BS EN 12201-2: 2003	Polyethylene (PE)
	BS 4991: 1974	Propylene copolymer
Hot and cold water supply	BS 7291-1: 2006	General requirements
	BS 7291-2: 2006	Polybutylene (PB)
	BS 7291-3: 2006	Cross-linked polyethylene (PE-X)

Table IX Sizes of polypropylene pipes (BS EN 1451-1: 2000) (inch-based series)

Nominal size (DN/OD)	Equivalent inch dimension (inch)	Nominal outside diameter (mm)	Mean outside diameter (mm)
34	1 1/4	34	34.6
41	1 1/2	41	41.0
54	2	54	54.1

3 MATERIALS FOR ELECTRICITY SUPPLY AND DISTRIBUTION

3.01 Electricity supply and distribution cables are mainly:

- Armoured cable for intake (not covered here, see the technical literature)
- PVC insulated, in conduits of steel or plastic
- PVC insulated, PVC sheathed
- Mineral insulated copper (or aluminium) conductors

General guidance on the use of 450/750 voltage cables is given in the standard BS 7540: 2005.

3.02 PVC double-insulated cables

These are normally used in electrical distribution for the smaller building types. Guidance on the use of PVC insulated cables is included in BS 6004: 2000. Table X gives the dimensions of PVC insulated cables, which are often accommodated in small ducts or voids in the construction. Conductor cross-sectional areas of 1.0 and 1.5 mm^2 are used for lighting circuits, while ring mains require conductors of 2.5 mm^2. Light and heavy duty cookers or showers require 6.0 and 10.0 mm^2 conductors respectively. Since earth-continuity conductors are now used in all circuits, all cable types have integral earth conductors. Cables with three insulated cores plus earth are used for circuits with two-way switching of lights. Flexible electrical cords for the connection of mobile and portable equipment are detailed in Table XI. Heat resisting (110°C) rubber cable is described in the standard BS 6007: 2006.

Table X Maximum dimensions of PVC insulated, PVC sheathed cable 300/500 volt (BS 6004: 2000)

Nominal cross-sectional area of single conductor (mm^2)	Single core diameter (mm)	Flat twin core dimensions (mm)	Flat three core dimensions (mm)
1.0	4.5	4.7 × 7.4	4.7 × 9.8
1.5	4.9	5.4 × 8.4	5.4 × 11.5
2.5	5.8	6.2 × 9.8	6.2 × 13.5
4.0	6.8	7.2 × 11.5	7.4 × 16.5
6.0	7.4	8.0 × 13.0	8.0 × 18.0
10.0	8.8	9.6 × 16.0	9.6 × 22.5

Table XI Maximum dimensions of flexible electric cords rated up to 300/500 V for connection of appliances and equipment (BS 6500: 2000)

Cross-sectional area of single conductor (mm^2)	Rubber insulated and sheathed (mm)			Rubber insulated and fibre braided (mm)		PVC insulated and sheathed (mm)			
	Twin	Three core	Four core	Twin	Three core	Parallel twin	Round twin	Three core	Four core
0.5	6.2	6.6	7.3	7.0	7.4				
0.75	6.6	7.2	7.8	7.3	7.8	4.5 × 7.2	7.2	7.6	8.3
1.0	7.2	7.8	8.3	7.7	8.2	4.7 × 7.5	7.5	8.0	9.0
1.5	8.8	9.3	10.3	9.2	9.8		8.6	9.4	10.5
2.5	10.2	10.9	12.1				10.6	11.4	12.5

Note: The core cables are colour coded: Twin – blue and brown, 3-core – green-and-yellow, blue and brown, 4-core – green-and-yellow, brown, black, grey or green-and-yellow, blue, brown, black, 5-core – green-and-yellow, blue, brown, black and grey.

3.03 Fire-resistant cables

Fire-resistant electric cables having low smoke emission when affected by fire are specified in BS 7629 Parts 1 and 2: 1997, for multicore and multipair cables respectively. The key dimensions are noted in Table XII. The Code of Practice (BS 5839-1: 2002) gives guidance on the design and operation of fire detection and alarm systems.

3.04 Cable trunking and conduit systems

Cable trunking systems are covered in BS EN 50085 Part 1: 2005, Part 2–1: 2006 and Part 2–3: 2001. Conduit systems for cable management are described in BS EN 61386 Parts 1, 21, 22 and 23: 2004, which give the standard sizes as 6, 8, 10, 12, 16, 20, 25, 32, 40, 50, 63 and 70 mm. Steel conduit is specified in BS 4568-1: 1970, and non-metallic non-circular conduits are specified in BS 4607-5: 1982. The dimensions are listed in Table XIII.

3.05 Boxes for electrical accessories

Boxes for the flush mounting of electrical accessories such as switches, socket outlets, cooker points, etc. are covered by BS 4662: 2006. These are summarised in Table XIV. The standard also quotes the internal dimensions for dry lining mounted boxes.

Table XII Dimensions of fire-resistant cables (BS 7629 Parts 1 and 2: 1997)

Number of cores (BS 7629-1: 1997)	Nominal cross sectional area of conductor (mm^2)	Approximate overall diameter (mm)
2	1.0	8.0
	1.5	8.5
	2.5	10.5
	4.0	13.5
3	1.0	8.0
	1.5	9.5
	2.5	12.0
	4.0	13.5
4	1.0	9.0
	1.5	10.5
	2.5	13.0
	4.0	15.0
7	1.0	11.0
	1.5	12.5
	2.5	15.0
Number of pairs (BS 7629-2: 1997)	**Nominal cross sectional area of conductor (mm^2)**	**Approximate overall diameter (mm)**
1	1.0	8.0
	1.5	8.5
	2.5	10.5
2	1.0	9.0
	1.5	10.5
	2.5	13.0
5	1.0	16.5
	1.5	20.5
	2.5	23.0

Note: Larger numbers of cores and pairs are listed in the two quoted standards.

Table XIII Steel and non-metallic conduits (BS 4568-1: 1970 and BS 4607-1: 1984)

Nominal size	Steel (BS 4568-1: 1970) Maximum outside dimensions (mm)		Non-metallic (BS 4607-5: 1982) Maximum outside dimensions (mm)
	Light gauge plain ends	Heavy gauge screwed or plain ends	
13			13.0 × 8.1
16	16.0	16.0	16.3 × 9.9
20	20.0	20.0	22.6 × 11.4
25	25.0	25.0	28.7 × 11.4
32	32.0	32.0	32.5 × 11.4

Table XIV Rectangular boxes for the accommodation of electrical wiring accessories (BS 4662: 2006)

Box type	External dimensions (mm)	Nominal depths (mm)
1 gang	75 × 75	16, 25, 35, 41, 47
2 gang	135 × 75	16, 25, 35, 41, 47
3 gang	195 × 75	16, 25, 35, 41, 47
4 gang	135 × 135	16, 25, 35, 41, 47
6 gang	195 × 135	16, 25, 35, 41, 47

4 BIBLIOGRAPHY AND REFERENCES

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TRADA Technology, 2004: '*High performance wood windows*', High Wycombe, TRADA Technology Ltd

BS 459: 1988 Matchboarded wooden door leaves for external use

BS 644: 2003 Timber windows. Factory assembled windows of various types. Specification

BS 1245: 1975 Metal door frames (steel)

BS 1567: 1953 Specification for wood door frames and linings

BS 4787-1: 1980 Internal and external doorsets, door leaves and frames. Specification for dimensional requirements

BS 4873: 2004 Aluminium alloy windows

BS 6180: 1999 Barriers in and about buildings. Code of practice

BS 6375-1: 2004 Performance of windows and doors. Classification for weathertightness and guidance on selection and specification

BS 6510: 2005 Steel-framed windows and glazed doors

BS 7412: 2002 Plastics windows made from unplasticized polyvinyl chloride (PVC-U) extruded hollow profiles

BS 8213 Windows, doors and rooflights:

Part 1: 2004 Design for safety in use and during cleaning of windows. Code of practice.

Part 4: 2007 Code of practice for the survey and installation of windows and external doorsets

BS EN 1529: 2000 Door leaves. Height, width, thickness and squareness. Tolerance classes

BS EN 12519: 2004 Windows and pedestrian doors. Terminology

BS EN 13501-2: 2003 Fire classification of construction products and building elements

BS EN 14220: 2006 Timber and wood-based materials in external windows, external door leaves and external doorframes. Requirements and specifications

BS EN 14221: 2006 Timber and wood-based materials in internal windows, internal door leaves and internal doorframes. Requirements and specifications

BS EN 14351-1: 2006 Windows and doors. Product standard, performance characteristics

PAS 23-1: 1999 General performance requirements for door assemblies. Single leaf external door assemblies to dwellings

4.02 Pipes for plumbing and drainage

BS 21: 1985 Specification for pipe threads for tubes and fittings where pressure-tight joints are made on the threads (metric dimensions)

BS ISO 161-1: 1996 Plastics. Pipes, fittings and valves. Nominal outside diameters and pressures. Metric series

BS 416-1: 1990 Discharge and ventilating pipes and fittings, sancast or spun in cast iron. Specification for spigot and socket systems

BS 437: 1978 Specification for cast iron spigot and socket drain pipes and fittings

BS 460: 2002 Cast iron rainwater goods. Specification

BS 3867: 1987 Outside diameters and pressure ratings for pipe of thermoplastics materials (inch series)

BS 4991: 1974 Specification for polypropylene copolymer pressure pipe

BS 5254: 1976 Specification for polypropylene waste pipe and fittings

BS 5422: 2001 Method for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range –40°C to +700°C

BS 5970: 2001 Code of practice for thermal insulation of pipework and equipment in the temperature range of –100°C to +870°C

BS 6362: 1990 Specification for stainless steel tubes suitable for screwing in accordance with BS 21 pipe threads for tubes and fittings where pressure-tight joints are made on the threads

BS 6700: 2006 Design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages. Specification

BS 7291 Thermoplastics pipes and associated fittings for hot and cold water for domestic purposes and heating installations in buildings:

Part 1: 2006 General requirements.

Part 2: 2006 Specification for polybutylene (PB) pipe and associated fittings.

Part 3: 2006 Specification for cross-linked polyethylene (PE-X) pipes and associated fittings

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Part 2: 1997 Inch-based series

BS EN 295-1: 1991 Vitrified clay pipes and fittings and pipe joints for drains and sewers. Requirements

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Part 2: 2005 Design

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BS EN 1057: 2006 Copper and copper alloys. Seamless, round copper tubes for water and gas in sanitary and heating applications

BS EN ISO 1127: 1997 Stainless steel tubes. Dimensions and conventional masses per unit length

BS EN 1329-1: 2000 Plastics piping systems for soil and waste discharge (low and high temperature) within the building structure. Unplasticised poly (vinyl chloride) (PVC-U). Specifications for pipes, fittings and the system

BS EN 1451-1: 2000 Plastics piping systems for soil and waste discharge (low and high temperature) within the building structure. Polypropylene (PP). Specifications for pipes, fittings and the system

BS EN 1452-1: 2000 Plastics piping systems for water supply. Unplasticised poly (vinyl chloride) (PVC-U). General

BS EN 1453-1: 2000 Plastics piping systems with structured-wall pipes for soil and waste discharge (low and high temperature) inside buildings. Unplasticised poly (vinyl chloride) (PVC-U). Specifications for pipes and the system

BS EN 1455-1: 2000 Plastics piping systems for soil and waste (low and high temperature) within the building structure. Acrylonitrile–butadiene–styrene (ABS). Specifications for pipes, fittings and the system

BS EN 1456-1: 2001 Plastic piping systems for buried and above-ground drainage and sewerage under pressure. Unplasticised poly (vinyl chloride) (PVC-U). Specifications for piping components and the system

BS EN 1519-1: 2000 Plastics piping systems for soil and waste discharge (low and high temperature) within the building structure. Polyethylene (PE). Specifications for pipes, fittings and the system

BS EN 1565-1: 2000 Plastics piping systems for soil and waste discharge (low and high temperature) within the building structure. Styrene copolymer blends (SAN+PVC). Specifications for pipes, fittings and the system

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BS EN ISO 6708: 1996 Pipework components. Definition and selection of DN (nominal size)

BS EN 10242: 1995 Threaded pipe fittings in malleable cast iron

BS EN 10220: 2002 Seamless and welded steel tubes. Dimensions and masses per unit length

BS EN 10226 Pipe threads where pressure tight joints are made on the threads:

Part 1: 2004 Taper external threads and parallel internal threads.

Part 2: 2005 Taper threads.

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BS EN 10241: 2000 Steel threaded pipe fittings

BS EN 10255: 2004 Non-ally steel tubes suitable for welding and threading. Technical delivery conditions

BS EN 10312: 2002 Welded stainless steel tubes for the conveyance of water and other aqueous liquids. Technical delivery conditions

BS EN 12056 Parts 1–5: 2000 Gravity drainage systems inside buildings

BS EN 12201-2: 2003 Plastics piping systems for water supply. Polyethylene (PE). Pipes

BS EN 12449: 1999 Copper and copper alloys. Seamless, round tubes for general purposes

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Part 1: 1970 Steel conduit, bends and couplers

BS 4607 Non-metallic conduit fittings for electrical installations:

Part 1: 1984 Specification for fittings and components of insulating material.

Part 5: 1982 Specification for rigid conduits, fittings and components of insulating material

BS 4662: 2006 Boxes for flush mounting of electrical accessories. Requirements and test methods and dimensions

BS 5839-1: 2002 Fire detection and alarm systems for buildings. Code of practice for system design, installation, commissioning and maintenance

BS 6004: 2000 Electric cables. PVC insulated, non-armoured cables for voltages up to and including 450/750 V, for electric power, lighting and internal wiring

BS 6007: 2006 Electric cables. Single core unsheathed heat resisting cables for voltages up to and including 450/750 V, for internal wiring

BS 6500: 2000 Electric cables. Flexible cords rated up to 300/500 V, for use with appliances and equipment intended for domestic, office and similar environments

BS 7211: 1998 Electric cables. Thermosetting insulated, non-armoured cables for voltages up to and including 450/750 V, for electric power, lighting and internal wiring, and having low emission of smoke

BS 7540 Electric cables. Guide to use for cables with a rated voltage not exceeding 450/750 V.

Part 1: 2005 General guidance:

Part 2: 2005: Harmonized cable types from HD 21 and HD 22.

Part 3: 2005 National standard cables not included in HD 21 and HD 22

BS 7629 Specification for 300/500 V fire resistant electric cables having low emission of smoke and corrosive gases when affected by fire:

Part 1: 1997 Multicore cables.

Part 2: 1997 Multipair cables

BS 7671: 2001 Requirements for electrical installations. IEE wiring regulations, sixteenth edition

BS EN 50085 cable trunking systems and cable ducting systems for electrical installations:

Part 1: 2005 General requirements.

Part 2–1: 2006 Cable trunking systems and cable ducting systems intended for mounting on walls and ceilings.

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BS EN 60670 Boxes and enclosures for electrical accessories for household and similar fixed electrical installations:

Part 1: 2005 General requirements.

Part 22: 2006 Particular requirements for connecting boxes and enclosures

BS EN 61386 Conduit systems for cable management:

Part 1: 2004 General requirements.

Part 21: 2004 Particular requirements. Rigid conduit systems.

Part 22: 2004 Particular requirements. Pliable conduit systems.

Part 23: 2004 Particular requirements. Flexible conduit systems

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39 Thermal environment

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KEY POINTS:
- *Safety and comfort for the inhabitants are the main considerations for an internal environment*
- *Conservation of energy and reduction of emissions come a close second*

Contents

1 INTRODUCTION

1.01

Thermal design is concerned with the heat transfer processes that take place within a building, and between the building and its surroundings and the external climate, **39.1**. It is primarily concerned with providing comfort and shelter for the building's occupants and contents. Thermal design therefore includes consideration of the

- Climate
- Building form and fabric
- Building environmental services, and
- Occupants and processes contained within the building.

It is also concerned with the energy used to provide heating, cooling and ventilation of buildings, and the local and global impact of energy use. The thermal design should be integrated with the visual and acoustic aspects of the design in order to achieve an overall satisfactory environmental solution.

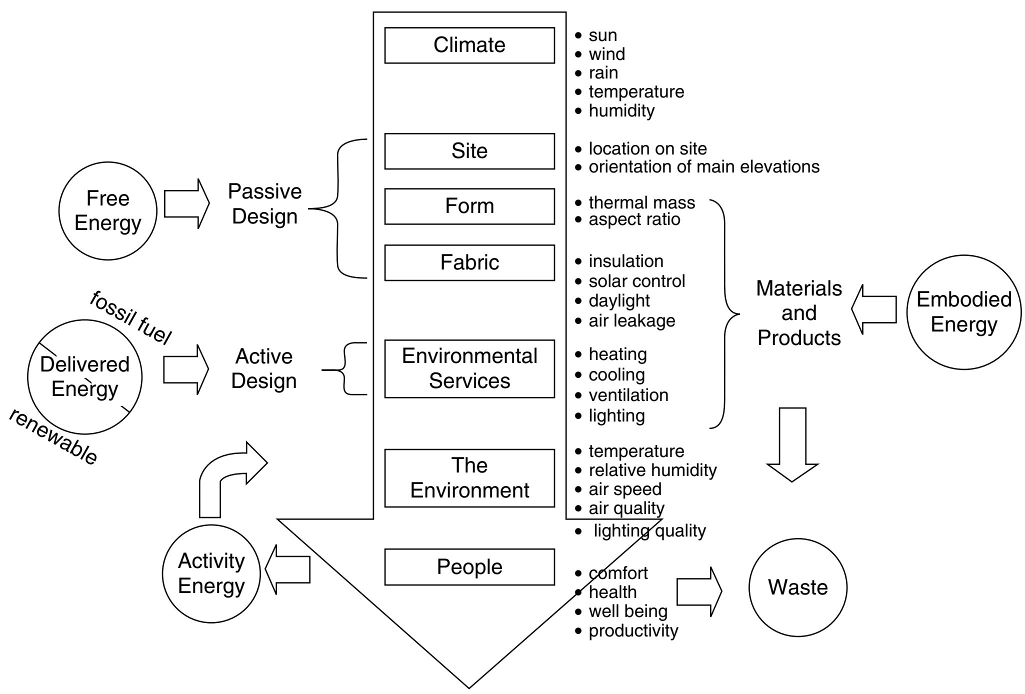
1.02 Three stages to thermal design

Stage 1: Internal environmental conditions for occupants or processes

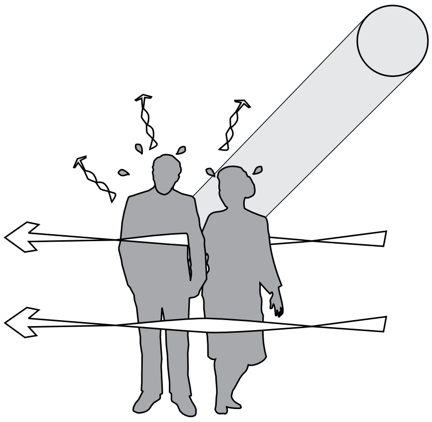
The prime aim is to create spaces that are comfortable, healthy and productive for their occupants, **39.2** People will typically spend 90% or more of their time in buildings. The environments people live and work in must promote a good quality of life. Thermal conditions should be within acceptable comfort limits and the indoor air quality should be free from any harmful pollutants. Buildings must also provide appropriate thermal conditions for their contents, processes and for maintaining the building fabric itself. The required environmental conditions of all spaces should be clearly defined at the initial design stage in relation to the activities and contents of the space.

Stage 2: Climate modification through the building envelope

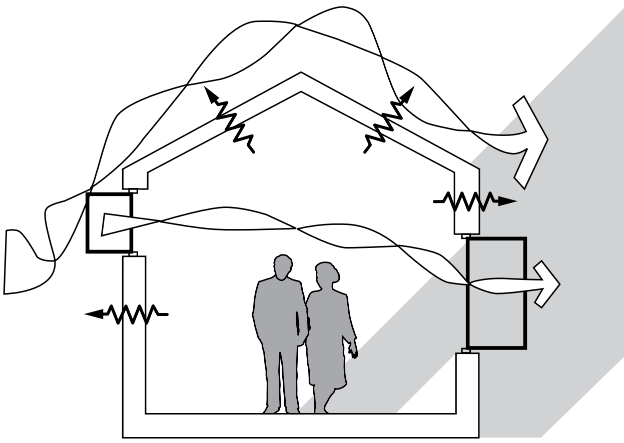
Buildings can be designed to interact with the external environment in order to benefit from the natural energy of the sun and wind, **39.3**. The envelope of the building can be used to 'filter' or 'modify' the external climate to provide internal comfort conditions for much of the year without the use of fuel. The heat from the sun can be used to heat spaces in winter or to drive air movement for ventilation and cooling through buoyancy forces. The building form and fabric can be used to control solar gains in summer to avoid overheating. The wind can also be used to provide ventilation and cooling. The fabric of the building can be used to insulate



39.1 *Thermal design to achieve comfort for a given climatic condition. Passive design is related to building form and fabric. Active design is related to mechanical services, energy use and environmental impact. The environmental conditions must be suitable for the health and comfort of the occupants. There are a number of energy inputs associated with a buildings construction and operation*



39.2 *Thermal comfort is influenced by air temperature, air movement, relative humidity and the surrounding radiant environment*



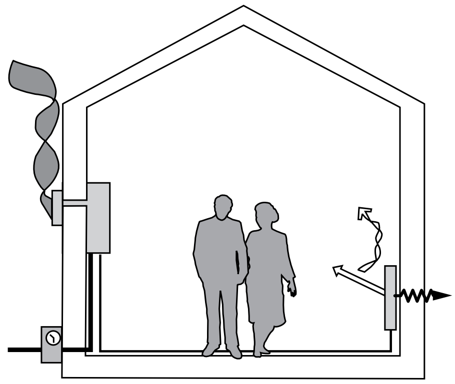
39.3 *Climatic modification can be achieved through manipulation of a building's form and construction*

against heat loss or gain, and to stabilise the internal environment against extremes of temperatures (hot or cold). The form, mass, orientation and construction of the building need to be designed in response to the climate and specific location. This is often termed 'passive design'.

Stage 3: Mechanical services

If a building is designed to respond positively to the climate then its dependence on mechanical services to heat, cool and ventilate spaces can be minimised, **39.4**. However, there are few climates in the world where mechanical systems can be eliminated altogether. In temperate climates such as the UK a heating system will still generally be required during the winter period, and some buildings require mechanical cooling in summer. In hot climates, mechanical cooling is often needed, sometimes the whole year round, for example, for commercial buildings. These services should be provided in an energy-efficient way in order to minimise energy use from fossil fuels, and to reduce the impact that buildings have on polluting the environment. Low and zero carbon sources of energy should be considered, such as renewable energy sources, including wind power, photovoltaics, solar thermal, biomass, combined heat and power (CHP) and ground source heat pumps. The mechanical systems and their controls should be designed to be able to respond to the specific needs of the occupants.

It is important to adopt a holistic integrative approach to thermal design incorporating an appropriate blend of architectural (passive design) and engineering (active design) solutions.



39.4 *Mechanical services should be designed to minimise energy use and environmental impact*

1.03 Energy inputs

Thermal design is closely associated with energy use. However, the energy inputs to a building, **39.1**, are not all associated with carbon emissions. It is only the energy from fossil fuel sources that have associated carbon emissions. There will be **free energy** from the sun, wind and external temperatures that can be used to heat, cool, light and ventilate the building. This passive design approach uses the buildings envelop, form and glazing to optimise the benefits from external environmental conditions.

The **delivered energy** is that used to provide power and heat to the environmental systems. This has traditionally been supplied from a centralised grid system and involves the use of fossil fuels either to generate electricity or to produce heat. The aim of sustainable design is to replace fossil fuel sources of delivered energy with renewable and low carbon energy supply systems.

The **embodied energy** is that associated with processed materials and products used during a buildings construction and fit-out. This includes the process energy to acquire natural resources and to produce the materials and components, and the transport energy associated with their production and delivery to site. As the delivered energy is reduced through a more energy efficient design, the embodied energy becomes of increasing significance. The embodied energy is closely linked with the life-cycle and environmental costs of raw materials and material manufacture, lifetime durability, and end of use disposal. In sourcing a building material or component the embodied energy is a major factor in determining its sustainability. The use of local materials is favoured as transportation energy costs are reduced. In general terms the more highly processed a material is the higher its embodied energy. The highest embodied energy is found in metals (steel requires 75,000 kWh/m^3), compared to building timber (typically 110 kWh/m^3) or those made from salvaged materials or local natural materials, which can require virtually no energy. It is also preferable to use reclaimed materials, or materials with a high recycled content such as metals although the process of recycling adds to their embodied energy. Sustainable design should encourage construction systems which use fewer materials. Some construction types are inherently more wasteful than others. Standardisation, the use of less packaging and using more locally sourced off-site construction methods should be encouraged. Transportation of materials also plays a significant role in embodied energy calculations, especially where buildings are remotely located. Typically the embodied energy of a house might be between 500 and 1000 kWh/m^2, whilst delivered energy for a house built to current standards might be about 50–100 kWh/m^2/year.

The **activity energy** is that derived from the use of the building. This is generally in the form of heat emitted from the processes of cooking, lighting, the use of small power, and the heat generated by the occupants themselves and the specific processes that occur in buildings. All these can provide a useful heat gain to the building in the winter, but can give rise to overheating in the summer and for some building types even in winter. In many countries, the energy use associated with occupant activities is increasing, through more consumer electrically powered goods. Typical internal energy loads are presented later in Table XXXIV.

2 HEAT TRANSFER MECHANISMS

2.01

There are four types of heat transfer that relate to thermal environmental design, **39.5**. These are conduction, convection, radiation and evaporation. They are described below with examples of how they relate to building thermodynamics.

Heat is a form of energy, measured in joules (J). The rate of energy use is termed power which is measured in watts (W), where;

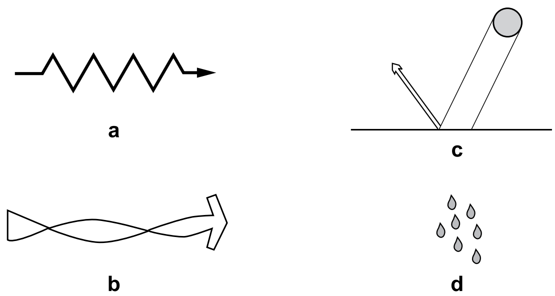
1 W = 1 J/s (1 kW = 1000 J/s)

Another unit of energy is the kilowatt-hour (kWh), where:

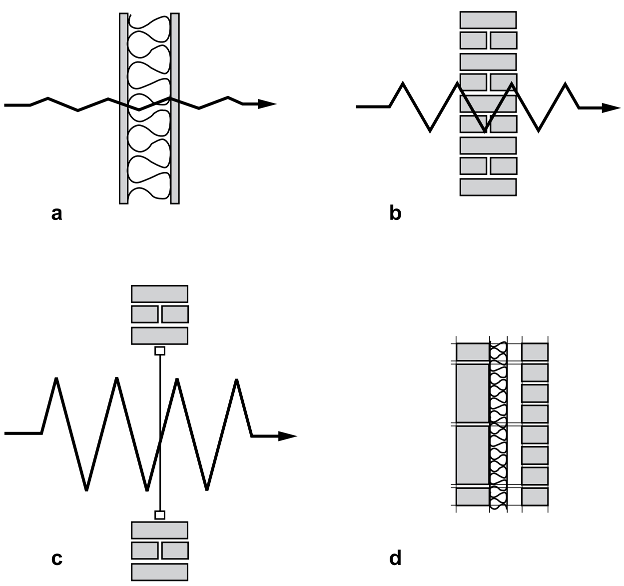
1 kWh = 3600 J (or 3.6 MJ)

and the therm, where:

1 therm = 29.3 kWh



39.5 *Heat is transferred by:* **a** *Conduction;* **b** *Convection;* **c** *Radiation;* **d** *Evaporation*



39.6 *Comparison of thermal conduction properties of different constructions.* **a** *Mineral wool has a low density (25 kg/m³) and is a good thermal insulator (k = 0.035 W/m·K).* **b** *Bricks have a relatively high density (1700 kg/m³) and is (k = 0.84 W/m·K).* **c** *Glazing has a relatively high density (1700 kg/m³) and a poor insulator (k = 1.05 W/m·K).* **d** *Walls need to have structural and weatherproofing properties as well as thermal insulation properties. Most wall constructions are therefore composed of a number of layers, the resistances of which can be added to give an appropriate overall thermal resistance of the wall*

Table I Thermal conductivity and density of common building materials

Material	Density (kg/m³)	Thermal conductivity (W/m·K)
Walls		
Brickwork (outer leaf)	1700	0.84
Brickwork (inner leaf)	1700	0.62
Cast concrete (dense)	2200	1.70
Cast concrete (lightweight, dry)	620	0.20
Concrete block (heavyweight)	2240	1.31
Concrete block (mediumweight)	1900	0.77
Concrete block (lightweight)	1760	0.66
Concrete block (insulating)	470	0.11
Cement mortar	1650	0.72
Fibre board (performed)	240	0.042
Plasterboard	950	0.16
Tile hanging	1900	0.84
Timber	720	0.14
Glass (solid)	2500	1.05
Surface finishes		
Rendering (moisture content 8%)	1330	0.79
Plaster (dense)	1200	0.52
Plaster (lightweight)	800	0.22
Calcium silicate brick	2000	1.50
Roofs		
Aerated concrete slab	500	0.16
Asphalt	1700	0.50
Bitumen/felt layers	1700	0.50
Screed	1200	0.41
Stone chippings	1800	0.96
Tile	1900	0.84
Wood wool slab	500	0.10
Floors		
Cast concrete	2000	1.13
Metal tray	7800	50.0
Screed	1200	0.41
Timber flooring	650	0.14
Wood blocks	650	0.14
Insulation		
Expanded polystyrene (EPS) slab	23	0.035
Mineral wool quilt	12	0.040
Mineral wool slab	25	0.035
Phenolic foam board	30	0.040
Polyurethane board	24	0.023
Paper (cellulose)	34	0.035
Straw bale	110	0.09
Sheeps wool	25	0.039

2.02 Conduction

Conduction normally applies to heat transfer through solids. It is the transfer of heat from molecule to molecule from relatively warm to cool regions. The rate of heat transfer through a solid is dependent on its thermal conductivity, or *k*-value. The *k*-value is loosely related to the density of the material, **39.6** (see Table I). High-density materials generally have high *k*-values – they are termed 'good conductors' of heat (e.g. high-density concrete and metals). Low-density materials have low *k*-values – they are termed 'good thermal insulators' (e.g. mineral fibre batts and low-density concrete blocks). The thermal resistance of a given thickness of material in a construction is calculated by dividing its thickness by its *k*-value:

$$R = x/k \qquad (1)$$

where R = thermal resistance ($m^2 \cdot K/W$)
x = thickness (m)
k = thermal conductivity (W/m·K)

Materials with a high thermal resistance provide good thermal insulation.

The resistivity, r, of a material is the inverse of its conductivity k, that is,

$$r = 1/k$$

Example 1

What is the thermal resistance of a wall comprising 102.5 mm brick, 100 mm mineral wool slab insulation, 100 mm lightweight concrete block?

Material	Thickness (m)	k-value (W/m·K)	Resistance (m^2·K/W)
Brick	0.1025	0.84	0.12
Insulation	0.1	0.035	2.86
Block (insulating)	0.1	0.11	0.91
Total thermal resistance			3.89

Notes:
(1) Values for conductivity are from Table I.
(2) The thermal resistance of each layer is calculated according to formula 1:$R = x/k$.
(3) The main contribution to the total thermal resistance is from the mineral wool slab insulation.
(4) Thermal resistance will be used later in the calculation of *U*-values (in Section 5).

2.03 Convection

Convection takes place in a fluid such as air or water. Once heated it becomes less dense and more buoyant. Fluids are normally heated by conduction from a warm surface such as the electric element in a hot water cylinder, or the hot surface of a panel heater. A cold surface will conduct heat from the adjacent fluid, thereby cooling the fluid. This will make the fluid more dense and cause the fluid to become less buoyant, for example, causing a downdraught from the internal surface of a cold window. For a typical room, the relatively warm and cool surfaces set up a series of interacting convective flow patterns. The convection of air in a room is an integral part of most heating systems.

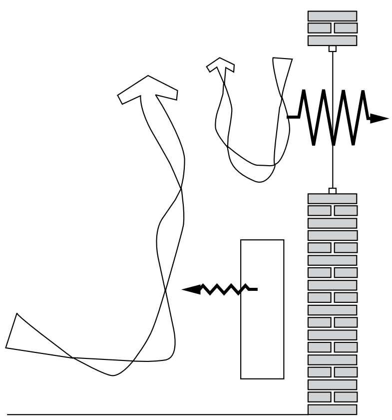
In the example, **39.7**, heat is conducted from the air to the cooler surface of the glazing, causing a downdraught. Heat is conducted to the air from the warmer surface of the panel heater, causing an updraught. Although panel heaters are usually called radiators they mainly provide heat (typically 60–70%) through convection. The formula for convective heat transfer from a surface to air is:

$$Q_c = h_c \times (t_a - t_s) \quad (2)$$

where Q_c = convective heat transfer (W)
h_c = convective heat transfer coefficient ($Wm^{-2}K^{-1}$)
t_a = air temperature (°C)
t_s = surface temperature (°C)

Heat flow upwards: $h_c = 4.3\ Wm^{-2}K^{-1}$
Heat flow downwards: $h_c = 1.5\ Wm^{-2}K^{-1}$
Heat flow horizontally: $h_c = 3.0\ Wm^{-2}K^{-1}$

Note: Values of h_c are at room temperature (21°C).

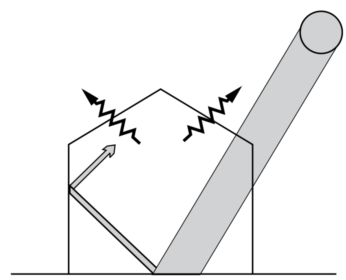


39.7 *Typical convection patterns generated by relatively warm (panel heater) and cool (glazing)*

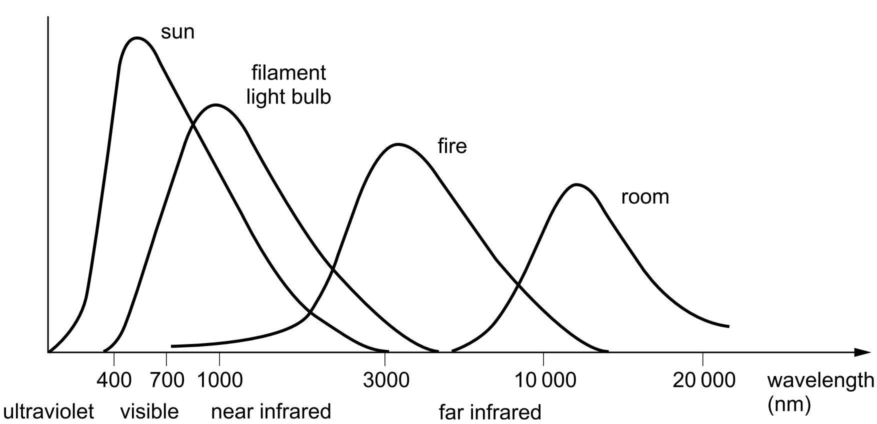
2.04 Radiation

Radiation is the transfer of heat between two surfaces without heating the air between them. Solar heat travels by radiation from the sun to the earth through the vacuum of space. Radiant heat is in the infrared part of the electromagnetic spectrum (which includes X-rays, ultraviolet, visible light, infrared, microwaves and radio, waves – which differ from each other by their wavelength and frequency). The sun emits radiation with wavelengths between 0.29 and 3.0 μm, which includes the visible spectrum (0.38 and 0.78 μm), **39.8**. The hotter the emitting body, the shorter the wavelength. Inflated radiation below a wavelength of 3.0 μm (or 3000 nm) is termed short-wave; above this it is termed long-wave. The sun therefore emits most of its heat energy as short-wave radiation, while lower-temperature surfaces, such as buildings, tend to emit only long-wave radiation.

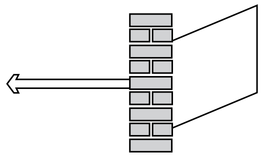
Glass is relatively transparent to short-wave radiation while opaque to long-wave radiation. This is the principle of the 'greenhouse effect', **39.9**, which is important in 'passive solar design'. The short-wave radiation from the sun passes through glass and warms up the internal surfaces, which in turn emit long-wave radiation which is 'trapped' within the space. The only heat loss therefore takes place by conduction through the glass. A similar effect takes place in the atmosphere which gives rise to global



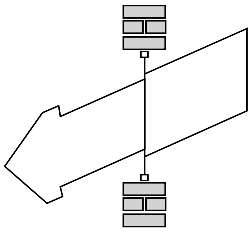
39.9 *Heat transfer process in a greenhouse, which forms the basis of passive solar design*



39.8 *Spectrum of long-wave (low-temperature) and short-wave (solar) radiation; Vertical axis is not to scale*



39.10 *Solar radiation incident on a solid wall*



39.11 *Radiation transmission through glass*

warming. The 'greenhouse gasses' (including carbon dioxide and methane) act like the glass in the greenhouse in letting through the short wave solar radiation but blocking the longer wave radiation re-emitted by the earths surface.

Solar radiation incident on solid walls will heat up the external wall surface, **39.10**. This heat is conducted through the wall where it will result in a rise in the internal surface temperature. The internal surface will then radiate long-wave radiation in proportion to its surface temperature and emissivity (see **2.06**). Normal glazing, however, is mostly transparent to 'short-wave' solar radiation and radiative heat is transmitted directly through the glass, **39.11**. Some glass types are designed to be more absorbing in order to reduce the direct solar transmission (see also Section 5).

2.05 The Stefan–Boltzmann law

The amount of radiation emitted by a surface is related to its temperature and emissivity according to the Stefan–Boltzmann law:

$$Q_r = \left(5.673 \times 10^{-8}\right) \times E \times T^4 \qquad (3)$$

where Q_r = radiation emitted by the surface
E = surface emissivity
T = surface temperature (°C)
5.673×10^{-8} = Stefan–Boltzmann constant (W/m^2 K^4)

2.06 Emissivity and absorptance

The emissivity of a surface is the amount of radiation emitted by the surface compared to that radiated by a matt black surface (a 'black body') at the same temperature. The best emitters are matt dark surfaces and the worst are silvered surfaces (although they are good reflectors of radiation). The emissivity of a surface varies between 0 and 1, with most common building materials, such as bricks and plaster, having an emissivity of about 0.95. The absorptance is the amount of radiation absorbed by a surface compared to that absorbed by a black body. For low-temperature surfaces the absorptance and emittance are similar (Table II).

2.07 Evaporation

Evaporation takes place when a liquid such as water changes state to a vapour. A vapour is a mixture of gases which exerts a vapour pressure. The water molecules that escape from the liquid tend to have a higher energy content than those left behind and so the average energy content of the liquid is reduced, and therefore its temperature is also reduced. In order for evaporation to take place, the vapour pressure of water (in the form of droplets or a wetted surface) must be greater than the partial pressure of the water vapour in the surrounding atmosphere. The lower the relative humidity of the air, the greater the evaporation that will take place. The evaporation rate can be calculated as follows:

$$W = \frac{(8.3 \times 10^{-4})}{135} h_c \times (p_{va} - p_s) \qquad (4)$$

where W = rate of evaporation from the surface
h_c = convective heat transfer coefficient
p_{va} = vapour pressure in air
p_s = saturation vapour pressure at surface temperature.

Evaporation produces local cooling on wetted surfaces. This can be used to advantage in hot countries where roof ponds, cooled by evaporation, can be used to cool the roof construction. The tradition in some hot dry countries is to simply spray the floors of courtyards with water to cool the floor surface. Air passed over wetted surfaces is cooled and its moisture content is raised. The rate of evaporation increases with increased liquid temperature, reduced vapour pressure of the surrounding atmosphere, or increased air movement across the wetted surface.

Condensation is the reverse of evaporation and takes place when air comes into contact with a relatively cold surface. The air adjacent to the cold surface is cooled and becomes saturated and the vapour condenses into a liquid forming droplets on the surface (condensation is dealt with in more detail in Section 5).

Table II Surface emissivities/absorptivities

Finish	Absorptivity	Emissivity
Aluminium, dull/rough polished	0.40–0.65	0.18–0.30
Aluminium, polished	0.10–0.40	0.03–0.06
Asbestos cement, old	0.83	0.95–0.96
Black matt	0.95	0.95
Chromium plate	0.20	0.20
Galvanised iron, old	0.89–0.92	0.89
Glass	See manufacturer's data	0.84
Glass (low e)	See manufacturer's data	0.15
Grey paint	0.95	0.95
Light green paint	0.95	0.95
Limestone	0.33–0.53	0.90–0.93
Red clay brick	0.94	0.94
Marble	0.44–0.592	0.90–0.93
White paint	0.89	0.89
Wood, pine	0.95	0.95

2.08 Thermal capacity

The thermal capacity of a material is a measure of its ability to store heat from the surrounding air and surfaces. Generally, the more dense a material, the greater its capacity to store heat (Table III). Therefore, high-density materials, such as concrete, will store more heat than low-density materials, such as mineral wool. The thermal capacity of a material can be calculated from the formula:

$$\begin{aligned}\text{Thermal capacity} &= \text{volume } (\text{m}^3) \times \text{density } (\text{kg/m}^3) \\ (\text{J/K·m}^3) &\quad \times \text{specific heat } (\text{J/kg·K})\end{aligned} \qquad (5)$$

Dense masonry materials typically have 100 times the thermal capacity of lightweight insulating materials (Table III).

Table III Density, specific heat and thermal capacity of common materials

Material	Density (kg/m^3)	Specific heat (J/kg·K)	Thermal capacity (J/K·m^3)
Granite	2880	840	2419×10^3
Brick	1920	840	1613×10^3
Concrete (dense)	2200	840	1848×10^3
Concrete (light)	620	840	521×10^3
Mineral fibre	24	710	17×10^3
Polystyrene board	23	1470	34×10^3

2.09 Thermal capacity and response

Lightweight buildings will respond quickly to heat gains, **39.12**, from either internal sources (people, lights, machines) or external sources (solar radiation, high external air temperatures). They have a relatively low thermal capacity. The internal air will therefore warm up quickly as the mass of the building will have a relatively low capacity to absorb internal heat. They will also cool down quickly when the heat source is turned off, as there is little residual heat in the construction to retain air temperatures. They are more likely to overheat during warm weather and be cool during colder weather. They therefore require a more responsive heating/cooling system, and are more suited to intermittent occupancy.

Heavyweight buildings are slower to respond to changes of temperature, **39.12**, and therefore have the potential to maintain a more stable internal environment. Buildings constructed of heavyweight materials will have a high thermal capacity. They will be slow to heat up as the mass of the building will absorb heat from the space. However, they will also be slow to cool down and are able to retain relatively high internal air temperatures between heating periods. Heavyweight buildings can maintain relatively cooler internal environments in warmer weather by absorbing peaks in heat gains. Typical cooling effects may be up to 3° to 5°C, **39.13**, reduction in internal air temperature peaks due to thermal mass effects. In addition, the mean radiant temperature will be lower due to the lower surface temperatures. The use of chilled surface cooling is discussed also in Section 8.32.

The thermal mass effect is related to the exposed surface area of material and its thickness and heat capacity. Surface area is relatively more important that thickness of material. For example, for absorbing short-term (diurnal) peaks in heat gain the thermal mass thickness need only be about 5 to 10 cm, **39.13**.

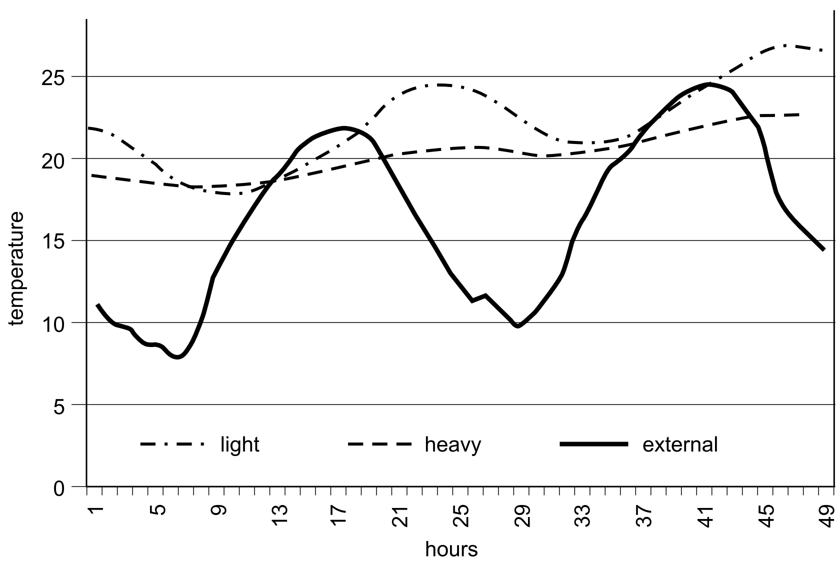
3 THERMAL COMFORT

3.01

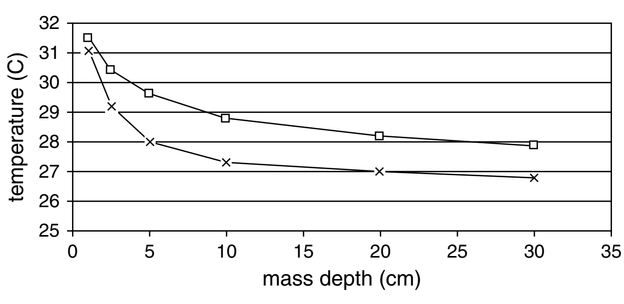
The body produces heat through metabolic activities and exchanges heat with its surroundings by conduction, convection and radiation (typically 75%), and evaporation (typically 25%). Thermal comfort is achieved when there is a balance between metabolic heat production and heat loss. It is mainly dependent on the thermal environmental conditions and the activity and clothing of the person in that environment.

3.02 Metabolic activity

The human body produces metabolic heat as a result of its muscular and digestive processes. It has to maintain a constant core temperature of 37°C. If the core body temperature is reduced by more than about 1°C hypothermia sets in; if it increases by more than about 1°C the person may suffer a heat stroke. The body must therefore lose the metabolic heat it generates in a controlled way. Clothing is one way of controlling heat loss. There are also physiological control mechanisms; for example, shivering when cold increases metabolic activity; the formation of 'goose-pimples' increases the body's surface resistance to heat loss; sweating when warm increases heat loss by evaporation. The heat generated by metabolic activity is measured in units of MET (1 MET = 58.2 W/m^2 of body surface area; the average surface area of an adult is 1.8 m^2). Typical values of MET for different activities are given in Table IV.



39.12 *Thermal responses of lightweight and heavyweight buildings against external temperature over a two-day period*



39.13 *Typical reduction in peak temperatures with increasing thermal mass thickness without night cooling (night time infiltration 0.1 ac/h; daytime ventilation 1 ac/h), and with night cooling (night time ventilation 5.0 ac/h; daytime ventilation 1 ac/h)*

3.03 Clothing

Clothing provides insulation against body heat loss. The insulation of clothing is measured in units of CLO (1 CLO = 0.155 m^2·K/W; the units are those of thermal resistance). Values of CLO for typical clothing ensembles are given in Table V.

3.04 Air temperature

Air temperature is often taken as the main design parameter for thermal comfort. The CIBSE recommended range for internal air

Table IV Metabolic heat generation for different activities at 20°C in MET and in watts (W) for sensible (S) and latent (L) heat loss

Activity	MET	S(W)	L(W)
Seated at rest (theatre, hotel, lounge)	1.1	90	25
Light work (office, dwelling, school)	1.3	100	40
Standing activity (shopping, laboratory)	1.5	110	50
Standing activity (shop assistant, domestic)	2.2	130	105
Medium activity (factory, garage work)	2.5	140	125
Heavy work (factory)	4.2	190	250

Table V Clothing resistance in CLO and thermal resistance

	CLO	($m^2 \cdot K/W$)
Nude	0	0
Light summer clothes	0.50	0.08
Light working ensemble	0.7	0.11
Winter indoor	1.0	0.16
Heavy business suit	1.5	0.23

temperature is between 19 and 23°C in winter and not exceeding 27°C in summer. The air temperature gradient between head and feet is also important for comfort; the temperature at feet should generally not be less than 4°C below that at head.

3.05 Radiant temperature is a measure of the temperature of the surrounding surfaces, together with any direct radiant gains from high temperature sources (such as the sun). The *mean radiant temperature* is the area-weighted average of all the surface temperatures in a room. If the surfaces in a space are at different temperatures then the perceived radiant temperature in a space will be affected by the position of the person in relation to the various surfaces, with the closer or larger surface areas contributing more to the overall radiant temperature. Comfort can be affected by radiant asymmetry, and people are especially sensitive to warm ceilings (a 10°C radiant asymmetry from a warm ceiling can give rise to 20% comfort dissatisfaction). The *vector radiant temperature* is a measure of the maximum difference in a room between the radiant temperatures from opposite directions.

3.06 Relative humidity (RH) of a space will affect the rate of evaporation from the skin. The RH is a percentage measure of the amount of vapour in the air compared to the total amount of vapour the air can hold at that temperature. When temperatures are within the comfort range (19–23°C) the RH has little effect on comfort as long as it is within the range 40–70%. At high air temperatures (approaching average skin temperature of 34°C) evaporation heat loss is important to maintain comfort. Wet bulb temperature is a measure of the temperature of a space using a wetted thermometer. A 'dry bulb' temperature sensor will exchange heat with the surrounding air by convection. A wet bulb thermometer loses additional heat by evaporation and can be used in combination with a dry bulb, to obtain a measure of RH by referring to the *psychrometric chart*, **39.14**. An example of the use of this is shown in **39.15**, where a dry bulb temperature (dbt) of 19°C and a wet bulb temperature (wbt) of 14°C indicates a relative humidity (RH) of 60%.

3.07 Air speed

Air speed is a measure of the movement of air in a space. People begin to perceive air movement at about 0.2 m/s. Air speeds greater than 0.2 m/s can produce a 20% and greater comfort dissatisfaction due to perceived draught. For most naturally ventilated spaces the air speed will be less than 0.15 m/s, away from the influence of open windows and in the absence of major downdraughts from cold internal surfaces. For mechanically ventilated spaces, the air speed is generally greater than 0.15 m/s and could be greater than 0.2 m/s in areas close to air supply devices or where supply air jets are deflected by downstand beams or other geometric features of the space, and such speeds should be avoided. It is possible to counter draught discomfort to a certain extent by increasing air temperatures, as indicated in **39.16**.

3.08 Thermal comfort: compensation and adaption

The perception of thermal comfort is a function of the combination of the physical environment (air and radiant temperature, air movement and relative humidity) and the activity and clothing level of the person. To some extent these factors are compensatory. For example, during cool conditions, an increase in air movement can be compensated by an increase in air temperature, while in warm conditions, an increase in relative humidity can be compensated for by an increase in air movement. People can also adapt their clothing levels, activity levels and posture in response to the prevailing thermal conditions. In this way they are varying either their rate of metabolic heat production or their rate of body heat loss. Thermal indices use combinations of the comfort parameters in a compensatory way to provide a single measure of thermal comfort.

The *resultant temperature*, sometimes called *globe temperature*, can be used to give a more representative measure of comfort than air temperature alone. It is a combination of air temperature and mean radiant temperature, in a proportion comparable to that of the body's heat loss. At low air speeds (< 0.1 m/s) the following relationship can be applied:

$$t_{res} = 0.5\, t_{mrt} + 0.5\, t_a \qquad (6)$$

where t_{res} = resultant temperature (°C)
t_{mrt} = mean radiant temperature (°C)
t_a = air temperature (°C)

The resultant temperature can be measured at the centre of a black globe of 100 mm diameter (although globes between 25 and 150 mm will give acceptable results).

The *corrected effective temperature* (*CET*) relates globe temperature, wet bulb temperature and air speed. It is equivalent to the thermal sensation in a standard environment with still, saturated air for the same clothing and activity. CET can be represented in nomogram form as shown in **39.17**.

3.09 PMV and PPD

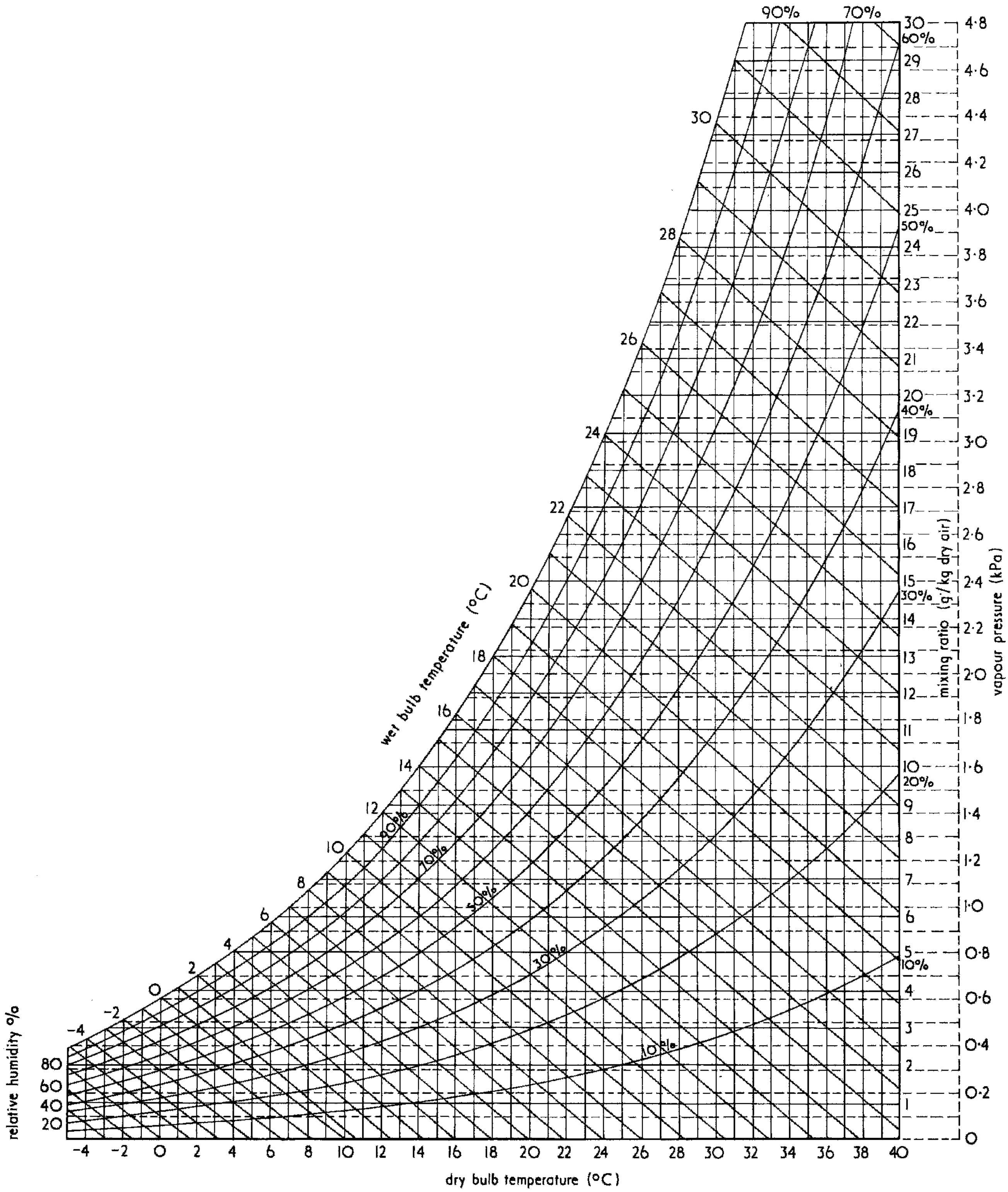
The *predicted mean vote* (*PMV*) is a measure of the average response from a large group of people voting on the scale below:

hot	+3
warm	+2
slightly warm	+1
neutral	0
slightly cool	– 1
cool	– 2
cold	– 3

The PMV can be calculated from *Fanger's comfort equation* which combines air temperature, mean radiant temperature, RH and air speed together with estimates of activity and clothing levels. The *percentage people dissatisfied* (*PPD*) provides a measure of the percentage of people who will complain of thermal discomfort in relation to the PMV. This is shown graphically in **39.18** and can be calculated from:

$$PPD = 100 - 95 \exp(10.03353\, PMV^4 - 0.2179\, PMV^2) \qquad (7)$$

The implication of PPD is that there is no condition where everyone will experience optimum comfort conditions. It predicts that for a typical occupied work place, there will always be 5% of people who will report discomfort.

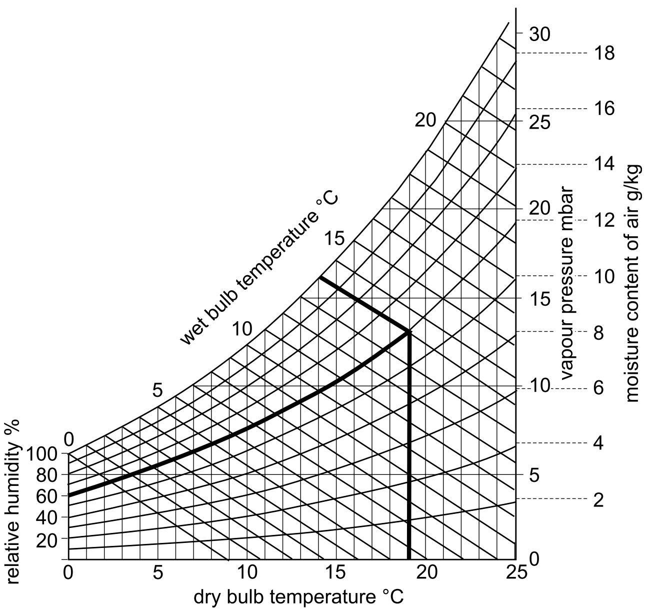


39.14 *Psychrometric chart (from figures in CIBSE Guide). This relates dry bulb temperature, wet bulb temperature and moisture content to relative humidity (RH)*

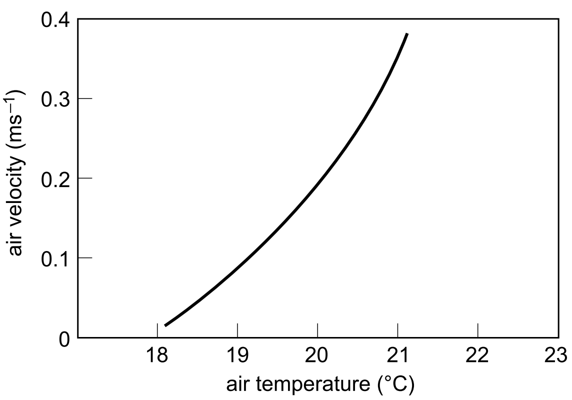
3.10 Sick building syndrome (sbs)

This is a term used to describe a set of commonly occurring symptoms that affect people at their place of work, usually in office-type environments, and which disappear soon after they leave work. These symptoms include dry eyes, watery eyes, blocked nose, runny nose, headaches, lethargy, tight chest, and difficulty with breathing. A typical percentage of symptom reporting for air-conditioned offices is shown in **39.19**. The *personal symptom index* (*PSI*) is often used as a measure of the average number of symptoms per person for a whole office or zone.

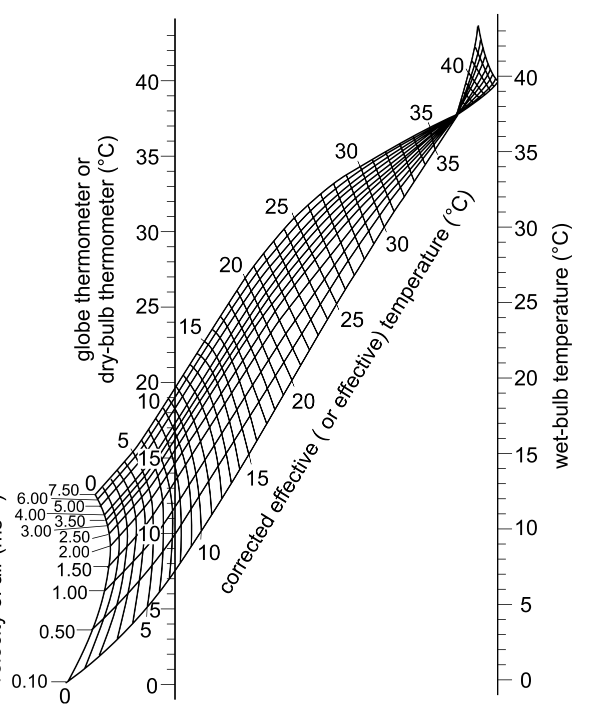
Workers who report high levels of symptoms also often report problems associated with thermal comfort, and in general perceive the air quality as stale, dry and warm. Studies have indicated that air-conditioned buildings appear to have a higher level of complaint of sbs than naturally ventilated buildings. Possible reasons for this include cost cuts in their design, difficulties and complexities in their maintenance and operation, problems associated with hygiene and cleanliness (especially the air-distribution ductwork) and low ventilation effectiveness due to short-circuiting between supply and extract. Workers with a higher risk of symptoms are those in



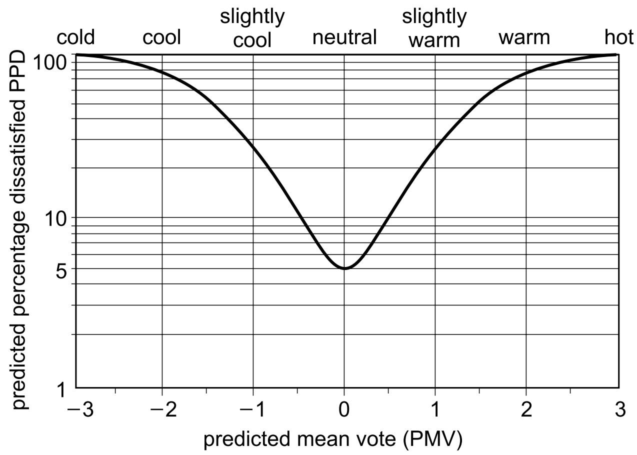
39.15 *A psychrometric chart showing that a dry bulb temperature of 19°C and a wet bulb temperature of 14°C relates to an RH of 60%*



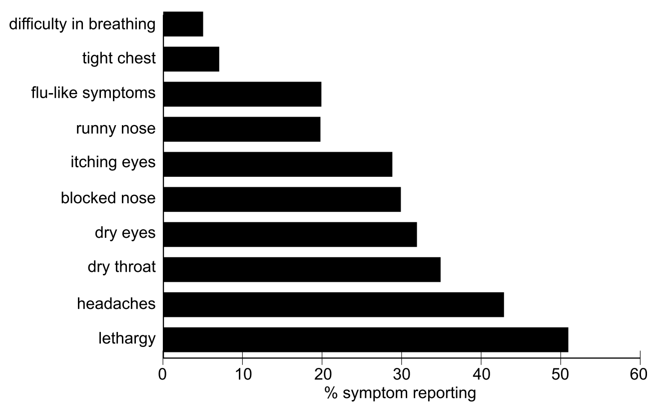
39.16 *The interaction of air temperature and air movement on perceived comfort*



39.17 *Nomogram for estimating corrected effective temperature (CET)*



39.18 *PPD as a function of PMV*



39.19 *Sample percentage sick building syndrome symptom reporting for air conditioned offices*

open-plan offices more than those in cellular ones, clerical workers more than managerial, women more than men, those in public sector buildings more than private, those in air-conditioned offices more than naturally ventilated ones, and those buildings where there is poor maintenance and poor operation of controls.

3.11 Ventilation and indoor air quality

Ventilation is required to maintain good air quality for health and comfort. Tables VI to VII give recommended values for internal temperatures, infiltration rates and ventilation rates. The outside air requirement for occupants is generally taken as 10l/s/person. Ventilation is considered in more detail in Section 6.

4 SITE AND CLIMATE

4.01

The site and climatic conditions have a major impact on the thermal design of a building, and should be considered during the early stages of design. Also, the building will modify the existing climate of the site to create a specific microclimate surrounding itself and affecting the microclimate of existing neighboring buildings. Climate data is available for many parts of the world, often as hourly values compiled into a standard *Test Reference Year* (*TRY*) format.

The climate conditions that relate directly to thermal design include:

- Solar radiation, sun path and cloud cover
- Wind speed and direction
- Air temperature
- Relative humidity; and
- Rainfall and driving rain index.

Table VI Air and infiltration rates for building types

Type of building	Air t_{el} (°C)	Air infiltration allowance (h^{-1})
Art galleries and museums	19–21	1
Assembly and lecture halls	22–23	0.5
Airport terminals:		
Baggage reclaim	12–19	
Check-in areas	18–20	
Customs areas	12–19	
Departure lounges	19–21	
Banking halls	19–21	1–1.5
Bars	20–22	1
Canteens and dining rooms	22–24	1
Churches and chapels	19–21	0.5–1
Computer rooms	19–21	
Conference/board rooms	22–23	
Dining and banqueting halls		0.5
Exhibition halls:	19–21	0.5
Factories:		
Sedentary work	19–21	
Light work	16–19	
Heavy work	11–14	
Up to 300 m^3 volume		1.5–2.5
300 m^3 to 3000 m^3		0.75–1.5
3000 m^3 to 10,000 m^3		0.5–1.0
Over 10,000 m^3		0.25–0.75
Fire stations, ambulance stations:		
Watch rooms	22–23	0.5–1
Recreation rooms	20–22	0.5–1
Gymnasia		0.75
Flats, residences and hostels:		
Living rooms	20–23	1
Bedrooms	17–19	0.5
Bed-sitting rooms		1
Bathrooms	26–27	2
Toilets	19–21	1.5
Service rooms		0.5
Hall/Stairs/Landing	19–24	1.5
Kitchen	17–19	
Public rooms		1
Hospitals:		
Wards and patient area	22–24	2
Circulation spaces	19–24	1
Consulting/treatment rooms	22–24	
Nurses stations	19–22	1
Operating theatres	17–19	0.5
Waiting rooms		1
Storerooms		0.5
Hotels:		
Bathrooms	26–27	1
Bedrooms	19–21	1
Public rooms		1
Corridors		1.5
Foyers		1.5
Laboratories		1
Law courts	19–21	1
Libraries:		
Reading rooms	22–23	0.5–0.7
Stack rooms	19–21	0.5
Store rooms	15	0.25
Offices:		
General	21–23	1
Executive	21–23	
Open plan	21–23	
Private		1
Storerooms		0.5
Police cells	19–21	5
Railway/coach stations		
Concourse (no seats)	12–19	
Ticket office	18–20	
Waiting room	21–22	
Restaurants and cafes	22–24	1
Schools and colleges:		
Classrooms	19–21	2
Lecture rooms	19–21	1
Studios	19–21	1
Retail buildings:		
Shopping malls	19–24	
Small shops, department stores	19–21	
Supermarkets	19–21	
Sports pavilions:		
Dressing rooms	22–24	1
Hall	13–16	
Squash courts	10–12	
Swimming pools:		
Changing rooms	23–24	0.5
Pool hall	23–26	0.5
Television studios	19–21	
Warehouses:		
Working and packing spaces		0.5
Storage space		0.2

The values quoted for rates of air infiltration in this table should not be used for the design of mechanical ventilation, air conditioning or warm air heating systems.

Table VII Mechanical ventilation rates for various types of building

Room or building		Recommended air change rates* (h^{-1})
Boiler houses and engine rooms		15–30
Banking halls		6
Bathrooms, internal		6†
Battery charging rooms		up to 5†
Canteens		8–12‡
Cinemas		6–10‡
Dance halls		10–12‡
Dining and banqueting halls, restaurants		10–15‡
Drying rooms		up to 5
Garages:	public (parking)	6† minimum
	repair shops	10† minimum
Hospitals:	treatment rooms	6
	operating theatre	15–17
	post-mortem room	5
Kitchens:	hotel and industrial	20–60†
	local authority	up to 10†
Laboratories		4–6
Laundries		10–15
Lavatories and toilets, internal		6–8†
Libraries:	public	3–4‡
	book stacks	1–2
Offices, internal		4–6‡
Sculleries and wash-ups, large-scale		10–15†
Swimming baths:	bath hall	
	changing areas	10
Theatres		6–10‡

* The recommended air change rates do not apply in cases of warm-air heating, when the rate may be dictated by the heat requirements of the building or room.
† Refers to extract ventilation.
‡ The supply air at the recommended rate will not necessarily be all outdoor air, the required quantity of outdoor air must be checked against the number of occupants at a desirable rate per person.

4.02 Solar radiation and sun path

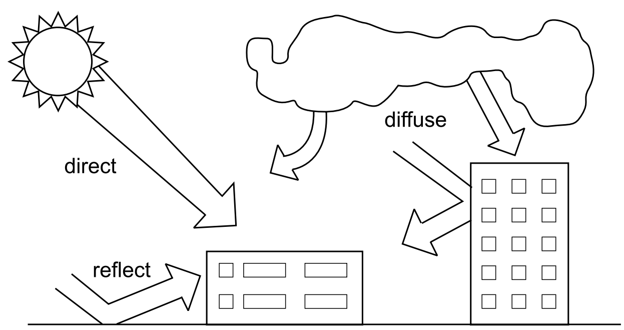
Solar radiation impacts on the building in three forms, **39.20**:

- Direct radiation, from the position of the sun in the sky
- Diffuse radiation, from the whole of the visible sky; and
- Reflected radiation (*albedo*) from adjacent surfaces.

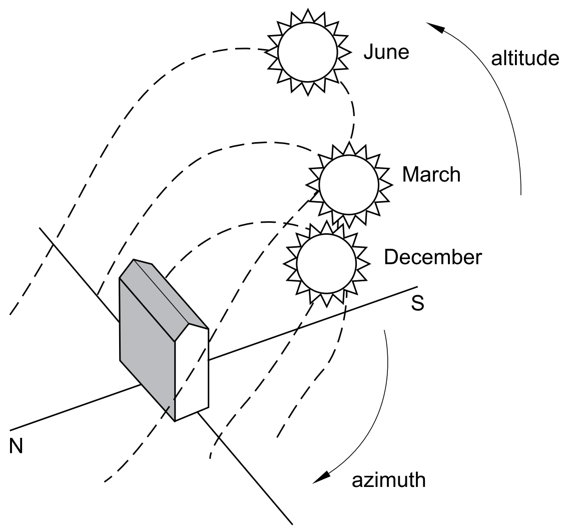
All three components will vary according to time of day, time of year and cloud cover, and how much sky is seen by the building depending on natural and man-made obstructions. The solar path can be determined from the altitude and azimuth angles of the sun as in **39.21**. Typical values of solar radiation are given in (Tables VIII and IX, and the effect of sun angle and overshadowing in **39.22**. The annual variation of possible hours of daily sunshine for the UK is presented in **39.23**.

The main component of solar radiation is the direct radiation, but the reflected radiation can be significant where there are hard light-coloured reflective surfaces adjacent to the building, either from the built form itself or from existing buildings and landscaping. Table X contains data on reflected radiation for different surfaces (the solar absorption of a surface is 1 – reflectance).

Cloud cover is measured in octals on a scale of 0 to 8, with 0 being completely cloudless and 8 completely overcast. The diffuse radiation component will be higher for an overcast sky as shown in



39.20 *Direct, diffuse and reflected solar radiation*



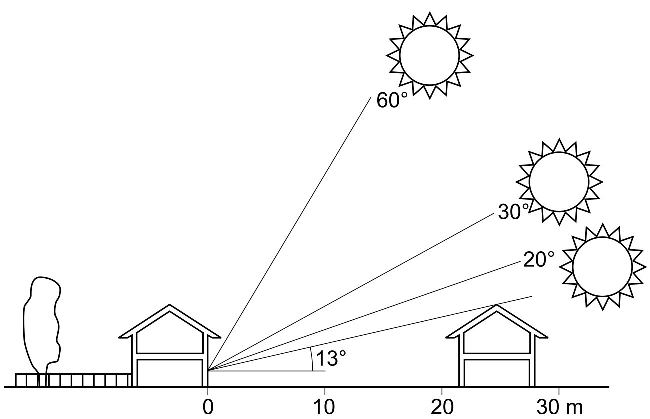
39.21 *Sun angles indicating azimuth and altitude*

Table VIII Solar attitude, and direct and diffuse solar radiation (cloudy and clear sky) at mid-day for South-east England

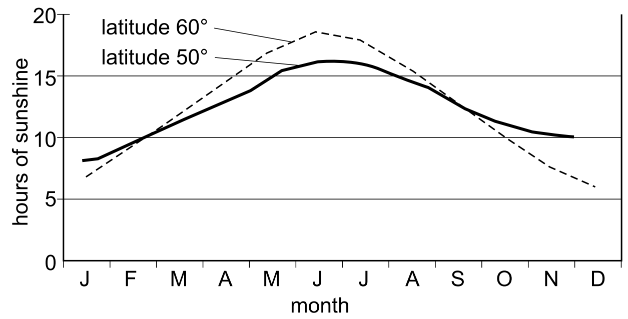
Month	Altitude	Direct Normal (W/m^2)	Diffuse (W/m^2)	
			Cloudy	Clear
June	64	900	310	100
July/May	60	895	295	100
August/April	52	865	255	95
September/March	40	815	195	85
October/February	2	700	140	75
November/January	20	620	90	60
December	17	560	75	50

Table IX Daily mean solar Irradiances (W/m^2) on vertical and horizontal surface. Diffuse radiation for cloudy/clear sky conditions

	S	SE/SW	E/W	NE/NW	N	H	Diffuse
June	105	135	140	85	35	295	120/50
July/May	115	140	135	75	20	270	110/45
August/April	150	150	115	45	5	215	90/40
September/March	175	145	80	20	0	140	60/30
October/February	165	120	50	5	0	80	35/20
November/January	125	90	25	0	0	35	20/15
December	100	70	20	0	0	25	15/10



39.22 *Sun angle and overshadowing*



39.23 *The annual variation of possible hours of sunshine for the UK. Northern regions receive more hours in summertime*

Table X Reflected radiation for different surfaces

Surface	Reflectance
Concrete	0.2–0.45 (weathered to clean)
Polished aluminium	0.7
White paint	0.6–0.75
Aluminium paint	0.45
Grass	0.33
Desert ground	0.25
Sand	0.18
Water	0.02–0.35 (for angle of incidence = 0–80°)

Table VIII. Cloudiness (C) is a measure of the proportion of cloud in the sky. C is zero for a clear sky and 1 for an overcast sky.

4.03 External air temperature

The external air temperature will affect the rate of transmission and convective heat loss from a building. It will typically vary over a 24-hour period (the diurnal variation) and over a year (seasonal variation). It will also vary with location. Table XI presents the average monthly external air temperature for different locations within the UK. **39.24** shows the typical diurnal temperature variations for southern England.

4.04 Sol-air temperature

When solar energy is absorbed by an external wall it has the same effect, in relation to heat loss, as a rise in external air temperature. The sol-air temperature is the external air temperature which in the absence of solar radiation, would give rise to the same heat transfer through the wall as takes place with the actual combination of external temperature and incident solar radiation.

$$t_{sa} = (\alpha I_s + \varepsilon I_1)R_{so} + t_{ao} \quad (8)$$

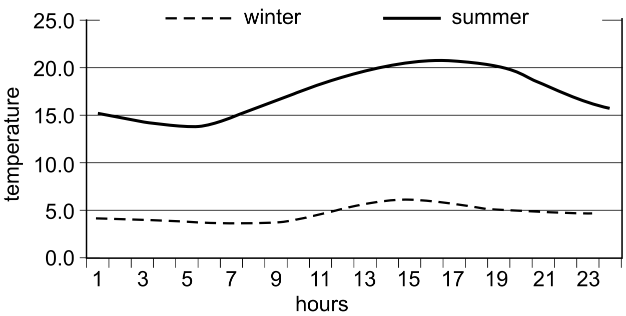
where t_{sa} = sol-air temperature
t_{ao} = sol-air temperature
α = solar absorptance
ε = long-wave emissivity
R_{so} = external surface resistance
I_s = solar irradiance (W/m^2)
I_1 = long-wave radiation loss (W/m^2)
= 93–79 C (horizontal surfaces)
= 21–17 C (vertical surfaces)
C = cloudiness (see para **4.02**)

4.05 External relative humidity

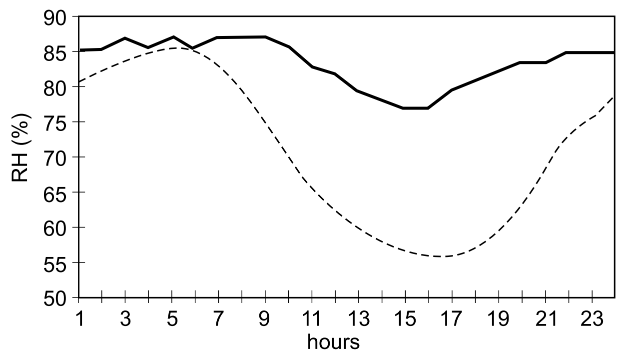
The external RH will vary with external air temperature and moisture content of the air. During periods of warmer weather, the RH may be relatively low due to the higher external air temperatures, although at night it will rise as the air temperature falls, **39.25**. During cold weather the external RH can rise typically to over 90%. **39.26** presents seasonal average RH values.

