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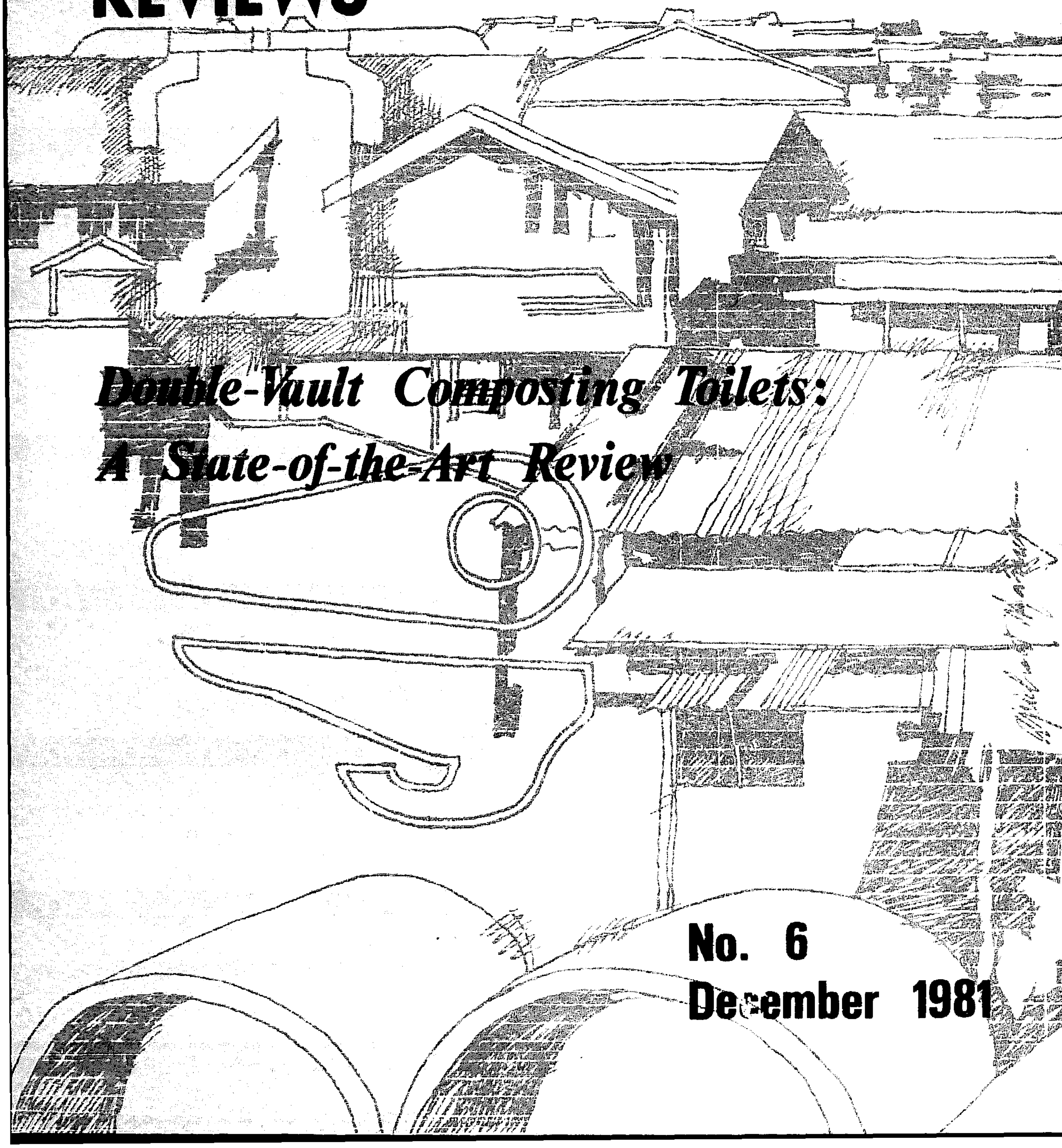

Double-Vault Composting Toilets: A State-of-the-Art Review

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DOUBLE - VAULT COMPOSTING TOILETS :
A STATE-OF-THE-ART REVIEW

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ENVIRONMENTAL SANITATION INFORMATION CENTER
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--- A STATE-OF-THE-ART REVIEW ---

by

Prof. Witold Rybczynski

The intractable problem of sanitation seems to be always with us. Ever since the link between unhygienic waste disposal and disease was established, efforts have been made to find the device that will resolve the problems. The final solution has been elusive, to say the least. At first it seemed simple. To Dr. Poore, and his disciple Mohandas Gandhi, it sufficed to bury excreta in the soil. Elaborations followed, including the earth closet, pit latrine and, with the introduction of the water-trap, septic tanks and aqua-privies. Each device, in its day, was touted as *the* solution; each, of course, was improved, and sometimes replaced. Today the spotlight falls on the double vault composting toilet, a technology which, though hardly new as I will show, does seem to offer a number of distinct advantages over its predecessors. If it is unlikely to be the last word in sanitation, it is certainly a step forward.

A report of the widespread use of the double vault composting (DVC) toilet in the then Democratic Republic of Vietnam appeared in 1974.(1) According to this and other accounts, over 600,000 tons of fertilizer were produced annually in hundreds of thousands of rural DVC toilets. The apparent success and scale of this technology aroused the interest of sanitarians around the world, and the DVC toilet began to be reconsidered as a waste disposal solution. Reconsidered, because although the DVC toilet had been mentioned in the literature on sanitation, on and off, for the last sixty years, greater attention had been paid to more "sophisticated" solutions such as the aqua-privy.

The recent upsurge in interest in the DVC toilet has unfortunately created a certain amount of confusion as regards its design, construction and operation. I hope that this paper will help to clarify the situation, so that the rush to adopt this technology in countries where it is not indigenous will have a greater chance of success.

Before describing current applications of the DVC toilet it would be useful to examine its antecedents.

1. HISTORICAL DEVELOPMENT

The immediate predeçessor of the DVC toilet is probable the so-called *earth closet,* invented in 1860 by Henry Moule, an English vicar. Moule had been active in the great 1849-54 cholera epidemic, which presumably had stimulated his awareness of the role of proper sanitation in reducing disease. The earth closet, which replaced the pit latrine or cesspool, consisted simply of an enclosed vault or removable bucket below the toilet seat. Each time that the earth closet was used, a small quantity of dry, powdered earth, or ashes, was sprinkled over the fresh excreta. Although composting was not fully understood at the time, a 1905 sanitation manual does describe the soil or ashes as "disintegrating the organic matter, converting it into the condition in which lit naturally exists in fertile soil."(2) The contents of the earth closet were usually left undisturbed for at least six months, to be finally removed by "responsible servants" for eventual disposal in the field or garden.

The Rev. Moule established an "Earth Closet Company" which manufactured a hopper-shaped device whereby a measured quantity of dried earth was "flushed" each time that a handle was pulled (Fig.1). Moore reports that earth closets were even used in multi-story buildings; each closet was connected to a chute which led down to a large cart which was emptied once a month.(3) Although "wet" systems such as the septic tank and underground sewer ultimatedly displaced the earth closet, it continued to be used in rural England until the 1930s.(4)

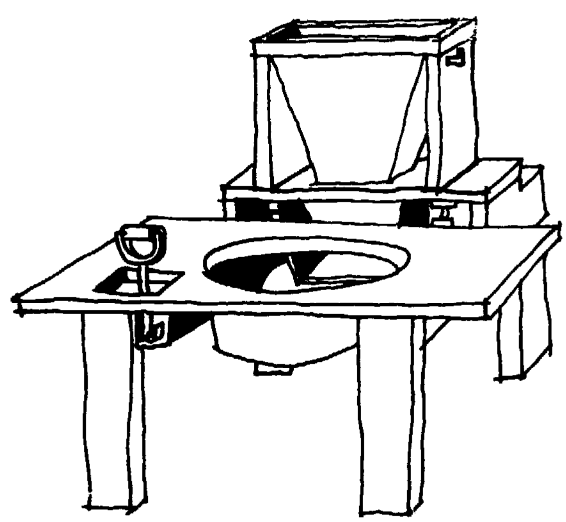


Fig. 1 Moule's Earth Closet

It is easy to forget the debate that raged in the nineteenth century in England, and elsewhere, concerning the introduction of waterborne sanitation; the latter was by no means universally accepted as a beneficial of progressive invention. Poore quotes an apparently enlightened (also rare, one guesses) engineer, Charles Richardson, who wrote, "This century (i.e. the nineteenth) has been by far the most remarkable, in the intellectual history of the world, for its great progress in the scientific discovery and invention. But in the midst of all the beneficial inventions made during the period, there is one which is wholly *evil* - I mean the water-closet."(5) The main objection to waterborne sanitation was that it "enlarged" a small problem into a big one through the addition of water, that the contaminated sewage represented an environmental hazard, and that liquid sewage was much more unmanageable than solid excreta and would be less likely to be reused as fertilizer (which at the time did turn out to be the case, though contemporary sewage farming may be reversing this trend). In a statement often mistakenly attributed to Gandhi, Poore made the case for simple sanitation: "The only engineering implements which the cottager with a bit of garden requires for his sanitation are a water-pot and a spade."(5)

The earth closet was also known in the United States, though less widely used. An American antecedent of the DVC toilet, however, was probably the *concrete vault privy*, described by Hopkins.(6) This type of privy was apparently used when a high water table threatened flooding of the toilet pit. The construction consisted of a water-tight concrete compartment, which was not only ventilated but bore a striking resemblance to later composting toilet designs (Fig.2). According to Hopkins, "the excreta was stored for at least six months, during which period the material becomes more or less stabilized." There is no mention made of adding organic wastes to the vault, so that "more or less stabilized" is probably an understatement.

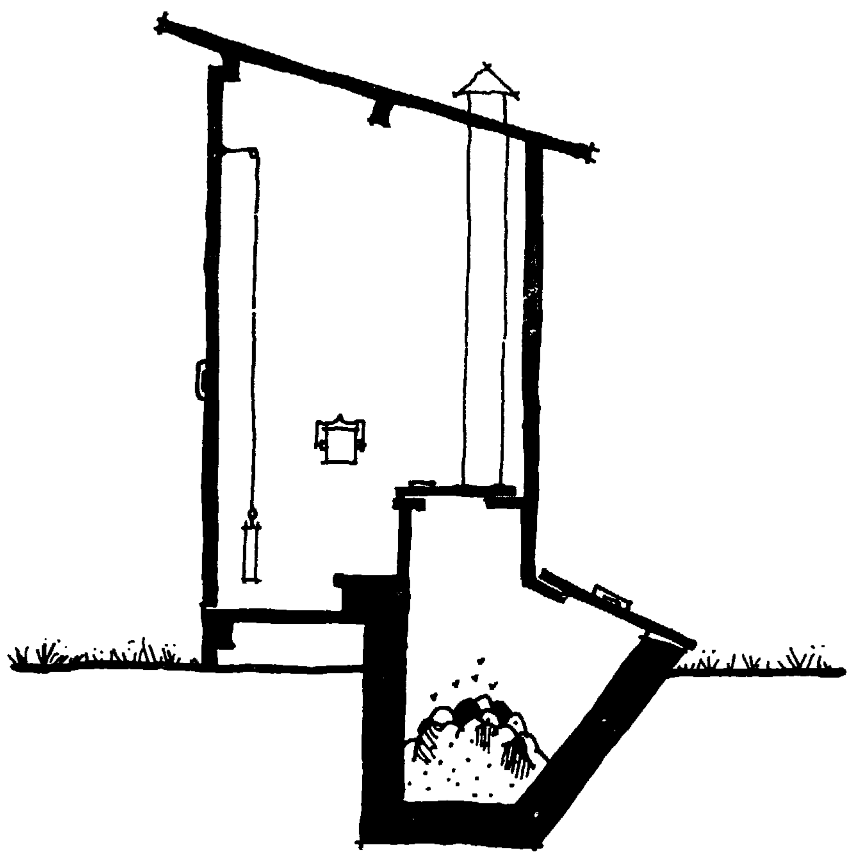


Fig. 2 American Concrete Vault Privy (after Hopkins)

These types of early vault prives did not meet with great success. The United States Army, in 1917, developed a *two vault privy* (probably the first on record) for use on military bases, and which was large enough to store the excreta of one family for up to six months. Again, composting being not yet well understood, no organic materials was added to the toilet so that the excreta simply turned septic and liquified. Hardenbergh reported that the experiment was finally abandoned; not only were strong odours present in the toilet, but great difficulty was encountered in removing the less than solid contents.(7)

A number of important principles which would be incorporated into the DVC toilet were elaborated in these early designs. The earth closet showed the importance of adding some dry, powdered material to cover the excreta and absorb excess urine. The concrete vault privy, though unsuccessful in operation, did elaborate a physical design for the removal of material from the vault. The two vault privy recognized the necesscity of permitting the contents of one vault to remain undisturbed for the required period, so that when material was removed there would be no fresh excreta present. The only missing ingredient was an understanding of the biology of the composting process itself.

This was supplied by Sir Albert Howard who, in the 1930s in India, perfected a technique for the anaerobic decomposition of organic wastes which is usually referred to as the Indore or Bangalore composting process. The organic wastes, including human or animal excreta, are left undisturbed for up to one year (Moule's guess was almost right). More importantly, the proportion of excreta to organic refuse should be about 1:5 by volume, which will result in the desired Carbon/Nitrogen ratio of 30:1, and the moisture content should be about 50-60%.(8)

Howard's work was directed both at producing fertilizer and finding a method for treating human excreta, or night-soil as it was then called. Much of Indian sanitation then, and now, consisted of so-called "service latrines" from which the excreta were collected by scavengers. Howard combined this night-soil with alternating layers of organic waste, in large pits or in open piles, with a covering of soil. If the piles were turned, composting could be accomplished in as little as a month, if they were left undisturbed it would take a year. The earliest compost privies which were built in India were small-scale versions of the Indore process, with an individual pit covered by a squatting plate. When the pit was full it was covered over and the plate moved to a new pit. This practice quickly led to the idea of two alternatively used pits, and the DVC toilet was born.

2. DEFINITION

DVC toilets are defined, for the purpose of this paper, as having three identifying characteristics. First, the excreta is deposited into one of two vaults, compartments or pits, which are used alternatively. Second, while one vault is in use, the excreta is retained and composted in the other vault for an extended period of time. Third, when the composting period is over, the humus is removed from the vault for use as fertilizer.

The nomenclature in the literature on sanitation is often inconsistent and sometimes confusing. DVC toilets with pits, instead of vaults, are sometimes referred to as "permanent improved pit latrines" or "emptyable ventilated twin pit latrines". The terms "earth closet", "double septic bin" and "offset pour-flush toilet" have also been used in reference to what are essentially DVC toilets. However, the confusion is not only semantic: there are important distinctions between DVC toilets which have the above three characteristics in common. Not all DVC toilets require ventilation; not all require that organic refuse be added; retention times vary from a few months to a few years; some DVC toilets require urine separation, some do not; some DVC toilets are dry, some could be called semi-dry, and some are used in conjunction with a water-seal. It would be incorrect to say that there is one type of DVC toilet - I have been able to identify at least four categories - and, not surprisingly, this had led to a certain amount of obfuscation in the literature, and, more importantly, misunderstanding in the field.

There is an important distinction, however, to be made between the DVC toilet and another type of composting toilet, the multrum or continuous composting toilet. The *multrum* is distinguished from the DVC toilet in that it consists of a *single* compartment within which composting takes place. A sloping bottom and a baffle ensure that composted material can be removed periodically. It is by no means clear to me that the multrum is more complicated to operate than the DVC toilet, as a recent World Bank report has concluded (9) - a current research project in Mexico will provide important information in this regard.(10) However, at this time, although the multrum has been used in the United States, Canada and Europe, there is very little experience with its use in the tropics, whereas the DVC toilet has found wide application in a number of less developed countries and hence provides the focus for this paper.

3. ANAEROBIC DVC TOILET WITH ORGANIC REFUSE

Wagner and Lanoix, in their famous monograph on rural sanitation, described a twin-vault composting toilet based on the Indore composting process.(11) The origin of this design is not given (it somewhat resembles the American concrete vault privy), indeed it is unclear when and where it was ever used, but it has been widely reproduced in the literature and a number of variations have been built. The two vaults are completely buried and access is, rather awkwardly, from above and one side (Fig.3). Although this design has what appears to be a solid bottom, it "need not be water-tight" according to the authors, and one must assume that urine and anal-cleansing water do seep out, preventing flooding of the vault. There is no provision for ventilation or for preventing odours from entering the toilet room. Although this DVC toilet was first published by the World Health Organization in 1958, there have not been many applications documented, which may be due to the poor design, or to the rather tentative endorsement that it received from Wagner and Lanoix.

A number of DVC toilets with organic refuse have been built in the 1970s, usually as part of experimental research projects. Winblad proposed a design which is partly buried, ventilated and which drains excess water and urine into the ground (Fig.4).(12) A watertight DVC toilet, resembling the WHO-type, is reported in Botswana.(13) A similar design is being tested in Mexico in an urban site (14); the Mexican model has only one defecation hole and a moveable baffle which diverts the excreta into one vault or the other. A simple rectangular design has been built and tested in Tanzania (Fig.5).(15)

The operation of these DVC toilets is simple and requires the addition of organic refuse once a week, roughly five times as much refuse as excreta (by volume). The actual amounts will vary with diet and body size, though the WHO suggests that a wet weight of about 1 kg of excreta per person per day (approximately 1 liter of urine) is an average figure.(11) Thus the dimensions of most of these kind of DVC toilets are about 1-1.5 cubic meters per vault, which, for a family of five will ensure a retention period of 6-12 months. Once one vault is full it is sealed up and its companion put to use. When the second

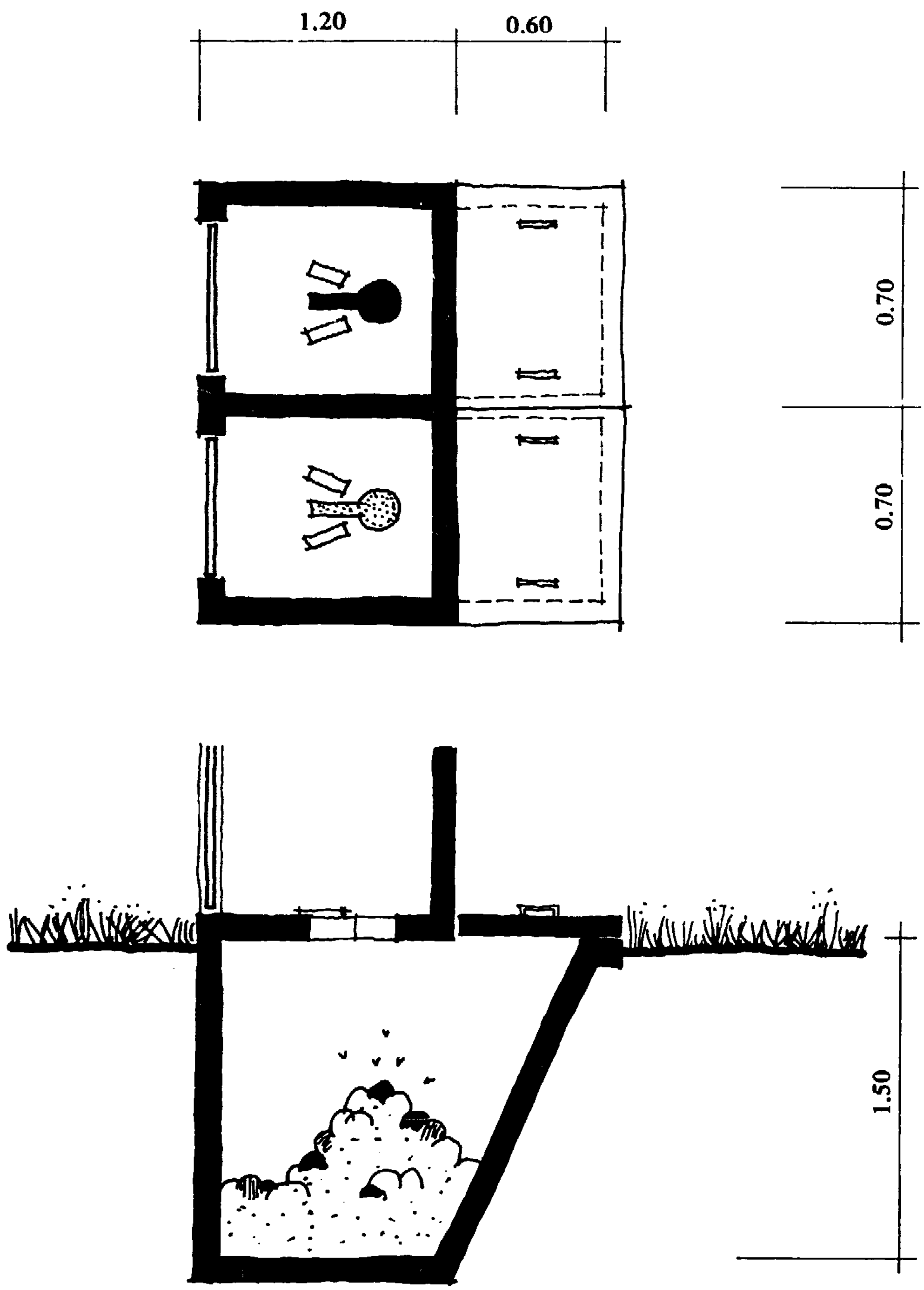


Fig. 3 W.H.O. Composting Toilet (after Wagner & Lanoix)

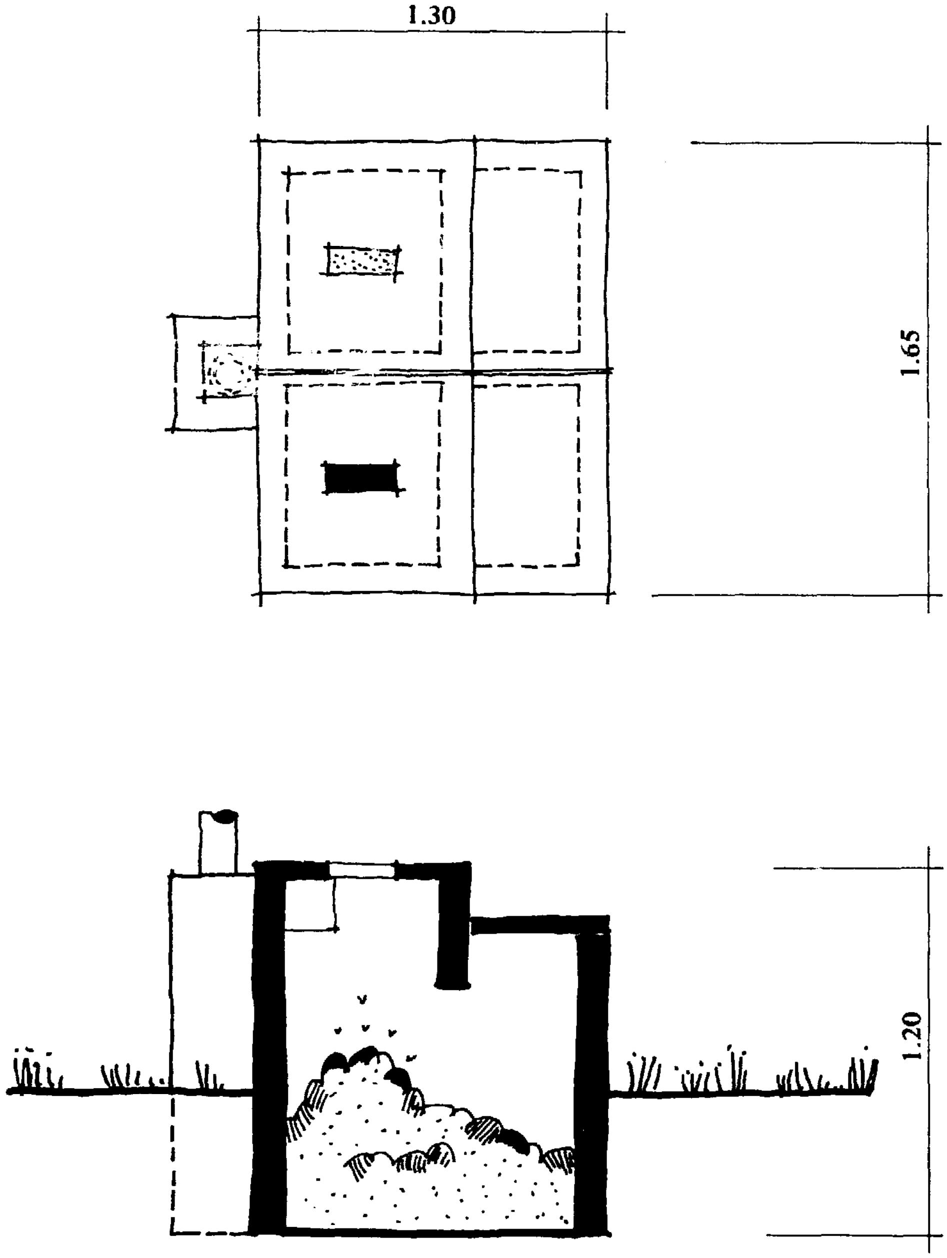


Fig. 4 Tanzanian DVC Toilet (after Winblad)

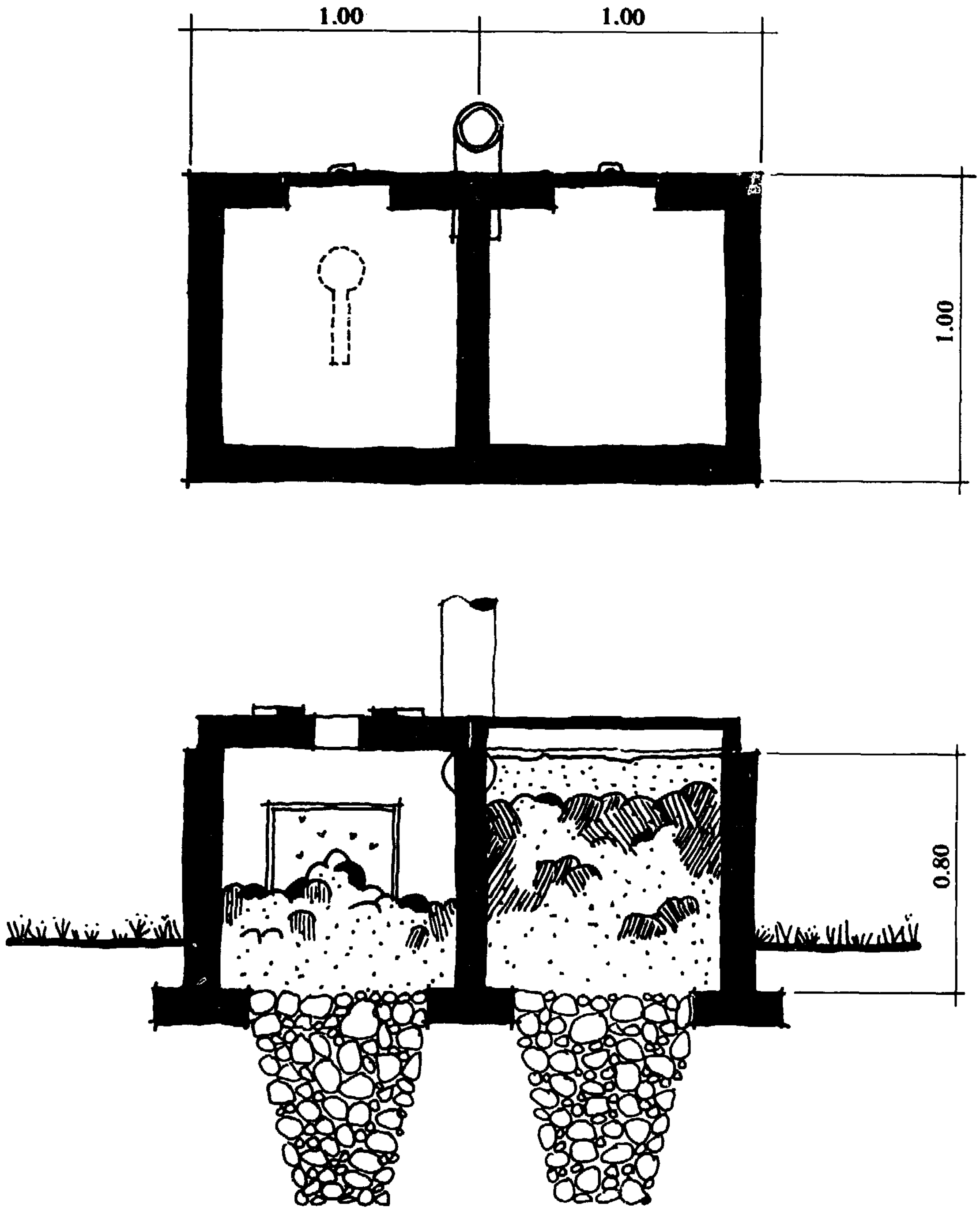


Fig. 5 DVC Toilet with soakaway

vault is full, the first is emptied and the cycle recommences.

Although Wagner and Lanoix stated that anaerobic composting for a period of at least six months would "ensure destruction of pathogens and ova of helminths", it is now generally acknowledged that anaerobic DVC toilets do not achieve *complete* destruction of pathogens. The highest temperature recorded in an African research project in a DVC toilet was 43 degrees Celsius.(15) Since 60 degree Celsius is required to destroy the hardiest ova (Ascaris), it is unlikely that a six month period of primarily anaerobic composting would be totally effective. A World Bank planner's guide recommends a retention period of one year to ensure that very few viable Ascaris ova would remain.(9) It is not clear that a longer period than that would achieve any further significant benefits. Undoubtedly, as the number of installations increases, and as monitoring continues, it will be possible to be more definite about an ideal retention period.

DVC toilets with organic refuse should not have water-tight vaults. Simbeye reports that the Tanzanian DVC toilets, which were constructed out of concrete, experienced high moisture levels which significantly slowed down decomposition.(16) Winblad warns that water-tight vaults will require a reduction in water input (e.g. anal cleansing) and may even require urine separation.(12) Where solid bottomed DVC toilets have performed successfully, it is likely that excess urine and anal cleansing water has seeped out through cracks and fissures.

The problem of excess liquids in the vault is best avoided by allowing these to infiltrate into the ground. Wright describes the original Indian version of the DVC toilet (sometimes called the Paunar latrine) which uses simply excavated pits.(17) The only fabricated element is a concrete cover which incorporates the squatting plate, and a brick wall that divides the pit in two. Such a toilet obviously depends on soil that is neither too rocky (which would prevent infiltration), nor too sandy (which would lead to cave-ins).

The British Building Research Establishment has recently proposed a design for a DVC toilet of the Paunar sort which is referred to as the "permanent improved pit" (PIP) and, quixotically, as the "revised earth closet" (REC II).(18) Both designs consist of a segmented concrete slab, which can be removed for access, over a pit with a dividing wall (Fig.6). The slab incorporates holes for two toilet seats and two vent pipes, while a rectangular collar beam supports the slabs and reinforces the edge of the pit. A large number of these DVC toilets are currently being built in Botswana (19), and similar installations have been reported in Mozambique.(20) Although at first sight the REC II and PIP seem to be simple solutions, the duplication of vent pipes and seats, the size of the pit and the necessity of spanning the large excavation will undoubtedly raise costs significantly. The retention period for the REC II is planned to be two years, after which time the pit is to be mechanically emptied.

The necessity for constructing a slab to span the composting vaults, which is both expensive and complicated (as well as using reinforced concrete), is neatly avoided in the *sopa sandas* (simple latrine). The sopa sandas was apparently developed by Dr. Kessel at the Sevagram Ashram in India in 1952.(21) The pits are offset from the squatting plate and an inclined chute connects the two (Fig.7). To prevent flies and rodents access to the vault, the end is covered with a hinged flap. The first chute was made from sheet metal with a rubber flap, subsequent installations have used baked earthen pans and chutes, as well as more expensive glazed ceramic. Sopa sandas have been built both with two pans and chutes, and with one pan and a Y-shaped chute that carries the excreta to either vault as required. The organic refuse is added to the vault all at once, before it is used, rather than continuously. When the vault is

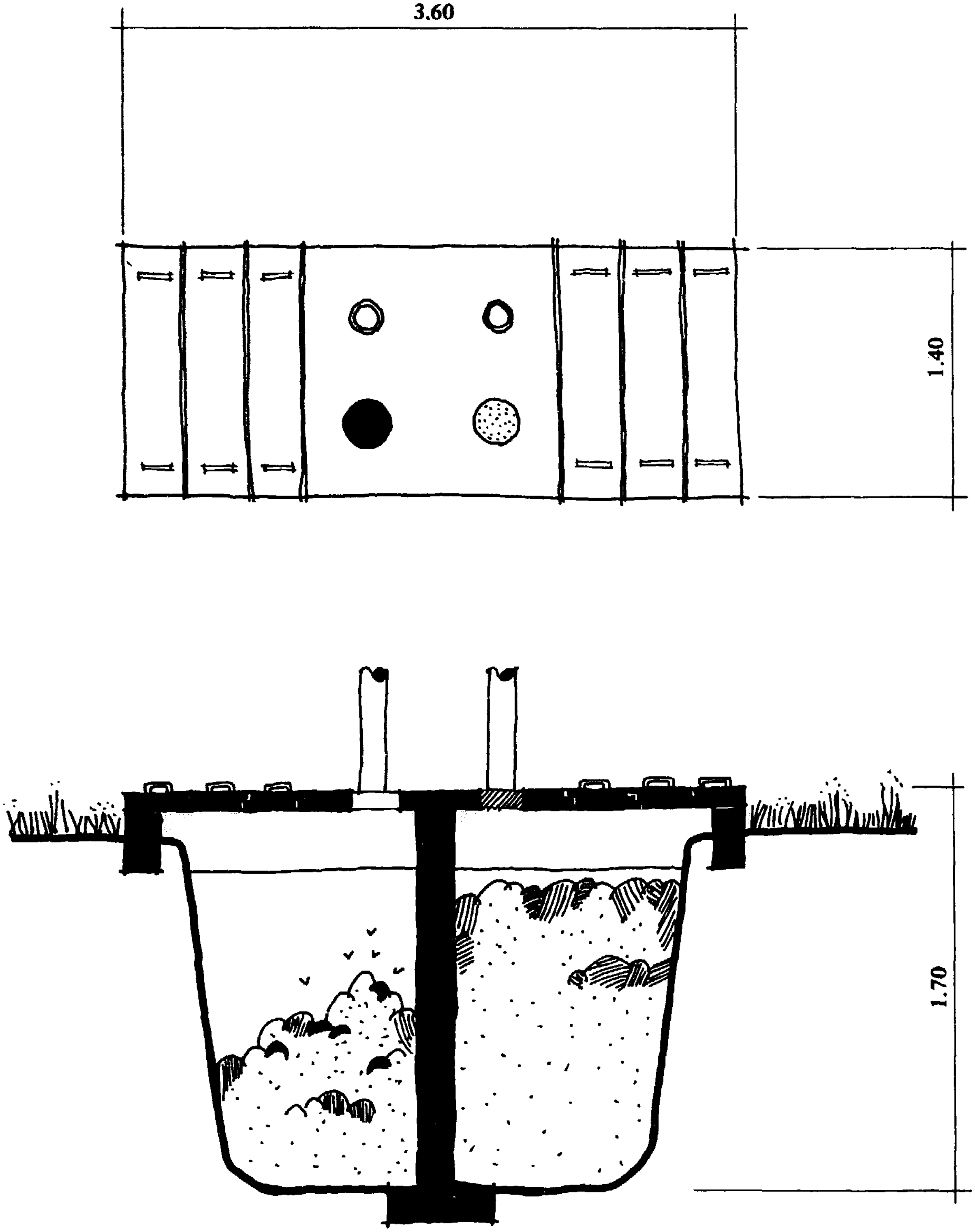
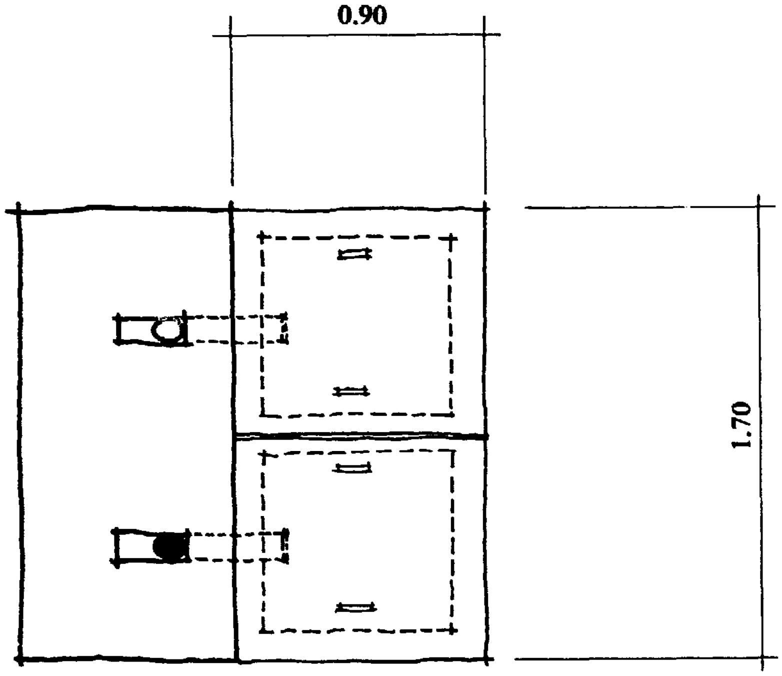


Fig. 6 REC II, Botswana (after Carroll)



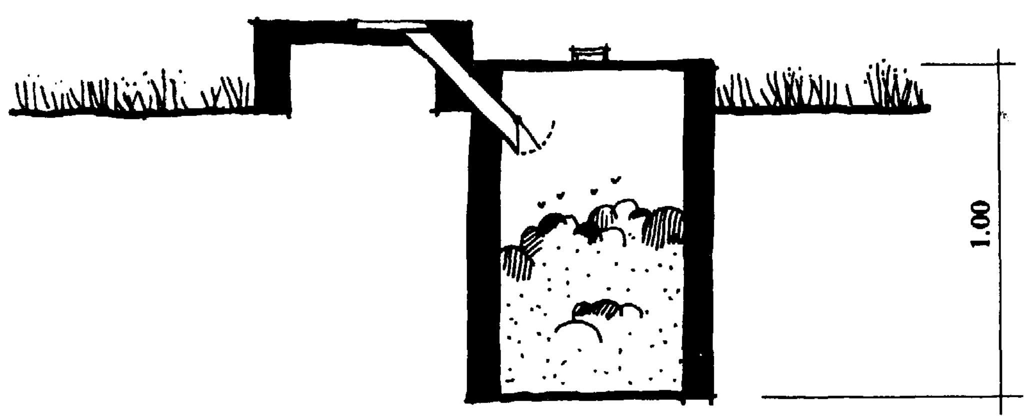


Fig. 7 Sopa Sandas (after Maharashtra Gandhi Smarak Nidhi)

filled it is sealed, organic refuse added to the adjoining vault, and the adjoining pan is used. The vaults have no bottoms and excess liquid is infiltrated into the ground. No vent pipes are required.

The sopa sandas has a number of advantages: extremely low cost through offsetting the vaults and eliminating vent pipes; simple operation since organic waste is only added once every six months; it easily accepts anal cleansing water since the floor of the vaults is permeable. The sopa sandas DVC toilet has been in continual use in India for the last twenty years, and has been popularized by such volunteer organizations as Maharashtra Gandhi Smarak Nidhi, which, in 1970 constructed about 20,000 such latrines (22), and by 1980 had built 60,000 latrines in Maharashtra state.(23)

4. ANAEROBIC POUR-FLUSH DVC TOILET

The second category of DVC toilet is really a simple adaptation of the sopa sandas latrine, but results in a radical improvement as regards the user. The one drawback of the sopa sandas is that if the flap closes imperfectly or malfunctions, it becomes very easy for flies and smells to leave the composting vault. In the 1960s, in Ahmedabad, India, Ishverbhai Patel, attempting to upgrade the sopa sandas, substituted a pour-flush pan for the mechanical trap, with the result that a permanent water-seal separated the user from the composting feces.(24) There is only a single squatting plate: the drain pipe leads to a junction box which serves to divert the wastes to either one vault or the other (Fig.8). Just as the sopa sandas, the vault is three quarters filled with organic refuse, after which the concrete cover is replaced. Since the composting vault has perforated sides and bottom, the flushing water and urine percolate through the pile of organic material and are infiltrated into the ground. Once the vault is full, which normally takes 6-12 months, it is sealed, the diverter in the junction box is moved, and the adjoining vault is put into operation.

The pour-flush DVC toilet has a number of advantages, but the overwhelming one is that, as far as the user is concerned, the toilet has the cleanliness and convenience of all water-flushed systems. Also, more than one toilet can be connected to the composting vault, and indeed there are many in use in Indian schools and in communal latrine installations. Whereas the sopa sandas must be in close proximity to the vault, the pour-flush pan can be a small distance away, as long as the drain pipe is properly inclined. The use of a single pan not only reduces cost but also eliminates the confusion that is reported to arise when two holes lead to both vaults being used simultaneously.(11) (16)

The pour-flush latrine with two vaults resembles the P.R.A.I. (Planning Research Action Institute, Lucknow) latrine, except that the latter has but a single pit. The Patel design, by introducing a second pit, also permits a sufficient retention time before the compost is handled, and is thus properly considered as a DVC toilet (it is in fact referred to as a "composting privy" by Patel(24). Although there are specific reports that organic waste is added to the pour-flush DVC toilet,(24) as it is to the sopa samdas (21), this does not appear to be the case with all pour-flush DVC toilet installations. Pathak, of the Sulabh Shauchalaya Santhsan, a private organization which has constructed over 35,000 such these toilets in the state of Bihar, dose not mention the addition of any organic refuse as being necessary.(25) Neither does the National Environmental Engineering Research Institute, which is likewise promoting a pour-flush DVC toilet.(26) It is unclear what effect the lack of carbon will have on the anaerobic decomposition of the excreta, though Golueke states that a too low carbon-nitrogen ratio will result mainly in a loss of nitrogen through

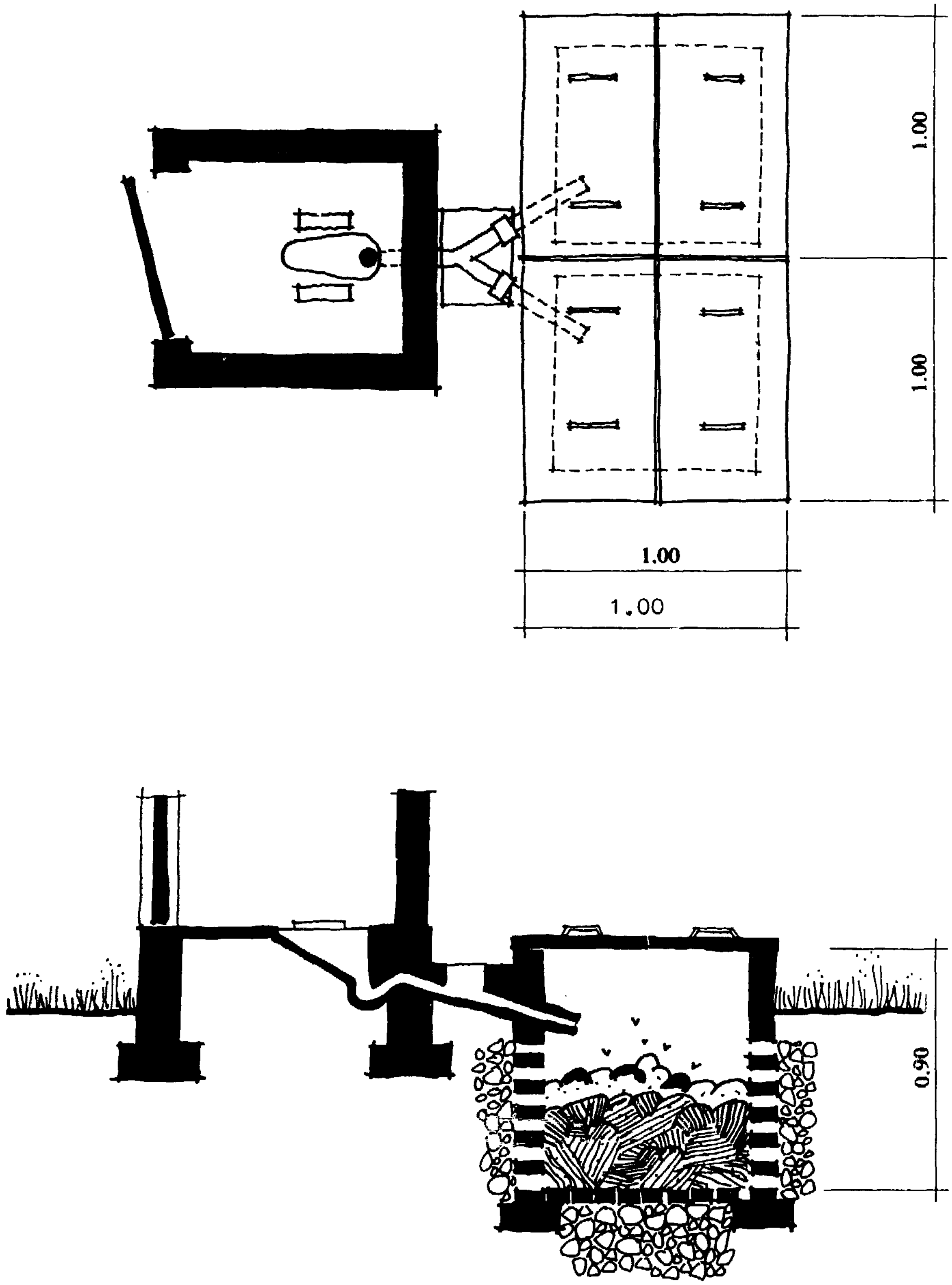


Fig. 8 Pour-flush DVC Toilet (after Patel)

the production of ammonia, which should not affect the composting process, though it would affect the chemical composition of the final compost.(39) Pathak reports that the compost produced by pour-flush DVC toilets (without any added organic wastes) contained 1.6%-1.8% nitrogen, 1.6% phosphorous and 1% potassium.(25) This is low when compared to compost produced by a multrum-type composting toilet (2.4% N, 3.6% P and 3.9% K) (27), and indicates that the lack of organic wastes is affecting the quality of the compost.

The pour-flush DVC toilet has had considerable success in India. The UNDP Global project, which is underway in 110 towns in seven states in India, is converting bucket latrines into pour-flush DVC toilets on an extremely large scale.

5. ANAEROBIC DVC TOILET WITH URINE SEPARATION

In 1948, Appasaheb Patwardhan working in the Gopuri ashram in Maharashtra state, built the first DVC toilet which prevented urine from entering the composting vault.(24) He had observed that composting pits were continually flooded during heavy rains, and tried to build a completely water-tight vault, above ground. In this case the moisture level was still too high due to the urine input, so he separated the urine and drained it away from the squatting plate. The resulting DVC toilet became known as the *gopuri* latrine (Fig.9). It should be emphasized that the gopuri latrine was always coupled with urine separation. Some of the non-Indian literature (12) (17) describes the gopuri as a DVC toilet with organic refuse, which is incorrect.

The separation of urine from feces is not as far-fetched as it sounds, and has been practiced by the Chinese for some time - they separated urine and collected it separately, recombining it later for large scale composting.(28) Morse visited Japan in 1877 and reported seeing porcelain and wood urinals in privies, which reduced the wetness of the excreta, which itself was collected in wooden barrels to be reused as fertilizer.(29) Multi-story buildings in Yemen are reported to have tall chutes which collect only feces, while urine is drained to one side of the squatting plate and to a soak-away.(12) Nor has urine separation been confined to Asia; a Danish auditor, H.C. Sonnin, proposed an improved bucket latrine which kept urine and feces separated, as early as 1806.(30) This type of urine separation seems to have been prevalent in Denmark, Sweden and Norway, although British sanitarians were aware of it and pointed out the necessity of minimizing urine input in earth closets.(5)

Urine separation is greatly facilitated by the fact that, in the traditional squatting position, both men and women urinate forward.(31) It suffices to have a depression or pan just ahead of the drop-hole, and urine can be drained off. This becomes more complicated in the sitting position (since women then urinate more vertically) and it is necessary to devise a special semi-squatting seat to achieve urine separation.(32)

In a DVC toilet with urine separation, the amount of organic waste (carbon) that needs to be added is very small since most of the urine (nitrogen) is no longer present. As a result the volume of the vault is smaller than that of the DVC toilet with organic waste.

DVC toilets with urine separation have been used on a large scale in two countries - India and Vietnam - but with very different results. During the years 1950-52, a few thousand gopuri toilets were built in the state of Maharashtra. It is reported that due to an inadequate educational program, they were improperly used - too much water was allowed to enter the vaults - and the

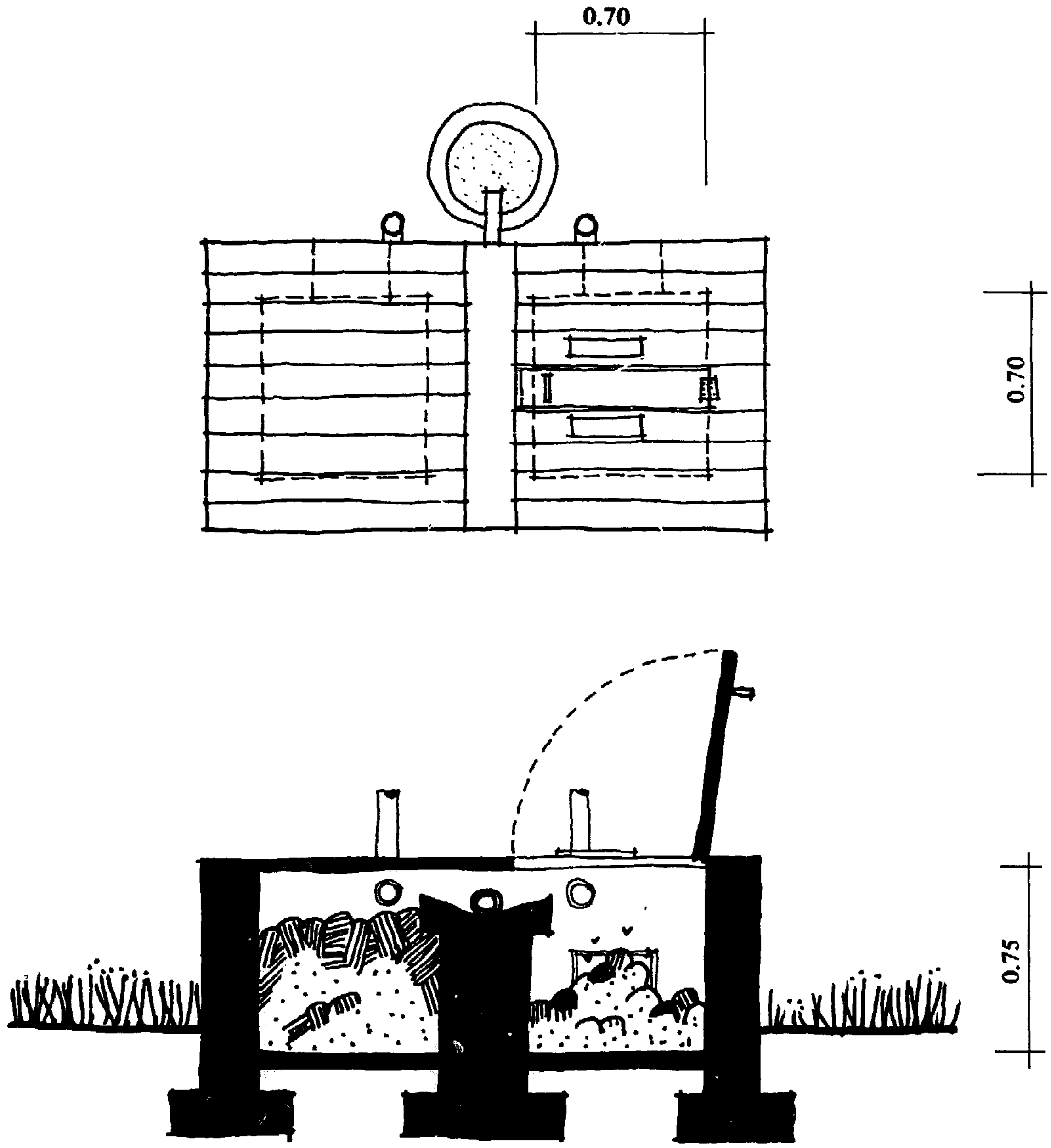


Fig. 9 Gopuri Latrine (after Patel)

gopuri was henceforth largely abandoned.(24) In fact, the sopa sandas was developed specifically as its replacement.