Table XI UK average daily temperatures (1941–1970)

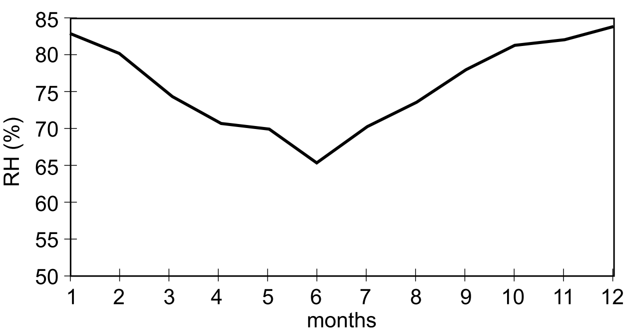
	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Belfast													
Max	5.8	6.5	9.0	11.8	14.7	17.4	18.1	18.0	16.0	12.9	8.9	6.7	12.1
Min	1.3	1.1	2.4	3.9	6.1	9.2	10.7	10.5	9.3	7.2	3.9	2.5	5.7
Mean	3.5	3.8	5.7	7.9	10.4	13.3	14.4	14.3	12.7	10.1	6.4	4.6	8.9
Glasgow													
Max	5.5	6.3	8.8	11.9	15.1	17.9	18.6	18.5	16.3	13.0	8.7	6.5	12.3
Min	0.8	0.8	2.2	3.9	6.2	9.3	10.8	10.6	9.1	6.8	3.3	1.9	5.5
Mean	3.1	3.5	5.5	7.9	10.7	13.6	14.7	14.5	12.7	9.9	6.0	4.2	8.9
London													
Max	6.1	6.8	9.8	13.3	16.8	20.2	21.6	21.0	18.5	14.7	9.8	7.2	13.0
Min	2.3	2.3	3.4	5.7	8.4	11.5	13.4	13.1	11.4	8.5	5.3	3.4	7.0
Mean	4.2	4.5	6.6	9.5	12.6	15.9	17.5	17.1	14.9	11.6	7.5	5.3	10.0
Cardiff													
Max	6.8	6.9	10.0	13.2	16.2	19.2	20.4	20.1	18.0	14.5	10.2	8.0	13.0
Min	1.5	1.5	2.8	5.0	7.7	10.7	12.3	12.3	10.7	8.0	4.7	2.7	6.0
Mean	4.1	4.2	6.4	9.1	11.9	14.9	16.3	16.2	14.3	11.3	7.5	5.3	10.0



39.24 *Diurnal UK variations for winter (January) and summer (June) for south-east England*



39.25 *Diurnal RH variation for January (solid) and June (dotted)*



39.26 *Seasonal average daily RH values for the UK*

4.06 Rainfall and driving rain index

Rainfall can affect thermal performance. If an external surface is wet then it will lose heat by evaporation and this will reduce the external surface temperature, sometimes to below air temperature, increasing heat loss. Wind-driven rain ('driving rain') can penetrate some constructions, causing a reduction in thermal resistance. In areas of high incidence of driving rain, care must be taken to select constructions that provide protection against rain penetration.

4.07 Wind

The impact of wind on a building has two main consequences for thermal design. It affects the connective heat loss at the external surfaces, as well as the ventilation and infiltration rate and the associated heat loss.

4.08 Wind speed and direction

Wind speed is measured in m/s or sometimes in knots where 1 knot equals 0.4 m/s. Wind direction is usually measured at eight points of the compass or, when required in more detail, in degrees clockwise from south. The wind speed and direction can be represented by a *wind rose*, **39.27**, which indicates the relative frequency and speed of wind from different directions.

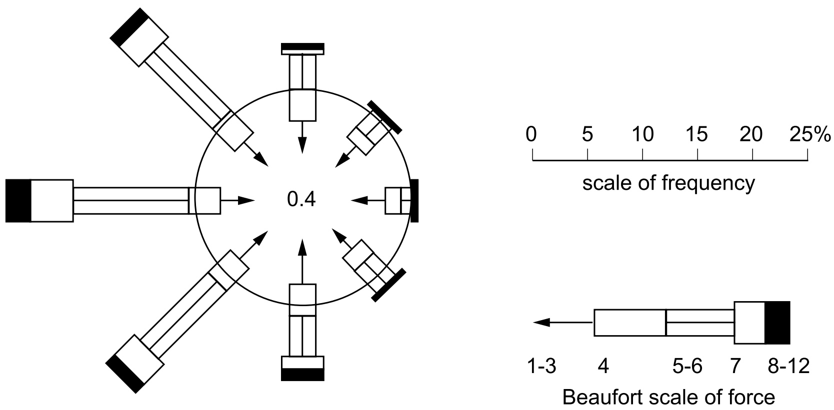
Wind speed increases with height due to the frictional drag of the ground. The profile of variation with height is called the *boundary layer*, and it will vary from town to open country locations, as shown in **39.28**, and according to the relationship:

$$v/v_r = k\,H^{a} \qquad (9)$$

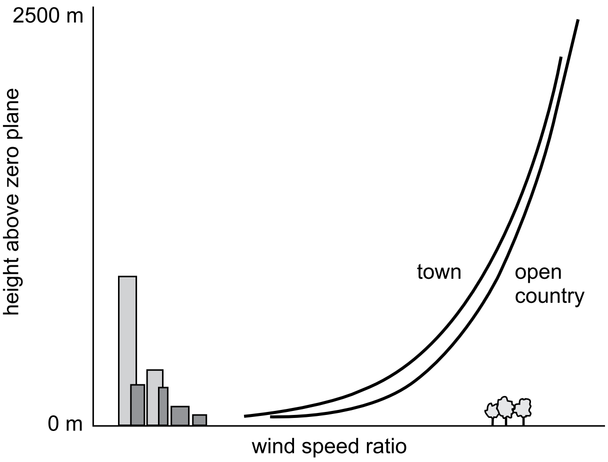
where v = mean wind speed (m/s) at height H (m)
v_r = mean wind speed (m/s) at height 10 m
values of k and a from Table XII

4.09 Dynamic and static wind pressures

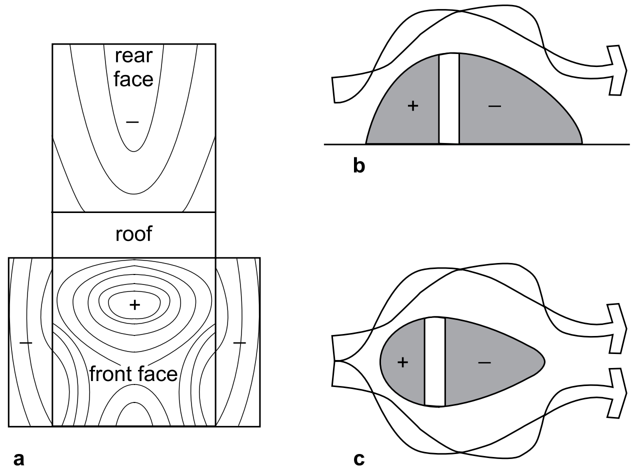
The static pressure (P_s) of the air is the pressure in the free-flowing air stream (as shown on the isobars of a weather map). Differences in static pressure arise from global thermal effects and cause windflow. The dynamic pressure (P_d) is the pressure exerted when the wind comes into contact with an object such as a building, **39.29**. The total or stagnation pressure (P_t) is the sum of the static and dynamic pressures. In most cases P_s can be ignored in thermal design as it is usual to deal with pressure differences across a building, i.e. the difference in P_d. The dynamic wind pressure is related to the air density (r) and the square of the wind speed (v).



39.27 *Standard wind rose*



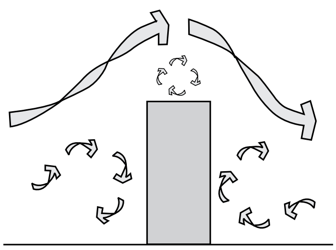
39.28 *Boundary layer wind profile*



39.30 *Wind pressure over a building envelope:* **a** *Pressure distribution;* **b** *Section;* **c** *Plan*

Table XII Values of coefficients for formula (9)

Terrain	k	A
Open, flat country	0.68	0.17
Country with scattered wind breaks	0.52	0.20
Urban	0.35	0.25
City	0.21	0.33



39.29 *Typical wind flow pattern around a high-rise building*

4.10 Pressure coefficients

The impact of wind on the building form generally creates areas of positive pressure on the windward side of a building and negative pressure on the leeward and sides of the building. The pressure coefficient is the relative pressure at a specific location on the building and it can be used to calculate the actual dynamic pressure for a given wind speed.

$$P_d = C_p \times 0.5\,\rho v^2 \text{ (Pa)} \tag{10}$$

where ρ = density of the air (kg/m^3)
v = wind speed (m/s) at a reference height, h (m)
C_p = pressure coefficient measured with reference to the wind speed at the height h.

The pressure coefficients are dependent on general building form, as shown in the example in **39.30**. A scale model of the building can be placed in a wind tunnel to predict C_{ps}. Building form is the main determinant of pressure distribution for a given wind direction. Openings should then be located to produce the required 'cross-ventilation' from pattern, **39.31**.

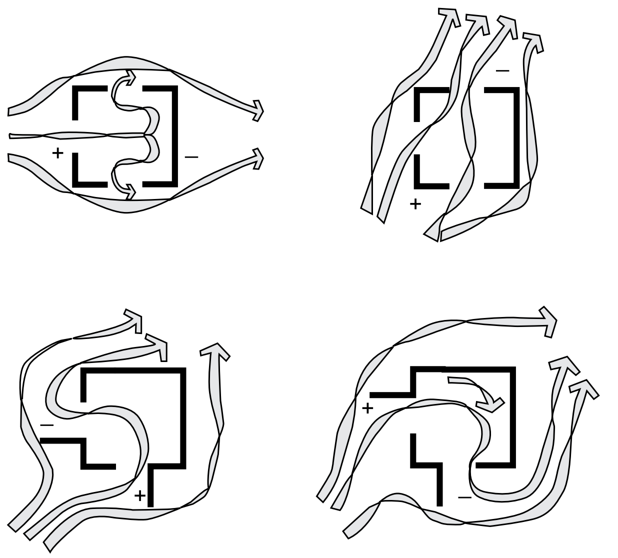
4.11 External sheltered areas

There are 'rules of thumb' which can be applied to estimate the impact of wind on buildings, in relation to creating external sheltered areas (e.g. courtyards). These are shown in **39.32**. The figures show that distances between buildings should be less than about 3.5 times the building height, in order to create shelter from the prevailing wind.

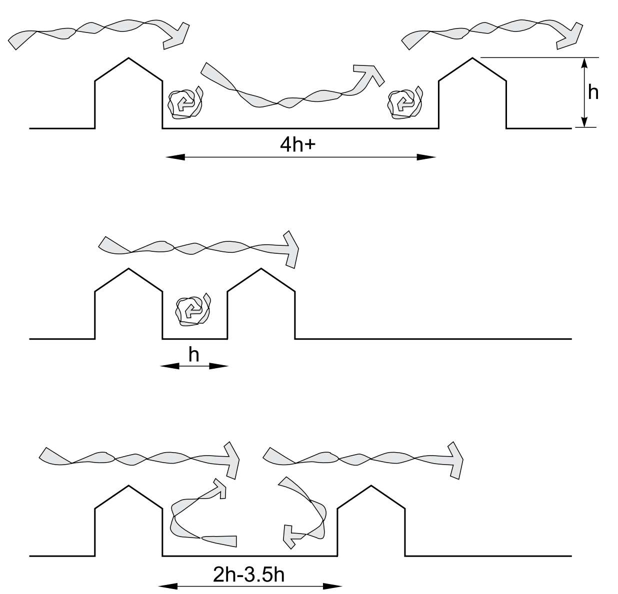
Barriers can be used to reduce wind speed and create external sheltered areas. Porous barriers are often more suitable than 'hard' barriers as they reduce wind speed and do not induce counter wind flow areas as shown in **39.33**. High wind conditions can be created by downdraughts from tall buildings (as in **39.29**), wind 'canyons' or acceleration around corners **39.34**.

4.12 Site analysis

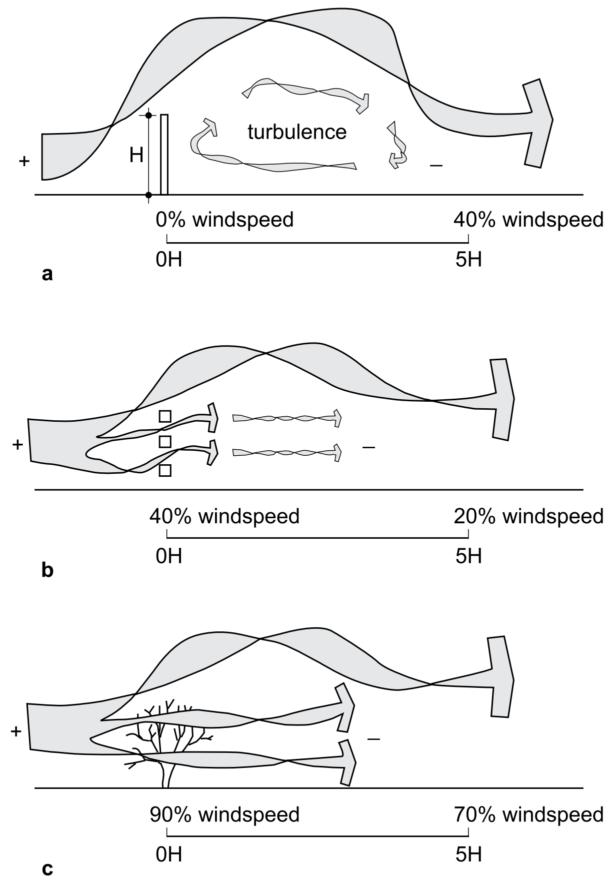
An overall site analysis should identify the prevailing wind, the seasonal sun paths, and existing shelter and obstructions, well as other aspects, such as noise sources and views, as in **39.35**.



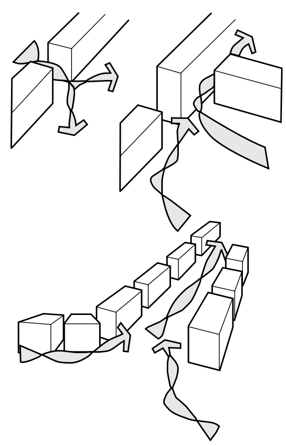
39.31 *Pressure coefficients can be manipulated by the form of the building*



39.32 *Building spacing and provision of sheltered external spaces*



39.33 *Barriers and their effect on wind flow:* **a** *Dense barrier;* **b** *Medium barrier;* **c** *Loose barrier*



39.34 *Localised high wind speeds can be caused by 'canyon' effects and acceleration around corners*

4.13 Global warming

It is now generally accepted that there will be global warming based on the past emission of greenhouse gasses. The prediction average temperature rise due to global warming for the UK is between 3 and 6°C by the end of the century. Buildings should therefore be designed to respond to future weather data rather than historical data. The thermal design will be affected by increases in temperature and increases in extreme events of wind and rain. In some countries there may be untypical cooler periods, for example in the hotter places where heating was not required there may be the need in future, while in more temperate climates cooling may become more an issue. The predicted increase in summer temperatures in temperate climates might lead to the adoption of a heavyweight construction with ventilation night cooling more than lightweight constructions, especially for dwellings.

5 BUILDING FABRIC

5.01 *U*-values

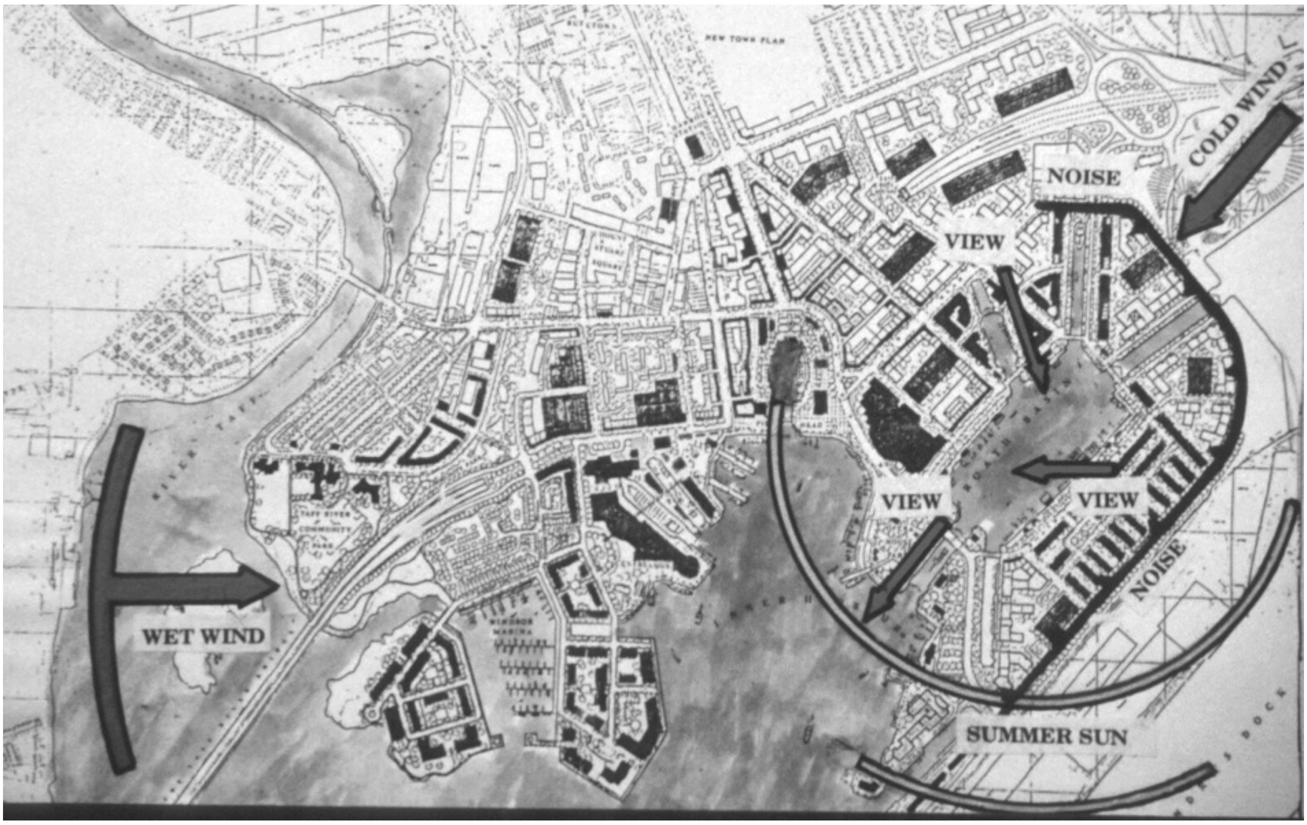
The *U*-value of the wall, roof or floor element of a building can be used to provide an estimate of its heat loss. The *U*-values of typical construction types are given in Table XIII. The *U*-value of a wall construction can be calculated using the following procedure:

1 Calculate the resistance of the individual layers of the construction (see Section 2 and refer to *k*-values in Table I).

$$R_{1,2,3...} = x/k \qquad (11)$$

where $R_{1,2,3...}$ = thermal resistance of element 1, 2, 3 . . . ($m^2 \cdot K/W$)
x = thickness (m)
k = thermal conductivity ($W/m \cdot K$)

2 Select the appropriate values for the internal and external surface resistances (R_{si} and R_{se}) by referring to Tables XIV and XV.



39.35 *Example of environmental site analysis*

3 Select the appropriate resistance of any air cavities (R_{cav}) by referring to the standard Table XVI.

4 Calculate the total thermal resistance (R_{total}) of the wall using the following formula:

$$R_{total} = R_1 + R_{su} + R_3 + \cdots + R_{si} + R_{se} + R_{cav} \qquad (12)$$

5 Calculate the U-value, that is, the conductance, of the wall using the following formula:

$$U\text{-value} = 1/R_{total} \qquad (13)$$

The heat loss (Q_f) associated with an element of the construction of area (A) and with a temperature difference (D_T) across it can be estimated as follows:

$$Q_r = U \times \text{area} \times \text{temperature difference} \qquad (14)$$

Example 2

U-value calculation

Calculate the U-value of the insulated cavity wall construction shown in **39.36** for a normal site. Estimate the rate of heat loss through 10 m^2 of the fabric for a 20°C temperature difference across the wall.

The calculation is carried out in Table XVII; giving a total resistance of 4.32 m^2·K/W.

Hence U-value = 1/4.32 = 0.23 W/m^{2}K

and heat loss Q_t = 0.23 × 10 × 20 = 46 W

5.02 Thermal insulation

A high standard of thermal insulation in buildings in a temperate climate such as in the UK has the following benefits:

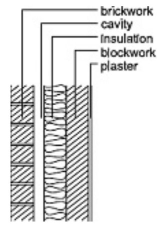
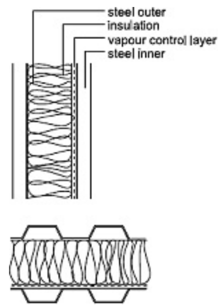
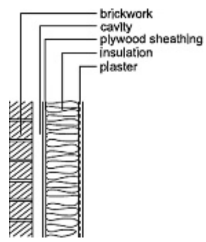
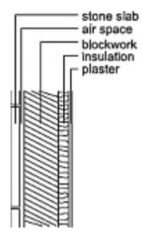
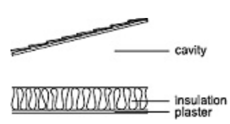
- It reduces the rate of heat loss, and therefore buildings use less energy to maintain comfortable internal thermal conditions. This also means that people are more able to afford to heat their buildings to comfortable conditions, and
- It raises internal surface temperatures and therefore reduces the risk of surface condensation.

5.03 Types of insulation

Most thermal insulating materials have k-values of 0.3–0.4 W/m·K. The most common types are:

- Mineral fibre – this can be glass fibre or rock fibre and is available in lower-density roll form or higher-density batt form. The roll form is usually used to insulate roofs, while the batt form is often used in walls where, because of its greater rigidity, it is more appropriate to vertical fixing. Mineral fibre insulation forms a good attachment to the inner skin of the construction, leaving no air gap. It is often used in wall and roof industrial cladding type constructions. Mineral fibre may also be in a loose form that can be 'blown' into a cavity, to 'cavity fill' an existing or new construction (see below).
- Rigid board – this is usually made from foamed plastic or foamed glass. k-values are typically 0.037 W/m·K. It can be gas filled to give lower k-values, although boards which use ozone-depleting gases should be avoided. If rigid board insulation is used, it is essential to achieve a good attachment to the inner skin of the construction in order to avoid airflow between the inner skin and the insulation layer, which will detract from its U-value performance. The cavity should be kept clean and mortar 'snobs' and other sources of blockage on the inner skin should be eliminated before the insulation is fixed. Rigid board insulation is often used in composite 'factory made' cladding system constructions, where it is installed between two layers of metal sheeting.
- Blown insulation cavity fill, including mineral or cellulose fibres or plastic granules. Insulation is blown into the cavity after completion of construction. Care is needed in installing blown insulation in order to avoid any voids in the insulation in areas where the insulation has difficulty in penetrating, for example, blocked areas of the cavity. This method of cavity insulation has the advantage that it can be applied to existing constructions.
- Recycled paper insulation, for example, produced from 100% recycled newspaper, has very low embodied energy compared to most other insulation materials. It has a k-value of 0.035 W/m·K.

Table XIII Typical constructions and their *U*-values

Construction type	Element	x	k	R	Drawing
Cavity wall construction	Rse	–	–	0.04	
	Brickwork	0.1025	0.77	0.13	
	Cavity	0.05	–	0.18	
	Insulation	0.100	0.035	2.86	
	Blockwork	0.100	0.11	0.91	
	Plaster	0.013	0.18	0.072	
	Rsi	–	–	0.13	
	TOTAL			4.32	
					U-value = 0.23 W/m^{2}K
Metal cladding	Rse	–	–	0.04	
	Steel outer	–	–	–	
	Insulation	0.200	0.040	5	
	Steel inner	–	–	–	
	Rsi	–	–	0.13	
	TOTAL			5.17	
					U-value = 0.19 W/m^{2}K
Timber frame wall construction	Rse	–	–	0.04	
	Brickwork	0.105	0.77	0.136	
	Cavity	–	–	0.18	
	Plywood sheathing	0.01	0.13	0.077	
	Insulation	0.150	0.035	4.29	
	Vapour control layer	–	–	–	
	Plasterboard	0.0125	0.21	0.060	
	Rsi	–	–	0.13	
	TOTAL			4.9	
					U-value = 0.20 W/m^{2}K
Cladding wall construction	Rse	–	–	0.04	
	Stone slab	0.030	2.9	0.01	
	Brickwork	0.1025	0.77	0.13	
	Insulation	0.100	0.035	2.86	
	Rsi	–	–	0.13	
	TOTAL			3.17	
					U-value = 0.32 W/m^{2}K
Roof construction with insulation	Rse	–	–	0.04	
	Roof tile	0.0125	0.84	0.015	
	Cavity	–	–	0.18	
	Insulation	0.20	0.04	5.0	
	Plasterboard	0.0125	0.21	0.060	
	Rsi	–	–	0.10	
	TOTAL			5.4	
					U-value = 0.19 W/m^{2}K

- Low-density concrete blocks. Blocks with densities down to 480 kg/m^3 give thermal insulation with *k*-values of 0.11 W/m·K. Such blocks are normally 210 mm in thickness and are used for the inner skin of a construction; this may be an infill panel or a loadbearing wall. They contribute to the thermal insulation of cavity construction, especially when the cavity needs to be left empty for weather resistance in exposed locations. Lightweight blockwork requires sufficient expansion joints to avoid cracking.

5.04 Thermal bridging

Thermal bridging takes place through the details of a construction that have relatively low thermal resistance to heat flow; they have a high *U*-value in comparison with the rest of the construction. Common areas of thermal bridging are around windows, doors and structural elements. Heat will flow from high to low temperatures by conduction along the path of 'least thermal resistance'. In the case of jambs, sills, lintels and floor edges, the least resistance path will generally be along the highly

Table XIV Internal surface resistance, Rsi

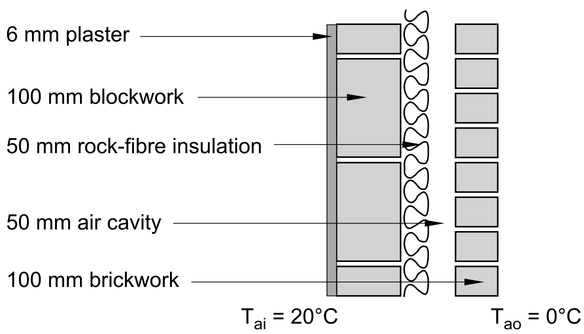
Building element	Direction of heat flow	Surface resistance ($m^2·K/W$)
Walls	Horizontal	0.13
Ceilings or roofs (flat or pitched), floors	Upward	0.10
Ceilings or floors	Downward	0.17

Table XV External surface resistance, Rse

Building element	Direction of heat flow	Surface resistance ($m^2·K/W$)		
		BS EN ISO 6946 (normal design value)	Sheltered	Exposed
Wall	Horizontal	0.04	0.06	0.02
Roof	Upward	0.04	0.06	0.02
Floor	Downward	0.04	0.06	0.02

Table XVI Values of surface and airspace resistance ($m^2·K/W$)

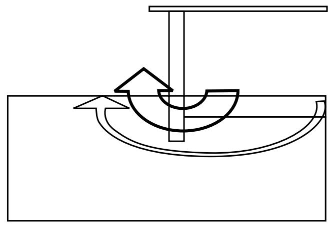
Structure	External surface resistance	Internal surface resistance	Airspace resistance
External walls	0.04	0.13	0.18
Party walls and internal partitions	0.13	0.13	0.18
Roofs:			
Pitched	0.04	0.10	0.16
Flat	0.04	0.10	0.16
Ground floors	0.04	0.17	0.21
Internal floors/ceilings	0.13	0.13	0.18



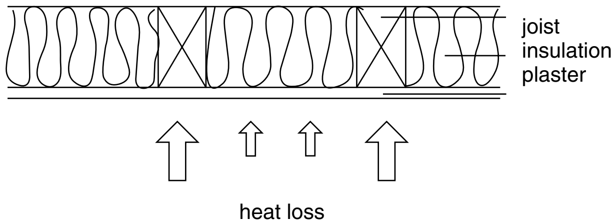
39.36 *Construction of wall in Example 2*

Table XVII Calculation for Example 2

Element	Thickness (m)	k-value (W/m·K)	Resistance ($m^2·K/W$)
Rsi	–	–	0.13
Plaster	0.013	0.16	0.08
Blockwork	0.1	0.11	0.91
Cavity Insulation	0.1	0.035	2.86
Airgap	0.05		0.18
Brickwork	0.1025	0.84	0.12
Rse	–	–	0.04
Total			4.32



39.37 *The edge losses are dominant in floor heat loss*



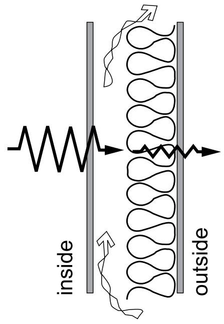
39.38 *Increase in heat loss through thermal bridging due to structural elements*

conductive materials such as metal and dense concrete. Heat loss at thermal bridges can be reduced by adding insulation and thermal breaks, and ensuring that the insulation is continuous over the building envelope. If thermal bridging occurs it will result in increased heat loss and increased risk of condensation. The heat loss through solid ground floors is a specific case where heat will follow the three-dimensional line of least thermal resistance as shown in **39.37**. The *U*-value of floors is therefore taken as an average value accounting for the high 'edge losses' and slab dimensions. Where there is thermal bridging in a construction, for example structural elements such as roof joists in ceilings, the reduction in thermal resistance should be considered in *U*-value calculations, **39.38**.

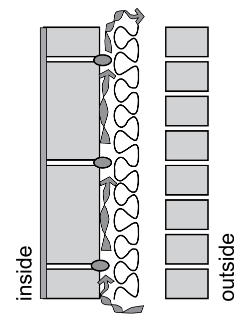
5.05 Installation of insulation

The following guidelines should be followed when designing an insulated construction:

- Insulation should always be located on the 'warm and dry side' of a ventilated cavity (unless informed otherwise, it is usual to assume that all cavities are ventilated). If a cavity or air gap is ventilated on the warm side of the insulation this could provide a 'short circuit' for heat loss as indicated in **39.39**.
- Avoid air infiltration through or around the insulation material as indicated in **39.40**. This will result in short-circuiting of heat loss.
- Ensure continuity of insulation at design details, e.g. eaves and floor junctions.



39.39 *Insulation should not be placed on the cold side of a ventilated cavity as its insulation value will be considerable reduced*



39.40 *Mortar snobs may distance the insulation from the inner skin introducing airflow on the warm side of the insulation and short-circuiting the heat flow through convective losses*

- Ensure that there is a vapour barrier on the warm side of the insulation to guard against condensation, and degrading of the insulation properties through dampness.
- Avoid compression of low-density insulation when installed in a construction.

5.06 Glazing
Glass is the main material used for glazing. It is available in a wide range of configurations with different thermal properties.

5.07 Thermal performance of glass
Glass is transparent to short-wave infrared radiation and opaque to long-wave radiation (see **2.04**). It is also a good conductor of heat. Although glass transmits the short-wave infrared part of the solar radiation spectrum, it will also reflect and absorb a proportion of the radiation as shown in **39.41**, the amount of which will vary with solar angle of incidence.

5.08 *U*-Value of glass
The main thermal resistance for a single layer of glass can be attributed to the surface resistances. The glass material itself has practically no thermal resistance.

Example 3
Calculate the U-value of a single layer of glass

Internal surface resistance is 0.13
External surface resistance is 0.04
For a *k*-value of glass of 1.05 and thickness of 6 mm the resistance can be calculated:
$R = 0.13 + 0.006/1.05 + 0.04$
Total resistance $(R) = 0.1757\ \text{m}^2{\cdot}\text{K/W}$
U-value is $1/R = 5.7\ \text{W/m}^2\text{K}$

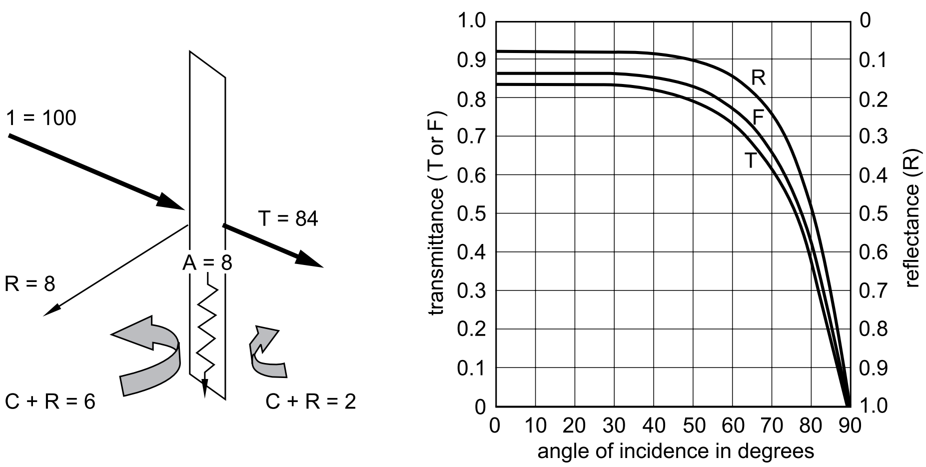
Adding layers of glass will improve the insulating properties of glazing due to the resistance of the trapped layer of air (or another gas). The thermal resistance of an air- or gas-filled cavity increases in proportion to its width up to about 20 mm and remains constant up to 60 mm, after which it decreases slightly. Increasing the layers of glass will reduce the solar transmittance by about 80% per layer (see Table XVIII) for standard glass.

The glazing frame can provide a thermal bridge, which will increase the overall *U*-value of the glazing system (Table XIX).

5.09 Low-emissivity glass
A coating of metal oxide can be applied to a glass surface to reduce its emissivity. This will reduce its long-wave radiation loss, which will reduce the overall transmission loss by about 30%. The low-emissivity coating is usually applied to the inside surface of the inner pane of a double-glazed unit.

5.10 G-value of glazing
The transmission of solar radiation can be reduced by different glazing treatment or the use of blinds or solar shading. Blinds can be incorporated within a layered glazing system to provide additional solar control **39.42**. Internal blinds convert short-wave radiant heat gains to convective and long-wave radiant heat gains. Blinds located externally or between layers of glass are more effective in reducing solar heat gains. In some cases it may be necessary to ventilate the cavity which contains the blinds, otherwise the solar heat gains ‘trapped’ within the glazing system may give rise to secondary heat gains through the heated internal glass surface. The g-value of a glazing system is a measure of the total solar gains to a space, which includes the direct ‘short wave’ transmitted gains through the glass and the secondary gains through the heated internal glass surface due to absorption of solar gains within the glazing system **39.43**. As a rule of thumb the internal glass surface temperature should be no more than 5°C above the internal air temperature in order to avoid excess secondary heat gains and thermal discomfort near the glazing zone.

5.11 Matrix glazing systems
Matrix glazing systems are designed to make maximum use of daylight, while at the same time controlling solar heat gain. They usually consist of a reflective matrix located between two layers of glass. The blades of the reflector are angled to respond to the particular orientation of the glass and the requirement accepting or rejecting the solar heat gains, **39.44**.



39.41 *Transmitted, reflected, absorbed and re-emitted solar radiation as a percentage of incident value for 4 mm single glazing, and graph indicating variation of solar transmittance with angle of incidence:*

Incident (I) = 100%
Reflected (R) = 8%
Transmitted (T) = 84%
Absorbed (A) = 8%

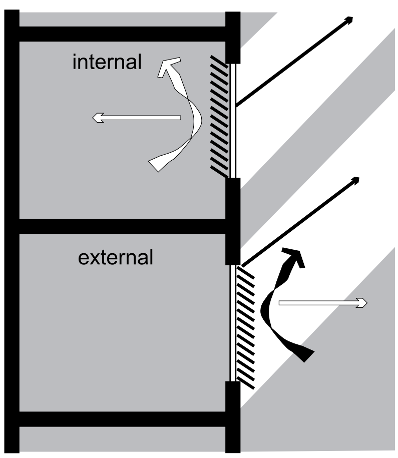
Convected and radiated inside (C + R) = 2%
Convected and radiated outside (C + R) = 6%

Table XVIII Solar transmission, total heat gains and light transmission for different glazing systems

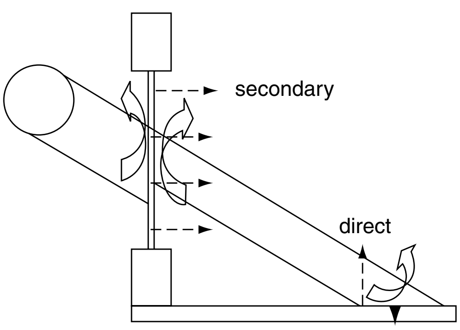
	Transmission	Total heat gain	Light
6 mm clear glass (×1)	84	86	87
6 mm clear glass (×2)	64	73	76
6 mm Spectrafloat (×1)	56	66	49
6 mm Antisun (×1)	45	60	75
6 mm Solarshield (×1)	9	22	16
Insulight Gold (×2)	14	22	26
6 mm clear glass + blind (×1)	9	47	–
6 mm clear glass + blind between layers of glass (×2)	8	24	–

Table XIX *U*-values of glazing systems

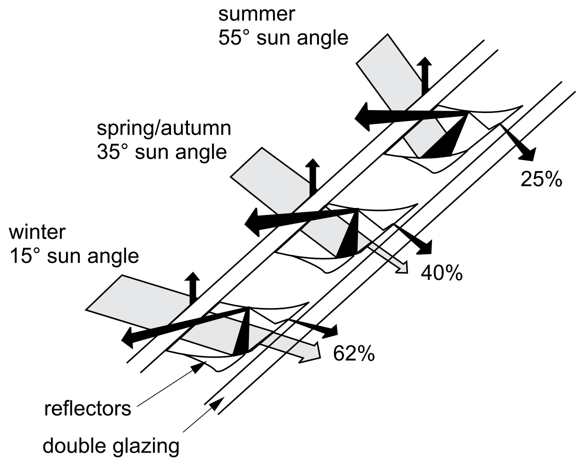
	glass	glass and frame
Single glazing	5.7	4.8
Double glazing	2.7–3.3	2.7–3.1
Double glazing, argon fill, low-E	1.2–2.3	1.7–2.5
Triple glazing	1.7–2.3	2.0–2.4
Triple glazing, argon fill, low-E	0.6–1.5	1.3–1.9



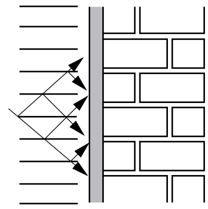
39.42 *Comparison of heat gains through external and internal shading. Typically there could be solar gain of 12% for external white louvres, and 46% for internal white louvres*



39.43 *Direct and secondary solar heat gains through a glazing system*



39.44 *Matrix glazing system*



39.45 *Transparent insulation material (TIM)*

5.12 Transparent insulation material (TIM)

This can be applied to the face of an opaque south-facing facade to provide insulation while at the same time allowing the passage of solar gains to the solid wall behind, **39.45**. It can also be installed between two layers of glass where light but not view is required.

6 CONDENSATION

6.01

Condensation occurs when moist air meets a relatively cool surface. Water condenses out of the air and is deposited on the cool surface. It can result in dampness, surface mould growth, and deterioration of the building fabric.

6.02 Terminology

- The amount of water vapour that the air can contain is limited and when this limit is reached the air is said to be *saturated.*
- The saturation point varies with temperature. The higher the air temperature, the greater the amount of water vapour it can contain.
- Water vapour is a gas, and in a mixture of gases such as air, the water vapour contributes to the total vapour pressure exerted by the air.
- The ratio of the vapour pressure in any mixture of water vapour and air to the vapour pressure of saturated air at the same temperature is the *relative humidity* (RH).
- If air is cooled it will eventually reach saturation point, that is, 100% RH, and any further cooling will cause the vapour to condense. The temperature at which condensation occurs is called the *dewpoint* temperature.

6.03 Surface condensation

When air with a relatively high RH comes into contact with a cold surface condensation can take place. The risk of surface condensation depends on:

- Air and surface temperature, and
- Moisture content of the air

6.04 Mould growth

Surface condensation can cause mould growth. Mould spores can germinate at RHs above 80%. If the RH is generally greater than 70% for long periods mould will spread.

6.05 Estimating surface temperature

The following formula can be used to estimate the surface temperature:

Temperature drop between the air and the surface

$$= \Delta T \times U \times R_{si} \quad (15)$$

where ΔT = inside/outside air temperature difference
U = wall U-value
R_{si} = internal surface resistance

Example 4

What is the internal surface temperature of single glazing (U-value – 5.8 W/m^{2}K), if the internal air temperature is 20°C and the external air temperature is 0°C? The internal surface resistance is 0.123 m^2·K/W.

$D_T = 20 \quad U = 5.8 \quad R_{si} = 0.123$

Temperature drop (air to wall surface) $= 20 \times 5.8 \times 0.123$
$= 13.9°C$

Therefore the internal surface temperature $= 20 - 13.7 = 6.1°C$

6.06 Surface temperature and *U*-value

The internal surface temperature is affected by the *U*-value of the construction element, **39.46**. The higher the *U*-value, the lower the internal surface temperature for a given heat input to the space. Thermal bridging constitutes a localised increase in *U*-value which will result in a lower surface temperature. High *U*-value elements at risk include single glazing and thermal bridging.

6.07 Moisture content of the air

Moisture is contained in the external air and this is added to by various building use activities (Table XX). The main moisture sources are:

External air: external air enters the building through ventilation. Its RH will depend on its moisture content and temperature. For example, on a typical winter's day external air at 90% RH and 5°C will contain about 5 g/kg (dry air) of water vapour. Saturated air at 0°C will contain 3.8 g/kg. These values can be obtained from the psychrometric chart, **39.14**; see para **3.06**.

Table XX Moisture addition to internal air

	kg/kg dry air
Dwelling	0.0034
Offices shops, classrooms	0.0017
Catering	0.0068

Table XXI Moisture content of materials

Material	Water content (litres/m^2)
105 mm brickwork	33
100 mm blockwork	40
150 mm in-situ concrete	30

Table XXII Moisture emission rates (four-person house)

Source	Litres per 24-hour period
4 persons asleep (8 hours)	1.0–2.0
2 persons active (16 hours)	1.5–3.0
Cooking	2.0–4.0
Bathing, dishwashing, etc.	0.5–1.0
Drying clothes	3.0–7.5
Pariffin heater	1.0–2.0
Daily total	5.0–10.0 (max 10–20)

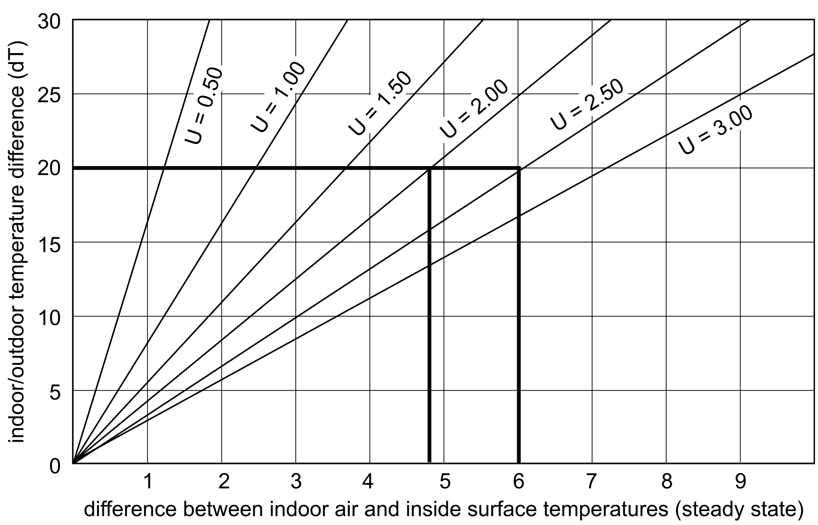
Drying out: building materials contain moisture (Table XXI). A building could take a year to dry out after construction. A new house might contain 4000 litres of water which will be released during the drying-out period.

Occupants: moisture is produced as a result of occupants' activities (Table XXII). On average, 3.4 g/kg of moisture is added to the air by internal activities in a house.

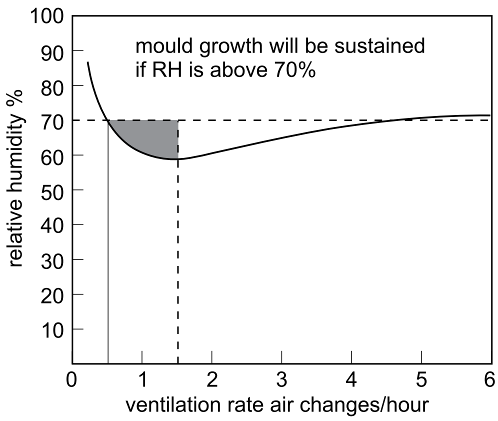
6.08 Causes of surface condensation

Minimising the risk of surface condensation requires a balanced approach to heating, ventilation and insulation, together with minimising moisture production:

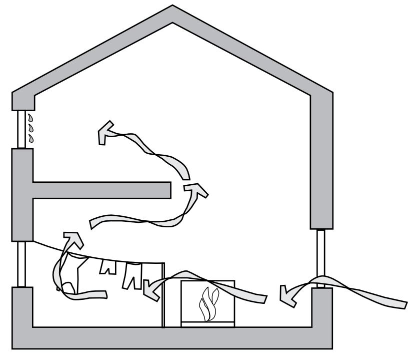
Heating: inadequate heating can result in low air temperatures and higher levels of RH. It also means colder surface temperatures. Intermittent heating can result in the fabric and surface temperatures significantly cooler than the air temperature (during warm-up). Warm moist air coming into contact with cool surfaces can then result in condensation. Partial heating of a house can result in warm, moist air



39.46 *Internal air-to-surface temperature versus inside/outside temperature difference for different U-values*



39.47 *Ventilation rate versus RH, indicating that low and high rates can give rise to higher RHs*



convecting to cooler rooms with cooler surfaces. Surface areas shielded from heating (e.g. behind wardrobes) will be more at risk.

Ventilation: low ventilation rates will result in a build-up of moisture in the air causing higher RHs. Too much ventilation could give rise to lower internal air temperatures which will again increase the RH, and also reduce surface temperatures. Ventilation should therefore be balanced as illustrated in **39.47**.

6.09 Estimating risk of surface condensation

The risk of surface condensation can be estimated if the RH and air and surface temperatures are known.

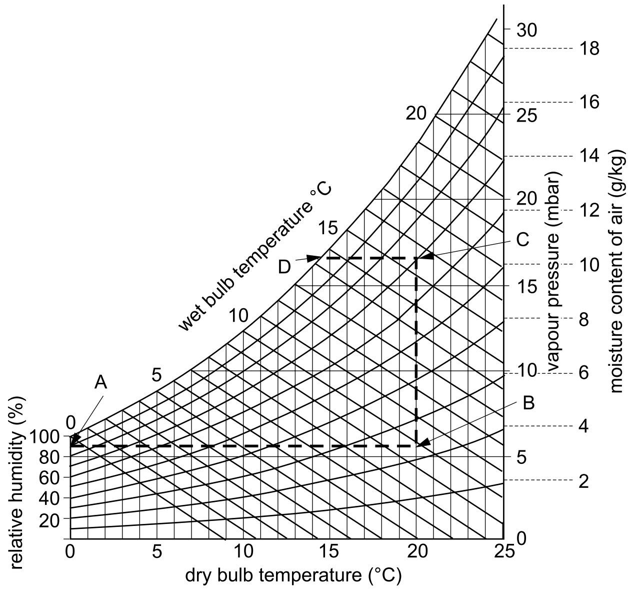
Example 5

Predict the risk of surface condensation using the psychrometric chart **39.48**

- The outdoor dry-bulb air temperature is 0°C and contains 3.8 g/kg of moisture, which gives an RH of 100% (point A).
- On entering the building the air warms to 20°C. If its moisture content remains the same, its RH will reduce to 27% (point B).
- Internal activities are assumed to generate additional moisture of 7 g/kg, increasing the RH to 70% (point C).
- The dewpoint temperature for air at 70% RH is 15°C (point D).

This means that condensation will occur if the air comes into contact with a surface at a temperature of 15°C or less.

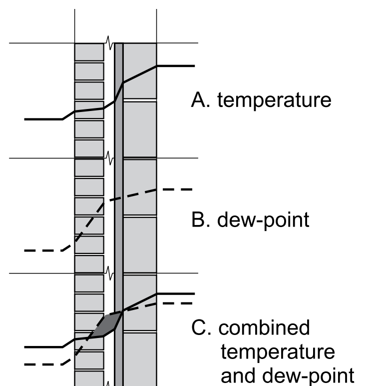
Referring to the graph in **39.46** for an internal/external air temperature difference of 20°C, surface condensation will occur if the *U*-value is greater than 2 W/m^{2}K, in which case the internal surface temperature will be 15°C, i.e. 5°C less than the air temperature.



39.48 *Illustration to Example 5: predicting the risk of surface condensation using a psychrometric chart*

6.10 Interstitial condensation

Condensation can occur within a construction. The dewpoint temperature profile of a wall can be predicted. If the actual temperature at any point within the construction falls below the dewpoint temperature then there is a risk of interstitial condensation taking place, as shown in **39.49**.



39.49 *Set of three diagrammatic representations of:*

A Temperature profile through wall,
B Dewpoint temperature profile, and
C Overlap of these two profiles indicating area of interstitial condensation risk

6.11 Vapour resistance

A material will resist the passage of vapour depending on its vapour resistivity or vapour resistance (Tables XXIII and XXIV) (analogous to thermal resistivity). The vapour resistance of a given thickness of material within a construction is:

$$V_r = x \times v_r \quad (16)$$

where v_r = vapour resistivity (Ns/kg·m)
x = thickness of material (m)
V_r = vapour resistance (Ns/kg)

6.12 Vapour pressure

The vapour pressure can be estimated from the moisture content using a psychrometric chart. The dewpoint temperature for a given vapour pressure will be the dry bulb temperature at 100% RH. The drop in vapour pressure across a given thickness of material in a construction is:

$$dV_p = (V_r/V_R) \times dV_p \quad (17)$$

Table XXIII K-value and vapour resistivity and resistances

Material	K-value (W/m·K)	Vapour resistivity (MNs/g)
Brickwork (heavyweight)	0.84	45–70
Concrete (blocks, lightweight)	0.66	15–150
Render	1.3	100
Plaster (cement based)	0.72	75–205
Wood (pine)	0.12	45–1850
Plywood	0.12	150–2000
Fibreboard	0.042	150–375
Hardboard	0.14	230–1000
Plasterboard	0.16	30–60
Compressed strawboard	0.1	45–70
Wood–wool slab	0.11	15–40
Expanded polystyrene	0.035	100–750
Glass wool	0.04	5–7
Phenolic (closed cell)	0.04	150–750

Table XXIV Vapour resistance of membranes

Membranes	Vapour resistance (MNs/g)
Average gloss paint	40–200
Polythene sheet	110–120
Aluminium foil	4000

where dV_p = drop in vapour pressure across a given thickness of material (kPa)
V_r = vapour resistance of material (Ns/kg)
V_R = vapour resistance of construction (Ns/kg)
dV_p = vapour drop across construction (kPa)

Example 6

Calculate the dewpoint temperature and actual temperature across a construction, **39.50**

1 Calculate thermal resistance of each layer.
2 Calculate temperature drop across each layer:

$$\Delta t = \Delta T \times U \times R_s \text{ (formula (15))}$$

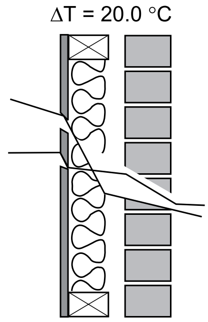
3 Plot temperature profile.
4 Calculate vapour resistance for each layer from formula (16).
5 Calculate vapour pressure drop across each layer from formula (17).
6 Calculate vapour pressure at the interface of each layer.
7 Look up dewpoint temperature on psychrometric chart, **39.14**
8 Plot dewpoint temperature profile.
9 Check crossover for condensation risk.

The calculation and results are shown in Table XXV.

7 INFILTRATION AND VENTILATION

7.01 Ventilation

Ventilation is the process of supplying and removing air by natural or mechanical means to and from any space. It is a combination of infiltration and purpose ventilation. Purpose ventilation can be either



39.50 *Construction of wall in Example 6*

natural (opening windows), or mechanical (turning on a fan), or a combination of each. Ventilation rate is measured in air changes per hour (ac/h), m^3/s or litres per second per person (1/s/p). Typical ventilation rates are in Table XXVI and more detailed rates can be found in Tables VI and VII.

7.02 Air infiltration

Air infiltration is the term used to describe the fortuitous leakage of air through a building due to imperfections in the structure, such as:

- Cracks around doors, windows, infill panels
- Service entries, pipes, ducts, flues, ventilators and
- Through porous constructions, bricks, blocks, mortar joints.

7.03 Natural ventilation

Natural ventilation is the movement of outdoor air into a space through intentionally provided openings, such as windows, doors and non-powered ventilators. This is in addition to the ventilation due to air infiltration. In many cases, for much of the year infiltration alone will provide sufficient outdoor air to ventilate the building. However, it is uncontrollable, and if excessive, it can incur a high-energy penalty and/or make the building difficult to heat (or cool) to comfort levels.

7.04 Mechanical ventilation

Mechanical ventilation is the movement of air by mechanical means to and/or from a space. It can be localised using individual wall or

Table XXVI Typical ventilation rates

Building type	l/s/person	ac/h
Domestic:		
Habitable rooms	–	1
Kitchens bathrooms	–	3
Offices	8	1–2
Schools	8.3	2–5
Bars	15	10–15

Table XXV Calculation for Example 6

	Temp.	Inside surface		Plaster-board		Insulation		Cavity		Brick		Outside surface	Temp.
Thickness				0.15		0.05		0.05		0.1			
Thermal resistance		0.12		0.9		2.5		0.18		0.12		0.055	2.1
Temperature drop		0.78		0.59		16.31		1.17		0.78		0.36	
Temperature	**20.0**		**19.2**		**18.6**		**2.3**		**1.2**		**0.4**		**0.0**
Vapour resistance (X × V_r)				7.9		2.8				6.3			
Vapour pressure crop				0.3		0.1				0.25			
Vapour pressure					1.0		0.9		0.9				0.65
Dewpoint temperature	**10.7**				**7.0**		**6.0**		**6.0**				**0.8**

roof fans, or centralised with ducted distribution. It is controllable and can, for example, incorporate a heat-recovery system to extract heat from exhaust air and use it to pre-heat supply air.

7.05 Build tight, ventilate right!

Infiltration is present in both naturally ventilated and mechanically ventilated spaces. It is considered 'best practice' to reduce the infiltration as much as possible by sealing measures, and then to depend on controllable natural or mechanical means to provide the main ventilation.

7.06 Ventilation effectiveness and efficiency

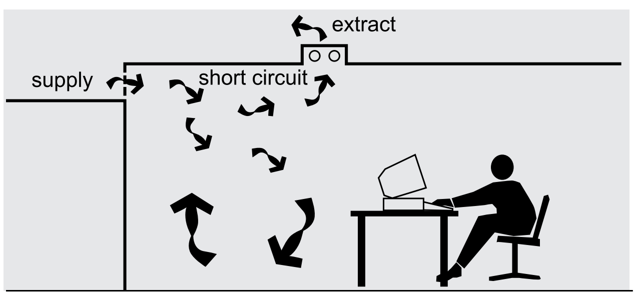
The term *ventilation effectiveness* is used to describe the fraction of fresh air delivered to the space that reaches the occupied zone. It should ideally be 100%. However, if air 'short-circuits' between supply and extract points then it could be greatly reduced, down to as low as 50%, **39.51**.

The term *ventilation efficiency* is used to describe the ability of a ventilation system to exhaust the pollutants generated within the space. For a specific pollutant, it is the mean concentration level of the pollutant throughout the space in relation to its concentration at the point of extract. The ventilation efficiency at a single location is the ratio of pollutant concentration at that location in the space to its concentration at the point of extract;

$$\text{Ventilation efficiency } E = (C_e - C_s)/(C_e - C_s) \qquad (18)$$

where E = ventilation efficiency
C_e = concentration of pollutant at exhaust
C_s = concentration of pollutant in supply

If there is a significant level of the pollutant in the supply air then this should be subtracted from the internal and exhaust concentration levels.



39.51 *Short-circuiting of air between supply and extract reduces ventilation effectiveness and efficiency*

7.07 Metabolic carbon dioxide as an indicator of air quality

Metabolic carbon dioxide is often used as an indicator of air quality. For naturally ventilated spaces in winter when windows are closed, the carbon dioxide level may rise to typically 1500 ppm for offices, and 2500 ppm for school classrooms. For mechanically ventilated buildings the carbon dioxide level should not rise above 1000 ppm and will generally be less than 800 ppm. Metabolic carbon dioxide can also be used to estimate ventilation efficiency using formula (18).

7.08 Ventilation heat loss

The air supplied to a space has to be heated in winter and sometimes cooled in summer. In a mechanical ventilation system this is achieved by pre-heating or cooling the air before it is delivered to the space. For natural ventilation it is usually achieved by incoming fresh air mixing with air already in the space and then this mixture is heated by the heating system, for example by contact with 'radiator' surfaces.

The air that is exhausted from the space, through natural or mechanical means, contains heat energy. For a mechanical ventilation system this heat is sometimes recovered through a heat exchanger – otherwise it is wasted. The ventilation component of heat loss can be a significant and sometimes major proportion of the total building heat loss. It can also be very variable, especially in naturally ventilated buildings, as it depends on external wind velocity and air temperature.

The heat lost or gained through ventilation can be estimated from:

$$Q_v = V_a \times \text{volume} \times \Delta T \times \rho C/3600 \qquad (19)$$

or

$$Q_v = V_1 \times \text{number of people} \times \Delta T \times \rho C/1000 \qquad (20)$$

where Q_v = heat loss or gain in watts
V_a = ventilation rate in air changes per hour (ac/h)
V_1 = ventilation rate in litres per second per person (1/s/p)
ρC = volumetric heat capacity of air = 1200 $\text{Jm}^{-3}\text{K}^{-1}$
ΔT = internal/external air temperature difference (°C).

An increase in internal/external temperature difference causes an increase in ventilation rate and an increase in heat loss or gain.

When designing a heating system the ventilation rate used to calculate the design heat loss should correspond to a design ventilation rate. However, when estimating seasonal energy performance the ventilation rate will be the average ventilation rate over a heating season.

7.09 Natural ventilation design

Natural ventilation through leakage and purpose ventilation is a result of two processes, termed *stack effect* and *wind effect.*

7.10 Stack effect

Stack effect occurs when there is a difference between the inside and outside air temperature. If the inside air temperature is warmer than the outside air it will be less dense and more buoyant. It will rise through the space escaping at high level through cracks and openings. It will be replaced by cooler, denser air drawn into the space at low level. Stack effect increases with increasing inside/outside temperature difference and increasing height between the higher and lower openings. The neutral plane, **39.52**, occurs at the location between the high and low openings at which the internal pressure will be the same as the external pressure (in the absence of wind). Above the neutral plane, the air pressure will be positive relative to the neutral plane and air will exhaust. Below the neutral plane the air pressure will be negative and external air will be drawn into the space.

The pressure difference due to stack is estimated from:

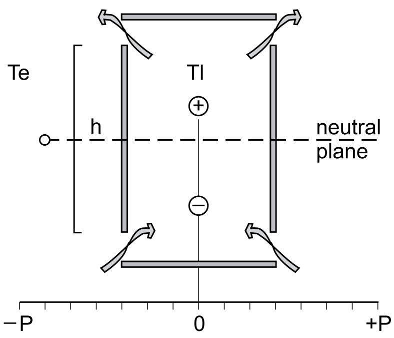
$$P_s = -\rho \times T \times g \times h \times (1/T_e - 1/T_i) \qquad (21)$$

where P_s = pressure difference in pascals (Pa)
ρ = density of air at temperature T
g = acceleration due to gravity = 9.8 m/s^2
h = height between openings (m)
T_i = inside temperature in kelvins, and
T_e = external temperature in kelvins.

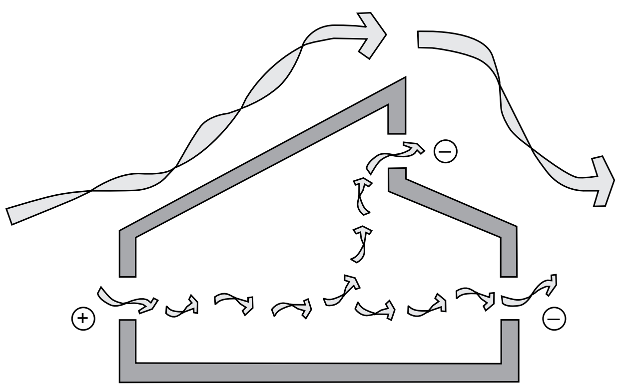
7.11 Wind effect

Wind effect ventilation, sometimes referred to as *cross-ventilation,* is caused by the pressure differences on openings across a space due to the impact of wind on the external building envelope, **39.53** Pressure differences will vary, depending on wind speed and direction and location of the openings in the envelope. The pressure at any point on a building envelope can be calculated for a given wind speed and direction if the pressure coefficient at the point is known (see **4.10**). Pressure coefficients are usually derived from wind tunnel tests. The pressure difference across a building due to wind can be estimated from:

$$P_w = 1/2\, \rho v^2 (Cp_1 - Cp_2) \qquad (22)$$



39.52 *Pressure gradient due to stack effect, indicating the location of the neutral plane*



39.53 *Wind driven cross-ventilation*

where P_w = pressure difference across the building (Pa)
Cp_1 and Cp_2 = pressure coefficients across the building in relation to the wind speed (v) and air density (ρ).

7.12 Ventilation strategies

39.54 presents a range of natural ventilation strategies with depths limits for single-sided and cross-ventilated spaces. **39.55** illustrates *passive stack ventilation* (*PSV*) used in domestic buildings.

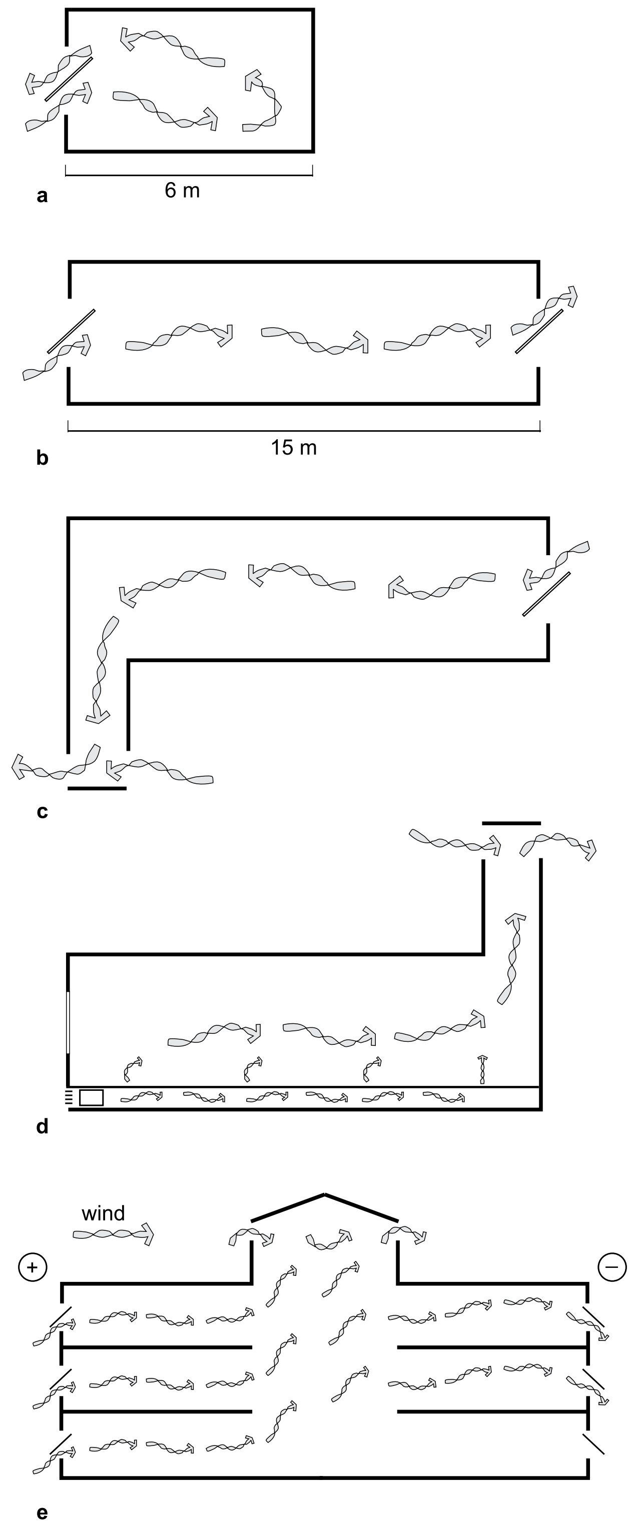
8 HEATING AND COOLING SYSTEMS

8.01

The purpose of heating systems is to maintain internal air and radiant temperatures within the comfort zone. During the ‘heating season’ a building will lose heat through the fabric and through air infiltration and ventilation. However, a building will also gain heat from internal sources (cooking, electric power and people) and from external solar heat gains through areas of glazing. A heating system is required to make up the difference between the heat gains and the heat losses. If a building is well insulated, has a low air infiltration rate and controlled ventilation then during the heating season, after some initial ‘warm up’ period, it can be heated sometimes entirely from the incidental heat gains. A heating system should be sized and controlled such that it can provide the appropriate amount of heat input when needed in an efficient and effective way.

8.02 Types of heating systems

There are direct and indirect heating systems. Direct systems are located in the space, and include solid fuel fires, gas fires, direct electric panel heaters and electric storage heaters. For industrial applications there are high-temperature gas-fired radiant tubes and plaques. The main types of indirect systems are wet central heating systems, **39.56**, and ducted warm air systems, **39.57**. There are also low-temperature ‘surface’ heating systems such as under-floor

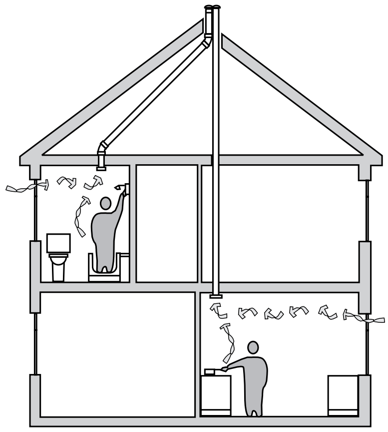


39.54 *Natural ventilation strategies:* **a** *Single-sided;* **b** *Cross-ventilation;* **c** *Cross-ventilation with chimney;* **d** *Cross-ventilation with underfloor supply;* **e** *Atrium: stack and wind effects*

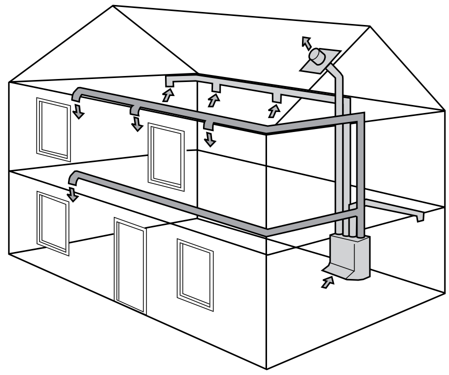
heating, and ceiling and wall systems, where heat is input to the buildings internal surface or mass.

8.03 Heat distribution

Heat can be distributed in water or in air. As water has a higher specific heat capacity than air, it requires smaller pipes in comparison to air ducts for the same heat transfer (Table XXVII). Water distribution can be ‘gravity’ feed or pressurised. An open system will require a header tank, whereas a pressurised system is sealed



39.55 *Passive stack ventilation (PSV) can be used instead of mechanical ventilation for local extract, for example in kitchens and bathrooms*



39.57 *Domestic mechanically ventilated heat recovery system with extract in kitchen and bathroom and supply in living spaces, with heat recovery in cooker hood*

and requires a pressurisation unit. Pressurised systems can be used to carry water at temperatures higher than 100°C, and are sometimes used for commercial and industrial systems.

Table XXVII Water is more efficient than air in transferring heat because it has a higher volumetric specific heat capacity (it energy content per unit volume)

Specific heat capacity	Volumetric specific heat (kJ/kg·K)	Capacity (kJ/m^3·K)
Water	4.2	415
Air	1.01	1.2

8.04 Heat emitters

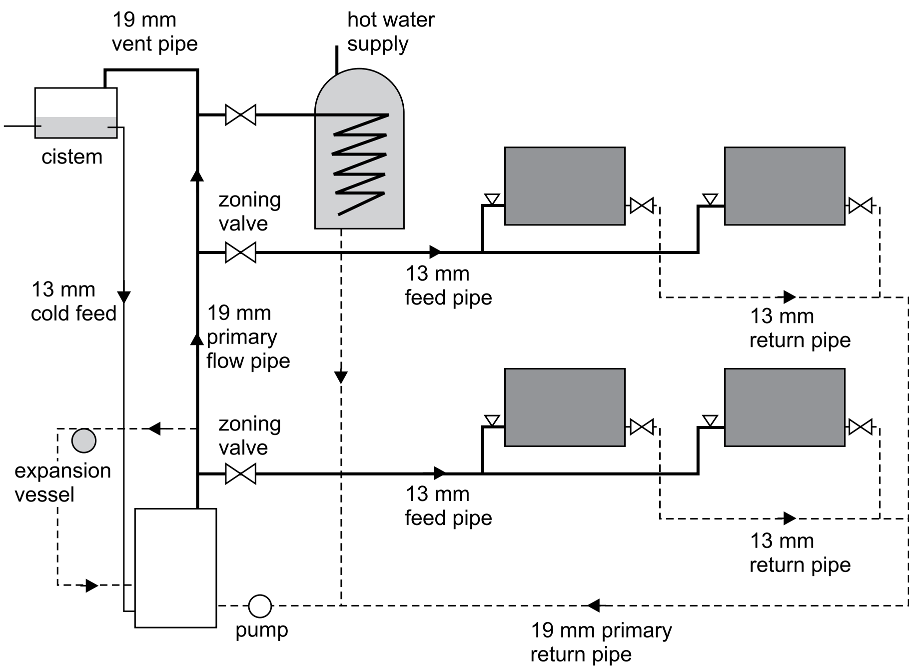
Surface panel or tube heaters emit heat by a mixture of convection and radiation. The balance changes with surface temperature and finish. For low-temperature emitters the heat output is mainly convection, whereas for high-temperature emitters the radiant component of heat output increases (see Table XXVIII). In some cases the convective heat component may not be useful, as for overhead industrial localised heating systems. Some emitters, for example electric storage heaters, use a combination of heated surface plus forced convection.

8.05 Boilers

Boilers convert fuel to heat. In doing so they produce products of combustion which must be flued. The boiler efficiency (see Table XXIX) is a measure of the conversion of the energy in the fuel (its calorific value) to the useful heat extracted. Condensing boilers are also able to recover latent heat from the flue gases and therefore have a higher efficiency. Boiler efficiency is usually reduced at part-load operation. In larger buildings, modular boilers allow maximum efficiency with sequencing a number of smaller boilers instead of a few large ones so that the majority operate at full-load. Combination boilers allow for direct heating of domestic hot water, thus avoiding the need for storage and reducing the standing heat losses.

8.06 Distribution losses

There will be heat loss associated with the distribution system. Pipes and ducts should be well insulated (Table XXX). There will



39.56 *Domestic two-pipe wet central heating system with flow and return to each radiator. The system can either be pressurised using an expansion vessel (dotted circuit); or gravity feed, in which case it requires a header tank located above the top radiator*

Table XXVIII Radiant and convective output from heated surfaces, based on heating surface emissivity of 0.9

Type	Surface temperature (°C)	Direction of heat flow	Heat output (W/m^2)	
			Convective	Radiant
Underfloor heating	24	up	18	27
Low temperature radiators	40	vertical	75	114
Domestic radiators	70	vertical	255	330
Medium pressure hot	110	down	178	727
water panels		vertical	558	727
Gas-fired radiant tubes*	150		1709	1078
	300		4414	4367
	500		8627	15184

* Gas radiant tubes are usually mounted at a high level and operate between 150 and 500°C. The convective component is generally lost to the high level; the radiant component is based on a floor level temperature of 18°C.

Table XXIX Boiler efficiencies

System	Seasonal efficiency %
Condensing boilers:	
underfloor or warm water system	90 or greater
standard size radiators, variable temperature circuit (weather compensation)	87
standard fixed temperature emitters (83°C flow, 72°C return)	85
Non-condensing boilers:	
modern high efficiency non-condensing boilers	82
good modern boiler design closely matched to demand	80
typical good existing boiler	70
typical existing oversized boiler (atmospheric cast-iron sectional)	45–70
Oil	65–85
Coal	55–65

Table XXX Heat losses from pipes and ducts

Type	Fluid temperature (°C)	Heat loss (W/m)	
		Uninsulated	With 25 mm insulation
15 mm dia pipe	50	32	6
	70	62	11
500 mm dia duct	40	333	47

also be standing 'case' heat losses associated with the boiler, which may be considered useful (although it is uncontrolled) if they contribute to space heating.

8.07 Building 'design heat loss'

Fabric and ventilation heat loss has been explained in Sections 5 and 6. The *design heat loss* of a building is its heating demand for a given external air temperature, which will vary for different parts of the UK. It can be estimated as follows:

Fabric heat loss rate	Q_f (W/°C)
Ventilation heat loss rate	Q_v (W/°C)
Total heat loss rate	$Q = Q_f + Q_v$ (W/°C)
Design internal air temperature	T_i (°C)
Design external air temperature	T_e (°C)

$$\text{Design heat loss} = Q \times (T_i - T_e)(W) \quad (23)$$

8.08 Seasonal energy use

The seasonal energy use can be calculated from the design heat loss, but using some form of seasonal temperature instead of a design temperature. Also, an allowance has to be made for system efficiency and incidental heat gains. The seasonal temperature can be in the form of a heating season average temperature or *degree days* (Table XXXI). If average temperature is used, then some account of seasonal heat gains are required. Degree days already assume some level of useful heat gains in relation to a *base temperature*; which is the temperature below which heating is required. The standard base temperature is 15.5°C, which takes account of typical internal heat gains.

Table XXXI Seasonal energy design temperatures

Region	Seasonal average temperature T_{sa} (°C)	Annual Degree Days
Thames Valley	7.5	2120
South Eastern	6.7	2427
Southern	7.8	2265
South Western	8.3	1949
Seven Valley	7.2	2211
Midland	6.7	2507
West Pennines	6.7	2362
North Western	6.4	2532
North Eastern	5.9	2510
East Pennines	6.6	2373
East Anglia	6.7	2451
Borders	6.1	2709
West Scotland	5.8	2585
East Scotland	6.0	2719
North-east Scotland	5.5	2886
Wales	7.2	2244
Northern Ireland	6.4	2522

Table XXXII Solar heat gains

	Single glazing			Double glazing		
	S	SE/SW	E/W	S	SE/SW	E/W
J	14	12	6	12	10	5
F	19	16	11	16	13	9
M	35	31	23	30	26	19
A	35	34	30	29	29	26
M	42	44	42	35	37	35
J	41	45	46	35	38	39
J	39	43	42	33	36	35
A	40	41	37	34	34	31
S	39	36	29	33	30	24
O	31	27	18	26	22	15
N	19	16	9	16	13	7
D	14	12	5	12	10	4

8.09 Heat gains

There will be heat gains from internal activities and solar effects (Table XXXII). For domestic buildings, the internal gains can be estimated depending whether the household has high, medium or low activities (Table XXXIII). Not all the internal gains will usefully supplement the heating. Some may cause overheating and some may occur where or when they are not required.

8.10 Environmental temperature

It is more accurate in cases where the radiant temperature is significantly different from air temperature to calculate the heat transfer to the internal surface of a wall using the *environmental temperature* which combines air temperature and mean radiant temperature:

$$t_{ei} = 2/3\ t_{mrt} + 1/3\ t_{ai} \quad (24)$$

where t_{ei} = environment temperature
t_{mrt} = mean radiant temperature, and
t_{ai} = air temperature.

39.58 illustrates the use of resultant temperature (formula (6)), environment temperature (formula (24)) and sol-air temperature (formula (8)).

Table XXXIII Domestic Internal heat gains

Heat source	Total heat gain (kWh/day)	
	Low	High
Occupants	4.02	5.46
Lighting	2.17	2.50
Cooker	2.89	4.25
Refrigerator	1.44	1.44
Television	0.45	0.54
Hot water	3.70	4.70
TOTAL	14.67	18.89

This may also apply to cooling where a low radiant component of the environment temperature may improve comfort because it is more comfortable to exchange heat by radiation to surrounding (cooler) surfaces than by convection to the surrounding air.

8.11 Seasonal energy use (*E*)

To calculate the seasonal energy use for space heating:

(i) Using average temperature:

$$E = ((Q_f + Q_v) \times (T_i - T_{sa}) \times \text{number of hours} - \text{seasonal heat gains}) \times eff \qquad (25)$$

where E = the seasonal energy use (W)
Q_f = fabric heat loss
Q_v = ventilation heat loss
T_i = average internal temperature
T_{sa} = seasonal average temperature (Table XXXII)
eff = efficiency of heating system.

(ii) Using degree days:

$$E = (Q_f + Q_v) \times \text{degree days} \times 24 \times eff \qquad (26)$$

8.12 Carbon dioxide emissions

Table XXXIV gives the carbon dioxide emissions associated with fuel use.

Table XXXIV Carbon dioxide emission factors for UK in 2000–2005

Fuel	Carbon emission per unit of delivered energy ($kgCO_2$/kWh)
Natural gas	0.19
Liquid petroleum gas (LPG)	0.214
Gas oil/burning oil	0.26
Coal	0.30
Electricity (average of public supply)	0.43

Example 7

Calculation of seasonal heating, fuel use and carbon dioxide emission from a modern detached house located in Cardiff, and heated by a gas condensing boiler.

Fabric heat loss

Element	*Area (m^2)*	*U-value ($W/m^2/°C$)*	*Heat loss (W/°C)*	
Walls	115	0.23	26.45	Table XIII
Roof	35	0.19	6.65	Table XIII
Floor	35	0.25	8.75	
Windows	30	2.00	60.0	Table XX
Total			102.0	

Example 7 *continued*

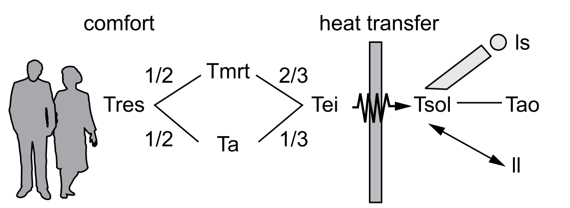
Ventilation heat loss			Formula (19)
Air change rate (/h)	*Volume (m^3)*	*Heat loss (W/°C)*	
0.75	210	52.5	Table XXVII
Total heat loss		155	

Seasonal heat loss (October–May)		Formula (25)
External temperature	7	Table XXXII
Internal temperature	17	
Hours of use	5760	
Seasonal heat loss (kWh/year)	8910.7	

Heat gains

Windows	*Area (m^2)*	*Unit gains (kWh/m^2)*	*Total gains (kWh)*	
Solar gains				Table XXXIII
South	10	190	1900	
North	5	0	0	
East	5	110	550	
West	10	110	1100	
Total			3550	
Internal gains				Table XXXIV
People	4	370	1480	
Hot water			450	
Electrical			1100	
Cooking			950	
Total			3980	

Total heat gains (kWh/year)	7530	
Assume 50% of the gains contribute to useful heating	3765	
Heating system load (kWh/year)	5145.7	Formula (25)
Heating system efficiency (%)	88	Table XXX
Heating system fuel use (gas) (kWh/year)	5847	
Carbon dioxide emission associated with heating fuel use (kg/year)	1111	Table XXXV



39.58 *Resultant temperature, environmental temperature and sol-air temperature*

8.13 Mechanical ventilation

Mechanical ventilation may be required in buildings as an alternative or in addition to natural ventilation. Specific applications include:

- Deep plan spaces which cannot be ventilated from the side by natural means
- Spaces with a high occupancy or high heat gain
- Spaces with high source levels of pollution, including industrial processes and moisture in kitchens and bathrooms
- Where the external air quality may be poor and so the external air needs to be filtered or taken in at high level and
- Where high ventilation rates are required in winter, mechanical ventilation (with pre-heated air) can be used without incurring cold draughts.