In Vietnam, beginning in 1961, a urine separating DVC toilet resembling the gopuri has been part of a large and apparently successful rural sanitation program (Fig.10). (33) It is reported that by 1972 there was, on the average, one DVC toilet for each 1.4 rural households.(34)

The Indian and Vietnamese designs are very similar, although the latter is

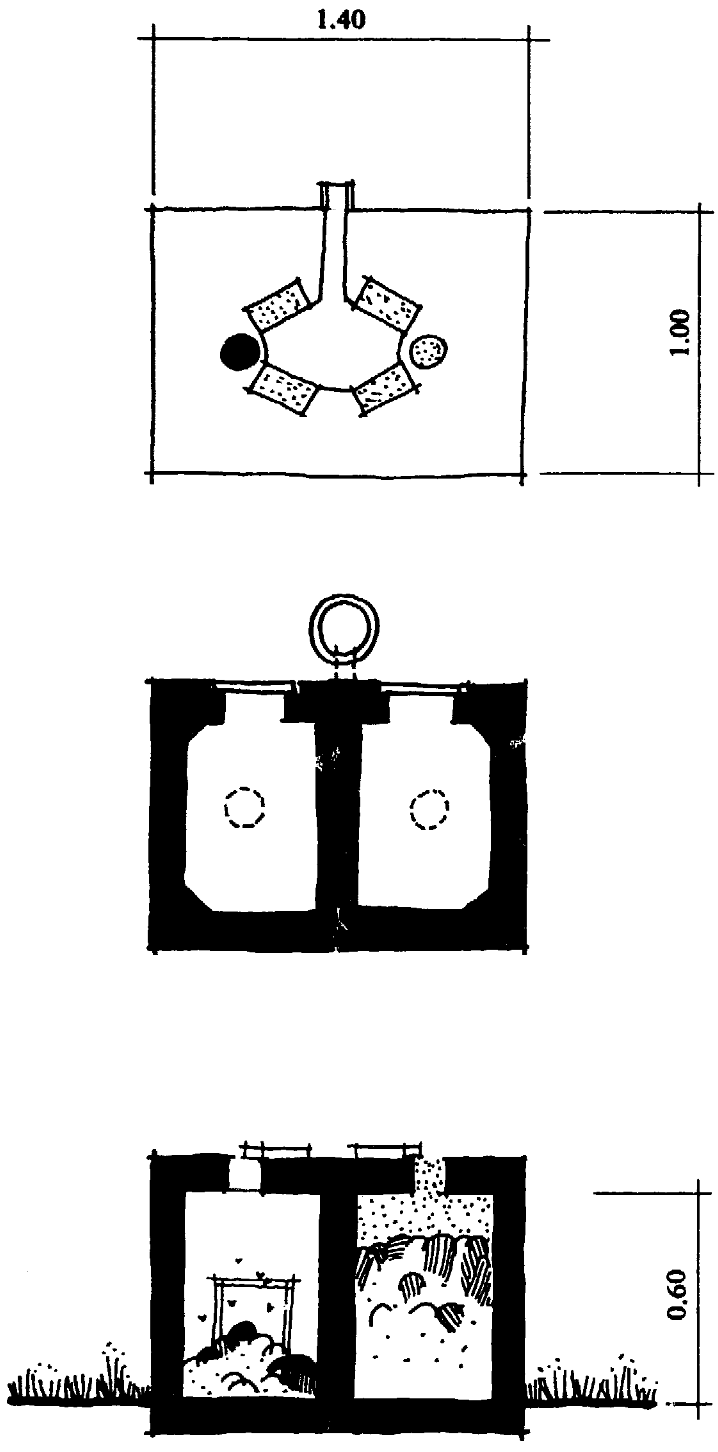


Fig. 10 Vietnamese DVC Toilet (after Duc)

usually somewhat smaller in volume, reflecting a shorter retention period (2 months versus 3-6 months). Both are usually built above ground. The main difference is in the squatting plate. The Vietnamese plate is concrete with two defecation holes and a depression to carry off the urine, whereas the Indian design used wooden planks and a gutter below the plate.

The operation of the two is similar. Before use, the bottom of the vault is covered with dry earth or ashes, and, each time the toilet is used, ashes or earth are sprinkled over the fresh feces. When the vault is three quarters full, it is topped up with ashes and sealed. The function of the ashes, as Gotaas has observed in regard to anaerobic composting, is to "act as a buffer and keep the pH from becoming too low".(8) As in the old earth closet, the ashes also cover the feces and absorb some of the moisture. Nimpuno has pointed out that the ashes also absorb many of the aromatic gases produced in the latter stages of anaerobic decomposition.(35) The Vietnamese models are usually shown without any vent pipe (33), though some authors claim that vent pipes are used to prevent bad smells (36), while others maintain that vents have been found to be unnecessary.(37) The gopuri is sometimes shown with vents and sometimes without. I have personally used a Vietnamese-type toilet without any vent pipe for a number of months and never encountered any bad odours.

The DVC toilet with urine separation is primarily anaerobic, though Nimpuno claims that after the vault is sealed "the temperature rises dramatically: in five days from 30 to 45 degrees Celsius peaking after twenty days at 52-60 degrees Celsius, and then slowly dropping off after 45 days to the original temperature again".(35) Vietnamese authorities report that after 7-8 weeks, 85% of the Ascaris larvae, and a similar proportion of the total helminth population are destroyed.(37) The conversion of excreta to fertilizer is faster in the absence of organic refuse. The urine, which is drained off, is collected for use as a nitrogenous fertilizer, diluted with water.(36) This practice will be generally safe, except in those areas affected by urinary schistosomiasis.(9)

The main advantage of the DVC toilet with urine separation is that it is completely water-tight and that it requires no additional organic refuse, except for ashes. The disadvantage, as the Indian experience shows, is that it is particularly susceptible to failure in the event of improper use.

The successful adaptation of the DVC toilet to Vietnamese circumstances certainly calls into question the long-held conviction that "proper composting in privy pits is rather complicated and may well be, in the beginning, beyond the comprehension of most rural families."(11) On the other hand, can the Vietnamese technology be transferred to other countries, or will results follow the gopuri experience? So far one of the few attempts to introduce the DVC toilet with urine separation has been reported in Guatemala.(38) This is an extremely small project but results are encouraging and indicate that this technology may have application outside Asia.

6. AEROBIC DVC TOILET

There are two types of composting: anaerobic and aerobic. Anaerobic bacteria do not require oxygen, and hence the process can take place in a sealed container. The main disadvantage of anaerobic composting is that it does not produce temperatures high enough to destroy pathogens and ova. Aerobic composting, on the other hand, is an exothermic process which develops temperatures of up to 70 degrees Celsius within the compost pile.(39) Since, as has already been mentioned, the most resistant of the pathogens, the Ascaris ova, is destroyed at 60 degrees Celsius, the great advantage of aerobic composting is that it offers a greater certitude of pathogen destruction.

An aerobic DVC toilet, called the Farallones composting privy, has been developed in California in 1974 by Van der Ryn.(40) It resembles the Gopuri in configuration (Fig.11) and is ventilated, the floor is solid and the two vaults are watertight. The cover of the vaults is fixed, and a drop-hole is provided over only one vault. Before use, the bottom of this vault is lined with 15 cm of organic material. As the toilet is used, organic refuse is added to the excreta. What differentiates the Farallones privy is the fact that once a month the access door is opened and the pile is manually turned with a pitchfork, thus introducing oxygen into the compost. At the end of six months the compost is transferred to the adjoining vault (over the low partition wall) and allowed to age for another six months before being removed.

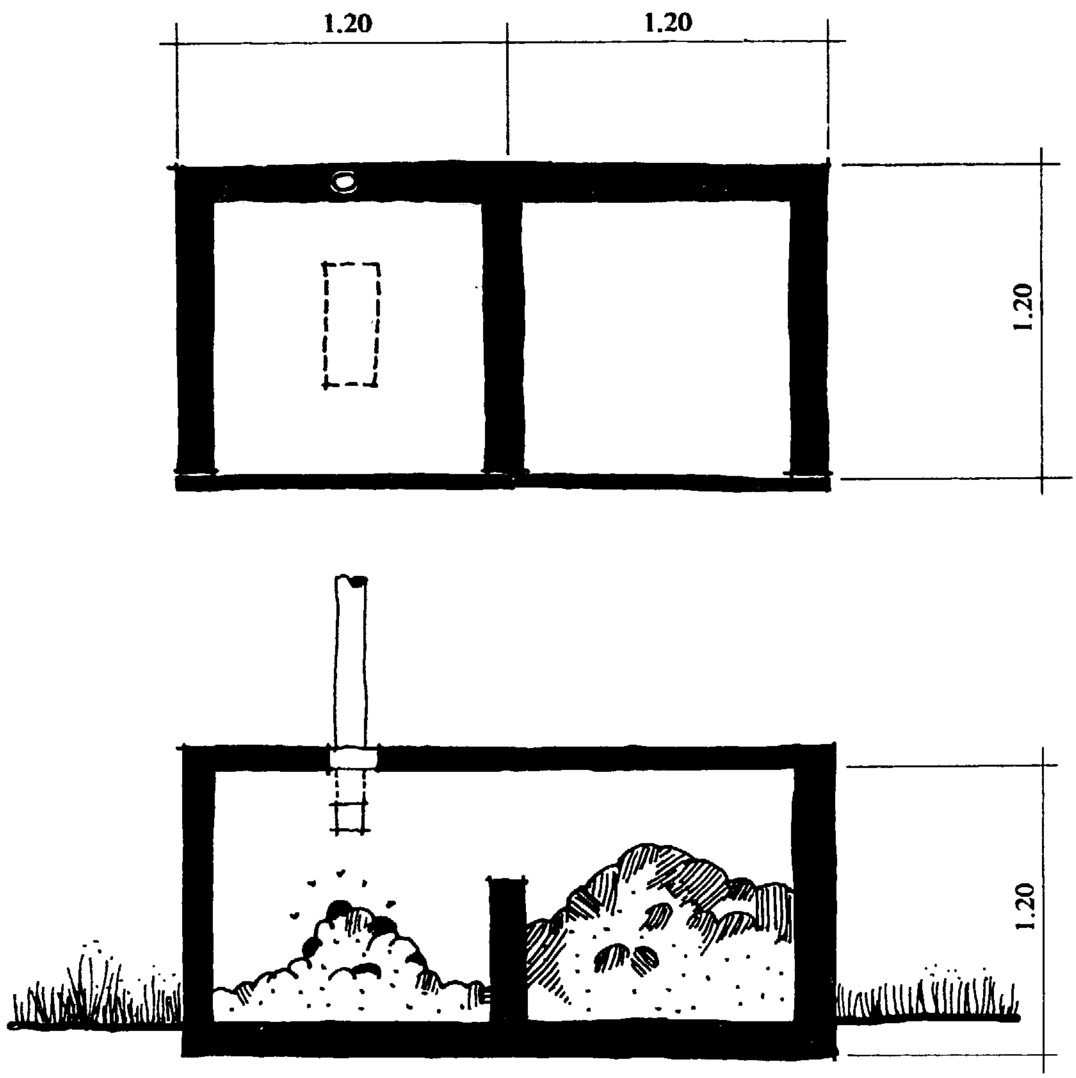


Fig. 11 Farallones Privy (after Van der Ryn)

Like any DVC toilet which is watertight, this design may experience difficulty if too much urine accumulates. One source reports that excess urine will require more frequent turning of the pile (41), while another simply recommends urine separation.(42) In any event, it is advised to add a quantity of dry sawdust, shredded leaves, rice hulls or chaff (a la earth closet) each time the toilet is used.(43)

Critics of the Farollones privy have pointed out that it "should work well but unfortunately it involves handling of fresh excreta and it is therefore unacceptable for health reasons".(44) The health hazard of handling the excreta, even if only for a few minutes a month, must of course be weighed against the increased pathogen destruction achieved by aerobic composting. There have not been many attempts to implement aerobic DVC toilets in developing countries, but a significant number have been built in northern California (largely by owner-builders) and the state authorities have played an active role in monitoring existing installations. It is very probably that *"properly constructed and maintained* (my italics), the composting privy is a safe, low cost, non-polluting and odor free alternative."(43) Before dismissing this option it should be remembered that, as the World Bank warns, *all* DVC toilets probably require "an extremely high degree of user care and motivation... for satisfactory operation."(9)

7. FOUR TYPES OF DVC TOILETS: GENERAL CONCLUSIONS

I have described four different types of categories of DVC toilets; it might be useful at this point to summarize. On the basis of the evidence in the technical literature, the pour-flush DVC toilet seems to be the most all-around successful solution. It does not require reinforced concrete or vent pipes. It gives the convenience and hygienic standard of a water-borne system at extremely low cost, while preserving the important characteristic of all composting toilets, that of providing fertilizer for reuse. The pour-flush version is simple to use since organic material is only added once per cycle, if at all, and the user does not need to concern himself with day to day adjustments. The fact that the composting vaults are offset means that construction costs are probably the lowest of all DVC toilets (see section 9: ECONOMICS).

The disadvantage of the pour-flush DVC toilet is that proper composting may be disrupted by rain flooding, and environmental pollution may result if there is a high water table. In that event the water-tight above ground DVC toilets, either aerobic, or anaerobic with urine separation, are possibilities. Both are more complicated to operate on a day-to-day basis, both are more susceptible to malfunction, and one, the aerobic DVC, presents particular problems with handling fresh excreta. One advantage of the water-tight DVC toilets is that all the materials are contained in the composting vault, and consequently the nutrient value of the fertilizer is likely to be higher than with DVC toilets that infiltrate urine into the ground. However, where water is used for anal cleansing, either by tradition or religious prescription, a water-tight DVC toilet cannot be used.

On the face of it, the DVC toilet with organic refuse seems the least attractive solution. The construction cost is high since the toilet is located over the pit. The cost of vent pipes and duplicated squatting plates must also be considered, and the provision of organic refuse daily also may represent a problem.(15) In any situation where soil conditions, as well as cultural mores, permit the use of a DVC toilet with organic refuse, the pour-flush DVC toilet will probably be a less expensive, and higher quality, alternative. In arid areas, or whenever water is in short supply, the sopa sandas is probably the most successful DVC toilet with organic refuse.

8. RURAL OR URBAN?

Are DVC toilets strictly a rural technology, or do they have application in cities and towns? The Vietnamese installations have been almost completely rural, which has led some observers to assume that this solution should be confined to villages. Others have questioned the availability of organic refuse in towns, as well as the lack of sufficient demand for fertilizer.(9) The lack of solid waste removal in most low income areas in developing country cities would seem to argue the case for urban DVC toilets as useful "garbage disposal".(16) The presence of domestic gardens in most site and services projects would presumably stimulate demand for the compost.

The pour-flush DVC toilets in India have been installed largely in towns and cities, for instance in Patna and Ranchi, both cities of cover 100,000 persons. The UNDP Global Project is likewise aimed at urban communities. The REC II DVC toilet in Botswana is being used in low rise high density housing and an urban DVC project is underway in Mexico.(13) The pour-flush latrines installed by Sulabh Shauchalaya have been installed in urban houses with the composting vaults in the courtyard, and in some cases even *within* the house.

The main constraint on using infiltration-type toilets in urban areas is usually thought to be ground contamination. The World Bank considers that the maximum density for such systems is 500-600 persons per hectare (two-story houses), but hastens to point out that pit latrines have been found to operate successfully at higher densities.(45) Caldwell, some time ago, pointed out that the contamination from dry pit latrines was contained in a small area (46); a recent study in Kenya found that pit latrines were being successfully used at relatively high densities.(47) Pathak points out that since the composting vault is so shallow, in the pour-flush DVC toilet, the chance of ground water pollution is virtually nil.(25)

The question of whether DVC toilets can be successfully used in urban areas is particularly important as there are so few low cost urban options. Most urban alternatives to conventional underground sewers, such as small diameter sewers or cartage systems, are still extremely costly.(48) Current experience indicates that the main constraint to the urban use of appropriate DVC toilets is more likely to be access to ground level, and not density *per se*. Since most low-income urban housing in the less developed countries is 1-2 storeys, the potential for urban DVC toilets is quite large.

9. ECONOMICS

The construction cost of a DVC toilet will vary considerably with local labor and materials costs. Likewise important will be the mode of implementation, whether user-built, locally contracted or part of a large site and services project. There are no cost figures for the Vietnamese design, but as it is usually built out of locally-available materials (stone, earth, mud-dried brick), and apparently by the users, its cost could be expected to be very low.(36) Patel reprots that the cost of the gopuri is less than US$ 25, while the sopa sandas cost US$ 15-20.(21) In 1972, sopa sandas were built by the users for a material cost of US$ 10, (22) while pour-flush DVC toilets were built for US$ 40.(49) The estimated cost of the water-seal DVC toilet to be built by the UNDP Global Project in India is US$ 40-50, depending on the materials and design.(50)

On the other hand, DVC Toilets which have been built in Africa have proved to be much more expensive. The REC II in Botswana has an estimated cost of US$ 200 (19), while the WHO-type concrete DVC toilet, built likewise in Botswana as part of a different research project, is reported to have cost about US$ 400.(14) The difference between the African and the Indian costs is due partly to increased material costs in Africa, and also to the longer experience with DVC toilets in India. The fact that the Indian DVC toilets usually utilize offset pits and rarely use concrete undoubtedly also accounts for their lower cost. Any DVC toilet which requires reinforced concrete, ventilation pipes (usually galvanized metal), a double squatting plate or extensive blockwork will probably be too costly for most low-income users.

Alternative solutions to sanitation may require, in addition to unconventional technologies, unconventional implementation strategies, based increasingly on local resources and initiative. Pathak reports that public pour-flush DVC toilets are operated by a local private organization in Patna, India.(49) These installations, 20-40 stalls, are open 24 hours a day. The user pays for the use of the toilet - about one cent - for which he receives also soap powder (women and children do not pay). This money is spent on maintenance, caretakers' wages and cleaning materials, and since about 100 persons per day use each stall, the municipality is not required to spend money on maintenance and repairs.

The financing of waterborne sanitation is expensive and far beyond the economic means of the low-income user - which is one reason why countries such as India are increasingly turning to dry options, such as the DVC toilet. The large scale implementation of DVC toilets will still require some subsidy in the form of low interest loans to householders, or in some cases outright grants. Roy estimates that the annual interest and repayment of loan charges for the Indian pour-flush DVC toilet will be about US$ 5 per househole, which is almost the same as is currently paid to scavenger.(50) Other projects have been described where the entire cost of the pour-flush DVC toilet, up to the plinth, have been covered by municipal subsidies.(49)

10. DVC TOILETS AND EXCRETA REUSE

A final point needs to be made concerning the selection of DVC toilets. Unlike the aqua-privy or the septic tank, the DVC toilet is not a technique for excreta *disposal,* but rather for excreta *reuse.* This is a vital difference. As part of a comprehensive program (as in Vietnam), the DVC toilet can produce not only health improvements but also agricultural benefits. As I have shown, the historic function of the DVC toilet, and of its predecessors, has been closely linked to fertilizer production, and it is likely that this will continue to be the case, whether the compost is used in the field or in the garden. It is unlikely that the DVC toilet can, or should be, divorced from this function.

The DVC Toilet can produce substantial economic benefits. The Indian National Environmental Engineering Institute has calculated the cash value of compost produced by pour-flush DVC toilets is about US$ 10 per year, in which case the capital cost of construction could be repaid in five years.(26) Roy estimates that the sale of compost could pay for maintenance of pour-flush DVC toilets.(50) Whether or not the compost has an economic value, it is obvious that in both India and Vietname the production of fertilizer is an important reason for the choice of DVC toilets.

The adoption of DVC toilets thus might be said to depend on a demand for composted human wastes for fertilizer, but, importantly, this demand may be actual or potential. In societies where human excreta is used in agriculture, such as India, China or Vietnam, a DVC toilet represents a modification of current practice, rather than a new attitude towards reuse. On the other hand, in most parts of Africa raw excreta is rarely used as fertilizer, and in Latin America, although sewage is used for irrigation, the idea of reusing human wastes directly is certainly not traditional. In such cultures, the demand for composted excreta, while not actually present, *may* be stimulated once the technology is accepted, and the number of DVC installations in countries without a recent tradition of excreta reuse, such as Tanzania, Botswana, Mozambique, Argentina (51), Guatemala, Mexico and the United States, indicate that DVC toilets are by no means a "regional technology".

Of course, these initial efforts have not always met with success. It is reported that in Tanzania "many people loathe working with composted humus, which many people regard as feces" (27), and that in Botswana, "traditional attitudes militate against reuse of human waste on an individual basis".(14) Nevertheless, as Iwugo (52) points out, it would be premature to make any judgements about the reuse of composted human excreta in agriculture in Africa since there are so few instances of successful composting actually in operation. Most traditional (negative) attitudes towards the reuse of excreta (in Africa or elsewhere) have been formed on the experience of raw or partially digested human excreta, *not* compost. Whether or not the latter will meet with similar resistance remains to be seen.

It is possible that under certain circumstances, the DVC toilet may have advantages that outweigh the fact that reuse is not the main consideration. The REC II is being built in Botswana, which has no tradition of excreta reuse. Nevertheless, the DVC toilet has a number of features that make it preferable to the single pit latrine. The fact that there are two pits means that excreta handling is much safer and more hygenic. Even when vault emptying is to be done by municipal authorities, as is the case with the REC II, the use of two vaults gives much more leeway as to emptying schedules than does a single compartment cartage system. Finally, composted excreta is a dry, non-smelling material which is considerably easier to handle than liquified, partially decomposed excreta. This fact may also affect popular attitudes to handling composted excreta, once the system is put into use.

DVC toilets with urine separation have been introduced to Guatemala and after one year experience a number of interesting observations have been reported.(38) Acceptance of this new device was often based (naturally enough) on perceived utility. For instance, people who lived next to fields in which they were used to defecate did not see much point in building a toilet. On the other hand, when people lived 200-400 meters away from a defecation area, "enthusiasm for this type of toilet is astonishing". The study team also found a consistent correlation between the physical appearance of the privy enclosure and interior, and the microbiological properties of the compost. The clear implication is that people who are able to keep the privy clean and tidy are also able to follow the required directions for operating the DVC toilets.

The successful implementation of DVC toilets often seems to depend as much on supervision, education and propaganda as on the design of the technology. Duc makes the point that periodic inspections of toilets must be made with "recommendations" given to the user on any shortcomings that need to be rectified.(37) The Sulabh Shauchalaya provides a five year guarantee to the owners of its pour-flush DVCs and gives free inspections and repairs and will evacuate the vault if requested.(25) CEMAT, in Guatemala, encouraged each family using a DVC toilet to appoint one of its members in rotating fashion to make periodic checks on the state of the toilet.(38) The Gandhi Smarak Nidhi contacted 90% of DVC owners (50% more than once) during a program where over 20,000 toilets were built.(22)

Laws and regulations may also play a role: the government of Bihar imposed a fine or one-month imprisonment on persons who did not convert bucket latrines into pour-flush DVC toilets (for which subsidies and loans were available).(49) The role that proscriptive regulations played, and continue to play, in improving sanitation in the industrialized countries is easily forgotten. Their adoption of hygienic standards in sanitation, and the maintenance of these standards, was neither spontaneous nor voluntary. There is no reason to believe that improvements in sanitation in the developing countries can be achieved without similar enforcement of *appropriate* standards and practices.

11. DVC TOILET SELECTION

A recent World Bank report on sanitation technologies (9) includes a three stage algorithm for technology selection. The second stage concerns DVC toilets, one out of eleven alternatives. Since this paper has explored DVC toilets in greater detail, I have developed a complimentary algorithm (Fig. 12) for selecting one out of the four DVC toilet types, which can be inserted in the appropriate place in the large selection algorithm.

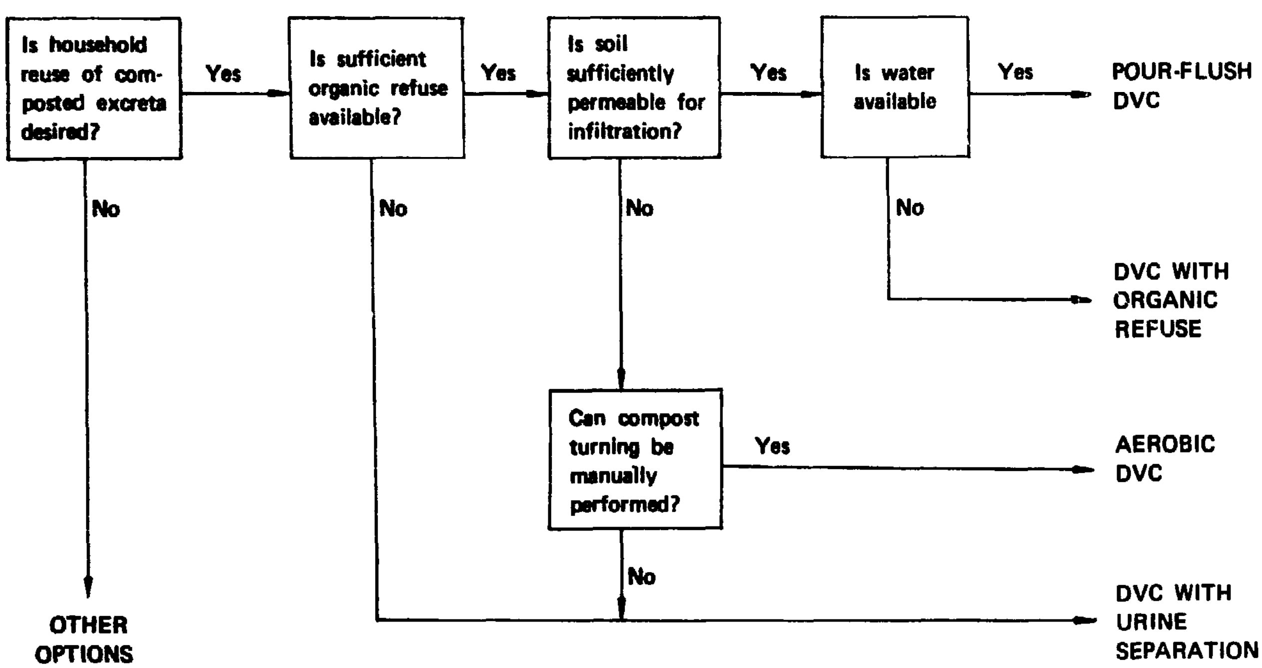


Fig. 12 Algorithm for DVC Toilet Selection

The selection of a particular type of DVC toilet depends on a number of external variables, as with any sanitation option. Most DVC toilets are dry and will operate well with an extremely low level of *water supply* except for possibly the pour-flush DVC which might require a yard tap. Since most of the DVCs infiltrate urine into the ground, *soil condition* must be a consideration, though a water table even within 0.5 meters of ground level ought not to impair proper functioning. Watertight DVC toilets, such as the Farallones or Vietnamese type, can be built on impermeable soil. *Housing density* will also limit the types of DVC toilets used, though considerably less than it would pit latrines or septic tanks. From a strictly environmental point of view, most DVC toilets could be used in high density, ground-related housing.

Whether a new technology such as composting toilets is introduced through private initiative, or by state edict, it is likely that the process of implementation will be lengthy. McMichael (34) reports that the proliferation of DVC toilets in Vietnam was not without setbacks and acceptance was by no means immediate, but required a patient campaign of explanation and arrangement jointly conducted by health and political workers. The relationship between educational programs and technological innovations, in a field such as sanitation, is crucial, and though the focus of this paper has been necessarily on matters technological, that is not meant to suggest that the DVC toilet is in any way a "technological fix". It would be well to recall the warning of John Wallace (53), a British engineer working in Bombay at the end of the nineteenth century:

> "There is no *best kind* of latrine unless a cultivated field could be so designated; but, as traditional custom leaves its mark even upon our simplest natural functions, the design of a good latrine involves a very considerable knowledge of human nature as well as of natural phenomena".

ACKNOWLEDGEMENTS

I wish to acknowledge the assistance of my friend and colleague, Prof. Vikram Bhatt, who provided mush useful information on the Indian experiences with DVC toilets. Information was also provided by Blakely Bruce, Dr. Krisno Nimpuno of Bouwcentrum International Education, Dr. Michael McGarry, as well as John M. Kalbermatten and Richard Middleton, of the World Bank.

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NOTE

The dimensions given on the diagrams are approximate and for comparative use only.

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FOREWORD

In this appendix, we present drawings of various low-cost sanitation systems. This appendix is a supplement of this issue and is not directly connected to the paper by Prof. Rybczynski.

We have deliberately excluded the septic tank since this option will be presented in a separate issue in the near future.

Diversified sources have been used so that the reader can have an overview of the various alternatives, which can be used as a basis for comparative assessment. But in presenting these various information sources, some discrepancies in data as well as inconsistencies in terminology are unavoidable, even after ENSIC has converted the dimensions to metric measurements (in centimeter), and made some editorial changes.

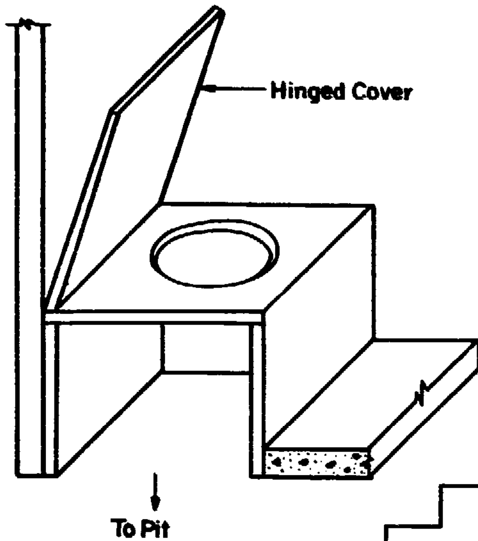
Details of construction methods and materials are indicated insofar as this was possible in terms of the space restrictions. Nevertheless, this appendix should not be considered a manual. It is intended simply to give the reader some indications for further reading, depending on whichever aspects he may wish to study at length.

Although checks have been made as carefully as possible, some errors may still exist. In this case, we apologise to the authors as well as to readers for any inadvertent mistakes.

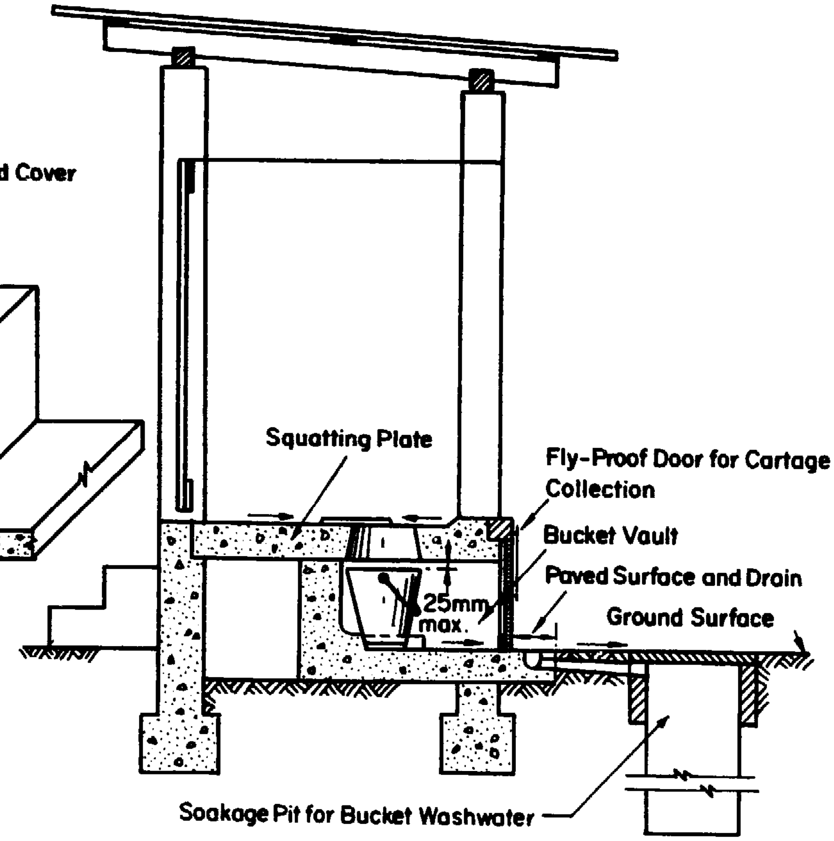
ENSIC welcomes any suggestions and comments on this new way of giving additional information in a pictorial form related to the main topics covered by review papers.

The Editors

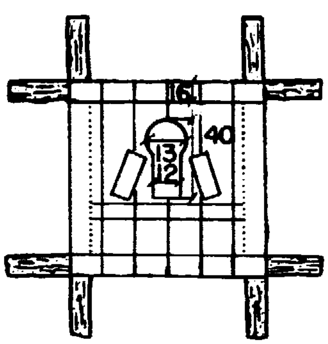
BUCKET LATRINE (2)

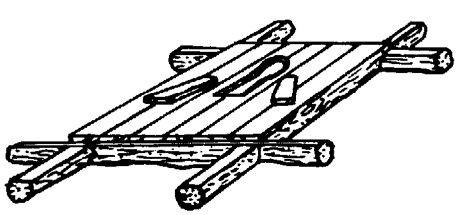


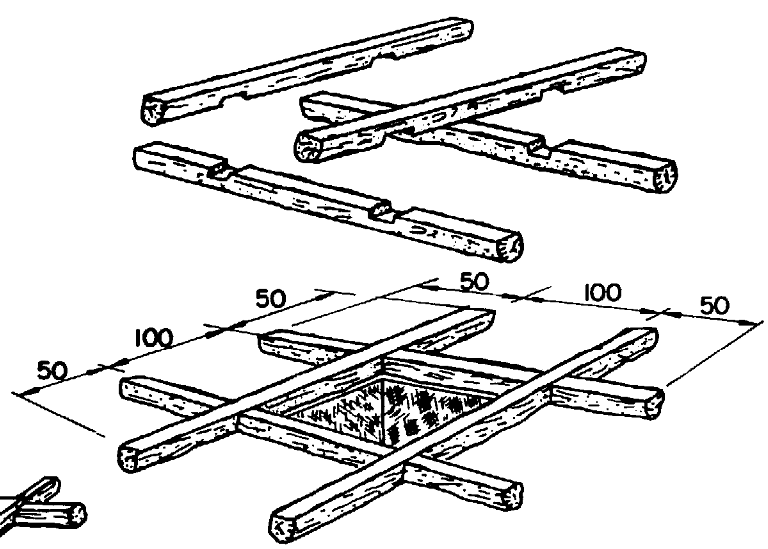
Pedestal Seats for Pit Latrine



ALTERNATIVE BASE USING HEWN LOGS (13)

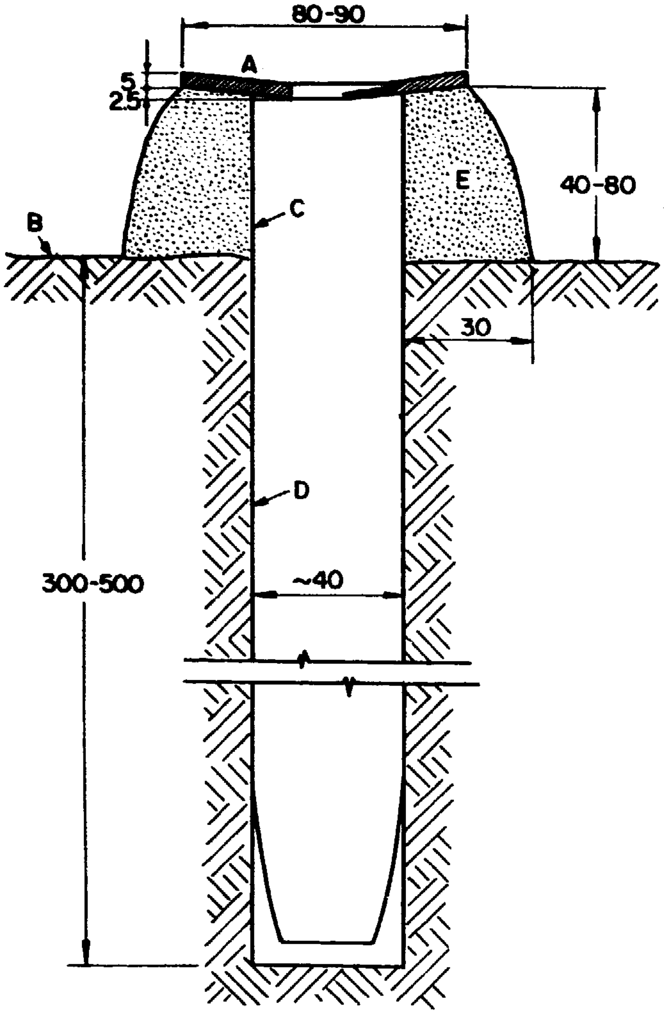




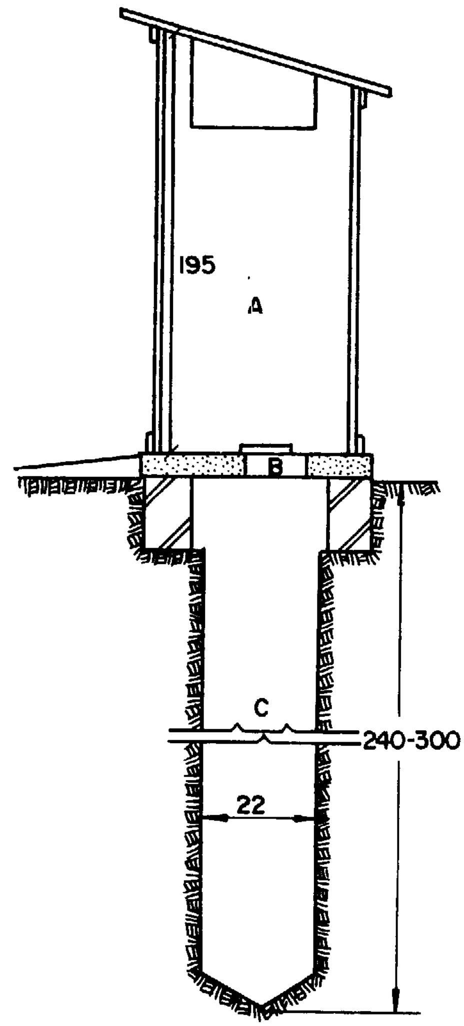


Note : In Termite-infested Areas, Use Treated Wood or Termite Barrier.

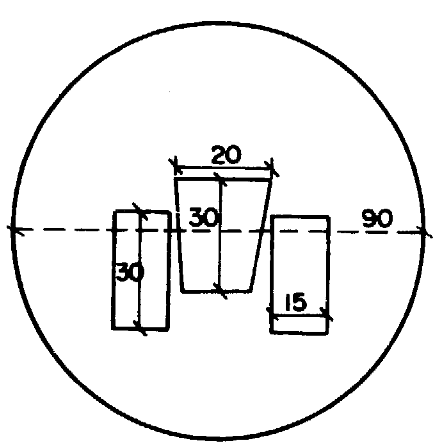
BORE HOLE LATRINE (4, 13)



A – Round Slab with Slope to Centre
B – Original Ground
C – Bamboo Lining Required in Mound
D – Bamboo Lining Full Length If Required
E – Tamped Earth Mound

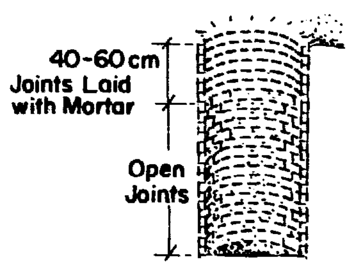


A – Enclosure of Latrine
B – Squatting Plate with Opening
C – Hole

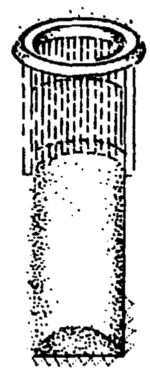


Circular Seat of Concrete

ALTERNATIVE PIT DESIGNS (2,13)

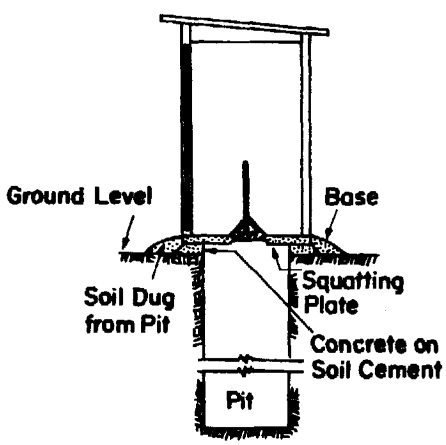


Circular Pit with Brick Lining

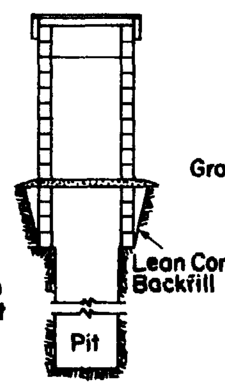


Round Pit with Partial Lining of Tree Limbs

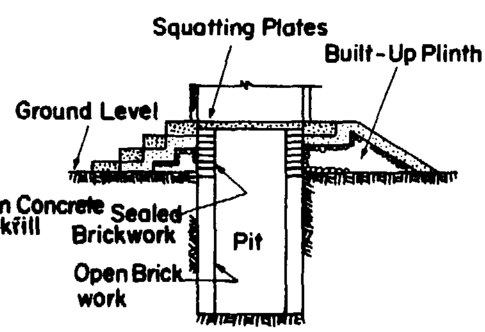
Bored Pit with Concrete Lining



Unlined Pit

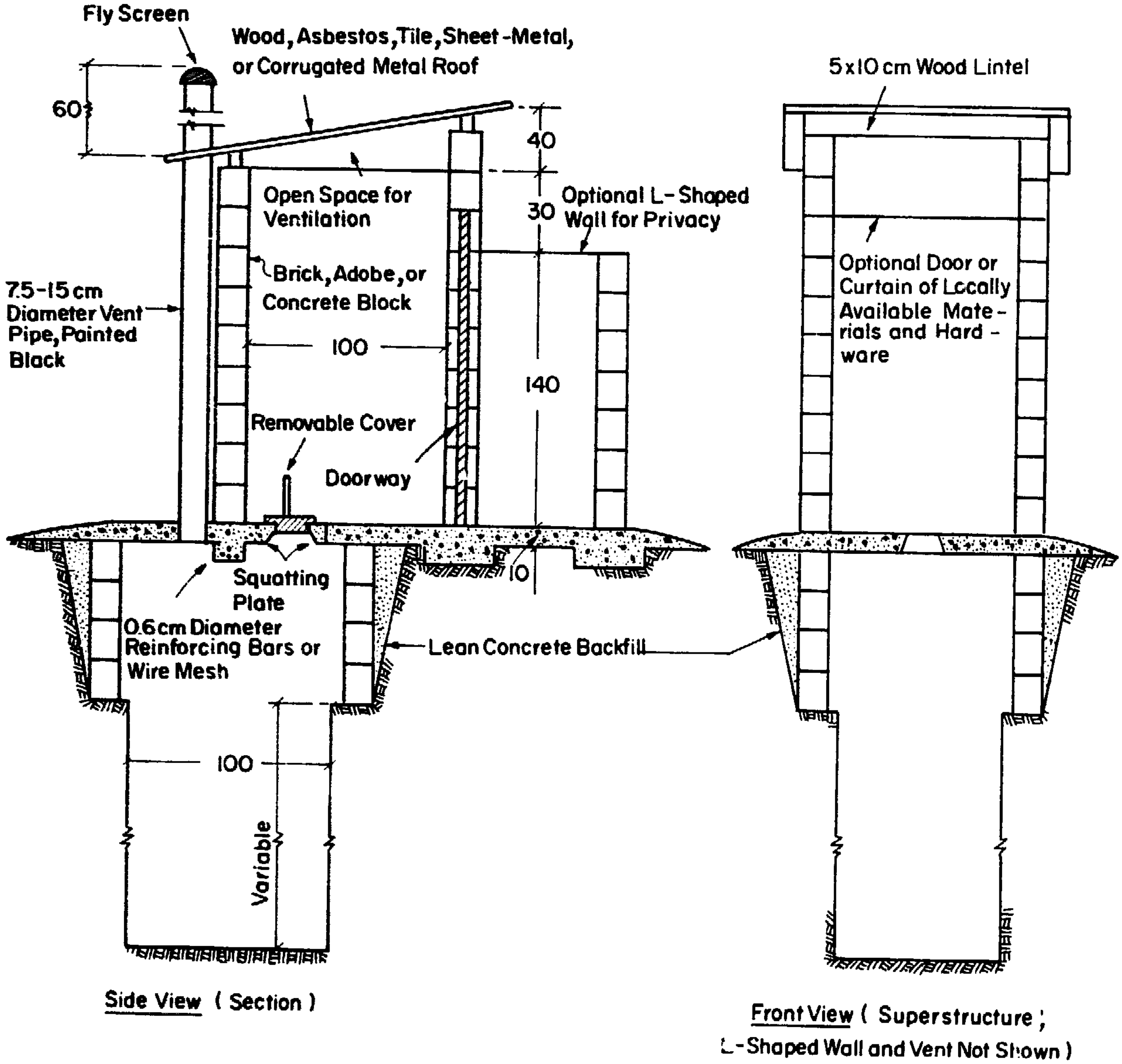


Square Pit with Partial Concrete-Block Lining



Raised Pit Latrine for Use in Areas of High Groundwater Table

VENTILATED IMPROVED PIT LATRINE (2)



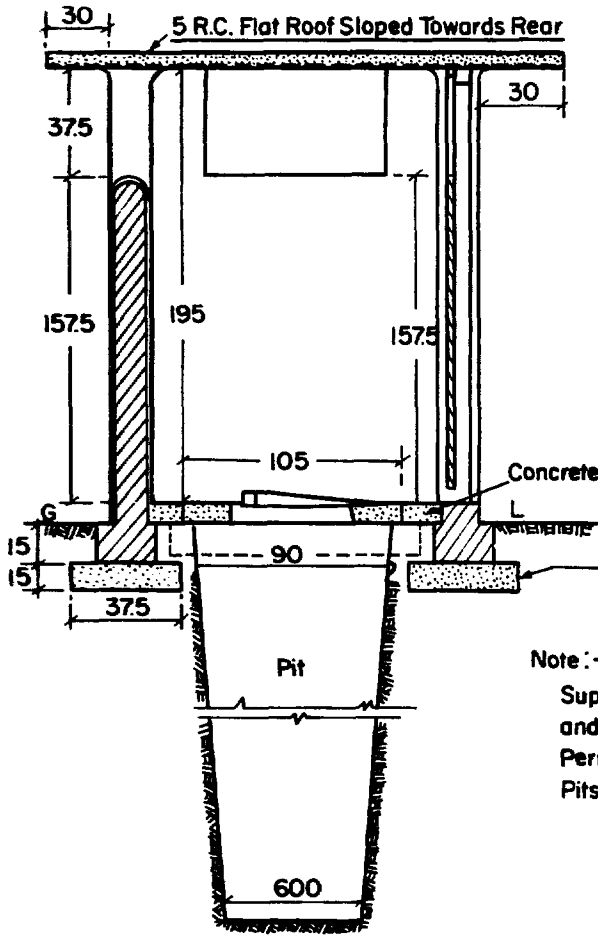
Side View (Section)

Front View (Superstructure ; L-Shaped Wall and Vent Not Shown)

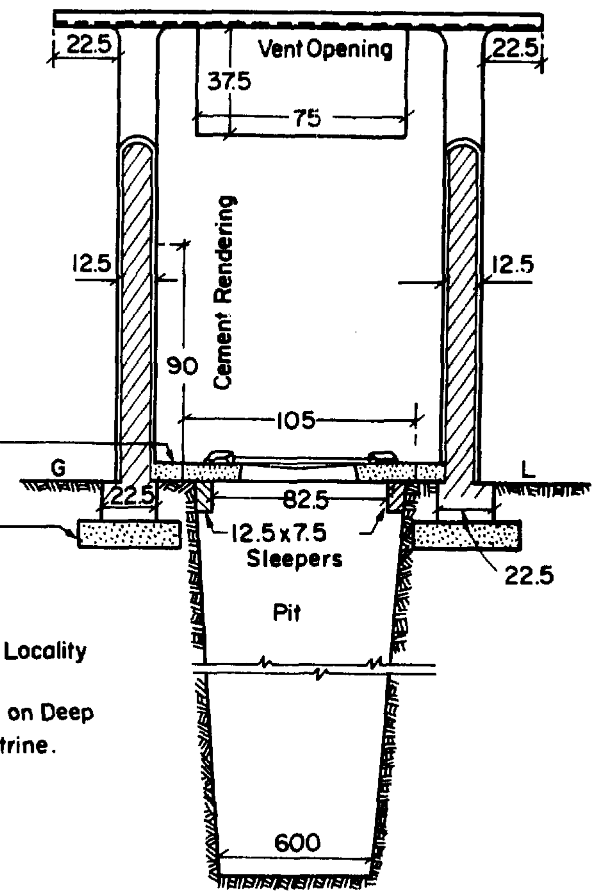
Note :-

Side View. Pedestal Seat or Bench May Be Substituted for Squatting Plate. An Opening for Desludging May Be Provided Next to Vent. Dimensions of The Bricks or Concrete Blocks May Vary According to Local Practice. Wooden Beams, Flooring, and Siding May Be Substituted for Concrete Block Walls and Substructure.

PIT LATRINE (12)



Section



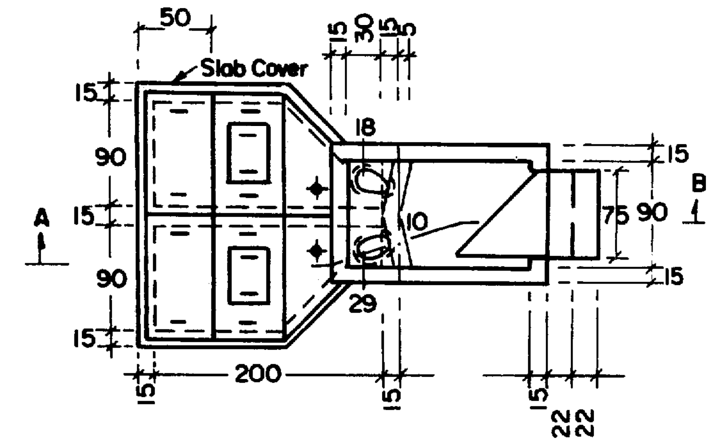
Section

Note :-

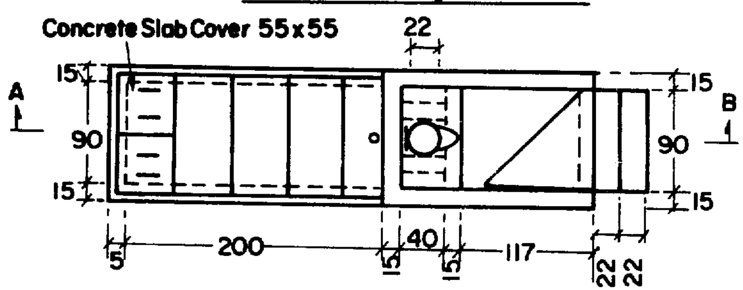
Superstructure May Be of Any Material Available in The Locality and To Suit Individual Pocket.

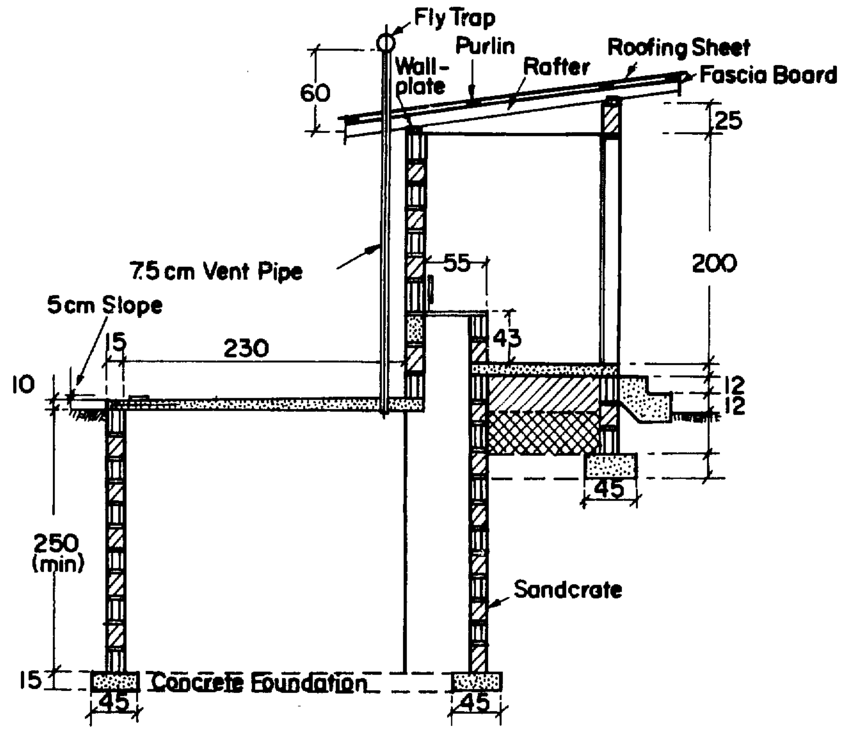
Permanent Superstructure Should Only Be Constructed on Deep Pits (37.5-50 Deep) and in Case of Pits Outside The Latrine.