8.14 Mechanical extract

Local mechanical extract can be used to exhaust pollutants at source (e.g. in kitchens, bathrooms and toilets; and locally for industrial processes such as solder baths and welding booths).

8.15 Mechanical supply systems

Mechanical supply systems can be used in situations where a positive flow needs to be established between a space and its surroundings. Examples are:

- In a house or apartment to maintain a minimum ventilation rate and reduce condensation risk
- Mechanical induction systems where high-velocity warm air is supplied to a space, and extract is through natural leakage and
- Mechanical supply to an office and extract naturally, perhaps through an atrium or chimney/tower.

8.16 Balanced supply and exhaust

Mechanical ventilation systems in larger buildings usually have a balanced supply and extract, **39.59**. This allows:

- Control of higher ventilation rates
- Heating and/or cooling of incoming air
- Filtration of incoming air
- Humidity control of air and
- Heat recovery from exhaust to supply air.

8.17 Air supply rates

If the air supply is for ventilation, then the volume flow rate can be estimated from the number of occupants in the space. This will be typically 10 litres/second/person for normal environments, that is, average levels of pollution. If air is required as the sole source of heating then the volume flow rate can be estimated from the following formulae:

$$\text{Volume flow rate} = \text{design heat loss}/\left((T_{su} - T_{ex}) \times C_p\right) \quad (27)$$

where T_{su} = supply air temperature
T_{ex} = extract air temperature, and
C_p = volumetric specific heat of air

In modern 'low energy' buildings, including dwellings, the rate of air supply for ventilation is similar to that required to meet the design heat loss. Therefore warm air systems incorporating heat recovery can prove an appropriate option for a combined heating and ventilation system.

Example 8

Calculate the volume flow rate of air to ventilate a 1000 m² office space, height of 2.5 m, occupied by 100 people. If the design heat loss of the space is 15 kW, what is the volume flow rate required to heat the space if the supply air temperature is 30°C and the extract is 23°C?

$$\begin{aligned}\text{Ventilation volume flow rate} &= (100 \times 8)/1000\\ &= 0.8\,\text{m}^3/\text{s}\\ &= 0.8 \times 3600/2500\\ &= 1.12\,\text{ac/h}\end{aligned}$$

$$\begin{aligned}\text{Heating volume flow rate} &= 15000/((30 - 23) \times 1200)\\ &= 1.8\,\text{m}^2/\text{s}\\ &= 1.8 \times 3600/2500\\ &= 2.6\,\text{ac/h}\end{aligned}$$

8.18 Air distribution

For a mechanical ventilation system air is distributed from an air handling unit (AHU) to the space through a system of ducts, **39.60**. The cross-section area of the AHU and ducts depends on the air speed for a given volume flow rate, and can be calculated from:

$$csa = \text{volume flow rate}/\text{air speed} \quad (28)$$

where csa is the cross-sectional area in m².

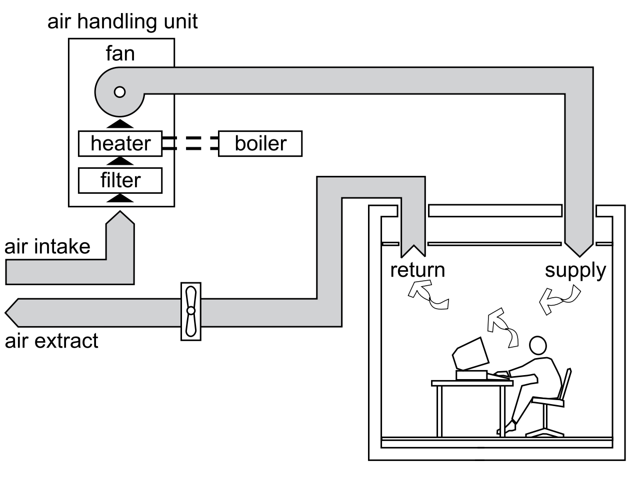
The velocity through the AHV would typically be 2 m/s. The velocity through the main riser ducts may vary from 3 m/s (low velocity) to 7 m/s (medium velocity).

8.19 Fan power

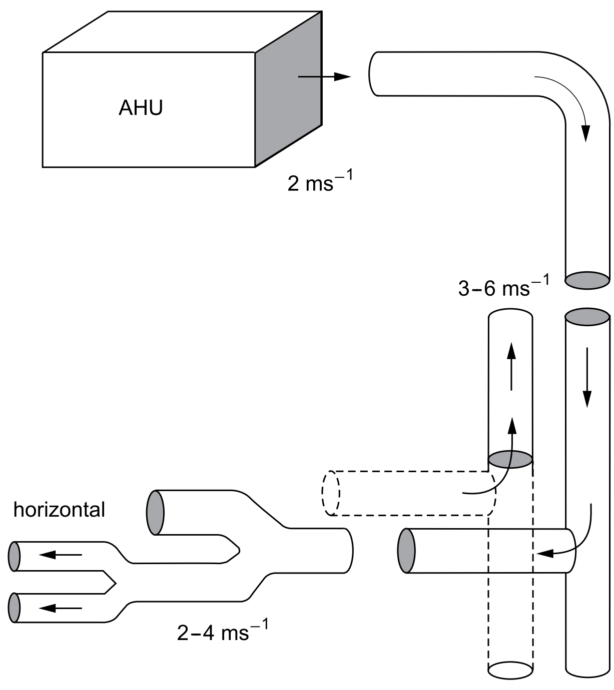
The fan power required to supply the air through the ducted system depends on the volume flow rate and the pressure drop in the system, which are related to the air speed. For an energy-efficient mechanical ventilation system with low duct velocity, the *specific fan power* could be less than 2 kW/m³ of air supply.

8.20 Heat-recovery systems

An advantage of mechanical ventilation is that it can use heat recovery. This can be applied at all scales of building from domestic to large-scale commercial. It is especially appropriate to maintaining energy efficiency in full fresh-air systems. Heat recovery is only worth while if the recovered heat is useful and is greater than the energy used due to the increase in fan power from the increase pressure drop of the heat-recovery equipment. Table XXXV lists



39.59 *Components of one type of balanced supply and extract mechanical ventilation system*



39.60 *Ducted air distribution system indicating velocity ranges*

Table XXXV Heat recovery systems and typical efficiencies

Heat recovery system	Efficiency %
Plate heat exchangers	40 and 60
Thermal wheels	79–82
Run-around coils	45 and 60
Double accumulators	85–95

the efficiency ranges of heat-recovery systems. Heat recovery systems should have a by-pass option to reduce fan power when heat recovery is not needed.

8.21 Air cooling systems

Some buildings require cooling in addition to what can be achieved from ventilation alone. Such buildings may have a high internal heat gain, where mechanical ventilation will not provide sufficient cooling, especially during warm weather. The building itself may be located in a hot climate, where air-conditioning with cooling and humidity control is necessary. Cooling of air is achieved by passing the air over cooling coils in the AHU.

8.22 Heat gains

The main reason for mechanical cooling is in response to heat gains from people, office machinery, lighting, solar gains and high external air temperatures. Solar gains have been discussed in **4.02**. Internal gains from lighting and machines can be high (Table XXXVI), but they are often overestimated, which can result in over capacity of the system design. Wherever possible internal heat gains should be minimised by specifying low energy lighting and other electrical equipment.

Table XXXVI Internal heat gains for a typical office

Factor	Heat gain (W/m^2)
People	10
Equipment (computers, copiers, etc.)	15–25
Lighting	10–25
TOTAL	35–60

8.23 Room air delivery

Chilled air can be delivered to the space, either in a mixing mode or a displacement mode.

8.24 Mixing mode of air delivery

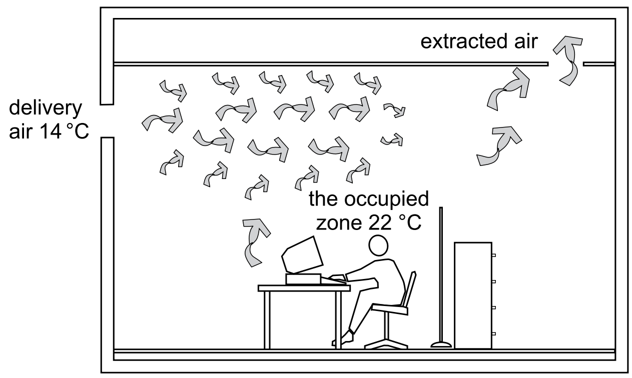
The air supplied to the space is typically about 13°C at the design cooling load. The air is jetted into the space such that it mixes with air already in the space by entrainment and when the air enters the occupied zone it is at the appropriate temperature, speed and RH for comfort, **39.61**. Air may be supplied from the perimeter, the ceiling or even the floor.

8.25 Coanda effect

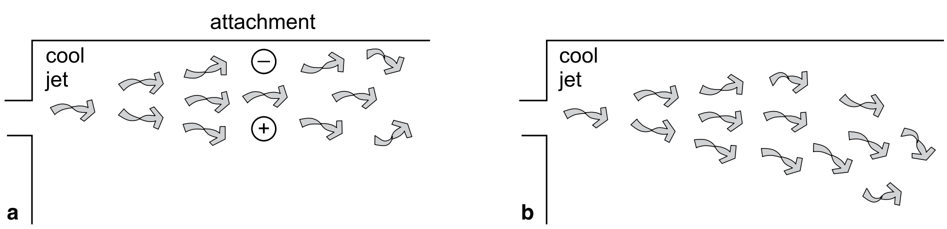
Ceiling systems often rely on the *coanda effect*, **39.62a**, to ensure that the cool supply air remains at high level ('sticks' to the ceiling) until it is mixed. The coanda effect does not work at low jet velocities and the jet becomes 'unstuck' and can cause cold air 'dumping', **39.62b**.

8.26 Displacement air delivery

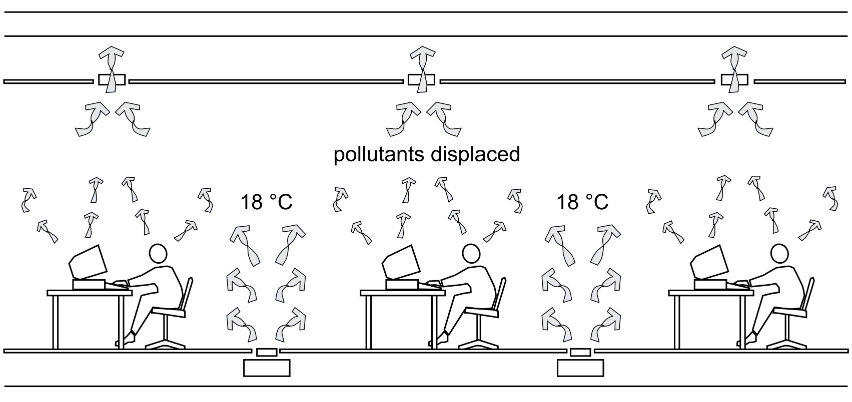
Air is supplied to the space at a low velocity such that it displaces the air already in the space towards the ceiling extract, **39.63**. Air is usually supplied at the floor or through low-level diffusers.



39.61 *Mixing mode of air delivery*



39.62 *Coanda effect*



39.63 *Air displacement system*

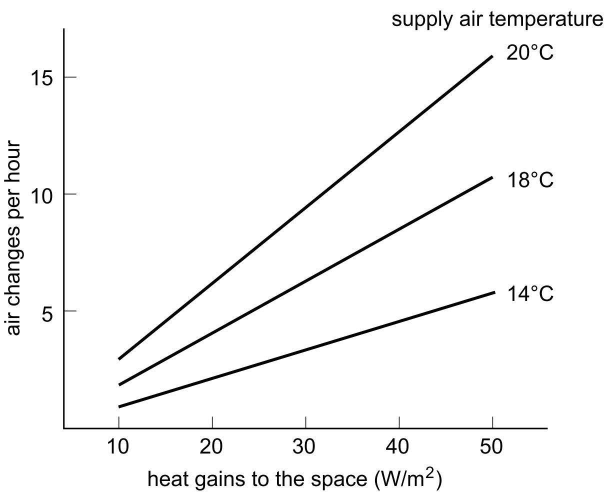
However, some floor systems, that use *swirl* diffusers, are assumed to be displacement but are really mixing systems. The temperature of the air supply for these systems is usually above 18°C to avoid draughts.

8.27 Air supply

The temperature and volume flow rate of the supply air will often determine the type of system used. Displacement systems should have air delivery temperatures greater than 18°C or they are likely to cause cool draughts. So if low-temperature supply is needed to deal with a high heat load, then mixing systems are usually more suitable. **39.64** shows the relationship between air supply temperature, volume flow and internal heat gains.

8.28 Central air-conditioning systems

39.65 illustrates a typical central air-conditioning system layout. Such systems may supply air with a variable air volume (VAV) or a constant air volume (CAV).



39.64 *Relation between volume flow, supply air temperature and cooling load*

8.29 Variable air volume (VAV)

In this system the volume of air is controlled in response to the cooling load. As the cooling load is reduced the volume of air is also reduced until a minimum air supply is reached, after which the supply air temperature is increased.

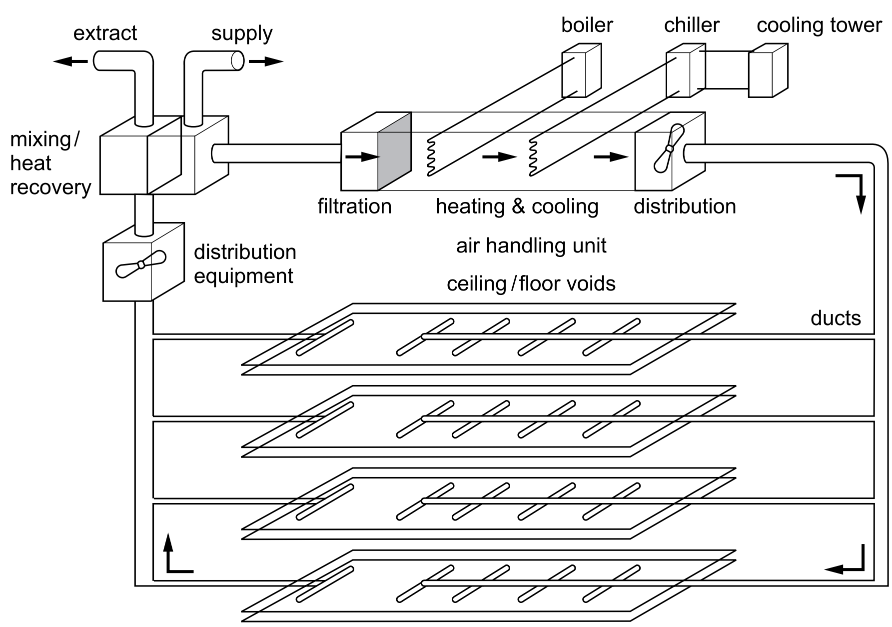
8.30 Constant air volume (CAV)

With this the air is supplied at a constant volume and the temperature of the air is varied in response to the space cooling or heating load.

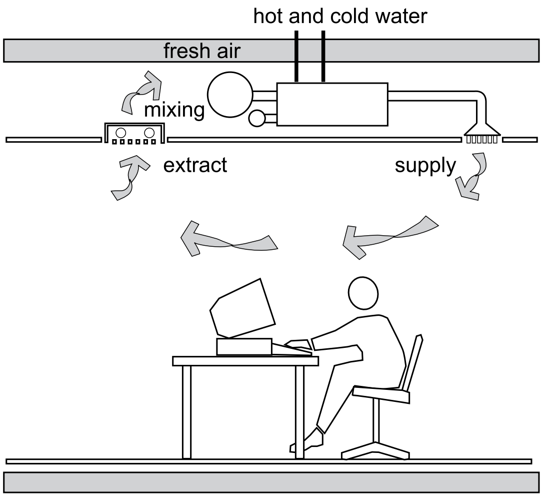
8.31 Localised systems are usually either fan coil units or heat pump units. They can be located around the perimeter of a space or in the ceiling void, **39.66**. A space may have multiple units, or one unit may supply a single floor. They usually take air from the space and heat or cool it as demanded. Ventilation air can either be supplied directly to the unit from outside or be ducted separately from a central unit which only supplies ventilation air requirements and not heating and cooling requirements. Fan coil units are served by hot and cold water systems that supply the main heating and cooling load.

8.32 Chilled surface cooling systems

Passive cooling is achieved by means of introducing chilled surfaces in a room, which could be naturally chilled, for example using night ventilation, or actively chilled, by water or air, **39.67**. These surfaces absorb heat from the air in the space by convection/conduction and radiative heat exchange from warmer surfaces, including people. Chilled surface cooling devices can be in the form of fins, panels or beams. Sometimes the whole surface is cooled or heated, for example through passing water or air through the concrete floor slab and exposing the slab soffit to the room. In cooling mode, surface temperatures vary from typically 17°C for panels or beams to 20°C for chilled ceilings, with respective cooling loads of typically 70(+)W/m^2 down to 30 W/m^2. To avoid the risk of condensate forming on the chilled surfaces in situations of high relative humidity, sensors can be incorporated into the design to raise the surface temperatures. Alternatively, if mechanical ventilation is used the ventilation air can be dehumidified at the AHU. Air leakage through the façade should be minimised to avoid uncontrolled moist air entering the space. Chilled surface cooling systems can be combined with displacement ventilation, **39.68**.



39.65 *Layout of a central air conditioning system*



39.66 *Ceiling fan coil system*

8.33 Refrigeration

Cooling systems require some form of refrigeration equipment in order to extract heat from the cooling fluid that flows in the cooling coils in the air handling unit, or in the passive cooling system. A standard heat pump circuit is shown in **39.69** and an absorption circuit in **39.70**.

8.34 Ground cooling

Ground cooling can be used for an air based ventilation cooling system by passing the supply air through pipes buried in the ground. The ground temperature at depths of 2 m or more remains fairly constant throughout the year. The amount of cooling obtained depends on the volume supply rate and the exposed contact surface area of the pipes. Alternatively air may be passed through a labyrinth of tunnels which have a high thermal mass in order to pre-cool it. In any system the heat absorbed by the mass must be extracted through night ventilation or natural seasonal effects. During the heating season the supply air may also be pre-heated through the same system, when the external air temperature is lower than the ground or labyrinth surface temperature.

8.35 Hybrid systems

Hybrid, or mixed-mode, systems combine mechanical and natural ventilation in either a spatial or a seasonal mix. Seasonal hybrid buildings may be naturally ventilated in summer and mechanically ventilated in winter. Spatial hybrid buildings may have spaces that are both naturally ventilated (say, at the perimeter) and mechanically ventilated (say, in the depth of space).

8.36 Space for services

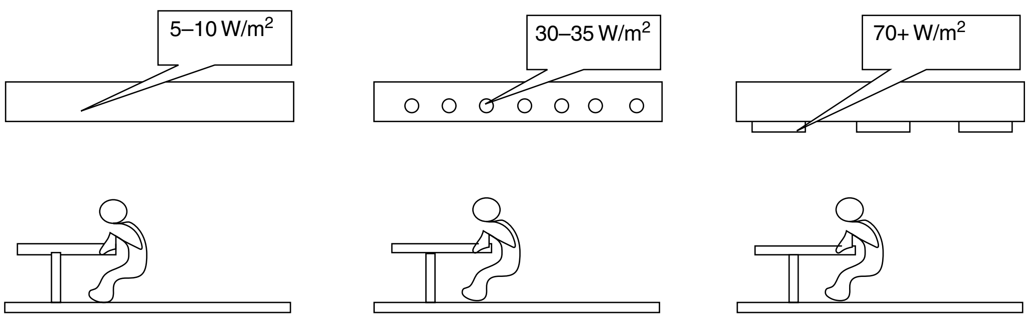
The space requirements for the location of mechanical services and their distribution systems can be considerable: typically 2–15% depending on building type, and must be considered early in the design process (Table XXXVII).

8.37 Zero carbon buildings

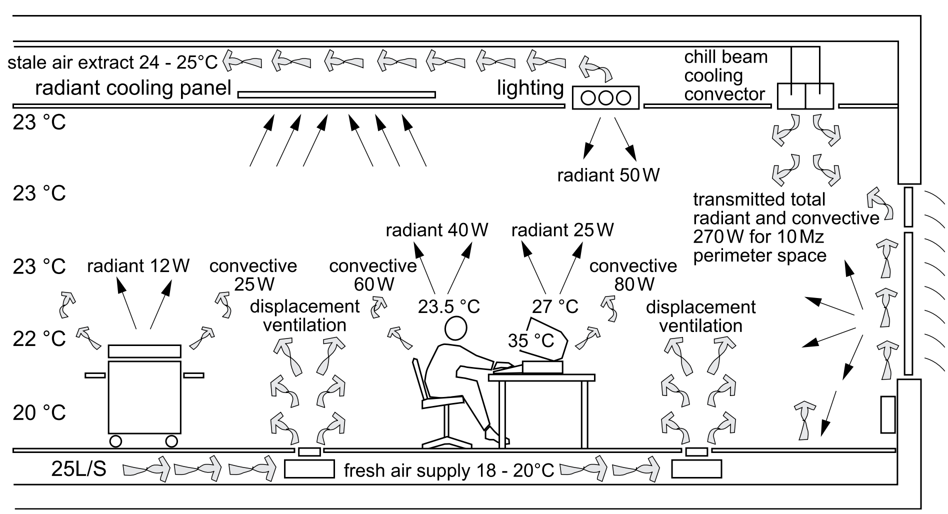
Zero carbon buildings combine a reduced energy demand for heating, cooling, ventilation, lighting, cooking and electrical appliance load, with the use of renewable energy sources, such as solar

Table XXXVII Typical space requirements for different systems for an office building as a percentage of total floor space

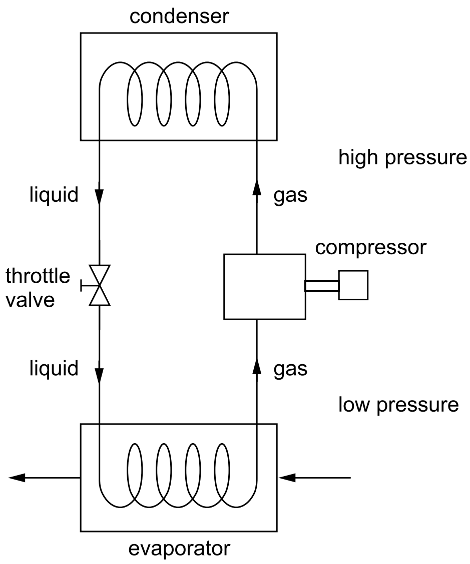
	Natural ventilation	Mechanical ventilation	Air conditioning
AHUs	–	2	4
Boilers	1.5	1.5	1.5
Chillers	–	–	2
Total	1.5	3.5	7.5



39.67 *Chilled surface cooling system and their approximate cooling capacities*



39.68 *Passive cooling systems (chilled beams or panels) can be combined with displacement ventilation*



39.69 *Diagrammatic heat pump circuit. The refrigerant is in a liquid state as it enters the evaporator where it absorbs heat and changes state to gas. It is compressed to a hot gas and enters the condenser where it gives out heat and returns to liquid state. In reverse operation it can be used to cool*

thermal, solar PV, wind and biomass. An optimum balance of demand reduction and renewable energy supply is needed and this may differ for different building types and location. This definition of zero carbon only addresses the operating energy of the building. Other definitions might include the use of renewable energy through the lifetime of the building to offset the embodied energy incorporated in the building construction, or even to offset some lifestyle energy uses, such as transport, food and consumer goods. All definitions of zero carbon buildings imply:

- Energy demand reduction through reduced internal loads and passive design
- Renewable energy systems, building integrated or community based
- Energy storage either through local or grid systems (e.g. 2-way flows).

9 PREDICTION AND MEASUREMENT

9.01

There are a number of prediction and measurement techniques now available that the designer can use to help achieve a good thermal design. Prediction techniques can be used during the design to inform the design process. Measurement techniques can be applied after construction, during the 'hand-over' period, in order to check the thermal design performance. Some of the more common techniques are introduced below.

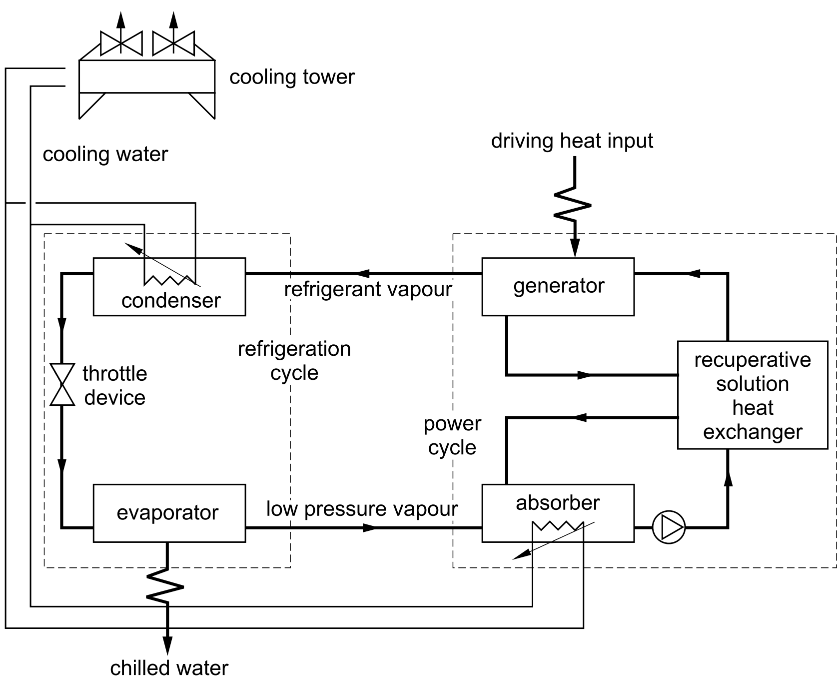
9.02 Building energy models

Computational dynamic building energy models can be used to predict the time-varying thermal performance of a building. They are able to predict the dynamic performance of a building and can account for the thermal capacity of the structure as well as time-varying response to internal heat gains and solar radiation **39.71**. They will predict on a regular time interval (usually hourly) the following parameters:

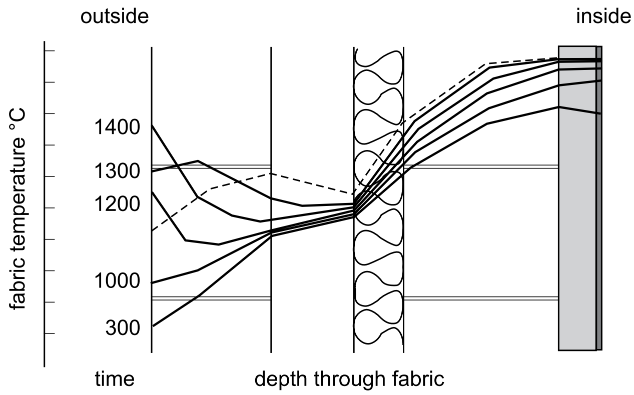
- Internal air temperature
- Internal surface temperatures (including those from chilled surface cooling systems)
- Temperatures and heat flows within constructions (e.g. in relation to thermal mass effects)
- Internal relative humidity
- Energy used for space heating or cooling and
- Temperature profiles through the construction (including glazed facades)

These values can be predicted for each space in the building over any time period (e.g. day, week, year). The models require the following input data:

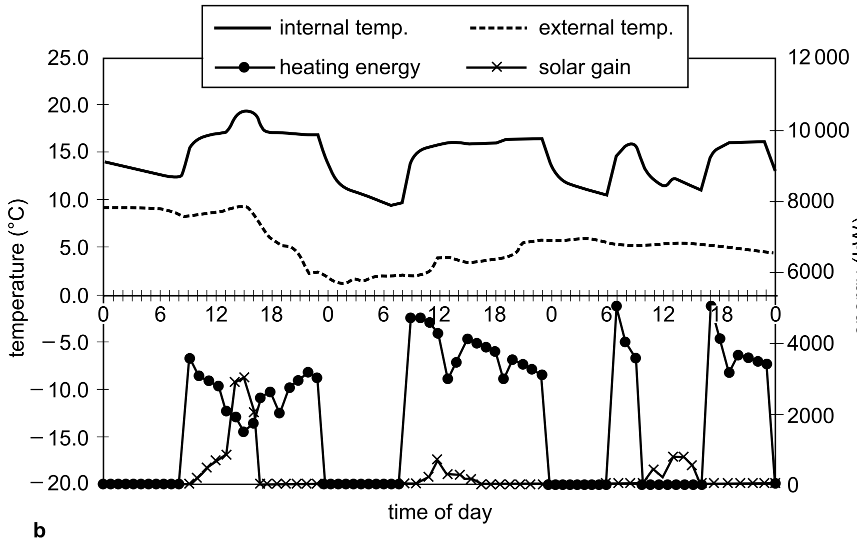
- Meterological data: temperature, solar, wind. This is available in standard *test reference year* (*TRY*) format for various sites
- Construction data: *k*-values, density, specific heat capacity, and dimensions for materials used
- Building geometry: areas and locations of walls, floors, etc.
- Occupancy patterns: hours of use, energy use, activities and
- Heating, ventilating and cooling operation: times of use, system and control details.



39.70 *Schematic diagram of an absorption cooling system. Refrigerant vaporised in the generator passes to the condenser where it rejects heat and condenses. Its pressure (and temperature) is then reduced by a throttling device before it enters the evaporator, here it absorbs heat from the chilled water circuit and becomes a low-pressure vapour. It then returns to the absorber*

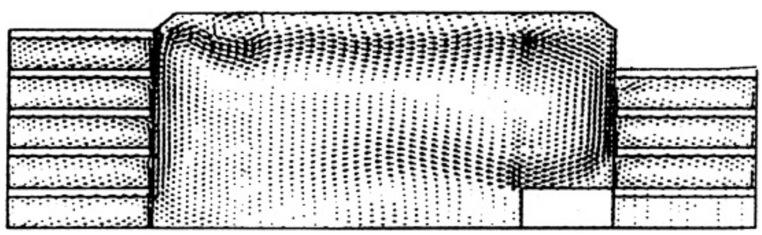


a



b

39.71 *Example of the results of the building energy model HTB2:* **a** *Predicting the temperature profile through a wall over time;* **b** *Forecasting the internal air temperature and energy use as they vary with external temperature and solar gain over a three-day period*



39.72 *Example of the use of computational fluid dynamics (CFD) to predict air movement in an atrium atrium*

9.03 Ventilation and airflow models

Network models

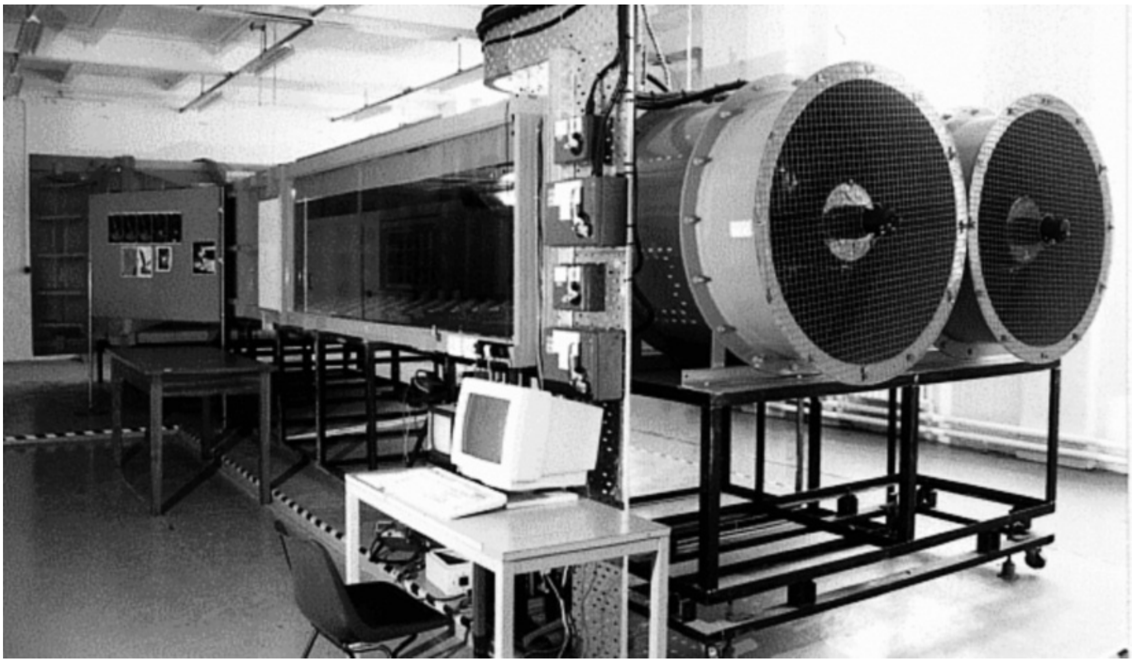
Network or *zonal* models can be used to calculate the flow of air between one or more zones in a building and between the spaces and outside. They are computer based and calculate the flows between pressure nodes both within and outside the building. Their main advantage is that they can be used to calculate inter-zone flows and therefore air change rates, ventilation heat transfer and the transfer of contaminants. They can be used to study new building forms, can handle a wide range of opening and crack types and can predict the interaction of buoyancy and wind-driven effects.

Computational fluid dynamics (CFD) models

CFD can be used to predict the internal airflow and heat distribution, driven by the combination of the external forces of wind and stack and the internal forces from buoyancy (warm or cold surfaces) and momentum (airjets) sources, **39.72**. It can also be used to predict the ventilation rate and the dispersal of a pollutant through the space or smoke movement in the event of a fire. CFD can be used to predict the external wind flow around a building and the resulting pressure field from which the pressure coefficients (C_p) can be calculated. It is therefore an extremely versatile and useful technique in the field of ventilation and air quality prediction. It is, however, highly complex and requires a high level of skill and understanding of ventilation design, building physics and computational numerical techniques in order to obtain credible solutions. However, models are becoming easier to use by the non-specialist and the need to use such models in ventilation design will eventually result in their widespread use.

Wind tunnel modelling

A physical model of a building and its surroundings can be constructed and placed in a wind tunnel, **39.73**, where it is subjected to



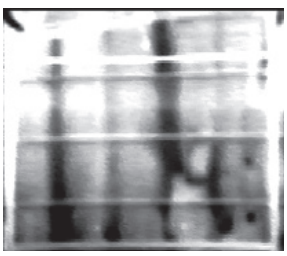
39.73 *Boundary layer wind tunnel and model at the Welsh School of Architecture used for measuring C_{ps}*

a controlled wind flow. Pressure sensor taps can be installed at various points on the building envelope, corresponding to ventilation openings. The pressure at each opening can be measured. This can then be related to the free wind pressure, at a point of known height above the surface, in order to obtain the C_p value as described in Section 4.

9.04 Thermographic surveys

All objects emit heat energy (i.e. infrared radiation), the amount being dependent on the surface temperature and its emissivity. *Thermography* is the term used to describe the process of making this heat energy visible and capable of interpretation. An infrared camera can be used to scan the surfaces of a building and produce a 'live' heat energy picture that can be viewed. The picture appears in colour or greyscale. The differences in colour or tones of grey correspond to differences in surface temperature across the surface being viewed. Surface temperature differences of the order of 0.5°C can be identified. Areas of defective or missing insulation can be detected by identifying locally warm (viewed from the outside) or cool (viewed from the inside) surface areas. If there is air leakage into a building it can produce a locally cooled area on

a



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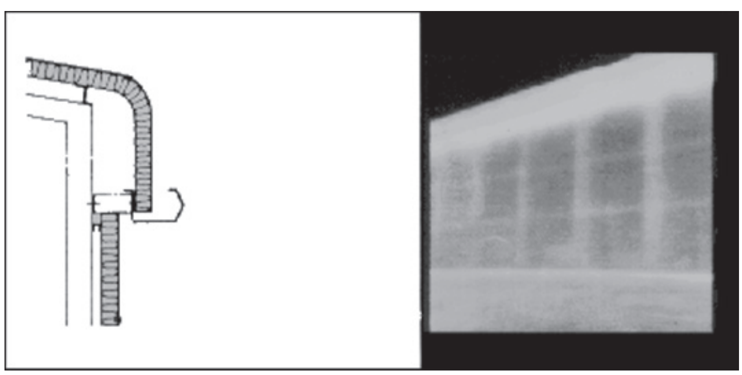

39.74 *Examples of thermographic images:* **a** *Finding missing insulation;* **b** *Showing air leakage when viewed from inside;* **c** *Air leakage viewed from outside* the internal surface which can be detected by the camera. If there is air leakage to the outside this can produce a locally heated area. **39.74** presents some examples of thermographic images.

9.05 *U*-value measurement
The *U*-value of a construction can be estimated from measurements of internal and external surface temperature and heat flux. These measurements need to be carried out over a period of time to minimise the effects of thermal capacity. For lightweight cladding constructions an estimate of the *U*-value can be achieved in about eight hours. In heavyweight masonry construction a period of a week to ten days may be needed. Measurements should be carried out on a north-facing wall or roof to avoid interference from solar gains.

9.06 Air leakage measurements offer a means of assessing the relative airtightness of different buildings by comparison with standard values. The air leakage of a building can be measured by pressurising or depressurising the building using a fan and measuring the volume flow of air needed to maintain a fixed pressure difference between inside and outside.

Table XXXVIII Air leakage standards, for 50Pa Internal/ external pressure difference of 50Pa (from BSRIA)

	$m^3/h/m^2$ @ 50Pa
Domestic	7
Commercial	
Natural ventilation	10
Air conditioning	5
Industrial	15
Stores	5

Air leakage rate standards are normally specified either for whole buildings (in air changes per hour) or in normalised form relating to envelope area (m^3s^{-1} per m^2 of envelope area). Table XXXVIII presents typical design air leakage values.

If there is air leakage into a building it can produce a locally cooled area on the internal surface which can be detected by the camera. If there is air leakage to the outside this can produce a locally heated area.

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40 Light

Joe Lynes

CI/SfB: (63)
UDC: 644.3
Uniclass: U631

Joe Lynes is a consultant

KEY POINTS:
- *Increased emphasis on energy conservation with sophisticated controls*
- *Good maintenance is essential*

Contents

1 A PASSIVE SOLAR RESOURCE

1.01 Siting and orientation

Thermal applications of solar energy have long been recognised. The potential of sunlight, direct and diffused, in saving electrical energy by reducing the demand for artificial lighting, is less obvious. Here early decisions on siting and orientation may be more effective than later decisions on fenestration. Detailed guidance on the strategy of daylighting is contained in Littlefair (1991).

High-rise buildings should ideally be sited to the north, and lowrise or low-density buildings to the south of a new development, taking care not to overshadow existing buildings. Full advantage should be taken of south-facing slopes. Terraced housing should run east-to-west, so that one wall can face south. Detached or semi-detached dwellings can be on north-south link roads. Courtyards should be open to the southern half of the sky. Garages should face north. The pitch of north-facing roofs should be shallow to minimise overshadowing.

1.02 Site planning criteria

The daylight illumination reaching any point depends largely on how much sky is visible from the point in question. The amount of light striking a window (and hence entering a room) on a densely overcast day is roughly proportional to the angle θ, **40.1**, i.e. to the effective angle in degrees subtended in a vertical plane by the sky visible from the centre of the window.

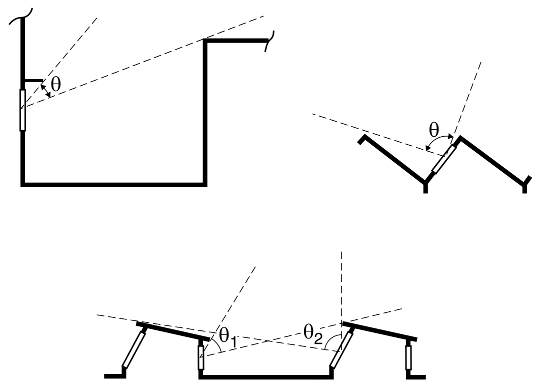
The BRE Report expresses the daylight reaching a vertical wall or window, on a densely overcast day, in terms of the *vertical sky component* SC_v. This is the direct *illuminance* (lux) on the vertical surface, expressed as a percentage of the simultaneous horizontal illuminance under an unobstructed overcast sky. An unobstructed vertical wall would have a vertical sky component of 39 per cent.

An additional check on the penetration of daylight is provided by the *no-sky line*, **40.2**. This is a 'line' (actually a surface in three-dimensional space) which divides a room into two parts: one part is exposed to a view of the sky, the other part receives no direct daylight at all. The latter zone is disadvantaged with regard to both view and natural lighting.

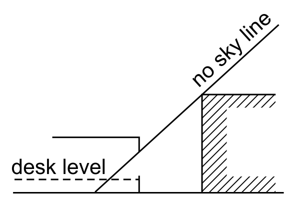
Incident sunlight is expressed in terms of probable sunlight hours. These are the total number of hours per year when the sun would, under typical cloud conditions, shine directly onto a given point. The recommendations in the BRE Report are summarised below in paras **1.03** to **1.07**.

1.03 New developments – daylight potential

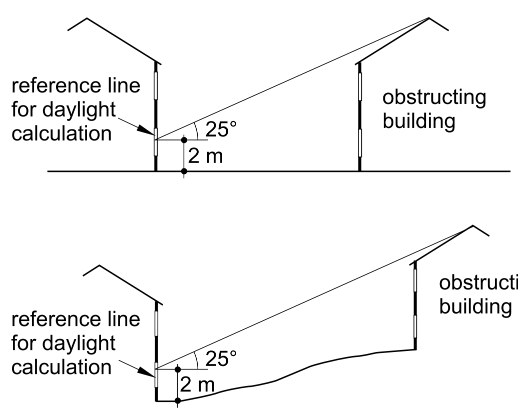
Two alternative checks are recommended to ensure that surrounding obstructions do not unduly detract from the natural lighting in a room. First, from a standard reference height 2 m above ground level, check whether any visible obstruction projects above the 25° horizontal roofline limit, **40.3**. Odd trees may be ignored. If the 25° line is substantially clear of obstruction then a target vertical sky component of at least 27 per cent should be achieved. If this first check fails, the obstruction may still be narrow enough to allow adequate daylight around its sides. To check this, it is necessary to ensure that every point along the standard 2 m reference line is



40.1 θ *is the angle subtended at the window by the visible sky*



40.2 *No sky is directly visible from indoors to the left of the no-sky line*



40.3 *The 25° criterion*

within 4 m (measured sideways) of a point which does have a vertical sky component of 27 per cent or more. The BRE Report contains a *skylight indicator* for estimating vertical sky components on an obstructed site.

1.04 New developments – sunlight potential

In a new dwelling, and in any other new buildings in which sunlight would be desirable, two recommendations for incident sunlight should both be met:

(a) One principal window wall should face within 90° of due south, and
(b) Along this window wall, every point on the standard 2 m reference line should be within 4 m (measured sideways) of a point exposed to at least one quarter of the annual probable hours of sunlight on an open site. These hours of exposure should include at least 5 per cent of probable hours of sunlight in the six winter months between 21 September and 21 March.

The BRE Report contains *sunlight availability indicators* for three latitudes: 51.5°N (London), 53.5°N (Manchester) and 56°N (Glasgow). These can be used for estimating hours of probable sunlight on an obstructed site.

1.05 Existing buildings – daylight protection

If any part of a new building or extension, seen from the lowest window of an existing building, projects above the 25° horizontal reference limit, **40.3**, then two further tests must be applied:

(a) The vertical sky component at the centre of each existing main window must be not less than 27 per cent, and not less than 0.8 times its previous value, and
(b) The area of the *working plane within the no-sky line*, **40.2**, must not be less than 0.8 times its previous value.

The BRE *skylight indicator* is designed for checking vertical sky components.

In some cases, legal rights to light may supplement the BRE recommendations. A right to light may be gained either by legal agreement or if a window has received the light without interruption for 20 years or more. Infringement of a right to light is judged by comparing *sky factor* contours indoors before and after the infringement.

1.06 Existing buildings – sunlight protection

If an existing living room has a main window facing within 90° of due south, one of two alternative conditions should be met: either

(a) No part of a new building, seen from the centre of the window and projected onto a vertical plane perpendicular to the window wall, is more than 25° above the horizon, or
(b) The point at the centre of the window, on the indoor plane of the window wall, must be exposed to at least a quarter of annual probable sunlight hours, including at least 5 per cent of annual probable sunlight hours in the six winter months between 21 September and 21 March, and not less than 0.8 times its previous sunlight hours in either period.

1.07 Adjoining development land

For a building to be a 'good neighbour', it should stand well back from the plot boundary to avoid unduly restricting well-daylit development on adjoining properties. A neighbouring site will have acceptable daylight protection if, along each common boundary line, one of the following alternative criteria is met: either.

(a) No new building, seen from a point 2 m above ground level and projected onto a vertical plane perpendicular to the boundary, is more than 43° above the horizon, or
(b) Every point 2 m above the boundary line should lie within 4 m (measured along the boundary) of a point which has a vertical sky component (facing the new obstruction) of 17 per cent or more.

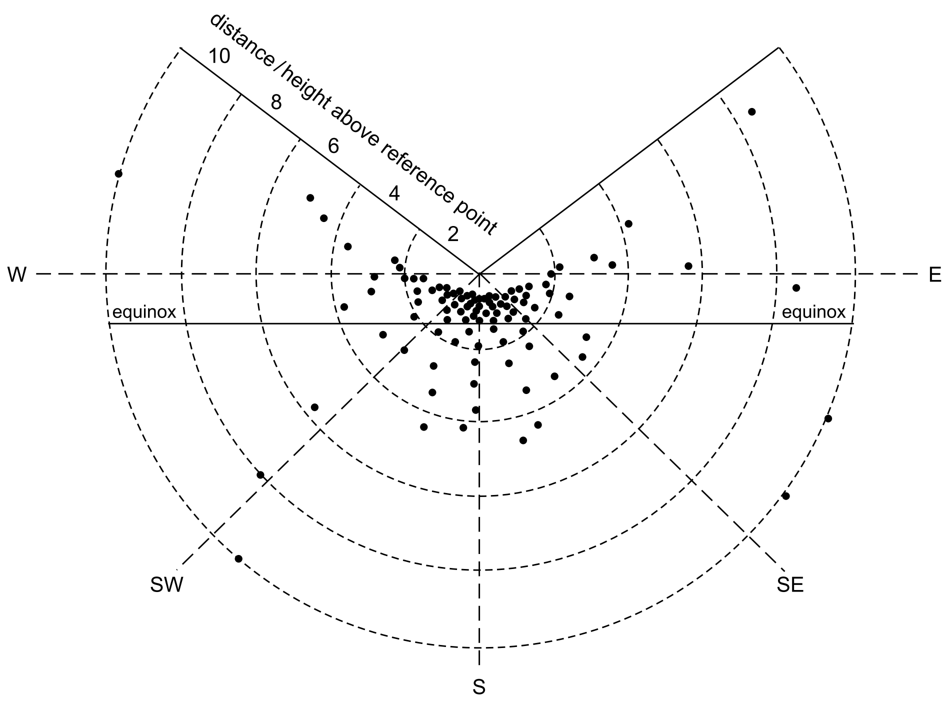
Note: There is no protection for sunlight (or view), as distinct from daylight, along boundaries.

1.08 BRE site planning aids

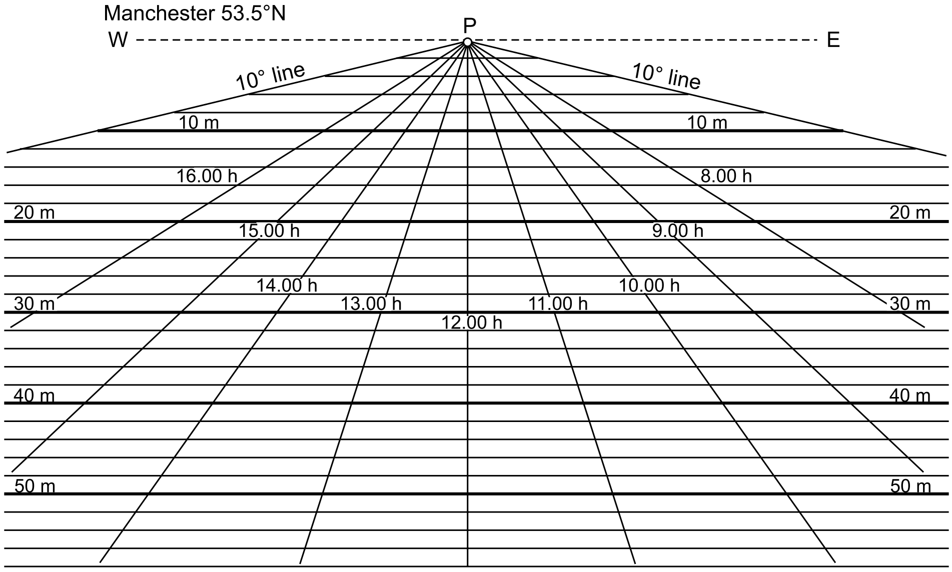
The Building Research Establishment has issued a number of indicators to assist designers in meeting their site planning recommendations:

- *Skylight indicator,* **40.3**
- *Sunlight availability indicator*, **40.4**
- *Sun-on-ground indicator*, **40.5**
- *Sunpath indicator*, **40.6**
- *Solar gain indicator*, **40.7**

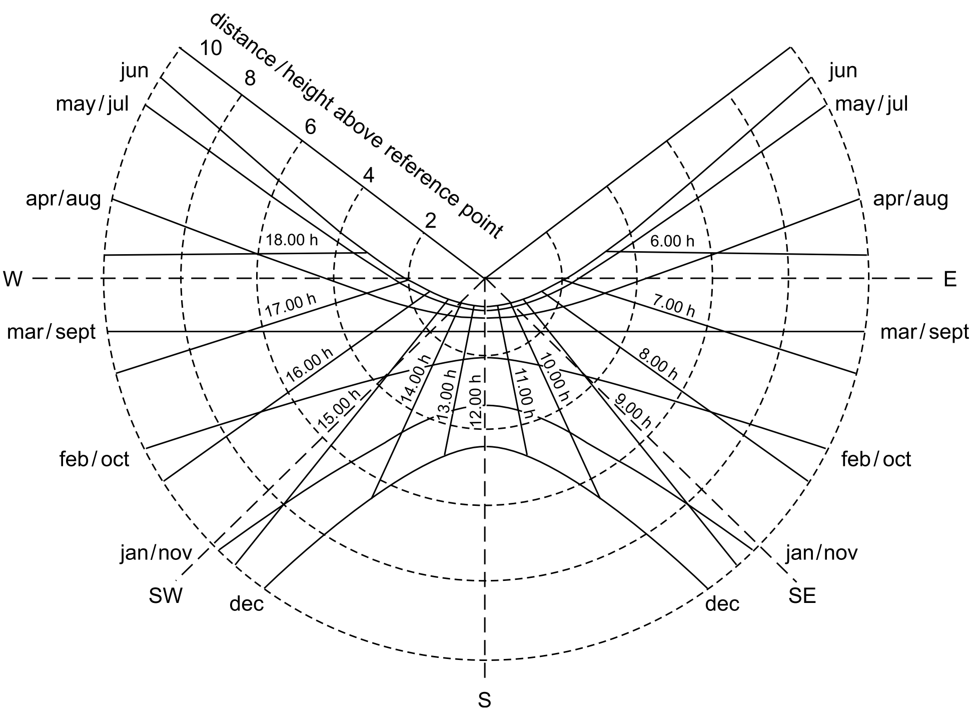
Table I summarises the BRE criteria, indicating which planning aid is applicable to each criterion.



40.4 *Sunlight availability indicator for latitude 53.5°N. The annual total of unobstructed hours of probable sunlight would be 1392 hours*



40.5 *Sun on ground indicator for 21 March, latitude 53.5°N*



40.6 *Sunpath indicator for latitude 53.5°N*

1.09 Solar geometry

The sun's apparent position in the sky is specified in terms of two angular coordinates:

- The *altitude* γ in degrees above the horizon
- The *azimuth* α in degrees clockwise in plan, measured from due north

These coordinates are given by the equations:

$\gamma = \arcsin(\sin\phi \sin\delta - \cos\phi \cos\delta \cos 15t)$ equation (1)

$\alpha = \arccos[(\sin\delta - \sin\phi \sin\gamma)/(\cos\phi \cos\gamma)]$ equation (2)

where

ϕ = geographical latitude of site (positive in the northern hemisphere)

δ = *solar declination* (north is positive, south negative)

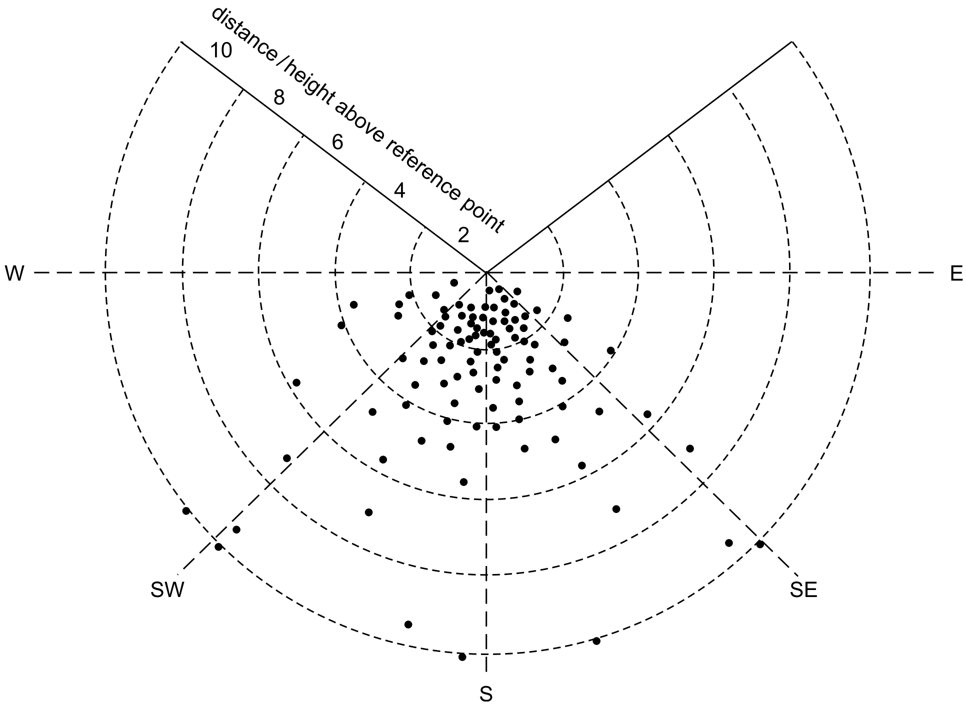
t = hours since midnight (note that the term $15t$ is in degrees)

The *altitude* of the sun at noon is $(90° - \phi - \delta)$.

1.10 Sunlight – the use of models

A simple block model is adequate for most studies of solar penetration. It can be illuminated by a pearl household lamp located as far from the model as possible to ensure near-parallel 'sunlight'. Better still, in conjunction with the matchbox sundial, one can use the real sun outdoors as a light source. The relative positions of source and model are so arranged that the direction of the incident light will replicate the direction of the sun's rays at the time and season under investigation.

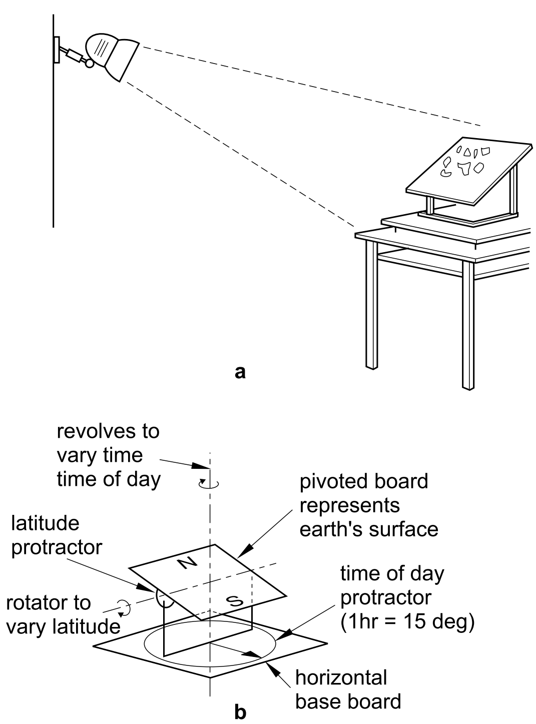
One way of bringing the correct angles of sunlight to bear on the model is to mount it on a *heliodon*, **40.8**. A simple turntable carries a platform which is tilted so as to be parallel to the earth's surface at the relevant latitude, ground at the north pole usually being taken as horizontal. The artificial sun is moved above or below this horizontal datum plane, depending on the season; it may slide up and down a vertical scale, **40.9**, whose solstice-to-solstice height subtends 23.4° at the centre of the tilted heliodon platform. The



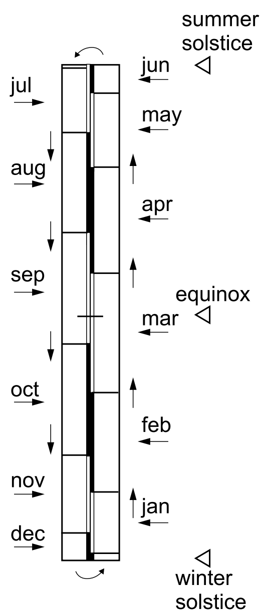
40.7 *Solar gain indicator for latitude 53.5°N. Solar radiation on unobstructed south-facing window = 322 kWh/m² during the heating season*

Table I Solar declination

Date	Solar declination
22 June	23.4°N (Summer solstice)
21 May/24 July	20°N
26 April/28 Aug.	10°N
21 March/23 Sept.	0° (Equinox)
23 Feb./20 Oct.	10°S
21 Jan./22 Nov.	20°S
22 Dec.	23.4°S (Winter solstice)



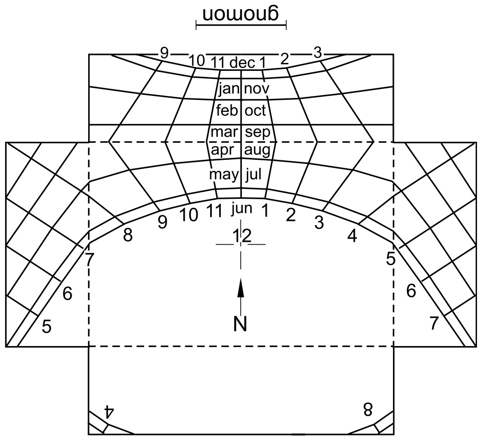
40.8 *The heliodon:* **a** *In use;* **b** *Explanatory diagram*



40.9 *Graduated season scale for heliodon. A lamp slides up and down this scale to simulate the sun's position month by month*

centre of the vertical scale should be level with the platform. The earth's daily rotation is simulated by spinning the tilted platform so that the movement of shadows throughout a chosen day can be observed.

The matchbox sundial, **40.10**, has been described as the beggar's heliodon. It comprises a stick (the 'gnomon') standing in a folded tray which fits inside a matchbox. A grid of lines on the tray traces the the position of the shadow of the tip of the gnomon at different hours and seasons. The seven monthly shadow orbits correspond to the dates and *solar declinations* shown in Table I. The matchbox sundial illustrated is suitable only for latitude 53.5°N. To use it elsewhere, tilt it about an east-west axis through an angle equal to the difference in latitude, shadows being shorter as you approach the equator.



40.10 *Matchbox' sundial for latitude 53.5°N*

Align the north point on the sundial with the north point of the model. Shine a distant lamp on the sundial, casting the shadow of the gnomon at the month and time of day under consideration. The pattern of sunlight and shadow should be correct on the model. Ideally this is a three-person activity. The first person – the tallest! – holds the lamp as far from the model as possible. The second watches the sundial and directs the first accordingly. The third takes photographs – always from due north in the northern hemisphere, otherwise the shadow of the photographer, camera and tripod will appear in the photograph. Remember to include in each photograph a card to show the time and date under investigation. Otherwise you may not be sure afterwards which photograph is which!

The alternative 'aviator method' avoids the need for colleagues, and for plunging your environment into darkness, but there are no photographs to show for it. This approach depends on the fact that the sun never 'sees' a shadow. Solar shadows are cast only on surfaces hidden from direct sunlight. Place a matchbox sundial, correctly orientated, beside a model. Align your eye with the tip of the gnomon, and with the chosen time and date marks. Those parts of the model which you can see from that position will be sunlit at the chosen time. Those parts which are concealed will be in shadow. The aviator method also works with a heliodon if you place your eye in the position of the 'sun'.

Model studies are useful for three types of sunlight investigation:

1 Seeing how far direct sunlight can penetrate inside a modelled room, and how effectively it is controlled by sunbreaks.
2 Seeing how adjacent buildings intercept each others' sunlight.
3 Measuring the sunlight illumination received indoors after reflection from the ground and from nearby sunlit buildings; this is applicable to dry tropical areas, not to the UK.

2 DAYLIGHT INDOORS

2.01 Daylight factors

Daylight design in the UK has traditionally been based on the convention of a Standard Overcast Sky for three reasons:

(a) Prudence: if the natural lighting is sufficient on an overcast day it is likely to be more than adequate when the sun shines.
(b) Convenience: a densely overcast sky looks the same whichever direction (in plan) one faces – north, south, east or west. The effect of orientation vanishes from the calculation but not, one hopes, from the designer's awareness!
(c) Given the overall brightness profile of a Standard Overcast Sky, the *illuminance* at any given point indoors must be directly proportional to the simultaneous outdoor illuminance under the unobstructed overcast sky vault, whether the sky itself is bright or dull.

The constant ratio of indoor to unobstructed outdoor illuminance is usually expressed as a percentage, and is referred to as the *daylight factor.* Thus the daylight factor at a given point may be defined as the *illuminance* (lux) at that point, expressed as a percentage of the simultaneous horizontal illuminance under an unobstructed overcast sky.

Until recently it was customary to specify natural lighting levels in terms of the minimum daylight factor in a given interior. This involved a painstaking calculation at the end of which there was little assurance that people's impression of daylit spaces would actually correlate with the minimum daylight factors. The current trend is to express the natural lighting of a room in terms of the average (as distinct from the minimum) daylight factor. This requires only a back-of-the-envelope calculation (see para **2.03** below), and yields, for each room, a single figure which characterises the daylight level.

Limitations of the average daylight factor must not be overlooked. In a medium-sized room we can usually form a unitary impression of the daylighting: we sum it up as 'bright', 'adequate', 'dim', etc. as the case may be. But in a deeper side-lit space our impression is more complex; one side of a room may look bright, the other side dim by comparison. To interpret an average daylight factor with discernment we need to know at what point the concept will break down.

Broadly speaking, a side-lit room is too deep – or the daylighting unbalanced – when either the *no-sky line*, **40.2**, cuts off a substantial area of the working plane, and/or

when $l/w + l/h > 2(1 - R_b)$ equation (3)

where l = depth of room from window to back wall
w = width of room measured across the window wall
h = height of window head above floor
R_b = area-weighted average *reflectance* in back half of room

Unless the average daylight factor has been ruled out by one of the above considerations, it may be quoted with confidence to characterise the daylit appearance of a room. Thus an average daylight factor greater than 5 per cent will generally give the impression of generous daylighting (except, of course, on a dull day or in the evening), while an average below 2 per cent would be judged gloomy; electric lighting would be switched on as soon as an occupant entered.

2.02 The use of models

Scale model rooms have often been used for the prediction of daylight factors. The basic laws of illumination (the additivity, inverse square and cosine laws) dictate that daylight factors in a perfectly scaled model must agree with those in the full-scale building. Unfortunately immediate application of this principle is fraught with pitfalls for the unwary.

Architectural models commissioned for other purposes are unlikely to be suitable. Joints and corners must be perfectly light-tight. Walls must be opaque: balsa and white card are out. Surface colours, and especially *reflectances*, must be correctly simulated. Glass *transmittance* must also be correct or, failing that, must be offset by applying a correction factor to the end result. Outdoor obstructions must be properly scaled, at least with regard to angular subtense, and also finished appropriately. Finally the measured daylight factor must be adjusted to take account of dirt on the glass and on room surfaces, and to allow for any curtains or glazing bars, and for absorption of light by furniture and other impediments.

In principle the daylight factor inside a model can be obtained by measuring the indoor illuminance at some chosen position with a lightmeter, and expressing it as a percentage of the illuminance on the roof of the model. This assumes that the roof is exposed to the whole sky vault; otherwise it will be necessary to take directional readings of sky brightness. It assumes too that the sky is densely overcast; this requirement follows from the definition of a *daylight factor*.

The necessity of waiting for overcast conditions to occur unaccompanied by rain, snow or gusty winds has led, logically enough, to the development of artificial skies, providing a Standard Overcast brightness profile at the flick of a switch. These too have their pitfalls. Mirror-box skies produce multiple reflections of the model at horizon level. Those too small to accommodate a model inside will be unsuitable for testing rooflights. Sky domes suffer from parallax and horizon errors unless they are very large compared with the model under test.

Since most of the potential errors would cause daylight measurements in models to be overestimated, one can anticipate that, unless exceptional precautions are taken, the measured daylight factors will considerably exceed those in the real building. This need not discourage the use of models. Indeed one may wonder why a designer should bother with daylight factors when he or she can judge and fine-tune the daylit appearance of his or her model by eye. The best advice must be to formulate in advance the questions – they may be qualitative rather than numerical which the model study is designed to answer. Analysis of these key questions may well reveal that specific daylight factors are unimportant, and that more may be learned by studying a model under real sky conditions, facing alternately towards and away from the sun, than by leaving the overcast sky convention to dictate a programme of expensive measurements which may turn out to be irrelevant.

2.03 Calculating the average daylight factor

The average daylight factor df is given by the following equation:

$$df = (T \times W \times \theta \times M)/[A(1 - R^2)] \text{ per cent} \qquad \text{equation (4)}$$

where T = transmittance of glazing material (clear single glazing = 0.85; clear double glazing = 0.75)
W = net area of glazing material
θ = vertical angle of sky seen from centre of window, **40.1**
M = maintenance factor, Table II
A = total area of interior surfaces: floor + ceiling + walls, including windows
R = area-weighted average reflectance of interior surfaces

2.04 Shaping a window

Increasingly the prime function of a window is as much to provide a view as to illuminate the interior. In principle the analysis of view presents no great problem. A straight line can be drawn from the eye of an occupant to an object of regard outside the building. If the straight line passes through a window opening, in both plan and section, then the object will be visible; if not it may be necessary to alter the shape or position of the window.

Table II Maintenance factors for natural lighting (from BS 8206 Part 2 and the CIBSE Window Design (Guide)

Location of building	Inclination of glazing	Non-industrial or clean industrial work	Dirty industrial work
Non-industrial or clean industrial area	Vertical	0.9	0.8
	Sloping	0.8	0.7
	Horizontal	0.7	0.6
Dirty industrial area	Vertical	0.8	0.7
	Sloping	0.7	0.6
	Horizontal	0.6	0.5

In practice, occupants move around, and the indoor end of the straight line moves with them; usually a good view from the back of a room is harder to accommodate than a view from just inside a window. The choice of desirable objects of regard is usually easier in reality than in theory; but it is a choice that needs to be made consciously and deliberately if the window is to be optimised.

The skyline plays a key role. Ideally the view of the skyline should not be interrupted by the window head. Should this be impracticable, some direct view of the sky remains desirable, if only to reveal the clarity or cloudiness of the sky.

But the need for a view interacts with other aspects of the environment. A direct view of the sky can be a source of discomfort ('glare'), especially if the patch of sky is close to the direction of the sun. On the other hand, the daylight factor at the back of a room depends largely on the amount of sky directly visible, see para **1.02**. Thus there is a potential conflict between the imperatives of view, comfort and uniform daylighting. This conflict can be resolved only by prioritising. The relative importance of the three factors will largely determine the right shape and position for each window.

3 WINDOW DESIGN

3.01 A sequence for window design

We return to equation (4) for the average daylight factor in para **2.03**. Inspection of the expression suggests a natural sequence for window design decisions.

Stage 1

The first item to be fixed in the equation is the angle θ defining the position of exterior obstructions. This depends mainly on the spacing and massing of surrounding buildings. The block layout is effectively fixed quite early in the design process, well before fenestration has been thought about. Access, prospect, privacy, site utilisation and microclimate are some of the formative factors at this stage. Because these will act as constraints on the daylight factor, the determination of the angle θ is identified as the first stage in window design. Some relevant criteria and design aids are listed in Table III.

Stage 2

A side-lit room may be too deep to be satisfactorily daylit. This outcome was discussed in para **2.01** above. It occurs when the no-sky line seriously encroaches on the working plane, or when equation (3) in para **2.03** is true.

If the room is indeed too deep for stand-alone natural lighting, the average daylight factor cannot be a valid design criterion. Instead the windows should be optimised mainly for view and for thermal factors and, if daylight linked controls, as in section **9**, are contemplated, for the dimming and extinction of the row of luminaires closest to the window wall. Unless the room survives the two tests in Stage 2 the designer should proceed straight to Stage 4, omitting Stage 3 of the window design sequence.

Stage 3

The window area W is estimated by inverting equation (4):

$$W = df \times A\ (1 - R^2)/(T \times \theta \times M)$$

At this point there is the usual conflict between visual and thermal considerations. The average daylight factor *df* is proportional to the window area *W*, but so is the winter heat loss through the windows, and so (other things being equal) is the daily mean solar cooling load. Passive solar design, harnessing both daylight and solar gain, will optimise by reducing heat loss through the glazing. Other approaches to design must face and resolve a three-way

Table III BRE criteria and planning aids

Criterion	Where	Standard	Indicator	Short cut	Count
Daylight potential	New-build	Within 4 m of SC_v 27%	Skylight indicator	Clear above 25°	54 crosses
Daylight protection	Existing window	SC_v at window at least 27%	Skylight indicator	Clear above 25°	54 crosses
Daylight protection	Boundary	Within 4 m of SC_v 17%	Skylight indicator	Clear above 43°	34 crosses
Sunlight potential	New-build	1 principal wall within 90° of due south. Within 4 m of exposure to 25% of probable sunlight hours, including at least 5% in winter 6 months.	Sunlight availability indicator		25 and 5 dots
Sunlight protection	Existing window	25% of probable sunlight hours, including at least 5% in winter 6 months.	Sunlight availability indicator	Clear above 25°	25 and 5 dots
Sunlight protection	Open space	Not more than 2 fifths totally shaded at equinoxes.	Sun-on-ground indicator		Area shaded
Planning for sunlight			Sunpath indicator		
Passive solar gains	Passive solar buildings	Optimise, and watch summer overheating	Solar gain indicator		Each dot is 1% of available kWh

conflict. It is important to reconcile these pressures on the window area at this stage, before proceeding to Stage 4 which is concerned with optimising window shape and position for a given window area.

Stage 4

By this stage either the window area is established and the average daylight factor settled in Stage 3 or the room has been identified in Stage 2 as too deep for stand-alone natural lighting. In either case the shape and position of the windows have yet to be finalised, but the completion of the design is obviously simplified by the prior decisions in Stages 2 and 3.

The competing claims of view, visual comfort and daylight uniformity were reviewed in para **2.04** above. They centred on the visibility of the skyline. The avoidance of glare required as little visible sky as possible. A good view implied a good sight of the skyline itself but no additional access to the sky. Uniform daylighting mandated as much sky as possible visible from the depths of the room. The conflict must be resolved, in Stage 4 as in Stage 3, by identifying and balancing the relevant priorities.

Also in Stage 4 the possible advantages of multilateral fenestration may merit review. Windows in more than one wall may improve the natural lighting in two respects: by increasing the area of sky seen from the worst-lit parts of the room, and by reducing the brightness contrast between the sky and the window walls. In a naturally ventilated building they will also promote cross-ventilation, mitigating summertime overheating.

Applicability

Obviously the above idealised sequence is remote from the reality of window design. The results of applying it slavishly window-by-window would be a chaotic elevation, maybe unbuildable. A design sequence should provide a safety-net for an architect in trouble. He or she can retrace his or her steps and recognise false turns if need be. The key to good daylighting design is to identify significant crunch points: What is the most important or the most demanding room on a given facade? Design its windows properly. Propagate variants of the solution up and down the elevation. Then the windows will do their job, both as external visual elements and as components of the interior environment.

4 ELECTRIC LAMPS

4.01 Approved Document L

Approved Document L of the Building Regulations (of which there are two parts – one for dwellings, another for buildings other than dwellings) makes particular reference to lighting. Part L, which covers the conservation of fuel and power and came into effect in April 2006, contains a number of recommendations and requirements concerning the provision of artificial lighting.

4.02 New dwellings

When calculating the ‘‘dwelling CO2 Emission Rate’’ (DER), it should be assumed that the dwelling contains 30% low energy lighting.

Dwellings should be designed to favour low-energy light fittings. Part L describes this in the following way: ‘‘A way of showing compliance would be to provide lighting fittings (including lamp, control gear and an appropriate housing, reflector, shade or diffuser or other device for controlling the output of light) that only take lamps having a luminous efficacy greater than 40 lumens per circuit-Watt. Circuit-Watts means the power consumed in lighting circuits by lamps and their asociated control gear and power factor control equipment. Flourescent and compact flourescent lighting fittings would meet this standard. Lighting fittings for GLS tungsten lamps with bayonet cap or Edison screw bases, or tungsten halogen lamps would not.’’

The regulations also describe ‘‘reasonable provision’’ as fixed energy efficient light fittings that number not less than the greater of:

(a) one per 25 m^2 of dwelling floor area (excluding garages) or part thereof; or
(b) one per four fixed lighting fittings.

(Lighting fittings in less frequented areas like cupboards and other storage areas do not count.)

In terms of external lighting, the regulations specify that ‘reasonable provision’ could comprise:

EITHER: lamp capacity that does not exceed 150 W per light fitting and the lighting automatically switches off when there is enough daylight and when it is not required at night;

OR: the lighting fittings have sockets that can be used only with lamps having an efficacy greater than 40 lumens per circuit-Watt.

Table IV Building Regulations requirements satisfied if at least 95 per cent of the installed lighting circuit wattage is for lamps in this table

Lamps	Types permitted
High-pressure sodium Metal halide Induction lamps	All types and sizes
Fluorescent tubes	All 25 mm diameter (T8) lamps with low-loss or high-frequency control gear
Compact fluorescent	All sizes above 11 W

4.03 New buildings other than dwellings

The Building Regulations define ''reasonable provision'' as lighting with an average initial efficacy of not less than 45 lumens per circuit-Watt as averaged over the whole area of these types of space in the building.

Lighting controls should be provided to avoid unnecessary lighting during the times when daylight levels are adequate or when spaces are unoccupied.

Reasonable provision would be local switches in easily accessible positions within each working area, or at boundaries between working areas and circulation routes. The distance from any local switch to any luminaire it controls should generally not be more than six metres (or twice the height of the luminaire above the floor if this is greater). Where a space is a daylit space served by side windows, it would be reasonable for the perimeter row of luminaires to be separately switched.

Occupant control of local switching can be supplemented by other controls such as automatic systems which switch off lighting if they sense an absence of occupants or switch off (or dim) the lighting when there is sufficient daylight.

5 LUMINAIRES

5.01 Specification

The term 'luminaire' describes a complete lighting unit including lamp(s), optical components and control gear. It largely replaces the older term 'lighting fitting', which sometimes failed to embrace the necessary lamp. Manufacturers may include the following items in a luminaire specification:

- IP classification
- Light output ratio
- Flux fraction ratio
- Polar curve and/or intensity distribution data
- Spacing-to-height ratio
- Utilization factors
- Glare index table

Two aspects of lamp colour may be distinguished:

- The appearance of the source itself: warm, intermediate or cool
- Its effect on critical objects such as food or the human complexion: 'colour rendering'.

Colour characteristics of some lamp families are summarised in Tables V and VI.

5.02 IP Classification

The Ingress Protection (IP) system classifies the protection of luminaires against solids and moisture in terms of a two-digit number, e.g. IP54. The first digit covers the entry of solid objects, the second covers moisture penetration (see Table VII).

5.03 Light output ratio

The *light output ratio* (LOR) of a luminaire is the proportion of luminous flux (lumens) from the lamp(s) which emerges from the luminaire. The LOR for a bare lamp would be 1.00. The light output ratio for a fluorescent luminaire depends on the ambient temperature, so values are standardised at 25°C.

The LOR is sometimes split into two components. The downward light output ratio (DLOR) is the proportion of lamp flux which emerges from the luminaire in directions below the level of the luminaire. The upward light output ratio (ULOR) is the proportion of lamp flux which emerges from the luminaire in directions above the level of the luminaire.

Other things being equal, a luminaire having a high LOR is more efficient than one with a lower LOR.

Typical values:	Open reflector	0.7 to 0.8
	Enclosed diffuser, suspended or surface-mounted	0.6 to 0.7
	Recessed diffuser	0.5 to 0.6

5.04 Flux fraction ratio

The *flux fraction ratio* (FFR) of a luminaire is the ratio of the flux (lumens) emerging in directions above the level of the luminaire to the flux directed below the level of the luminaire. For a downlight, the FFR is zero; for an uplighter, infinity.

With a high FFR the ceiling may be more brightly lit than the working plane. With a low FFR the ceiling may look dark; so low-FFR luminaires work best when the ceiling and the floor both have a reasonably high reflectance. See also Table X below.

5.05 Intensity distribution

The luminous intensity of a given luminaire depends on the direction from which it is viewed. An uplighter has zero intensity except when seen from above. A downlight has zero intensity except from below. The distribution of intensity is usually plotted in polar co-ordinates, in the form of a polar curve or an iso-candela diagram. In a polar curve the radial distance in each direction is proportional to the corresponding intensity. In an iso-candela diagram loci of constant intensity are plotted on a spherical web analogous to the lines of latitude and longitude on a map of the world.