VENTED PIT LATRINE (II)

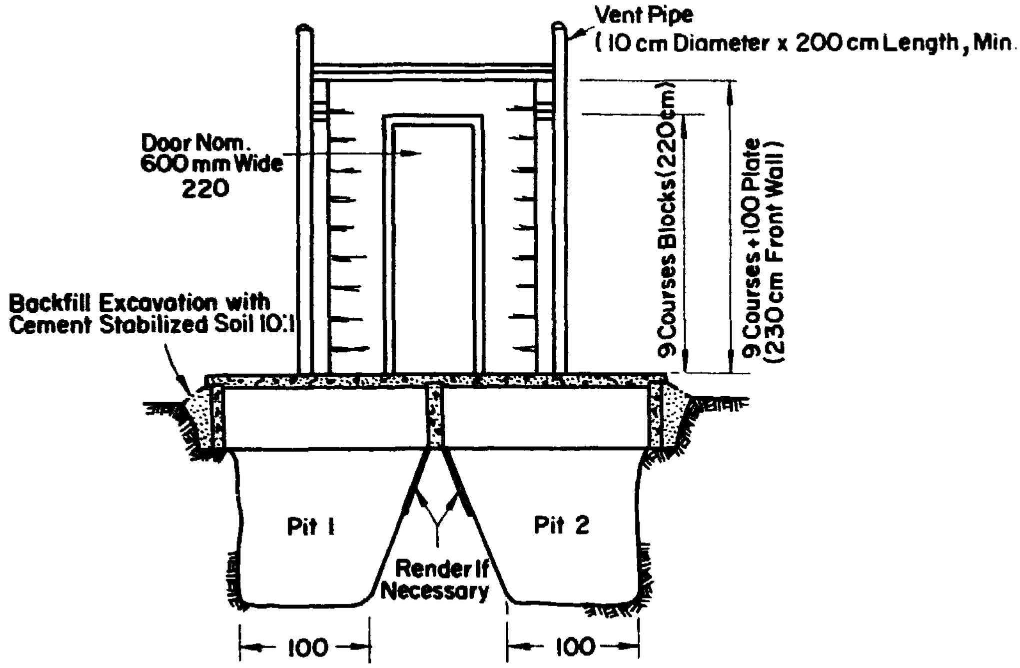


Plan of Alternating V.I.P. Latrine

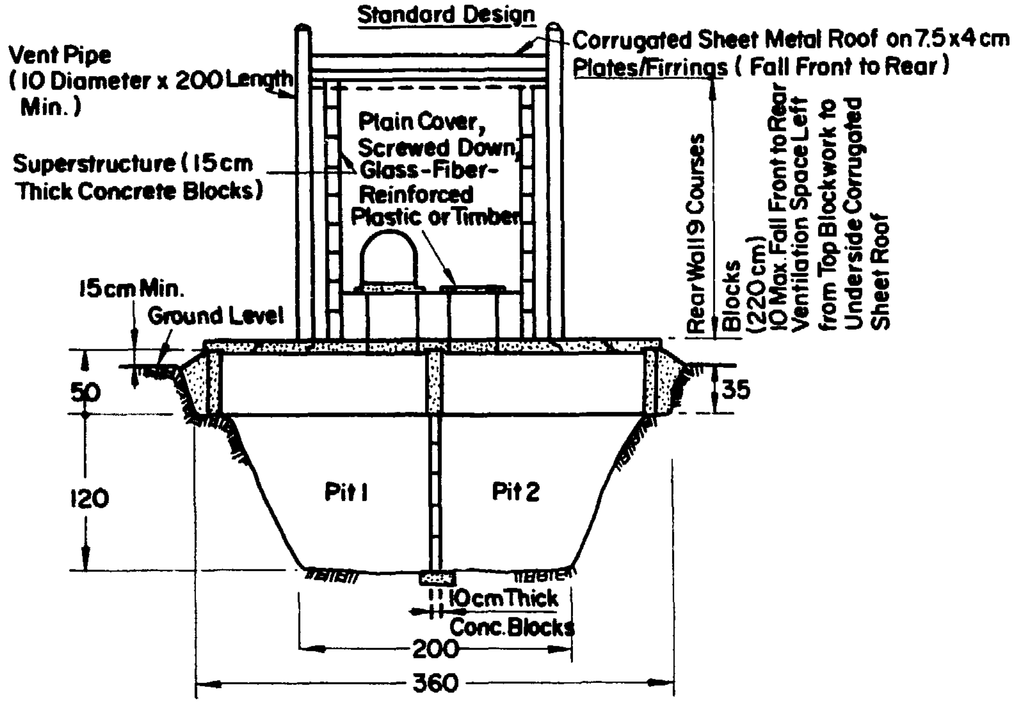




VENTILATED IMPROVED DOUBLE – PIT LATRINE (2)



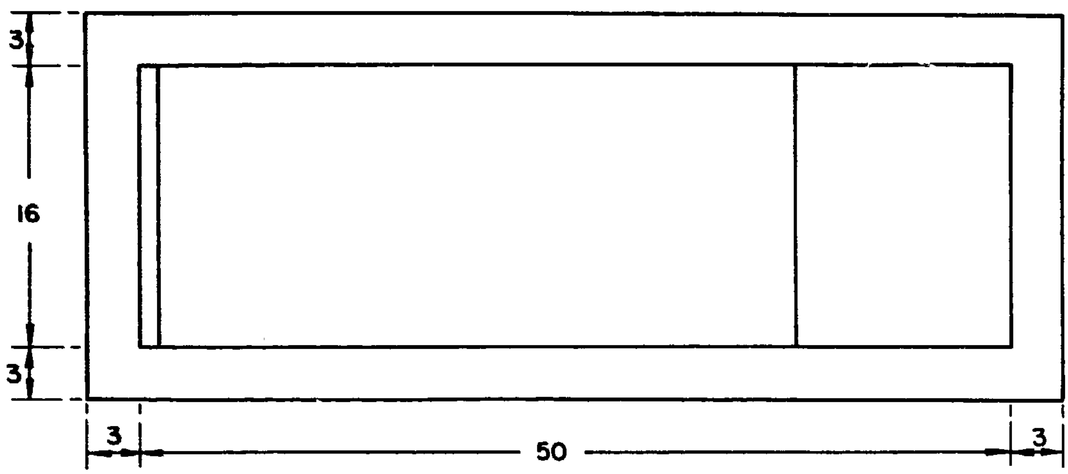
Standard Design



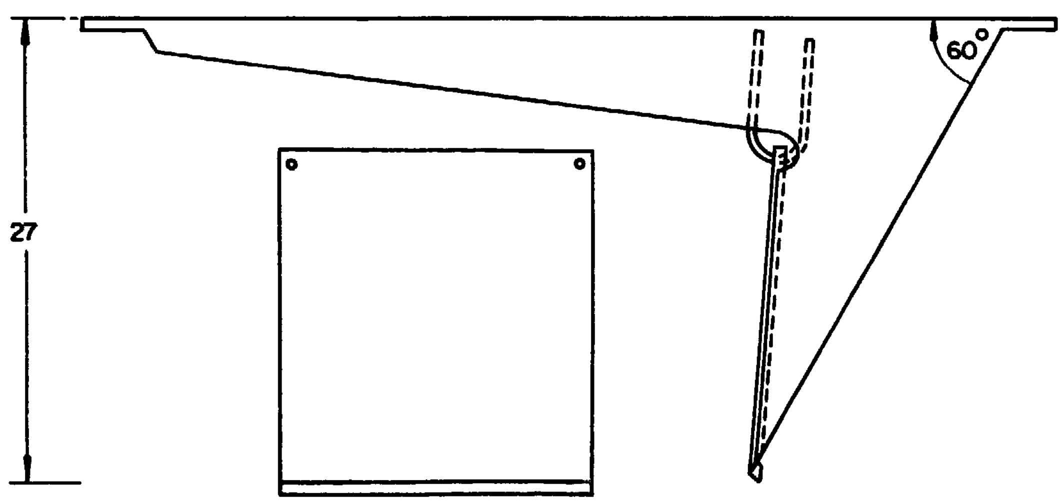
Optional Design

TANZANIAN FERROCEMENT "FLAP-TRAP" DESIGN FOR VENTILATED IMPROVED PIT LATRINES AND DOUBLE-VAULT COMPOSTING PRIVIES

(14)

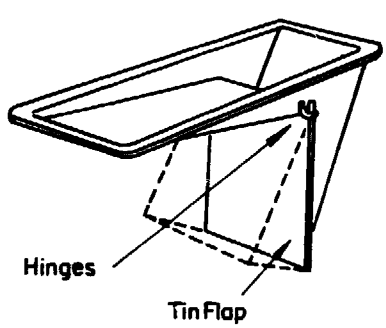


Plan



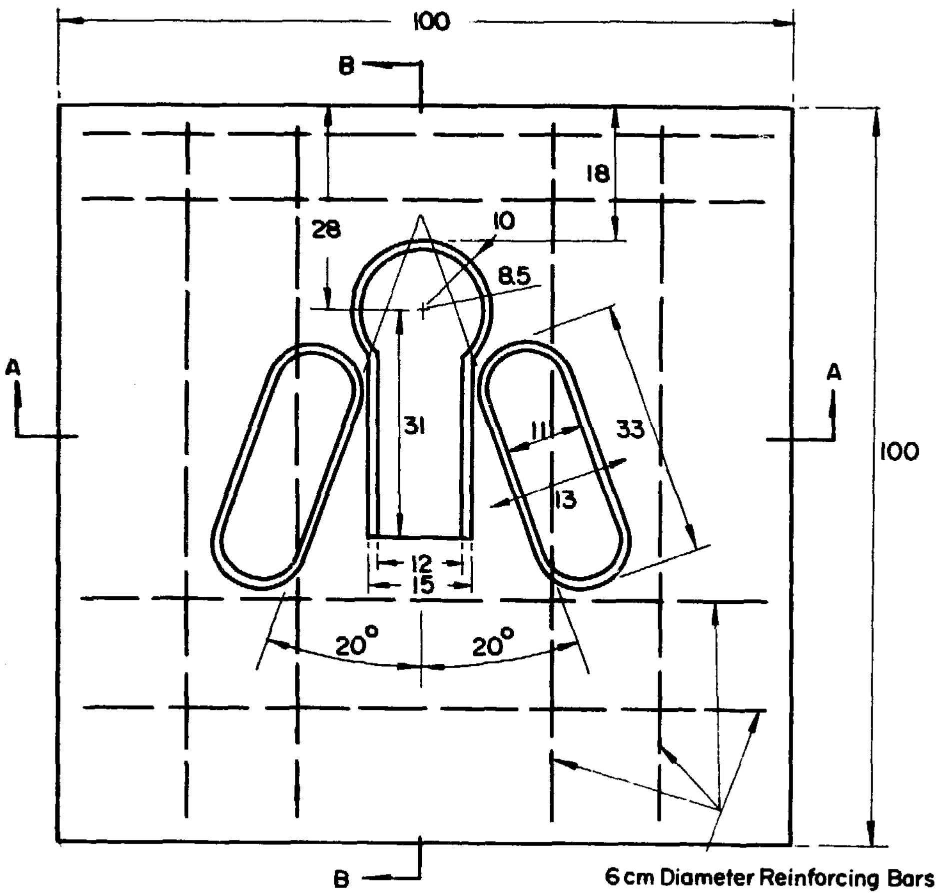
Front View

Section

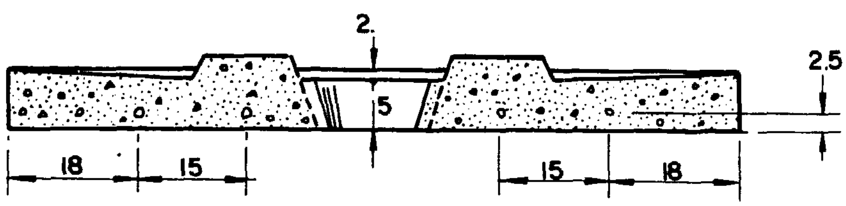


Side View

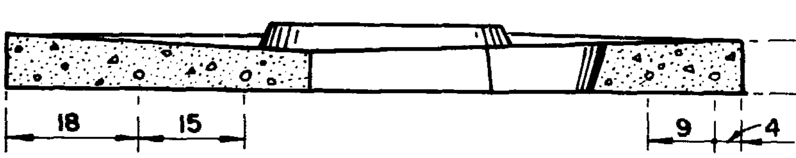
CONCRETE SQUATTING PLATE FOR VENTILATED IMPROVED PIT LATRINE (13)



Plan

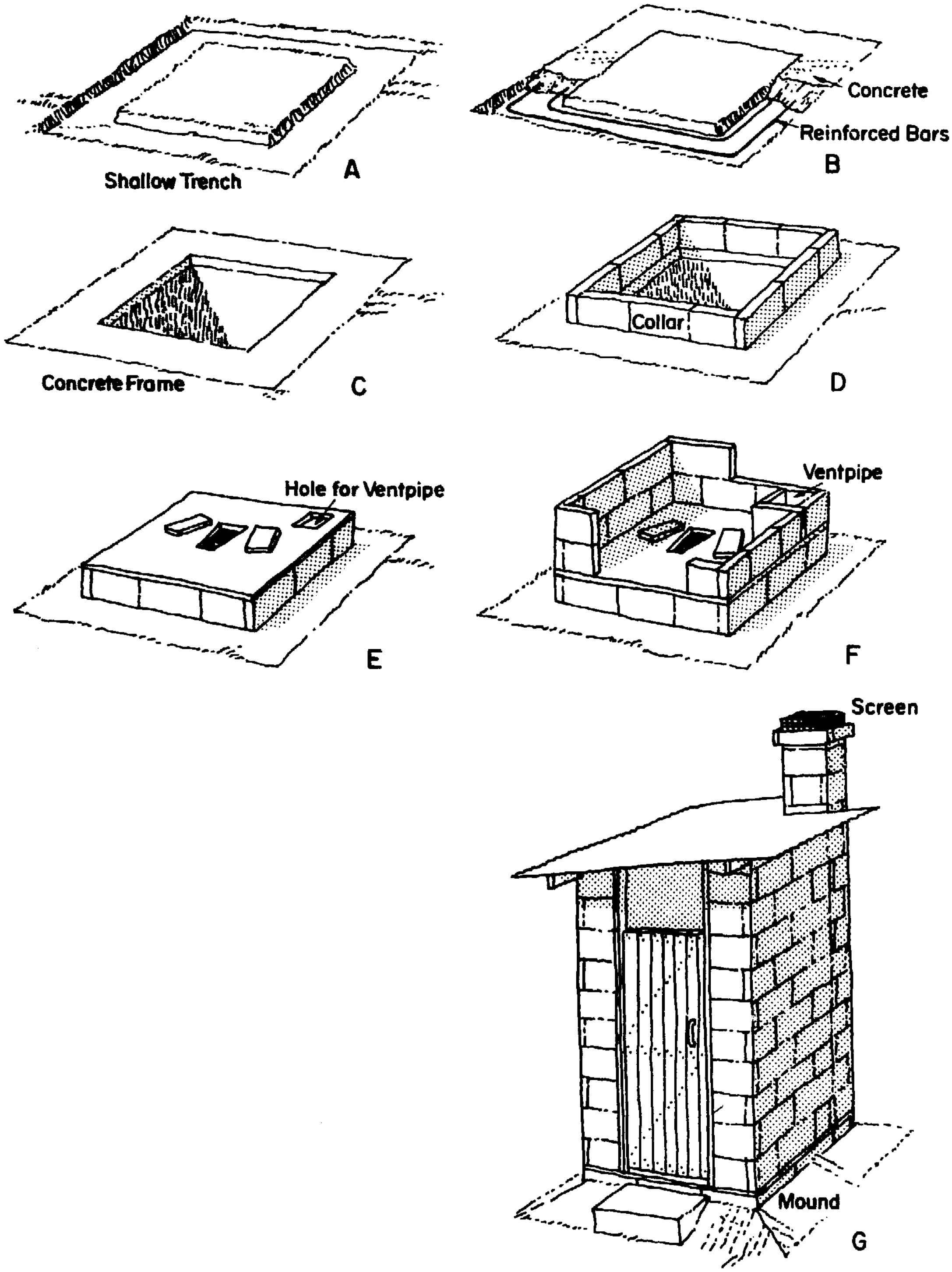


Section A-A

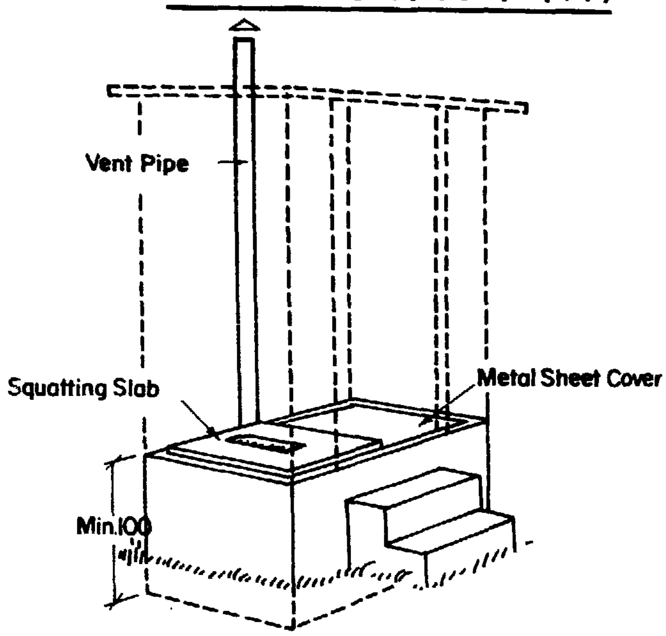


Section B-B

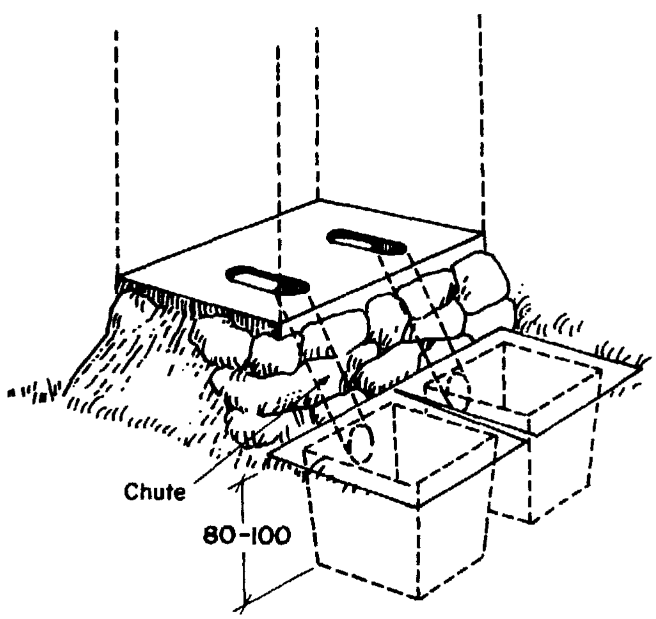
VIP LATRINE , CONSTRUCTION STEPS (14)



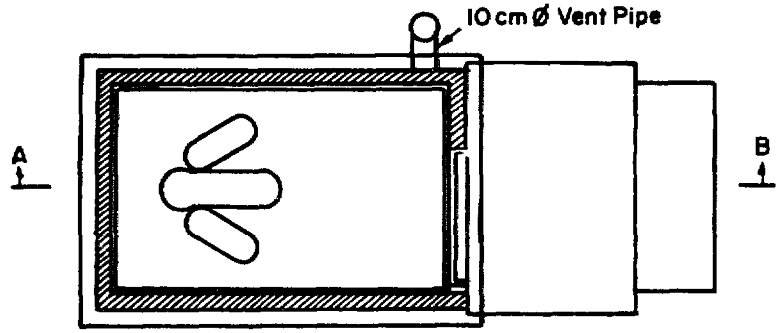
GOUPURI LATRINE (COMPOSTING PRIVY) USED IN INDIA (1964) (14)



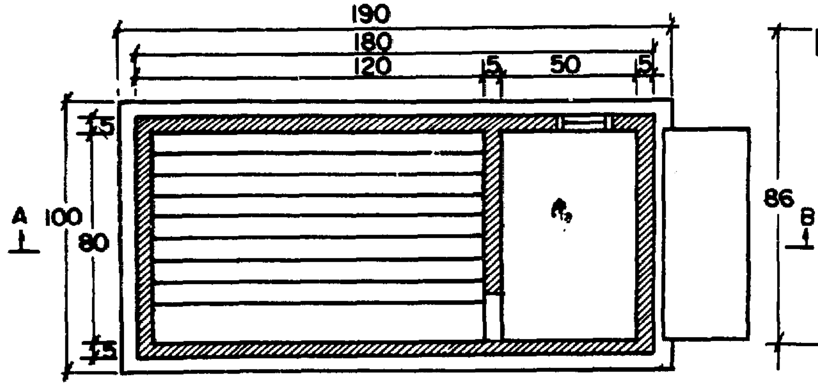
SOPA SANDAS LATRINE USED IN INDIA (1964)(14)



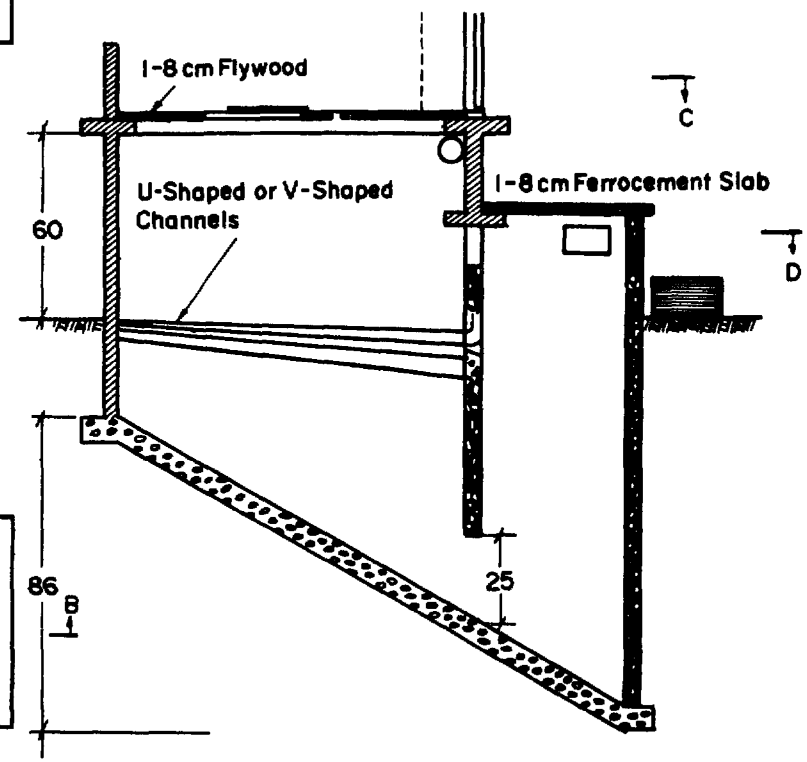
MULTRUM LATRINE (12)



Section C (Plan)

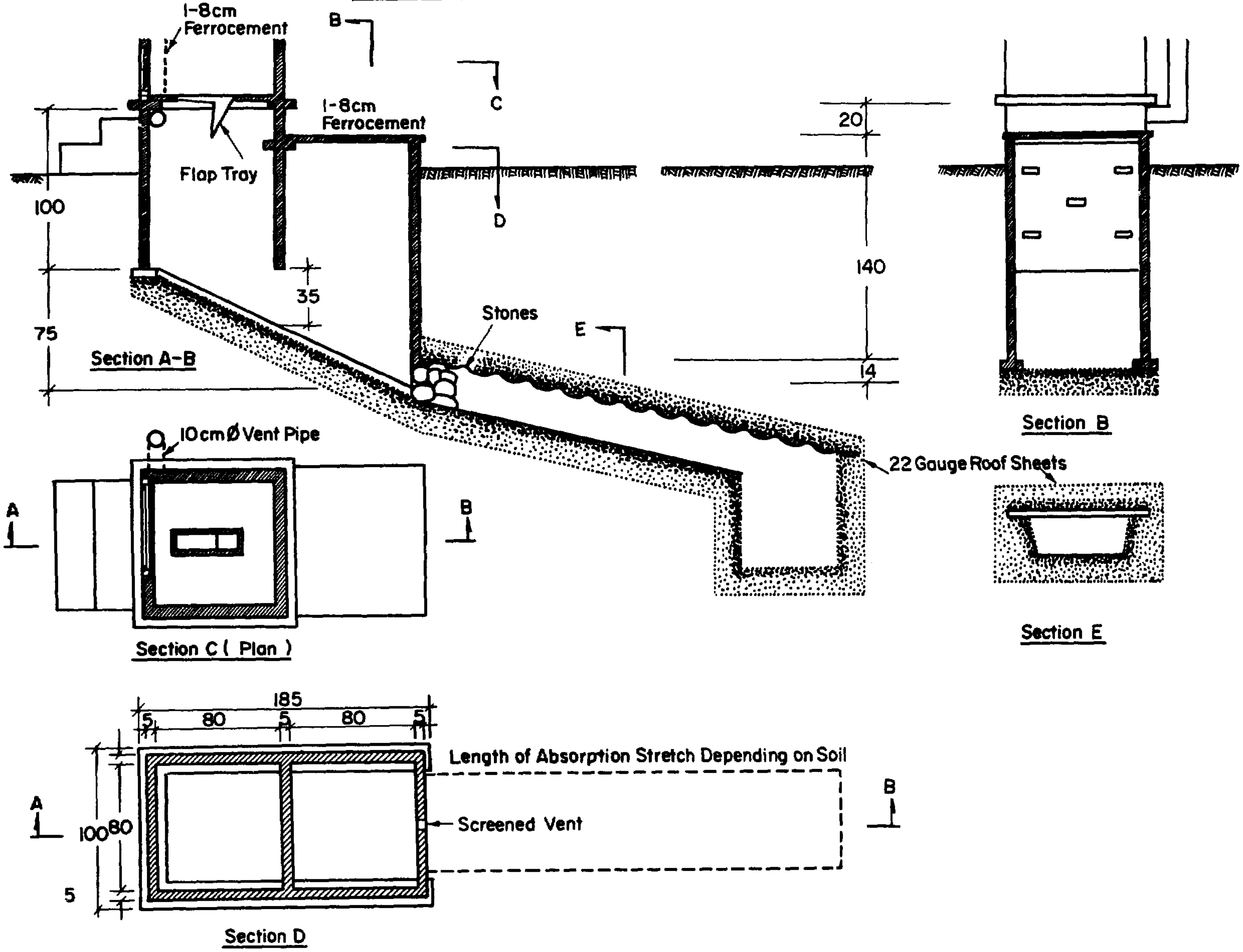


Section D

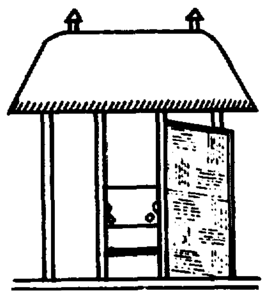


Section A-B

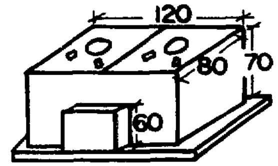
UTAFITI LATRINE (MULTRUM) IN TANZANIA (12)