Polar curves are tricky to interpret. The flux in different angular zones is not proportional to the areas swept out on the intensity distribution. Study a globe: the area within the Arctic and Antarctic

Table V Colour properties of tubular fluorescent lamps

Appearance of lamps	Colour inspection	Colour rendering suitable for		Factories
		Shops & offices	Offices	
Warm	Colour 93 Lumilux de Luxe 32 Polylux Deluxe 930	Colour 82 and 83 Energy Saver 183 Lumilux 31 and 41 Polylux 827 and 830	Deluxe Warm White	Colour 29 Warm White 29 Warm White 30
Intermediate	Chroma 50 Colour 94 Deluxe Natural 36 Lumilux de Luxe 22 Polylux Deluxe 940 Polylux Deluxe 950	Colour 84 Energy Saver 84 Lumilux 21 and 26 Kolor-Rite 38 Polylux 835 and 840	Colour 33 Cool White 20 and 33 Natural 25 Universal White 25	Colour 35 White 23 White 35
Cool	Artificial Daylight Biolux Colour 95 and 96 Colour Matching Lumilux de Luxe 12 Northlight 55	Colour 85 and 86 Lumilux 11 Polylux 860	Daylight 54	

Table VI Colour properties of other lamps

Lamp family	Appearance of lamp	Colour rendering
Filament	Warm	Excellent
High-pressure sodium		
Standard	Warm	Suitable for factories
Improved colour	Warm	Suitable for offices
Metal halide	Cool	Suitable for offices

Table VII Ingress protection system (IP)

First numeral	Protection	Solid objects excluded
0	Unprotected	No special protection
1	Protected against solid objects exceeding 50 mm in diameter	Human hands (but no protection against tampering)
2	Protected against solid objects exceeding 12 mm in diameter	Human fingers
3	Protected against solid objects exceeding 2.5 mm in diameter	Large tools
4	Protected against solid objects exceeding 1 mm in diameter	Small tools
5	Dust-protected	Dust penetration does not stop the equipment from working properly
6	Dust-tight	No dust can penetrate
Second numeral	**Protection**	**Liquids excluded**
0	Unprotected	No special protection
1	Protected against dripping water	Vertically falling drips have no effect
2	Protected against dripping water when tilted up to 15°	Vertically falling drips have no effect when luminaire is tilted up to 15° from its normal position
3	Protected against spraying water	No harm from water falling as spray at angles up to 60° from the vertical
4	Protected against splashing water	No harm from water splashed from any direction
5	Protected against water jets	No harm from water jets from any direction
6	Protected against heavy seas	Water from heavy seas or powerful jets shall not enter in harmful quantities
7	Protected against immersion	No harmful entry of water under defined conditions of pressure and time
8	Protected against submersion	Suitable for continuous submersion in water, under conditions to be specified by manufacturer

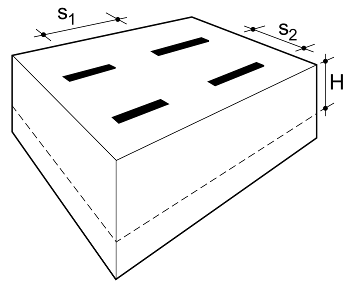
circles is far less than the area within the tropics, though the respective angular limits are the same size. So a given intensity near the vertical axis of a polar curve would contain less flux than the same intensity directed sideways.

Where polar curves and iso-candela diagrams come into their own is in predicting the direct horizontal *illuminance E* (lux) at different positions on a working plane. This is given by the 'cosine cubed' law:

$$E = (I \times \cos^3\theta)/h^2 \qquad \text{equation (5)}$$

where I is the intensity (candelas) in the direction of the chosen reference point
θ is the angle of incidence of light from a luminaire
h is the height (metres) of the luminaire above the working plane.

The cosine-cubed law is directly applicable only to a luminaire whose maximum dimension is less than one fifth of its distance from the reference point. If the luminaire is closer than this, divide it (conceptually) into n equal elements each sufficiently small to satisfy the cosine cubed law. The intensity of each element should be taken as one nth of the intensity from the whole luminaire, and each will have a different angle of incidence θ. The total direct illuminance is obtained by summing the contributions from the separate elements. Clearly this exercise is best left to the computer.



40.11 *Diagrammatic arrangement of a lighting installation. Key: S_1 = axial spacing, S_2 = transverse spacing, S/H = the spacing-to-height ratio (SHR)*

5.06 Spacing-to-height ratio

The spacing-to-height ratio (SHR) of a lighting installation is the ratio of the centre-to-centre distance between adjacent luminaires to their height above the *working plane,* **40.11**. The evenness of electric lighting depends on the spacing-to-height ratio: in general – there are exceptions – the closer the spacing, the more uniform the illumination.

Maximum SHRs should be found in luminaire catalogues. For axially symmetric luminaires a single value – SHR_{max} – is usually quoted. For disymmetrical luminaires (i.e. symmetrical about two vertical planes) two values, axial (SHR_{max}) and transverse ($SHR_{max\,tr}$), are often given. In this case the spacing is subject to three constraints:

(a) Axial spacing must not exceed SHR_{max}
(b) Transverse spacing must not exceed $SHR_{max\,tr}$
(c) (Axial SHR × transverse SHR) must not exceed $(SHR_{max})^2$.

Luminaires with very sharp gradients in their polar curves of transverse intensity may have additional spacing constraints. These are usually presented in a spacing chart showing acceptable combinations of transverse and axial spacing-to-height ratio.

Typical SHR_{max}:	Trough reflectors	1.5 to 1.8
	Enclosed diffusers	1.3 to 1.5
	Louvrered fittings	1.0 to 1.3

5.07 Utilization factors

The average *illuminance E* (lux) on the *working plane* is given by the expression:

$$E = (N \times n \times F \times UF \times MF)/A \text{ lux} \qquad \text{equation (6)}$$

where N = number of luminaires
n = number of lamps per luminaire
F = initial flux (lumens) from one lamp
UF = utilization factor
MF = maintenance factor
A = is the area of the working plane in m^2

Alternatively the lamp flux $(N \times n \times F)$ required to supply a given illuminance E is given by the expression:

$$N \times n \times F = (E \times A)/(UF \times MF) \text{ lumens} \qquad \text{equation (7)}$$

Utilization factors are tabulated by luminaire manufacturers. They depend mainly on the choice of luminaire, on the shape and size of the interior, and on the reflectances of the bounding surfaces of the interior. The shape of the interior is embodied in the *room index, K,* so this is one of the parameters in every utilization factor table.

5.08 Maintenance category

The maintenance category of a luminaire is an alphabetical classification which indicates how rapidly the *luminaire maintenance factor* will decrease in a given environment. Examples from each category are listed in Table VIII.

The concept of *luminaire maintenance factor* is still in its infancy. It is envisaged that in due course manufacturers will be in a position to quote LMF profiles for their products. The maintenance category should therefore be regarded as a stop-gap grading system.

Table VIII Luminaire maintenance categories (CIBSE Code for Lighting, 2006)

Maintenance category	Typical luminaire
A	Bare lamp batten
B	Open top reflector (ventilated self-cleaning)
C	Closed top reflector (unventilated)
D	Enclosed (IP2X)
E	Dustproof (IP5X)
F	Uplighter

5.09 Glare index

The glare index of a lighting installation predicts the incidence of discomfort or distraction by bright luminaires. The Unified Glare Rating (UGR) contains ratings which are typically in the region of 16 to 28.

Manufacturers have been encouraged to publish tables of 'uncorrected' glare index for each of their luminaires. These are given as a function of the direction of view (endwise or crosswise in relation to a linear luminaire), the surface reflectances and the room dimensions (length and width expressed as multiples of the height of the luminaires above eye level). Uncorrected glare indices relate to luminaires, 2 m above eye level, powered by lamps emitting 1000 lumens per luminaire. The correction to be added for other mounting heights and lamp outputs is:

$$4 \times \log_{10}\mathrm{H} + 6 \times \log_{10} (n \times F) - 19.2 \qquad \text{equation (8)}$$

where H = height of luminaires above eye level (metres)
n = number of lamps in each luminaire
F = luminous flux from each bare lamp (lumens)

The current glare index system will shortly be replaced by an internationally accepted UGR system. The form in which luminaire data is to be presented is still under discussion, but present-day limiting glare indices are unlikely to change.

6 PLANNING AN OVERALL LIGHTING SYSTEM

6.01 The lumen method

The lumen method, using equations 6 and 7 from **5.07** above, can be used to plan lighting systems, but the increasing use of software is making these calculations less common. These equations suggest a natural sequence for electric lighting design decisions.

Stage 1

The first decision is the choice of target illuminance *E*. The CIBSE code recommends values of *standard maintained illuminance* for over 600 different locations or activities. A few examples are given in Table IX.

The flow chart, **40.12**, is used when the circumstances or demands of the task in hand are more relaxed or more severe than usual. The dashed lines in the figure offer a compromise expedient when this is appropriate. The target illuminance thus obtained is known as the *design maintained illuminance*.

In many cases, especially in dwellings or in public areas, the visual task is hard to identify, and the illuminance is calculated to provide the right atmosphere for getting together or for relaxing. Especially where this is the case, listed values of standard maintained illuminance should be treated as a point of departure, not as a target. If a designer seeks a subdued atmosphere a lower value would be right; if a brighter ambience is envisaged, a higher illuminance would be justified.

Table IX Standard maintained illuminance (from CIBSE Code for Lighting)

Walkways	50 lux (can range from 5 to 100 lux)
Corridors	100 (can range from 20 to 200 lux)
Loading bays	150 (specialist guidance recommended)
Machine and urbine halls	200
Classrooms	300 (500 lux for adult education)
General offices	200 to 500
Drawing offices	750
General inspection and precision assembly	200 to 1000
Minute assembly	2000

Stage 2

The second decision is the broad choice of lamp type. Apart from cost, three factors dominate this choice:

(a) Efficacy (lumens per watt).
(b) Lamp colour balance: warm, intermediate or cool.
(c) Colour rendering.

A high efficacy will reduce energy consumption and hence running costs, air pollution and greenhouse gas emissions.

Stage 3

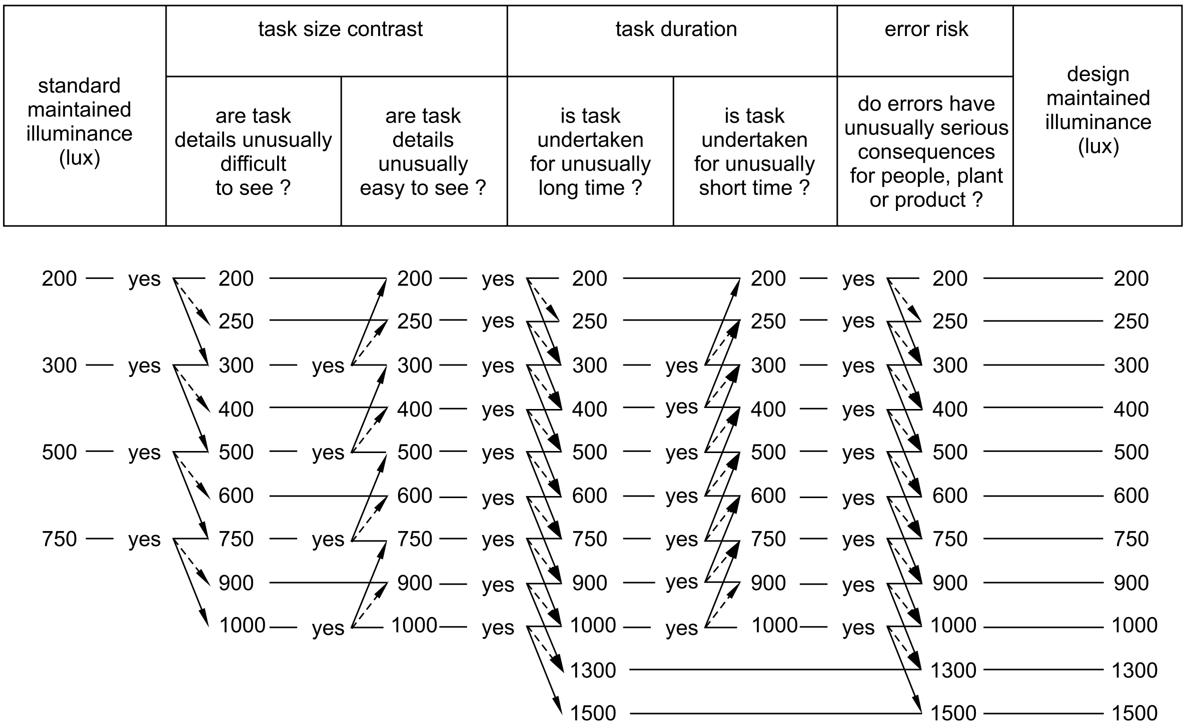
The third decision is the broad choice of luminaire family. To a large extent the character of the space will dictate the character of the luminaire. A utilitarian space demands a utilitarian luminaire while a reassuring space calls for a domestic style of luminaire. The principal photometric quantities governing the choice of luminaire are:

(a) The intensity distribution (polar curve); see para **5.05** above. The general effect of alternative distributions is listed in Table X. Do not read too much into this table. Lighting alone has only a modest effect on the environment; it is psychologically powerful only as a reinforcement to the other resources of interior design. Colour, texture, furnishings and lighting should be designed hand in hand for the best effect.
(b) The light output ratio; see para **5.03** above. A high light output ratio will reduce energy consumption, but it generally has much less effect on energy costs than the choice of illuminance in Stage 1 or the choice of lamp efficacy in Stage 2.

If a wise choice is made at this Stage there should be little problem in satisfying the glare check in Stage 7.

Table X The effect of luminaire intensity distribution on the atmosphere in a room

Flux fraction ratio	Spread of downward light		
	Tight	Medium	Widespread
0 to 0.1	Concentration on task in hand	Dark ceiling may look oppressive	Danger of glare?
0.1 to 0.8	Well-mannered, formal	Safe, characterless?	Welcoming, expansive
over 0.8	Dignified	Safe, relaxing	Relaxing



40.12 *Design maintained illuminance flow chart*

Stage 4
The fourth decision relates to cleaning and maintenance. The various components of the *maintenance factor* – the *lamp lumen maintenance factor*, the *lamp survival factor*, the *luminaire maintenance factor* and the *room surface maintenance factor* – must be separately evaluated and subsequently combined. This is no mere mechanical chore. It involves the consideration of alternative maintenance regimes and cleaning schedules, and may well call for retrospective changes in Stages 2 and 3.

Stage 5
The fifth decision involves sizing the lighting installation. The principal terms in the equation for the lumen method have been settled in Stages 1 to 4. The total required lamp flux ($n \times N \times F$) is now calculated using equation (7).

Stage 6
The sixth decision decomposes the lamp flux $n \times N \times F$ into its three components:

n: In most non-fluorescent luminaires, n (the number of lamps per luminaire) = 1. In the case of fluorescent luminaires it is wise to standardise on a single size and colour of lamp throughout a given project. This simplifies lamp replacement, minimises storage difficulties and helps to obviate the 'strawberry and vanilla' effect of different tube colours side by side in the same room or even the same luminaire. Different lighting levels in different rooms are then achieved by using different numbers of tubes in each luminaire.

N: *Where an even overall spread of light is wanted, the spacing-to-height ratio* imposes a lower limit on N (the number of luminaires); see para **5.06** above. In practice the spacing-to-height ratio should play only a minor part in determining N Where the layout of workstations is known it should logically dictate the luminaire layout. Where the activity involves some focus of emphasis, that focus should be selectively illuminated, and the geometry of the lighting layout might revolve about the focus. In any case the layout should respect the structural grid.

A lighting calculation is sometimes held to justify an excessive number or an aggressive layout of luminaires. This is nonsense: no lighting calculation should ever be permitted to dictate design priorities, and no designer should ever offer such an excuse for abdication.

F: *Once* n and N are fixed, the lamp flux F will determine the wattage of each lamp. Available lamps will never provide the precise lamp flux mandated by a lumen calculation. A neighbouring value should be selected and, if the lighting level has been wrongheadedly specified too tightly, it may be necessary to rerun the lumen method equation and check the illuminance.

Stage 7
The final stage comprises a check on the glare index of the installation; see para **5.09** above. In the case of linear luminaires, this stage provides an opportunity to optimise their orientation. Glare is not the only factor which should govern the way they are aligned. The orientation may also be chosen to minimise the shadow cast by the body onto the desk or table, to reduce shiny reflections in the task, to emphasise one or other dimension of a room, to guide visitors along a preferred route and/or to signal their arrival by a change of layout, illuminance, mounting height, etc.

Applicability
This idealised sequence, like its counterpart for window design, para **3.01**, bears little resemblance to the everyday practice of lighting design, where many decisions are justifiably based on precedent, experience or habit. The advantage of a step-by-step procedure appears when a designer is stuck. He or she can then reassess earlier decisions in their logical sequence, identifying and correcting the blockage.

7 DISPLAY LIGHTING

7.01 Luminaires for display lighting

The effectiveness of display lighting depends as much on the skill of the person responsible for aiming it as on the accuracy of the specifier. The latter would be well advised to consider who is likely to take charge of it once his or her back is turned. It may well be a caretaker, a shop assistant or a clerk of works, with no training in display lighting techniques. If so, any track lighting is likely to become poorly positioned and wrongly aimed. Fixed lighting, perhaps above egg-crate louvres, may well be preferable. The following notes relate mainly to track lighting, but the same principles apply to fixed lighting.

In a space where visitors are free to move around it is virtually impossible to light vertical surfaces without shining light straight into somebody's eyes. To avoid this, start from the principal entrance and plan a route through the exhibits. Run lighting track across, not along, this route. Arrange spotlights to shine over the shoulders of visitors following the preferred route. At each point along the route, make sure that the next stopping point is attractively lit, to encourage circulation in the right direction. Visitors moving the opposite way will face darker surfaces and will have to brave the dazzle of spotlights planned for their more accommodating brethren. They may take the hint.

Track lighting should preferably be 2.5 to 3 m high. Lower mounting would invite glare, tampering, and discomfort from heat radiated from the lamps. Higher mounting would make aiming more difficult, and spotlights might remain unadjusted month after month.

Spotlights are available with widely varying degrees of 'punch'. Some are tightly concentrated; others diffuse their output more widely. Published *performance cones* give a graphic indication of the angles at which the beam intensity from a spotlight is at 50 per cent of its peak value. Beam diameters and maximum illuminances are often shown for surfaces facing the spotlight at various distances. Illuminances at other distances and inclinations may be estimated form the cosine cubed law, para **5.05** equation (5) above.

Do not confuse the performance cone with the *cutoff line*. The latter may also be a cone, and can register as a conic section, usually a hyperbola, dividing directly lit from unlit areas of a wall. It is wise to anticipate the nature and position of cutoff lines. They can show up as scallops disconcertingly unrelated to the illuminated target.

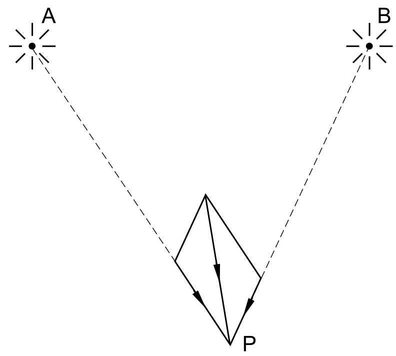
7.02 Planning display lighting

Effective display lighting depends as much on darkness as on illumination. Objects will stand out only if they look significantly brighter than their surroundings. Brightness has two aspects:

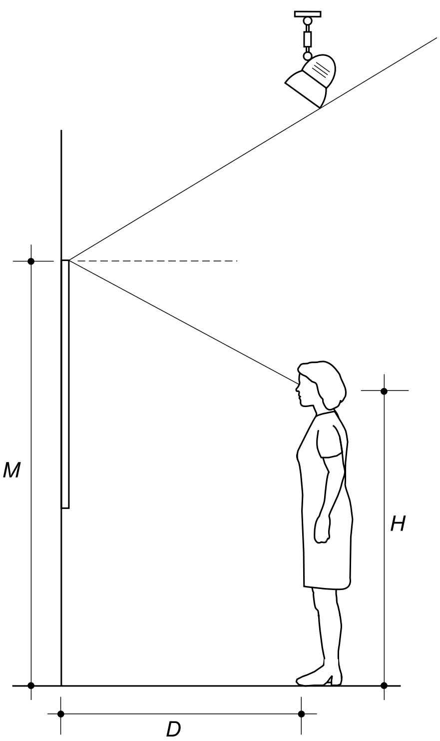
(a) *Illuminance*: to appear noticeably brighter the illuminance on a surface should be at least three times the background illuminance; to stand out strongly would require a ratio of 10:1 or more.
(b) *Reflectance*: if an object has a lower reflectance than its background it will respond much less to an increase in illuminance; spotlighting may well be inappropriate, and the profile of the beam may need careful trimming to the profile of the target.

The overall pattern of light and shade deserves careful consideration. To pick out a single focus of attention is simple and always effective. To highlight two objects risks an impression of disunity. To spotlight more than three requires some skill, and invites confusion.

The predominant direction of the lighting is also important. Illumination has vectorial properties. Ignoring interreflected light, the *illumination vector* due to each spotlight is equal to the illuminance on a surface facing the source. However, the illumination vector must not be confused with the illuminance. Illuminances from different sources are added together by simple arithmetic, but illumination vectors obey the parallelogram law for vectorial addition, **40.13**. The vector resultant of two sources is represented in magnitude and direction, by the diagonal of a parallogram of illumination vectors. Spotlights shining from opposite directions may produce a zero resultant: the lighting would have no clear direction. Most objects look more attractive under a sideways vector than under a vector from straight overhead or from below; compare a side-lit room with a room lit by an overhead array of luminaires. However, a vector shining along the direction of view tends to flatten the object, and a vector in the opposite direction tends to show the object in silhouette. The direction of the illumination vector, and the strength of the directional flow of light, are under the designer's control, and should be part of his or her vocabulary.



40.13 *The illuminance vector at P due to sources A and B is the diagonal of the parallelogram whose sides are the vectors due to A and B*



40.14 *For picture lighting assume D = length of picture diagonal, M = height of top of tallest picture frame, H = eye level of short adult, say 1.5 m*

The lighting of paintings, notice-boards, chalk-boards, etc. must meet two constraints:

(a) It must not produce shiny reflections, which reduce legibility, and
(b) It must provide reasonably even illumination over the target surface.

The best position for the luminaire is shown in **40.14**. If it were mounted closer to the target surface, the foot of the target would look dimly lit compared with the top. If it were further back, a visitor would see shiny reflections.

In conclusion, the Golden Rule for successful spotlighting is 'Light objects, not people'. The positioning of luminaires should be constrained as much by the need to avoid glare and distraction as by the need to reveal an illuminated object.

8 VISUAL DISPLAY TERMINALS

The front surface of a visual display terminal (VDT) acts as a partial mirror. Screen visibility is impaired when specular reflections approach or exceed the brightness of the luminous pixels.

Side windows present a double problem. If operators face a window they suffer because it is much brighter than the VDT. If their backs are to the window they will pick up its reflection in the VDT screen. The face of the VDT should ideally be at right angles to the face of the window. If there are windows on two adjacent walls this remedy may fail, and solid screens might be considered.

In a private office the choice of luminaire is seldom critical; a ceiling-mounted fitting would not normally be reflected in the display screen. In an open-plan office the choice is more restricted.

If the height of the ceiling is greater than 2.5 m uplighters containing metal halide or high-pressure sodium lamps, possibly integrated into the office furniture, should be suitable. If the ceiling height exceeds 3.5 m, one might consider direct-indirect lighting, suspended uplighters or column-mounted uplighters. For ceiling heights below 2.5 m the best solution is a modular VDT luminaire providing a suitable illuminance (perhaps 300 lux) on the desk, with restricted light sideways to reflect in the screen.

9 LIGHTING CONTROLS

Five families of electric lighting controls may be distinguished as follows.

9.01 Constant illuminance control

Dimmable high-frequency fluorescent luminaires can be linked to indoor photocells set to sustain the *design maintained illuminance*. Otherwise a clean installation of new lamps would provide a substantially higher illuminance, with a correspondingly high energy consumption. As time passes the controls will gradually pass additional power to the lamps, to compensate for the effects of dirt and deterioration. When the lamps are fully loaded the time is overdue to alert the maintenance staff to clean the luminaires. This system has an additional advantage when the room changes from one use to another which permits a lower task illuminance: the setting can be adjusted to maintain the reduced lighting level.

9.02 Daylight linking

One or more rows of luminaires along a window wall may be linked to either interior or exterior photocells which monitor daylight levels and adjust the electric lighting accordingly, either by top-up (dimming) or by simple on/off switching. Note that high-intensity discharge lamps are unsuitable for dimining. Control zones should be parallel to the windows. Daylight linking can be combined with the occupancy detection system below.

9.03 Manual switching

Manual switching is particularly suitable for intermittently occupied spaces. Switches should be close to the luminaires they control. As a rule of thumb, the number of switches in a space should be not less than the square root of the number of luminaires. Thus twelve luminaires would require at least four switches. Options include low-voltage switching, pull-cords and remote ‘wireless’ switches such as ultrasonic or infrared; or a telephone signal to an energy-management system.

9.04 Time switching

Electric lighting is switched off automatically at a control panel at the same time each day, to coincide with work breaks, e.g. at midday. It is better to switch half the lights at first, the rest 10 minutes later. Users are then free to relight the lamps they still need. This system shares the responsibility for energy saving with the occupants, whose understanding and co-operation should be assured in advance.

There are several alternative methods for implementing a synchronised or staggered switch-off:

- Low-voltage wiring to a relay in each lighting circuit
- A mains-borne signalling system
- A one-second interruption of the mains supply to each luminaire, causing latching relays to switch off.

In each case pull-switch or other manual overrides should be provided, for occupants to switch lamps straight back on if needed.

9.05 Occupancy-linked switching

The aim of occupancy-linked lighting controls (presence detectors) is to operate the lighting when, but only when, somebody is there to make use of it. The best application is where occupancy is infrequent or unpredictable, e.g. private offices, conference rooms, toilets, warehouse storage aisles, photocopy rooms, and bookcase lighting in libraries.

Some units beep or flash a warning signal just before lights are turned off, so that an undetected occupant can wave an arm and avoid being left in the dark. Fluorescent lamps require a time delay before switching off, as repeated switching shortens lamp life. Occupancy-linked discharge lamps with long restrike times should be supplemented by separate background lighting.

Occupancy detectors are particularly suited to daylit spaces, and may be combined with daylight sensors. Presence detectors can double as part of a security system. At night or at weekends they can activate an alarm instead of working the lights. They can also assist security patrols at night. However, since they react to movement a motionless occupant may escape detection.

Occupancy detectors may be triggered by air movement, by a flapping curtain, or by events in a corridor outside the monitored space. Ultrasonic detectors seem more prone than passive infrared detectors to these extraneous stimuli. The sensitivity of some units can be adjusted to minimise these failings, at the price of their effective surveillance area. But the best arrangement is always to insist on manual-on/automatic-off occupancy controls with a manual override.

10 GLOSSARY

Altitude
The angle in degrees, subtended at a viewpoint, between a chosen point and the horizon. The solar altitude is the altitude of the sun above the horizon.

Azimuth
An angle in plan, also called *bearing*. The solar azimuth is usually measured from due north.

Candela see *luminous intensity.*

Circuit wattage
The power consumed by the lamps in an electric lighting system, by their control gear, and by associated equipment for power factor correction.

Cutoff line
The line above (or in the case of an uplighter, below) which a lamp is not visible. Strictly speaking, the cutoff line is a surface in three dimensions. The cutoff line for a window is the *no-sky line*, see para **7.01**.

Daylight factor
Equal to the illuminance (lux) at an indoor point, expressed as a percentage of the simultaneous horizontal illuminance under an unobstructed overcast sky outside, see para **2.01**.

Design maintained illuminance
The target value for lighting design. It is derived from the *standard maintained illuminance* by following the flow chart **40.12**, see para **6.01**.

Direct-indirect lighting
Provided by a luminaire designed to combine the photometric characterictics of an uplighter and a downlight. It provides upward and downward illumination, sometimes in variable proportions, but little or no light sideways.

Efficacy (h)
For an electric lamp, equal to its luminous flux output (lumens), divided by the electric power consumed (watts).

Flux, see *luminous flux*

Glare index
Predicts the incidence of discomfort or distraction by bright luminaires, see para **5.09**.

Illuminance (E)
The degree of concentration of light in lux striking a surface. Illuminance is measured by a special lightmeter – an illumination photometer; photographic lightmeters are unsuitable.

Illumination vector
The difference in *illuminance* at a point between opposite sides of a small flat surface so orientated that this difference is a maximum. The direction of the vector is then normal to the surface; the positive direction is from higher to lower illuminance. Illumination vectors obey the parallelogram law for vector addition. See para **7.02**.

Initial lumens
The flux from a clean lamp once its output is reasonably steady; for fluorescent and other discharge lamps this condition is said to be reached after 100 hours of normal operation.

Intensity see *luminous intensity.*

IP (Ingress Protection) classification
Provides a two-digit classification of the protection of luminaires against solid objects and moisture, e.g. IP54. The first digit refers to solids, the second to moisture.

Lamp survival factor (LSF)
The proportion of lamps in an installation still operating after a given interval. In calculating the *maintenance factor*, assume LSF = 1.0 unless bulk relamping is to be carried out without previous spot replacement of failed lamps.

Lamp luminous flux maintenance factor (LLMF)
The output (in lumens) of the lamps in an installation after a given interval, expressed as a fraction of their initial output. Curves of LLMF for different lamp types are available from manufacturers.

Lumen see *luminous flux*

Luminaire maintenance category
An alphabetical classification indicating the speed at which the luminaire maintenance factor will depreciate in a given environment.

Luminaire maintenance factor (LMF)
The light output ratio of a luminaire after a given interval, expressed as a fraction of its light output ratio when clean. The LMF includes the effect of dirt deposited on or inside the luminaire, but not the regular lamp lumen depreciation which is monitored separately by the lamp luminous flux (lumen) maintenance factor. Luminaire manufacturers should be approached for this information. If it is not available, one can refer to standard values for different luminaire maintenance categories.

Luminous flux (ϕ)
The rate in lumens at which light energy is emitted from a source or received by a surface. For a given illuminance E lux, the flux striking a surface will be proportional to the area A (m^2):

$$\phi = E \times A \text{ lumens} \qquad \text{equation (9)}$$

Hence 1 lux = 1 lumen per square metre.

Luminous intensity
Light from a point source obeys the inverse square law: the illuminance E lux on an element facing the source is inversely proportional to the square of the distance d metres between the source and the element. In other words, the product $E \times d^2$ is constant. The constant $E \times d^2$ is known as the luminous intensity, or simply the intensity, of the source. It is expressed in candelas (formerly candle-power). The product $E \times d^2$ will not be constant unless the distance d is quite large compared to the maximum dimension of the luminaire in question. In practice the distance should be at least five times the longest dimension of the luminaire. See also para **5.05**.

Lux see *illuminance.*

Maintenance factor (MF)
The ratio of the illuminance (lux) of a lighting system, or, in the case of natural lighting, the daylight factor, after a given interval, expressed as a fraction of the illuminance or daylight factor when the same installation was clean and newly commissioned. The maintenance factor for electric lighting may be decomposed into four components:

$$\text{MF} = \text{LLMF} \times \text{LSF} \times \text{LMF} \times \text{RSMF}$$

where LLMF = *lamp luminous flux (lumen) maintenance factor*
LSF = *lamp survival factor*
LMF = *luminaire maintenance factor*
RSMF = *room surface maintenance factor*

See Table II for maintenance factors for natural lighting.

No-sky line
The dividing line, **40.2**, in a room between the area which is exposed to a direct view of the sky, and the area which receives no direct daylight at all.

Performance cone
Gives a graphical indication of the angles at which the beam luminous intensity from a reflector lamp or a downlighter falls to 50 per cent of its peak value. Performance cones often include values of beam diameter and maximum illuminance at various distances from the luminaire. They are a convenient way to compare different forms of spotlight. See para **7.01**.

Probable sunlight hours
The long-term average number of hours per year when direct sunlight is visible from a given point. Typical cloud conditions are taken into account.

Reference plane see *working plane.*

Reflectance (R)
The proportion of incident light which a surface reflects. A perfectly white surface would have a reflectance of 1.00, a perfectly black surface would have zero. Table XI gives some values for typical surfaces.

Room Index (K)
Specifies the proportions of a room, insofar as they affect the utilisation factor. Other things being equal, two interiors having the same room index will have the same utilisation factor for a given luminaire, whatever their geometrical differences.

For a square room I metres square $K = 1/2\,h$

For a rectangular room I metres long and w metres wide $K = (I \times w)/[(I + w)h]$ where h = height (m) of centroid of luminaires above the working plane. For a non-rectangular interior K = (floor area + ceiling area)/(wall area between the working plane and the plane of the luminaires).

Room surface maintenance factor (RSMF)
The illuminance after a set time expressed as a fraction of the illuminance when the room was newly decorated. Depreciation of lamp and luminaire outputs are not included in the RSMF; they are monitored separately by the lamp luminous flux maintenance factor and the luminaire maintenance factor respectively.

Sky factor
The horizontal illuminance (lux) at a given point due to light received directly through an unglazed window opening from a sky of uniform brightness, expressed as a percentage of the horizontal illuminance under an unobstructed vault of the same sky. See para **1.05**.

Skylight indicator
40.15, for checking the daylight potential of new buildings and daylight protection for existing buildings. It provides an estimate of the vertical sky component on a built-up site. The centre of the semi-circular indicator corresponds to the position in plan of the reference point. Its base should run along the plane of the window wall. Radial distances correspond to the ratio (distance of obstruction on plan)/(height of obstruction above reference point). Each little cross stands for a vertical sky component of 0.5 per cent. Count how many crosses fall within the outline of the sky. Divide by 2. The answer equals the vertical sky component, expressed as a percentage.

Solar declination
At any moment the sun is precisely overhead at some point on the earth's surface. The latitude of this point depends on the season, and is known as the solar declination. Some values of solar declination are shown in Table I.

Solar gain indicator
40.7, checks solar radiation (direct and diffuse, but not reflected), striking a vertical south-facing wall or window. Values are summed over the heating season (1 October to 30 April). They do not cover the summer months, so provide no check on summertime overheating. With this limitation in mind, they provide valuable data for passive solar design, indicating the potential contribution of solar radiation to space heating. The indicator is strictly applicable only to a south-facing vertical wall. Do not use it for sloping windows, or for vertical planes facing more than 30° away from due south. The indicator, for the appropriate latitude, is aligned in the same way as the *sunlight availability indicator*. Each of the 100 dots stands for 1 per cent of incident solar radiation during the heating season. The total incident radiation is one hundredth of the exposed dots, multiplied by the maximum value, in kWh/m^2, which is marked on the caption of each indicator.

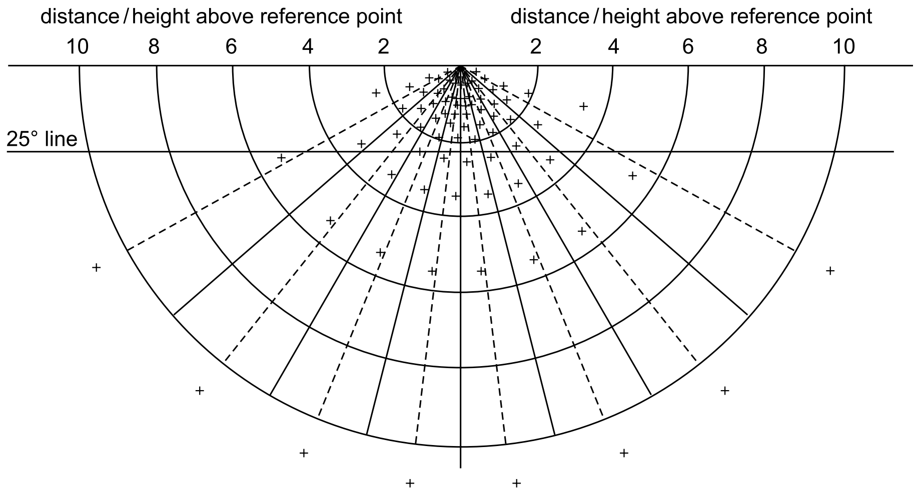
Table XI Approximate reflectances of typical building finishes from CIBSE Code for Lighting

Building surface	Material or finish	Reflectance
Ceilings	White emulsion paint on plain plaster surface	0.8
	White emulsion paint on acoustic tile	0.7
	White emulsion paint on no-fines concrete	0.6
	White emulsion paint on wood-wool slab	0.5
Walls	White emulsion paint on plain plaster surface tiles, white glazed	0.8
	Brick, white gault	0.7
	Plaster, pink	0.65
	White asbestos cement	0.4
	Brick, concrete, light grey	
	Portland cement, smooth	
	Stainless steel	0.35
	Brick, fletton	0.3
	Concrete, light grey	0.25
	Portland cement, rough (as board marked)	
	Brick, London stock	
	Timber panelling: light oak, mahogany, gaboon	
	Timber panelling: teak, afromosia, medium oak	0.2
	brick, concrete, dark grey	
	Brick, blue engineering	0.15
	Chalkboard, painted black	0.05
Floors and furniture	Paper, white	0.8
	Cement screed	0.45
	PVC tiles, cream	
	Carpet: light grey, middle buff	
	Timber: birch, beech, maple	0.35
	Timber: oak	0.25
	PVC tiles, brown and cream marbled	
	Carpet: turquois, sage green	
	Timber: iroko, keming, medium oak	0.2
	Tiles, cork, polished	
	Quarry tiles: red, heather brown	0.1
	Carpet, dark, 'low maintenance'	
	PVC tiles, dark brown	
	Timber, dark oak	

Spacing-to-height ratio (SHR)
The ratio of the centre-to-centre distance between adjacent luminaires to their height above the working plane, **40.11**. See para **5.06**.

Standard maintained illuminance
The illuminance in lux recommended for a given task under standardised conditions. Values of standard maintained illuminance are published in the CIBSE Code. They should be translated into design maintained illuminance values when a new lighting system is envisaged. See para **6.01**.

Sunlight availability indicator
40.4 for checking sunlight protection for existing buildings and sunlight potential for new buildings. It provides a measure of the *probable sunlight hours* on a built-up site. The centre of the indicator corresponds to the position in plan of the reference point. Radial



40.15 *Skylight indicator*

distances correspond to the ratio (distance of obstruction on plan)/(height of obstruction above reference point). Align the south-point of the indicator with the south-point of the site plan. Each of the 100 dots on the indicator stands for 1 per cent of the annual probable hours of sunlight. Choose the indicator whose stated latitude (51.5°, 53.5° or 56°) is closest to the geographical latitude of the site. If a dot is closer to the centre than any obstruction in that direction, then sunlight from that dot is unobstructed (unless, of course, it comes from behind the facade). Count the unobstructed dots. The total is the percentage of probable sunlight hours. Littlefair (1991) recommends an annual exposure to at least 25 unobstructed dots, including at least five from beyond the equinox line.

Sun on ground indicator
40.5, designed for site planning, and shows the length and direction of shadows at the equinox. The Building Research Establishment has issued indicators for the following latitudes – 51.5°, 53.5° and 56° – each at scales of 1:100, 1:200, 1:500 and 1:1250. Place the point P of the indicator over a reference point at ground level on plan. Line the south point of the indicator with the south point on the plan. Parallel east-west lines on the indicator show the heights of obstructions which would just intercept direct sunlight at the time indicated. Hence one can estimate the hours of potential sunlight reaching any point on the ground at the equinox. Sunlight less than 10° above the horizon is ignored.

Sunpath indicator
40.6, for checking times and seasons when direct sunlight strikes a given reference point on a built-up site. It is aligned and scaled in the same way as the *sunlight availability indicator*. Choose the indicator whose stated latitude (51.5°, 53.5° or 56°) is closest to the geographical latitude of the site. If a point on one of the sunpath lines is closer to the centre than any obstruction in that direction, then the sunlight at that moment is unobstructed (unless, of course, it comes from behind the facade).

Transmittance (T)
The proportion of luminous flux in lumens striking the upper surface of a transparent or translucent sheet which emerges from the lower surface. The transmittance of clear window glass is taken as 0.85; double glazing 0.75.

Utilisation factor (UF)
The fraction of luminous flux in lurnens generated by the lamps in an installation which eventually, after multiple reflection by surrounding surfaces, strikes the working plane. It does not include any allowance for the effect of dirt; this is embodied in the maintenance factor. See para **5.07**.

Vertical sky component (SC_v)
The illuminance in lux on a vertical element at a point due to direct light from the overcast sky vault, expressed as a percentage of the simultaneous horizontal illuminance under the whole unobstructed sky vault.

Working plane, or reference plane
The flat plane on which the visual task is located. In a corridor this would be at floor level. In a shop, at counter height. In an office 0.7 m, a factory or kitchen 0.85 m above floor level. Unless otherwise stated the working plane is assumed to be horizontal.

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41 Sound

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Updated by Chris Steel of the Robin Mackenzie Partnership, building acoustics consultants

CI/SfB: (P)
UDC: 534.84
Uniclass: U37

KEY POINTS:

- *Current Building Regulations in England and Wales now require completion testing or registration with a recognized provider as proof of compliance*
- *Insulation requirements now extend to include school design in England and Wales*

Contents

1 INTRODUCTION

Sound affects the occupants of a building in two distinct ways:

- The quality of sounds generated within, e.g. a concert hall
- Annoyance with loud noise. (*Noise* is a term used to describe unwanted sound.)

The factors that determine sound quality are still imperfectly understood, despite much recent research and experience. The same is true to a lesser extent of the factors affecting noise. Part of the difficulty is that asking someone how he feels about his environment may itself modify his reactions. Very loud prolonged sounds, such as occur in some industries, can result in permanent damage to the ear. The fear that they can damage buildings has been exaggerated, and need not normally be considered by the architect. Many acoustical problems in buildings can be avoided by considering the broad requirements early in the design process. Later on, rectification is rarely satisfactory or economical.

Changes to the building regulations in England and Wales has increased the level of expectation in achieving the minimum sound insulation criteria set out in the Building Standards regulations and now includes acoustic comfort in communal areas, noise control in domestic like areas (i.e. halls of residents) and suitable acoustic standards in schools. These changes have increased need for designers to be aware of acoustics but also to be more aware of when the services of a qualified acoustic consultant are required.

2 FUNDAMENTAL ACOUSTICS

Sound is perceived when the eardrum is set vibrating by variations in the air pressure just outside the ear. These pressure variations will have been caused by some vibrating object, said to radiate sound. The simplest kind of sound is a single pure tone, for which the graph of air pressure plotted against time produces a sine wave, **41.1**. The greater the *amplitude A* of the pressure variation, the louder the tone. The more rapid the variation (i.e. the higher the *frequency*), the higher the pitch of the tone.

2.01 Sound pressure level

The *sound pressure* of a pure tone generally means the root mean square (rms) value of the variation in pressure of the air due to the sound, not the amplitude or peak value *A*. This is because the rms value is the best measure of energy whether the sound is a pure tone or not. For a sine wave, the rms value is the amplitude divided by $\sqrt{2}$.

Audible sound pressures extend approximately from 2×10^{-5} Pa (the quietest sound that most people can hear – the *threshold of hearing*) to 100 Pa (sound so loud that it starts to be actually painful). This enormous range is telescoped by using a logarithmic notation employing the *decibel.*

The *sound power* of a pure tone is proportional to the square of the pressure. The ratio of the powers of two sounds is therefore the square of the ratios of the pressures. The *sound pressure level*, L_p of a given sound expressed in decibels is ten times the common logarithm of the ratio of its power and that of the internationally recognised threshold of hearing: i.e.

$$L_p = 10\log_{10}\left(\frac{p_1^2}{p_0^2}\right) = 20\log_{10}\left(\frac{p_1^2}{2\times10^{-5}}\right)\text{decibels (dB)}$$

Expressed in this way, the audible range extends roughly from 0 dB SPL to 134 dB SPL. A sound usually seems twice as loud when its pressure has trebled, i.e. it has increased by 10 dB.

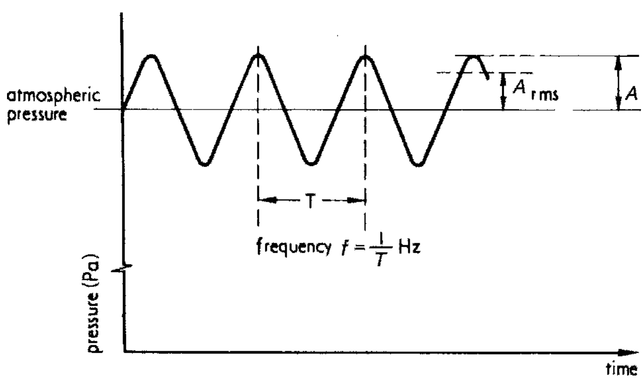
2.02 Sound power level

The sound power of a source, measured in Watts, is deduced from measurements of sound pressure in a well-defined acoustical environment, such as an *anechoic chamber* or a *reverberation room.* The range of powers being even greater than that of pressure levels, decibel notation is again used. The international reference level for sound power is 1 pW, so the sound power level L_w is given by

$$L_w = 10\log_{10}\left(\frac{W_1}{10^{-12}}\right)\text{ dB}$$

where W_1 is the sound power in Watts.

The SPL produced at a particular place will depend on the distance, orientation and sound power level of the source; and also on the amount of acoustical absorption present. It is important in any application to distinguish between sound pressure level and sound power level as they are usually numerically quite different.



41.1 *Sinusoidal variation of air pressure at a point, due to a pure tone*

2.03 Frequency

The frequency of a pure tone is measured in hertz (Hz), equal to and formerly called cycles per second, **41.1**. The human range of audible frequencies varies, but is roughly from 20 to 20 000 Hz. The ability to hear higher-frequency sounds progressively deteriorates with age.

Any steady sound, however complex, can be reproduced by combining enough pure tones of the right amplitudes and frequencies. Thus, if we know the behaviour of a material, wall or room, etc. with regard to the audible spectrum of pure tones, we can predict the behaviour with any steady sound.

The acoustical properties of materials or rooms are described in relation to contiguous frequency bands. Octave-band measurements are carried out where economy is needed. One-third octave bands are used when greater accuracy is required.

Octave-band centre frequencies: 63, 125, 250, 500, 1000, 2000, 4000 Hz

One-third-octave band centre frequencies: 50, 63, 80, 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1000, 1250, 1600, 2000, 2500, 3150, 4000, 5000, 6300, 8000 Hz

2.04 Reverberation time

The reverberation time is defined as the time taken for an interrupted sound to fall in level by 60 dB. The reverberation time and its variation with frequency is probably the most significant measurable factor determining the acoustical character of a room and it can be calculated from Sabine's formula

$$T = \frac{0.16}{S_\alpha + xV}$$

where V = room volume in m^3
S_α = total surface absorption in m^2
x is a coefficient related to the sound attenuation of air.

The total surface absorption is obtained by adding together the separate areas of absorbent:

$$\text{Sa} = S_1a_1 + S_2a_2 + S_3a_3 + \cdots + S_na_n$$

where S_1 is the area in m^2 with absorption coefficient α_1, etc. Table I gives examples of typical absorption coefficients.

The Norris–Eyring formula is accepted as more accurate for rooms with a high average absorption coefficient

$$T = \frac{0.16V}{S[-2.30\log(1-\alpha)] + xV}$$

The range of T varies from 0.25 s for a small pop recording studio, to over 10 s for a large cathedral. For clear speech in a lecture hall or theatre, T should be between 0.7 and 1.0 s. Outside these limits, a specially designed speech reinforcement system will be required.

Table I Absorption coefficients

	Frequency Hz						
	63	125	250	500	1000	2000	4000
Air, x (per m^3)	0	0	0	0	0.003	0.007	0.023
Audience seated in fully upholstered seats (per person) m^2	0.15	0.18	0.40	0.46	0.46	0.51	0.46
Orchestral player with instrument (average), m^2	0.18	0.37	0.8	1.1	1.3	1.2	1.1
Carpet, pile over thick felt on concrete floor	0.05	0.07	0.25	0.5	0.5	0.6	0.65
Plaster, on solid backing	0.05	0.03	0.03	0.02	0.03	0.04	0.05

For most uses, the reverberation time should be the same for low, middle and high frequencies. A moderate rise in the bass reverberation time is acceptable for speech, and is often considered preferable for music. In large auditoria, the high-frequency reverberation time inevitably falls because the enclosed air has a high absorption value. In any case, allowance must be made for the absorption of the audience, usually the greatest single component.

The acoustical shortcomings inevitable in multi-purpose auditoria can be alleviated by installing an electro-acoustic enhancement system such as the assisted resonance system at the Royal Festival Hall in London. A variety of competing systems are now available.

3 ROOM SHAPE AND QUALITY

3.01 Preferred dimensions – large auditoria

The size of a room is usually determined by factors other than the acoustics. Very large auditoria are difficult to fill with sound. Most of the direct sound will never reach the remoter parts, and the large surface area produces a corresponding absorption resulting in a weak level of reverberant sound. Little evidence for an ideal set of proportions exists for auditoria of conventional shape. Unconventional shapes introduce the risk of incorporating intolerable defects which prove impracticable to correct.

Successful traditional concert halls are usually rectangular both in plan and section, e.g. Symphony Hall, Boston. This shape is convenient, and produces the reverberation time of up to two seconds preferred for symphonic music. With careful design, modern halls of non-rectangular shape can be extremely successful, a particular example being St David's Hall, Cardiff. Where a shorter reverberation time is desired, other shapes are satisfactory, such as the horseshoe of the traditional opera house, and the fan for a theatre. The likelihood of audible echoes in large auditoria can usually be predicted, but conditions producing them are too various to summarise. Elimination of echoes is often expensive rather than technically difficult, an elegant example being the 'flying saucers' in the Royal Albert Hall, London.

Auditoria for speech and drama have clarity as a prime requirement. The shape should ensure that the audience receives strong sound reflections immediately after the direct sound. For musical performances, many prefer early sound reflections arriving at the listener from a lateral direction.

3.02 Preferred dimensions – small rooms

Small rooms can present serious acoustical problems, being often bedevilled with colouration, that is, the excessive accentuation of one or more notes of particular pitches. We particularly notice this phenomenon in bathrooms and telephone boxes, and it comes from the fact that the dimensions of these small rooms are comparable with the wavelengths of speech. The wavelength λ in m of a tone of frequency f in Hz is given by $\lambda = c/f$ where c is the velocity of sound (approximately 340 m/s in air). Colourations are particularly evident in rectangular rooms where the length, breadth and height bear a simple numerical ratio to each other; the theory for this is well understood. However, the ideal proportions have still to be discovered.

3.03 Acoustical models

It has become quite usual to build a scale model of a proposed auditorium for acoustical testing. Any defects revealed by the tests can be dealt with before the full-scale auditorium is built. Models are particularly useful where an auditorium of novel shape is being considered.

The scale factors range from 1:50 to 1:8. The 1:50 model gives less accurate results than models of larger scale, but this disadvantage is generally outweighed by the lower costs of building, testing and modifying the smaller model.

An alternative is to build a digital computer model of the proposed auditorium. A number of programmes are available which claim adequately to simulate the behaviour of sound in a mathematical model of the room. More recent digital simulation programmes claim to enable the designer to listen to sounds processed by the computer as though the listener were present in the completed hall.

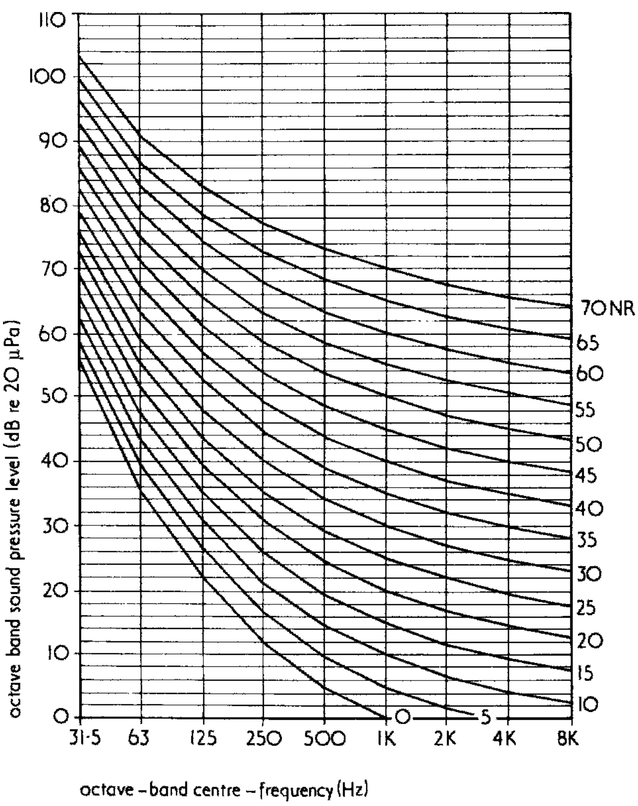
4 NOISE

4.01 Noise criteria

As the human ear is most sensitive to frequencies between 1 and 3 kHz, a 1 kHz tone will sound much louder than a 100 Hz tone of the same sound pressure level. Any measuring of loudness must take this frequency sensitivity into account, and the simplest of sound-level meters has a device which roughly compensates for it called the A-weighting network. Readings from such a meter are designated A-weighted sound pressure levels (symbol L_{pA}) to distinguish them from plain unweighted dB SPL (symbol L_p). Although the loudness and annoyance of a sound can depend on other factors than the A-weighted sound pressure level, it is a useful measure for many of the sounds encountered in and around buildings.

A building performance specification may contain criteria expressed in A-weighted sound pressure levels for various areas, but where ventilation noise is likely to be significant, it is more usual for them to be given in Noise Criteria (NC) curves, or the similar Noise Rating (NR) curves, **41.2**. These plot octave-band SPL against frequency. If NR-35 is specified, for example for a private office, then the noise level in any octave band should not exceed that indicated for the NR-35 line on the graph. The preference for the NC and NR criteria rather than the A-weighted SPL criterion arises from the octave-band data used in the design of mechanical services systems.

Noise criteria are commonly specified as maxima rather than optimal levels, and this is a reflection of frequent failures to meet the criteria many years ago. Unexpectedly, noisy systems are now much less likely and the consequences of systems, which are too, quiet are now often a matter of some concern. An office may be so quiet that private conversation can easily be overheard and occasional outside noises may be particularly distracting. In such a circumstance, a continuous masking (sometimes called *white*) noise may be deliberately introduced to help to drown other sounds, using loudspeakers or by increasing the ventilation system noise.



41.2 *Noise rating curves*

Apart from A-weighted SPL, NC and NR ratings for noise, there are others the architect may encounter. Each has its merits, but most require rather more than a simple sound level meter for measurement. Some of these are:

$L_{A10,T}$ — The A-weighted sound pressure level of a noise exceeded for 10% of a given time interval T

$L_{A10,(18\,h)}$ — The average of the values of L10 measured hourly between 06.00 and 24.00 h on a normal working day. Used for planning and design as an index of road traffic noise

$L_{Aeq,T}$ — The equivalent continuous A-weighted sound pressure level. This is the notional constant sound level which would give the same A-weighted sound energy as that of the actual varying sound over a specified period of time, T. This has become the preferred index for characterising a wide range of different kinds of sounds which are not steady. $L_{Aeq,T}$ is used in a number of countries for rating industrial and transport noise.

$L_{Ar,T}$ *rating level* — The measured equivalent continuous A-weighted sound pressure level plus any adjustment for the character of the noise. An adjustment would commonly be made for whines, hisses, screeches, hums, bangs, clicks, clatters or thumps.

All the above are measured in decibels. Considerable confusion may arise if the particular index is not identified in each case.

4.02 Internal noise sources

Because effective noise insulation is often impractical and usually costly, noise-producing areas should be sited away from noise sensitive areas. In modern non-industrial buildings, the mechanical plant room is likely to be the noisiest area, especially if it contains heavy and inherently unbalanced plant. Chillers and large boilers can present severe noise problems particularly at low frequencies where curative measures are difficult. A buffer zone formed by a corridor or storage area around the plant room is a useful noise control measure.

The airborne noise radiated by industrial machinery can usually be calculated sufficiently accurately using the manufacturer's sound power level data. If the calculated noise level is too high, the reverberant noise level can be reduced by lining part of the plant room surfaces with an efficient acoustical absorbent; otherwise more costly measures may be necessary. The noise transmitted into the structure of the building via the machinery mounts, etc. is much more difficult to estimate. This is because the basic mechanical noise-generating characteristics of the machine are generally not known, and also because the ways in which sound propagates through building structures are imperfectly understood. In designing noise-isolation measures, rule-of-thumb methods are frequently used. They do not always work, and a long and expensive investigation is then needed to discover why; sound may easily propagate through structures with relatively little attenuation.

Many structure-borne noise problems are avoided by siting the plant room in a basement. When specifying ventilation noise levels, etc. the designer should take into account the noise arising from activities within the areas served, so that the criteria are compatible. In some circumstances, impact noise from footsteps can be a problem.

As well as the effects on people within the building, due consideration must be given to the effects on the neighbourhood. Roof-mounted cooling towers may produce a noise problem in residential areas. Discotheques, nightclubs and other performance venues employing high-powered amplification systems are a potential noise nuisance. Planning conditions are often imposed on such developments and the planning authority may need convincing that adequate sound-insulation measures will be incorporated.

4.03 External noise sources

The most important kind of external noise affecting buildings is transport noise from road traffic, aircraft and railways. An essential characteristic of such sources is that they are not generally under the control of those affected by their noise. It is therefore essential to assess the likely level of external noise to which a proposed building is to be subjected. If this is done early enough in the design process, the scheme can be economically produced to alleviate the effects of the noise.

An example of planning against noise profoundly influencing the design is the five- to eight-storey Byker Wall in Newcastle upon-Tyne. Here, a barrier against the noise from an adjacent motorway is formed by a long block of flats. The flats all have small windows facing the motorway and the noise-sensitive rooms are on the quiet side of the barrier. The whole structure protects more conventional dwellings on the side remote from the traffic.

Where the source of noise is known, it is often possible to calculate the likely noise level from its characteristics and the geometry of the site. In the UK, there is now an official procedure for calculating the noise from motor vehicles, and this is recommended as preferable to measurement. At first sight this seems strange, but in practice it can be difficult to achieve a valid measurement. Some cynics have suggested that in the British Isles the prevailing wind direction and speed and the rainfall are such that valid 18-h traffic noise measurements are impossible except on a few days in the year!

Other sources of transport noise, such as railways, are not so well documented; direct site measurements may be the only course to take. In the case of the International Conference Centre in Birmingham with its concert hall and a railway line underneath, the main problem was structure-borne sound. A major part of the building was constructed on foundations incorporating vibration isolating elements.

Aircraft are a well-publicised source of serious noise, and there are usually severe planning restrictions on dwellings close to airports. However, hotels are often built here, and with care in siting and design the noise problems can be successfully overcome. Public concern about jet engine noise has led to the development of quieter engines, and we can look forward to a diminution of the problem as the older aircraft are replaced. Other sources of noise that may have to be considered in particular situations include helicopters, hovercraft and industrial plant.

5 SOUND INSULATION

When a sound wave strikes a wall, only a fraction of the incident sound energy is transmitted through the wall. The ratio of the incident to the transmitted sound energy, expressed in decibels, is called the sound reduction index. It can be properly measured only in a laboratory. The reduction in sound pressure level between adjacent rooms in an actual building depends not only on the sound reduction index of the separating wall, but also upon its area, the acoustic absorption present in the receiving room and the amount of transmission by *flanking paths* (see **5.04**). Neglecting flanking transmission, the relation between the average sound level difference between two rooms and the sound reduction index of the separating wall is

$$L_{p1} - L_{p2} = R + 10\log(A/S)$$

Where L_{p1} = sound pressure level averaged over the room containing the source
L_{p2} = sound pressure level averaged over the receiving room
R = sound reduction index of the separating wall
S = area of separating wall in m^2
A = acoustic absorption of receiving room in m^2 units.

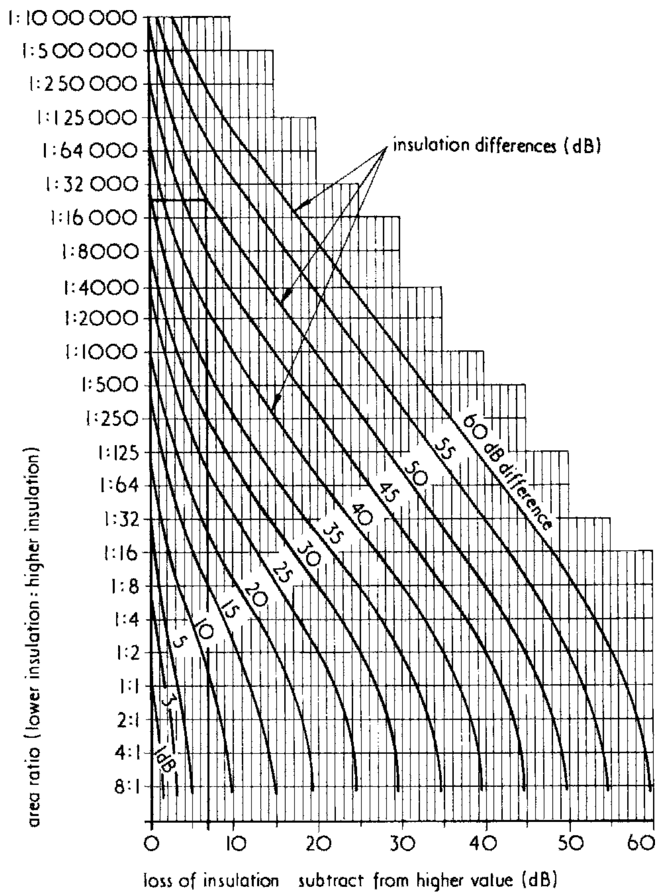
Often A is comparable in size to S, making the level difference $L_{p1} - L_{p2}$ vary little from the sound reduction index R so that it is commonly referred to simply as the 'sound insulation'.

5.01 Composite insulation

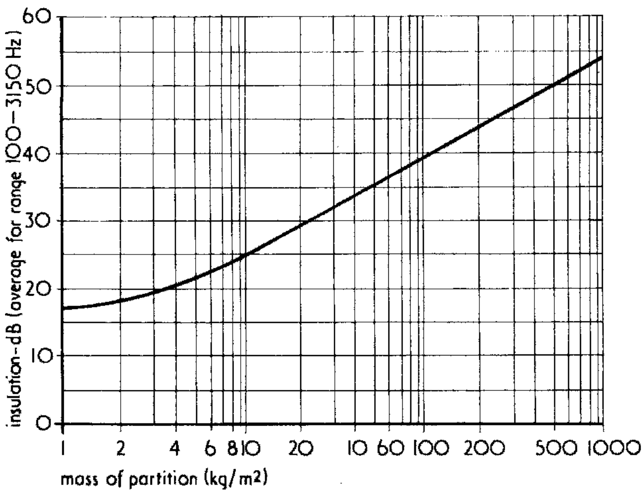
41.3 is an aid for calculating the sound insulation of a partition composed of two different materials. Consider a wall consisting of brickwork with insulation 45 dB and a glazed area amounting to one-fifth the total wall area of insulation 25 dB. On the vertical axis of **41.3**, the area ratio 1:4 meets the 20 dB difference curve at 13 dB on the horizontal axis. The composite insulation is therefore 45 − 13 = 32 dB.

5.02 Mass law

To a first approximation the insulation of a single leaf wall or floor depends on its mass per unit area. From **41.4** the insulation



41.3 *Variation in construction. An extreme example: a storey-height crack 0.2 mm wide in a wall of 10 m^2 could result in an insulation loss of 7 dB (From Guidance Note: Sound Insulation, HMSO, 1975)*



41.4 *Relationship of sound insulation to mass per unit area (from same as* **41.3***)*

averaged over the frequency range 100–3150 Hz increases by about 5 dB for each doubling of mass (the *mass law*).

5.03 Coincidence effect

The sound insulation also increases by 5–6 dB for each doubling of frequency provided the partition is very limp, for example a lead sheet. However, most partitions are fairly stiff. With some materials the stiffness combines with the mass in such a way as to produce a resonance effect, seriously reducing the insulation below the mass-law value. This resonance, called the coincidence effect, is caused by flexural waves in the partition, and its significance depends on its nature and thickness. For a 215 mm brick wall, the effect occurs at about 100 Hz, which is generally too low to matter. Window glass has coincidence frequencies in the upper audible range.

5.04 Flanking transmission

In real buildings, sound is transmitted from one room to an adjacent room via many paths, **41.5**. Where the separating wall has a sound reduction index of 35 dB or less, most of the sound is transmitted through the wall. If, however, we try to improve the insulation by using a heavier wall, the *flanking paths*, or indirect transmission routes, become more important. In fact, it is difficult to achieve better than 60 dB sound level difference without special measures, such as carefully designed structural discontinuities, to reduce the flanking transmission.

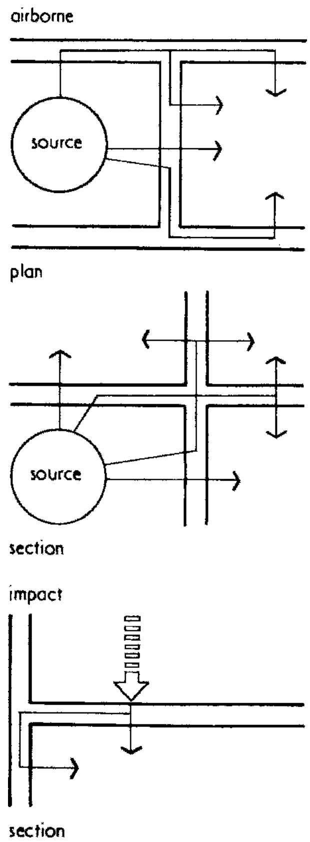
5.05 Openings

Any kind of opening in a partition will seriously impair the sound insulation. The effect can be assessed by using **41.3**, and assigning a value of 0 dB for the insulation of the opening.

5.06 Double walls

Two single walls, each of 30 dB sound insulation, when combined would not produce 60 dB but only about 35 dB; the doubling of the mass per unit area adding 5 dB by the mass law. However, separating the two walls several metres apart would, if there were no flanking transmission, approach 60 dB. Practical double walls lie between these extremes, but it is difficult to theorise how a particular combination will actually behave.

Double walls and multi-leaf partitions are used where the required mass of a single leaf would be excessive. They improve dramatically on the mass law at middle and high frequencies, but at low frequencies the insulation is usually little better, and sometimes worse than a single leaf of the same mass per unit area.



41.5 *Sound transmission paths (from same as* **41.3***)*

5.07 Floors

The insulation of floors against airborne sound follows the same laws as for walls. An additional problem is the direct structural excitation of a hard-surfaced floor by footsteps, **41.5c**. If a carpet is unacceptable, a floating floor must be used if footstep noise is to be reduced in the room underneath. The resilient element for such a floor may be of mineral wool, slab or blankets, rubber, expanded polystyrene or springs, but it is essential that the particular material that is chosen is known to be effective and durable. Care must be taken not to bridge this resilient element with any rigid connection to the base floor.

The airborne sound insulation of a floor can be improved by suspending an impermeable ceiling below it, but the improvement is often limited by structural limitations on its weight and by height considerations.

5.08 Windows

The windows are usually the weakest part of the envelope where sound insulation is concerned. The mass per unit area of the glazing is generally small compared with the rest of the envelope. Table II is a guide to the sound insulation of different windows. In order to obtain the highest insulation double glazing will be required, at least one pane of which is sealed. Specially, designed sound-attenuated ventilation will then be required.

5.09 Doors

Single doors having a sound insulation greater than 35 dB are expensive and difficult to install. Seals are required around the edge to prevent leakages, and where these are effective they make the door hard to open and close. Magnetic door seals similar to those on refrigerators are a small improvement. The most effective solution where the space is available is the use of two moderately insulating doors separated by an absorbent-lined 'sound lock'.

Table II Sound insulation of windows (from BRE Digest 140)

Description	Sound reduction (av. 100–3150 Hz)
Any type of window when open	About 10–15 dB
Ordinary single openable window closed but not weather-stripped, any glass	Up to 20 dB
Single fixed or openable weather-stripped window, with 6 mm glass	Up to 25 dB
Fixed single window with 12 mm glass	Up to 30 dB
Fixed single window with 24 mm glass	Up to 35 dB
Double window, openable but weather-stripped, 150–200 mm air space, any glass	Up to 40 dB
Double window in separate frames, one fixed, 300–400 mm air space, 6–10 mm glass, sound-absorbent reveals	Up to 45 dB

5.10 Barriers

Barriers that intercept the line-of-sight between a sound source and the receiver are a common method of reducing a noise level. Outdoors, they are used as a shield against traffic and aircraft noise, and some types of machinery. Indoors, they are used in open-plan offices and schools, and for altering the acoustics of broadcasting and recording studios.

The psychological effect of a visually opaque barrier can be very strong, giving a misleading impression of its acoustical effectiveness. For example, a line of trees is often proposed as a sound barrier although the measured acoustical effect is small. A bank of trees about 9 m in depth would be needed to provide an adequate acoustic screen for a motorway, for example.

There have been extensive theoretical studies on the effectiveness of barriers in idealised situations, but not much has resulted which can be applied in practice. Quite apart from the nature and geometry of the barrier itself, its performance can depend appreciably on the frequency of the sound, the weather and the nature of the ground between source and receiver. As a rough guide, screen-type barriers 1–4 m high and mass about 10 kg/m^2 can give transmission losses of 5–20 dB.

5.11 Enclosures

Enclosures are used to suppress the noise from a stationary machine or item of plant such as a diesel generator. For them to be effective, they should have few or no openings. Where this is not possible because of the need to ventilate, properly designed attenuated air routes are required. The effectiveness of the enclosure is enhanced by lining internally with an acoustical absorbent. Telephone hoods are an example of a partial enclosure, the effectiveness of which depends on how well the user obstructs the opening.

5.12 Cost and the designer

Structures designed to give a higher-than-average degree of sound insulation, such as broadcasting studios, are usually costly. The mass law, providing only a 5 dB increase for doubling the material used, illustrates how quickly the law of diminishing returns sets in. Attempts to beat the mass law by installing double or multi-leaf partitions incur the penalty of loss of usable space.

It is usually difficult to increase the sound insulation of an existing modern building. Older buildings of heavy construction have been successfully converted into broadcasting and recording studios. Several local radio stations in the UK can bear witness to this.

Because it is generally costly to increase sound insulation, the acoustical designer is rarely allowed the luxury of a safety margin. Unfortunately, the design of sound-insulating structures is still an imprecise science, and an economically designed building can fail to meet the expected performance. No reputable and knowledgeable acoustical consultant will guarantee the success of his or her design, any more than a doctor would guarantee to cure a patient. The acoustical consultant's task is to achieve the right balance between a design that is too costly initially and one for which failure would be disastrous.

6 ACOUSTICAL TEST DATA

Laboratory test data when required as proof of performance should be conducted in accordance with the relevant ISO standards and it is suggested that NAMAS or UKAS accredited data is a positive indication of a high level of accuracy regarding the repeatability and reproducibility of the test results. With regards to on site test data, it is now required in England and Wales and under the code for sustainable homes that testing be conducted by either a UKAS or ANC registered tested. For the rest of the UK, it is suggested that where on site performance testing is conducted the tester be a registered member of the Institute of Acoustics.

7 STANDARDS AND CODES OF PRACTICE

There are a growing number of national, European and international standards and codes of practice, some of which are listed in the Bibliography at the end of this chapter. These are invaluable in defining the methods used in testing acoustical materials, measuring environmental noise, traffic noise, etc. These advances enable a more objective assessment to be made of an acoustical material, device or situation.

8 LEGISLATION

The architect has now to take into account a growing body of legislation concerned with reducing the objectionable effects of noise generated within his or her building, and the effects of external noise sources on the occupants. The Building Regulations lay down the requirements for sound transmission of walls, floors and stairs in dwellings. In addition, in England and Wales, the legislation also includes control of reverberation times in common areas as well as sound insulation and control of the acoustic environment within schools (detailed in Building Bulletin 93) and habitable areas (i.e. university halls).

In dwellings, the general requirement is that the relevant element shall resist the transmission of airborne/impact sound. Useful guidance on methods to achieve the requirements is given in Approved Document E (for England and Wales), Technical Booklet G/G1 (for Northern Ireland) or Section 5 (for Scotland). In addition, compliance with the legislative guidance in England and Wales can be achieved by constructing in accordance with the details issued under the Robust Details.

Designers should be aware that completion in England and Wales is demonstrated by either undertaking a minimum of 10% on site testing or by registration with a compliance scheme (Robust Details). A higher percentage of acoustic testing would also be required should the designer wish to gain points under the Code for Sustainable Homes. Current regulations apply to conversions as well as to new constructions with differing requirements for each being applied in England and Wales. See Table III.

In other countries, other forms of legislative control apply. In the USA, the Environmental Protection Agency demands that a proposed development is preceded by an Environmental Impact Statement to show that no noise nuisance will result from it. European countries have specific noise limits for sanitary facilities such as WCs. Many countries have strict planning controls near known noise sources such as airports, and some provide financial assistance to insulate against sound in the proximity of motorways, etc.

Table III Sound insulation values for testing

Regulations	Walls		Floors	
	Mean value	Individual value	Mean value	Individual value
England and Wales ADE				
Dwelling-houses and flats – Purpose Built	$D_{nT,w} + C_{tr}$ 45 dB	N/A	$D_{nT,w} + C_{tr}$ 45 dB $L'_{nT,w}$ 62 dB	N/A
Dwelling-houses and flats – Purpose Built	$D_{nT,w} + C_{tr}$ 43 dB	N/A	$D_{nT,w} + C_{tr}$ 45 dB $L'_{nT,w}$ 64 dB	N/A
Scotland Section 5*				
Dwelling Houses – purpose built and conversion	$D_{nT,w}$ 53 dB	$D_{nT,w}$ 49 dB	$D_{nT,w}$ 52 dB $L'_{nT,w}$ 61 dB	$D_{nT,w}$ 48 dB $L'_{nT,w}$ 65 dB
Northern Ireland TB G /G1				
Dwelling Houses – purpose built and conversion	$D_{nT,w}$ 53 dB	$D_{nT,w}$ 49 dB	$D_{nT,w}$ 52 dB $L'_{nT,w}$ 61 dB	$D_{nT,w}$ 48 dB $L'_{nT,w}$ 65 dB
Dwelling Houses – conversion	N/A	$D_{nT,w}$ 49 dB	N/A	$D_{nT,w}$ 48 dB $L'_{nT,w}$ 65 dB

* Note: At the time of publication, the Scottish regulations were under review

9 BIBLIOGRAPHY

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ISO EN BS 717 *Methods for rating the sound insulation in buildings and of building elements*

BS 3638 *Method for measurement of sound absorption in a reverberation room*

BS 6864 *Laboratory tests on noise emission from appliances and equipment intended for use in water supply installations*

BS 4142 *Method for rating industrial noise affecting mixed residential and industrial areas*

ISO 6242–3 *Building construction – Expression of user's requirements – Part 3: Acoustical requirements*

ISO 1996 *Acoustics – Description and measurement of environmental noise*

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Part 2 Acquisition of data pertinent to land use

Part 3 Application to noise limits

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42 Fire

CI/Sfb (K)
UDC: 614.84
Uniclass: U32

Beryl Menzies

Beryl Menzies is a consultant in fire safety

KEY POINTS:
- *Consider from first principles how a fire can start*
- *Then how can it grow?*
- *Will it threaten life, property or both?*
- *How can it be fought?*
- *How will people escape?*
- *Only after considering all these points, refer to regulations.*

Contents

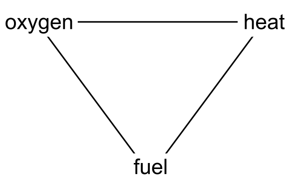
1 INTRODUCTION

When designing a building with fire safety in mind, particularly ease of escape, it is important not to forget the needs also for usability and security. If the fire measures are seen to be too onerous (for example, a multiplicity of fire doors) they will be circumvented (propped open) and their purpose will be frustrated. Fire escape doors are often weak points when it comes to unauthorised ingress, particularly in places of public assembly.

2 COMPONENTS OF FIRE

2.01

Fire is combustion producing heat and light. Combustion will occur and continue if three factors are present: oxygen, heat and fuel. These are generally referred to as the combustion triangle, **42.1**.



42.1 *Triangle of fire*

2.02

Fire can be extinguished by removing one side of the combustion triangle:

- Starve or limit the fuel by removing it
- Smother by limiting or stopping the further supply of oxygen, or
- Cool by dissipating the heat faster than it is generated.

2.03

A source of heat comes into contact with a combustible material (the fuel) which ignites and supports combustion while oxygen is present. The heat sources within a building are many – cooking, smoking, heating equipment, overheating/faulty equipment (particularly electrical).

2.04

Three kinds of fuel have been identified:

- Tinder, material ignitable by a match which will continue to burn after its removal
- Kindling, material which will ignite and burn if associated with sufficient tinder, but in which a match will not produce a continuing fire, and
- Bulk fuel, which needs kindling to cause to burn.

2.05

The fuel may be present in the building structure, fittings and/or contents and can be in the form of solids, liquids or gases. Most organic materials will burn. Certain materials spontaneously combust and care is required in their storage, e.g. linseed oil, certain chemicals, grains. Certain industrial processes involving high levels of dust, e.g. printing, flour mills, can result in flash fires. Specialist advice should be sought in respect of these matters.

2.06

The initial source of heat cannot ignite most bulk fuels unless the fire is able to follow the tinder-kindling chain. Of course, this does not apply when the bulk fuel is itself highly combustible; but it does apply to elements of building construction and to many stored materials.

This leads to the point that fire risks in most buildings can be greatly reduced if measures are taken to avoid build-ups of tinder. Dust, waste paper, sawdust, rags, etc are materials which will act as tinder; so will a number of man-made organic materials which are now coming under stricter control.

2.07 Smoke

This is formed when organic materials decompose by heat giving off tarry and sooty decomposed materials. It is likely that most smoke will be generated by the building contents.

2.08 Heat

This can be transmitted in three forms:

- Conduction – heat energy is passed from one molecule to the next. The conductivity of a material (which varies with the material) may affect the fire resistance of a component or structure. A steel member in contact with combustible materials may transfer the heat generating a fire or damage away from the original source.
- Radiation – heat is transmitted in straight lines without any contact between the radiating material and the target which may absorb or reflect the heat. The intensity reduces inversely as the square of the distance from the source of radiation. Combustible materials placed in close proximity to a radiant fire will ignite.
- Convection – only occurs in liquids and gases. The heated combustion gases become buoyant and rise through voids and shafts with the potential of causing ignition in other areas of a building.

3 PRINCIPLES OF FIRE PROTECTION

Note: specific recommendations relating to periods of fire resistance for specific uses, structural elements etc are given in various codes only some of which are referred to here.

3.01 Potential problems

- Unrestricted growth and spread of a fire within a building that will cause extensive damage and may result in its collapse,
- Rapid spread of fire across surfaces within the building, ignition of adjacent fuels, means of escape prejudiced,
- Spread of fire, smoke and hot gases in a building through ducts, voids and shafts affecting the means of escape, access for fire-fighters and causing extensive damage to decorations and property,
- Spread of fire to adjacent buildings affecting life safety and property,
- Loss of contents, disruption of work, loss of trade/production.

3.02

The aim of fire precautions within a building is to inhibit the growth and to restrict the spread of any fire. The influencing factors are:

- The size of building – area, height, volume
- The layout and configuration within the building
- The uses accommodated, and the requirements of the occupants
- The construction materials, linings and claddings
- The type of construction
- The services installed
- The furniture.

3.03

The precautions are:

- Protection of loadbearing structure to prevent untimely collapse, limitation of combustibility of key structural elements
- Adequate and appropriate provisions for means of escape
- Access for firefighters up to and through the building to reach the seat of the fire and promptly extinguish it
- Compartmentation and separation to restrict spread of fire, maintenance of these by protection of openings, fire stopping and cavity barriers within concealed spaces
- Safe installation and maintenance of services, heat-producing equipment and user equipment
- Separation of different uses to protect, for example, a risk to sleepers from commercial uses
- Enclosure of high risks with fire-resisting construction to protect adjacent areas
- Active fire-extinguishing installations to detect and/or contain fire in its early stages and restrict its spread and growth
- Limitation of flame spread by selective use of materials
- Fire-resisting external walls and/or space separation to prevent spread of fire to adjacent properties, protection of openings in external walls, limited flame spread across external walls and roofs, use of insulation with limited combustibility to restrict ignition and spread
- The provision of natural or mechanical ventilation, smoke extraction and/or smoke control measures to facilitate means of escape and firefighting
- Management training and procedures for evacuation, maintenance of fire precautions, risk analysis, management policy.

3.04 Growth and spread

An analysis of the growth and spread of fire is explained in detail and substantiated by Malhotra in BRE publication BR 96 *Fire Safety in Buildings.*

3.05 Fire load and ignitability

The majority of a fire load within a building will be its contents, over which a designer may have no influence. Some types of occupancies have controls relating to the ignitability of furniture (domestic and assembly buildings under licensing legislation, hospitals and prisons under government directives), Table I. Electricity, often cited as the cause of fires, while not it itself a risk presents a potential hazard

Table I Classification of purpose groups (from Approved Document B, Table DI)

Title	Group	Purpose for which the building or compartment of a building is intended to be used
Residential (dwellings)	1(a)*	Flat or maisonette.
	1(b)**	Dwellinghouse which contains a habitable storey with a floor level which is more than 4.5 m above ground level.
	1(c)**	Dwellinghouse which does not contain a habitable storey with a floorlevel which is more than 4.5 m above ground level
Residential (Institutional)	2(a)	Hospital, home, school or other similar establishment used as living accommodation for, or for the treatment, care or maintenance of persons suffering from disabilities due to illness or old age or other physical or mental incapacity, or under the age of 5 years, or place of lawful detention, where such persons sleep on the premises.
(Other)	2(b)	Hotel, boarding house, residential college, hall of residence, hostel, and any other residential purpose not described above.
Office	3	Offices or premises used for the purpose of administration, clerical work (including writing, book keeping, sorting papers, filing, typing, duplicating, machine calculating, drawing and the editorial preparation of matter for publication, police and fire and rescue work), handling money (including banking and building society work), and communications (including postal, telegraph and radio communications) or radio, television, film, audio or video recording, or performance (not open to the public) and their control.
Shop and Commercial	4	Shops or premises used for a retail trade or business (including the sale to members of the public of food or drink for immediate consumption and retail by auction, self-selection and over-the-counter wholesale trading, the business of lending books or periodicals for gain and the business of a barber or hairdresser and the rental of storage space to the public) and premises to which the public is invited to deliver or collect goods in connection with their hire repair or other treatment, or (except in the case of repair of motor vehicles) where they themselves may carry out such repairs or other treatments.
Assembly and Recreation	5	Place of assembly, entertainment or recreation; including bingo halls, broadcasting, recording and film studios open to the public, casinos, dance halls; entertainment-conference, exhibition and leisure centres; funfairs and amusement arcades; museums and art galleries; non-residential clubs, theatres, cinemas and concert halls; educational establishments, dancing schools, gymnasia, swimming pool buildings, riding schools, skating rinks, sports pavilions, sports stadia; law courts; churches and other buildings of worship, crematoria; libraries open to the public, non-residential day centres, clinics, health centres and surgeries; passenger stations and termini for air, rail, road or sea travel; public toilets; zoos and menageries.
Industrial	6	Factories and other premises used for manufacturing, altering, repairing, cleaning, washing, breaking-up, adapting or processing any article; generating power or slaughtering livestock
Storage and other non-residential†	7(a)	Place for the storage or deposit of goods or materials [other than described under 7(b)] and any building not within any of the purpose groups 1 to 6.
	7(b)	Car parks designed to admit and accommodate only cars, motorcycles and passenger or light goods vehicles weighing no more than 2500 kg gross.

* Includes live/work units that meet the provisions of paragraph 2.52 of Volume 2 of Approved Document B.

** Includes any surgeries, consulting rooms, offices or other accommodation, not exceeding 50 m^2 in total, forming part of a dwelling and used by an occupant of the dwelling in a professional or business capacity.

† A detached garage not more than 40 m^2 in area is included in purpose group 1(c); as is a detached open carport of not more than 40 m^2, or a detached building which consists of a garage and open carport where neither the garage nor open carport exceeds 40 m^2 in area.

when brought into contact with combustible material; all new electrical installations should be installed in accordance with the current edition of the regulations of the Institution of Electrical Engineers and existing installations periodically examined and tested for potential risks.

3.06 Smoke

The limitation of smoke spread is considered mainly as an aspect of safe means of escape. Specific limitations of smoke production are not, to date, generally specified. There is no generally accepted test related to smoke emission. The production of toxic gases which accompanies all fires would be very difficult to specify.

3.07 Combustibility

While it would be possible to construct a totally non-combustible building, it is not practical and not required by legislation; although some codes do relate means of escape to a classification based on the 'combustibility' of a building. Non-combustible materials should be used where hazardous conditions are anticipated or there is a need to maintain the integrity of a structure for the maximum time, e.g. a compartment wall or floor, or an escape stair in a high building.

3.08 Fire resistance

The need for an degree of fire resistance within a structure may be dictated by Building Regulations (Table II), insurance or damage-limitation requirements. The prevention of untimely collapse allows evacuation, containment of a fire and therefore protection of adjacent areas, and access for firefighters. This is essential in high-rise buildings. Factors relating to the need for fire resistance are building height and size, occupancy and anticipated fire severity. While a specific period of fire resistance may be specified and an element constructed accordingly, it should not be assumed that the period will be attained; it may be longer or shorter due to, among other factors, interaction with other elements or non-maintenance, or more severe fire conditions than those anticipated in the test.

Table II Minimum periods of fire resistance

Purpose group of building	**Minimum periods of fire resistance (minutes) in a:**					
	Basement storey[$] including floor over		**Ground or upper storey**			
	Depth (m) of a lowest basement		**Height (m) of top floor above ground, in a building or separated part of a building**			
	More than 10	**Not more than 10**	**Not more than 5**	**Not more than 18**	**Not more than 30**	**More than 30**
1 Residential:						
a. Block of flats						
– not sprinklered	90	60	30*	60**†	90**	Not permitted
– sprinklered	90	60	30*	60**†	90**	120**
b. Institutional	90	60	30*	60	90	120#
c. Other residential	90	60	30*	60	90	120#
2 Office:						
– not sprinklered	90	60	30*	60	90	Not permitted
– sprinklered[2]	60	60	30*	30*	60	120#
3 Shop and commercial:						
– not sprinklered	90	60	60	60	90	Not permitted
– sprinklered[2]	60	60	30*	60	60	120#
4 Assembly and recreation:						
– not sprinklered	90	60	60	60	90	Not permitted
– sprinklered[2]	60	60	30*	60	60	120#
5 Industrial:						
– not sprinklered	120	90	60	90	120	Not permitted
– sprinklered[2]	90	60	30*	60	90	120#
6 Storage and other non-residential:						
a. any building or part not described elsewhere:						
– not sprinklered	120	90	60	90	120	Not permitted
– sprinklered[2]	90	60	30*	60	90	120#
b. car park for light vehicles:						
i. open sided car park[3]	Not applicable	Not applicable	15*+	15*+[4]	15*+[4]	60
ii. any other car park	90	60	30*	60	90	120#

Single storey buildings are subject to the periods under the heading 'not more than 5'. If they have basements, the basement storeys are subject to the period appropriate to their depth.

$ The floor over a basement (or if there is more than 1 basement, the floor over the topmost basement) should meet the provisions for the ground and upper storeys if that period is higher.

* Increased to a minimum of 60 minutes for compartment walls separating buildings.

** Reduced to 30 minutes for any floor within a flat with more than one storey, but not if the floor contributes to the support of the building.

Reduced to 90 minutes for elements not forming part of the structural frame.

+ Increased to 30 minutes for elements protecting the means of escape.

† Refer to paragraph 7.9 regarding the acceptability of 30 minutes in flat conversions.

Notes:
1. Refer to Table A1 for the specific provisions of test.
2. 'Sprinklered' means that the building is fitted throughout with an automatic sprinkler system in accordance with paragraph 0.16.
3. The car park should comply with the relevant provisions in the guidance on requirement B3, Section 11.
4. For the purposes of meeting the Building Regulations, the following types of steel elements are deemed to have satisfied the minimum period of fire resistance of 15 minutes when tested to the European test method:
   (i) Beams supporting concrete floors maximum Hp/A = 230 m^{-1} operating under full design load.
   (ii) Free standing columns, maximum Hp/A = 180 m^{-1} operating under full design load.
   (iii) Wind bracing and struts, maximum HP/A ~ 210 m^{-1} operating under full design load.
   Guidance is also available in BS 5950 Structural use of steelwork in building. Part 8 Code of practice for fire resistant design.

3.09 Fire compartments

These are formed around areas of different uses or hazards, or to divide an area into a size in which it is considered a fire could be contained and dealt with by firefighters, and thereby protecting adjacent areas. The addition of automatic active measures such as sprinklers to contain and control the growth of a fire allows larger compartments or, in some cases, their omission. If the only consideration is life safety, it can be argued that if all persons can safely escape there is no need for compartmentation, and the potential exists for reduced fire resistance. This principle is often adopted in low-rise or single-storey buildings. However, in the case of high-rise or buildings with phased or staged evacuation, compartmentation is an essential part of the safety package. Flats and maisonettes are constructed such that every unit is a compartment; in the event of a fire it is only necessary initially to evacuate the unit on fire.

Effective compartmentation requires attention to detail. Openings, including those for ventilation and services, must be protected; where shafts perforate compartment floors 'protected shafts' should be detailed, Table III.

3.10

Compartments within residential, institutional and health buildings require careful consideration as they form an essential part of the scheme for means of escape. All floors should be compartment floors. It is recommended that compartments do not exceed 2000 m^2 in multi-storey hospitals and 3000 m^2 in single-storey hospitals. In non-residential buildings floors over and generally within basements and any floor at a height of 30 m above ground level should be constructed as compartment floors.

3.11 Growth

To limit the growth of fire within the main structural elements is generally relatively easy provided that they do not contain large voids. The addition of linings and claddings can facilitate the rapid spread of fire beyond its area of origin. Flame can spread quickly in all directions and fixings are important. It has been found by experiment that the better the material is as an insulator, the greater the likelihood that flame spread will be more rapid and further.

3.12 Surface spread of flame

This is generally tested in accordance with BS 476 Part 7 1971, the results being classified 1 to 4 (Class 1 being very good, Class 4 very poor) on the basis of flame spread from the point of ignition. Class 0 is a classification defined for the purposes of recommendations under the building Regulations (not a British Standard). Current codes vary in their recommendations but generally all escape routes and circulation spaces should have Class 0, all other areas other than small rooms Class 1.

3.13 Ventilation

Ventilation to release heat and control and/or dispel smoke from a fire will allow easier and rapid access by fire fighters to extinguish a fire. Its relationship to means of escape is outlined elsewhere.

Ventilation can be natural or mechanical. The latter is preferable as it is controllable, can be activated automatically and, when designed correctly, not influenced by wind, internal layout and configurations, outside temperature or stack effect. It does, however, add considerable cost, as it is necessary to safeguard its operation by using fans tolerant of high temperatures, protected wiring, fire and smoke dampers, automatic detection, secondary

Table III Maximum dimensions of multi-storey non-residential buildings and compartments (from Approved Document B, Table 12)

Purpose group of building or part	Height of floor of top storey above ground level (m)	Floor area of any one storey in the building or any one storey in a compartment (m^2)		
		In multi-storey buildings		In single-storey buildings
Office	No limit	No limit		No limit
Assembly and recreation				
Shop and commercial:				
a. Shops – not sprinklered	No limit	2000		2000
Shops – sprinklered[1]	No limit	4000		No limit
b. Elsewhere – not sprinklered	No limit	2000		No limit
Elsewhere – sprinklered[1]	No limit	4000		No limit
Industrial[2]				
Not sprinklered	Not more than 18	7000		No limit
	More than 18	2000[3]		N/A
Sprinklered[1]	Not more than 18	14,000		No limit
	More than 18	4000[3]		N/A
	Height of floor of top storey above ground level (m)	**Maximum compartment volume m^3**	**Maximum floor area (m^2)**	**Maximum height (m)[4]**
		Multi-storey buildings	**Single-storey buildings**	
Storage[2] and other non-residential:				
a. Car park for light vehicles	No limit	No limit	No limit	No limit
b. Any other building or part:				
Not sprinklered	Not more than 18	20,000	20,000	18
	More than 18	4000[3]	N/A	N/A
Sprinklered[1]	Not more than 18	40,000	No limit	No limit
	More than 18	8000[3]		

Notes:
[1] 'Sprinklered' means that the building is fitted throughout with an automatic sprinkler in accordance with paragraph 0.16.
[2] There may be additional limitations on floor area and/or sprinkler provisions in certain industrial and storage uses under other legislation, for example in respect of storage of LPG and certain chemicals.
[3] This reduced limit applies only to storeys that are more than 18 m above ground level. Below this height the higher limit applies.
[4] Compartment height is measured from finished floor level to underside of roof or ceiling.

power supplies and monitoring. It may require sophisticated computerised controls.

3.14

Opinions vary on the design of mechanical smoke extract systems, and the need or otherwise to incorporate fail-safe measures. It is necessary to determine if the system is for smoke extraction or smoke control. There is no generally accepted comprehensive code for mechanical smoke control systems; specialist advice should be sought.

3.15 Natural ventilation

Natural ventilation by the provision of open, openable or breakable vents, is usually intended for operation by the firefighters who will take into consideration aspects of wind etc. Openings should aggregate not less than 5% of a total floor area within basements and areas of high or special risk, and 2.5% above ground. If vents are not accessible, they should be permanent, open automatically or open by remote control.

3.16

The use of natural ventilation in large open areas such as single-storey factories, auditoria, exhibition halls and the like will necessitate the formation of smoke reservoirs to restrict the spread of smoke. See BRE publications Digest 260, *Smoke control in buildings: design principles* and BR 186 *Design principles for smoke ventilation in enclosed shopping centres.*

3.17

Specific access for firefighters will allow their prompt action. Access is required up to, into, and through a building. Various dimensional information is given below but it should be remembered that fire equipment is not standardised; it is also constantly changing, giving many variations in sizes and weights.

If a building is provided with a fire main, access is required to within 18 m of the inlet to a dry riser or the access to a firefighting shaft containing a wet riser. The setdown point should be within sight of the dry riser inlet or shaft access.

No appliances should have to reverse more than 20 m. Dead-end roads should be provided with hammerhead turning spaces if longer than this, Tables IV, V and VI, **42.2** to **42.5**

3.18 Firefighting shafts

Access into the building should be provided via a firefighting shaft. In the cases of all buildings and those with deep basements this should incorporate a firefighting lift to transport equipment and personnel at speed. In all cases it should include a staircase 1.1 m in width between walls or balustrades, ventilated or pressurised, entered from the floor areas via a lobby, both of which are separated from the remainder of the building by 2-hour fire-resisting construction. BS 5588 Part 5 details the technical and dimensional specification for a firefighting shaft. The criteria for the provision and number of shafts in any particular building is set out in that Part of the BS 5888 series relating to the specific use or within Building Regulations. A firefighting lift can be one normally used for passengers; it should not be one used as a goods lift, **42.6**, **42.7**.

3.19

The spread of fire to adjacent buildings can be prevented by:

- Clear space
- Fire-resisting walls,
- External walls of limited combustibility and limited surface spread of flame, and/or
- Roof coverings resistant to penetration of fire.

If precautions are taken within a building to limit a fire's growth and spread, it can be assumed that its effects on an adjacent building are reduced. Openings in an external wall or walls having no fire resistance present weaknesses to an adjoining building by radiation and convection. If property protection in addition to life safety is a consideration, then all buildings should be considered as being of equal risk.

If life safety is the only factor, then residential, assembly and recreational uses are at greater risk from external fire sources, and

Table IV Fire service vehicle access to buildings not fitted with fire mains (from Approved Document B, Table 19)

Total floor area of building (m^2)	Height of floor of top storey above ground	Provide vehicle access to:	Type of appliance
up to 2000	up to 11 over 11	see paragraph 16.2 15% of perimeter	pump high reach
2000–8000	up to 11 over 11	15% of perimeter 50% of perimeter	pump high reach
8000–16,000	up to 11 over 11	50% of perimeter 50% of perimeter	pump high reach
16,000–24,000	up to 11 over 11	75% of perimeter 75% of perimeter	pump high reach
over 24,000	up to11 over 11	100% of perimeter 100% of perimeter	pump high reach

Table VI Dimensions required for fire appliances (see 42.3)

Dimension	Description	Type of appliance	
		Turntable ladder	Hydraulic platform
A	Maximum distance of near edge of hardstanding from building	4.9 m	2.0 m
B	Minimum width of hardstanding	5.0 m	5.5 m
C	Minimum distance of further edge of hardstanding from building	10.0 m	7.5 m
D	Minimum width of unobstructed space for swing of appliance platform	NA	2.2 m

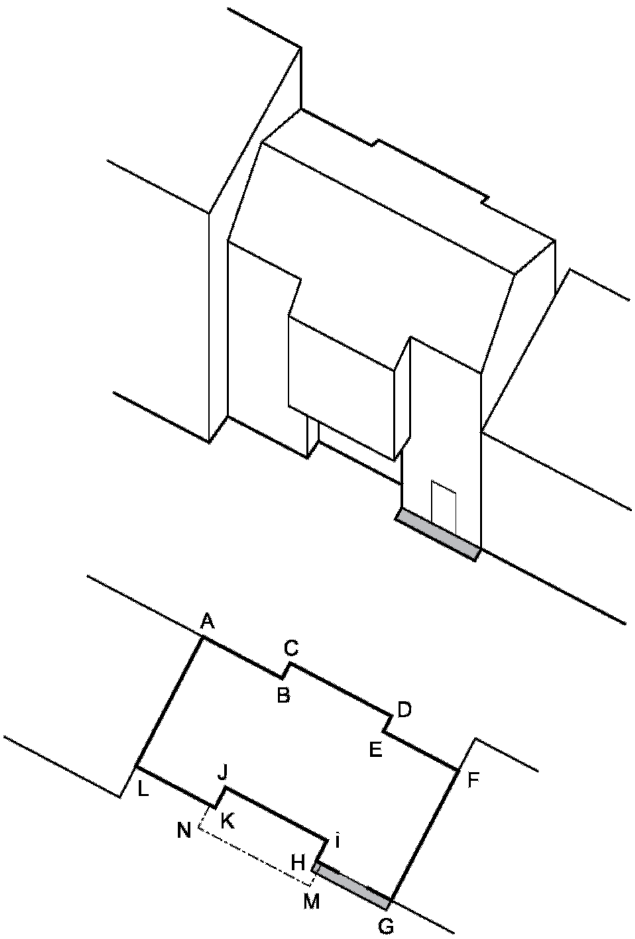
Table V Typical vehicle access route specification (from Approved Document B, Table 20)

Appliance type	Minimum width of road between kerbs (m)	Minimum width of gateways (m)	Minimum turning circle between kerbs (m)	Minimum turning circle between walls (m)	Minimum clearance height (m)	Minimum carrying capacity (tones)
Pump	3.7	3.1	16.8	19.2	3.7	12.5
High Reach	3.7	3.1	26.0	29.0	4.0	17.0

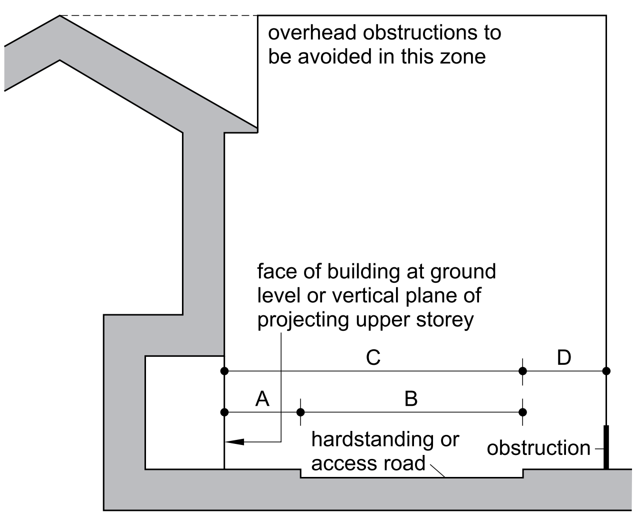
Notes:

(1) Fire appliances are not standardised. Some fire services have appliances of greater weight or different size. In consultation with the Fire Authority, Building Control Authorities and Approved Inspectors may adopt other dimensions in such circumstances.

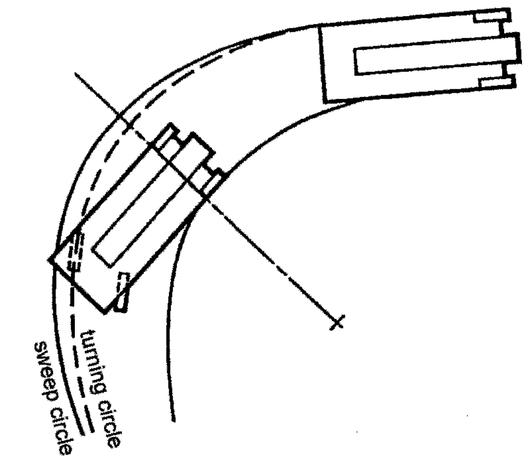
(2) Because the weight of high-reach appliances is distributed over a number of axies, it is considered that their infrequent use of a carriageway or route designed to 12.5 tonnes should not cause damage. It would therefore be reasonable to design the roadbase to 12.5 tonnes, although structures such as bridges should have the full 17 tonnes capacity.



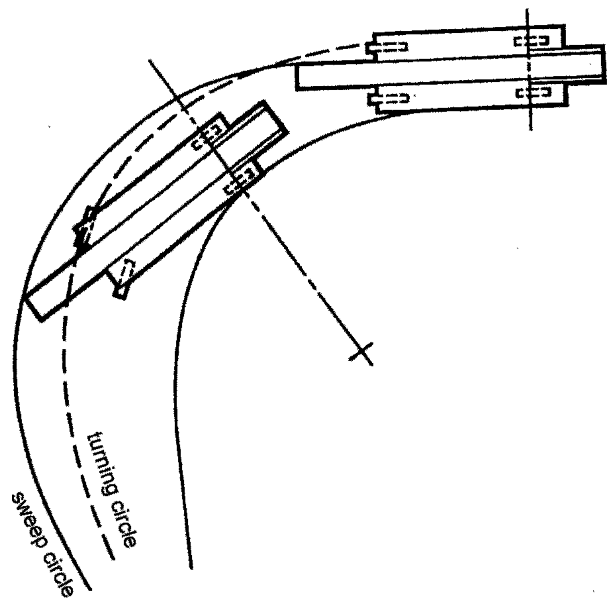
42.2 *Example of building footprint and perimeter. The building is AFGL where walls AL and FG are shared with other buildings. The footprint is the maximum aggregate plan perimeter found by the vertical projection of any overhanging storey onto a ground storey: i.e. ABCDEFGHMNKL. The perimeter for the purposes of the table is the sum of the lengths of the two external walls taking account of the footprint, i.e. (A to B to C to D to E to F) + (G to H to M to N to K to L). If the dimensions of the building require vehicular access by the table, the shaded area illustrates a possible example of 15% of the perimeter. Note the there should be a door into the building in this length. If the building has no walls common with other buildings, the lengths AL and FG would be included in the perimeter. From Approved Document Part B 2006*



42.3 *Relationship between building and hardstanding or access roads for high-reach fire appliances. For key, see Table VI. From Approved Document Part B 2006*



42.4 *A pumping appliance (drawing not to scale) Max length 8.5 m, max height 3.3 m, max width 2.3 m, max weight 13.21 ts, on front axle 5.5 ts, on rear axle 6.1 ts, max wheelbase 3.81 m, rear wheel track 2 m, ground clearance 229 mm, roadway width required 3.66 m, turning circle 16.75 m, sweep circle 18.3 m*

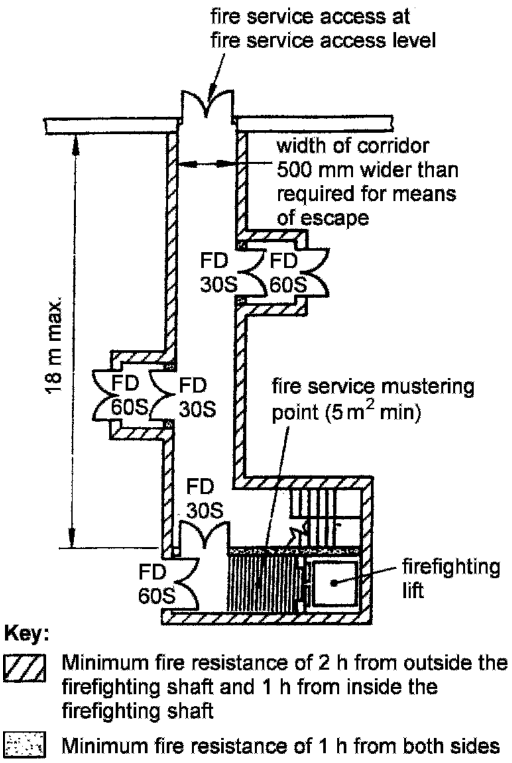


42.5 *A hydraulic platform and turntable ladders (drawing not to scale) max length 10 m, max height 3.5 m, max width 2.5 m, max width with jacks out 4.4 m, laden weight 16.25 t, av. weight front axle 6 t, av. weight rear axle 10 t, max wheelbase 5.33 m, rear wheel track 2 m, min ground clearance 229 mm, road width required 6 m, turning circle 21.5 m, sweep circle 24.5 m. The overhang of the booms on the headrest do not exceed 1.83 m from foremost part of the vehicle. Turntable ladders and hydraulic platforms ('cherry-pickers') are fitted with four ground jacks as stabilisers, for which the working load is normally less than 7.5 t*

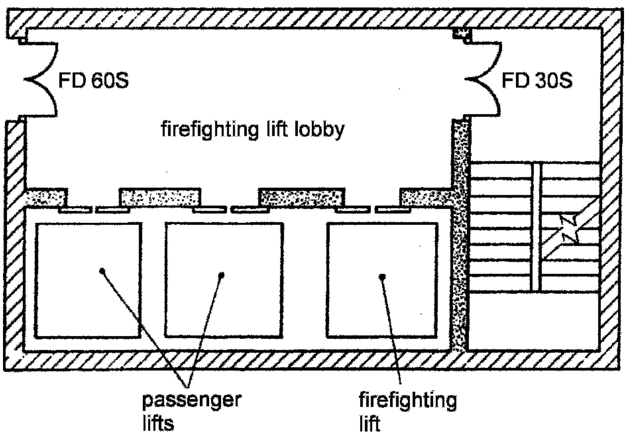
warrant additional safeguards. It is generally assumed that only one compartment is involved in a fire and as such the risk emanates only from its external enclosures.

3.20

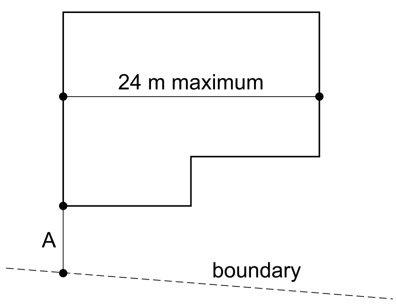
Methods generally used for determining the necessary degrees of protection are based on acceptable percentages of 'unprotected areas' (openings, non-fire-resisting walls, combustible claddings and insulation) having regard to heat radiation exposure from a known use. The basis of the necessary calculations are set out in BRE document BRE 187 *External fire spread: building separation and boundary distances;* Approved Document B makes recommendations



42.6 *Typical firefighting shaft layout at fire service access level, access via a corridor*



42.7 *Passenger lifts within the firefighting shaft. Firefighting lobbies should have a clear floor area of not less than 5 m^2. The clear floor area should not exceed 20 m^2 for lobbies serving up to four lifts, or 5 m^2 per lift for lobbies serving more. All principal dimensions should be not less than 1.5 m and should not exceed 8 m in lobbies serving up to four lifts, or 2 m per lift in lobbies serving more*



42.8 *Permitted unprotected areas in small residential buildings*

Table VII Unprotected areas for small resedential buildings. See 42.8 (from Approved Document B, Vol 1, Diagram 22)

Minimum distance (A) between side of building and relevant boundary (m)	**Maximum total area of unprotected areas (m^2)**
1	5.6
2	12
3	18
4	24
5	30
6	no limit

Table VIII Permitted unprotected areas in small buildings or compartments (from Approved Document B, Table 15)

Minimum distance between side of building and relevant boundary (m)		**Maximum total percentage of unprotected area (%)**
Purpose groups Residential, Office, Assembly and Recreation (1)	**Shop and Commercial Industrial, storage and other Non-residential (2)**	**(3)**
n.a	1	4
1.0	2	8
2.5	5	20
5.0	10	40
7.5	15	60
10.0	20	80
12.5	25	100

Notes:
n.a. = not applicable.
(1) intermediate values may be obtained by interpolation.
(2) For buildings which are fitted throughout with an automatic sprinkler system, meeting the relevant recommendations of BS 5306 Part 2, the values in columns (1) and (2) may be halved, subject to a minimum distance of 1 m being maintained.
(3) In the case of open-aided car parks in purpose group 7(b) the distances set out in column (1) may be used instead of those in column (2).

in relation to small buildings or compartments, both residential in Table VII and **42.8** and non-residential in Table VIII.

3.21

Combustible claddings and insulation present a risk, especially in tall buildings. While claddings and their supports are not always required to be fire-resisting, insulation at a height exceeding 15 m is recommended to be of limited combustibility, **42.9.**

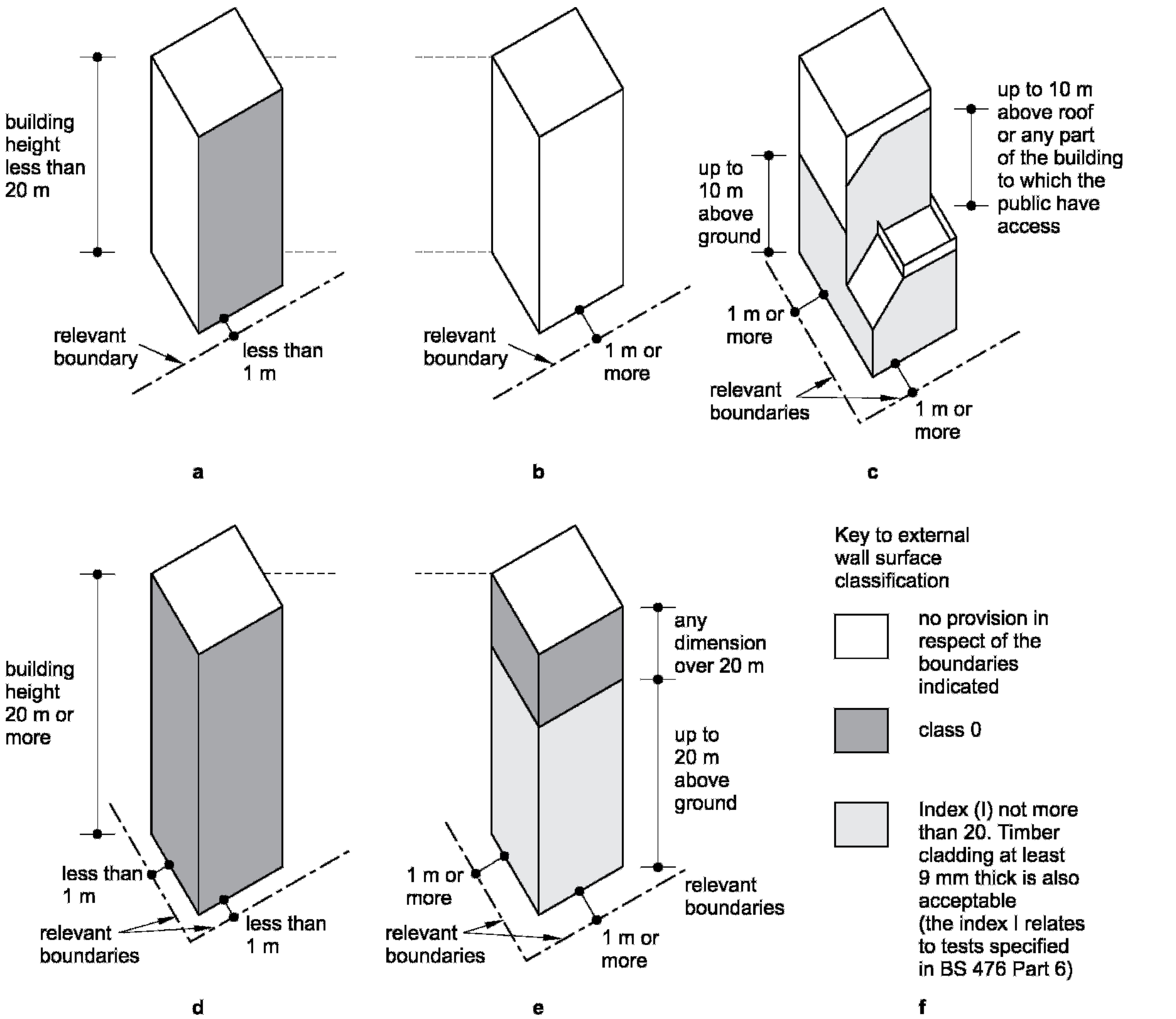
3.22 Roof coverings

Roof coverings (not structures) in close proximity to boundaries should have limited flame spread and penetration to fire. The performance of coverings is designated by reference to BS 476 Part 3 which classifies the results on the flame spread and time taken to penetrate; AA being the best (specimen not penetrated within one hour, no spread of flame), DD the worst (penetrated in preliminary flame test, extensive and continuing spread of flame). The addition of a suffix 'x' denotes one or more of dripping from the underside, mechanical failure, development of holes. Approved Document B sets out specific classification recommendations relating to distances from the boundary, Table IX together with recommendation for plastic rooflights, **42.10** and Table X.

4 MEANS OF ESCAPE

4.01

There are numerous codes and guides relating to means of escape from various uses, some of which, as they have evolved, have overlapped and derived different recommendations for the same matters. Occasionally, they include matters outside those of life safety. Generally, means of escape is the provision of safe routes for persons to travel from any point in a building to a place of safety.



42.9 *Provisions for external surfaces of walls.* **a** *Any building.* **b** *Any building other than as shown in* **c**. **c** *Assembly or recreational building of more than one storey.* **d** *Any building.* **e** *Any building.* **f** *Key to external wall surface classification*

Table IX Limitations on roof coverings* (from Approved Document B, Table 16)

Designation† of covering of roof or part of roof		Minimum distance from any point on relevant boundary			
National class	**European class**	**Less than 6 m**	**At least 6 m**	**At least 12 m**	**At least 20 m**
AA, AB or AC	B_{ROOF}(t4)	●	●	●	●
BA, BB or BC	C_{ROOF}(t4)	○	●	●	●
CA, CB or CC	D_{ROOF}(t4)	○	●[1] [2]	●[1]	●
AD, BD or CD	E_{ROOF}(t4)	○	●[1] [2]	●[1]	●[1]
DA, DB, DC or DD	F_{ROOF}(t4)	○	○	○	●[1] [2]

Notes:

* See paragraph 14.8 for limitations on glass; paragraph 14.9 for limitations on thatch and wood shingles; and paragraphs 14.6 and 14.7 and Tables 18 and 19 for limitations on plastic rooflights.

† The designation of external roof surfaces is explained in Appendix A. (See Table A5, for notional designations of roof coverings.)

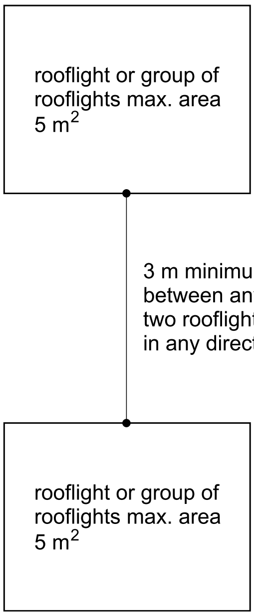
Separation distances do not apply to the boundary between roofs of a pair of semi-detached houses (see 14.5) and to enclosed/covered walkways. However, see Diagram 30 if the roof passes over the top of a compartment wall. Polycarbonate and PVC rooflights which achieve a Class 1 rating by test, see paragraph 15.7, may be regarded as having an AA designation.

Openable polycarbonate and PVC rooflights which achieve a Class 1 (National class) or Class C-s3, d2 (European class) rating by test, see paragraph 10.7, may be regarded as having an AA (National class) designation or B_{ROOF}(t4) (European class) classification.

● Acceptable.
○ Not acceptable.

[1] Not acceptable on any of the following buildings:
a. Houses in terraces of three or more houses.
b. Industrial, storage or other non-residential Purpose Group buildings of any size.
c. Any other buildings with a cubic capacity of more than 1500 m^3.

[2] Acceptable on buildings not listed in Note 1, if part of the roof is no more than 3 m^2 in area and is at least 1500 mm from any similar part, with the roof between the parts covered with a material of limited combustibility.



42.10 *Limitations on spacing and size of plastic rooflights having a Class 3 or TP(b) lower surface: see Table IX. Note: the surrounding roof covering should be of limited combustibility for at least 3 m*

4.02

At the time of writing, various aspects of fire safety, particularly the basis on which adopted standards and practices are founded, are under review. However, there is nothing to stop an alternative, innovative or unorthodox approach to means of escape being adopted. Fire-engineering solutions may be used where the established practices are unsuitable; here methods such as smoke control and automatic detection and suppression are used to evolve a package of safety measures for a specific user and building design requirements. It should be noted that a change in specific user may require a reassessment of the fire safety provisions.

4.03

Whatever method is adopted, the means of escape must be tailored to the individual occupancy and building. Where a project is speculative a judgment must be made as to the necessary provisions for means of escape: to assume the worst case may not be feasible, although it will result in a level of provision acceptable for the majority of occupancies. In the case of designs such as atria, persons should be at no greater risk than those in a nonatrium building.

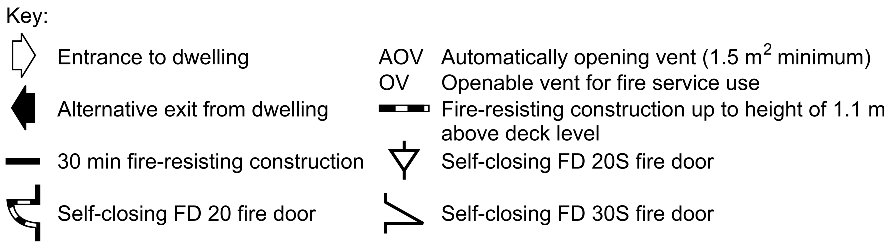
4.04

The aim is to make provision such that escape can take place unaided. The occupants of some buildings, however, will not be able to achieve this. There are certain basic principles and provisions accepted as necessary for the provision of minimum means of escape. These are:

- Exits and escape routes of adequate number and width within a reasonable distance of all points in the building
- An alternative means of escape (in the majority of cases)
- Protected escape routes where necessary
- Lighting and directional signage
- Readily openable exit doors
- Smoke control to safeguard escape routes
- Separation of high or special risks
- Access for fire brigade to attack the seat of a fire swiftly for protection of life
- Audible/visual warning of fire and active measures
- First aid fire appliances, and
- Instruction of action to be taken in the event of a fire and evacuation procedure.

Table X Plastics rooflights: limitations on use and boundary distance (from Approved Document B)

Minimum classification on lower surface	**Space which rooflight can serve**	**Minimum distance from any point on relevant boundary to rooflight with an external designation of:**	
		AD BD CD (National class) or E_{ROOF}(t4) (European class) CA CB CC or D_{ROOF}(t4) (European class)	**DA DB DC DD (National class) or F_{ROOF}(t4) (European class)**
Class 3	a. Balcony, verandah, carport, covered way or loading bay, which has at least one longer side wholly or permanently open	6 m	20 m
	b. Detached swimming pool		
	c. Conservatory, garage or outbuilding, with a maximum floor area of 40 m^2		
	d. Circulation space (except a protected stairway)	6 m	20 m
	e. Room		
		Minimum distance from any point on relevant boundary to rooflight with an external surface classification of:	
		TP(a)	**TP(b)**
1. TP(a) rigid	Any space except a protected stairway	6 m	Not applicable
2. TP(b)	a. Balcony, verandah, carport, covered way or loading bay, which has at least one longer side wholly or permanently open	Not applicable	6 m
	b. Detached swimming pool		
	c. Conservatory, garage or outbuilding, with a maximum floor area of 40 m^2		
	d. Circulation space (except a protected stairway)	Not applicable	6 m
	e. Room		



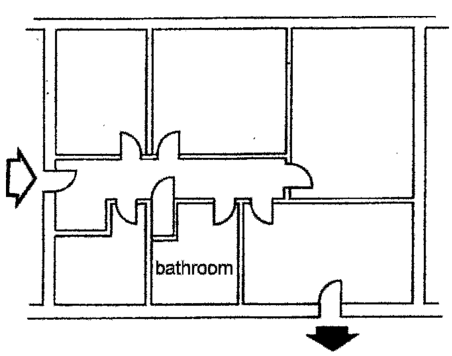
42.11 *Key to following drawings* **42.12** *to* **42.35**
The entrance and alternative exit doors may need to be fire doors, and compartment walls need to be fire-resisting

4.05
The last three items are additional to structural provision for means of escape. However, some procedures for evacuation and the life safety systems associated with certain designs of building, e.g. atria and shopping malls, and certain uses, e.g. hospitals, necessitate the utilisation of active measures to provide effective means of escape-pressurisation/depressurisation of escape routes to control smoke, automatic detection by heat and smoke detectors, etc.

4.05
The concept for escape from flats and maisonettes differs from that of other uses. This is based on the high standard of compartmentation and separation recommended in Approved Documents Part B, in particular B3 Internal Fire Spread (structure). Major factors are difficulties in alerting the population of the block to a fire (fire alarms in this situation being a potential source of acute nuisance), and also in ensuring that everyone in fact is evacuated.

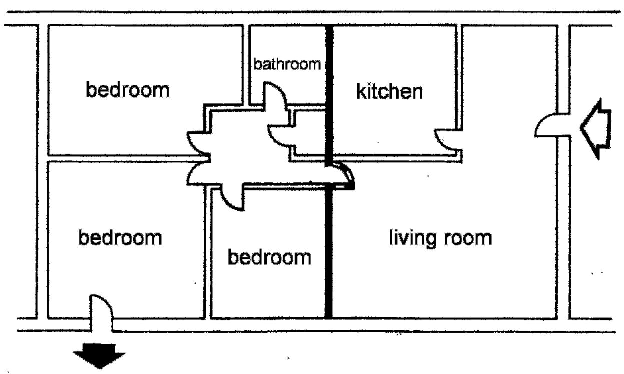
4.06
Each residential unit is a separate fire compartment, and it is considered only necessary initially to evacuate the unit on fire. Consequently the necessary width of escape exits and routes may be minimalised. The spread of fire and smoke is controlled under the principles of smoke containment. As it has been shown that most fires are containable within the room of origin, the current edition of BS 5588 Part 1 (Code of practice for residential buildings) and Approved Document B have reduced the recommendations relating to fire separation within the unit from those previously given. The travel distance, any alternative means of escape, and the layout dictate the level of internal protection necessary, which influences the common area protection, **42.11** to **42.35**.

4.07
Parts 2 and 3 of BS 5588 (fire precautions in the design, construction and use of buildings) deals with offices and shops respectively.

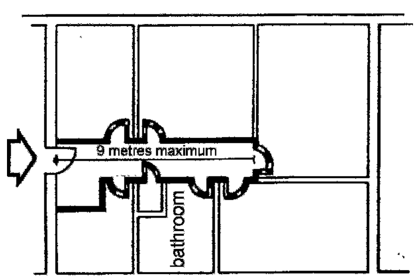


42.12 *Flat with alternative exit and where all habitable rooms have direct access to an entrance hall*

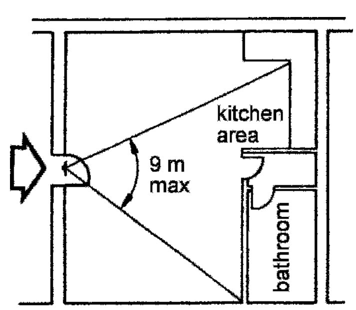
4.08 Number of exits and escape routes
In order to determine the number of exits from a room or storey, their occupancy must be established. This may be known, or it can be assessed by the use of recognised space factors for specific uses. These are only indicators and can be varied. These numbers will also affect the width of escape routes. In existing buildings the



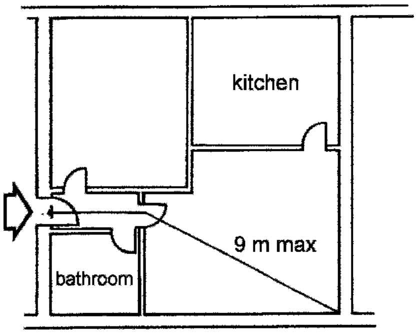
42.13 *Flat with alternative exit and where all habitable rooms do not have direct access to an entrance hall. The fire-resisting partition separates living and sleeping accommodation*



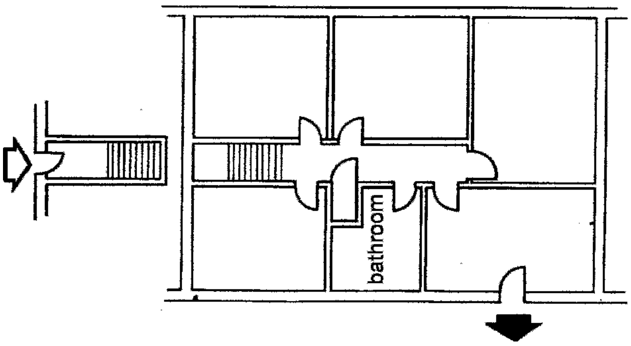
42.14 *Flat with a protected entrance hall and restricted travel distance. If the partitions between bathroom and adjacent rooms have 30 minutes fire resistance, then the partition between it and the entrance hall need not be fire-resisting and its door need not be a fire door. The cupboard door need not be self-closing*



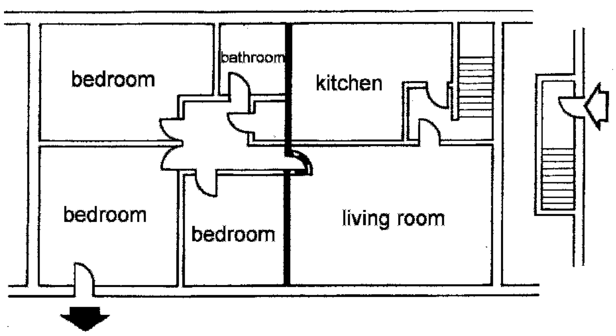
42.15 *Open-plan flat (bed-sitter) with restricted travel distance*



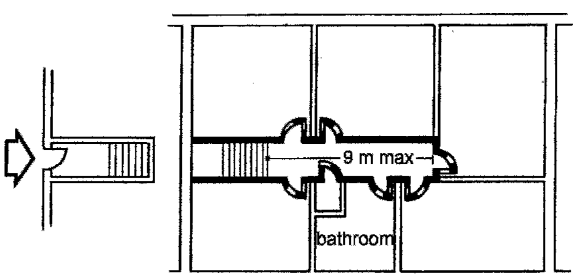
42.16 *Flat with separate habitable rooms and restricted travel distance*



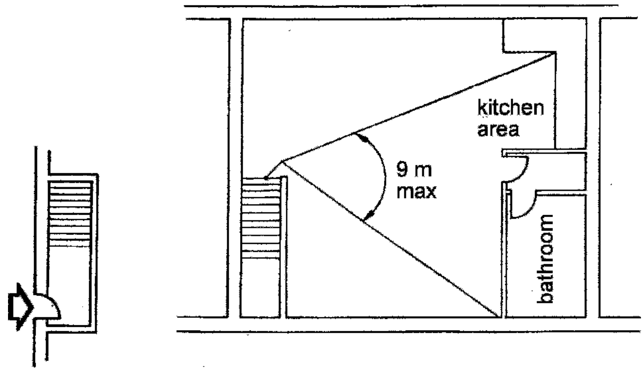
42.17 *Flat entered from above or below with an alternative exit and where all habitable rooms have direct access to an entrance hall*



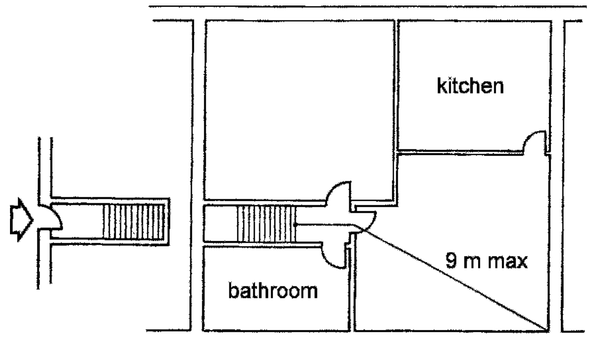
42.18 *Flat entered from above or below with an alternative exit and where all habitable rooms do not have direct access to an entrance hall. The fire-resisting partition separates living and sleeping accommodation*



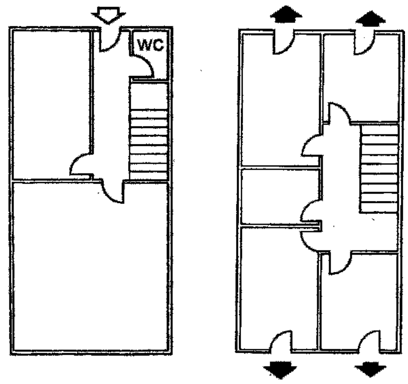
42.19 *Flat entered from below with a protected entrance and restricted travel distance. If the partitions between bathroom and adjacent rooms have 30 minutes fire resistance, then the partition between it and the entrance hall need not be fire-resisting and its door need not be a fire door. The cupboard door need not be self-closing*



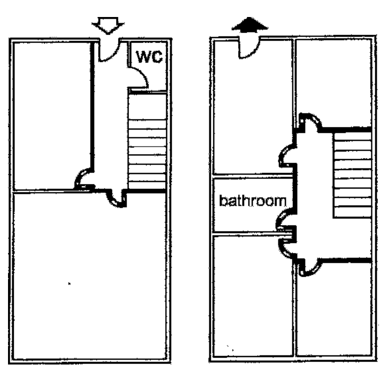
42.20 *Open-plan flat (bed-sitter) entered from below with a restricted travel distance*



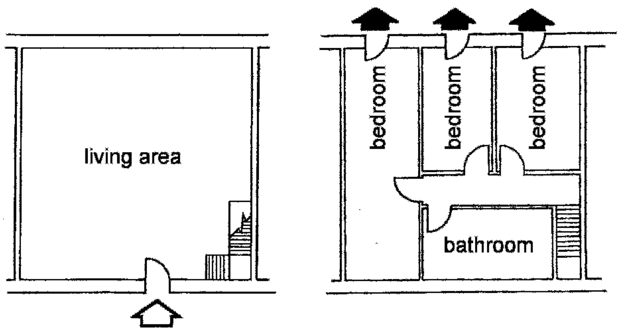
42.21 *Flat with separate habitable rooms entered from below with a restricted travel distance*



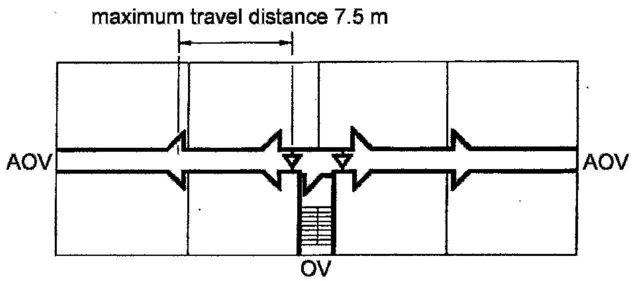
42.22 *Maisonette with alternative exits from each room not on the entrance floor level*



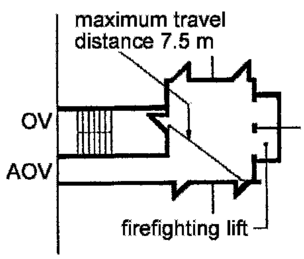
42.23 *Maisonette with protected entrance floor and landing. If the partitions between bathroom and adjacent rooms have 30 minutes fire resistance, then the partition between it and the entrance hall need not be fire-resisting and its door need not be a fire door*



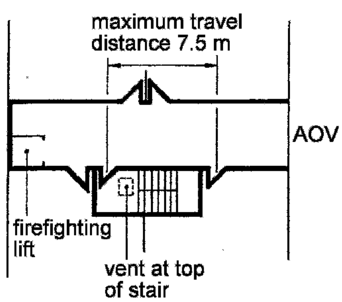
42.24 *Open-plan maisonette*



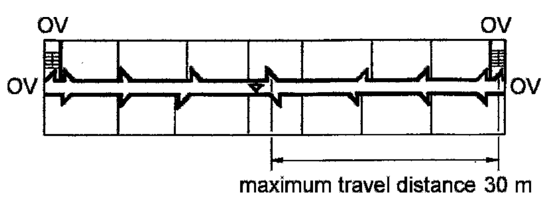
42.25 *Common escape routes in single stair buildings more than 11 m high with corridor access dwellings. Where all dwellings on a storey have independent alternative means of escape, the maximum travel distance may be increased to 30 m. Where a firefighting lift is required, it should be sited not more than 7.5 m from the door to the stair. The openable vents (OVs) to the stairway may be replaced by an openable vent over the stair*



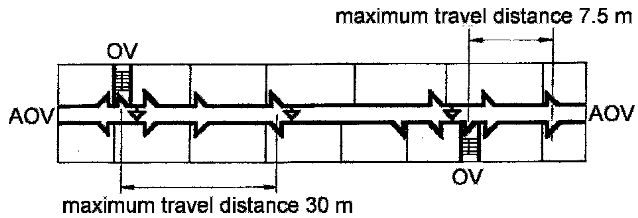
42.26 *Common escape routes in single stair tower blocks more than 11 in high, with the stair adjacent to an external wall. See riders to* **42.25**



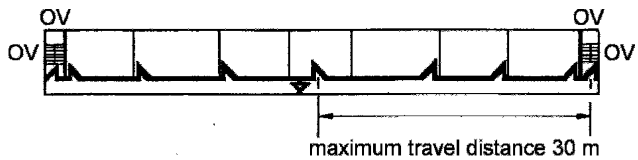
42.27 *Common escape routes in single stair tower blocks more than 11 m high with internal stair. See riders to* **42.25**



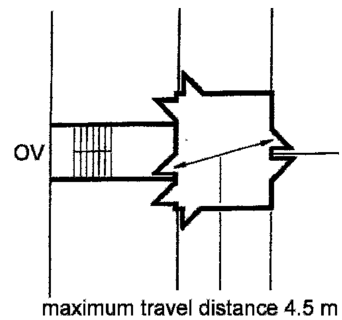
42.28 *Common escape routes in multi-stair buildings with corridor access dwellings and no dead-ends*



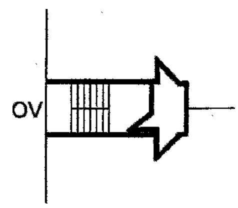
42.29 *Common escape routes in multi-stair buildings with corridor access dwellings and with dead-ends. The central fire door may be omitted where the maximum travel distance does not exceed 15 m*



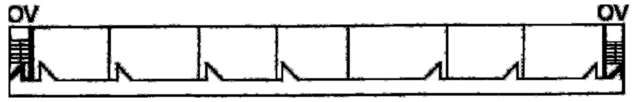
42.30 *Common escape routes in multi-stair buildings with corridor access dwellings on one side only*



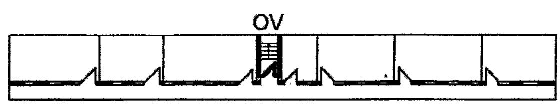
42.31 *Common escape routes in small single-stair buildings*



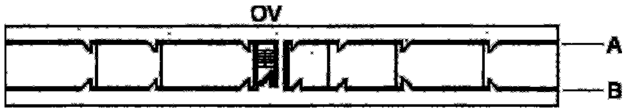
42.32 *Common escape routes in small single-stair buildings with not more than two dwellings per storey. The door between the stair and lobby should be free from security fastenings. Where the dwellings have protected entrance halls, the separation between the stair and the dwelling entrance doorts is not necessary*



42.33 *Common escape routes in balcony/deck approach multi-stair buildings*



42.34 *Common escape routes in balcony/deck approach single-stair buildings*



42.35 *Common escape routes in balcony/deck approach single-stair buildings with an alternative exit from each dwelling. One of the external enclosures A or B must be fire resisting*

width of doors, stairways, passages etc, if not to be altered, will dictate the numbers of people that can be accommodated, Tables XI, XII and XIII:

$$\text{Occupancy} = \frac{\text{Area of room or storey } (\text{m}^2)}{\text{Floor space per person } (\text{m}^2)}$$

Table XI Floor space factors(1) (from Approved Document B, Volume 2, Table C1)

Type of accommodation(2)(3)	Floor space factor m^2/person
1 Standing spectator areas, bar areas (within 2 m of serving point) similar refreshment areas	0.3
2 Amusement arcade, assembly hall (including a general purpose place of assembly), bingo hall, club, crush hall, dance floor or hall, venue for pop concert and similar events and bar areas without fixed seating	0.5
3 Concourse, queuing area or shopping mall(4)(5)	0.7
4 Committee room, common room, conference room, dining room, licensed betting office (public area), lounge or bar (other than in 1 above), meeting room, reading room, restaurant, staff room or waiting room(6)	1.0
5 Exhibition hall or studio (film, radio, television, recording)	1.5
6 Skating rink	2.0
7 Shop sales area(7)	2.0
8 Art gallery, dormitory, factory production area, museum or workshop	5.0
9 Office	6.0
10 Shop sales area(8)	7.0
11 Kitchen or library	7.0
12 Bedroom or study-bedroom	8.0
13 Bed-sitting room, billiards or snooker room or hall	10.0
14 Storage and warehousing	30.0
15 Car park	Two persons per parking space

Notes:
[1] As an alternative to using the values in the table, the floor space factor may be determined by reference to actual data taken from similar premises. Where appropriate, the data should reflect the average occupant density at a peak trading time of year.
[2] Where accommodation is not directly covered by the descriptions given, a reasonable value based on a similar use may be selected.
[3] Where any part of the building is to be used for more than one type of accommodation, the most onerous factor(s) should be applied. Where the building contains different types of accommodation, the occupancy of each different area should be calculated using the relevant space factor.
[4] Refer to section 4 of BS 5588-10:1991 Code of practice for shopping complexes for detailed guidance on the calculation of occupancy in common public areas in shopping complexes.
[5] For detailed guidance on appropriate floor space factors for concourses in sports grounds refer to '*Concourses*' published by the Football Licensing Authority (ISBN: 0 95462 932 9).
[6] Alternatively the occupant capacity may be taken as the number of fixed seats provided, if the occupants will normally be seated.
[7] Shops excluding those under item 10, but including – supermarkets and department stores (main sales areas), shops for personal services such as hairdressing and shops for the delivery or collection of goods for cleaning, repair or other treatment or for members of the public themselves carrying out such cleaning, repair or other treatment.
[8] Shops (excluding those in covered shopping complexes but including department stores) trading predominantly in furniture, floor coverings, cycles, prams, large domestic appliances or other bulky goods, or trading on a wholesale self-selection basis (cash and carry).

Table XII Floor space factors for assembly buildings (from BS 5588: Part 6, Table 3)

Description of floor space	Floor space per person (m^2)
1 Individual seating	0.4 to 0.5
2 Bench seating	0.3[1]
3 Dance area	0.5
4 Ice rinks	1.2
5 Restaurants and similar table and chair arrangements around a dance area	1.1 to 1.5
6 Bars without seating and similar refreshment areas	0.3
7 Standing spectator areas	0.3
8 Exhibition	1.5[2]
9 Bowling alley billiard or snooker hall	9.5
10 Museum/art gallery	5.0
11 Studio (radio, television, film, recording)	1.4

[1] If the number and length of benches is known, a factor of 450 mm per person should be used.
[2] Alternatively, a factor of 0.4 m^2 a may be used over the gross area of gangways and other clear circulation space between stalls and stands.
Note. These floor space factors are for guidance only and should not be taken as the only acceptable densities. Where the number of seats is known this should be used in preference to the floor space factors.

Table XIII Capacities of exits in shopping complexes other than from malls (from BS 5588 Part 10, Table 3)

Maximum number of persons	Width (mm)
50	800
110	900
220	1100
240	1200
260	1300
280	1400
300	1500
320	1600
340	1700
360	1800

Note 1. Other values of width for a maximum number of persons greater than 220 may be obtained by linear interpolation or extrapolation.
Note 2. For the purposes of this table, the width of a doorway is that of the leaf or leaves, and the width of a passage is between the sides at shoulder level (that is about 1.5 m above finished floor level).

4.10

Once the occupancy factor for an area is known the number of exits must equate to the necessary total width of escape required, although a minimum number of exits is specified within Approved Document B and Part 6 of BS 5588 (assembly buildings). Not less than two exits should be provided, except in the case of an occupancy of less than 50, or a small storey with a limited travel distance ('dead end').

4.11

The capacities of exits are given in various tables. Most recommendations equate to approximately 40 persons passing through a unit width of 500 mm in 2½ minutes. While not all exits need be of equal width, they should be evenly distributed to provide alternatives. Where there are two or more exits, it is assumed that fire may affect one of them, therefore the largest exit should be discounted. Hence the total number of exits = calculated number +1, Table XIV

Table XIV Widths of escape routes and exists (from Approved Document B, Table 4)

Maximum number of persons	Minimum width mm
50	750
110	850
220	1050
more than 220	5 per person

Table XV Limitations on travel distance (from Approved Document B, Volume 2, Table 2)

Purpose group	Use of the premises or part of the premises		Maximum travel distance(1) where travel is possible in: One direction only (m)	More than one direction (m)
2(a)	Institutional		9	18
2(b)	Other residential:			
	a. in bedrooms(2)		9	18
	b. in bedroom corridors		9	35
	c. elsewhere		18	35
3	Office		18	45
4	Shop and commercial(3)		18(4)	45
5	Assembly and recreation:			
	a. buildings primarily for disabled people		9	18
	b. areas with seating in rows		15	32
	c. elsewhere		18	45
6	Industrial(5)			
		Normal Hazard	25	45
		Higher Hazard	12	25
7	Storage and other non-residential(5)			
		Normal Hazard	25	45
		Higher Hazard	12	25
2–7	Place of special fire hazard(6)		9(7)	18(7)
2–7	Plant room or rooftop plant:			
	a. distance within the room		9	35
	b. escape route not in open air (overall travel distance)		18	45
	c. escape route in open air (overall travel distance)		60	100

Notes:
1 The dimensions in the Table are travel distances. If the internal layout of partitions, fittings, etc is not known when plans are deposited, direct distances may be used for assessment. The direct distance is taken as 2/3 rds of the travel distance.
2 Maximum part of travel distance within the room. (This limit applies within the bedroom (and any associated dressing room, bathroom or sitting room, etc) and is measured to the door to the protected corridor serving the room or suite. Sub-item (b) applies from that point along the bedroom corridor to a storey exit.)
3 Maximum travel distances within shopping malls are given in BS 5588: Part 10. Guidance on associated smoke control measures is given in a BRE report *Design methodologies for smoke and heat exhaust ventilation* (BR 368).
4 BS 5588: Part 10 applies more restrictive provisions to units with only one exit in covered shopping complexes.
5 In industrial and storage buildings the appropriate travel distance depends on the level of fire hazard associated with the processes and materials being used. Higher hazard includes manufacturing, processing or storage of significant amounts of hazardous goods or materials, including: any compressed, liquefied or dissolved gas, any substance which becomes dangerous by interaction with either air or water, any liquid substance with a flash point below 65°C including whisky or other spirituous liquor, any corrosive substance, any oxidising agent, any substance liable to spontaneous combustion, any substance that changes or decomposes readily giving out heat when doing so, any combustible solid substance with a flash point less than 120° C, any substance likely to spread fire by flowing from one part of a building to another.
6 Places of special fire hazard are listed in the definitions in Appendix E to Approved Document B.
7 Maximum part of travel distance within the room/area. Travel distance outside the room/area to comply with the limits for the purpose group of the building or part.

Table XVI Maximum travel distances in assembly buildings (from BS 5588: Part 6, Table 2)

Available direction of escape	Areas with seating in rows (m)	Open floor areas (m)
(a) In one direction only	15	18
(b) In more than one direction	32[1]	45[2]

1 This my include up to 15 m in one direction only.
2 This may include up to 18 m in one direction only.

Table XVII Maximum travel distances in stopping malls (from BS 5588: Part 10, Table 1)

Available direction of escape	Uncovered malls (m)	Covered malls (m)
(a) In one direction		
(1) malls at ground level	25	9
(2) malls not at ground level	9	9
(b) In more than direction		
(1) malls at ground level	not limited	45
(2) malls not at ground level	45	45

4.11

Alternatively, the number of exits may be determined by recommended travel distances, i.e. the actual distance to be traveled to the nearest exit, having regard to obstructions such as partitions. The distances currently recommended are historical, based on experience and accepted practice. They are not sacrosanct, but should be shorter rather than longer. Extension of travel distances may be justified where compensatory factors such as smoke control systems or early warning of fire is provided. Only one exit need be within the travel distance, alternatives may be at any distance, Tables XV to XVIII.

4.12 Alternative means of escape

A person should be able in most circumstances to turn their back on a fire and walk to an alternative exit. If escape is in one direction only, an exit or alternative escape route should be near enough for people to reach it before being affected by heat and smoke. The Scottish Building Regulations and the Home Office Guide for premises requiring a fire certificate recommend that the angle of divergence should be not less than 45° plus 2½° for every metre travelled in one direction, **42.36**, **42.37** and **42.38**.

4.13 Width of escape routes and exits

An escape route should be as wide or wider than an exit leading to it, and should be of uniform width. The width of a final exit should equate to the route or routes it serves. This may comprise the total number of persons descending a stair plus a ground-storey population plus those ascending from a basement.

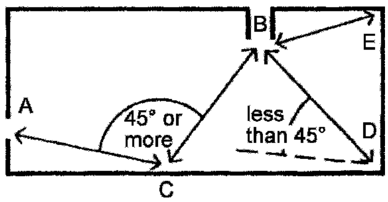
4.14

Unfortunately to date there is no agreed method of measuring width. In addition to means of escape, access for the disabled may be a consideration with specific details for projection of handrails. The variations should be accommodated by measuring an absolute clear width with no allowances for the projection of handrails, door thickness, etc, except door furniture with a

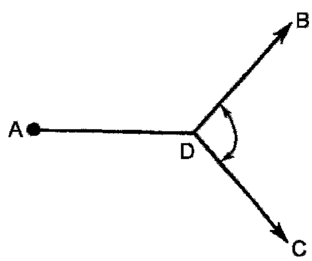
Table XVIII Maximum travel distances in shopping complexes other than in malls (from BS 5588: Part 10, Table 2)

Accommodation	Maximum part of travel distance within room or area		Maximum travel distance to nearest storey exit	
	Escape in one direction only (m)	Escape in more than one direction (m)	Escape in one direction only (m)	Escape in more than one direction (m)
Accommodation other than the following list	18	45[1]	18	45[1]
Engineering services installation rooms Boiler rooms Fuel storage spaces Transformer, battery and switchgear rooms Rooms housing a fixed internal combustion engine	9	18	18	45[1]

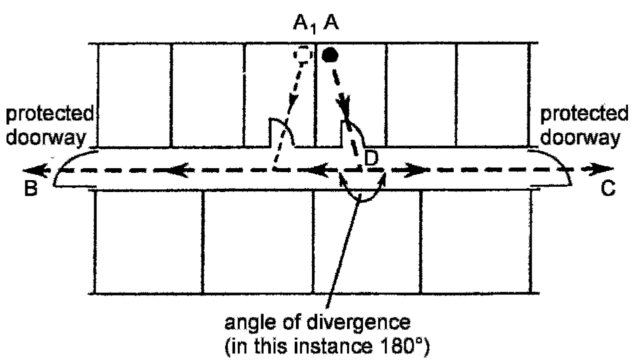
[1] This may include up to 18 in with escape in one direction only.



42.36 *Alternative escape routes are available from C because angle ACB is at least 45°, so that either CA or CB should be less than the maximum travel distance given in Table XV. Alternative routes are not available from D because angle ADB is less than 45°, so that DB should not exceed the distance for travel in one direction. There is also no alternative route from E. From Approved Document Part B, Volume 2, Diagram 11*



42.37 *Alternative escape routes in principle, A being the point of origin and D the point of divergence of alternative routes. Angle BDC = 45° + 2½° for each metre travelled from A to D*



42.38 *Alternative escape routes in practice*

maximum intrusion of 100 mm. The safe and rapid use of a stair is dependent on all persons being within reach of a handrail, therefore no staircase should exceed 1.4 m in width unless additional central handrails are provided.

4.15

The capacity and therefore the width of the a stair differ from that of a horizontal escape route being influenced by the rate of decent and the standing position on the stairs. The width necessary is also influenced by the type of evacuation – total or phased – the stair having to accommodate only the population of a phase in the latter instance:

Total evacuation: on the raising of the alarm the total population moves to evacuate the whole of the building in a single phase.

Phased evacuation: on the discovery of a fire the alarm is given in the following manner. The fire floor and the floor above are given the signal to evacuate immediately, all other floors are given the alert signal to stand by to evacuate. If the fire is extinguished no further evacuation is necessary; if not, the next two floors immediately above the initial phase are evacuated; and so progressively in separate phases of two floors up the building to the top. Evacuation then proceeds down the building, starting with the floors nearest the fire, until it is complete or the fire extinguished. As the population of only two floors are evacuated at a time, the stair width dimensions can be decreased.

4.16

As people remain in the building during the fire-phased evacuation, it can take place only if additional protective measures are incorporated:

- All compartment floors with openings through them protected to maintain compartmentation
- All stairs protected by lobbies or corridors of fire-resisting construction
- A fire alarm system incorporating a personal address system operated from a central control point from where occupants can be instructed and orderly evacuation directed
- An automatic sprinkler installation (although this may not be necessary in a low-rise building with, say, three phases of evacuation which would be complete within 30 minutes).

4.17

Phased evacuation is not generally accepted for any basements, assembly, hotel, recreational and similar buildings, and, to date, the majority of shops. However, in the case of mixed user and large complexes total evacuation may not be necessary or prudent and enforcing authorities should be consulted at an early stage.

4.18

Where two or more stairs are provided, it is reasonable to assume that one will not be available for use due to fire or smoke unless a sufficiently high degree of protection is afforded. If a stair is approached through a lobby, or protected by a pressure-differential smoke control system, it can be assumed that it will be available. Where such protection is not provided, a stair should be discounted

Table XIX Minimum widths of escape stairs (from Approved Document B, Table 6)

Situation of stair	Maximum number of people served[(1)]	Minimum stair width (mm)
1a. In an institutional building (unless the stair will only be used by staff)	150	1000[(2)]
1b. In an assembly building and serving an area used for assembly purposes (unless the area is less than 100 m^2)	220	1100
1c. In any other building and serving an area with an occupancy of more than 50	Over 220	See Approved Document
2. Any stair not described above	50	800[(3)]

Notes:
[1] Assessed as likely to use the stair in a fire emergency.
[2] BS 5588-5 recommends that firefighting stairs should be at least 1100 mm wide.
[3] In order to comply with the guidance in the Approved Document to Part M on minimum widths for areas accessible to disabled people, this may need to be increased to 1000 mm.

Table XX Capacity of a stair for basements and for total evacuation of the building (from: Approved Document B, Table 7; also BS 5588: Part 6, Table 5)

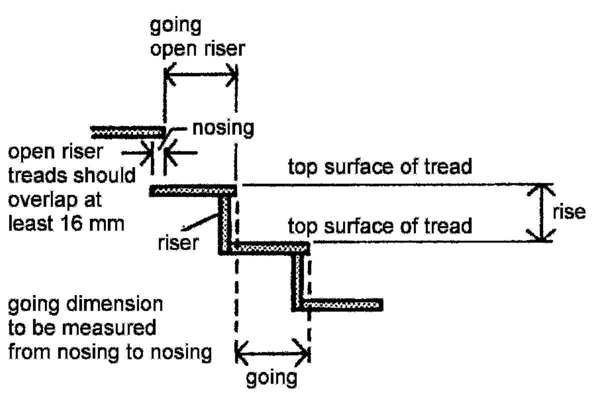
No. of floors served	Maximum number of persons served by a stair of width:								
	1000 mm	1100 mm	1200 mm	1300 mm	1400 mm	1500 mm	1600 mm	1700 mm	1800 mm
1	150	220	240	260	280	300	320	340	360
2	190	260	285	310	335	360	385	410	435
3	230	300	330	360	390	420	450	480	510
4	270	340	375	410	445	480	515	550	585
5	310	380	420	460	500	540	580	620	660
6	350	420	465	510	555	600	645	690	735
7	390	460	510	560	610	660	710	760	810
8	430	500	555	610	665	720	775	830	885
9	470	540	600	660	720	780	840	900	960
10	510	580	645	710	775	840	905	970	1035

Notes:
The capacity of stairs serving more than 10 storeys may be obtained by using the formula in para **419**.
This table can also apply to part of a building.

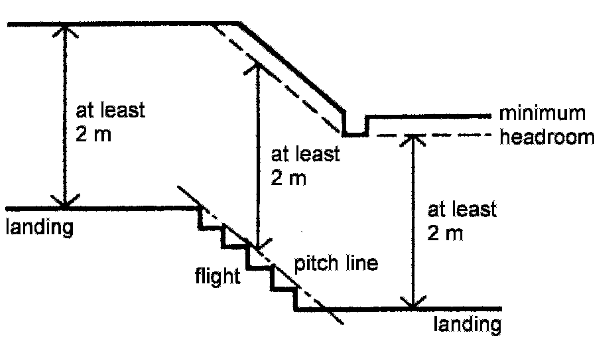
(number of stairs required = calculated number plus 1). Each stair should be discounted in turn, to ensure that the capacity of the remaining stairs in total is adequate, Tables XIX and XX.

4.19

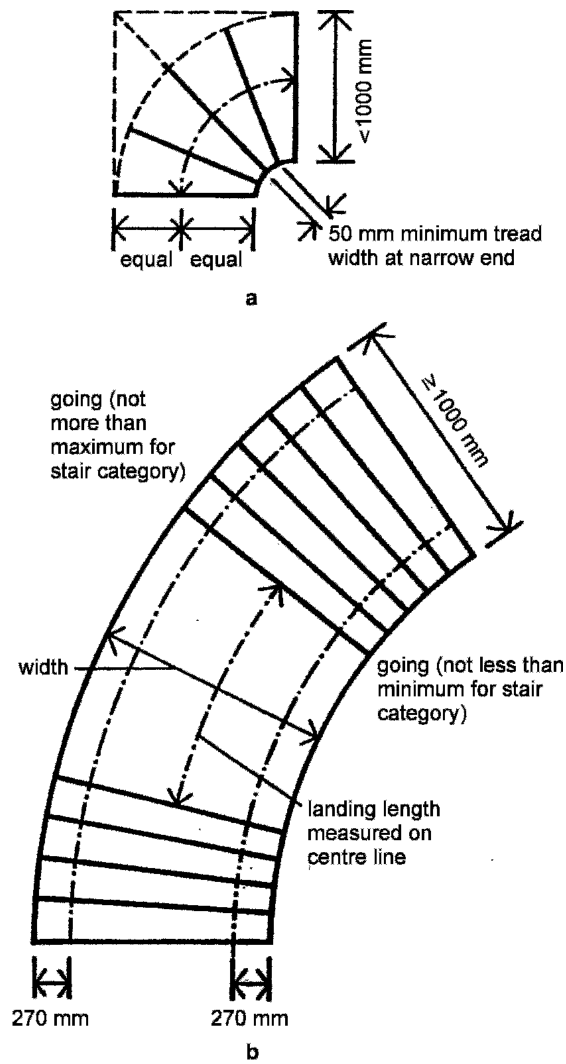
Stair design should accord with Approved Document K or BS 5395, Stairs, ladders and walkways, **42.39**, **42.40** and **42.41**, and Table XXI.