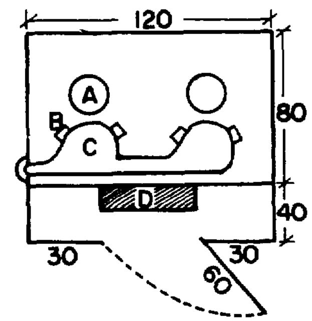
VIETNAMESE DOUBLE – VAULT COMPOSTING PRIVY (7)



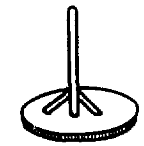
1. Front View



2. Privy for a Family of 5-10 Persons

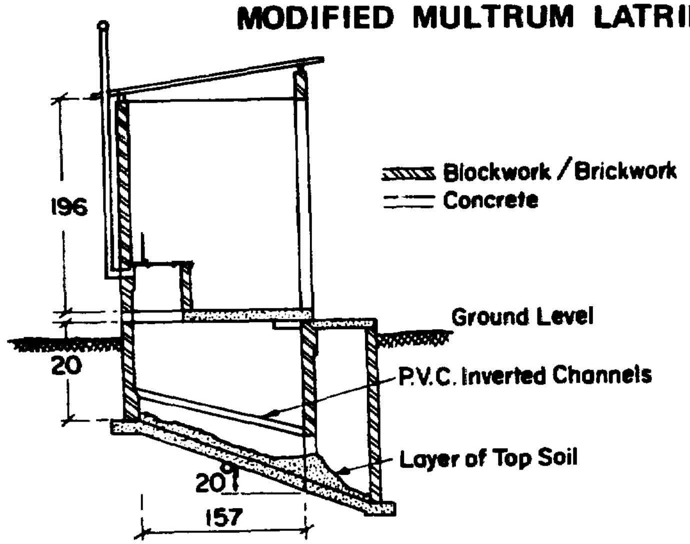


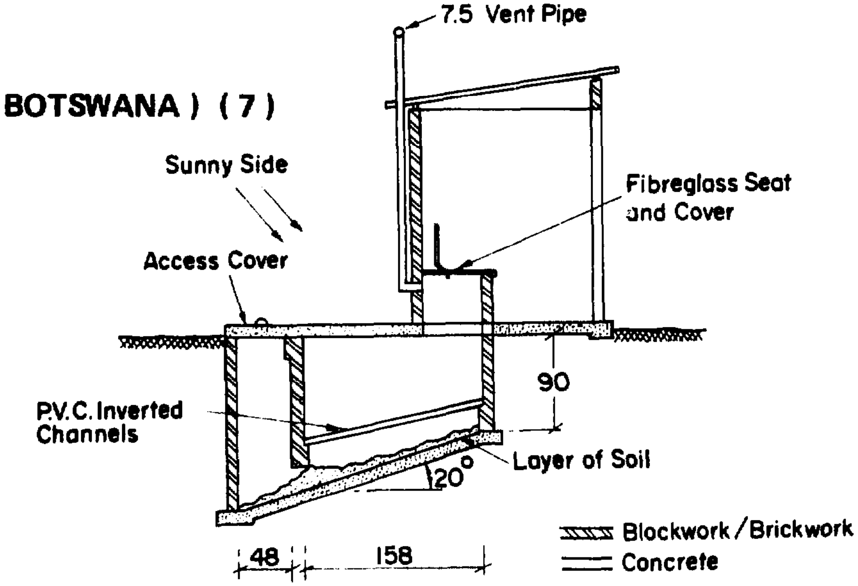
3. View from above: a) Hole b) Foot-Rests c) Evacuation Groove for Urine, which should not get mixed with the Faeces d) Steps



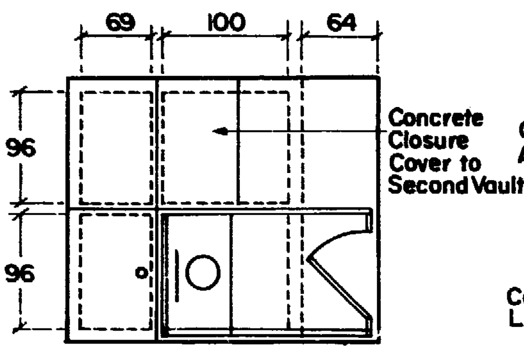
4. Wooden Cover with Handle to Close Hole after Usage

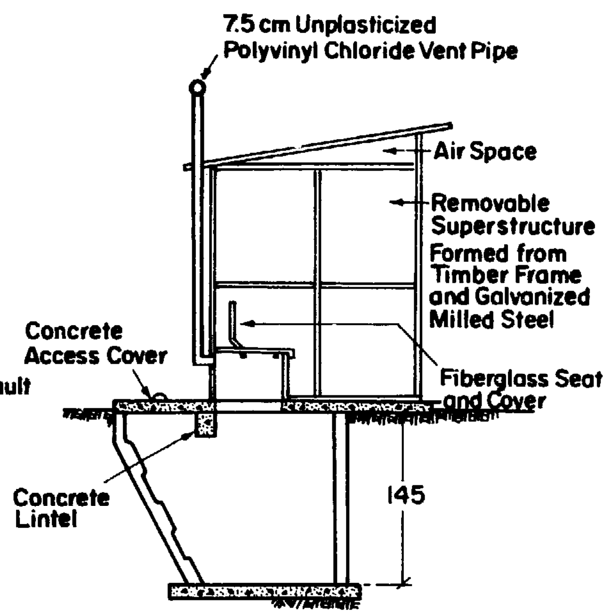
MODIFIED MULTRUM LATRINES (BOTSWANA) (7)





DOUBLE - VAULT COMPOSTING PRIVY (2)

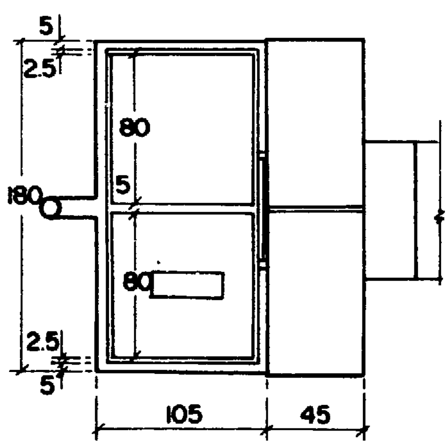


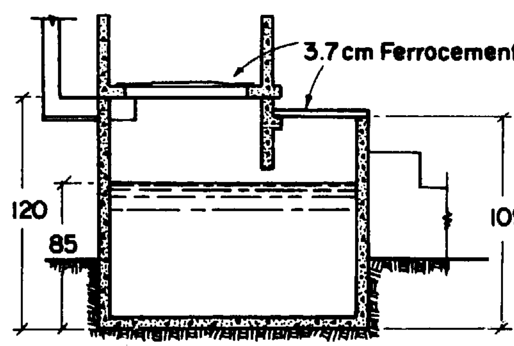


Plan

Section

Model Used in Botswana



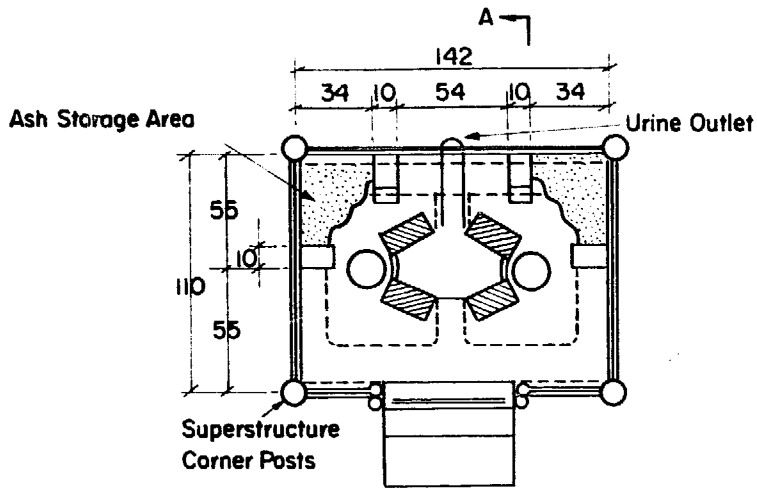


Plan

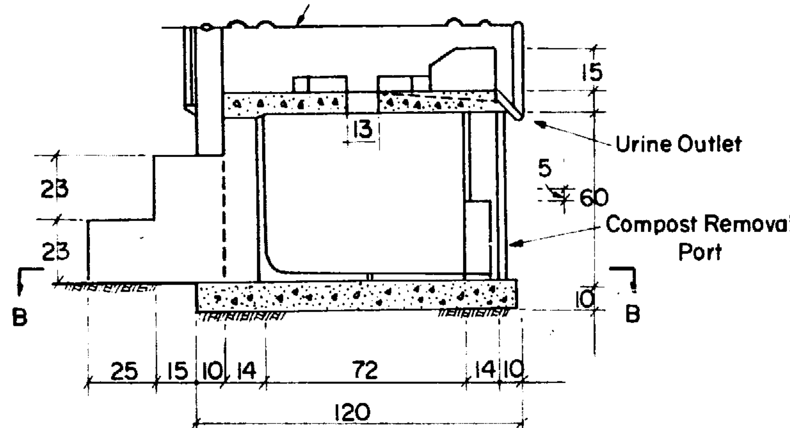
Section

Model Used in Tanzania

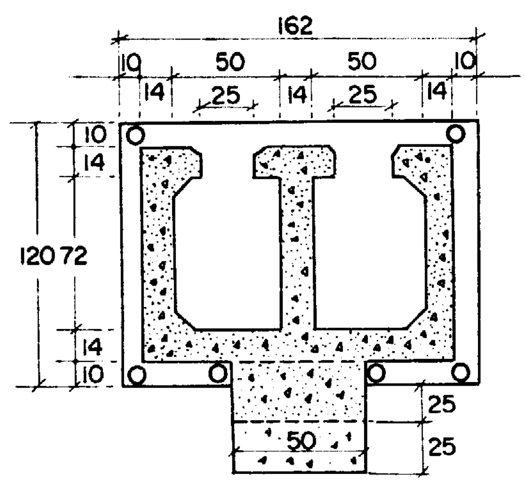
DOUBLE – VAULT COMPOSTING PRIVY USED IN VIETNAM (2)



Plan

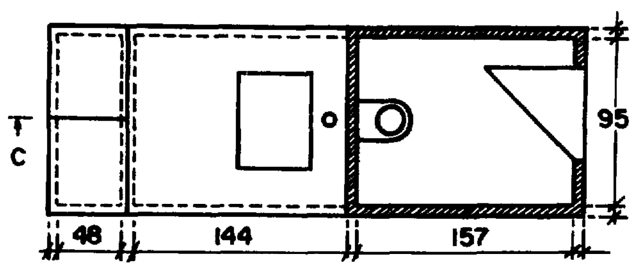


Section A-A

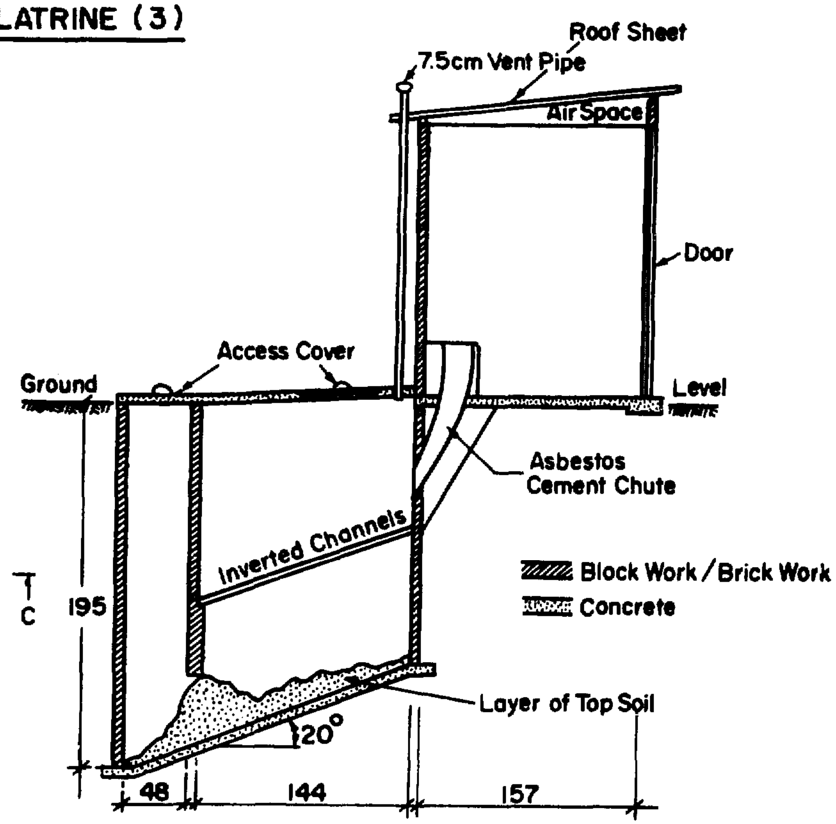


Section B-B

OFF-SET COMPOST VAULT LATRINE (3)

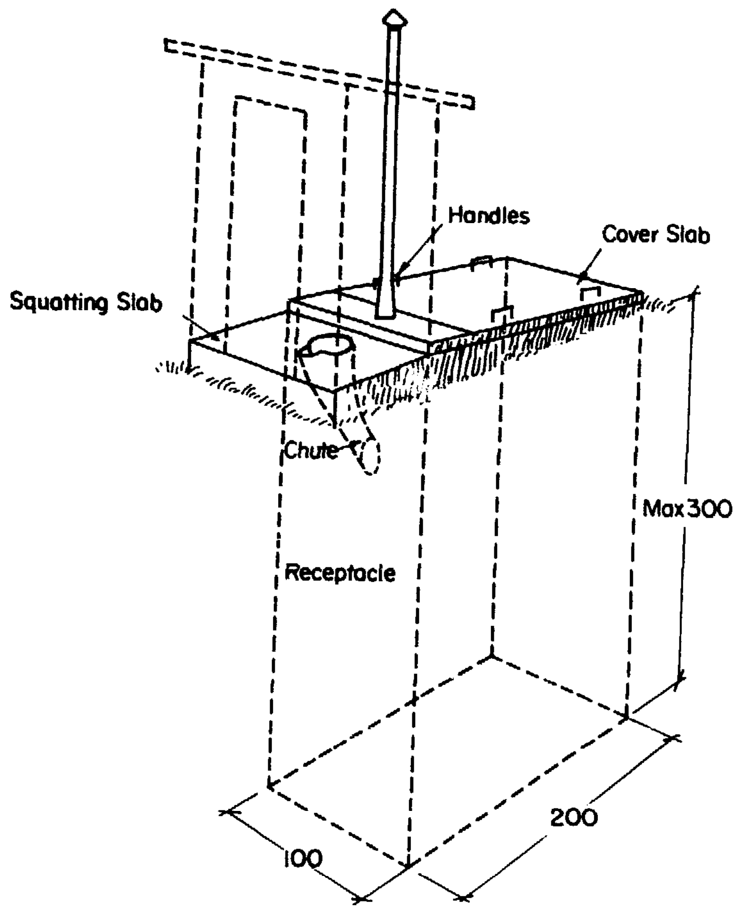


Plan

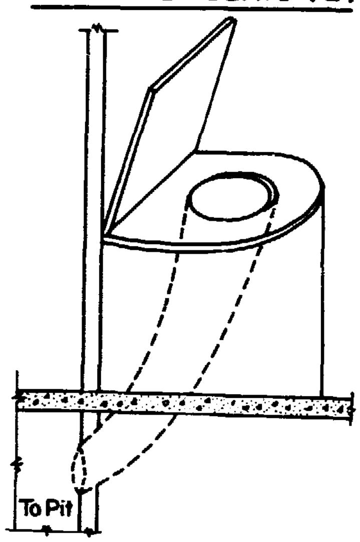


Section C-C

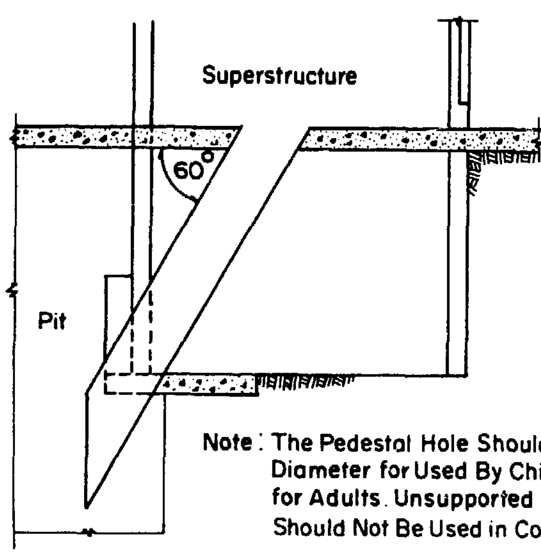
REED ODORLESS EARTH CLOSET (ROEC) (3)



PEDESTAL SEATS (2)

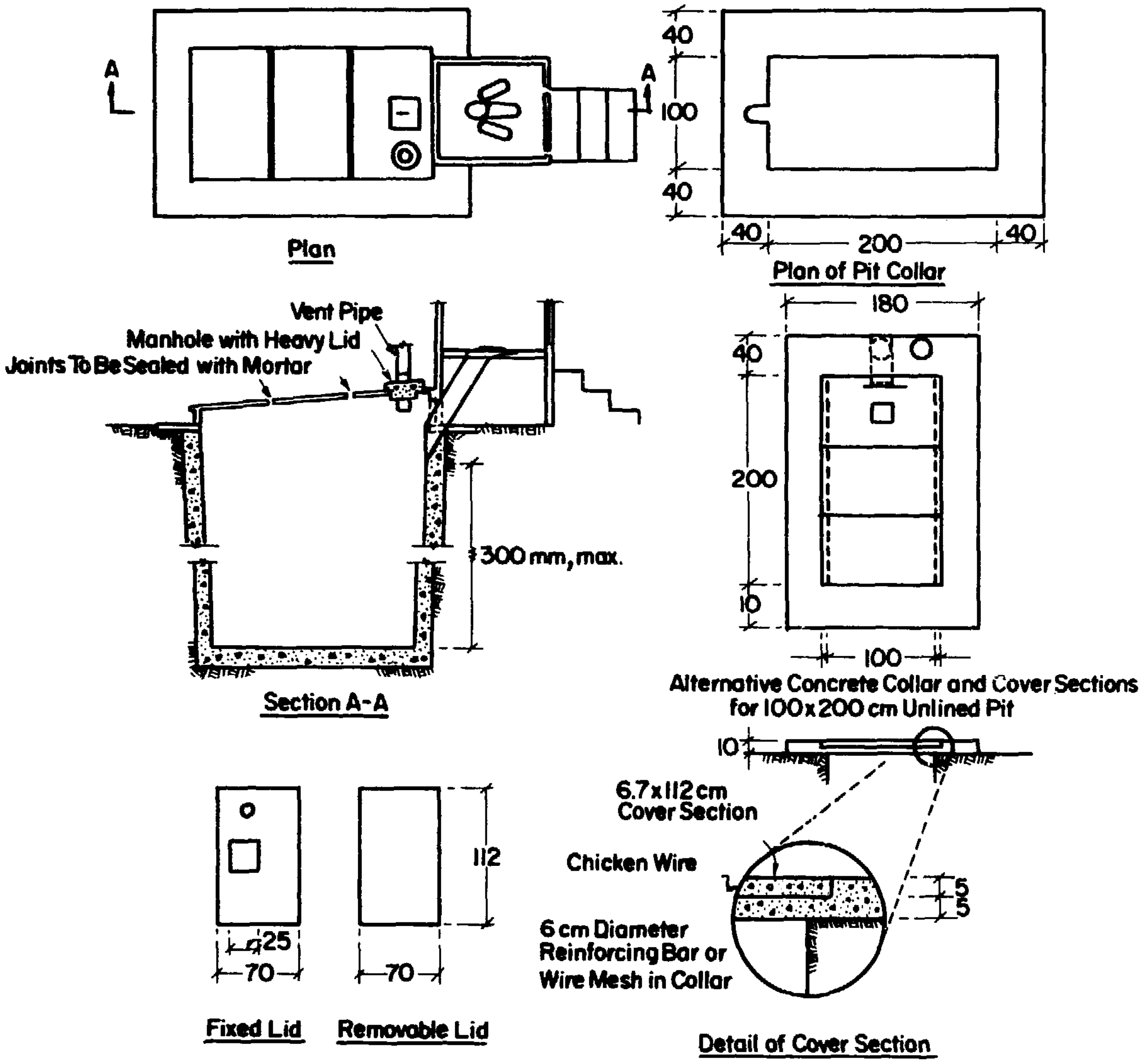


SQUATTING CHUTE (2)



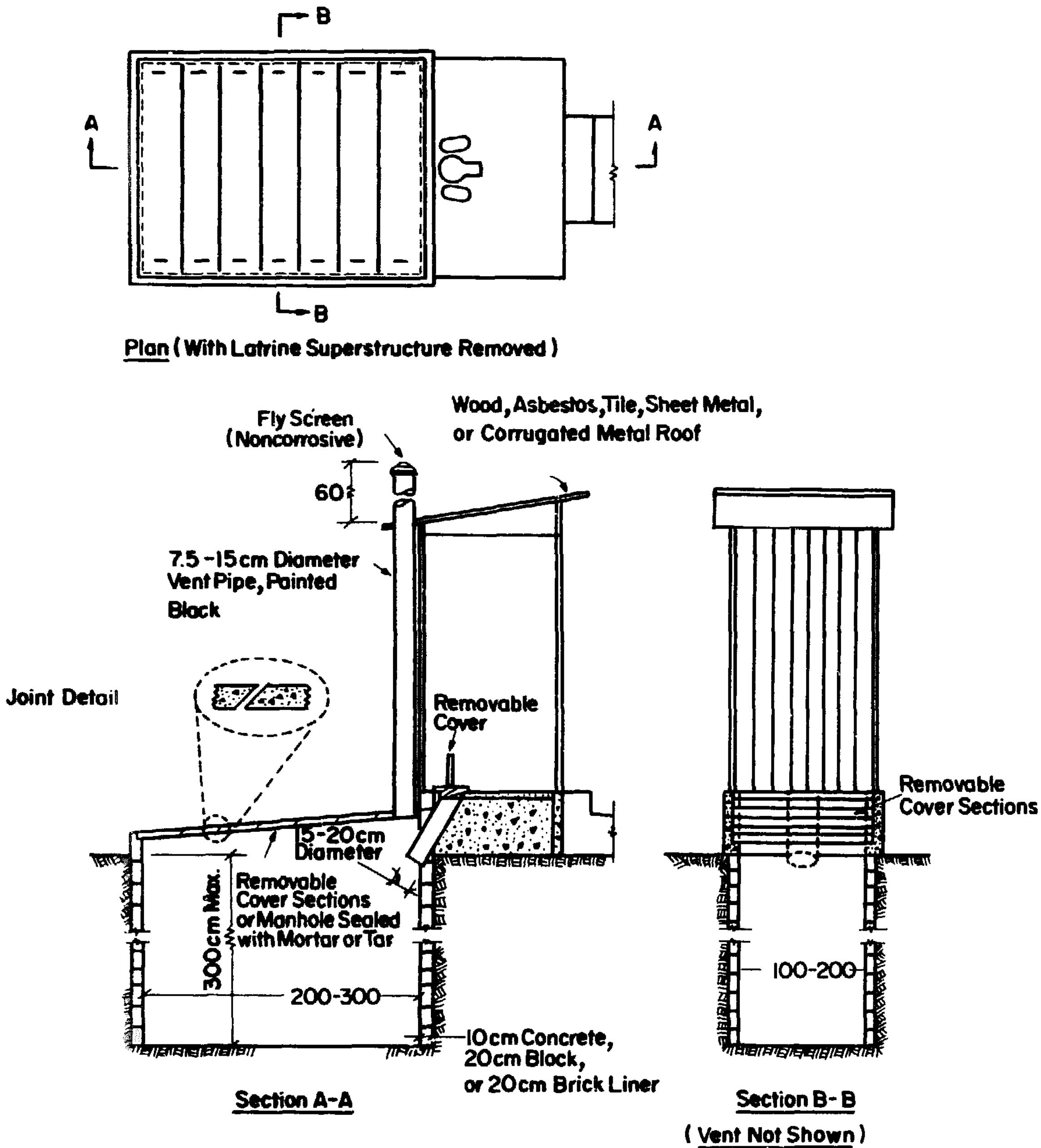
Note : The Pedestal Hole Should Be 10 cm in Diameter for Used By Children, 20 cm for Adults. Unsupported Fiberglass Should Not Be Used in Construction.