42.39 *Measuring rise and going on staircases*



42.40 *Measuring headroom on staircases*



42.41 *Measuring tapered treads.* **a** *Stair width less than 1 m.* **b** *Stair width equal to or greater than 1 m*

Table XXI Rise and going (from Approved Document K, Table 1)

	Maximum rise (mm)	Minimum going (mm)
1 Private stair	220†	220*
2 Institutional and assembly stair	180‡	280†
3 Other stair	190‡	250

* The maximum pitch for a private stair is 42°.
† If the area of a floor of the building is less than 100 m^2, the going may be reduced to 250 mm.
‡ For maximum rise for stairs providing the means of access for disabled people reference should be made to Approved Document M: Access and facilities for disabled people.

For buildings over 10 storeys Approved Document B recommends the use of the following formula to assess the capacity of stairs:

$$P = 200w + 50(w–0.3)(n–1)$$

where P is the number of people that can be accommodated
w is the width of the stair in metres
n is the number of storeys in the building

Where phased evacuation is envisaged, the minimum widths in Table XXII may be adopted.

Small buildings occupied by a limited number of persons and satisfying the criteria for travel distance and a single exit can have a single stairway, Tables XXIII and XXIV.

Table XXII Minimum aggregate width of stairs designed for phased evacuation (from Approved Document B, Table 38)

Maximum number of people in any storey	Stair width[1] (mm)
100	1000
120	1100
130	1200
140	1300
150	1400
160	1500
170	1600
180	1700
190	1800

[1] Stairs with a rise of more than 30 m should not be wider than 1400 mm unless provided with a central handrail (see para **4.6**). As an alternative to using this table, provided that the minimum width of a stair is at least 1000 mm, the width may be calculated from: [(P × 10) – 100 mm] where P = the number of people on the most heavily occupied storey.

Table XXIII Maximum permitted distances of travel* in small shops (from BS 5588: Part 2, Table 6)

	Maximum travel distance (m)	Maximum direct distance (m)
Ground storey with a single exit	27	18
Basement or first storey with a single stairway	18	12
Storey with more than one exit/stairway	45	30

* See footnote to **9.2.3** in BS 5588.

Table XXIV Capacity of a stairway for an office building permitted to be served by a single stairway (from BS 5588: Part 3, Table 6)

Maximum number of persons per storey	Width of stairway (mm)
50	900
more than 50	1100

4.20

The recommended widths assume a uniform distribution of population. If any floor within a building has a higher population, e.g. a conference room or restaurant, extra or wider stairs necessary to accommodate the increased population should extend down to the final exit.

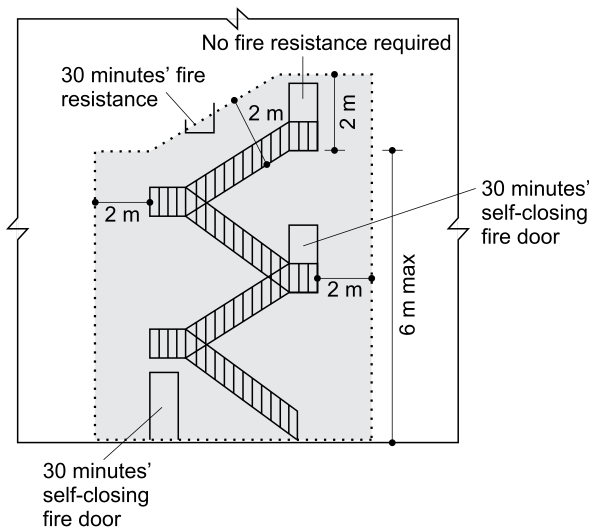
4.21

Separate stairs should be provided for use by residential or assembly occupancies independent of any other use. Where a totally independent escape can be provided from these higher risk uses, e.g. using an access deck or walkway, it is reasonable that some stairs may be shared.

4.22

The use of external stairs should be avoided if possible, due to the psychological effect of using unfamiliar external stairs at high levels and the effects of bad weather. The width and design of external stairs is the same as for internal ones. External stairs are not considered suitable for use by the general public, nor for nor hospital or similar uses. They should only be used as an alternative escape unless they are the only stair, **42.42**.

An external escape route should be protected against the accumulation of ice and snow. This may be in the form of an enclosure, partial shielding or trace heating



42.42 *Enclosure of escape stairs and ramps, not drawn to scale. The shaded area should have not less than 30 minutes fire resistance*

4.23 Escape routes

Recommendations related to means of escape are generally based on a 30-minute period of fire resistance. Higher periods may result by reason of the need to maintain compartmentation or provide firefighting shafts.

Escape stairs, other than external, should be enclosed by fire-resisting construction to protect against the effects of smoke, heat and fire, and to retard the progress of fire and smoke affecting escape routes. Escape routes should lead to final exits.

4.24

Additionally, lobbies or corridors of fire-resisting construction should be provided to give additional protection to stairs in the following positions:

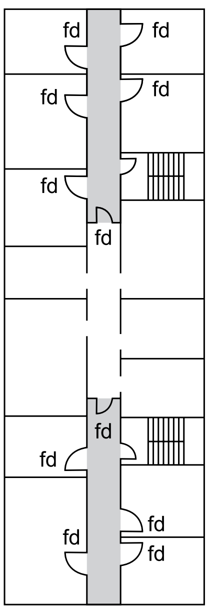
- Between a floor area and stair in all buildings over 20 m in height at all levels

- Between a stair and a basement storey as the stair is at greater risk from heat and smoke
- Between a stair and an enclosed car park
- Between a stair and a higher risk area, e.g. a boiler room
- Between a stair and a floor area in a single-storey building other than a small shop (see BS 5588 Part 2) to protect the stair from smoke
- In assembly buildings to protect the public and performers – where an opening occurs in a proscenium wall, and between stage and dressing-room corridors
- Where phased evacuation is used, and
- Where a stair is not discounted.

4.25
Escape routes do not necessarily have to be enclosed; in some situations this would create great problems – open-plan offices, exhibition halls, warehouses, factories.

4.26
Where a corridor dead-end situation exists, the escape route must be protected against fire, heat and smoke by fire-resisting construction, as it may be necessary to pass the room on fire to reach the exit, **42.43**.

4.27
Where a corridor connects escape routes, it should be protected against the ingress of smoke. To be effective, the construction should be from structural floor to structural floor or imperforate suspended ceiling. The corridors should also be subdivided by cross-corridor doors to inhibit the progress of smoke. These doors do not necessarily require fire resistance. Their purpose is to make it possible to take an alternative means of escape, not to subdivide the corridor at given intervals. Corridors exceeding 12 m should be subdivided (not subdivided at 12 m intervals), **42.44**.



42.43 *Dead-end corridors continued past stairway*

4.28 Lighting and directional signage
General artificial lighting should be provided for persons to move about a building effectively and safely.

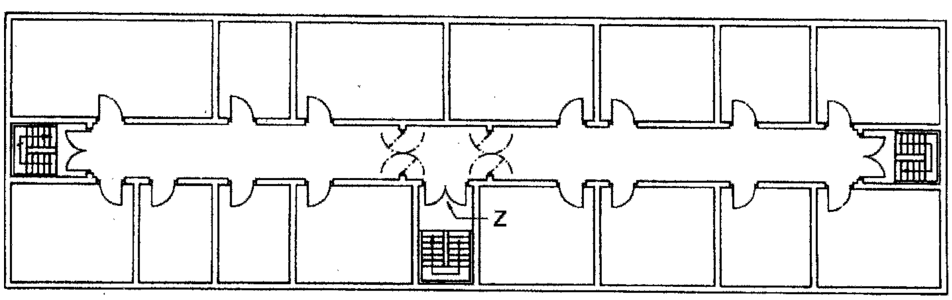
4.29 Emergency lighting
This should be provided in the those areas necessary for escape purposes in case the artificial lighting fails. It may be a maintained system (continuously illuminated in conjunction with the general lighting) or be non-maintained; only coming into operation on the failure of the general lighting. Maintained systems are usually provided in areas with large numbers of the public unfamiliar with their surroundings, and where darkened situations may be common.

Escape lighting should be provided in:

- Areas occupied or used by the public
- Windowless accommodation
- Escape routes, including internal corridors without borrowed light
- Basements
- Areas used outside normal daylight hours, and
- Rooms containing essential equipment.

4.30 Signs
These are required to indicate the way to exits, and the exits themselves. Preferred colours, sizes, typeface and graphics are set out in BS 5499. The criterion is that signs should be distinguishable against their background and surroundings and be of a size that can be read at the required distance. If the use of the building warrants, the signs may have to be in more than one language. Signs should also be provided to indicate fire doors, and those that should be kept locked shut. In public assembly areas, signs are usually internally illuminated; elsewhere it is normally sufficient for escape lights to be positioned so as to illuminate a sign.

4.31 Fastenings
Fastenings on exit doors should allow exit without the use of a key or other device. Unless careful consideration is given to fastenings security may be undermined. The degree of security required will depend on the use of the building and user requirements. Access *into* a building is not required for escape purposes: re-entry into a floor area is neither necessary nor desirable. Fastenings that prevent a person entering a floor area from a staircase are acceptable. This is often a necessity to prevent theft in offices, factories and hotels and the like. The use of electronic fastenings and the use of card systems or similar to gain entry are acceptable provided that on the raising of the fire alarm or failure of the electrical system all



42.44 *Corridors connecting alternative exits. Doors to central stairway should be at position Z, doors may also be required across the corridors* locks 'fail-safe' in the unlocked position. However, consideration should also be given to the possibility of criminals setting off a false fire alarm in order to circumvent security arrangements.

4.31

Panic bolts and latches are most suitable where there are large numbers of persons. Turnbuckle locks with lever handles are commonly used where no public is involved. These may not be suitable in some institutional buildings, or places used predominantly by the elderly or disabled who may find a small turnbuckle difficult to operate; appropriate door ironmongery should be fitted in these circumstances.

4.32 Smoke control

If a smoke control system is for life safety purposes, it is essential that its initiation is automatic on the detection of smoke; and if mechanical, that it remains operational at all times by the use of duplicate equipment and secondary power supplies etc. Specialist advice should be sought regarding the type, design and installation of a life safety system.

4.32

The measures required to protect a means of escape from the effects of smoke will depend on the escape scheme adopted. Where escape is over a reasonable travel distance, the enclosure of the routes by partitions constructed to resist smoke, i.e. to maintain their integrity, should be adequate. Some smoke will enter escape routes, but should not reach a level to make their use untenable in the time it takes to reach an exit.

As described earlier, the addition of lobbies will retard the entry of smoke. Ventilating the lobbies will further dilute the smoke and hopefully direct it away from the escape route. It is also possible to protect escape routes from the ingress of smoke by the use of pressure differentials to retard the movement of smoke whereby fans, ducts and vents are used to create different pressures between the fire and protected area (pressurisation or depressurisation). Any such system should be designed and installed with the recommendations of BS 5588 Part 4 (under major revision).

4.33 Mechanical ventilation

These systems should not adversely affect a means of escape by perforation of enclosures without adequate protection, or by directing smoke into escape routes. Systems should have regard to BS 5720 and BS 5588 Part 9.

4.34 Ancillary accommodation

Service areas such as boiler and switch rooms should include provision in accordance with Tables XXV and XXVI.

4.35 Escape for people with disabilities

Escape for disabled people should be provided from all buildings to which they have access. BS 5588 Part 8 gives guidance on means of escape for them. Buildings designed particularly for use by persons with disabilities will require specific additional facilities and protection to escape routes depending on the disability. In any case, controlled escape by effective management is vital and assistance should be available.

The Building Regulations require access for disabled persons to the majority of buildings; therefore a number of factors to facilitate their escape will exist – additional width escape routes to accommodate wheelchairs, position and height of guarding on stairs and ramps. Also, in some cases lifts, if adequately protected, may be used by them in the event of fire. It may be necessary to construct protected refuges adjacent to lifts and stairs for those in wheelchairs and with limited mobility to await the use of a lift or assistance to evacuate the building.

When assessing escape arrangements for disabled people it is important not to consider only those that are in wheelchairs. Among others, blind people need help to find the exits, and deaf people require audible warnings to be duplicated by visual ones.

4.36 Fire safety management

This is the prevention and control of a fire, and the maintenance of the fire safety facilities. The understanding and maintenance of these is essential, particularly in a large or complex building; therefore the occupier/management should have comprehension of the safety measures incorporated into the design of the building. This means that the designer must supply all relevant information in a fire safety manual. Details should include:

- The basis on which the means of escape was planned
- The type of management structure and staff responsibilities envisaged
- Operational details of mechanical and electrical systems, and
- Record drawings of active and passive protection measures.

5 MATERIALS

5.01

The materials forming a building should be chosen having regard to the safety of the structure and occupants. The adequacy of their resistance or their ability to sustain load for any particular period may necessitate their protection to prevent the premature failure of the structure by collapse or failure of loadbearing capacity. Additional resistance may be achieved by protective coverings, casings or membranes.

Table XXV Maximum permitted part of travel distance in certain areas of ancillary accommodation (from BS 5588: Part 3, Table 8)

Areas of ancillary accommodation	Cross-reference	Maximum part of travel distance within the room (m)	
		For escape in one direction only, or in directions less than 45° apart that are not separated by fire-resisting construction	For escape in more than one direction in directions 45° or more apart, or in directions less than 45° apart but separated by fire-resisting construction
1 Higher fire risk areas other than items 2, 3, 4 and 5	11.6		
2 Transformer and switchgear rooms	12.2		
3 Boiler rooms	14.6.2	6	12
4 Some fuel storage spaces	14.7		
5 Room housing a fixed internal combustion engine	14.8		

See 1

Table XXVI Structural fire protection of areas of ancillary accommodation (from BS 5588: Part 3, Table 9)

Area of ancillary accommodation	Cross-reference	Structural fire protection: the area of ancillary accommodation should be separated from other parts of the building by:
1 Storage area not greater than 450 m^2 (see notes 1 and 2)	18	Robust construction having a minimum standard of fire resistance of 30 min (see note 3)
2 Repair and maintenance workshops and reprographic rooms (see note 1)	20	
3 Kitchens (separately or in conjunction with an associated restaurant/canteen)	21	
4 Transformer, switchgear and battery rooms, for low voltage or extra low voltage equipment	12.2	
5 Loading bays	18	Robust construction having a minimum standard of fire resistance of 60 min (see note 3)
6 Storage areas greater than 450 m^2 (see notes 1 and 2)	18	
7 Service installation rooms other than those covered by items 4 and 10 to 14 inclusive		
8 Car parks within or adjoining an office building and not greater than 450 m^2 in area	19	
9 Car parks within or adjoining an office building and greater than 450 m^2 in area	19	Robust construction having a minimum standard of fire resistance equivalent to that required of the elements of construction of the building and in no case less than 60 min (see note 3)
10 Boiler rooms (see note 4)	14.6	
11 Fuel storage spaces (see notes 4 and 5)	14.7	
12 Transformer and switchgear rooms for equipment above low voltage	12.2	
13 Rooms housing fixed internal combustion engines	14.8	
14 Any higher fire risk area other than items 10 to 13	11.6	

Notes:
(1) Not higher fire risk areas.
(2) Other than refuse storage.
(3) Any openings in the required constriction should be protected by doors having a similar standard of fire resistance.
(4) Other than oil fired boiler installations and oil storage.
(5) Other than liquefied petroleum gas storage.

5.02

Fire resistance relates to the form of construction, not the material, and is stated in terms of performance in relation to British Standards methods of test:

- Loadbearing capacity (resistance to collapse)
- Integrity (resistance to fire penetration), and
- Insulation (resistance to transfer of excessive heat).

5.03

The criterion *loadbearing capacity* has replaced stability. In line with international practice, under BS 476 Part 22, non-loadbearing elements are assessed only for integrity and insulation. Loadbearing elements are tested in accordance with Part 21. BS 476 Part 8 is still often referred to, although superseded in 1987 by Parts 20, 21, 22 and 23. When tested specifications are used, the construction must replicate that tested in total. Consideration of products or systems having an Agrément Certificate issued by the British Board of Agrément or a product complying with a European Technical Approval (refer to the EEC Construction Products Directive) may be of use.

5.04

Regard should be given to the ease of acquiring the required fire protection, ease of construction, and durability. Although the last is not required under the Building Regulations, a material should be 'fit for the purpose'. There are several terms used in Approved Document B issued in support of the Building regulations specifically relevant to materials and their choice.

5.05

Restriction of the spread of flame across the surface of a material is an important factor of fire safety, as it affects fire growth and spread, and means of escape. The surface spread is referred to in terms of class classification in accordance with BS 476 Part 7 1971 and reference to Class 0. Flame spread can be reduced by the application of chemicals in the form of a surface application or pressure impregnation. In the latter case mechanical damage to the surface exposing a substratum will not be detrimental to the material. Materials chosen for low spread of flame properties may later be compromised by inappropriate painting.

5.06 Steel

Exposed steel can lose strength very quickly when exposed to fire; buckling and collapsing in as little as 10 to 15 minutes. The actual temperature at which it starts to lose strength depends on the type of steel, whether it is in tension or compression, and its restraint if any. Encasing the steel insulates it against temperature rise. Protection can be in the form of concrete, fire-retardant boards, fibrous sprayed or intumescent coatings; or suspended ceilings. Water cooling has been used to protect columns.

5.07 Aluminium

Some forms fail structurally at quite low temperatures but it has good properties for flame spread.

5.08 Concrete

This loses its crushing strength in fire, Table XXVII. The heat of the fire also affects the strength of steel reinforcement. Adequate concrete cover is essential, and may require the addition of mesh reinforcement to restrict spalling; this is caused by the reinforcement expanding with heating.

Table XXVII Behaviour of concrete in fire

Temperature (°C)	Permanent loss of compressive strength as demonstrated by crushing test
250	5%
600	64%
1200 and above	collapse

5.09 Clay masonry, brickwork

As a form of ceramic clay performs well at high temperatures albeit some expansion may take place. Any steel in clay can expand causing failure and should be protected.

5.10 Timber

This performs better than steel in a fire. It is a low conductor of heat; it progressively chars, protecting itself with a charcoal layer. The charring rate can be assessed, and the ability of the residual timber to sustain the required loads calculated – see BS 5268 Part 4 Section 4.1 Method of calculating fire resistance of timber members. Timber studwork with plasterboard can easily achieve 30 minutes' fire resistance, one hour with additional protection. Existing timber floors can be upgraded to improve their fire resistance by the addition of soffit protection and insulation – see BRE Digest 208, *Increasing the fire resistance of existing timber floors.*

5.11 Asbestos

This is no longer used in its basic form for health reasons.

5.12 Protective board, plasterboard, mineral fibre boards

This is used to protect structural members, and form fire-resisting enclosures on suitable frames. Some forms of construction and systems can achieve in excess of 2 hours, fire resistance when constructed correctly. Care is necessary when cutting for services, etc to maintain the fire resistance. There are many proprietary systems utilising protective boards on timber and metal frames.

5.13 Glass

Plain glass (also depending on whether it is toughened or laminated) offers negligible fire resistance. Wired glass can achieve a 1 hour standard of fire resistance in terms of integrity but with little insulation. Recent developments have resulted in plain glass giving 15 minutes, insulation. Insulating fire-resisting glazing can achieve in excess of 2 hours; the size of glazing panels may be restricted.

5.14 Plastics

Thermosetting (harden when heated) and thermoplastic (soften on heating). Plastics often fall from their supports, making an assessment of their action in fire difficult under test conditions. The material may not burn, but can drip flaming droplets and spread fire. See Approved Document B regarding the acceptable use of thermoplastic materials for ceilings, rooflights and lighting diffusers.

5.15 Doors and shutters

Wooden, glass, metal or composite, Table XXVIII. Some can achieve a fire resistance in excess of 4 hours. They are tested with regard to their integrity and insulation; most do not require insulation. Shutters are generally held open and close on the actuation of a fusible link, or automatically following detection of heat or smoke. Doors are designated according to their performance in minutes in terms of their integrity. Doors forming part of a protected enclosure (stair, lobby or corridor) for means of escape should have not less than a 30-minute standard of fire resistance. Additionally these doors should be able to resist the passage of

Table XXVIII Provisions for fire doors (from Approved Document B, Table B1)

Position of door	Minimum fire resistance of door in terms of integrity (minutes) when tested to BS 476-22[(1)]	Minimum fire resistance of door in terms of integrity (minutes) when tested to the relevant European standard[(3)]
1 In a compartment wall separating buildings	As for the wall in which the door is fitted, but a minimum of 60	As for the wall in which the door is fitted, but a minimum of 60
2 In a compartment wall:		
a. If it separates a flat from a space in common use;	FD 30S[(2)]	E30 Sa[(2)]
b. Enclosing a protected shaft forming a stairway situated wholly or partly above the adjoining ground in a building used for Flats, Other Residential, Assembly and Recreation, or Office purposes;	FD 30S[(2)]	E30 Sa[(2)]
c. enclosing a protected shaft forming a stairway not described in (b) above;	Half the period of fire resistance of the wall in which it is fitted, but 30 minimum and with suffix S[(2)]	Half the period of fire resistance of the wall in which it is fitted, but 30 minimum and with suffix Sa[(2)]
d. enclosing a protected shaft forming a lift or service shaft;	Half the period of fire resistance of the wall in which it is fitted, but 30 minimum	Half the period of fire resistance of the wall in which it is fitted, but 30 minimum
e. not described in (a), (b), (c) or (d) above.	As for the wall it is fitted in, but add S (2) if the door is used for progressive horizontal evacuation under the guidance to B1	As for the wall it is fitted in, but add Sa[(2)] if the door is used for progressive horizontal evacuation under the guidance to B1
3 In a compartment floor	As for the floor in which it is fitted	As for the floor in which it is fitted
4 Forming part of the enclosures of:		
a. a protected stairway (except as described in item 9); or	FD 30S[(2)]	E30 Sa[(2)]
b. a lift shaft (see paragraph 5.42b); which does not form a protected shaft in 2(b), (c) or (d) above.	FD 30	E30
5 Forming part of the enclosure of:		
a. a protected lobby approach (or protected corridor) to a stairway;	FD 30S[(2)]	E30 Sa[(2)]
b. any other protected corridor; or	FD 20S[(2)]	E20 Sa[(2)]
c. a protected lobby approach to a lift shaft (see paragraph 5.42)	FD 30S[(2)]	E30 Sa[(2)]
6 Affording access to an external escape route	FD 30	E30
7 Sub-dividing:		
a. corridors connecting alternative exits;	FD 20S[(2)]	E20 Sa[(2)]
b. dead-end portions of corridors from the remainder of the corridor	FD 20S[(2)]	E20 Sa[(2)]
8 Any door within a cavity barrier	FD 30	E30
9 Any door forming part of the enclosure to a protected entrance hall or protected landing in a flat;	FD 20	E20
10 Any door forming part of the enclosure		
a. to a place of special fire risk	FD 30	E30
b. to ancillary accomodation in care homes (see paragraph 3.50)	FD30	E30

Notes:
[1] To BS 476-22 (or BS 476-8 subject to paragraph 5 in Appendix A).
[2] Unless pressurization techniques complying with BS EN 12101-6:2005 Smoke and heat control systems – Part 6: Specification for pressure differential systems – Kits are used, these doors should also either:
(a) have a leakage rate not exceeding 3 m^3/m/hour (head and jambs only) when tested at 25 Pa under BS 476 *Fire tests on building materials and structures*, Section 31.1 *Methods for measuring smoke penetration through doorsets and shutter assemblies, Method of measurement under ambient temperature conditions*; or
(b) meet the additional classification requirement of Sa when tested to BS EN 1634-3:2001 *Fire resistance tests for door and shutter assemblies*, Part 3 – *Smoke control doors*.
[3] The National classifications do not automatically equate with the equivalent classifications in the European column, therefore products cannot typically assume a European class unless they have been tested accordingly.

smoke at ambient temperatures; these are generally denoted by the suffix ‘S’, i.e. FD30S.

Most door sets require the addition of an intumescent strip to attain a 30-minute standard of fire resistance. The seal intumesces at high temperature swelling to seal any imperfections of fit or gaps and thereby protecting the edges of the door to maintain its integrity. The ambient temperature seal, which may be in the form of a brush, retards the passage of smoke around the door when the fire is at a lower temperature but possibly producing large quantities of smoke. Various codes require ‘S’ doors in different situations. To be effective for means of escape doors must be self-closing. Where a door is in constant use it may be acceptable to use a hold-open device (usually electromagnetic) to avoid it being edged open or damaged.

5.16 Materials for fire stopping and cavity barriers

These must effectively close a concealed cavity, and stop spread of fire and smoke around a service or element, by sealing an imperfection of fit. The material must be capable of sustaining movement, including expansion, be adequately fixed, and, in the case of barriers, have fire resistance. Materials include intumescent mastics, fire-protective boards, cement mortar, gypsum plaster and glass fibre; there are numerous proprietary systems.

5.17 Intumescent coatings

These are formed of differing materials with varying characteristics and foam on exposure to heat to form a protective coating. They can be used to improve fire resistance and reduce surface spread of flame. If adopted the following points should be considered:

- The intumescent system must be compatible with the material to be protected.
- The system must suit site conditions by virtue of the necessary mode of application, and in accordance with that tested and achieving the required standard. This includes atmospheric conditions,
- Not all are suitable in areas of high humidity
- Protection against mechanical damage may be necessary
- The possible damage of the protection by secondary fixings, follow-on trades or water damage.

6 FIRE PROTECTION APPLIANCES AND INSTALLATIONS

6.01

Fire protection appliances and installations are increasingly forming a part of an overall fire protection system. Active extinguishing systems are often installed to compensate for inadequate structural protection, or to facilitate an innovative concept or design which would be hampered by protective construction or division by fire walls.

6.02

The following brief descriptions give an indication of some of the appliances and systems available, and their application. The adoption of any particular system requires careful consideration – the nature of the risk, effectiveness of protection, reliability, ease of maintenance. Specialist advice should be sought. Reference should be made to the relevant British Standards – see Section 9. Although the use of a foreign system or component is not prohibited, the prior agreement and approval of any enforcing authority, insurer or water undertaker should be obtained.

6.03 Hand fire appliances: extinguishers, fire buckets, fire blankets

First aid appliance for use by general public. The extinguishing medium of hand-held extinguishers varies to suit the risk; they are colour coded for quick reference.

6.04 Hose reels

First aid appliance for use by occupants and firefighters; connected to a pressurised water supply.

6.05 Automatic sprinklers

These provide an automatically released water spray above a fire to contain its growth and inhibit its spread. There are various types and systems for specific areas, applications and risk categories. It should be noted that some systems are meant for property protection only, and that special provisions relate to life safety. Certain situations are not considered suitable for protection by sprinklers because of the potential water damage (art galleries, museums, historical libraries), the risk of accidental discharge or the unsuitability of water as the extinguishing medium for certain processes and materials. There may also be a need to provide large volumes for on-site water storage.

6.06 Water drenchers

A curtain of water, usually to protect the outside of a building or the safety curtain of a theatre.

6.07 Water spray projector systems

For fires involving oils or similar flammable liquids.

6.08 Hydrant systems (sometimes known as mains)

A rising main to deliver water for firefighting onto the floor of a building via landing valves. A wet rising main is a pipe permanently charged with water and is generally installed in buildings above 60 m in height; beyond the pumping capabilities of a fire service pumping appliance; it requires water storage. A dry riser is a pipe charged by a fire service pump at ground/access level; it can be at any height but is generally provided in a building over 18 m. Any horizontal section should not exceed 12 m in length unless the delivery of the required rate of water at each outlet can be proven hydraulically. Falling or dropping mains deliver water to low levels. Private hydrants are provided within the curtilage of a site where statutory hydrants are too distant or where the risk is such as to require large volumes of water immediately.

6.09 Foam installations

Of limited application; generally for the extinction of flammable liquid fires. May require space for on-site foam-making equipment. There are various forms; specialist advice will be needed. A foam inlet is a fixed pipe through which foam can be pumped to protect rooms containing oil fuel, oil fired boilers etc.

6.10 Gaseous and vaporising liquid installations

These can be:

Carbon dioxide to protect an enclosed area acting in the main by dilution of the atmosphere. Not suitable for all fires. Satisfactory for electrical, computer and telephone equipment, flammable liquids, some chemicals, libraries, archives, art stores, diesel engines and textiles.

Vaporising liquids (halogenated hydrocarbons). Because of the stated detrimental effects of halon on the atmosphere alternatives are being developed; the Building Research Establishment should be consulted for information on acceptable alternatives.

Dry powder installations are suitable for use on flammable liquid and metal fires. Clearance after use is a problem.

6.11 Automatic detectors

Note that their effectiveness is dependent upon the correct selection and siting – see the various Building Research Establishment reports:

Smoke detectors detect the presence of smoke by optical (obscuration) or ionisation methods and raise an alarm. Ionisation detectors are sensitive in the early stages of a fire when smoke particles are small; most suitable in a controlled environment such as a computer suite. Optical detectors react to the visible products of combustion and are the most effective.

Heat detectors detect heat at a pre-selected temperature or on a rapid rise in temperature. Use where smoke may be present as part of process or function but regard should be had to normal temperature of area where sited.

Radiation and ultraviolet detectors respond to distinctive flame flicker. Suitable for large open areas and can detect certain chemical fires.

Laser beam detectors: rising hot air affects laser beam being projected onto receiver by obscuration or movement. Suitable for covering large open areas but note that the receiver may be subject to building movement; beware of false alarms from falling objects or birds.

6.12 Fire alarms manual and automatic (as defined in BS 5839 Part 1)

The system must be carefully chosen to meet specific needs – property or life safety; special needs of those with impaired hearing or sight; public entertainment application (possibly muted alarms) or a specific evacuation procedure (two stage/phase evacuation).

6.13

A manual system (gongs, handbells, etc) is only to be used in exceptional cases for very small buildings or specific areas. An automatic system in which an alarm of fire can be initiated automatically by the breaking of a call point or by a detector is the more common form. The complexity of the evacuation may require a message relayed via a public address system, initial alarms and alert signals, or the provision of fire telephones. Modern systems can be highly technical, incorporating computers and other data-processing equipment; specialist advice should be obtained at an early stage in any design.

7 STATUTORY REQUIREMENTS

7.01

The statutory requirements to provide fire precautions almost without exception relate to life safety and the dimmution of fire, although in consequence a degree of property protection is achieved. Some counties and most major conurbations have local Acts or bylaws in relation to access for firefighting. Many large towns and cities have provisions relating to 'large' buildings. At the time of writing the legislation relating to fire is under major review, with a view to rationalisation and streamlining aimed at deregulation. This will involve the repeal of many Acts and Regulations where the Building Regulations have a similar requirement, and extension of existing fire safety legislation to encompass uses such as public entertainment currently dealt with under numerous statutes. A list of national legislation relating to fire is contained in Section 8.

7.02

The Building Regulation (England and Wales) are substantive; the Scottish Building Regulations are currently prescriptive (but are under review); the Building Regulations (Northern Ireland) are currently prescriptive.

7.03

The fire safety aspect of the Regulations in England and Wales (Part B) applies to all buildings other than certain prisons. While there is an Approved Document of technical standards to Part B there is no obligation to adopt its recommendations. Provided that the substantive requirement is fulfilled any solution acceptable to the enforcing authority (or Approved Inspector) may be used. If a recognised code is used it is only necessary for the purposes of fulfilling the statutory requirement to adopt the recommendations pertaining to the requirement. However, care should be exercised, as any one recommendation may be reliant on the adoption of another. Section 9 details current codes and guides.

7.04

The requirements for fire safety under the building Regulations of England and Wales are:

BI: Means of escape. The building shall be designed and constructed so that there are means of escape in case of fire from the building to a place of safety outside the building capable of being safely and effectively used at all material times.

B2: Internal fire spread (linings)

(1) To inhibit the spread of fire within the building the internal linings shall
  (a) resist the spread of flame over their surfaces; and
  (b) have, if ignited, a rate of heat release which is reasonable in the circumstances
(2) In this paragraph 'internal linings' means the materials lining any partition, wall, ceiling or other internal structure.

B3: Internal fire spread (structure)

(1) The building shall be designed and constructed so that, in the event of fire, its stability will be maintained for a reasonable period.
(2) A wall common to two or more buildings shall be designed and constructed so that it resists the spread of fire between those buildings. For the purposes of this subparagraph a house in a terrace and a semi-detached house are each to be treated as a separate building.
(3) To inhibit the spread of fire within the building, it shall be subdivided with fire-resisting construction to an extent appropriate to the size and intended use of the building.
(4) The building shall be designed and constructed so that the unseen spread of fire and smoke within concealed spaces in its structure and fabric is inhibited.

B4: External fire spread

(1) The external walls of the building shall resist the spread of fire over the walls and from one building to another, having regard to the height, use and position of the building.
(2) The roof of the building shall resist the spread of fire over the roof and from one building to another, having regard to the use and position of the building.

B5: Access and facilities for the fire service

(1) The building shall be designed and constructed so as to provide facilities to assist firefighter in the protection of life.
(2) Provision shall be made within the site of the building to enable fire appliances to gain access to the building.

7.05

B2, B3(1), (2) and (4), B4 and B5 apply to all buildings; certain prisons are exempt from the other requirements.

7.06

The Building Regulations relate to a building under construction, certain changes of use, and certain extensions and alterations. Once occupied the Fire Precautions Act may be applicable. To avoid any potential conflict, the Department of the Environment and the Home Office have issued an advice document to enforcing authorities on how the required consultation process should take place. The document, *Building Regulation and Fire Safety Procedural*

Guidance, also provides a guide for an applicant through the approval procedure outlining the aims and varying responsibilities of the authorities concerned.

7.07

Section 13 of the Fire Precautions Act 1971 imposes a 'statutory bar' on a Fire Authority preventing them making the issue of a fire certificate conditional on works to the means of escape approved under the Building Regulations, provided that such matters were shown on deposited plans, and circumstances have not changed. If such matters did not have to be shown the statutory bar does not apply.

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BS 5306: Fire extinguishing installations and equipment on premises
- Part 2: Specification for sprinkler systems
- Part 3: Code of practice for selection, installation and maintenance of portable fire extinguishers

BS 5446: Components for automatic fire alarm systems for residential premises
- Part 1: Specification for self-contained smoke alarms and point type smoke detectors

BS 5449: Fire safety signs, notices and graphic symbols
BS 5588: Fire Precautions in the design, construction and use of buildings
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- Part 5: Access and facilities for firefighting
- Part 6: Code of practice for places of assembly
- Part 7: Code of practice for the incorporation of atria in buildings
- Part 8: Code of practice for means of escape for disabled people
- Part 9: Code of practice for ventilation and air conditioning ductwork
- Part 10: Code of practice for shopping complexes
- Part 11: Code of practice for shops, offices, industrial, storage and other similar buildings
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43 Security

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1.01 Crimes
The main types of crime are:

1 Pilferage by staff or other insiders
2 Pilferage by public (shoplifting)
3 Vandalism without gain to the perpetrator
4 Casual break-ins
5 Planned break-ins
6 Attacks on persons for immediate gain (muggings, etc)
7 Various types of kidnapping, hijacking, etc, mainly for ransom
8 Bomb attacks, etc, for political objectives
9 Fraud
10 Assaults for other than immediate gain (racism, 'fun', vengeance, etc)
11 Arson
12 Motor vehicle crime
13 Anti-social behaviour

Table I indicates which particular building types are subject to these crimes and suggests suitable precautionary measures. Most combative measures are designed either to slow up criminals until they feel vulnerable to discovery or else makes it difficult for them to remain unobserved.

1.02 Fences
Where commercial or industrial site perimeter protection is indicated a fence is better than a wall as one can see through it. It should be not less than 2.5 m high and topped with two strands of barbed wire. Fences higher than 2 m will require planning approval, and a form of protection such as barbed wire may possibly be the subject of a public liability claim. If a wall has to be used, it should have barred openings in it.

In the domestic situation, openings in walls may be inappropriate. Walls and wooden fences can successfully be protected with trellis topping.

1.03 Windows
Window panes less than 0.05 m^2 in area cannot be climbed through. Larger panes should be as large as possible. Laminate glass may be used, particularly near door locks.

For more security windows should be barred or fitted with grilles. Vertical bars are more effective than horizontal. Ideally, the bars should be of square cross-section minimum 20 mm at a maximum spacing of 125 mm and built in 75 mm. Transverse tie-bars should be provided at 600 mm centres.

1.04 Front doors
The 'last door out' (which cannot be barred or bolted from inside) should be as stout as possible, in any case more than 44 mm thick. It should be solid (not of hollow construction) and the hinge should be internal. When opening in, the stop should be formed by rebating the solid and not planted; otherwise the tongue of the lock is readily accessible. The lock should be a mortice lock to BS 3621: 1963 or equivalent, although some prefer rim locks as mortice locks can weaken a door. If more than one lock is fitted they should be well spaced apart (approximately one third the door height).

Fire regulations require door locks to be openable from inside without a key: this conflicts with security as it facilitates an intruder's escape. In cases when there are more than a few people inside the building, or where the occupiers are unfamiliar with it, the fire escape requirements are paramount. This does not generally apply to most small domestic premises, where it is usually possible to secrete a key in proximity to the door. Locks that are key lockable from outside but have no keyhole inside and are not unlockable in any other way should not be used as legitimate occupiers may be inadvertently locked in.

Security experts also recommend non-key-operated bolts and chains in addition to locks. The disadvantage of these is that a successful intruder will use them to avoid being interrupted. However, such an interruption may lead to violence; the balance of opinion favours their provision and use.

A letter plate in the door should be sized and positioned so that it cannot be used to gain entrance: the minimum distance between it and the lock should be more than 400 mm. There have been disquieting examples of arson using letter boxes. Consideration may be given to to the provision of a letter box separate from the house on the Continental pattern.

Unless there is another method of identifying callers, a lensed spyhole should be provided. Glass in doors or adjacent to them should be laminated.

1.05 Other doors
All external doors should be of similar construction to front doors. Doors that are outward opening should be fitted with hinge-side bolts to prevent ingress by hinge removal. Patio doors are particularly vulnerable, and a supplementary steel roller-shutter may be necessary. Other than this, ensure minimum three-point locking, an anti-lift device and laminated glass in the outside layer of sealed units. French windows may also need supplementary shutters, but espagnolette locking bolts are a minimum requirement, on each leaf if double. Doors from integral garages should be as secure as external doors. Other internal doors are best left unlocked to avoid unnecessary damage.

1.06 Defensible space
The layout of any site, industrial, commercial, residential or otherwise should be considered from a security point of view. If possible, ensure that all normal and possible entry and exit points to buildings are under casual observation from neighbours or passers-by. In flats, restrict access to the rear of the building, and provide all footpaths with good lighting. Additional external lighting incorporating passive infrared detectors can be most useful.

Appropriate planting can reinforce barriers, but make sure that vegetation does not affect visibility, or trees provide easy ways over barriers.

Table I Relationship between crime and building type

Type of building	Principal risks	Vulnerable points	Design solutions
Single person/family dwellings	4, 5, 11	Ground-floor doors and windows	Doors and windows fitted with security locks that cannot be opened by merely breaking the glass
			Overlooking of all doors and windows from neighbouring properties, with adequate lighting from street lights etc
		Upper windows near to low-level roofs, drainpipes, etc	Anti-climb paint or barbed wire on drainpipes
			Locks and visibility as above
Flats	3, 4, 5, 6, 11, 13	Door to flat, particularly where this opens off internal lobby, as no window is allowed by fire regulations. This means that criminals can often proceed without the possibility of being seen from a neighbouring flat	Solid door with bolts at hinge side in addition to security locks, bolts and spyhole
			Good lighting, proof against interference
			Minimum length of corridors, few corners
Multi occupancy dwellings	3, 4, 5, 6, 11, 13	Generally as flats	Generally as flats
Hostels	1, 4, 11	Communal areas	No architectural measures other than ensuring that fire exits cannot be used for unauthorised ingress
		Rooms	
Hotels	1, 4, 5, 13	Kitchens, linen stores, rooms	Ensure that all exits are under constant casual observation at all times. This makes it difficult for staff or intruders to remove their booty
			A substantial safe should be provided near the reception for guests' valuables. Safe less than 600 kg weight must be secured against bodily removal
			Master key system for rooms under good control
Shops	1, 2, 4, 5, 8, 9, 10, 11, 13	Ground-floor doors and windows	Security locks and easy observation
		Back-up stores and rear corridors	Should be designed to be under constant casual observation. If not architecturally possible closed-circuit television can be used, although this may affect trade by alienating customers
		Unfrequented areas of sales floor, fitting rooms in garment shops	
Offices	1, 4, 5, 8	Ground-floor doors and windows, particularly rear fire escapes	Panic-type locks on rear escape doors. All areas under constant casual observation
			Supply all staff with lockable furniture for personal valuables
			Consider a secure store for expensive items
			Computers to be fitted with anti-theft devices
Factories and storage buildings	1, 4, 5, 8, 9, 11, 13	Ground-floor doors and windows, lorry-loading banks	Doors barred with heavy-duty locks-in many cases machinery for cutting through such devices will be to hand
			Constant casual observation, including security patrolling at night
			Good fencing around the site, with permanent lighting of the area between fence and building
Sports buildings	1, 3, 5, 6, 8, 9, 10, 11, 13	Changing rooms, cash desk	Stout lockers, good observation, substantial safe for takings, if must be left on premises
Restaurants	1, 8, 9, 13	Kitchens, stores, cash desk	Constant casual observation
Banks	5, 7, 8, 9	Almost everything	Sophisticated security measures that are not generally known outside the particular organisation
Car parks	1, 2, 3, 4, 6, 8, 9, 10, 12, 13		Observation at all times, including the use of lighting and closed-circuit television. In this case public acceptance is universal

1.07 References

BS 8220: Guide for security of buildings against crime
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44 Access and inclusion

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KEY POINTS:

- *Consider the needs of all disabled people not just wheelchair users, who form a small percentage of such a diverse group of people.*
- *At some times in their lives, people may require the same provision that is made for disabled people; flexibility is all important*

Contents

1 INCLUSIVE DESIGN

1.01 Design principles

Good design reflects the diverse nature of people and does not impose barriers of any kind. Designing inclusively guarantees accessibility to all, including disabled people, older people and families with small children.

'The Principles of Inclusive Design' (CABE) encourage high quality, inclusive design in the built environment. Incorporating these principles ensure projects are:

- Inclusive – everyone uses safely, easily and with dignity
- Responsive – takes into account of what people say they need and want
- Flexible – allows different people to use in different ways
- Convenient – everyone uses without too much effort or separation
- Accommodating – for all, regardless of age, gender, mobility, ethnicity or circumstances
- Welcoming – no disabling barriers that might exclude some people
- Realistic – recognising that one solution may not work for all and offering additional solutions as required

1.02 Design process

In order to deliver inclusive environments, the principles of inclusive design must be integrated into the design process from first principles. Making environments easy to use for everyone requires consideration other than just physical factors. These include signage/way-finding, lighting, visual contrast, controls and door furniture, and materials.

Inclusive design relates as much to the design process as to the final product, bonding user-experience with professional expertise and management practice. The process extends from inception, through the planning process, detailed design, construction to occupation, management and operation.

The goal of creating aesthetic and functional environments that can be used equally by everyone, irrespective of age, gender, faith or disability, requires a creative and inclusive design process working towards accommodating a diverse range of users.

Following the minimum provisions of the building regulations or best practice guidance alone will not deliver inclusive projects. For this, the involvement of design team, client and community are required.

2 PEOPLE

2.01 Disabled people

The UK's Disability Discrimination Act 1995 (DDA) defines a person as having a disability if they have a physical or mental impairment, which has a substantial and long-term adverse effect on their ability to carry out normal day-to-day activities. It is estimated that approximately 20% of the UK population (over 10 million people) may have rights under the DDA.

While the spatial needs of wheelchair users and people with mobility impairments are important in terms of designing the physical environment, it is also necessary to understand the barriers experienced by people with learning difficulties and mental illness, visual impairments and hearing impairments as well as conditions such as HIV, cancer, heart disease or diabetes.

2.02

In general, designing to provide access, whether physical or intellectual, will yield results that benefit the community at large. Many aspects of an inclusively designed environment will be helpful to all or most disabled people (and many others as well). In order to deliver the whole, it is useful to understand the diverse and complex nature of disability, recognising that degrees of disability vary greatly as do the combinative effect of multiple impairments.

2.03 Statistics

Some key statistics relating to disability are:

- Some 70% of disabled people in the UK have reduced or limited mobility. They represent 14% of the overall population
- Wheelchair users account for only 0.85% of the general population
- About 2 million people in the UK (approximately 4% of the UK population) define themselves as having a sight problem or seeing difficulty
- There are over 8 million deaf or hard of hearing people in the UK (14.5% of the population)
- there are 700,000 in the UK who are severely or profoundly deaf
- 14% of the UK population have difficulty on reaching, stretching or having reduced dexterity
- 5.6 million people have difficulty with physical coordination
- 3.9 million people in the UK have difficulty learning and understanding
- 700 000 people have difficulties in perceiving risk

2.04 Older people

The number of older people in the population is increasing. Many of them have or will have an impairment of some kind. Over the next 30 years, while the overall population is expected to rise by less than 7%, the proportion of the population over 65 will increase by approximately 40%, doubling the number of people over 65. In addition, the proportion of the population over 80 is expected to treble.

There is a correlation between the age and disability. Approximately 5 million people over the age of 65 have a long-standing illness and more than half the population over 75 has some kind of disability. Two-thirds of disabled people are over pension age.

Table I Dimensions for British people aged 65–80

	Men percentiles			Women percentiles		
	5th	50th	95th	5th	50th	95th
Standing						
1. Stature	1575	1685	1790	1475	1570	1670
2. Eye height	1470	1575	1685	1375	1475	1570
3. Shoulder height	1280	1380	1480	1190	1280	1375
4. Elbow height	975	895	975	740	810	875
5. Hand (knuckle) height	670	730	795	645	705	760
6. Reach upwards	1840	1965	2090	1725	1835	1950
Sitting						
7. Height above seat level	815	875	930	750	815	885
8. Eye height above seat level	705	760	815	645	710	770
9. Shoulder height above seat level	520	570	625	475	535	590
10. Length from elbow to fingertip	425	460	490	390	420	450
11. Elbow above seat level	175	220	270	165	210	260
12. Thigh clearance	125	150	175	115	145	170
13. Top of knees, height above floor	480	525	575	455	500	540
14. Popliteal height	385	425	470	355	395	440
15. Front of abdomen to front of knees	210	280	350	325	295	365
16. Buttock–popliteal length	430	485	535	430	480	525
17. Rear of buttocks to front of knees	530	580	625	520	565	615
19. Seat width	305	350	395	310	370	430
Sitting and standing						
20. Forward grip reach	700	755	805	640	685	735
21. Fingertip span	1605	1735	1860	1460	1570	1685
23. Shoulder width	400	445	485	345	385	380

People also tend to shrink slightly with age. More significantly, the body tends to be less flexible in regard to adapting to dimensionally unfavourable situations. Older people tend to have more than one impairment. It is, therefore, more important that design allows for older people.

Table I gives dimensions for people between the ages of 65 and 80.

2.05 Children and adolescents

Statures (or equivalents) for various ages in Britain are given in Table II (Statures (or equivalents) for Britons in various age groups).

Where facilities are to be used solely by small children, specific heights should be adjusted to meet their requirements There are approximately 3.3 million families in the UK with children under 5. Design in general should also consider the needs of children, for example, when providing family facilities or sinks at lower heights in toilets.

It is also worth noting that approximately 7% of children in the UK are disabled (around 770 000). Disabled children and young people currently face multiple barriers, making it more difficult for them to achieve their potential, achieve the outcomes their peers expect and to succeed in education.

Disabled parents and carers should be considered at all stages of the design process.

2.06 Large people

Obesity also needs to be considered. The prevalence of obesity in children aged under 11 increased from 9.9% in 1995 to 13.7% in 2003. This trend is expected to continue. Since the 1980s, the prevalence of obesity in adults has trebled. Well over half of all adults in the UK are either overweight or obese, almost 24 million adults.

Pregnant women, like large people, can be disadvantaged by the design of the environment. Long routes and stairs can be very tiring, narrow seats, doors and small toilet cubicles are other common barriers.

In certain buildings such as football stadia, deliberately narrow doorways are used to ensure control over entry. In these cases, and also where turnstiles are used, additional provision for large people should be made.

Table II Statures (or equivalents) for Britons in various age groups

	Percentiles		
	5th	50th	95th
New-born infants	465	500	535
Infants less than 6 months old	510	600	690
Infants 6 months to 1 year old	655	715	775
Infants 1 year to 18 months	690	745	800
Infants 18 months to 2 years	780	840	900

	Boys/men percentiles			Girls/women percentiles		
	5th	50th	95th	5th	50th	95th
Children, 2 years old	850	930	1010	825	890	955
Children, 3 years old	910	990	1070	895	970	1045
Children, 4 years old	975	1050	1125	965	1050	1135
Children, 5 years old	1025	1110	1195	1015	1100	1185
Children, 6 years old	1070	1170	1270	1070	1160	1250
Children, 7 years old	1140	1230	1320	1125	1220	1315
Children, 8 years old	1180	1280	1380	1185	1280	1375
Children, 9 years old	1225	1330	1435	1220	1330	1440
Children, 10 years old	1290	1390	1490	1270	1390	1510
Children, 11 years old	1325	1430	1535	1310	1440	1570
Children, 12 years old	1360	1490	1620	1370	1500	1630
Children, 13 years old	1400	1550	1700	1430	1550	1670
Children, 14 years old	1480	1630	1780	1480	1590	1700
15 years old	1555	1690	1825	1510	1610	1710
16 years old	1620	1730	1840	1520	1620	1720
17 years old	1640	1750	1860	1520	1620	1720
18 years old	1660	1760	1860	1530	1620	1710
Aged 19–25	1640	1760	1880	1520	1620	1720
Aged 19–45	1635	1745	1860	1515	1615	1715
Aged 19–65	1625	1740	1855	1505	1610	1710
Aged 45–65	1610	1720	1830	1495	1595	1695
Aged 65–85	1575	1685	1790	1475	1570	1670
Elderly people	1515	1640	1765	1400	1515	

Where there is fixed seating, for example, in a theatre, there should be a number of easily accessed amenity seats, which may have increased legroom, have removable arms or fold-down arms and may include a space for an assistance dog.

3 MOBILITY EQUIPMENT

3.01 Key dimensions

Wheelchair users need quite a lot of space to move comfortably and safely; people who walk with two sticks may require a wider circulatory route than someone using a wheelchair. It is worth noting that a double pushchair may be wider than an occupied electric wheelchair.

3.02 Wheelchairs users

The range of wheelchair dimensions is considerable, particularly given the overall length and width that an occupied wheelchair may extend to. The figures given for the width of a wheelchair user do not usually make allowance for their elbows and hands. The ISO standard for wheelchairs (ISO 7193) notes that to propel a wheelchair manually a clearance of not less than 50 mm, preferably 100 mm, on both sides is required.

At the present time, the maximum length a conventional wheelchair user with leg supports or an electric scooter is likely to occupy is 1600 mm. Conventionally seated wheelchair users do not usually occupy a length of more than approximately 1250 mm. However, if a wheelchair user has a companion then their combined length of the space they occupy will be typically 1375 mm – design guidance allows for 1570 mm.

The average height of wheelchair users is 1080 mm but can range as high as 1535 mm. The average height of a scooter user is approximately 1170 mm but can range as high as a maximum of 1500 mm.

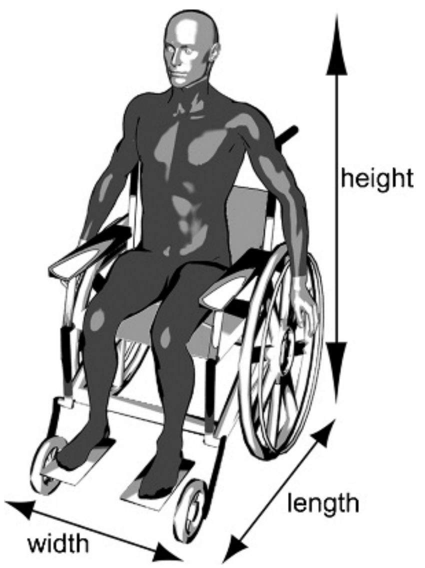
In designing for wheelchair users, the critical dimensions are:

- eye height, around 120–130 mm below seated height, giving a 5th–95th % range for wheelchair users from 960 to 1250 mm (1080–1315 mm for scooter users)
- knee height, 500–690 mm
- seat height, 460–490 mm
- ankle height, manual wheelchair users, 175–300 mm; electric wheelchair users, 380–520 mm
- height to bottom of foot support, 60–150 mm.

The ground clearance offered by typical scooters currently on the market can vary from 80 to 125 mm. The climbing capacity of typical scooters on the market also varies depending on the motor power and battery charge; however, most vary between 10° and 20°.

3.03 Wheelchair-user dimensions

These dimensions exclude the wheelchair user and only consider length and width, **44.1**. Dimensions in Table III are given for occupied and unoccupied wheelchairs over a range of wheelchair types including scooters.



44.1 *Wheelchair dimensions*

Table III Wheelchair dimensions

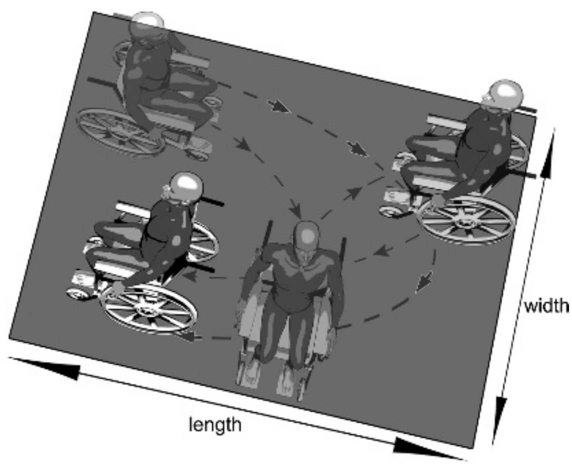
Chair type (excluding children)	Occupied		Unoccupied	
	Length (mm)	Width (mm)	Length (mm)	Width (mm)
Manual wheelchair	850–1250	560–800	700–1200	560–750
Attendant propelled	1200–1570	560–700	800–1350	550–660
Electric wheelchair	860–1520	560–800	700–1400	560–750
Electric scooter	1170–1600	630–700	1170–1500	620–640

3.04 Pushchair dimensions

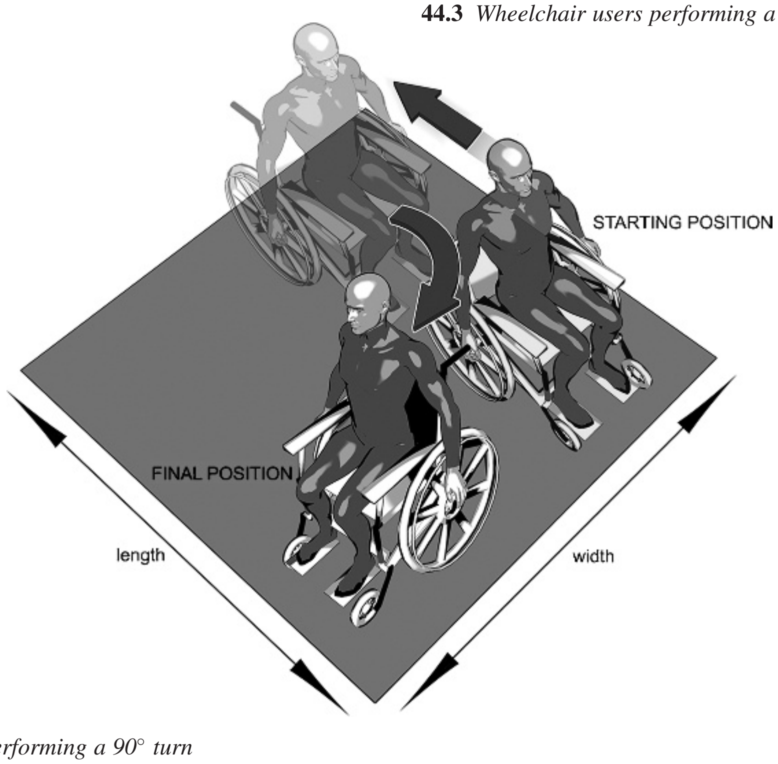
The length and width dimensions of child pushchairs are very much variable. There is not, as is the case with manual wheelchairs, a standard model for informing design criteria. Table IV gives common dimensions.

3.05 Turning spaces

Mobility aid vehicles clearly need adequate space to turn around and this will need to be considered in particular along circulation routes and in queue systems, Tables V and VI.



44.3 *Wheelchair users performing a 180° turn*



44.2 *Wheelchair users performing a 90° turn*

Table IV Pushchair dimensions

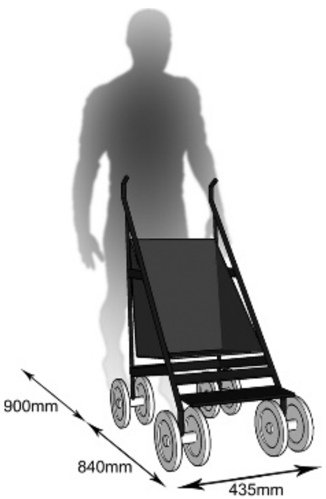
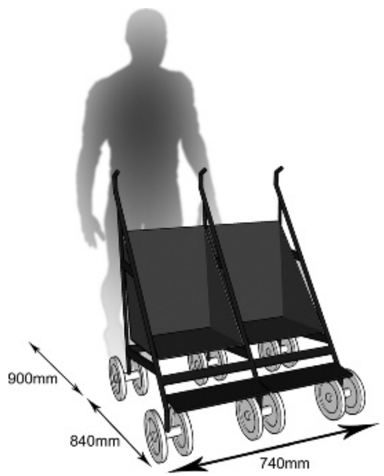
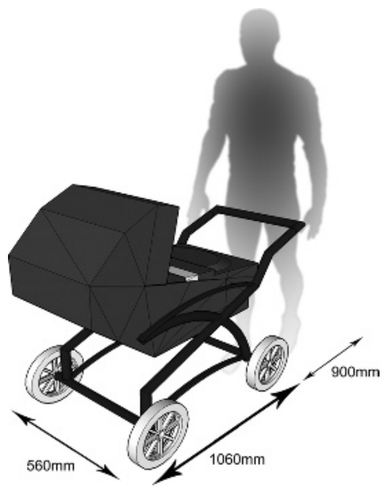
Single buggy	Double buggy	Single Pushchair	Double pushchair	Double pushchair
				
Length = 840 mm Width = 435 mm	Length = 840 mm Width = 740 mm	Length = 1060 mm Width = 560 mm	Length = 860 mm Width = 950 mm	Length = 1210 mm Width = 560 mm

Table V Space required for users of self-propelled wheelchairs to turn through 90°, 44.2

Chair type	Space required	
	Length (mm)	Width (mm)
Manual wheelchair	1345*	1450*
Attendant propelled	1200–1800	1500–1800
Electric wheelchair	1600*	1625*
Electric scooter	1400–2500	1300–2500

* Ninety per cent of users.

Table VI Space required for users of self-propelled wheelchairs to turn through 180°, 44.3

Chair type	Space required	
	Length (mm)	Width (mm)
Manual wheelchair	1950*	1500*
Attendant propelled	1600–2000	1500–1800
Electric wheelchair	2275*	1625*
Electric scooter	2000–2800	1300–2200

* Ninety percent of users.

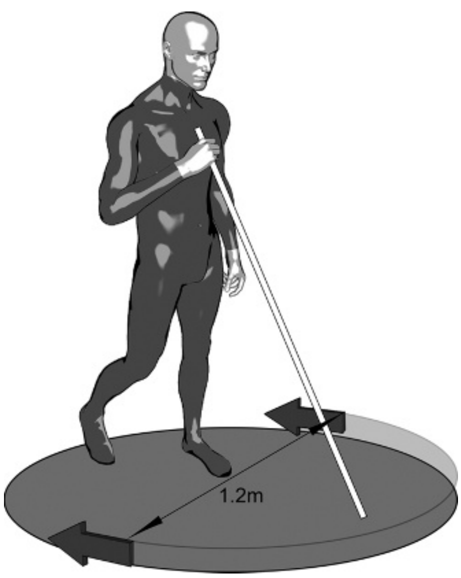
3.06 Considerations for people that use a stick, cane or crutches

It is important to consider people with a visual impairment that use a cane, **44.4**, or people with a mobility impairment that may prefer to walk using crutches, **44.5** and **44.6**.

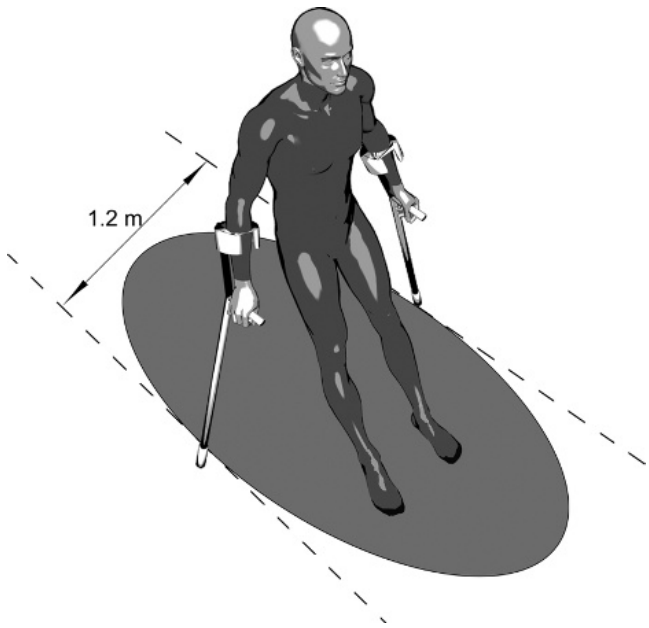
Most people who use crutches use them for a short time following an accident, and will be inexpert in their use. Users fall into two broad groups: those who have some use of both legs and feet, and those who have use of only one leg. Those who can use only one leg require a handhold wherever there are steps, even at a single step at a building threshold.

3.07 Space provision for assistance dogs

Assistance dogs include guide dogs and hearing dogs. While people primarily with sensory impairments have an assistance dog, people with mobility impairments and wheelchair users may also have an assistance dog. Inclusive Mobility identifies that people with assistance dogs require a clear unobstructed width of at least 1100 mm.



44.4 *Blind person with cane*



44.5 *Person on crutches*

44.6 *Person with a walking frame*

4 REACH RANGES

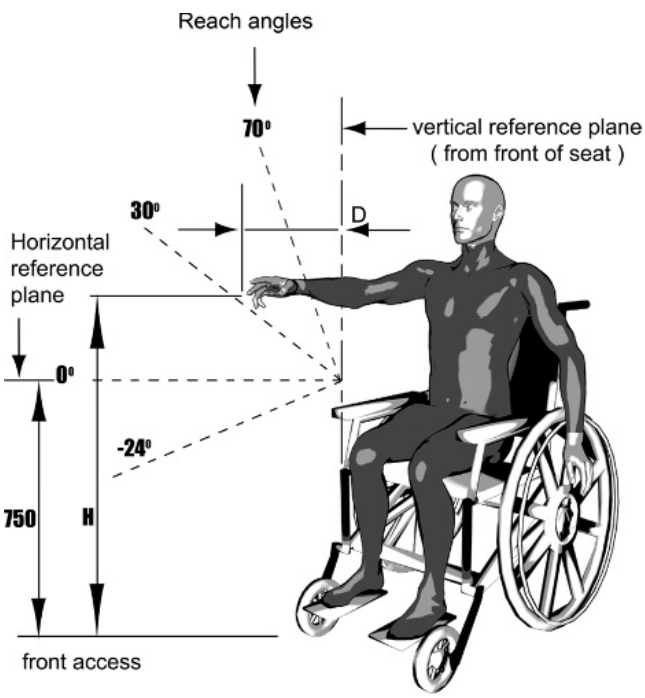
4.01

The distance and angle that an individual can reach is dependent on their size, agility, dexterity and whether they are seated or standing. The ability of a seated person, for example, in a wheelchair to reach, forward, sideways, upwards or downwards is different than someone standing.

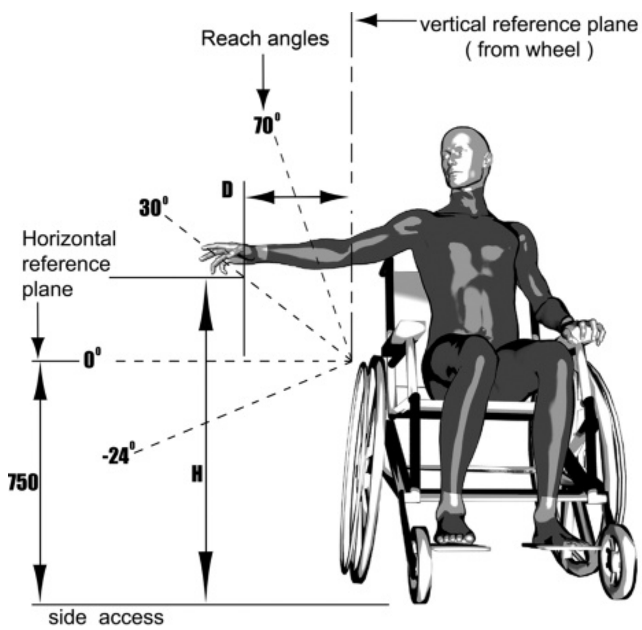
Table VII Reach ranges

Person	Access	Reach angle	Height (H)		Depth (D)	
			Comfortable	Extended	Comfortable	Extended
Wheelchair user	Front	+70	1000	1150	90	120
		Horizontal* (750)	–	–	180	230
		−24	650	650	120	200
	Side	+70	1060	1170	100	135
		Horizontal** (750)	–	–	220	310
		−24	665	630	165	230
Ambulant disabled	Front	+70	1500	1625	200	250
		Horizontal (850)	–	–	280	400
		−24	750	700	180	310

* With suitable knee recess provided.
** With suitable knee recess provided.



44.7 *Front access*



44.8 *Side access*

Reach distance forms an arc, based on shoulder level. Reach range can be described as easy or comfortable (reach without much movement of the torso) or maximum or extended (just possible with movement of the torso). Research carried out for the preparation of BS 8300:2001 gives figures for comfortable and extended reach ranges, Table VII, **44.7** and **44.8**.

5 WALKING DISTANCES

5.01 Mobility ranges

Walking distances were researched in some detail in the late 1980s. US regulations, for example, note that on distances over 100 feet (30 m) disabled people are apt to rest frequently. These regulations suggest that to estimate travel times over longer distances, allowance should be made for 2 minutes rest time every 30 m.

Research based on a follow-up study to the London Area Travel Survey found that of disabled people who were able to walk, approximately 30% could manage no more than 50 m without stopping or severe discomfort. A further 20% could only manage between 50 and 200 m.

Mobility ranges vary enormously between individuals with age and disability, while factors such as weather, topography (gradients) and obstacles can also affect mobility ranges.

In pedestrian schemes, travel distances should not exceed:

- 50 m on unprotected routes
- 100 m on covered routes
- 200 m on completely enclosed routes.

Where gradients exist travel distances should be reduced. Conversely, the provision of seating and resting places can extend the distance people can traverse. The recommended maximum distance on level ground between resting places should be no more than 50 m.

5.02 Changes in level

Any gradient less than 1:60 can be considered level. Changes in level cause problems for many people, particularly people with mobility or visual impairments. Even a single step can prevent access for someone with a mobility impairment and can present a trip hazard for all people.

Where changes in level cannot be avoided, slopes or ramps should be designed in a user-friendly manner, although it should be noted that ramps are not always the ideal solution and can take up a great deal of space.

Slopes or ramps provide access for people who use wheels, such as wheelchair users or parents with pushchairs. However, some people may find it easier to negotiate a flight of steps than a ramp and for them, the presence of handrails for support is essential. Where a change in level no greater than 300 mm, a ramp may be acceptable as the only means of access, avoiding the need for steps. Otherwise, steps would also be required.

Where ramps are provided, they should be no steeper than 1:12 but preferably 1:20. Table VIII indicates the maximum length of a ramp before level landings are required.

Table VIII Maximum ramp length between landings

Gradient	Length of ramp between level landings (m)
1:20	10
1:19	9
1:18	8
1:17	7
1:16	6
1:15	5
1:14	4
1:13	3
1:12	2

It should be noted that if the level change exceeds 2 m, then the ramps become very difficult to use for many people including wheelchair users. There should be an alternative means of access for wheelchair users, such as a lift. (Details of lifts are given in Chapter 20.)

Many people find long flights of stairs difficult to use; therefore, the maximum recommended number of steps should be 12 in a flight. If there are successive flights, it is important there are resting places, at least 1200 mm long (preferably 1800 mm) across the full width of the stair. There should be an unobstructed landing space at the top and bottom of a flight of stairs to avoid any collision.

The design of suitable stairs will be dependent on a variety of factors such as location (external or internal), building type, floor-to-floor levels and other dimension constraints as well as whether they are fire escape stairs. As a rule of thumb, a comfortable step will have a rise of between 150 and 170 mm with a going between 280 and 425 mm deep, with a preference a minimum of 300 mm.

Stair risers should be closed. Steps without projecting nosings remove a potential trip hazard. If necessary, the projection of a step nosing over the tread should be a maximum of 25 mm. All nosings should be made apparent on both the riser and tread, which will assist people ascending and descending the stair.

Stairs and steps should have a minimum clear width between handrails of 1000 mm. A handrail should be provided on both sides of the stair to allow people a choice as some people may only have strength on one side of their body.

If the width of stairway is greater than 1800 mm there should be central/additional handrails to give people extra support. The channels themselves should not be less than 1000 mm between handrails. This precludes the design of stairs between 1800 and 2000 mm in width.

6 TOILETS

6.01

Without adequate toilets many people, especially disabled people, are limited in their ability to go out to work, to shop and so forth. The majority of disabled people do not require the use of unisex wheelchair accessible WCs.

It is important that all toilet facilities are accessible, catering for a wide range of people, including older people and children. Therefore, things such as door opening pressures, range of heights of sinks and urinals, easy to use door furniture and tap design are key design factors in making all toilets useable.

Another consideration is that women may require to use toilets more frequently than men and on average take longer than men (this is particularly true during particularly during menstruation or during and after pregnancy). The British Toilet Association recommends that twice the number of male cubicles plus number of male urinals is the appropriate number of cubicles for women.

6.02 Children's toilets

Children are often not considered in the design of toilets. Many children can be deterred from independent use of toilet facilities by poor design and specification. It should also be possible in developments that are likely to have many children using them, for example, leisure facilities, to provide separate children's toilets. These could be provided with associated family facilities, such as nappy-changing facilities. Nappy-changing facilities must never be situated in accessible toilets. It is important that separate wheelchair accessible nappy-changing areas are provided.

There are approximately 1.6 million people who have continence problems. Up to 4 million people, mainly men, affected by 'shy bladder syndrome' (avoidant paruresis) and therefore the layout of toilets should provide 'line of sight' privacy', an adequate number of cubicles and privacy screens.

6.03 Adult-changing facilities

In larger developments, consideration should also be given to adult-changing facilities. Some people, including people with profound and multiple disabilities, need to be laid flat to be changed within WC accommodation. If adult-changing facilities are not provided, people may have to change a person on the floor. This is undignified, unhygienic and involves heavy lifting by others, such as carers or personal assistants, which could cause serious back injuries.

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45 Access for maintenance

CI/Sfb: (75)
UDC: 624.059
Uniclass: MX22

KEY POINTS:
- *Health and safety considerations are of the highest priority*
- *Design that does not take maintenance into account is unacceptable*

Contents

1 METHOD AND FREQUENCY OF CLEANING

1.01 Method

The methods by which windows and facades are to be regularly cleaned and maintained must be considered at an early stage of design, and the necessary equipment incorporated into the structure. Recent incidents and subsequent legislative measures reinforce this, and failure to ensure proper provision may result in very expensive remedial work.

Regular washing with cold or warm water (sometimes with a mild detergent) is normally adequate, applied either by swab with chamois leather to dry and scrim to polish; or by squeegee, which is much quicker over large areas and when used from cradles. Between 400 m^2 and 500 m^2 in eight hours is average, using a squeegee in ideal conditions.

1.02 Frequency

Table I shows some recommendations for frequency of washing according to locality, and Table II gives frequency of washing particular building types in non-industrial areas. For industrial areas and cities the interval between cleans should be halved.

Table I Recommended frequency of cleaning per year

Location	Ground floor facing street	Other windows	Rooflights
London postal area and smoky industrial areas of large cities	16	8	2
Semi-industrial towns	12	6	2
Non-industrial towns	8	4	1

Table II Recommendations for frequency of washing of particular building types

Type of building	Side windows	Rooflights
Offices	Every 3 months*	Every 12 months
Public offices, banks, etc	2 weeks	3 months
Shops	Outside every week Inside every 2 weeks	6 months
Shops (in main streets)	Outside daily Inside every week	3 months
Hospitals	3 months	6 months
Schools	3–4 months	12 months
Hotels (first class)	2 weeks	3 months
Factories (precision)	4 weeks	3 months
Factories (heavy work)	2 months	6 months
Domestic (by contract)	4–6 weeks	–

* Ground-floor windows facing streets should be cleaned at twice this frequency

2 ACCESS

2.01 Internal or external access?

Type of access is decided by:

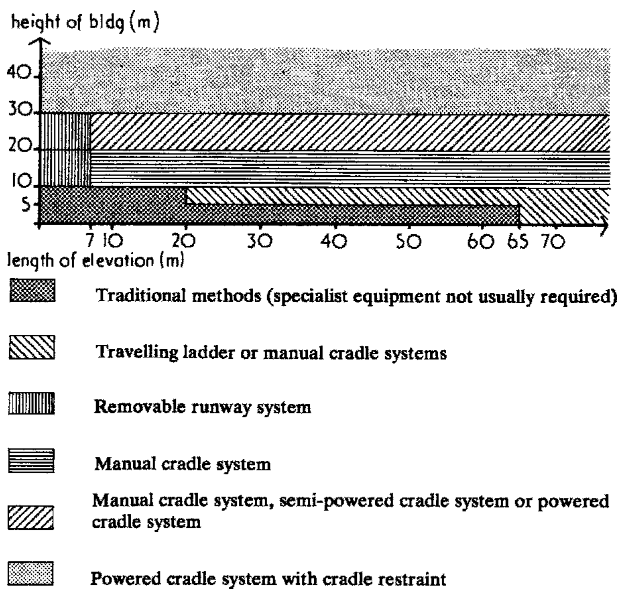
- Method and frequency of cleaning
- Capital and running costs
- Whether cleaned by tenants or professional window cleaners
- Safety requirements
- Appearance of equipment when not in use.

A general guide to selecting external types of access is shown in **45.1**. When selecting internal types of access, take into account possible problems:

- Type of window (especially high-rise housing)
- Method of cleaning adjacent exterior cladding
- Freak draughts and disruption to air-conditioning when opening windows
- Disruption to furniture and activities; possible damage to property
- Relative cost of providing opening windows (for cleaning from inside) against cost of cradle (for cleaning from outside)
- Safety (beware cleaners, especially tenants, having to lean out to clean adjacent fixed lights).

Cleaning the internal glass face is usually no problem unless inaccessible.

Often two separate contractors are given the work of cleaning the inside and outside faces. Cleaning the outside from the outside will usually give better results, and can effect long-term savings over the extra cost of providing opening windows to allow cleaning from inside.

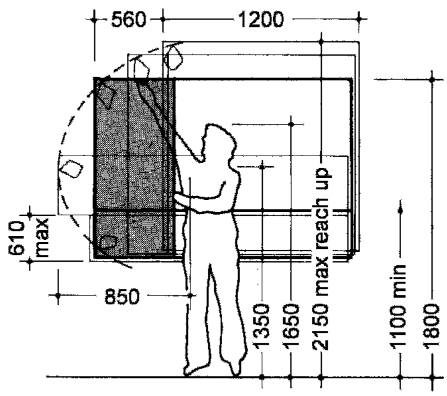


45.1 *Chart for selecting system for external access*

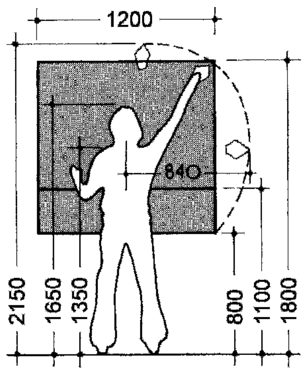
3 INTERNAL ACCESS

3.01 Ergonomics

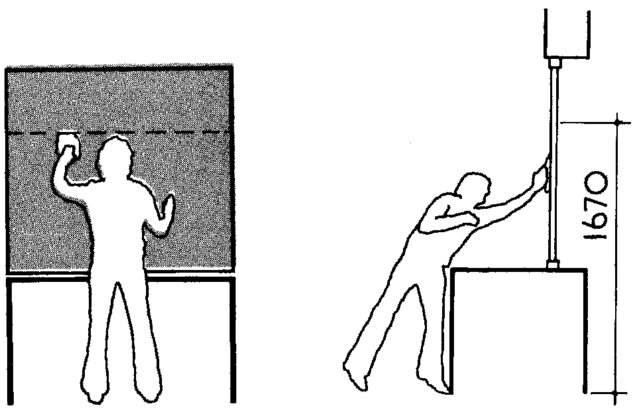
Human dimensions related to window cleaning are shown in **45.2** to **45.5**. and **Table III**.



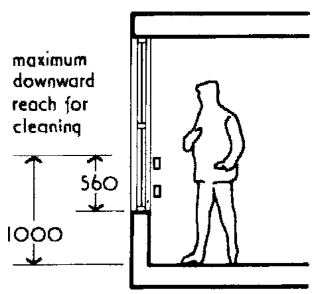
45.2 *Exterior reach to adjacent fixed light through opening light. Shaded area is average acceptable size for ease of cleaning*



45.3 *Interior reach to fixed, reversible or pivot window*



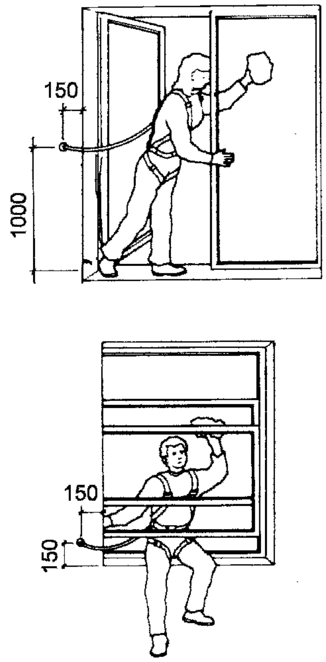
45.4 *Reach becomes less over bench or worktop*



45.5 *Dimensions of fixed light heights and guard rails for domestic buildings*

3.02 Types of window

To avoid accidents with small children, all opening windows, except possibly those less than 1.5 m above the ground outside, should now be fitted with devices to prevent them normally opening to leave a gap more than about 100 mm. This device has to be removeable for cleaning purposes, but the method should obviously be child proof. When any degree of leaning-out to clean windows is involved, a safety harness linked to an internal anchorage must be used. Two such examples are shown in **45.6**.



45.6 *Two situations where cleaning access is from the inside, but when a properly anchored safety harness should be used*

- Side-hung casements should have offset pivot hinges to give minimum 100 mm gap, set well forward of the frame which should not be fixed more than 100 mm in from the external face. Consider using Continental-type inward-opening casements which solve most window-cleaning problems.
- Double-opening windows have both side hinges and hopper hinges allowing for easy cleaning and safety.
- Hopper windows opening inwards must be low and narrow for easy cleaning. If high and large, they can be dangerous.
- Vertical and horizontal sliding sash windows should not be used for internal cleaning.
- Horizontal and vertical pivot windows are satisfactory for internal cleaning if they can be fully reversed and securely fixed with locking bolts both when reversed for cleaning and open normally for ventilation.
- Sliding projecting windows can be dangerous for internal access cleaning unless maximum depth is 750 mm, but even then cleaning can be hazardous.

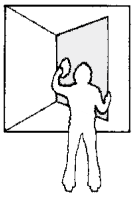
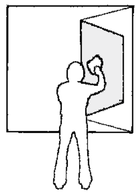
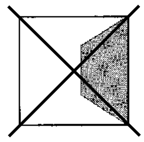
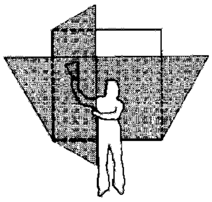
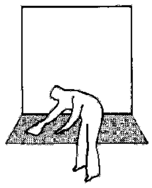
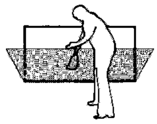
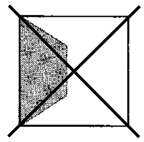
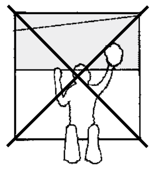
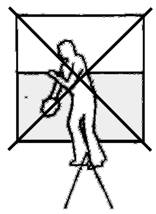
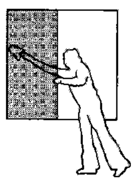
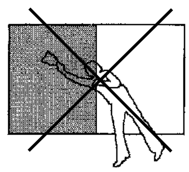
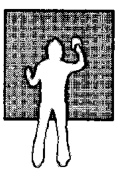
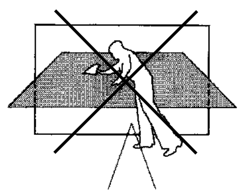
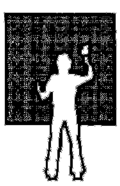
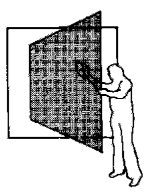
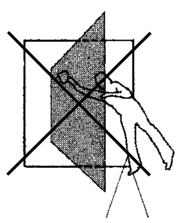
4 EXTERNAL ACCESS

4.01 Manual cleaning: access from ground

Type of access can be initially assessed from **45.1**. Manual cleaning methods with access from the ground include:

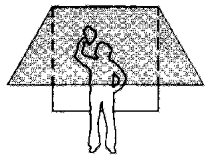
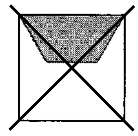
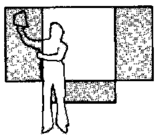
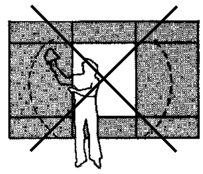
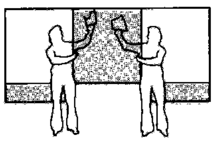
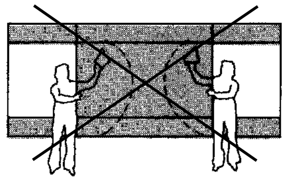
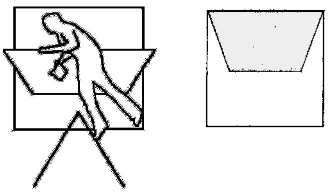
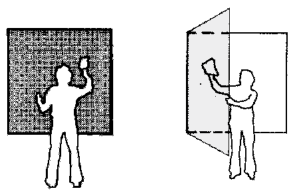
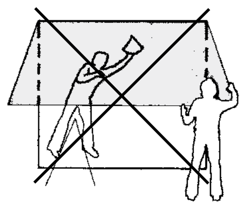
- On foot: maximum window height 1.8 m providing there are no awkward projections.
- Single part ladder: up to 3 m, but awkward with long horizontal windows (use travelling ladders – see para **4.02**. Long-handled squeegee can sometimes be used instead.

Table III Access to external faces from the inside Note: shaded area indicates glass face

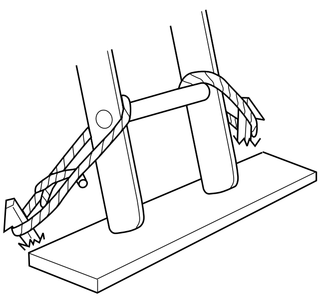
Good	Satisfactory	Bad
Casement		
 (1) Inward opening	 (2) Outward opening with extending hinges	 (3) Outward opening
Double opening hopper		
 (4)	 (5) Inward opening  (6)	 (7) Outward opening
Vertical slide		
		 (8)  (9)
Horizontal slide		
	 (10) Top corner reach possible (see **45.2**)	 (11) Corner reach not possible
Horizontal pivot		
 (12) Completely reversible		 (13) Not completely reversible and too high (see 3)
Vertical pivot		
 (14) Completely reversible	 (15) Not reversible but at correct height (see **45.3**)	 (16) Not reversible and too high (see **44.3**)

(Continued)

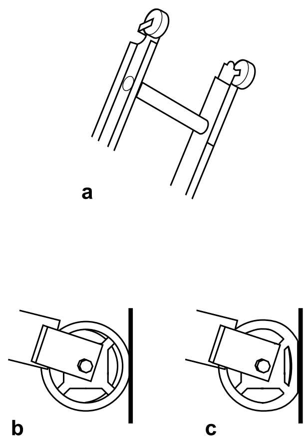
Table III (Continued)

Good	Satisfactory	Bad
Top hung		
	 (17) Top-hung opening in	 (18) Top-hung opening out is impossible to clean
Fixed adjacent		
 (19) Corner reach possible		 (20) Corner reach impossible
	 (21) Centre reach possible	 (22) Centre reach impossible
Access to internal faces Double glazing		
 (23) Fully reversible pivot	 (24) Inward opening casement	 (25) Top-hung opening. Too large and distorts when held by corner

- Ladders over 3 m must be secured. Maximum 9 m, safe inclination 83°. Securing can be with mechanical anchorage, as to the ground, **45.7**. The top of the ladder can be restrained using proprietary 'D' wheels, **45.8a**. These rubber wheels with hollows between the rib and the hub are stiff enough to stay round, **45.8b**, when the ladder top to which they are fixed is moved up or down the wall. When the ladder is in use, the wheel is pressed against the wall and becomes the D-shape that holds it securely, **45.8c**.
- Mechanical ladder on mobile chassis. Can be either freestanding or leant against a wall. More rigid than simple ladders but still only gives access to limited areas.
- Single stepladder in the form of a mobile trestle. Maximum height is 5.4 m.
- Lightweight portable scaffolding. Height is maximum three times least base dimension unless weighted, tied back to building, or outriggers fitted. Special scaffolds can be made to suit building design. Provides safe, rigid platform leaving both hands free.



45.7 *Ladder with feet supported and fixed in natural ground*



45.8 *Ladder with top restraint (Ladderfix Ltd).* **a** *'D' wheels fitted to ladder.* **b** *D wheel able to roll.* **c** *D wheel under load*

- Zip-up staging in light, hinged aluminum alloy sections each 2.14 m high × 1.6 m long × 1.35 m wide. Height is maximum four times least base dimension, but outriggers and restraint can increase this ratio. Again, variations are possible to suit building design.
- Mobile folding and telescopic platforms, only for use as secondary access for difficult areas. Generally of fixed height between 12 m and 15 m.

4.02 Manual cleaning using permanent access

There are five main possibilities:

- Balconies: but only if all windows can be reached, otherwise some other forms of access will be needed.
- Sills and ledges: if continuous, more useful to a professional window cleaner than a balcony. Construction Regulations 1966 suggest 630 mm as minimum width, but some cleaners will accept 300 to 500 mm width. A ledge from which a fall of 2 m or more is possible must be provided with either a guard rail or a continuous safety harness anchorage, as in **45.9**. Ledges requiring the operative to clip, unclip or reclip his safety harness while on the ledge are not acceptable.
- Catwalks: mainly for lateral movement. Must be level and non-slip. Maximum gradient of 20°. with regularly spaced stepping laths for sloping roofs; above 20° needs steps. Internal catwalks need 2 to 2.15 m headroom. Minimum footing width 630 mm (870 mm if materials put on gangway): guard rails between 900 mm and 1150 mm above platform when more than 2 m above ground; toe boards 150 mm deep with maximum distance of 750 mm between the board and lowest guard rail.
- Fixed ladders: use steps up to 70°, rungs over 70° pitch, **45.10.** and **45.11**. Vertical ladders not recommended, but where necessarily used must be caged. Use landings every 6 m height positioned to break fall, or use metal mesh safety cage over the ladder.
- Travelling ladders: with top and bottom fixings on continuous rail or channel to allow ladder to slide along and round the facade. Useful for long bands of glazing up to 4.5 m high; can be fixed at almost any angle.

5 ROOF SUSPENSION SYSTEMS

5.01 Temporary systems

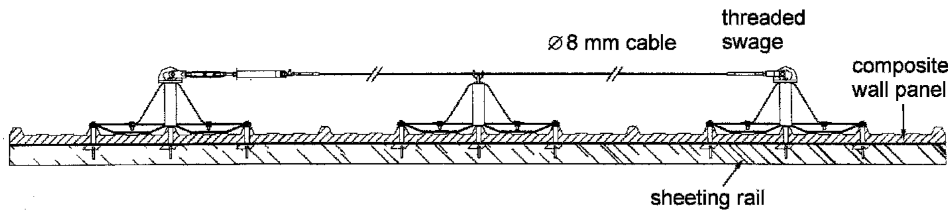
These are usually hired and erected and dismantled each time. There are two systems:

- Counterweighted system as shown in **45.12**. Rather unwieldy and limited; roof structure and parapet must be capable of taking load.
- Fixed davits as shown in **45.13**. Same problems as the counterweight system but safer, although horizontal traverse is more difficult.

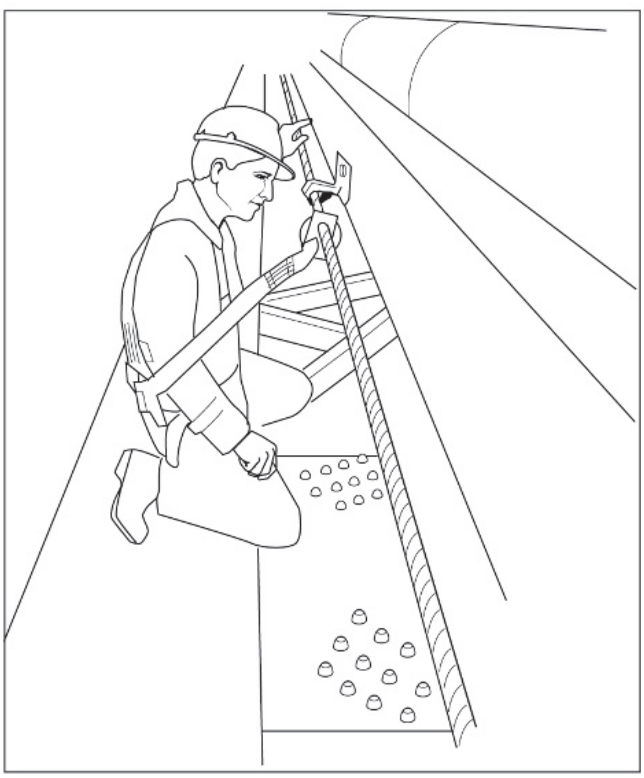
There are also a few proprietary portable gantry systems.

5.02 Permanent systems: trolley units

A permanent system is usually desirable and for frequent cleaning soon covers the extra initial cost; but unless carefully designed and integrated with the structure and facade it can look very unsightly.

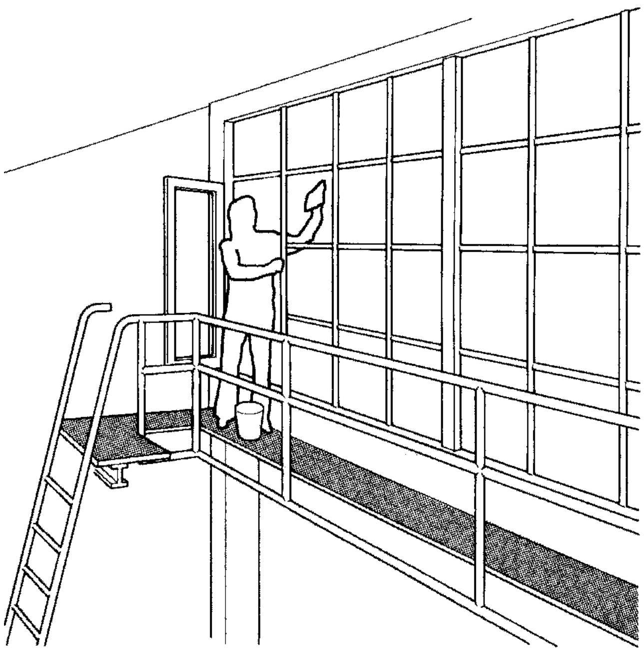


a

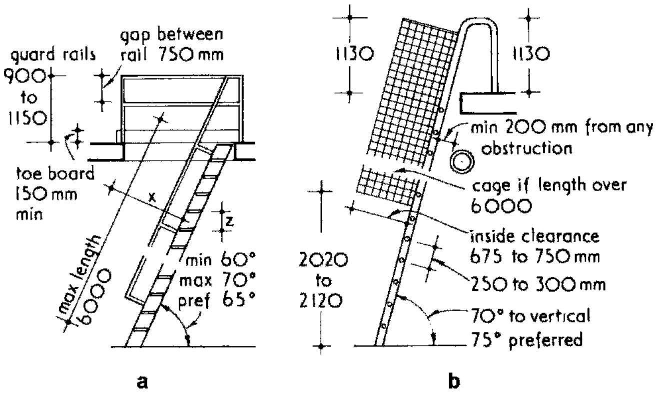


b

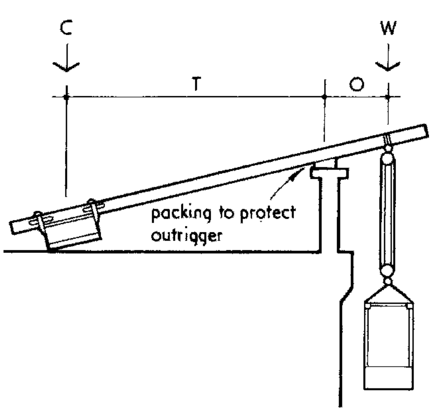
45.9 *A continuous wire cable with harness-clip that rides through the anchor fixings (Latchways plc).* **a** *Fixing to a wall.* **b** *In use*



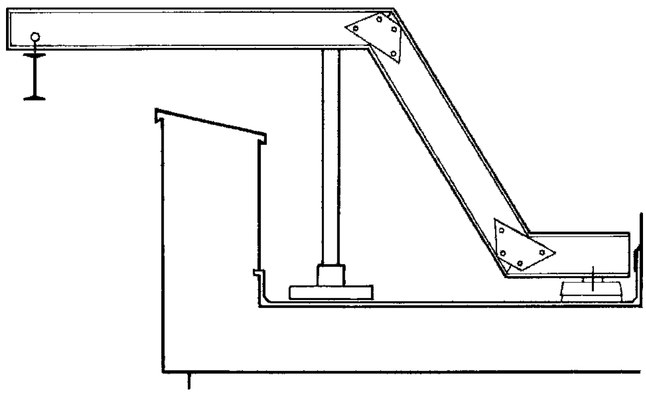
45.10 *Fixed ladder leading to interior catwalk*



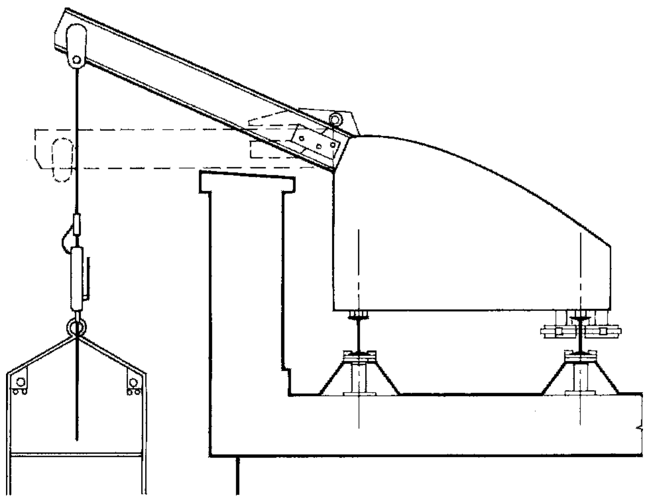
45.11 *Recommended dimensions for fixed ladders and landings, based on Construction Regulations 1966 (with additional information from Industrial Data Sheet 53) (Australian Department of Labour).* **a** *up to 70°*
x = head clearance, min 1050 mm for 60° slope, 950 mm for 70° slope
z = steps, minimum width 100 mm, 200 to 250 mm rise flight width 450 to 750 mm. **b** *over 70° with cage*



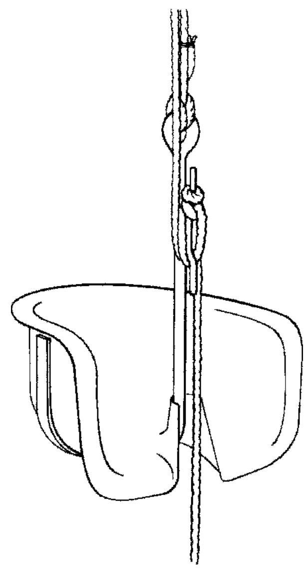
45.12 *Cradle using counterweight system*
To balance C × T = W × O
for safety C × T should not be less than three times W × O



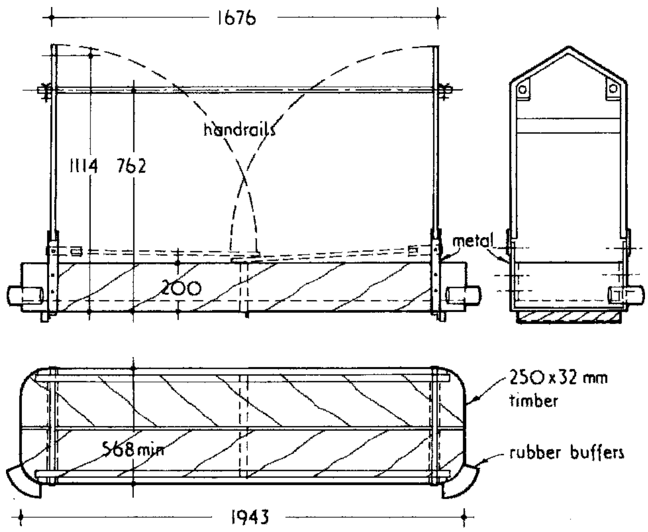
45.13 *Fixed davits on a roof with parapet*



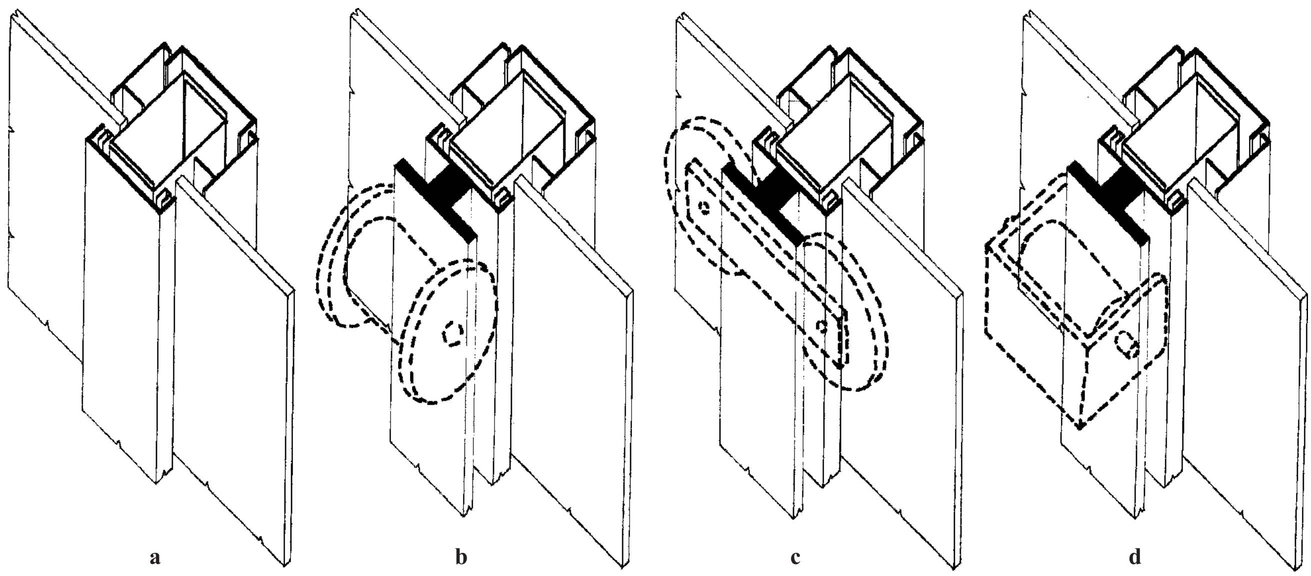
45.14 *Hand-operated roof trolley travelling on twin track. The boom can be lowered to the horizontal to deal with projections on the face of the building*



45.15 *Bosun's chair in performed plastic*



45.16 *Standard timber cradle.* ***a*** *Side elevation.* ***b*** *End elevation.* ***c*** *Plan*



45.17 *Mullion guides.* **a** *Standard mullion.* **b** *Roller on guide to prevent lateral movement.* **c** *Casters on guide to prevent outward movement.* **d** *Standard roller*

In all cases roof structure and finishes must be able to carry the imposed loads. There are two elements to consider: the roof trolley system and the suspended chair or cradle (see para **5.03**) There are two trolley systems:

- Manual roof trolley consisting of a continuous rail, often RSJ, positioned about 450 mm in front of the wall face, to which the cradle is attached by ropes and castors. The most common is a pair of continuous rails, fixed to the roof about 750 mm apart, on which runs a cantilevered trolley, **45.14**.
- Powered roof trolley is the most efficient and safest and is essential for heights of over 45 m. It is also the most expensive, but can be relatively cheap for large buildings. It must be considered at the very earliest design stages. The general principle is the same as the manual trolley except that the unit is powered. Power supply needed is 440 V three-phase.

5.03 Suspended units

There are two basic types: chairs and cradles:

- Bosun's chair, **45.15**, extensively used for awkward areas and always used with manual gantries. A modern version is the facing bicycle, with pedals to work the winch.
- Manually operated cradle. A typical standard timber cradle is shown in **45.16.** Not recommended for heights over 30 m.
- Power-operated cradle. Sizes range from 1.8 to 9 m width; materials can be steel, aluminium or GRP.

In all cases some form of manual or mechanical chair or cradle restraint, and of independent safety harness for the occupants, must be provided. The only method to provide continuous restraint is a mullion guide, **45.17**.

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The Construction (Health, Safety and Welfare) Regulations 1996

BS 5974: 1990, *Code of practice for temporarily installed suspended scaffolds and access equipment*

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BS 8213: Part 1: 1991, *Code of practice for safety in use and during cleaning of windows and doors*

SI 1998/2307 *Lifting Operations and Lifting Equipment Regulations 1998*

SI 1997/831 *Lifts Regulations 1997*

SI 1999/3242 *Management of Health and Safety at Work Regulations 1999*

SI 1998/2306 *Provision and Use of Work Equipment Regulations 1998*

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HSG 150 *Health and safety in construction*

GS 42 *Tower scaffolds*

CIS No 5 *Temporarily suspended access cradles and platforms*

GS 31 *Safe use of ladders, step ladders and trestles*

46 Service distribution

CI/Sfb (28.8)
UDC: 696, 697
Uniclass: L782

KEY POINT:

- *The space required by services is often under-estimated in sketch designs*

Contents

1 INTRODUCTION

It is said that many modern buildings are in effect enclosures for the building services. Even in modest houses the space needed to provide those services now considered essential has become a significant quantity. The methods to be used in distributing services needs to be considered in the early design stage, as this may well control the final concept.

2 SERVICE ENTRIES/EXITS AND DISTRIBUTION

Table I lists the services that are to be provided with entries or exits into different types of buildings. Table II lists those that will be distributed around the building.

3 PLANT ROOMS AND DISTRIBUTION ZONES

3.01

Plant to service the building itself can be a major space-user. Some equipment can be accommodated within general areas; but some, for one reason or another, requires dedicated and segregated space. The main plant areas which may be needed in all kinds of buildings are:

- Intake rooms, for water, gas, electricity, communications
- Transformer chambers and switch rooms
- Tank rooms for water and oil
- Standby generator rooms
- Boiler and calorifier rooms
- Sewage pump rooms
- Lift motor rooms
- Air handling and conditioning plant rooms and
- Building management system control rooms

3.02

The relationships of plant rooms and risers to the forms of particular building types are summarized in Table III.

3.03 Heating, ventilation and air conditioning

Figures for estimating the amount of space to be allocated to HVAC plant are given in Table IV. The graphs in **46.1** to **46.5** indicate the space needed for HVAC risers.

3.04 Air ducts and plenums

Table V summarizes the factors to be taken in account **46.6** to **46.8** illustrate the importance of good early planning.

3.05 Boiler and calorifier plant

46.9 illustrates a boiler room and the dimensions are given in Table VI. **46.10** shows a calorifier installation with dimensions in Tables VII and VIII.

3.06 Air handling and conditioning plant

Table IX summarises the different possible arrangements for air handling units. **46.11** shows an air handling plant room. **46.12** is a full air air-conditioning plant with dimensions in Table X.

3.07 Fan coils

Fan coil units are approximately 250 mm deep. Their lengths depend on their ratings as follows:

1.0–1.2 kW sensible cooling, 820 mm
1.2–2.4 kW, 1135 mm
2.4–3.0 kW, 1335 mm
3.0–4.4 kW, 1925 mm

3.08 Electrical equipment

Table XI gives information enabling the allocation of space required for general electrical services, while Table XII covers the provision of stand-by plant that might be required in buildings such as hospitals. The space required for the electrical risers is given in Table XIII.

A transformer and associated switchgear chamber is shown in **46.13**, the dimensions for which are given in Tables XIV, XV and XVI.

3.09 Suspended ceilings and raised floors

46.14 to **46.18** show spaces required for horizontal distribution with explanation in Table XVII.

4 DOMESTIC HEATING AND HOT WATER

46.19 is a diagrammatic representation of a traditional domestic water-borne heating and stored hot water system. A diagram of the workings of this gas-fired boiler is shown in **46.20**. A more modern system using a combination boiler, which generates the hot water on demand, is shown in **46.21**, and the boiler in **46.22**. A domestic electric hot water storage heater is shown in **46.23**. Water storage in various building types is shown in Table XVIII.

5 MOBILE TELECOMMUNICATION INSTALLATIONS

5.01

One of the phenomena of recent time has been the growth of mobile communication systems. The original analogue network has been superseded by a more sophisticated array of phone, televisual, fax and internet systems using digital technology.

5.02 Digital (GSM) networks

These have a number of advantages over analogue systems:

- they can 'roam' across different countries,
- they can cope with many more users,
- they can offer a greater number of services including e-mail, text messaging (sms), fax, internet access and Wireless Application Protocol,
- they offer greater call clarity,
- they can provide greater protection against eavesdropping and fraud.

Table I Service entries and exits

Services	Industrial transport	Offices, shops, administration	Health	Catering	Recreation	Religious	Education, laboratories, art galleries, museums	Houses	Flats	Hostels, hotels
Electricity	High voltage Medium voltage Low voltage three-phase	Low voltage three-phase	Medium voltage Low voltage three-phase	Low voltage three-phase	Low voltage three-phase	Low voltage three-phase	Low voltage three-phase	Low voltage single-phase	Low voltage three-phase for lifts	Low voltage three-phase
Gas	Yes	Yes	Yes	Yes	Yes	Possibly	Yes	Yes	Yes	Yes
Heating oil	Possibly	Possibly	Possibly	Possibly	Possibly	Possibly	Possibly	Possibly	Possibly	Possibly
Hot water or steam for heating		Possibly	Possibly						Possibly	Possibly
Fresh water	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
High pressure water for sprinklers etc	Yes	Probably	Possibly	Possibly	Possibly	No	Possibly	No	No	Possibly
Sewerage	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Separate rainwater	Possibly	Possibly	Possibly	Possibly	Possibly	Possibly	Possibly	Possibly	Possibly	Possibly
Flue or flues	Yes	Yes	Yes	Yes		Only crematoria	No	Yes	Possibly	Possibly
Telephone	Many lines	Possibly many lines	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cable	Possibly	Unlikely	Possibly	Yes	Yes	Yes	Yes	Possibly	Yes	Yes
TV aerial feed									Yes	Yes

Table II Services to be distributed in buildings

Services	Industrial, transport	Offices, shops, administration	Health	Catering	Recreation	Religious	Education, laboratories, art galleries, museums	Houses	Flats	Hostels, hotels
Electricity	Medium voltage Low voltage three-phase Low voltage single-phase for power Low voltage single-phase for lighting	Low voltage three-phase Low voltage single-phase for power Low voltage single-phase for lighting Uninterruptible and protected power supply (UPS)	Low voltage three-phase Low voltage single-phase for power Low voltage single-phase for lighting Possibly UPS	Low voltage three-phase Low voltage single-phase for power Low voltage single-phase for lighting	Low voltage three-phase Low voltage single-phase for power Low voltage single-phase for lighting	Low voltage single-phase for power Low voltage single-phase for lighting	Low voltage three-phase Low voltage single-phase for power Ultra-low voltages (12 V DC, 6 V DC etc) UPS	Low voltage single-phase for power Low voltage single-phase for lighting	Low voltage three-phase Low voltage single-phase for power Low voltage single-phase for lighting	Low voltage three-phase Low voltage single-phase for power Low voltage single-phase for lighting Possibly UPS
Gas (for heating etc)	Yes	Probably	Probably	Yes	Probably	Possibly	Possibly	Yes	Probably (depending on construction)	Probably
Fresh water from mains	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Water from tank	Yes	Yes	Yes	Yes	Possibly	Possibly	Yes	Yes, as long as regulations insist	Yes, as long as regulations insist	Yes
Hot water for washing etc	Yes, or may be locally heated	Yes, or may be locally heated	Yes	Yes, or may be locally heated	Yes, or may be locally heated	Not likely	Yes, or may be locally heated	Yes	Yes	Yes
Dry riser	Possibly	Possibly	Possibly	No	No	No	Possibly	No	Yes	Possibly
Sewerage	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rainwater drainage	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Special drainage for contaminated water	Probably	No	Possibly	Possibly	No	No	Possibly	No	No	No
Hot water/steam for heating	Possibly	Possibly	Probably	Possibly	Probably	Possibly	Probably	Most probably	Most probably	Most probably
Fresh air/exhaust (ventilation)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Limited to bathrooms and kitchens	Limited to bathrooms and kitchens	Possibly
Conditioned air	Possibly	Probably	Probably	Probably	Possibly	No	Possibly	Unlikely	Unlikely	Possibly
Compressed air	Possibly	No	Possibly	No	No	No	Possibly	No	No	No
Gases such as oxygen, nitrous oxide etc	Possibly	No	Yes	No	No	No	Possibly	No	No	No
Telephone	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cable	Possibly	Possibly	Yes	Yes	Yes	Possibly	Yes	Possibly	Yes	Yes
TV aerial	No	No	Yes	Yes	Possibly	Possibly	Yes	Yes	Yes	Yes
Computer network	Yes	Yes	Yes	Possibly	Possibly		Yes	No	No	Possibly
Other communications	Public address Fire alarms Intruder alarms	Public address Fire alarms Intruder alarms	Fire alarms Possible intruder alarms	Fire alarms Intruder alarms	Public address Fire alarms Intruder alarms	Fire alarms	Public address Fire alarms Intruder alarms	Intruder alarms	Intruder alarms Entry phone systems	Public address Fire alarms Intruder alarms
Lamson tubes	Possibly	Possibly	Possibly	No	No	No	No	No	No	No

Table III Relationship of plant rooms and risers to building form

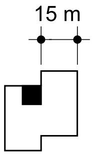
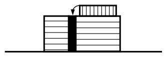
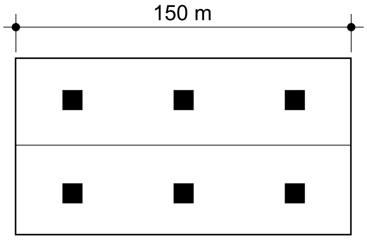
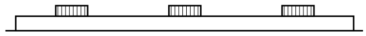
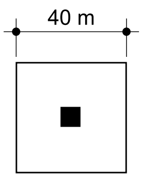
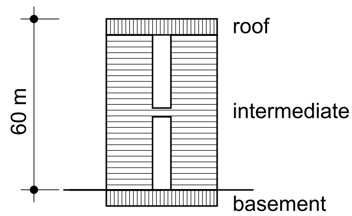
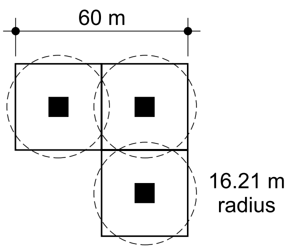
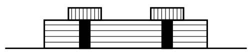
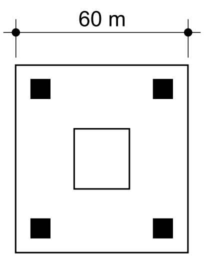
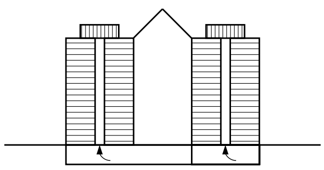
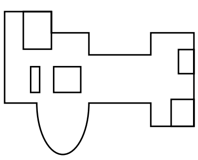
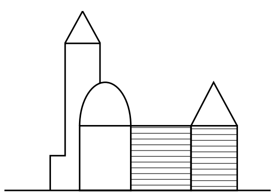
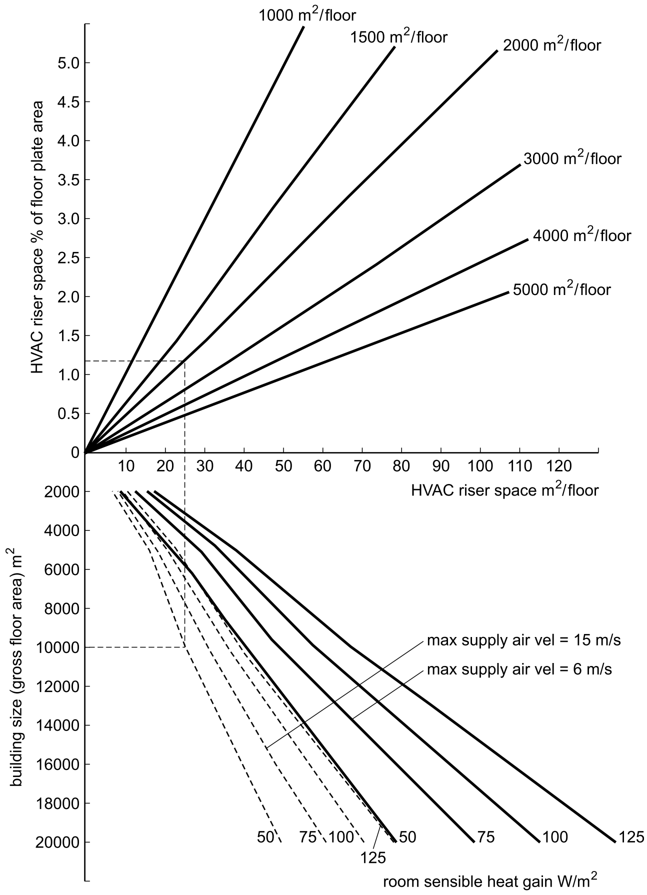
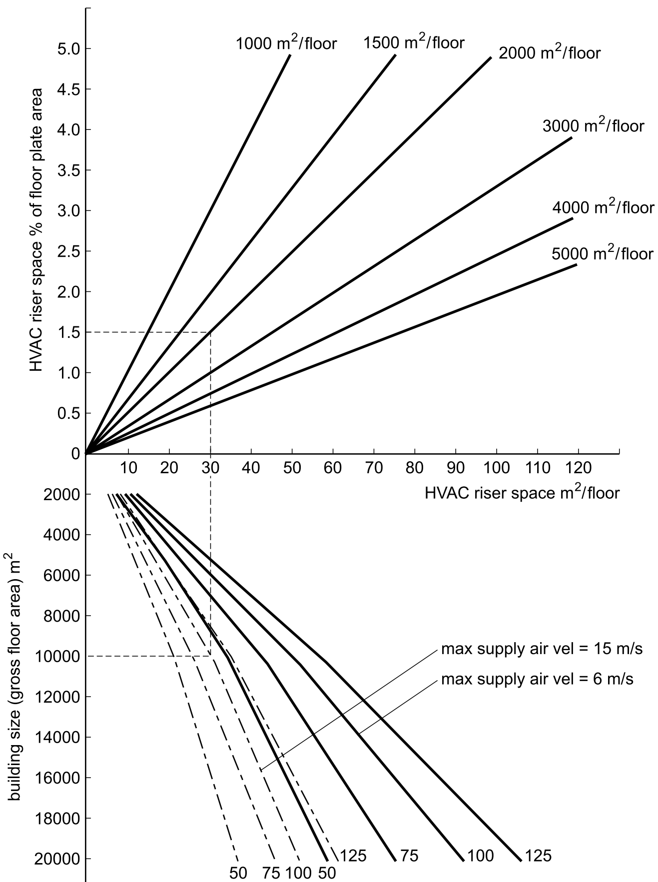
	Plan	Elevation	Comments
Key to table:		plant room	
Small building: up to 4 storeys up to 2500 m^2			One plant room, one riser. Location of riser not important due to small building size, although central location preferred. Plant room must relate to riser.
Large single storey building: min 4000 m^2			Several plant rooms, no risers. Plant adjacent to areas served. Some central plant, e.g. for gas intake, electrical intake and boilers may be required.
Large tall building: min 15 storeys			Plant room floors at basement and/or roof levels. Intermediate plant rooms may be required. Vertical distribution within the central core.
L-shaped building 1000–3000 m^2 3 to 10 storeys			Several plant rooms, several risers. Risers and air conditioning plant rooms related to vertical circulation routes. Separate energy plant room located at ground/basement level. Riser spacing related to economic horizontal length.
Atrium building: typically 2000 m^2 per floor 5 to 10 storeys	 atrium (typically 2000 m^2 per floor) (5-10 storeys)		Four roof air-conditioning plant rooms on roof, one basement energy plant room. Four risers related to vertical circulation routes. Basement plant room below atrium gives best connection to risers.
Specialised			Generally air-conditioning plant room on roof, energy plant in the basement. Several local plant rooms and distribution may be appropriate where areas have different services requirements.

Table IV Floor area percentages occupied by HVAC plant

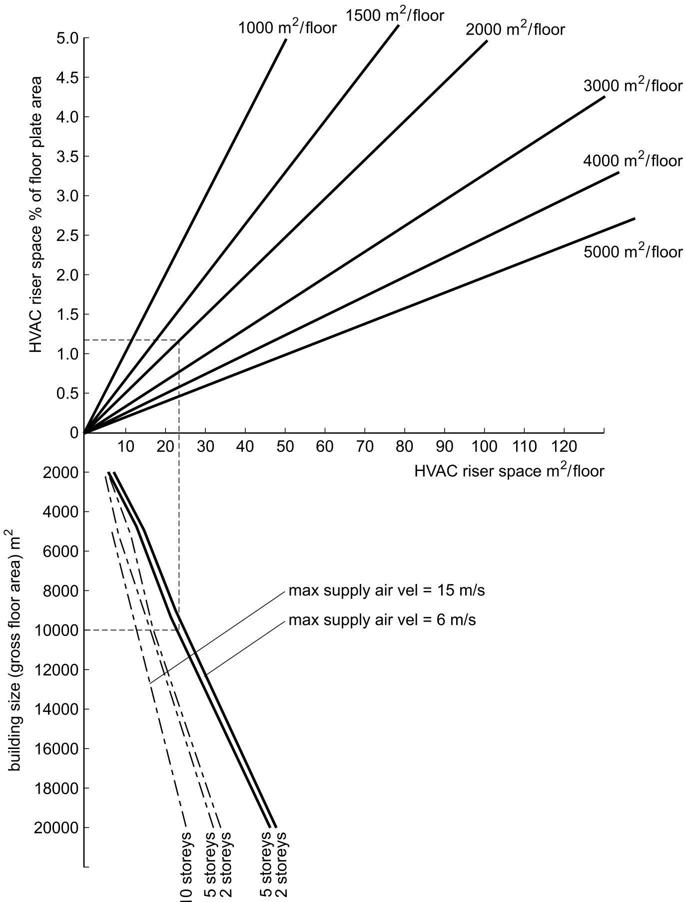
System type	Building size (m²)			
	2000	5000	10000	20000
OFFICES				
Heating only, natural ventilation:				
Central plant	1.1–1.4	0.7–0.8	–	–
Terminals: radiators	0.6–0.7	0.6–0.7	–	–
Heating only, mechanical ventilation:				
Central plant	1.1–1.4	0.7–0.8	–	–
Air handling plant	4.6–6.4	3.6–5.1	–	–
Terminals: radiators	0.4–0.5	0.4–0.5	–	–
Four-pipe fan coil system (3 ac/h primary air):				
Central plant	3.8–4.2	2.0–2.3	1.1–1.5	0.8–1.2
Air handling plant	4.6	2.7	1.6	1.6
Heat rejection cooling towers	1.2–1.4	0.6–0.8	0.4–0.6	0.3–0.5
Variations:				
Floor by floor AHU 5-storey	–	3.6	2.7	2.6
Floor by floor AHU 10-storey	–	5.4	3.5	2.6
Heat rejection by air-cooled condenser	3.2–4.3	1.8–2.8	1.2–2.4	0.7–2.4
Floor-mounted terminals	1.0	1.0	0.5	0.4
VAV and perimeter heating:				
Central plant	3.8–4.2	2.0–2.3	1.1–1.5	0.8–1.2
Air handling plant	7.5–10.8	6.0–9.0	4.0–8.7	2.3–7.7
Heat rejection cooling towers	1.2–1.4	0.6–0.8	0.4–0.6	0.3–0.5
Terminals: radiators	0.4–0.5	0.4–0.5	0.4–0.5	0.4–0.5
Variations:				
Floor by floor AHU 5-storey	–	6.0–12.0	4.8–10.4	3.7–9.2
Floor by floor AHU 10-storey	–	7.8–15.6	7.8–10.4	3.7–9.0
Heat rejection by air-cooled condensers	3.2–4.3	1.8–2.8	1.2–2.4	0.7–2.4
RETAIL				
Four-pipe fan coil system:				
Central plant	–	2.5–2.8	1.5–2.1	1.0–1.3
Air handling plant	–	3.4–3.5	3.2–3.3	3.1–3.2
Heat rejection cooling towers	–	0.8–1.0	0.5–0.7	0.5–0.7
Variations:				
Floor by floor AHU 2-storey	–	6.0–12.0	3.1	3.0
Floor by floor AHU 5-storey	–	7.8–15.6	3.9	3.0
Heat rejection by air-cooled condenser	3.2–4.3	1.8–2.8	2.0–3.7	1.9–3.3
VAV and terminal reheat:				
Central plant	–	2.5–2.8	1.5–2.1	1.0–1.3
Air handling plant	–	6.7–12.9	6.4–11.1	5.5–9.9
Heat rejection cooling towers	–	0.8–1.0	0.5–0.7	0.5–0.7
Variations:				
Floor by floor AHU 2-storey	–	6.5–12.2	6.1–12.0	5.9–11.8
Floor by floor AHU 5-storey	–	7.8–13.8	7.1–11.8	5.9–11.8
Heat rejection by air-cooled condenser	–	2.5–3.7	2.0–3.7	1.9–3.3
HOTELS				
Heated only, mechanical ventilation:				
Central plant	–	2.5–3.0	1.6–2.1	1.2–1.3
Air handling plant	–	5.0	4.8	4.7
Terminals: radiators	–	0.4	0.4	0.3
Four-pipe fan coil system:				
Central plant	–	2.5–3.0	1.6–2.1	1.2–1.3
Air handling plant	–	2.7	2.7	2.6
Heat rejection cooling towers	–	2.0–2.6	1.5–2.0	1.5–2.0
Variations:				
Floor by floor AHU 2-storey	–	3.3	2.8	2.6
Floor by floor AHU 5-storey	–	3.3	2.6	2.6
Heat rejection by air-cooled condenser	–	1.5–2.0	1.5–2.0	1.5–2.0
VAV and perimeter heating:				
Central plant	–	2.5–3.0	1.6–2.1	1.2–1.3
Air handling plant	–	6.0–7.0	4.4–6.0	4.7–5.9
Heat rejection cooling towers	–	0.6–0.7	0.4–0.5	0.3–0.4
Variations:				
Floor by floor AHU 2-storey	–	4.7–7.5	4.7–7.4	4.7–6.8
Floor by floor AHU 5-storey	–	5.0–8.4	5.0–7.2	4.6–6.5
Heat rejection by air-cooled condensers	–	2.0–2.6	1.5–2.0	1.5–2.0
Two pipe fan coils to bedrooms,	–	–	–	–
VAV and terminal reheat to public rooms:				
Central plant	–	2.5–3.0	1.6–2.1	1.2–1.3
Air handling plant	–	5.8–6.6	3.9–4.5	3.2–4.2
Heat rejection cooling towers	–	0.6–0.7	0.4–0.5	0.3–0.4
Variations:				
Floor by floor AHU 2-storey	–	4.7–5.7	4.2–5.2	4.0–4.9
Floor by floor AHU 5-storey	–	5.7–6.7	4.4–5.4	4.2–5.1
Heat rejection by air-cooled condenser	–	2.0–2.6	1.5–2.0	1.5–2.0
PLACES OF ASSEMBLY				
VAV and terminal reheat:				
Central plant	5.3–6.1	2.7–3.4	–	–
Air handling plant	7.8–11.4	6.5–3.4	–	–
Heat rejection cooling towers	1.3–1.8	0.8–1.2	–	–
Variation:				
Heat rejection by air-cooled condenser	4.2–5.9	2.7–3.7	–	–



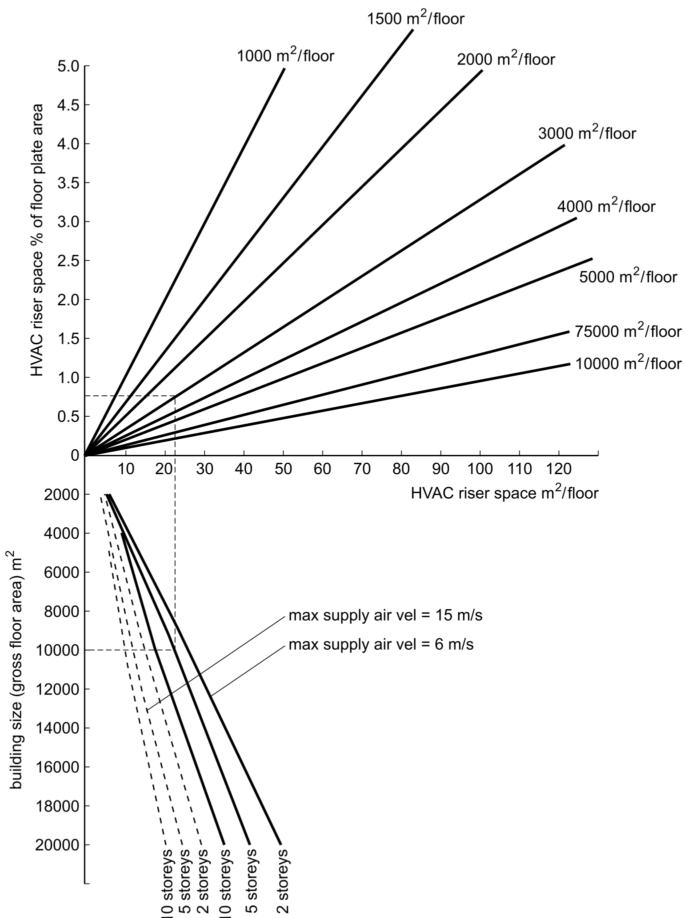
46.1 *HVAC riser space for VAV plus perimeter heating in two-storey buildings*



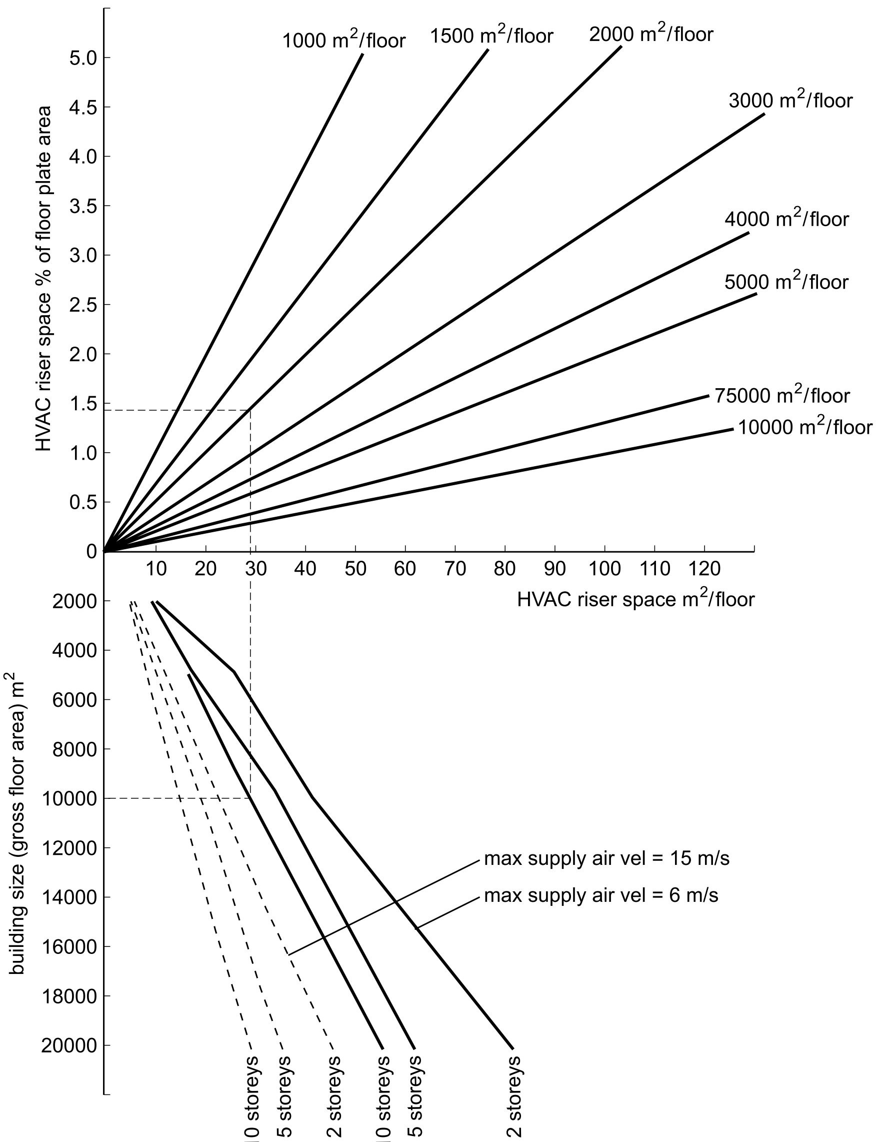
46.2 *HVAC riser space for VAV plus perimeter heating in buildings of five and more storeys*



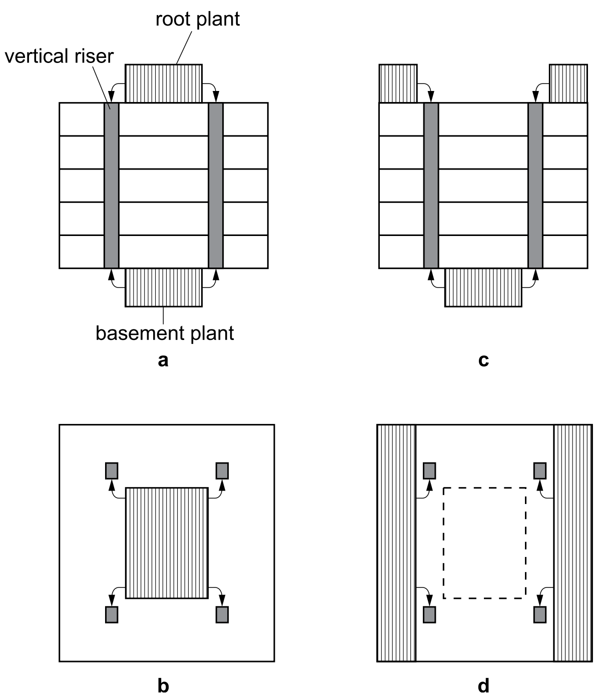
46.3 *HVAC riser space for four-pipe fan coil systems (primary air 3 ac/h)*



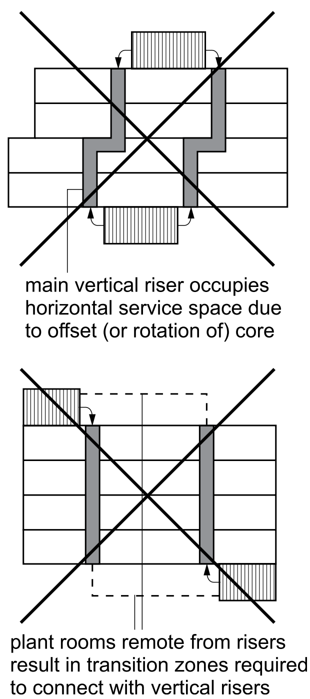
46.4 *HVAC riser space for heating only and 3 ac/h mechanical ventilation*



46.5 *HVAC riser space for heating only and 6 ac/h mechanical ventilation*



46.6 *Examples of showing good connection of plant areas to vertical risers.* **a** *Section.* **b** *Plan.* **c** *Section.* **d** *Plan*



46.7 *Examples of poor distribution efficiency: avoid these*

Table V Builder's work air ducts and plenums

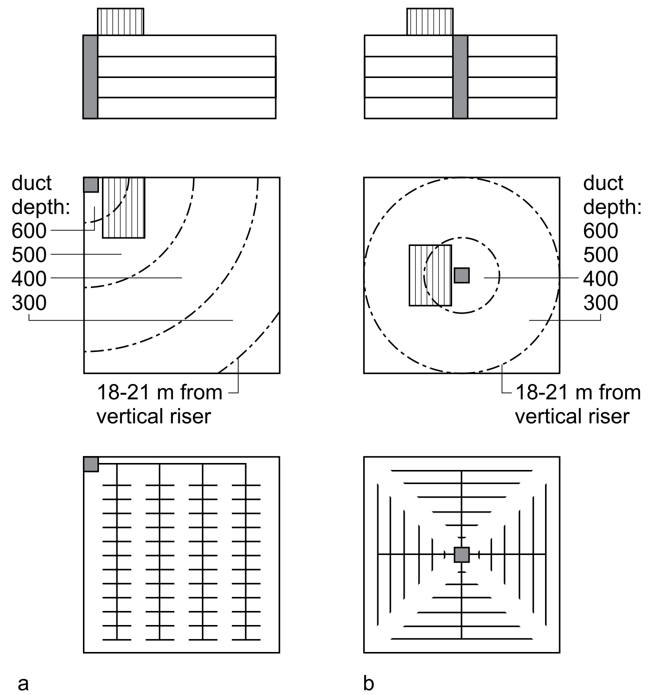
Notes on Use

1 The use of builder's work enclosures as air ducts and plenums should be very carefully evaluated at the early stages of design. In many cases, they do not represent a cheaper solution in terms of overall building costs. Sheet metal and building materials should be compared in terms of costs, performance and construction aspects.

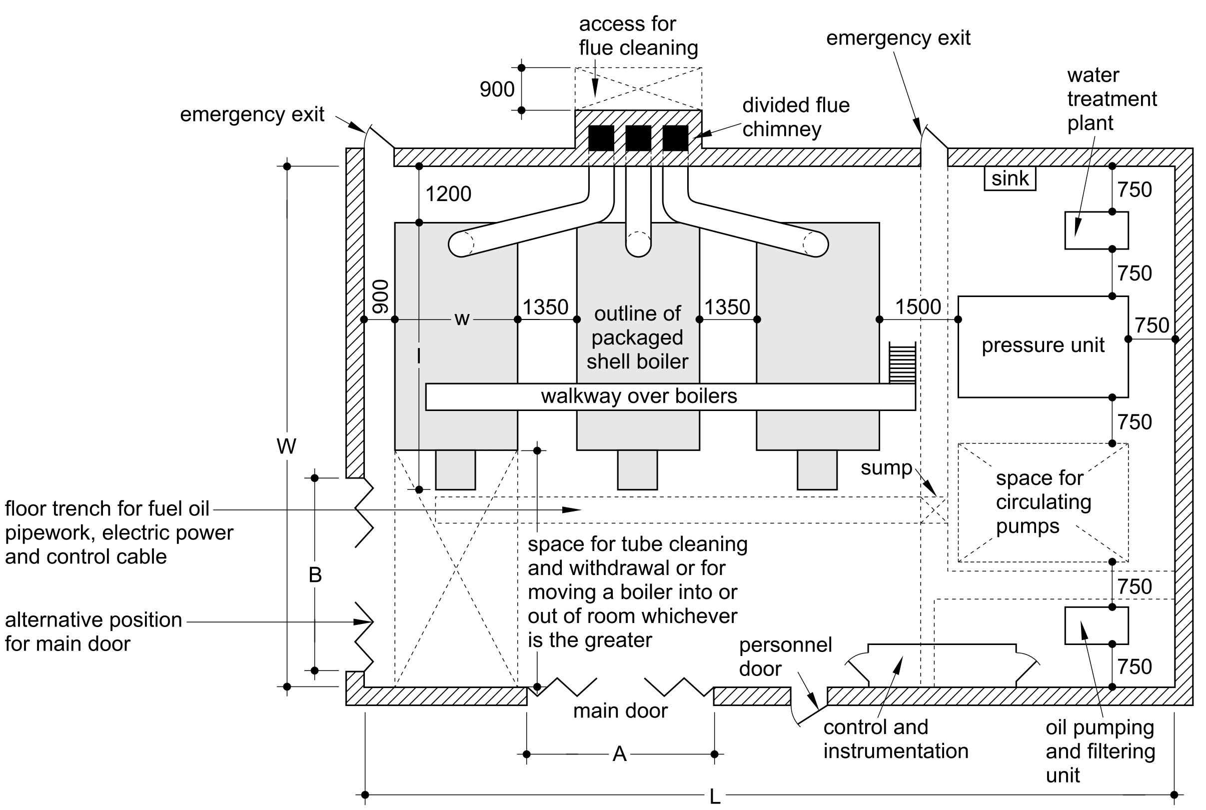
2 The use of builder's work supply ducts should be generally avoided. Filtered and thermally treated air requires careful handling. If such ducts are used, the expected standards of air tightness, insulation and moisture control are difficult and costly to achieve. Standards of workmanship should be very high and require great care to enforce in practice.

Summary of technical considerations

Energy implications	Increased fan power; friction coefficient increases for brick/block/concrete ducts when compared to sheet steel: × 1.4 for fair-faced brickwork × 2.0 for rough-finished brickwork Fan power is directly proportional to friction coefficient.
Thermal losses/gains	Thermal losses increase; greater absorption of heating or cooling energy by thermally heavy containing walls. System time constants increase, can impose control problems. Duct lining to reduce losses, must be considered with care to avoid introducing fine fibres into the air stream. Regular inspection and maintenance is required.
Leakage and filtration	Brick and blockwork is porous; settlement, expansion and contraction will result in significant leakage, particularly through mortar joints; not recommended without a generous allowance for leakage. Brick or blockwork must be rendered or plastered, preferably both sides. Access for personnel is required to allow for resealing of the duct. Adverse effect on the standard of filtration. Full consideration should be given to differential pressures across containing walls; if supply and extract ducts run adjacent, pressure differentials can be appreciable.
Construction constraints	Branches leaving large vertical risers can be problematic: (a) Detail of sheet steel duct connections is crucial. (b) Structurally, passing the branch through a highly stressed element of the building.
Specification	Involvement in the design of builders work ducts maybe outside the scope of the standard HVAC services, eg defined by ACE agreements. It is important to establish early in the design who will take responsibility for design and site supervision.



46.8 *Effects of riser location on duct depths.* **a** *A building 40 m square with air duct located at the corner. The longer the duct, the deeper it must be where it joins the riser. This increases the size of the suspended ceiling or raised floor zone.* **b** *With the riser located centrally the duct runs are shorter and their depths are reduced*



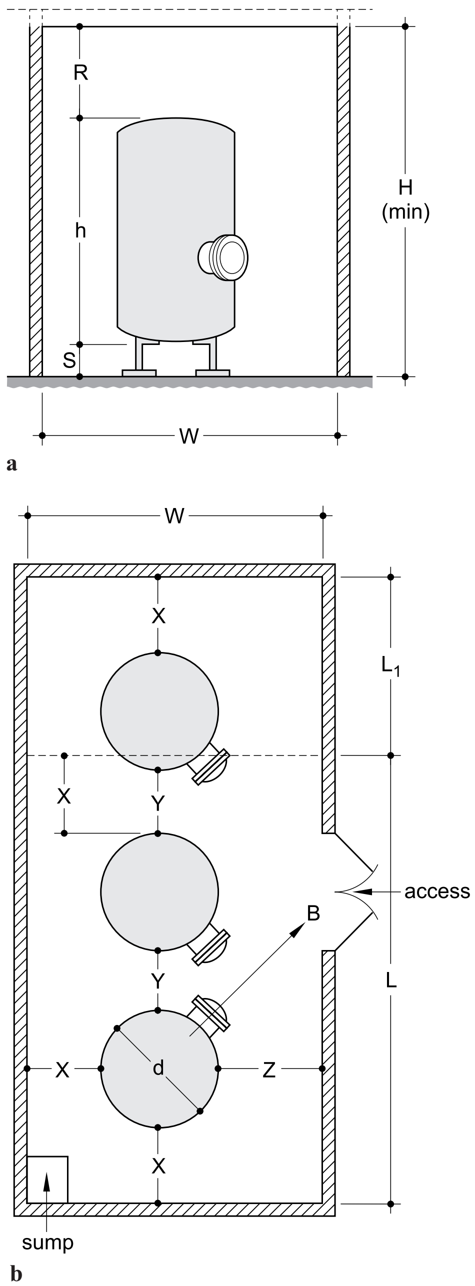
46.9 *Plant room space using oil-fired, three boiler installation*

Table VI Boiler and boiler room sizes

Total installed Boiler power kW	Clear dimensions of boiler room (mm)			Boiler dimensions (mm)			Boiler masses *t*	Minimum dimensions of door openings, (mm)		
	Length *L*	Width *W*	Height *H**	Length *l*	Width *w*	Height *H**		Width *A*	Width *B*	Height
9000	19500	12000	5400	6325	3175	3475	22	4200	3900	4200
7500	19200	11100	5100	5850	3125	3175	19	4200	3900	3900
6000	17400	10300	5100	6000	2700	3150	16	3600	3300	3900
4500	16800	10200	5100	5075	2650	3150	14	3600	3300	3900
3600	16200	9300	4500	4475	2450	2475	11	3300	3000	3000
3000	15600	9300	4500	5050	2375	2350	9	3300	3000	3000
2400	15300	9000	4500	4425	2300	2275	8	3300	3000	3000
1950	15000	8400	4200	4000	2275	2150	7	3300	3000	2700
1500	14400	7800	4200	3525	2000	1950	5	3000	2700	2700
1200	14400	7800	4200	3900	1950	2075	5	3000	2700	2700
900	14400	7800	3900	3750	1950	1975	4	3000	2700	2700
750	14100	7200	3900	2825	1800	1750	3	2700	2400	2400
600	14100	7200	3900	3075	1950	1975	3	3000	2700	2700
450	12900	6000	3900	2675	1500	1725	2	2400	2100	2400

* A nominal 2100 mm has been allowed between walkway and ceiling. This dimension may be reduced to 1500 mm locally under beams Location depends on building design

Some boilers require additional space, e.g. rear access doors, tube cleaning and withdrawal



46.10 *Vertical storage calorifier space requirements.* **a** *Section.* **b** *Plan. See Tables VI and VII and key*

Table VII Calorifier capacity and dimensions

Capacity litres	Dimensions including insulation, mm		Heater battery withdrawal (max) 8 mm	Dimensions Z mm
	Diameter *d*	Height *h*		
500	700	1800	800	750
650	800	1800	1000	750
800	850	1900	1000	750
1000	950	1900	1150	750
1200	1000	2100	1150	750
1500	1150	2100	1300	850
2000	1150	2500	1300	850
2500	1300	2600	1450	950
3000	1350	2700	1500	1050
4000	1450	3100	1600	1050
5000	1600	3100	1750	1150
6500	1700	3400	1850	1300

Dimension Z has been determined on the basis of angled withdrawal of the heater battery.

If battery withdrawal normal to the wall is required, dimension W should be increased by B–Z.

Inspection holes should be easily accessible.

Vertical spindle glandless in-line pumps can be accommodated within the overall space.

When horizontal direct-driven pumps are required, dimension W should be increased by 300 to 600 mm depending on the make of pump. Dimensions are based on conventional storage calorifiers.

Key to symbols used in Figure 46.10

X Space at sides and rear of calorifiers, nominal allowance 750 mm with a minimum of 700 mm.

Y Space between adjacent calorifiers, nominal allowance 600 mm with a minimum of 550 mm.

Z Space for withdrawal of heater battery.

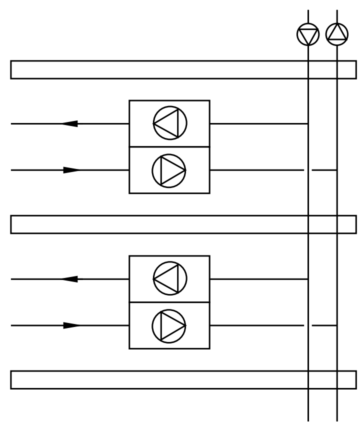
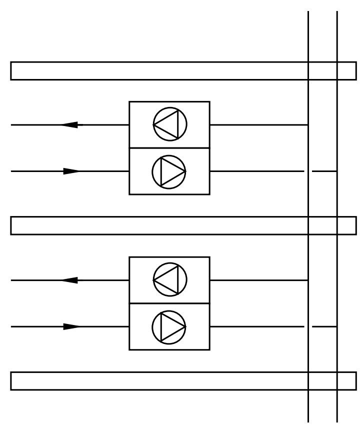
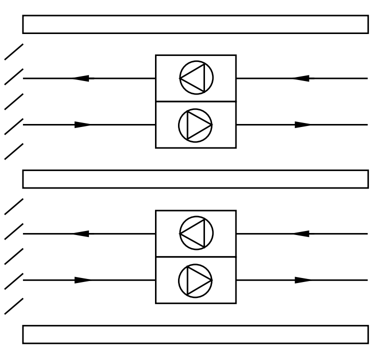
R Minimum space above calorifiers, dimensions allowed:
up to 1000 litres 750 mm
1200 to 3000 litres 1050 mm
4000 to 6500 litres 1350 mm

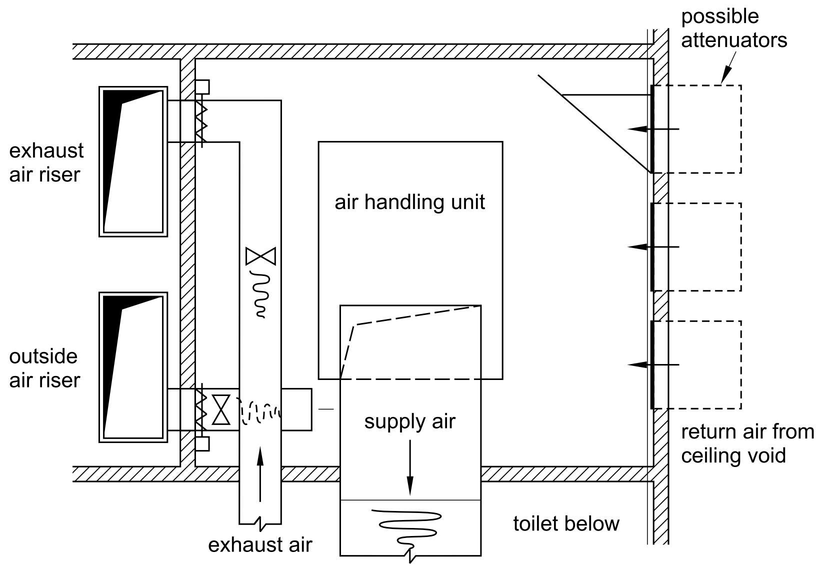
S Space for supporting feet or plinth, 100–300 mm depending on method of support.

Table VIII Spaces for multiple calorifiers

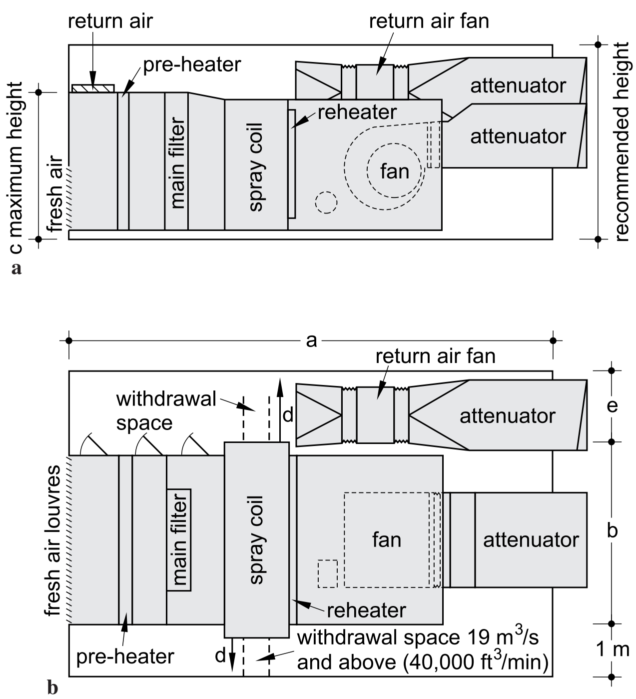
Total storage capacity and dimensions of spaces for two calorifiers				For each additional calorifier *add L* mm	Minimum width of door opening mm
Capacity litres	*L* mm	*W* mm	*H* (min) mm		
1000	3600	2400	3000	1500	800
1300	3600	2400	3000	1500	900
1600	3900	2400	3000	1500	900
2000	3900	2700	3000	1500	1200
2400	4200	2700	3600	1800	1200
3000	4500	2700	3600	1800	1200
4000	4500	2700	3900	1800	1200
5000	4800	3000	3900	2100	1600
6000	4800	3300	4200	2100	1600
8000	5100	3300	4800	2100	1600
10000	5400	3600	4800	2400	1800
13000	5700	3900	5100	2400	1800

Table IX Floor-by-floor AHU arrangements

Configuration	Comments
	Central fans serving main outdoor air and exhaust air risers. Size of risers can be minimised if only minimum fresh air supplied. Effectiveness of free cooling reduced.
	Outdoor air and exhaust air shafts, no rooftop air handling plant
	Floor by floor air and exhaust air. No rooftop air handling plant required and avoidance of risers within the building. Improves nett to gross floor area ratio. Problems could be experienced in siting outdoor air and exhaust air louvers on the building elevation.