REED ODOURLESS CLOSET (ROEC) - STRUCTURAL DETAILS (13)

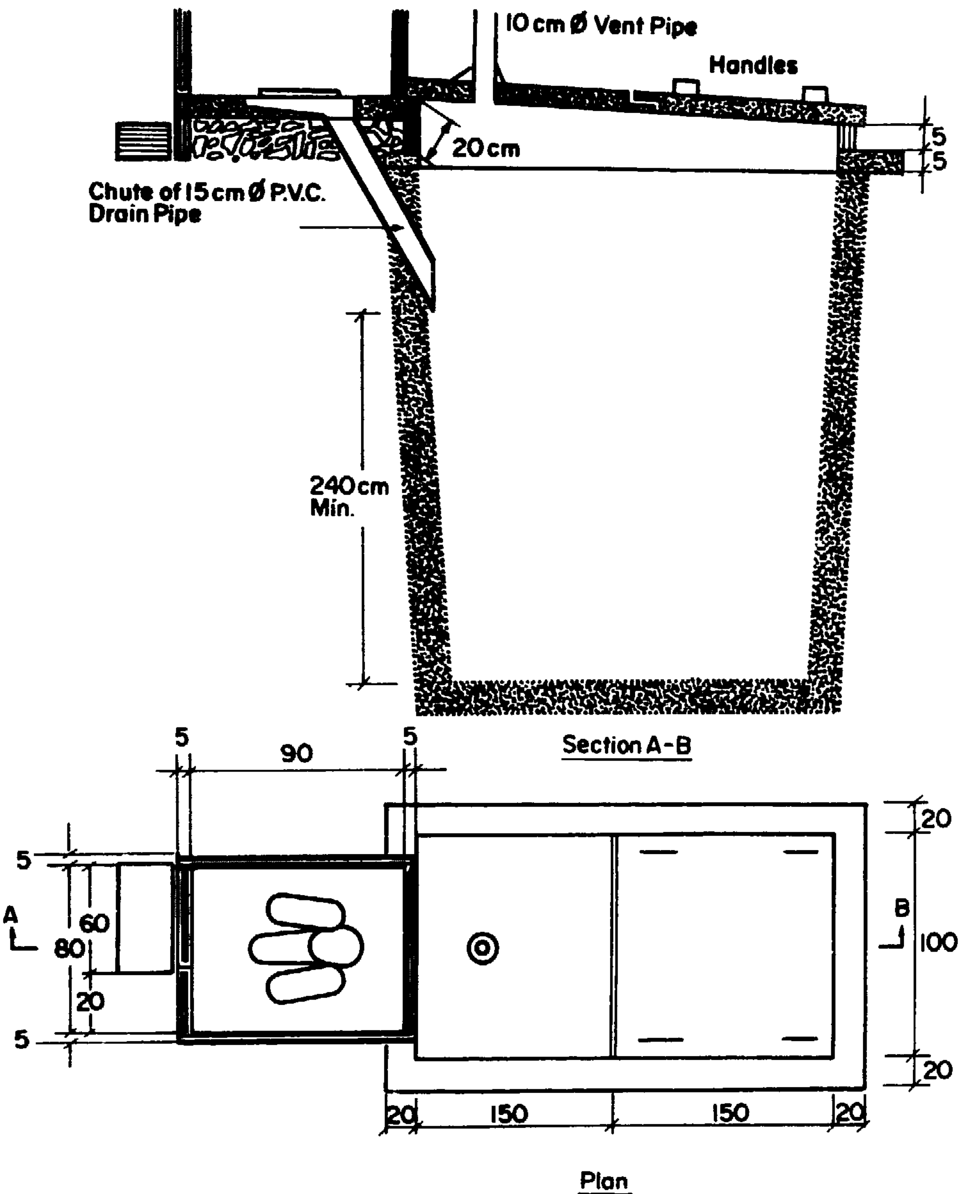


Note : Pedestal Seat with Curved Chute May Be Substituted for Squatting Plate. Construction Materials and Dimensions for Superstructure May Vary According to Local Practice. The Vent Should Be Placed for Maximum Exposure to Sunlight.

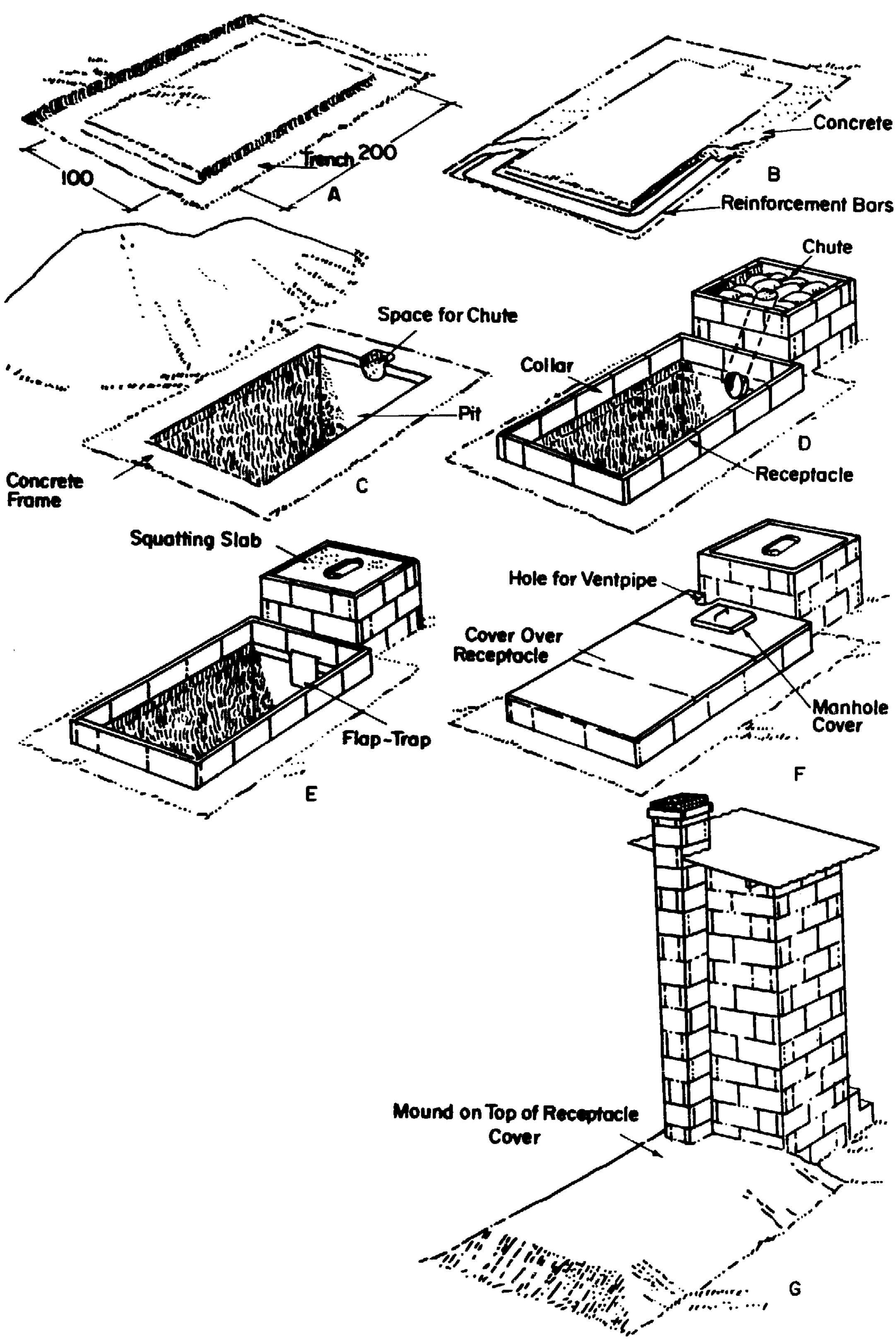
REED ODORLESS EARTH CLOSET (ROEC) (13)



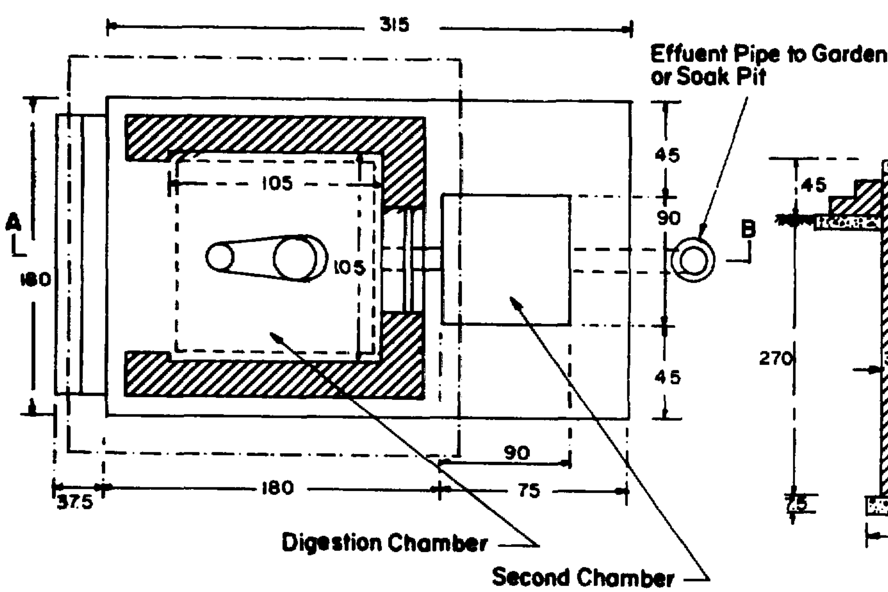
THE REED ODOURLESS EARTH CLOSET (ROEC)
RECENTLY TESTED IN TANZANIA (11, 12)

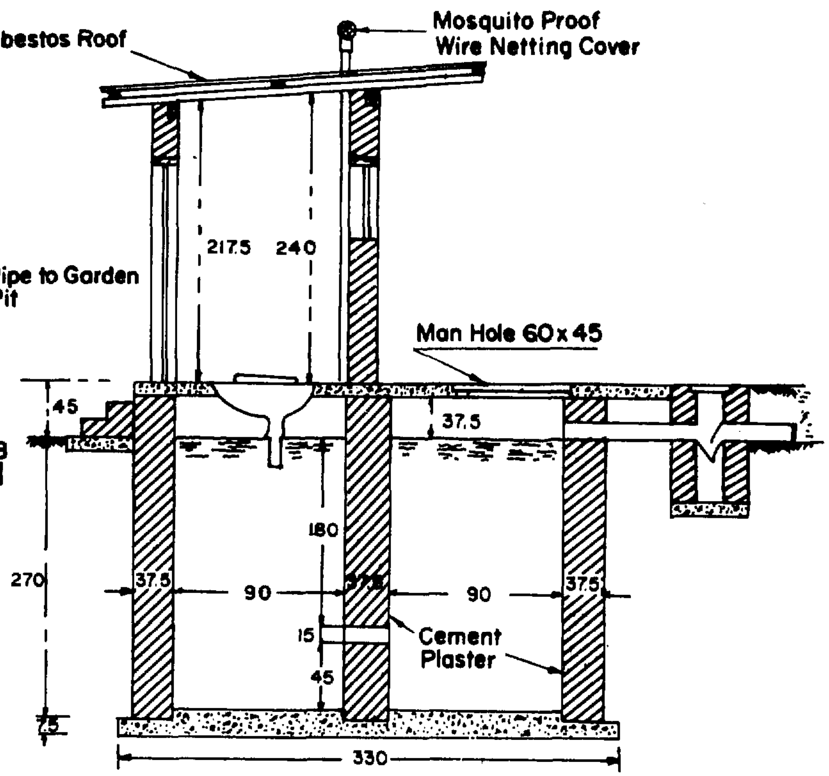


ROEC LATRINE, CONSTRUCTION STEPS (14)

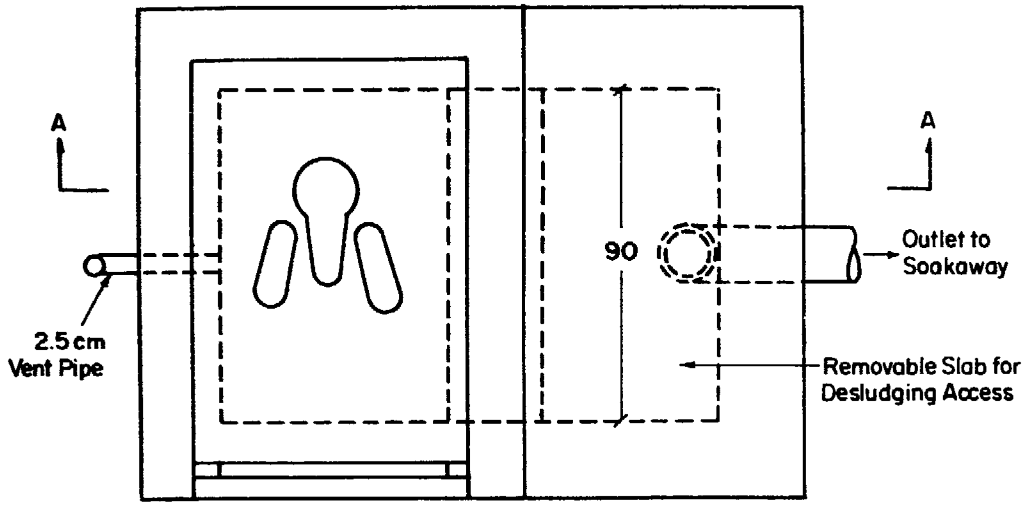


AQUA – PRIVY (12)

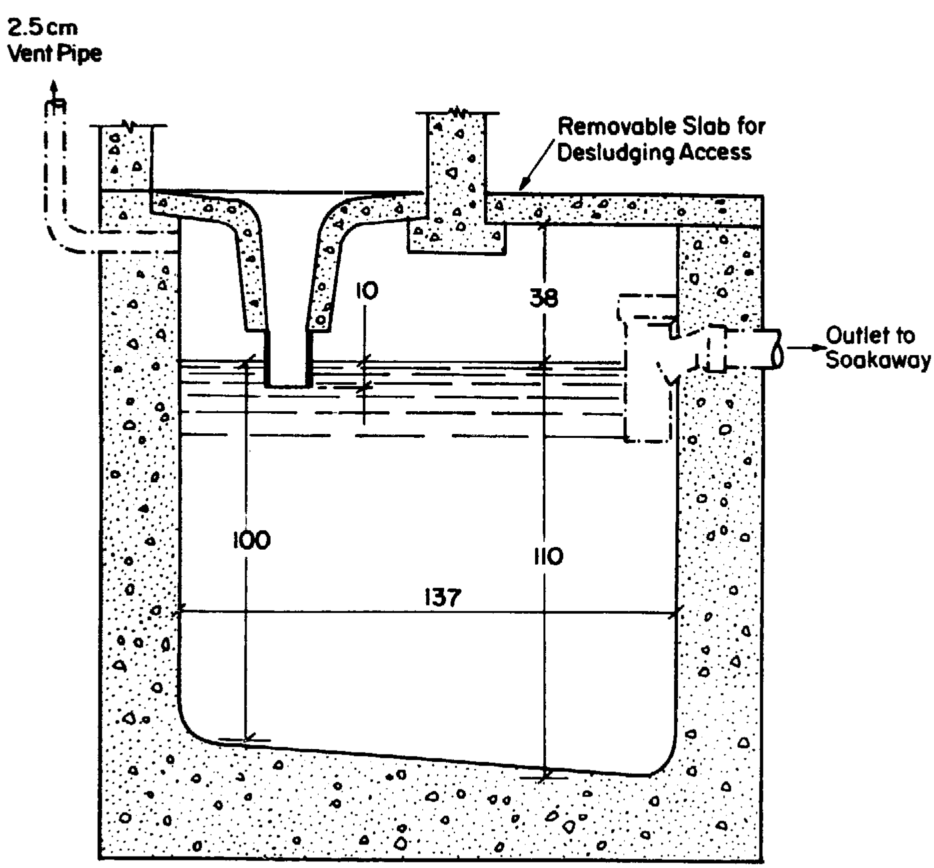




CONVENTIONAL AQUA-PRIVY (13)

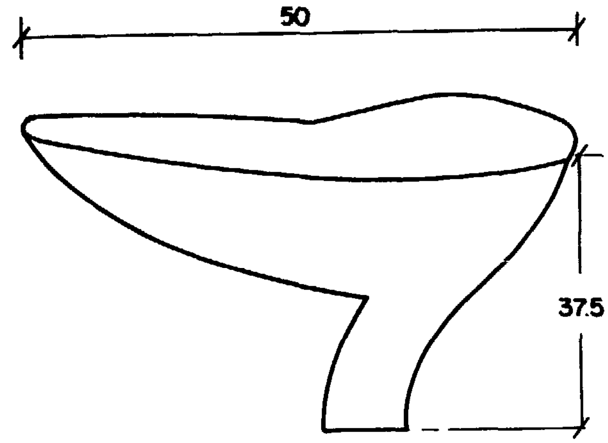


Plan

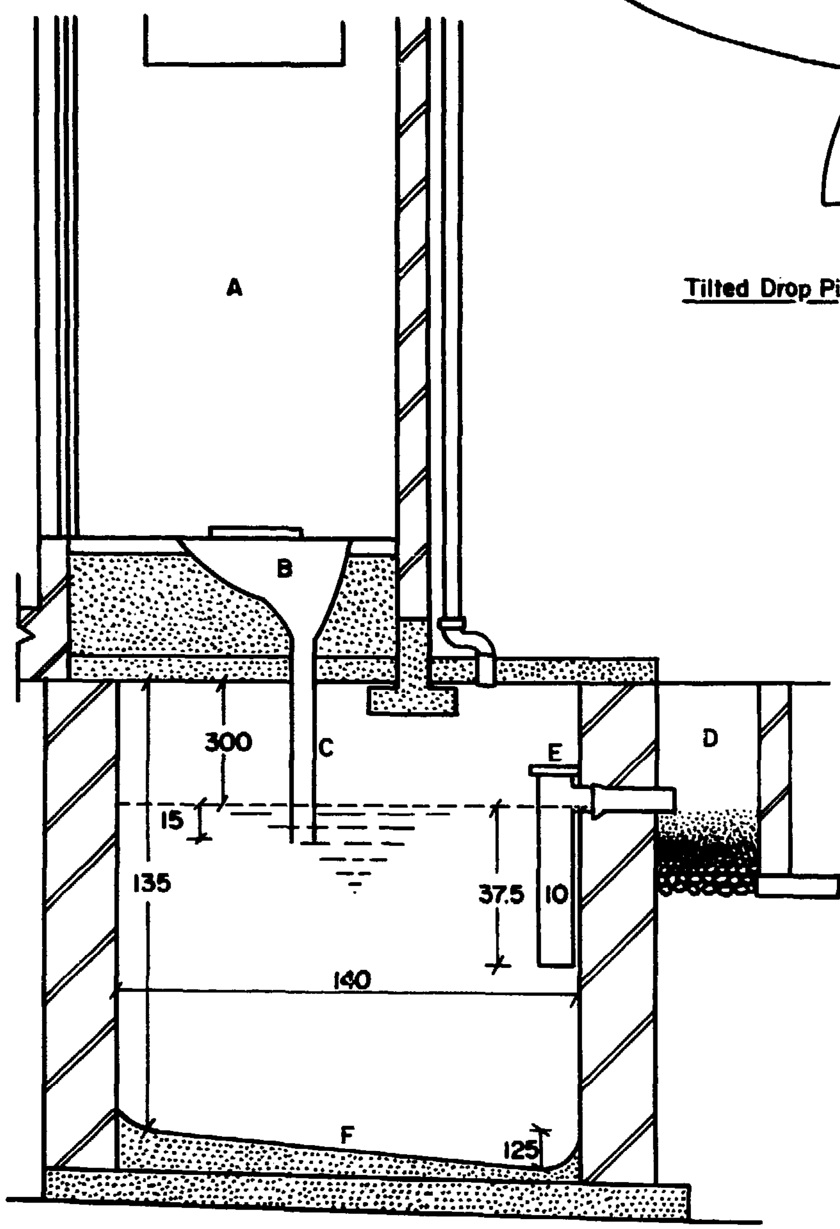


Section A - A

AQUA – PRIVY (4)

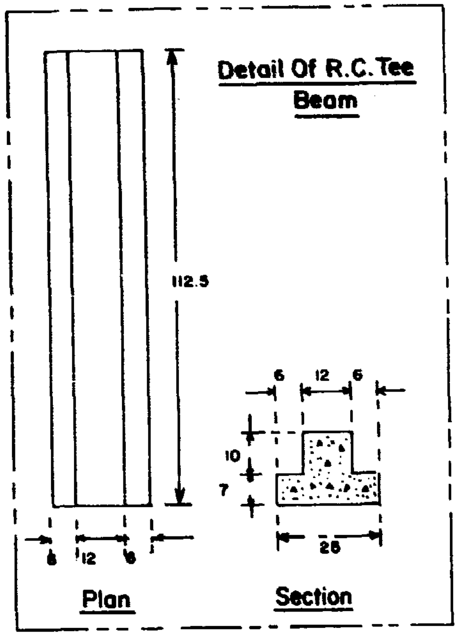


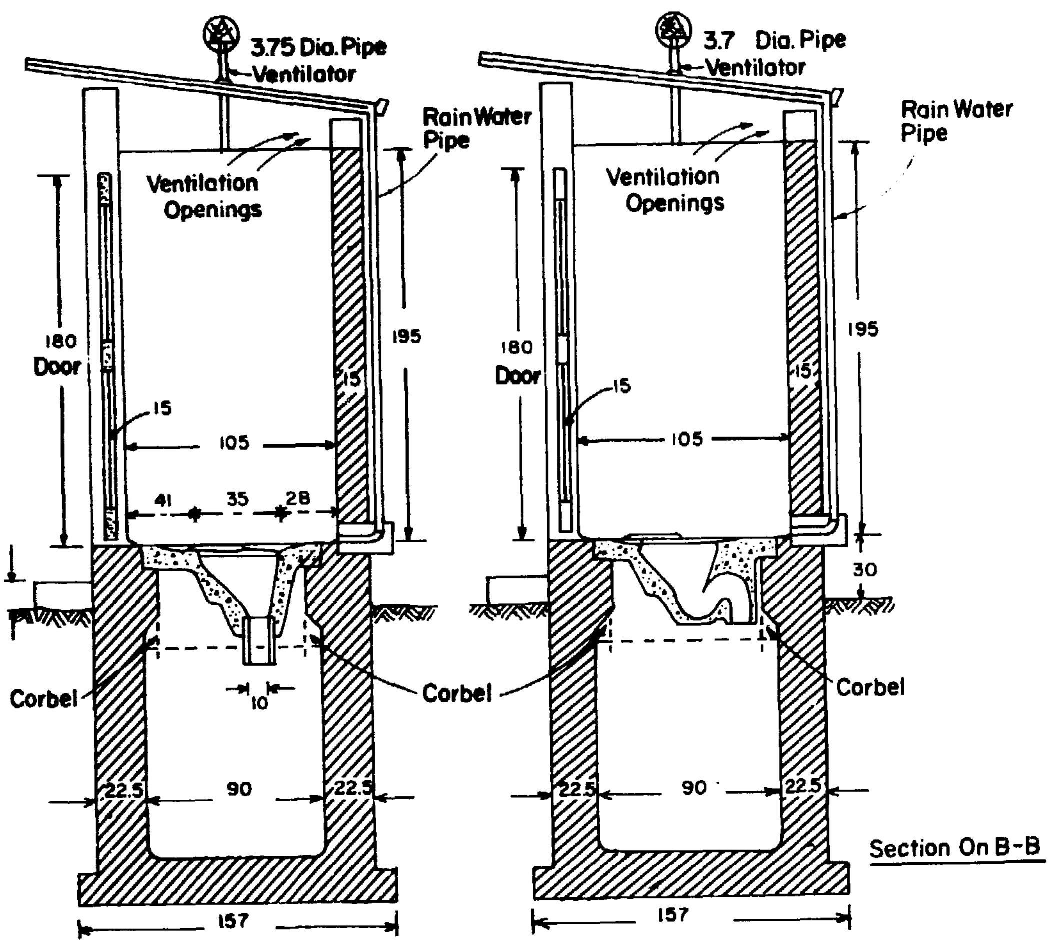
Tilted Drop Pipe Naigaon Model



A – Latrine
B – *Tub with Vertical Drop-Pipe*
C – Open Space within Tank
D – Filter Chamber
E – Outlet Pipe
F – Tank
G – R.C. Beam
H – Vent Pipe

EASTERN TYPE AQUA PRIVY WITH TWO COMPARTMENTS (8)