46.11 *Plant room for floor-by-floor VAV AHU*



46.12 *Built-up single duct air-conditioning plant room. Space additional to this will be required for withdrawing the coils, depending on the size and position of the equipment.* **a** *Elevation.* **b** *Plan*

Table X Air-conditioning plant sizes

Air volume m^3/s	Dimension (m)						Plant room			% of Building at OA m^3/min per m^2
	a	b	c	d	e	h	Area m^2	Minimum access m × m	m^2 per m^3/s	
9.438	9.40	3.12	2.55	2.85	1.15	3.50	49.60	2.00 × 2.00	5.25	3.50%
14.157	10.20	4.10	2.55	3.75	1.15	3.80	63.75	2.30 × 2.30	4.50	3.00%
18.875	10.60	4.10	3.20	1.90	1.40	4.20	68.80	2.60 × 2.60	3.65	2.40%
23.595	10.90	5.00	3.20	2.30	1.40	4.60	80.70	2.75 × 2.75	3.32	2.25%
28.314	11.20	5.00	3.80	2.30	1.70	5.10	86.20	3.10 × 3.10	3.05	2.00%

Table XI Percentage of gross floor area occupied by electrical plant

Installation	Building size (m^2)			
	2000	5000	10000	20000
GENERAL-PURPOSE OFFICE				
Electrical load (kVA)	40–110	100–280	200–560	400–1100
1 Transformer				
Liquid × 1	–	–	0.25	0.12–0.15
× 2	–	–	–	0.25
Cast resin × 1	–	–	0.22	0.10–0.14
× 2	–	–	–	0.17
2 HV switchroom				
RMU 1	–	–	0.28	0.14
2	–	–	–	0.21
Panels 1	–	–	0.33	0.17
2	–	–	–	0.22
3 LV switchroom				
rear access	1.67	0.67	0.33	0.17–0.18
front access	1.20	0.48	0.24	0.12–0.13
4 Packaged substation (1000 kVA)	–	–	0.69	0.35–0.42
GENERAL-PURPOSE OFFICE WITH AIR CONDITIONING				
Electrical load (kVA)	80–280	200–700	400–1400	830–2800
1 Transformer				
Liquid × 1	–	0.50	0.24–0.33	0.14–0.17
× 2	–	–	0.50	0.22–0.30
Cast resin × 1	–	0.44	0.20–0.27	0.12–0.15
× 2	–	–	0.34	0.14–0.21
2 HV switchroom				
RMU 1	–	0.56	0.28	0.14
2	–	–	0.42	0.21
Panels 1	–	0.46	0.33	0.17
2	–	–	0.44	0.22
3 LV switchroom				
rear access	1.67	0.67	0.37	0.25
front access	1.20	0.48	0.27	0.19
4 Packaged substation(s) (1000kVA)	–	1.46	0.6–0.91	0.37–0.82 (2 no)
HIGH-TECH OFFICE				
Electrical load (kVA)	190–460	730–1600	1400–3300	2900–6500
1 Transformer				
Liquid × 1	–	0.55–0.66	0.33	–
× 2	–	1.10	0.55–0.60	0.30
× 3	–	–	1.00	1.00–1.05
Cast resin × 1	–	0.49–0.54	0.27–0.30	–
× 2	–	0.76	0.34–0.41	0.21–0.23
× 3	–	–	0.68	0.34–0.40
2 HV switchroom				
RMU 1	–	0.56	0.28	0.14
2	–	–	0.42	0.21
3	–	–	0.56	0.28
Panels 1	–	0.66	0.33	0.17
2	–	0.44	–	0.22
3	–	0.55	–	0.28
3 LV switchroom				
rear access	1.65	0.74	0.51	0.46
front access	1.20	0.54	0.38	0.32
4 Packaged substation(s) (1000 kVA)	–	1.46–1.61	0.80–1.64 (2 no)	0.82 (2 no)–1.48 (4 no)
RETAIL				
Electrical load (kVA)	400–650	1000–1700	2000–3200	4000–6500
1 Transformer				
Liquid × 1	1.40	0.61–0.66	0.33	–
× 2	–	1.10	0.44–0.60	0.30
× 3	–	–	1.00	0.50–0.52
Cast resin × 1	1.10	0.54–0.60	0.30	–
× 2	–	0.67	0.38–0.41	0.45
× 3	–	–	0.68	0.36–0.41
2 HV switchroom				
RMU 1	1.40	0.56	0.28	–
2	–	–	0.42	0.21
3	–	–	0.56	0.28
Panels 1	1.70	0.66	0.33	–
2	–	0.88	0.44	0.22
3	–	–	0.55	0.28
3 LV switchroom				
rear access	1.65	0.74	0.51	0.46
front access	1.20	0.54	0.38	0.32
4 Packaged substation(s) (1000 kVA)	3.51	1.46–1.61	0.89–1.64 (2 no)	1.08 (4 no)–1.48 (6 no)
HOTEL				
Electrical load (kVA)	250	700	1500	3000
1 Transformer				
Liquid × 1	–	0.55	0.33	0.17
× 2	–	–	–	0.30
Cast resin × 1	–	0.49	0.27	0.15
× 2	–	–	–	0.19

(*Continued*)

Table XI (Continued)

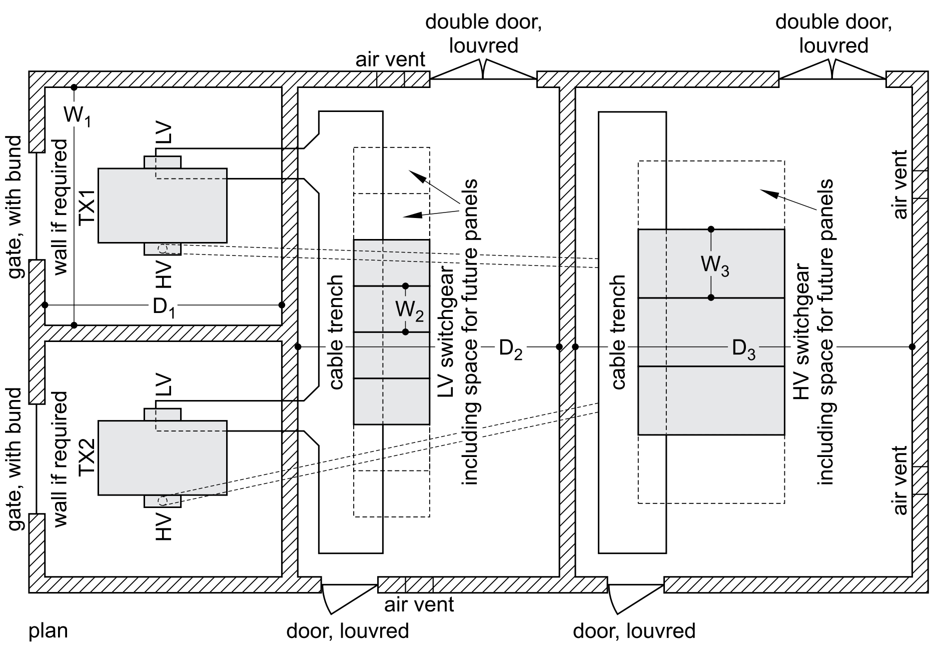
Installation	Building size (m^2)			
	2000	5000	10000	20000
2 HV switchroom				
RMU 1	–	0.56	0.28	0.14
2	–	–	0.42	0.21
Panels 1	–	0.66	0.33	0.17
2	–	–	0.44	0.22
3 LV switchroom				
rear access	1.67	0.73	0.51	0.46
front access	1.20	0.53	0.38	0.32
4 Packaged substation(2) (1000kVA)	–	1.46	0.91	0.82 (2 no)

Table XII Percentage of gross floor area occupied by standby electrical plant

Electrical load (kVA)	Space required (m^2)		
	200	500	1250
1 Generator single machine, water cooled –15 dBA enclosure	–	33	46
2 UPS:			
(a) static	17	25	–
(b) rotary	56	71	–
(c) battery	13	22	–

Table XIII Riser space for power distribution

Building type	Allowance	Comments
Speculative office	0.23–0.29	This includes provision for Landlord riser
High tech, dealing office	0.25–0.29	Applies where local PDUs are in use
	0.50–0.55	Applies where duplicate UPS distribution system is installed alongside a normal power distribution system
Hotels	For prestige high star-rated hotels, it is recommended that each room has its own separate lighting and power circuits. This will influence distribution board sizes and consequently riser space. Two cable trays should be installed per riser: one to support sub-mains distribution and the other to carry the numerous telecommunications cable, video, PA and other services found in a modern hotel. The latter tray should be sized at 300 mm per 150 bedrooms	



46.13 *Electrical sub-station space requirements*

Table XIV 116 V/433 V oil-filled transformer space requirements

Transformer rating *kVA*	Dimensions (m)			Area m^2	Weight kg
	D_1	W_1	H_1		
300	3.35	2.90	3.10	9.75	1439
500	3.50	3.00	3.30	10.50	2245
750	3.55	3.05	3.25	10.85	2910
1000	3.80	3.20	3.45	12.25	3590
1500	4.00	3.50	3.70	14.00	5180

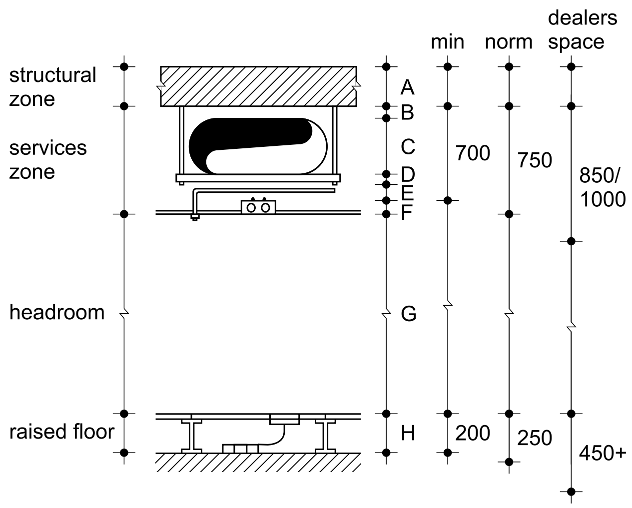
Table XV Switchgear, air circuit breaker, space requirements

Current rating *A*	Dimensions (m)			Area m_2	Weight kg
	D_2	W_2	H_2		
600	3.65	0.65	2.25	2.40	438
800	3.65	0.65	2.25	2.40	438
1200	3.85	0.70	2.30	2.70	535
1600	3.85	0.75	2.30	2.90	463
2400	3.85	0.95	2.30	3.65	590

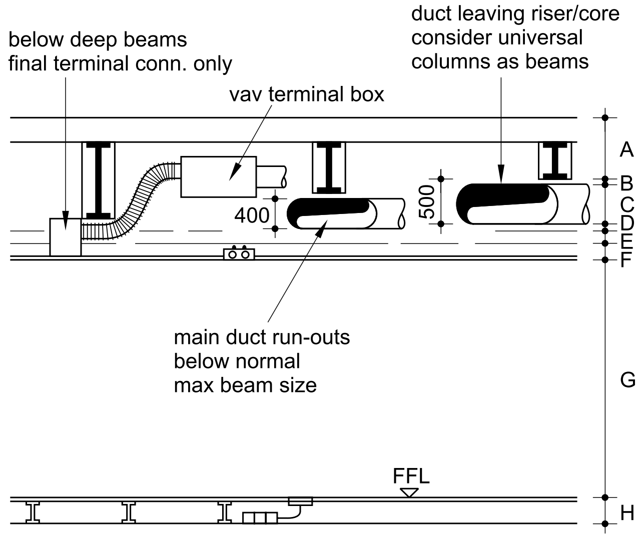
Table XVI HV switchgear, oil circuit breaker, space requirements

Max s/c rating MVA	Current rating *A*	Dimensions (m)			Area m_2	Weight kg
		D_2	W_2	H_2		
250/350	400	4.20	0.65	2.95	2.75	680
	800	4.20	0.60	2.25	2.55	680
	1200	4.20	0.65	2.95	2.75	680
	1600	4.65	0.95	2.30	4.45	1190
	2000	4.65	0.95	2.30	4.45	1220

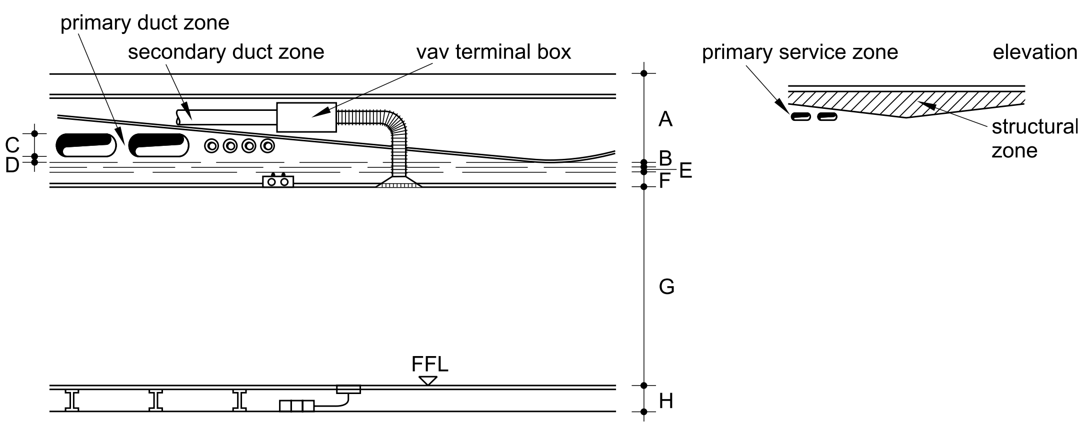
Transformer height H_1 includes necessary height clearance, H_2 and H_3 exclude clearances



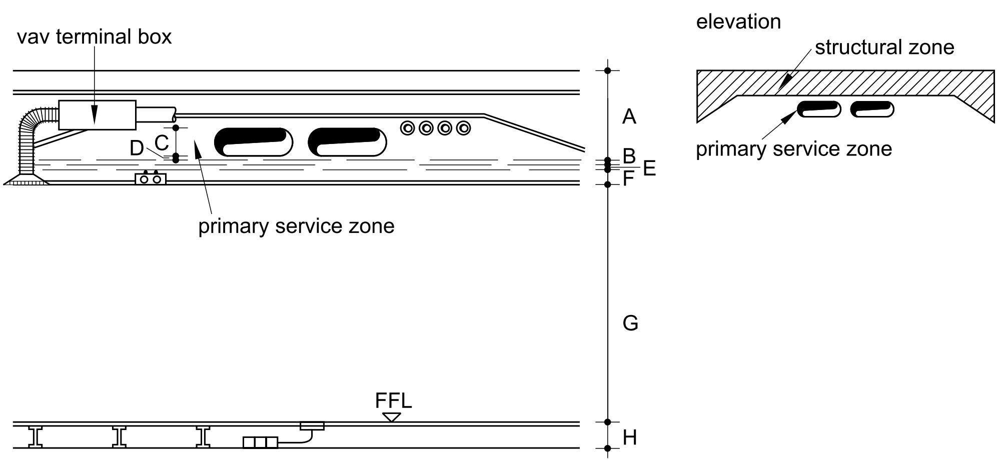
46.14 *Typical cross-section for structure and services Key for* **46.14** *to* **46.18** *is given in Table VII*



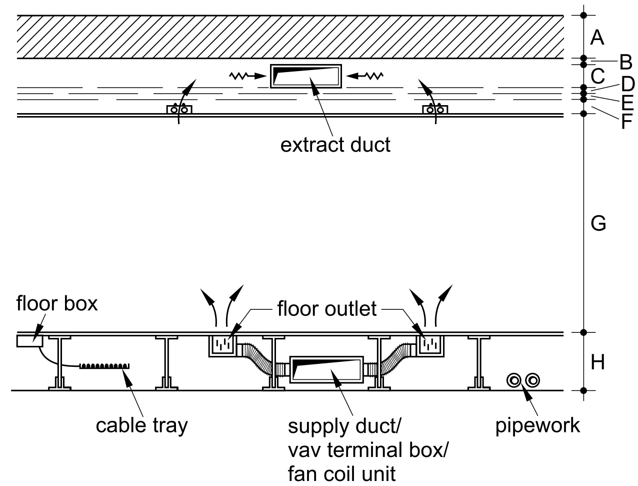
46.15 *Horizontal service distribution with universal steel beams*



46.16 *Horizontal service distribution with tapered beams*



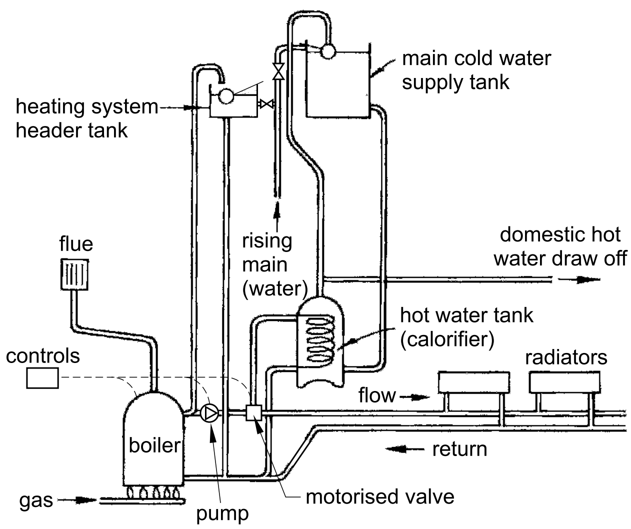
46.17 *Horizontal service distribution with haunched tapered beams*



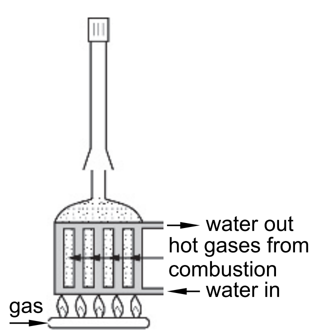
46.18 *Horizontal service distribution with floor supply system*

Table XVII Cross-sectional zones

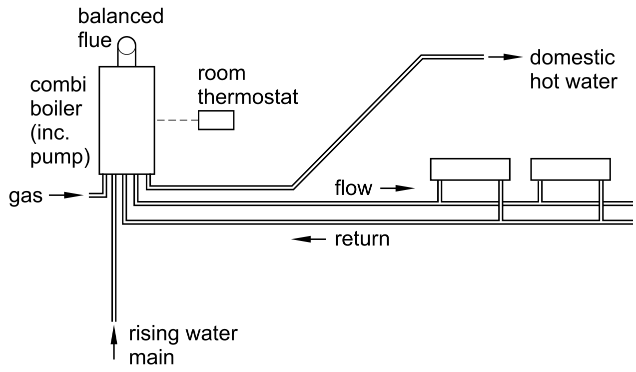
Zone	Letter	Comment
Structural	A	Specified by structural engineer
Services	B	50 mm deflection and tolerance
	C	Approximately 500 mm HVAC duct or terminal device
	D	50 mm support and tolerance
	E	50–150 mm sprinkler sub-zone
	F	150 mm lighting and ceiling sub-zone
Headroom	G	Specified by client and architect
Raised floor	H	Data, communications, small power



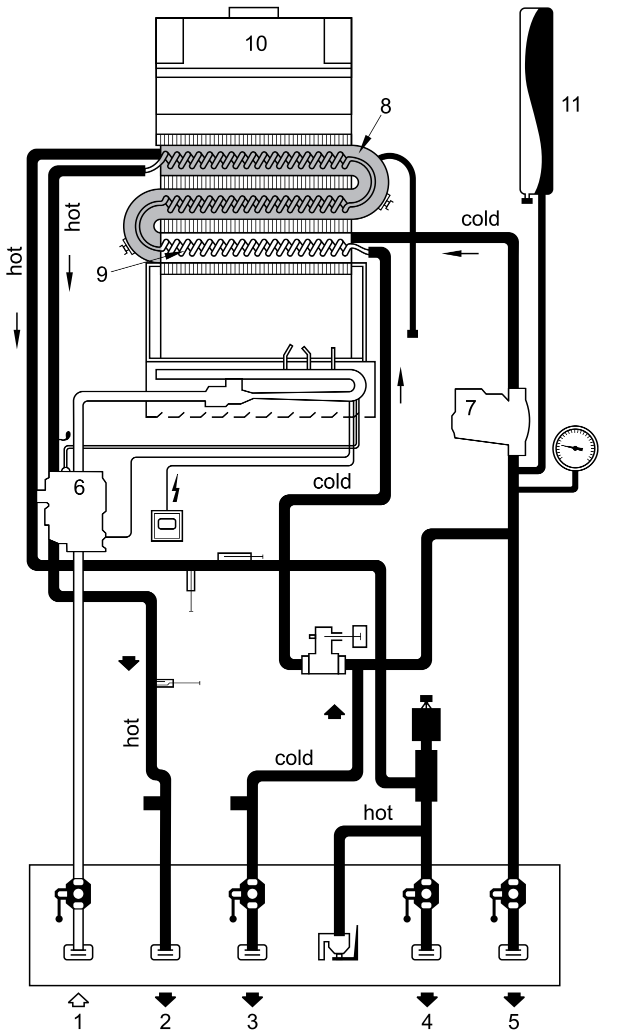
46.19 *Domestic central heating system using conventional gas boiler small bore pumped supply to radiators on two-pipe system, and gravity circulation to heat domestic hot water*



46.20 *Diagrammatic representation of a water boiler, in this case using gas*

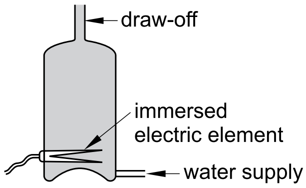


46.21 *Domestic central heating and hot water system using gas-fired combination boiler*



Key:
1 *Gas inlet*
2 *Domestic hot water supply*
3 *Water inlet*
4 *Heating water flow*
5 *Heating water return*
6 *Combination gas valve*
7 *Heating circulating pump*
8 *Heating element*
9 *Hot water coil*
10 *Balanced flue*
11 *Expansion vessel*

46.22 *Combination boiler*



46.23 *Diagram of electric immersion heater in hot water cylinder*

Table XVIII Water storage in various building types (based largely on CIBSE Guide Volume G Section 2.4)

Building type	Cold water storage (24 h supply) litre/person	Hot water storage (at 65°C) litre/person
Dwelling houses	22–300 litres per average accommodation unit more in luxury housing depending on facilities	45
Flats:		
social housing	227–300 litres per accommodation unit	23
average standard	227–300 litres per accommodation unit	32
luxury standard	more depending on facilities	32
Hotels:		
five star	135/bed	45
two star	135/bed	36
Hostels	90/bed	32
Nurses' homes	120	45
Colleges and schools:		
boarding	90	23
day, nursery and primary	15	4.5
day, secondary and technical	20	4.5
Sports pavilions	90	40
Restaurants (per meal)	7	6
Offices:		
with canteen	45	4.5
without canteen	40	4.5
Factories	depends on process	4.5
Hospitals:		
general	160†	27
maternity	190	32
infectious	170	45
mental	130	23
Nursing and convalescent homes	135	45
Children's homes and residential nurseries	135	25

† Cold water storage for hospitals can vary widely, given figures are approximate averages.

However, there are two disadvantages:

- digital technology uses telephones with smaller battery packs operating at lower power levels. This limits them to transmit over shorter distances (this is called the phones 'uplink').
- the base stations themselves using digital technology also cover a smaller area than equivalent analogue stations.

A greater number of radio base stations is therefore needed to maintain the same level of service and quality.

5.03 Radio base stations

There are three basic types of station:

- macro: lattice masts, slimline poles, National Grid pylons, flagpoles,
- rooftop (also macro): buildings, e.g. churches, hotels, offices, grain silos. See below on disguising techniques.
- micro: microcells, street furniture, indoor schemes, small antennas, CCTV, disguised as smoke alarms.

5.04 Masts

Originally with analogue technology sites were in high locations to serve the maximum area. Sites are now targetted to specific areas. High sites do not necessarily provide coverage into valleys or in building shadows.

In many positions they can be unashamed, but in other cases have been disguised. Vodafone has a tree mast in the North Yorks National Park, and an antenna on a real tree in Scotland.

They can often be shared by other telecommunication service providers in accordance with Government planning guidance.

In all cases of masts space is required for equipment including a cabin. This would be ideally 10 m square or typically 7 m square.

5.05 Antennas on buildings

This is the area in which architects are mostly concerned. The antenna will be approximately 2.4 m high, and the architect may incorporate some disguise. Because of the electro-magnetic force (EMF) there is an exclusion zone around the pole 2 m towards the outside and 1 m to the inside of the building. There will be also be need for rooftop space ideally 5 m square including a cabin typically $4.7 \times 2.5 \times 2.8$ m high

5.06 Disguising techniques

Normal building fabric such as stonework, brickwork, timber etc is opaque to the radio signals. However, grp (glass reinforced plastic) is transparent to them. Architects using this material can provide the necessary facility without radically affecting the building's appearance. For example, a slated mansard roof can have a section of slate replaced by matching grp so that the antenna can be housed within the roof space. The timber louvres of a church belfry can similarly be substituted by grp and the antenna housed within. Vodafone also use a grp 'chimney pot'.

5.07 Micro Cellular Technology

A recent innovation is the development of the Street Level Microcell (SLM) which has been designed to supplement coverage in an area of high customer usage such as city centres. In terms of size, both the antenna and equipment are very small, with the former being similar in appearance to an alarm box. This is normally located externally on the building at first or second floor level. The plastic casing enables the antennas to be painted to match the background material of the building, thereby minimising their visibility. The control equipment, a small cabinet, can be easily located unobtrusively within a building.

5.08 Other factors

In urban areas the connections between sites is usually via the fibre cabling already installed. This will require connection via a suitable route through the building. On existing buildings where no alternative exists, a false downpipe may be provided. Where there is no cabling available such as in rural areas, radio links through small dish aerials may be used.

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Appendix A
The SI system

Table I Base units of the SI system

Quantity	Name of unit	Unit symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin*	K
Amount of substance	mole	mol
Luminous intensity	candela	cd
Supplementary units		
Plane angle	radian	rad
Solid angle	steradian	sr

Table II Derived SI units

Quantity	Name of unit	Symbol	Remarks
Frequency	hertz	Hz	$1\,Hz = s^{-1}$
Force	newton	N	$1\,N = 1\,kg.m/s^2$
Pressure Stress	pascal	Pa	$1\,Pa = 1\,N/m^2$
Energy Work Quantity of heat	joule	J	$1\,J = 1\,N.m$
Power Radiant flux	watt	W	$1\,W = 1\,J/s$
Electric charge Quantity of electricity	coulomb	C	$1\,C = 1\,A.s$
Electric potential Potential difference Tension Electromotive force	volt	V	$1\,V = 1\,W/A$
Capacitance	farad	F	$1\,F = 1\,C/V$
Electrical resistance	ohm	Ω	$1\,\Omega = 1\,V/A$
Electrical conductance	siemens	S	$1\,S = 1\,\Omega^{-1}$
Magnetic flux	weber	Wb	$1\,Wb = 1\,V.s$
Magnetic flux density	tesla	T	$1\,T = 1\,Wb/m^2$
Inductance	henry	H	$1\,H = 1\,Wb/A$
Celsius temperature	degree Celsius	°C	$1\,°C = 1\,K$
Luminous flux	lumen	lm	$1\,lm = 1\,cdsr$
Illuminance	lux	lx	$1\,lx = 1\,lm/m^2$

Table III Multiples and submultiples of SI units

Power of 10	Prefix	Symbol
24	yetta	Y
21	zetta	Z
18	exa	E
15	peta	P
12	tera	T
9	giga	G
6	mega	M
3	kilo	k
2	hecto	h
1	deca	da
−1	deci	d
−2	centi	c
−3	milli	m
−6	micro	μ
−9	nano	n
−12	pico	p
−15	femto	f
−18	atto	a
−21	zepto	z
−24	yocto	y

Table IV Approved SI units, multiples and submultiples together with other units commonly in use. Based on BS 5555:1981 An asterisk indicates a unit outside the SI system currently recognised by the CIPM for a specific use

Item no in ISO 31:1992	Quantity	SI unit	Recommended multiples and sub-multiples	Other units which may be used	Remarks
1 Space and time					
1–1	Plane angle	rad (radian)	mrad μrad	degree (°) = π/180 rad minute (′) = (1/60)° second (″) = (1/60)′ grade (^{G}) = π/200 rad	Radians are principally used in purely mathematical situations. In practice, degrees and its subdivisions are normally used in the UK. The symbols °, ′ and ″ are exceptions in that there is no space between the value and the symbol. Decimal subdivisions of the degree are preferred to minutes and seconds; this facilitates the using of pocket calculators. On continental Europe, the grade (or its alternative name, the gon) is often used, always decimally subdivided.
1–2	Solid angle	sr (steradian)			
1–3	Length	m (metre)	km, cm, mm, μm, nm, pm, fm	*nautical mile 1 n mile = 1852 m exactly	The statute mile is currently intended to stay for the moment on road signs in the UK 1 mile = 1.609 344 km exactly. On road signs the mile is confusingly abbreviated m, ml is preferred.
1–4	Area	m^2	km^2, dm^2, cm^2, mm^2	*hectare (ha), *are (a) 1 ha = 10^4 m^2 1 a = 10^2 m^2	The square foot is still used by commercial estate agents in the UK 1 sq ft = 0.092 290 304 m^2 exactly. The acre is also commonly found in the UK 1 acre = 0.404 685 6422 ha exactly
1–5	Volume	m^3	dm^3, cm^3, mm^3	*litre (l), *hl, *cl, *ml 1 hl = $10^{-1}$$m^3$ 1l= 10^{-3} m^3 = 1 dm^3 1 cl = 10^{-5} m^3 1 ml = 10^{-6} m^3 = 1 cm^3	The abbreviations I and L may each be used for litre; the full name is often used to avoid confusion. The imperial pint (pt) has been approved for continuing use in the UK, but only for draught beer and for milk in bottles (not cartons!). 1 pt = 0.568 2451
1–6.1	Time	s (second)	ks, ms, μs, ns	minute (min) 1 min = 60s exactly hour (h) 1 h = 60 min exactly day (d) d = 24 h exactly	Other units such as week, month and year (a) are in common use; definitions of month and year often need to be specified
1–8.1	Angular velocity	rad/s			
1–10.1	m/s	m/h kilometre per hour (km/h) 1 km/h = (1/3.6) m/s			1 *knot = 1.852 km/h exactly (no abbreviation approved) Miles per hour (mph) are continuing on UK road signs 1 mph = 1.609 344 km/h exactly
1–11.1	m/s^2				
2 Periodic and related phenomena					
2–3.1	Frequency	Hz (hertz)	THz, GHz, MHz, kHz		
2–3.2	Rotational frequency	s^{-1}		min^{-1}	revs per min (r/min) and revs per sec (r/s) are also used
2–4	Angular frequency	rad/s			
3 Mechanics					
3–1	Mass	kg (kilogram)	Mg, g, mg, μg	tonne (t) unified atomic mass unit (u)	1 t = 10^3 kg tonne in the UK also called metric ton 1 u approx = 1.660 540 × 10^{-27} kg
3–2	Volumic mass Density Mass density	kg/m^3	Mg/m^3 kg/dm^3, g/cm^3 (all the same)	t/m^3, kg/l (kg/litre), g/ml, g/l	
3–5	Lineic mass Linear density	kg/m	mg/m		1 tex = 10^{-6}kg/m = 1 g/km The tex is used for textile filaments
3–7	Moment of inertia	$kg.m^2$			
3–8	Momentum	kg.m/s			
3–9	Force	N (newton)	MN, kN, mN, μmUM		
3–11	Moment of momentum Angular momentum	$kg.m^2$			
3–12.1	Moment of force	N.m	MN.m, kN.m, mN.m, μN.m		Moment of force is often called simply moment or bending moment
3–15.1	Pressure	Pa (pascal)	GPa, MPa, kPa, hPa, mPa, μPa	*bar = 100 kPa exactly 1 mbar = 1 hPa bars are used only in fluid pressures	
3–15.2	Normal stress	Pa	GPa, MPa, kPa		1 MPa = 1 N/mm^2

Table IV (Continued)

Item no in ISO 31:1992	Quantity	SI unit	Recommended multiples and sub-multiples	Other units which may be used	Remarks
3 Mechanics, *continued*					
3–23	Dynamic viscosity	Pa.s	mPa.s		poise (P) 1 cP = 1 mPa.s The poise is only used in conjunction with CGS units
3–24	Kinematic viscosity	m^2/s	mm^2/s		stokes (St) 1 cSt = 1 mm^2/s The stokes is used only in conjunction with CGS units
3–25	Surface tension	N/m	mN/m		
3–26.1	Energy	J (joule)	EJ, PJ, TJ, MJ, kJ, mJ	electronvolt (eV)	
3–26.2	Work			1 eV = (1.602 10 ± 0.000 07) × 10^{-19} J eV, MeV and GeV are used in accelerator technology	kilowatt-hour (kW.h) 1 kWh = 3.6 × 10^6 J = 3.6 MJ W.h, kW.h, MW.h, GW.h and TW.h are used in the electrical power industry
3–27	Power	W (watt)	GW, MW, kW, mW, μmUW		1 W = 1 J/s
4 Heat					
4–1	Thermodynamic temperature	K (kelvin)			
4–2	Celsius temperature	°C (no space beween value and symbol)			1 °C = 1 K The temperature in °C is the temperature expressed in kelvins minus exactly 273.15 K
4–3.1	Linear expansion coefficient	K^{-1}			
4–6	Heat, quantity of heat	J	EJ, PJ, TJ, GJ, MJ, kJ, mJ		
4–7	Heat flow rate	W	kW		1 W = 1 J/s
4–9	Thermal conductivity	W/(m.k)			
4–10.1	Coefficient of heat transfer	W/(m.K)			
4–11	Thermal insulance	m.k/W			
4–15	Heat capacity	J/K	kJ/K		
4–16.1	Massic heat capacity (was specific)	J/(kg.K)	kJ/(kg.K)		
4–18	Entropy	J/K	kJ/K		
4–19	Massic entropy	J/(kg.K)	kJ/(kg.K)		
4–21.2	Massic thermodynamic energy (was specific energy)	J/kg	MJ/kg, kJ/kg		
5 Electricity and magnetism					
5–1	Electric current	A (ampere)	kA, mA, μA, nA, pA		
5–2	Electric charge, quantity of electricity	C (coulomb)	kC, μC, nC, pC		1 A.h = 3.6 kC
5–3	Volumic charge, charge density	C/m^3	C/mm^3 or GC/m^3, MC/m^3 or C/cm^3, kC/m^3, mC/m^3, $\mu C/m^3$		
5–4	Areic charge, surface density of charge	C/m^3	MC/m^2 or C/mm^2, C/cm^2, kC/m^2, mC/m^2, $\mu C/m^2$		
5–5	Electric field strength	V/m	MV/m, kV/m or V/mm, V/cm, mV/m, μV/m		
5–6.1 5–6.2 5–6.3	Electric potential Potential difference tension Electromotive force	V (volt)	MV, kV, mV, V		
5–7	Electrical flux density	C/m^2	C/cm^2, kC/m^2, mC/m^2, $\mu C/m^2$		
5–9	Capacitance	F (farad)	mF, μF, nF, pF		
5–33	Resistance to direct current	Ω (ohm)	GΩ, MΩ, kΩ, mΩ, μΩ		
5–34	Conductance of direct current	S (siemens)	kS, mS, μS		1 S = 1/Ω
5–36	Resistivity	Ω m	GΩm, MΩm, kΩm, Ωcm, mΩm, μΩm, nΩm		μm = 10^{-2} Ωm (μmUmm^2)/m = 10^{-6} Ωm = μmUΩm are also used
5–37	Conductivity	S/m	MS/m, kS/M		
5–38	Reluctance	H^{-1}			
5–39	Permeance	H (henry)			

Table IV (Continued)

Item no in ISO 31:1992	Quantity	SI unit	Recommended multiples and sub-multiples	Other units which may be used	Remarks
5 Electricity and magnetism, *continued*					
5–49	Active power	W	TW, GW, MW, kW, mW, μW, nW		In electric power technology active power is expressed in watts, apparent power in volt amperes V.A and reactive power in vars (var)
5–52	Active energy	J	TJ, GJ, MJ, KJ		1 W.h = 3.6 kJ exactly TW.h, GW.h, MW.h, kW.h
6 Light					
6–3	Wavelength	m	μmUm, nm, pm	*ångström (Å)	1 Å R = 10^{-10}m = 10^{-4} μm Um= 10^{-1} nm
6–7	Radiant energy	J			
6–10	Radiant power energy flux	W			
6–13	Radiant intensity	W/sr			
6–15	Radiant exitance	w/m^2			
6–29	Luminous intensity	cd (candela)			
6–30	Luminous flux	lm (lumen)			
6–31	Quantity of light		lm.h	1 lm.h = 3600 lm.s exactly	
6–32	Luminance	cd/m^2			
6–33	Luminous exitance	lx (lux)			
6–35	Light exposure	lx.s			
6–36.1	Luminous efficacy	lm/W			
7 Acoustics					
7–1	Period, periodic time	s	ms, μs		
7–2	Frequency	Hz	MHz, kHz		
7–5	Wavelength	m	mm		
7–8	Volumic mass Mass density Density	kg/m^3			
7–9.1	Static pressure	Pa	nPa, μPa		
7–9.2	(Instantaneous) sound pressure				
7–11	(Instantaneous) sound particle velocity	m/s	mm/s		
7–13	(Instantaneous) volume flow rate	m^3/s			
7–14.1	Velocity of sound	m/s			
7–16	Sound power	W			
7–17	Sound intensity	W/m^2	mW/m^2, μW/m^2, pW/m^3		
7–18	Acoustic impedance	Pa.s/m^3			
7–19	Mechanical impedance	N.s/m	Mechanical impedance		
7–20.1	Surface density of mechanical impedance	Pa.s/m			
7–21	Sound pressure level		bel (B), dB	1 dB = 10^{-1} B	
7–28	Sound reduction index		B, dB		
7–29	Equivalent absorption area of surface or object	m^2			
7–30	Reverberation time	s			

Appendix B
Conversion factors and tables

Table I Conversion factors Bold type indicates exact conversions. Otherwise four or five significant figures are given.

Quantity	Conversion factors	
General purposes		
Length	1 mile	= 1.609 km
	1 chain	= **20.1168** m
	1 yard	= **0.9144** m
	1 foot	= **0.3048** m = **304.8** mm
	1 inch	= **25.4** mm = **2.54** cm
Area	1 square mile	= 2.590 km^2 = 259.0 ha
	1 hectare	= **10 000** m^2
	1 acre	= 4 046.9 m^2 = 0.40469 ha
		= **4 840** yd^2
	1 square yard	= 0.8361 m^2
	1 square foot	= 0.09290 m^2 = 929.03 cm^2
	1 square inch	= 645.2 mm^2 = 6.452 cm^2
Volume	1 cubic yard	= 0.7646 m^3
	1 litre	= **1** dm^3 = **1000** cm^3
	1 m^3	= **1 000** litres
	1 millilitre	= **1** cm^3 = **1000** mm
	1 cubic foot	= 0.02832 m^3 = 28.32 litre
	1 petrograd standard	= 4.672 m^3
	1 cubic inch	= 16 387 mm^3 = 16.387 cm^3
		= 16.387 ml = 0.016387 litre
Capacity	1 UK gallon	= 4.546 litre
	1 UK quart	= 1.137 litre
	1 UK pint	= 0.5683
	1 UK fluid ounce	= 28.413 cm^3
	1 US barrel (for petroleum)	= 159.0 litre
	1 US gallon	= 3.785 litre
	1 US liquid quart	= 0.9464 litre
	1 US dry quart	= 1.101 litre
	1 US liquid pint	= 0.4732 litre
	1 US dry pint	= 0.5506 litre
	1 US liquid ounce	= 29.574 cm^3
Mass	1 UK ton	= 1.016 tonne = 1016.05 kg
	1 US (or short) ton	= 0.9072 tonne = 907.2 kg
	1 kip (1000 lb)	= 453.59 kg
	1 UK hundredweight	= 50.80 kg
	1 short (US) hundred–weight	= 100 lb = 45.36 kg
	1 pound	= 0.4536 kg
	1 ounce avoirdupois	= 28.35 g
	1 ounce troy	= 31.10 g
Mass per unit length	1 UK ton per mile	= 0.6313 kg/m = 0.6313 t/km
	1 lb per yard	= 0.4961 kg/m
	1 lb per foot	= 1.4882 kg/m
	1 lb per inch	= 17.86 kg/m
	1 oz per inch	= 1.1161 kg/m
Length per unit mass	1 yd per lb	= 2.016 m/kg
Mass per unit area	1 ton per square mile	= 392.3 kg/km^2 = 0.3923 g/m^2
		= 3.923 kg/ha
	1 ton per acre	= 0.2511 kg/m^2
	1 hundred weight per acre	= 0.01255 kg/m^2
	1 lb per square foot	= 4.882 kg/m^2
	1 lb per square inch	= 703.07 kg/m^2
	1 oz per square yard	= 33.91 g/m^2
	1 oz per square foot	= 305.15 g/m^2
	1 kg/cm^2	= 10 t/m^2
Mass density (mass per unit volume)	1 ton per cubic yard	= 1329 kg/m^3 = 1.3289 t/m^3
	1 lb per cubic yard	= 0.5933 kg/m^3
	1 lb per cubic foot	= 16.02 kg/m^3
	1 lb per cubic inch	= 27.68 g/cm^3 = 27.68 t/m^3

Table I (Continued)

Quantity	Conversion factors	
Area coverage	× square yards per ton	$= \frac{1}{x} \times 1215$ kg/m^2
	× square yards per gallon	$= \frac{1}{x} \times 5.437$ litre/m^2
Volume rate of flow	1 cubic feet per minute	= 0.4719 litre/s
		= 471.9 cm^3/s
		= 0.0004719 m^3/s
	1 cusec (cu ft per sec)	= 0.02832 m^3/s ('cumec')
	1 cu ft per thousand acres	= 0.06997 litre/ha
		= 0.006997 m^3/km^2
		= 6997 cm^3/km^2
	1 cubic inch per second	= 16.39 ml/s
	1 gallon per year	= 4546 cm^3/a* = 0.004546 m^3/a
	1 gallon per day	= 4546 cm^3/d
	1 litre/s	= **86.4** m^3/d
	1 million gallons per day	= 0.05262 m^3/s
	1 gallon per person per day	= 4.546 litre/(person day)
	1 gallon per sq yd per day	= 0.005437 m^3/(m^2.d)
		= 0.000062928 mm/s
	1 gallon per cu yd per day	= 0.005946 m^3/(m^3.d)
	1 gallon per hour	= 4.5461 litre/h
	1 gallon per minute	= 0.07577 litre/s
	1 gallon per second	= 4.5461 litre/s
Fuel consumption	1 gallon per mile	= 2.825 litre/km
	1 mile per gallon	= 0.354 km/litre
	× miles per gallon	$= \frac{1}{x} \times 282.5$ litre 100 km
Velocity	1 mile per hour	= 1.609 km/h = **0.44704** m/s
	1 foot per minute	= **0.3048** m/min = 0.0051 m/s
	1 foot per second	= **0.3048** m/s
	1 inch per second	= **25.4** mm/s
	1 UK knot	= 0.5148 m/s = 1.853 km/h
		= 1.00064 international knot
Acceleration	1 foot per sec per sec	= **0.3048** m/s^2
	1 mile per hr per sec	= **0.44704** m/s^2
	1 g (standard gravity)	= **9.806 65** m/s^2
Heating		
Temperature	× Fahrenheit	$= \frac{5}{9} \times (\times - 32)$ °Celsius
Temperature interval	1°F	= 0.5556 K = 0.5556°C
Energy (heat)	1 British thermal unit	= 1055 J = 1.055 kJ
	1 Therm	= 105.5 MJ
	1 calorie	= **4.1868** J
	1 kilowatt–hour	= 3.6 MJ
	1 foot pound–force	= 1.356 J
	1 kilogram force–metre	= **9.806 65** J
Power (also heat flow rate)	1 J/s	= **1** W
	1 Btu per hour	= 0.293 07 W
	1 horsepower	= 745.70 W
	1 ft–lbf per second	= 1.356 W
	1 kgf–metre per second	= **9.806 65** W
	1 calorie per second	= **4.1868** W
	1 kilocalorie per hour	= **1.163** W
	1 metric horsepower	= 735.5 W
Density of heat flow rate	1 Btu per square foot hour	= 3.155 W/m^2

* a (for annum) is the symbol for year.

Table I (Continued)

Quantity	Conversion factors	
Thermal conductivity *k* value	1 Btu inch per square foot hour degree Fahrenheit	= 0.1442 W/(m.K)
Thermal transmittance or coefficient of heat transfer or thermal conductance or *U* value	1 Btu per square foot hour degree Fahrenheit	= 5.678 W/(m^2K)
Thermal resistivity 1/k value	1 sq ft hr °F per Btu inch	= 6.933 m.K/W
Thermal or specific heat capacity	1 Btu per lb °F 1 Btu per cu ft °F	= 4.187 (kJ.K) = 67.07 kJ/(m^3.K)
Calorific value	1 Btu per pound 1 Btu per cubic foot 1 Btu per gallon	= 2.326 kJ/kg = 37.26 kJ/m^3 = 37.26 J/litre = 232.1 J/litre
Refrigeration	1 ton	= 3517 W
Lighting	1 foot–candle	= 10.76 1×
Illumination	1 lumen per sq ft	= 10.76 1×
Lumination	1 candela per square inch 1 candela per square foot 1 apostilb	= 1550 cd/m^2 = 10.76 cd/m^2 $= \frac{1}{\pi}$ cd/m^2 = 0.3183 cd/m^2

Table I (Continued)

Quantity	Conversion factors	
Structural design (All tons are UK tons)		
Force	1 pound–force 1 kip–force 1 ton–force 1 kilogram–force 1 kilopond	= 4.448 N = 4.448 kN = 9.964 kN = 9.807 N = 9.807 N
Force per unit length	1 pound–force per foot 1 pound–force per inch 1 ton–force per foot 1 kilogram–force per metre 1 kilogram–force per centimetre	= 14.59 N/m = 175.1 kN/m = 175.1 N/mm = 32.69 kN/m = 9.807 N/m = 0.9807 kN/m
Force per unit area or Stress or Pressure	1 lbf per square foot 1 lbf per square inch 1 tonf per square foot 1 tonf per square inch 1 kgf per square metre 1 kgf per sq centimetre 1 bar 1 millibar 1 standard atmosphere 1 inch of mercury 1 foot of water	= 47.88 N/m^2 = 47.88 Pa = 0.04788 kN/m^2 = 6.895 kN/m^2 = 6.895 kPa = 107.3 kN/m^2 = 107.3 kPa = 15.44 MN/m^2 = 15.44 N/mm^2 = 15.44 MPa = 9.807 N/m^2 = 9.807 Pa = 98.07 kN/m^2 = 98.07 kPa = **100** kN/m^2 = **100** kPa = **100** N/m^2 = **100** Pa = **101.325** kPa = 3.386 kPa = 2.989 kPa = 300 mbar approx
Bending moment of torque	1 pound–force foot 1 pound–force inch 1 kip–force foot 1 kip–force inch 1 ton–force foot 1 ton–force inch 1 kilogram–force metre	= 1.356 Nm = 0.1130 Nm = 113.0 Nmm = 1.356 kNm = 0.1130 kNm = 113.0 Nm = 3.037 kNm = 0.2531 kNm = 253.1 Nm = 9.807 Nm

Table II Inches and fractions of an inch to millimetres (1/16 in increments up to 11 15/16 in)

	Inches	1/16	1/8	3/16	¼	5/16	3/8	7/16	½	9/16	5/8	11/16	3/4	13/16	7/8	15/16
		Millimeters														
0	–	1.6	3.2	4.8	6.4	7.9	9.5	11.1	12.7	14.3	15.9	17.5	19.1	20.6	22.2	23.8
1	25.4	27.0	28.6	30.2	31.8	33.3	34.9	36.5	38.1	39.7	41.3	42.9	44.5	46.0	47.6	49.2
2	50.8	52.4	54.0	55.6	57.2	58.7	60.3	61.9	63.5	65.1	66.7	68.3	69.9	71.4	73.0	74.6
3	76.2	77.8	79.4	81.0	82.6	84.1	85.7	87.3	88.9	90.5	92.1	93.7	95.3	96.8	98.4	100.0
4	101.6	103.2	104.8	106.4	108.0	109.5	111.1	112.7	114.3	115.9	117.5	119.1	120.7	122.2	123.8	125.4
5	127.0	128.6	130.2	131.8	133.4	134.9	136.5	138.1	139.7	141.3	142.9	144.5	146.1	147.6	149.2	150.8
6	152.4	154.0	155.6	157.2	158.8	160.3	161.9	163.5	165.1	166.7	168.3	169.9	171.5	173.0	174.6	176.2
7	177.8	179.4	181.0	182.6	184.2	185.7	187.3	188.9	190.5	192.1	193.7	195.3	196.9	198.4	200.0	201.6
8	203.2	204.8	206.4	208.0	209.6	211.1	212.7	214.3	215.9	217.5	219.1	220.7	222.3	223.8	225.4	227.0
9	228.6	230.2	231.8	233.4	235.0	236.5	238.1	239.7	241.3	242.9	244.5	246.1	247.7	249.2	250.8	252.4
10	254.0	255.6	257.2	258.8	260.4	261.9	263.5	265.1	266.7	268.3	269.9	271.5	273.1	274.6	276.2	277.8
11	279.4	281.0	282.6	284.2	285.8	287.3	288.9	290.5	292.1	293.7	295.3	296.9	298.5	300.0	301.6	303.2

Table III Feet to millimetres (up to 200 ft)

Feet	0	1	2	3	4	5	6	7	8	9
	Millimetres									
0	–	304.8	609.6	914.4	1219.2	1524.0	1828.8	2133.6	2438.4	2743.2
10	3048.0	3352.8	3657.6	3962.4	4267.2	4572.0	4876.8	5181.6	5486.4	5791.2
20	6096.0	6400.8	6705.6	7010.4	7315.2	7620.0	7924.8	8229.6	8534.4	8839.2
30	9144.0	9448.8	9753.6	10058.4	10363.2	10668.0	10972.8	11277.6	11582.4	11887.2
40	12192.0	12496.8	12801.6	13106.4	13411.2	13716.0	14020.8	14325.6	14630.4	14935.2
50	15240.0	15544.8	15849.6	16154.4	16459.2	16764.0	17068.8	17373.6	17678.4	17983.2
60	18288.0	18592.8	18897.6	19202.4	19507.2	19812.0	20116.8	20421.6	20726.4	21031.2
70	21336.0	21640.8	21945.6	22250.4	22555.2	22860.0	23164.8	23469.6	23774.4	24079.2
80	24384.0	24688.8	24993.6	25298.4	25603.2	25908.0	26212.8	26517.6	26822.4	27127.2
90	27432.0	27736.8	28041.6	28346.4	28651.2	28956.0	29260.8	29565.6	29870.4	30175.2
100	30480.0	30784.8	31089.6	31394.4	31699.2	32004.0	32308.8	32613.6	32918.4	33223.2
110	33528.0	33832.8	34137.6	34442.4	34747.2	35052.0	35356.8	35661.6	35966.4	36271.2
120	36576.0	36880.8	37185.6	37490.4	37785.2	38100.0	38404.8	38709.6	39014.4	39319.2
130	39624.0	39928.8	40233.6	40538.4	40843.2	41148.0	41452.8	41757.6	42062.4	42367.2
140	42672.0	42976.8	43281.6	43586.4	43891.2	44196.0	44500.8	44805.6	45110.4	45415.2
150	45720.0	46024.8	46329.6	46634.4	46939.2	47244.0	47548.8	47853.6	48158.4	48463.2
160	48768.0	49072.8	49377.6	49682.4	49987.2	50292.0	50596.8	50901.6	51206.4	51511.2
170	51816.0	52120.8	52425.6	52730.4	53035.2	53340.0	53644.8	53949.6	54254.4	54559.2
180	54864.0	55168.8	55473.6	55778.4	56083.2	56388.0	56692.8	56997.6	57302.4	57607.2
190	57912.0	58216.8	58521.6	58826.4	59131.2	59436.0	59740.8	60045.6	60350.4	60655.2
200	60960.0	–	–	–	–	–	–	–	–	–

Note: use Tables II and III together to obtain the metric equivalent of any dimension up to 200 ft. For example

56 ft 3¼ in: 56 ft = 17068.8
3¼ in = 95.3
TOTAL = 17164.1 mm = 17.164 m

Table IV Miles (up to 100 miles) to kilometres (to two places of decimals) may also be used to convert mph to kph

Miles	0	1	2	3	4	5	6	7	8	9
	Kilometres									
0	–	1.61	3.22	4.83	6.44	8.05	9.66	11.27	12.87	14.48
10	16.09	17.70	19.31	20.92	22.53	24.14	25.75	27.36	28.97	30.58
20	32.19	33.80	35.41	37.01	38.62	40.23	41.84	43.45	45.06	46.67
30	48.28	49.89	51.50	53.11	54.72	56.33	57.94	59.55	61.16	62.76
40	64.37	65.98	67.59	69.20	70.81	72.42	74.03	75.64	77.25	78.86
50	80.47	82.08	83.69	85.30	86.90	88.51	90.12	91.73	93.34	94.95
60	96.56	98.17	99.78	101.39	103.00	104.61	106.22	107.83	109.44	111.05
70	112.65	114.26	115.87	117.48	119.09	120.70	122.31	123.92	125.53	127.14
80	128.75	130.36	131.97	133.58	135.19	136.79	138.40	140.01	141.62	143.23
90	144.84	146.45	148.06	149.67	151.28	152.89	154.50	156.11	57.72	159.33
100	160.93	–	–	–	–	–	–	–	–	–

Table V Square inches (up to 100 sq in) to square millimetres (to one place of decimals)

Square inches	0	1	2	3	4	5	6	7	8	9
	Square millimetres (mm^2)									
0	–	645.2	1290.3	1935.5	2580.6	3225.8	3871.0	4516.1	5161.3	5806.4
10	6451.6	7096.8	7741.9	8387.1	9032.2	9677.4	10322.6	10967.7	11612.9	12258.0
20	12903.2	13548.4	14193.5	14838.7	15483.8	16129.0	16774.2	17419.3	18064.5	18709.6
30	19354.8	20000.0	20645.1	21290.3	21935.4	22580.6	23225.8	23870.9	24516.1	25161.2
40	25806.4	26451.6	27096.7	27741.9	28387.0	29032.2	29677.4	30322.5	30967.7	31612.8
50	32258.0	32903.2	33548.3	34193.5	34838.6	35483.8	36129.0	36774.1	37419.3	38064.4
60	38709.6	39354.8	39999.9	40645.1	41290.2	41935.4	42580.6	43225.7	43870.9	44516.0
70	45161.2	45806.4	46451.5	47096.7	47741.8	48387.0	49032.2	49677.3	50322.5	50967.6
80	51612.8	52258.0	52903.1	53548.3	54193.4	54838.6	55483.8	56128.9	56774.1	57419.2
90	58064.4	58709.6	59354.7	59999.9	60645.0	61290.2	61935.4	62580.5	63225.7	63870.8
100	64516.0	–	–	–	–	–	–	–	–	–

Table VI Square feet (up to 500 ft²) to square metres (to two places of decimals)

Square feet	0	1	2	3	4	5	6	7	8	9
	Square metres (m^2)									
0	–	0.09	0.19	0.28	0.37	0.46	0.56	0.65	0.74	0.84
10	0.93	1.02	1.11	1.21	1.30	1.39	1.49	1.58	1.67	1.77
20	1.86	1.95	2.04	2.14	2.23	2.32	2.42	2.51	2.60	2.69
30	2.79	2.88	2.97	3.07	3.16	3.25	3.34	3.44	3.53	3.62
40	3.72	3.81	3.90	3.99	4.09	4.18	4.27	4.37	4.46	4.55
50	4.65	4.74	4.83	4.92	5.02	5.11	5.20	5.30	5.39	5.48
60	5.57	5.67	5.76	5.85	5.95	6.04	6.13	6.22	6.32	6.41
70	6.50	6.60	6.69	6.78	6.87	6.97	7.06	7.15	7.25	7.34
80	7.43	7.53	7.62	7.71	7.80	7.90	7.99	8.08	8.18	8.27
90	8.36	8.45	8.55	8.64	8.73	8.83	8.92	9.01	9.10	9.20
100	9.29	9.38	9.48	9.57	9.66	9.75	9.85	9.94	10.03	10.13
110	10.22	10.31	10.41	10.50	10.59	10.68	10.78	10.87	10.96	11.06
120	11.15	11.24	11.33	11.43	11.52	11.61	11.71	11.80	11.89	11.98
130	12.08	12.17	12.26	12.36	12.45	12.54	12.63	12.73	12.82	12.91
140	13.01	13.10	13.19	13.29	13.38	13.47	13.56	13.66	13.75	13.84
150	13.94	14.03	14.12	14.21	14.31	14.40	14.49	14.59	14.68	14.77
160	14.86	14.96	15.05	15.14	15.24	15.33	15.42	15.51	15.61	15.70
170	15.79	15.89	15.98	16.07	16.17	16.26	16.35	16.44	16.54	16.63
180	16.72	16.82	16.91	17.00	17.09	17.19	17.28	17.37	17.47	17.56
190	17.65	17.74	17.84	17.93	18.02	18.12	18.21	18.30	18.39	18.49
200	18.58	18.67	18.77	18.86	18.95	19.05	19.14	19.23	19.32	19.42
210	19.51	19.60	19.70	19.79	19.88	19.97	20.07	20.16	20.25	20.35
220	20.44	20.53	20.62	20.72	20.81	20.90	21.00	21.09	21.18	21.27
230	21.37	21.46	21.55	21.65	21.74	21.83	21.93	22.02	22.11	22.20
240	22.30	22.39	22.48	22.58	22.67	22.76	22.85	22.95	23.04	23.13
250	23.23	23.32	23.41	23.50	23.60	23.69	23.78	23.88	23.97	24.06
260	24.15	24.25	24.34	24.43	24.53	24.62	24.71	24.81	24.90	24.99
270	25.08	25.18	25.27	25.36	25.46	25.55	25.64	25.73	25.83	25.92
280	26.01	26.11	26.20	26.29	26.38	26.48	26.57	26.66	26.76	26.85
290	26.94	27.03	27.13	27.22	27.31	27.41	27.50	27.59	27.69	27.78
300	27.87	27.96	28.06	28.15	28.24	28.34	28.43	28.52	28.61	28.71
310	28.80	28.89	28.99	29.08	29.17	29.26	29.36	29.45	29.54	29.64
320	29.73	29.82	29.91	30.01	30.10	30.19	30.29	30.38	30.47	30.57
330	30.66	30.75	30.84	30.94	31.03	31.12	31.22	31.31	31.40	31.49
340	31.59	31.68	31.77	31.87	31.96	32.05	32.14	32.24	32.33	32.42
350	32.52	32.61	32.70	32.79	32.89	32.98	33.07	33.17	33.26	33.35
360	33.45	33.54	33.63	33.72	33.82	33.91	34.00	34.10	34.19	34.28
370	34.37	34.47	34.56	34.65	34.75	34.84	34.93	35.02	35.12	35.21
380	35.30	35.40	35.49	35.58	35.67	35.77	35.86	35.95	36.05	36.14
390	36.23	36.33	36.42	36.51	36.60	36.70	36.79	36.88	36.98	37.07
400	37.16	37.25	37.35	37.44	37.53	37.63	37.72	37.81	37.90	38.00
410	38.09	38.18	38.28	38.37	38.46	38.55	38.65	38.74	38.83	38.93
420	39.02	39.11	39.21	39.30	39.39	39.48	39.58	39.67	39.76	39.86
430	39.95	40.04	40.13	40.23	40.32	40.41	40.51	40.60	40.69	40.78
440	40.88	40.97	41.06	41.16	41.25	41.34	41.43	41.53	41.62	41.71
450	41.81	41.90	41.99	42.09	42.18	42.27	42.36	42.46	42.55	42.64
460	42.74	42.83	42.92	43.01	43.11	43.20	43.29	43.39	43.48	43.57
470	43.66	43.76	43.85	43.94	44.04	44.13	44.22	44.31	44.41	44.50
480	44.59	44.69	44.78	44.87	44.97	45.06	45.15	45.24	45.34	45.43
490	45.52	45.62	45.71	45.80	45.89	45.99	46.08	46.17	46.27	46.36
500	46.45	–	–	–	–	–	–	–	–	–

Table VII Cubic feet (up to 100 ft³) to cubic metres (to two places of decimals)

Cubic feet	0	1	2	3	4	5	6	7	8	9
	Cubic metres (m^3)									
0	–	0.03	0.06	0.08	0.11	0.14	0.17	0.20	0.23	0.25
10	0.28	0.31	0.34	0.37	0.40	0.42	0.45	0.48	0.51	0.54
20	0.57	0.59	0.62	0.65	0.68	0.71	0.73	0.76	0.79	0.82
30	0.85	0.88	0.91	0.93	0.96	0.99	1.02	1.05	1.08	1.10
40	1.13	1.16	1.19	1.22	1.25	1.27	1.30	1.33	1.36	1.39
50	1.42	1.44	1.47	1.50	1.53	1.56	1.59	1.61	1.64	1.67
60	1.70	1.73	1.76	1.78	1.81	1.84	1.87	1.90	1.93	1.95
70	1.98	2.01	2.04	2.07	2.10	2.12	2.15	2.18	2.21	2.24
80	2.27	2.29	2.32	2.35	2.38	2.41	2.44	2.46	2.49	2.52
90	2.55	2.58	2.61	2.63	2.66	2.69	2.72	2.75	2.78	2.80
100	2.83	–	–	–	–	–	–	–	–	–

Table VIII Pounds (up to 500 lb) to kilograms (to two places of decimals)

Pounds	0	1	2	3	4	5	6	7	8	9
	Kilogrammes (kg)									
0	–	0.45	0.91	1.36	1.81	2.27	2.72	3.18	3.63	4.08
10	4.54	4.99	5.44	5.90	6.35	6.80	7.26	7.71	8.16	8.62
20	9.07	9.53	9.98	10.43	10.89	11.34	11.79	12.25	12.70	13.15
30	13.61	14.06	14.52	14.97	15.42	15.88	16.33	16.78	17.24	17.69
40	18.14	18.60	19.05	19.50	19.96	20.41	20.87	21.32	21.77	22.23
50	22.68	23.13	23.59	24.04	24.49	24.95	25.40	25.85	26.31	26.76
60	27.22	27.67	28.12	28.58	29.03	29.48	29.94	30.39	30.84	31.30
70	31.75	32.21	32.66	33.11	33.57	34.02	34.47	34.93	35.38	35.83
80	36.29	36.74	37.19	37.65	38.10	38.56	39.01	39.46	39.92	40.37
90	40.82	41.28	41.73	42.18	42.64	43.09	43.54	44.00	44.45	44.91
100	45.36	45.81	46.27	46.72	47.17	47.63	48.08	48.53	48.99	49.44
110	49.90	50.35	50.80	51.26	51.71	52.16	52.62	53.07	53.52	53.98
120	54.43	54.88	55.34	55.79	56.25	56.70	57.15	57.61	58.06	58.51
130	58.97	59.42	59.87	60.33	60.78	61.24	61.69	62.14	62.60	63.05
140	63.50	63.96	64.41	64.86	65.32	65.77	66.22	66.68	67.13	67.59
150	68.04	68.49	68.95	69.40	69.85	70.31	70.76	71.21	71.67	72.12
160	72.57	73.03	73.48	73.94	74.39	74.84	75.30	75.75	76.20	76.66
170	77.11	77.56	78.02	78.47	78.93	79.38	79.83	80.29	80.74	81.19
180	81.65	82.10	82.55	83.01	83.46	83.91	84.37	84.82	85.28	85.73
190	86.18	86.64	87.09	87.54	88.00	88.45	88.90	89.36	89.81	90.26
200	90.72	91.17	91.63	92.08	92.53	92.99	93.44	93.89	94.35	94.80
210	95.25	95.71	96.16	96.62	97.07	97.52	97.98	98.43	98.88	99.34
220	99.79	100.24	100.70	101.15	101.61	102.06	102.51	102.97	103.42	103.87
230	104.33	104.78	105.23	105.69	106.14	106.59	107.05	107.50	107.96	108.41
240	108.86	109.32	109.77	110.22	110.68	111.13	111.58	112.04	112.49	112.95
250	113.40	113.85	114.31	114.76	115.21	115.67	116.12	116.57	117.03	117.48
260	117.93	118.39	118.84	119.30	119.75	120.20	120.66	121.11	121.56	122.02
270	122.47	122.92	123.38	123.83	124.28	124.74	125.19	125.65	126.10	126.55
280	127.01	127.46	127.91	128.37	128.82	129.27	129.73	130.18	130.64	131.09
290	131.54	132.00	132.45	132.90	133.36	133.81	134.26	134.72	135.17	135.62
300	136.08	136.53	136.99	137.44	137.89	138.35	138.80	139.25	139.71	140.16
310	140.61	141.07	141.52	141.97	142.43	142.88	143.34	143.79	144.24	144.70
320	145.15	145.60	146.06	146.51	146.96	147.42	147.87	148.33	148.78	149.23
330	149.69	150.14	150.59	151.05	151.50	151.95	152.41	152.86	153.31	153.77
340	154.22	154.68	155.13	155.58	156.04	156.49	156.94	157.40	157.85	158.30
350	158.76	159.21	159.67	160.12	160.57	161.03	161.48	161.93	162.39	162.84
360	163.29	163.75	164.20	164.65	165.11	165.56	166.02	166.47	166.92	167.38
370	167.83	168.28	168.74	169.10	169.64	170.10	170.55	171.00	171.46	171.91
380	172.37	172.82	173.27	173.73	174.18	174.63	175.09	175.54	175.99	176.45
390	176.90	177.36	177.81	178.26	178.72	179.17	179.62	180.08	180.53	180.98
400	181.44	181.89	183.34	182.80	183.25	183.71	184.16	184.61	185.07	185.52
410	185.97	186.43	186.88	187.33	187.79	188.24	188.69	189.15	189.60	190.06
420	190.51	190.96	191.42	191.87	192.32	192.78	193.23	193.68	194.14	194.59
430	195.05	195.50	195.95	196.41	196.86	197.31	197.77	198.22	198.67	199.13
440	199.58	200.03	200.49	200.94	201.40	201.85	202.30	202.76	203.21	203.66
450	204.12	204.57	205.02	205.48	205.93	206.39	206.84	207.29	207.75	208.20
460	208.65	209.11	209.56	210.01	210.47	210.92	211.37	211.83	212.28	212.74
470	213.19	213.64	214.10	214.55	215.00	215.46	215.91	216.36	216.82	217.27
480	217.72	218.18	218.63	219.09	219.54	219.99	220.45	220.90	221.35	221.81
490	222.26	222.71	223.17	223.62	224.08	224.53	224.98	225.44	225.89	226.34
500	226.80	–	–	–	–	–	–	–	–	–

Table IX Pounds per cubic foot to kilogrammes per cubic metre (to one place of decimals)

Pounds per cubic foot	0	1	2	3	4	5	6	7	8	9
	Kilogrammes per cubic metre (kg/m^3)									
0	–	16.0	32.0	48.1	64.1	80.1	96.1	112.1	128.1	144.2
10	160.2	176.2	192.2	208.2	224.3	240.3	256.3	272.3	288.3	304.4
20	320.4	336.4	352.4	368.4	384.4	400.5	416.5	432.5	448.5	464.5
30	480.6	496.6	512.6	528.6	544.6	560.6	576.7	592.7	608.7	624.7
40	640.7	656.8	672.8	688.8	704.8	720.8	736.8	752.9	768.9	784.9
50	800.9	816.9	833.0	849.0	865.0	881.0	897.0	913.1	929.1	945.1
60	961.1	977.1	993.1	1009.2	1025.2	1041.2	1057.2	1073.2	1089.3	1105.3
70	1121.3	1137.3	1153.3	1169.4	1185.4	1201.4	1217.4	1233.4	1249.4	1265.5
80	1281.5	1297.5	1313.5	1329.5	1345.6	1361.6	1377.6	1393.6	1409.6	1425.6
90	1441.7	1457.7	1473.7	1489.7	1505.7	1521.8	1537.8	1553.8	1569.8	1585.8
100	1601.9	–	–	–	–	–	–	–	–	–

Table X UK gallons (up to 100 galls) to litres (to two places of decimals)

UK gallons	0	1	2	3	4	5	6	7	8	9
	Litres									
0	–	4.55	9.09	13.64	18.18	22.73	27.28	31.82	36.37	40.91
10	45.46	50.01	54.55	59.10	63.64	68.19	72.74	77.28	81.83	86.37
20	90.92	95.47	100.01	104.56	109.10	113.65	118.20	122.74	127.29	131.83
30	136.38	140.93	145.47	150.02	154.56	159.11	163.66	168.20	172.75	177.29
40	181.84	186.38	190.93	195.48	200.02	204.57	209.11	213.66	218.21	222.75
50	227.30	231.84	236.39	240.94	245.48	250.03	254.57	259.12	263.67	268.21
60	272.76	277.30	281.85	286.40	290.94	295.49	300.03	304.58	309.13	313.67
70	318.22	322.76	327.31	331.86	336.40	340.95	345.49	350.04	354.59	359.13
80	363.68	368.22	372.77	377.32	381.86	386.41	390.95	395.50	400.04	404.59
90	409.14	413.68	418.23	422.77	427.32	431.87	436.41	440.96	445.50	450.05
100	454.60	–	–	–	–	–	–	–	–	–

Table XI Acres (up to 1000 acres) to hectares (to two places of decimals)

Acres	0	1	2	3	4	5	6	7	8	9
	Hectares									
	–	0.40	0.81	1.21	1.62	2.02	2.43	2.83	3.24	3.64
Acres	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
	Hectares									
0	–	4.05	8.09	12.14	16.19	20.23	24.28	28.33	32.37	36.42
100	40.47	44.52	48.56	52.61	56.66	60.70	64.75	68.80	72.84	76.89
200	80.94	84.98	89.03	93.08	97.12	101.17	105.22	109.27	113.31	117.36
300	121.41	125.45	129.50	133.55	137.59	141.64	145.69	149.73	153.78	157.83
400	161.87	165.92	169.97	174.02	178.06	182.11	186.16	190.20	194.25	198.30
500	202.34	206.39	210.44	214.48	218.53	222.58	226.62	230.67	234.72	238.77
600	242.81	246.86	250.91	254.95	259.00	263.05	267.09	271.14	275.19	279.23
700	283.28	287.33	291.37	295.42	299.47	303.51	307.56	311.61	315.66	319.70
800	323.75	327.80	331.84	335.89	339.94	343.98	348.03	352.08	356.12	360.17
900	364.22	368.26	372.31	376.36	380.41	384.45	388.50	392.55	396.59	400.64
1000	404.69	–	–	–	–	–	–	–	–	–

Table XII Miles per hour (up to 100 mph) to metres per second (to two places of decimals)

Miles per hour	0	1	2	3	4	5	6	7	8	9
	Metres per second									
0	–	0.45	0.89	1.34	1.79	2.24	2.68	3.13	3.58	4.02
10	4.47	4.92	5.36	5.81	6.26	6.71	7.15	7.60	8.05	8.49
20	8.94	9.39	9.83	10.28	10.73	11.18	11.62	12.07	12.52	12.96
30	13.41	13.86	14.31	14.75	15.20	15.65	16.09	16.54	16.99	17.43
40	17.88	18.33	18.78	19.22	19.67	20.12	20.56	21.01	21.46	21.91
50	22.35	22.80	23.25	23.69	24.14	24.59	25.03	25.48	25.93	26.38
60	26.82	27.27	27.72	28.16	28.61	29.06	29.50	29.95	30.40	30.85
70	31.29	31.74	32.19	32.63	33.08	33.53	33.98	34.42	34.87	35.32
80	35.76	36.21	36.66	37.10	37.55	38.00	38.45	38.89	39.34	39.79
90	40.23	40.68	41.13	41.57	42.02	42.47	42.92	43.36	43.81	44.26
100	44.70	–	–	–	–	–	–	–	–	–

Table XIII Pressure and stress. Pounds–force per square inch to kilonewtons per square metre (to two places of decimals)

lbf per sq In	0	1	2	3	4	5	6	7	8	9
	kN/m^2 or kPa									
0	–	6.90	13.79	20.68	27.58	34.48	41.37	48.26	55.16	62.06
10	68.95	75.84	82.74	89.64	96.53	103.42	110.32	117.22	124.11	131.00
20	137.90	144.80	151.69	158.58	165.48	172.38	179.27	186.16	193.06	199.96
30	206.85	213.64	220.64	227.54	234.43	241.32	248.22	255.12	262.01	268.90
40	275.80	282.70	289.59	296.48	303.38	310.28	317.17	324.06	330.96	337.86
50	344.75	351.64	358.54	365.44	372.33	379.22	386.12	393.02	399.91	406.80
60	413.70	420.60	427.49	434.38	441.28	448.18	455.07	461.96	468.86	475.76
70	482.65	489.54	496.44	503.34	510.23	517.12	524.02	530.92	537.81	544.70
80	551.60	558.50	565.39	572.28	579.18	586.08	592.97	599.86	606.76	613.66
90	620.55	627.44	634.34	641.24	648.13	655.02	661.92	668.82	675.71	682.60
100	689.50	–	–	–	–	–	–	–	–	–

Note: the same table will convert kipf per.sq in to MN/m^2 or MPa

Table XIV British thermal units per hour to watts

Btu per hr	0	1	2	3	4	5	6	7	8	9
	W									
0	–	0.29	0.59	0.88	1.17	1.47	1.76	2.05	2.34	2.64
10	2.93	3.22	3.52	3.81	4.10	4.40	4.69	4.98	5.28	5.57
20	5.86	6.16	6.45	6.74	7.03	7.33	7.62	7.91	8.21	8.50
30	8.79	9.09	9.38	9.67	9.97	10.26	10.55	10.84	11.14	11.43
40	11.72	12.02	12.31	12.60	12.90	13.19	13.48	13.78	14.07	14.36
50	14.66	14.95	15.24	15.53	15.83	16.12	16.41	16.71	17.00	17.29
60	17.59	17.88	18.17	18.47	18.76	19.05	19.34	19.64	19.93	20.22
70	20.52	20.81	21.10	21.40	21.69	21.98	22.28	22.57	22.86	23.15
80	23.45	23.74	24.03	24.33	24.62	24.91	25.21	25.50	25.79	26.09
90	26.38	26.67	26.97	27.26	27.55	27.84	28.14	28.43	28.72	29.02
100	29.31	–	–	–	–	–	–	–	–	–

Table XV *U* value: British thermal units per square foot per hour per degree Fahrenheit to watts per square metre per kelvin

Btu per sq ft hr °F	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
	$W/(m^2K)$									
0	–	0.057	0.114	0.170	0.227	0.284	0.341	0.397	0.454	0.511
0.1	0.568	0.624	0.681	0.738	0.795	0.852	0.908	0.965	1.022	1.079
0.2	1.136	1.192	1.249	1.306	1.363	1.420	1.476	1.533	1.590	1.647
0.3	1.703	1.760	1.817	1.874	1.931	1.987	2.044	2.101	2.158	2.214
0.4	2.271	2.328	2.385	2.442	2.498	2.555	2.612	2.669	2.725	2.782
0.5	2.839	2.896	2.953	3.009	3.066	3.123	3.180	3.236	3.293	3.350
0.6	3.407	3.464	3.520	3.577	3.634	3.691	3.747	3.804	3.861	3.918
0.7	3.975	4.031	4.088	4.145	4.202	4.258	4.315	4.372	4.429	4.486
0.8	4.542	4.599	4.656	4.713	4.770	4.826	4.883	4.940	4.997	5.053
0.9	5.110	5.167	5.224	5.281	5.337	5.394	5.451	5.508	5.564	5.621
1.0	5.678	–	–	–	–	–	–	–	–	–

Table XVI Feet and inches (up to 100 ft) to metres and millimetres (to nearest millimetre)

Feet	Inches 0	1	2	3	4	5	6	7	8	9	10	11
	Metres and millimetres											
0	–	0.025	0.051	0.076	0.102	0.127	0.152	0.178	0.203	0.229	0.254	0.279
1	0.305	0.330	0.356	0.381	0.406	0.432	0.457	0.483	0.508	0.533	0.559	0.584
2	0.610	0.635	0.660	0.686	0.711	0.737	0.762	0.787	0.813	0.838	0.864	0.889
3	0.914	0.940	0.965	0.991	1.016	1.041	1.067	1.092	1.118	1.143	1.168	1.194
4	1.219	1.245	1.270	1.295	1.321	1.346	1.372	1.397	1.422	1.448	1.473	1.499
5	1.524	1.549	1.575	1.600	1.626	1.651	1.676	1.702	1.727	1.753	1.778	1.803
6	1.829	1.854	1.880	1.905	1.930	1.956	1.981	2.007	2.032	2.057	2.083	2.108
7	2.134	2.159	2.184	2.210	2.235	2.261	2.286	2.311	2.337	2.362	2.388	2.413
8	2.438	2.464	2.489	2.515	2.540	2.565	2.591	2.616	2.642	2.667	2.692	2.718
9	2.743	2.769	2.794	2.819	2.845	2.870	2.896	2.921	2.946	2.972	2.997	3.023
10	3.048	3.073	3.099	3.124	3.150	3.175	3.200	3.226	3.251	3.277	3.302	3.327
11	3.353	3.378	3.404	3.429	3.454	3.480	3.505	3.531	3.556	3.581	3.607	3.632
12	3.658	3.683	3.708	3.734	3.759	3.785	3.810	3.835	3.861	3.886	3.912	3.937
13	3.962	3.988	4.013	4.039	4.064	4.089	4.115	4.140	4.166	4.191	4.216	4.242
14	4.267	4.293	4.318	4.343	4.369	4.394	4.420	4.445	4.470	4.496	4.521	4.547
15	4.572	4.597	4.623	4.648	4.674	4.699	4.724	4.750	4.775	4.801	4.826	4.851
16	4.877	4.902	4.928	4.953	4.978	5.004	5.029	5.055	5.080	5.105	5.131	5.156
17	5.182	5.207	5.232	5.258	5.283	5.309	5.334	5.359	5.385	5.410	5.436	5.461
18	5.486	5.512	5.537	5.563	5.588	5.613	5.639	5.664	5.690	5.715	5.740	5.766
19	5.791	5.817	5.842	5.867	5.893	5.918	5.944	5.969	5.994	6.020	6.045	6.071
20	6.096	6.121	6.147	6.172	6.198	6.223	6.248	6.274	6.299	6.325	6.350	6.375
21	6.401	6.426	6.452	6.477	6.502	6.528	6.553	6.579	6.604	6.629	6.655	6.680
22	6.706	6.731	6.756	6.782	6.807	6.833	6.858	6.883	6.909	6.934	6.960	6.985
23	7.010	7.036	7.061	7.087	7.112	7.137	7.163	7.188	7.214	7.239	7.264	7.290
24	7.315	7.341	7.366	7.391	7.417	7.442	7.468	7.493	7.518	7.544	7.569	7.595
25	7.620	7.645	7.671	7.696	7.722	7.747	7.772	7.798	7.823	7.849	7.874	7.899
26	7.925	7.950	7.976	8.001	8.026	8.052	8.077	8.103	8.128	8.153	8.179	8.204
27	8.230	8.255	8.280	8.306	8.331	8.357	8.382	8.407	8.433	8.458	8.484	8.509
28	8.534	8.560	8.585	8.611	8.636	8.661	8.687	8.712	8.738	8.763	8.788	8.814
29	8.839	8.865	8.890	8.915	8.941	8.966	8.992	9.017	9.042	9.068	9.093	9.119
30	9.144	9.169	9.195	9.220	9.246	9.271	9.296	9.322	9.347	9.373	9.398	9.423
31	9.449	9.474	9.500	9.525	9.550	9.576	9.601	9.627	9.652	9.677	9.703	9.728
32	9.754	9.779	9.804	9.830	9.855	9.881	9.906	9.931	9.957	9.982	10.008	10.033
33	10.058	10.084	10.109	10.135	10.160	10.185	10.211	10.236	10.262	10.287	10.312	10.338
34	10.363	10.389	10.414	10.439	10.465	10.490	10.516	10.541	10.566	10.592	10.617	10.643
35	10.668	10.693	10.719	10.744	10.770	10.795	10.820	10.846	10.871	10.897	10.922	10.947
36	10.973	10.998	11.024	11.049	11.074	11.100	11.125	11.151	11.176	11.201	11.227	11.252
37	11.278	11.303	11.328	11.354	11.379	11.405	11.430	11.455	11.481	11.506	11.532	11.557
38	11.582	11.608	11.633	11.659	11.684	11.709	11.735	11.760	11.786	11.811	11.836	11.862
39	11.887	11.913	11.938	11.963	11.989	12.014	12.040	12.065	12.090	12.116	12.141	12.167
40	12.192	12.217	12.243	12.268	12.294	12.319	12.344	12.370	12.395	12.421	12.446	12.471
41	12.497	12.522	12.548	12.573	12.598	12.624	12.649	12.675	12.700	12.725	12.751	12.776
42	12.802	12.827	12.852	12.878	12.903	12.929	12.954	12.979	13.005	13.030	13.056	13.081
43	13.106	13.132	13.157	13.183	13.208	13.233	13.259	13.284	13.310	13.335	13.360	13.386
44	13.411	13.437	13.462	13.487	13.513	13.538	13.564	13.589	13.614	13.640	13.665	13.691
45	13.716	13.741	13.767	13.792	13.818	13.843	13.868	13.894	13.919	13.945	13.970	13.995
46	14.021	14.046	14.072	14.097	14.122	14.148	14.173	14.199	14.224	14.249	14.275	14.300
47	14.326	14.351	14.376	14.402	14.427	14.453	14.478	14.503	14.529	14.554	14.580	14.605
48	14.630	14.656	14.681	14.707	14.732	14.757	14.783	14.808	14.834	14.859	14.884	14.910
49	14.935	14.961	14.986	15.011	15.037	15.062	15.088	15.113	15.138	15.164	15.189	15.215
50	15.240	15.265	15.291	15.316	15.342	15.367	15.392	15.418	18.443	15.469	15.494	15.519
51	15.545	15.570	15.596	15.621	15.646	15.672	15.697	15.723	15.748	15.773	15.799	15.824
52	15.850	15.875	15.900	15.926	15.951	15.977	16.002	16.027	16.053	16.078	16.104	16.129
53	16.154	16.180	16.205	16.231	16.256	16.281	16.307	16.332	16.358	16.383	16.408	16.434
54	16.459	16.485	16.510	16.535	16.561	16.586	16.612	16.637	16.662	16.688	16.713	16.739
55	16.764	16.789	16.815	16.840	16.866	16.891	16.916	16.942	16.967	16.993	17.018	17.043
56	17.069	17.094	17.120	17.145	17.170	17.196	17.221	17.247	17.272	17.297	17.323	17.248
57	17.374	17.399	17.424	17.450	17.475	17.501	17.526	17.551	17.577	17.602	17.628	17.653
58	17.678	17.704	17.729	17.755	17.780	17.805	17.830	17.856	17.882	17.907	17.932	17.958
59	17.983	18.009	18.034	18.059	18.085	18.110	18.136	18.161	18.186	18.212	18.237	18.263
60	18.288	18.313	18.339	18.364	18.390	18.415	18.440	18.466	18.491	18.517	18.542	18.567
61	18.593	18.618	18.644	18.669	18.694	18.720	18.745	18.771	18.796	18.821	18.847	18.872
62	18.898	18.923	18.948	18.974	18.999	19.025	19.050	19.075	19.101	19.126	19.152	19.177
63	19.202	19.228	19.253	19.279	19.304	19.329	19.355	19.380	19.406	19.431	19.456	19.482
64	19.507	19.533	19.558	19.583	19.609	19.634	19.660	19.685	19.710	19.736	19.761	19.787
65	19.812	19.837	19.863	19.888	19.914	19.939	19.964	19.990	20.015	20.041	20.066	20.091
66	20.117	20.142	20.168	20.193	20.218	20.244	20.269	20.295	20.320	20.345	20.371	20.396
67	20.422	20.447	20.472	20.498	20.523	20.549	20.574	20.599	20.625	20.650	20.676	20.701
68	20.726	20.752	20.777	20.803	20.828	20.853	20.879	20.904	20.930	20.955	20.980	21.006
69	21.031	21.057	21.082	21.107	21.133	21.158	21.184	21.209	21.234	21.260	21.285	21.311

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Chapter numbers are given in **bold** followed by page numbers. **A** denotes Appendix A. **B** denotes Appendix B.

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