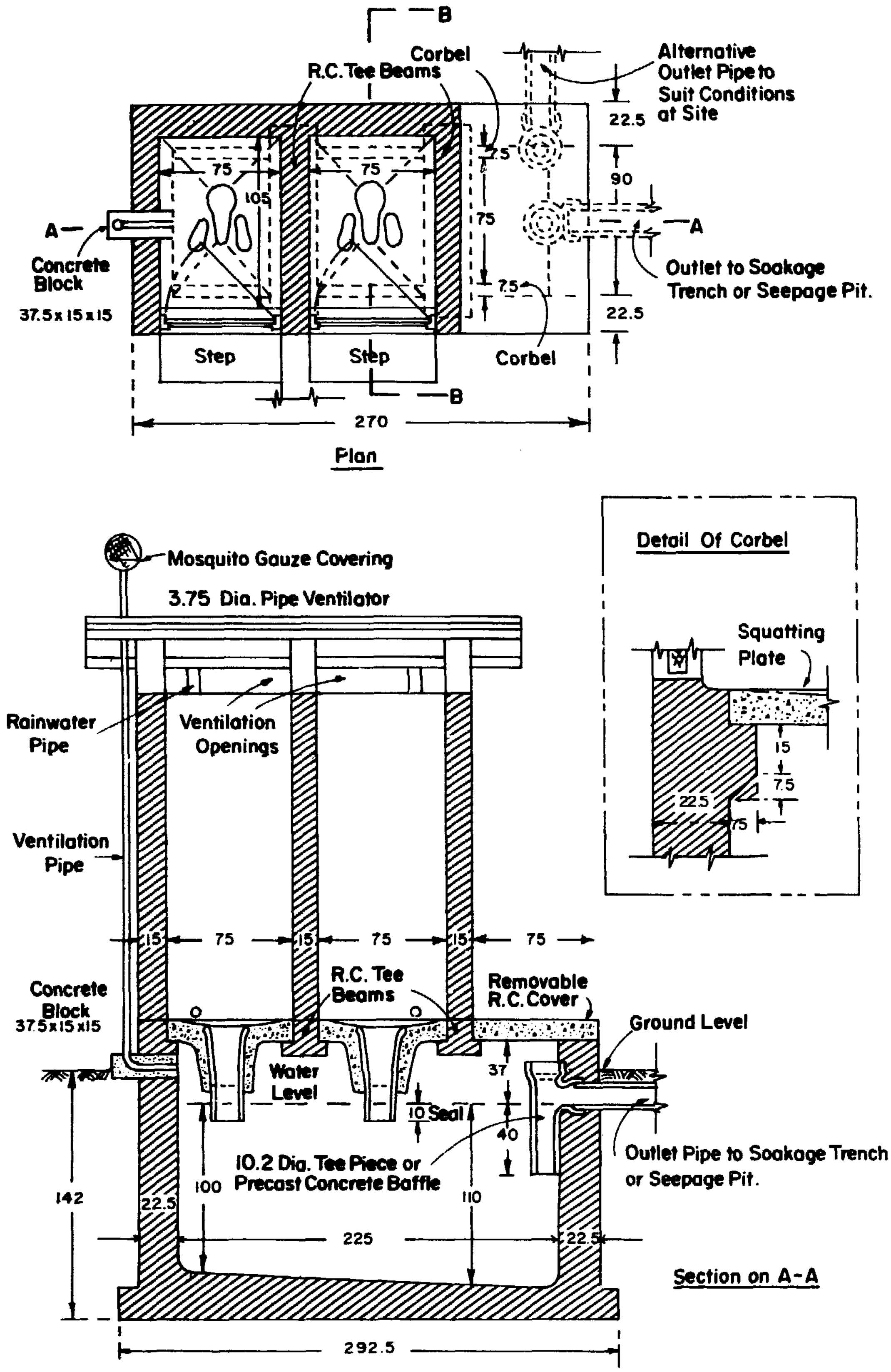




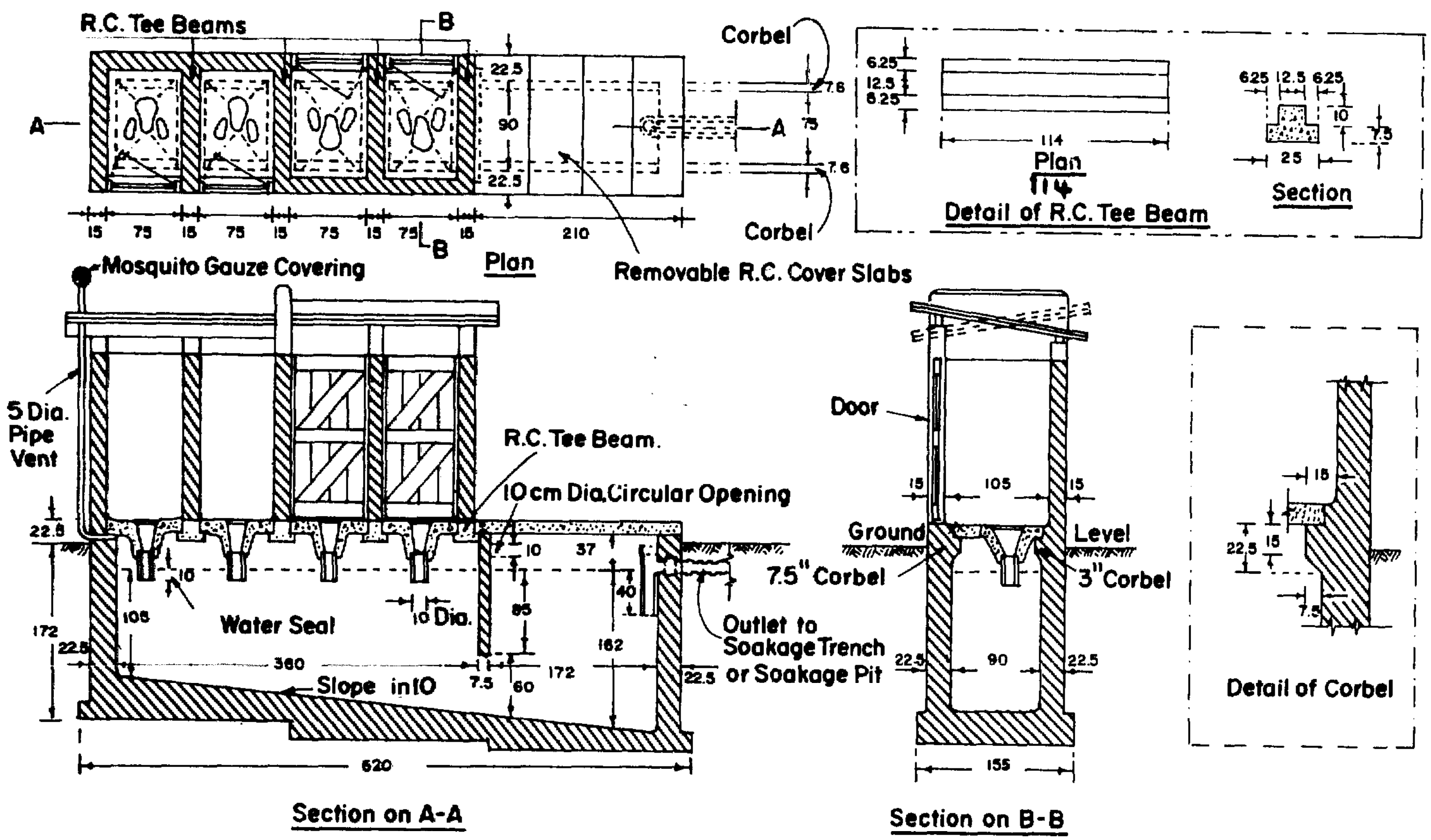
Aqua Privy

Pour Flush

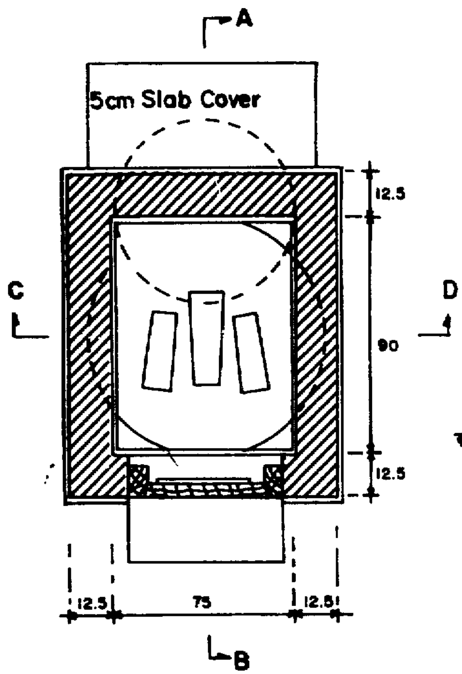
EASTERN TYPE AQUA-PRIVY WITH TWO COMPARTMENTS (8)



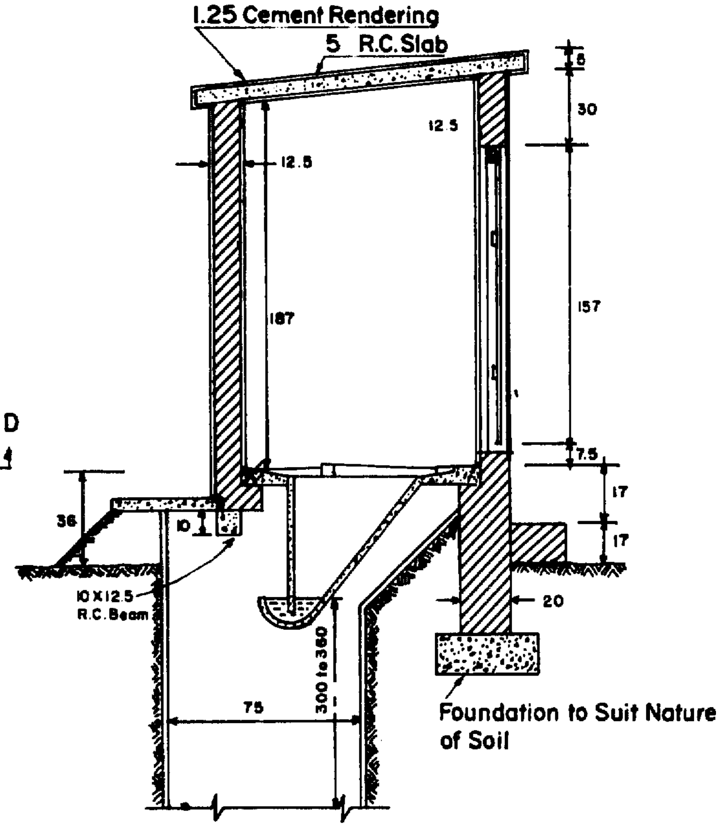
A COMMUNAL AQUA PRIVY SUITABLE FOR 50 USERS. (8)



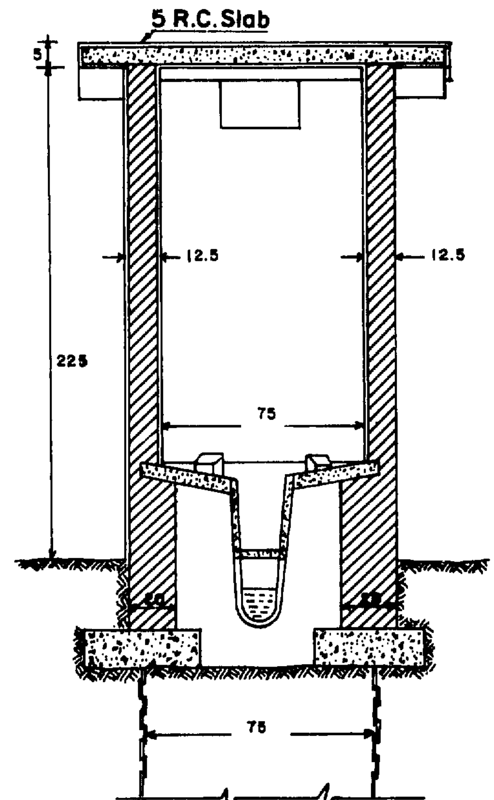
DUG WELL LATRINE (DEVELOPED IN SRI LANKA (12)



Plan

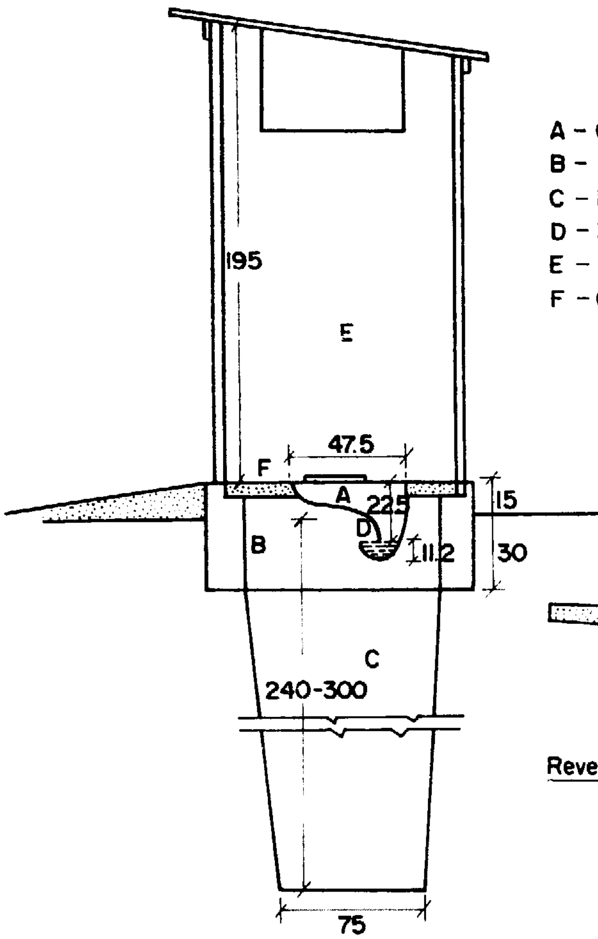


Section A-B



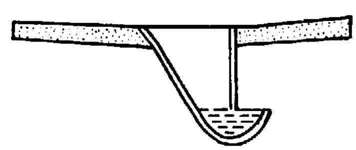
Section C-D

HAND-FLUSH LATRINE (4)



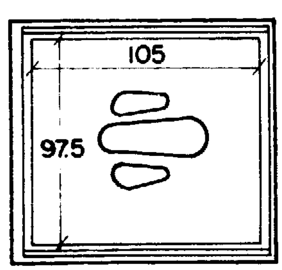
A – Cement Tub with 3/4" Water Seal
B – 1'6" Above Pit
C – Pit
D – 3/4" Water Seal in The Tub
E – Latrine
F – Cement Conc. Slab

Sectional Elevation



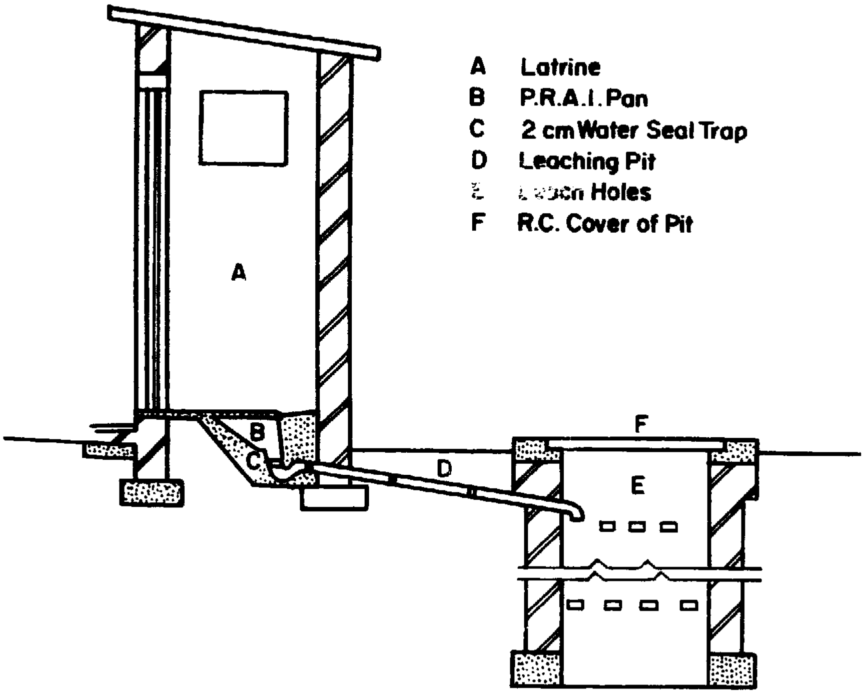
Reversed Water-Seal Pan with The Slab
Rasuliya Model

Plan

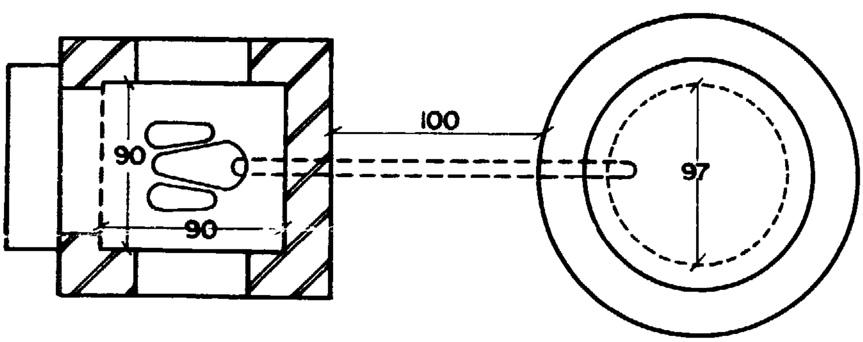


P.R.A.I. TYPE LATRINE (4)

PLANNING RESEARCH AND ACTION INSTITUTE, LUCKNOW



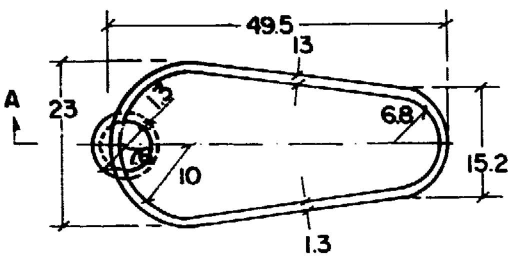
Sectional Elevation



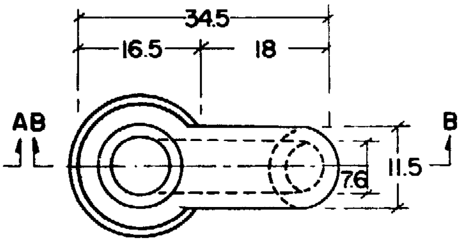
Plan

POUR – FLUSH UNITS FOR DISPLACED PITS (13)

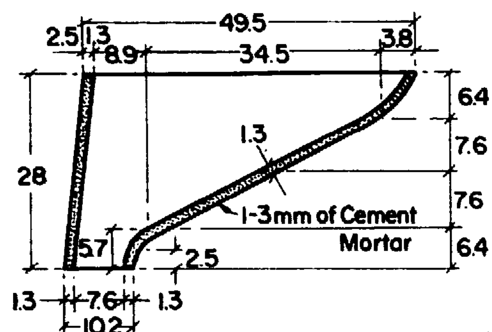
A. Cement Mortar or Ceramic Pan



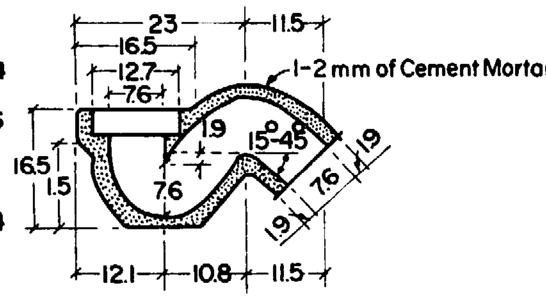
Plan of Squatting Plate (Pan)



Plan of Water -Seal Unit (Trap)

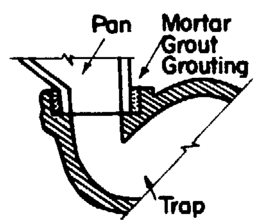


Section A-A

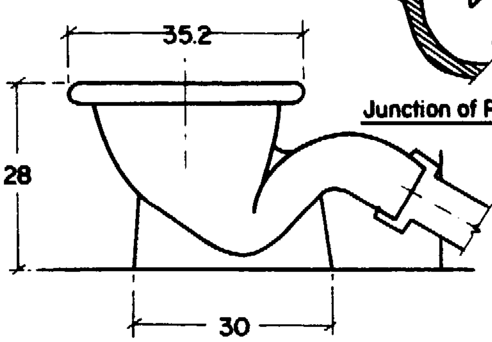


Section B-B

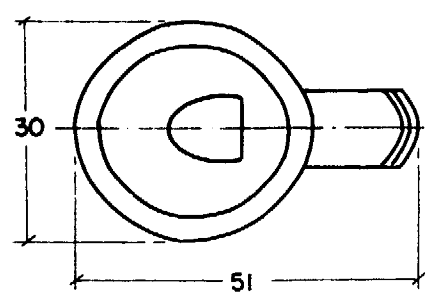
B. Ceramic Pedestal



Junction of Pan Trap

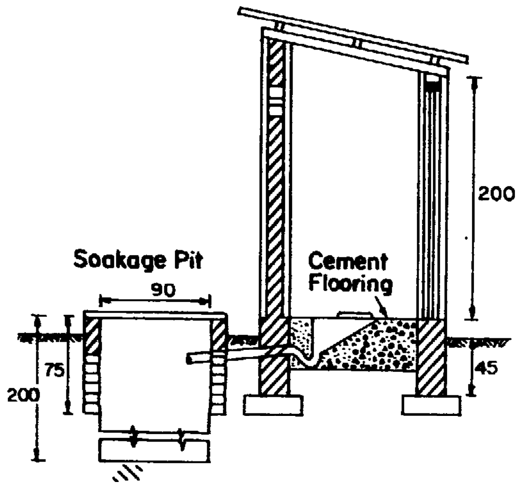


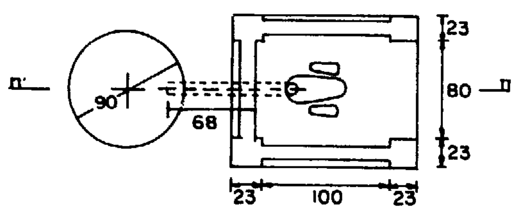
Side View



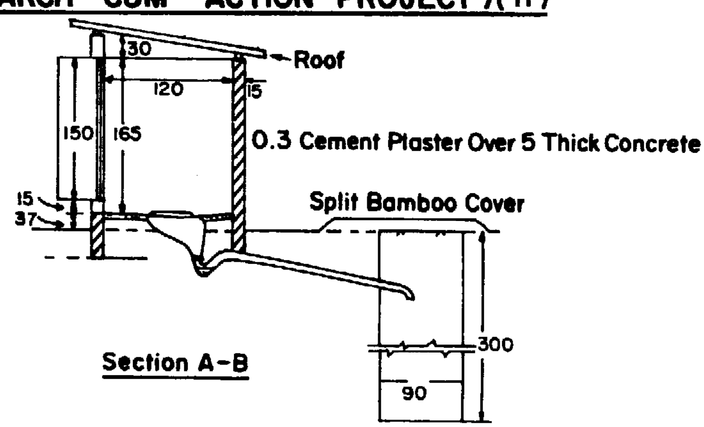
Top View

HAND-FLUSHED, WATER-SEAL LATRINE
(NEERI, NAGPUR, INDIA) (7)

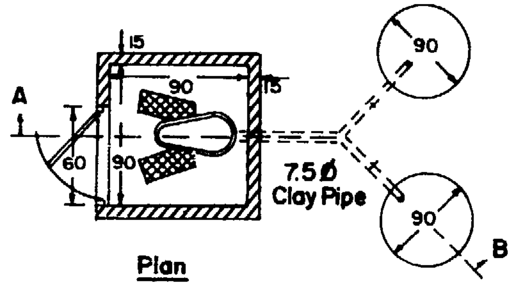




RCA LATRINE
(RESEARCH - CUM - ACTION PROJECT)(11)

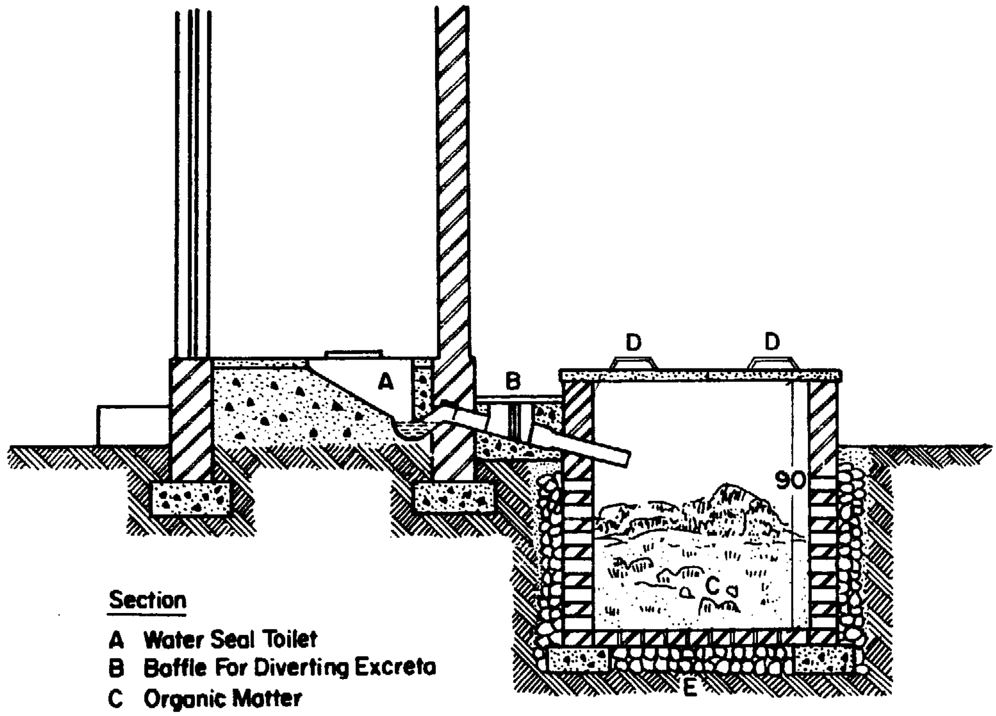


Section A-B



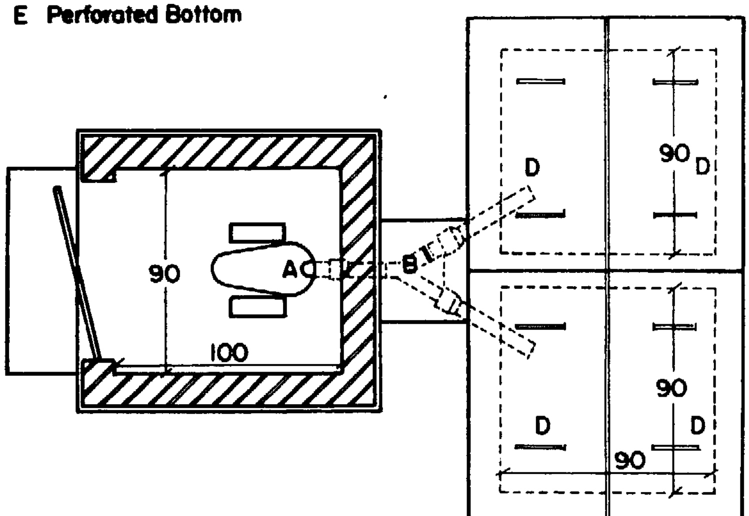
Plan

POUR-FLUSH DOUBLE-VAULT COMPOSTING PRIVY(10)



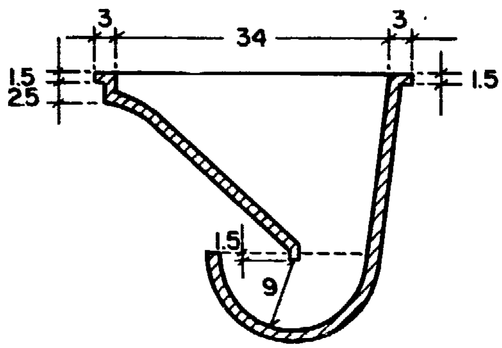
Section

- A Water Seal Toilet
- B Baffle For Diverting Excreta
- C Organic Matter
- D Cover
- E Perforated Bottom

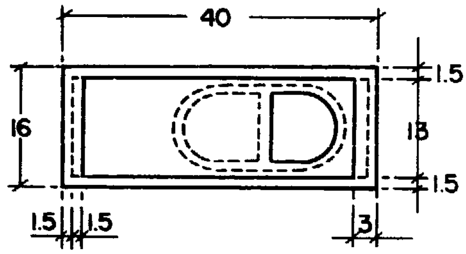


Plan

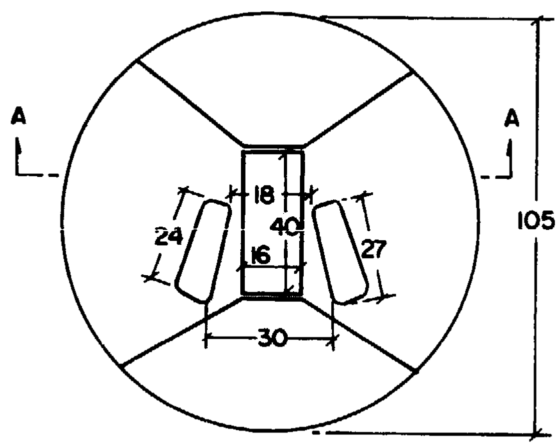
WATER-SEAL SQUATTING PLATE FOR POUR-FLUSH TOILETS LOCATED IMMEDIATELY ABOVE THE PIT (13)



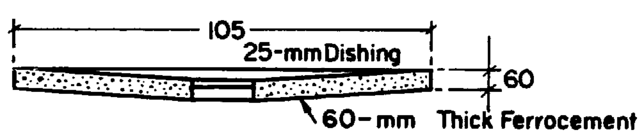
Sectional Elevation



Plan of Water Seal

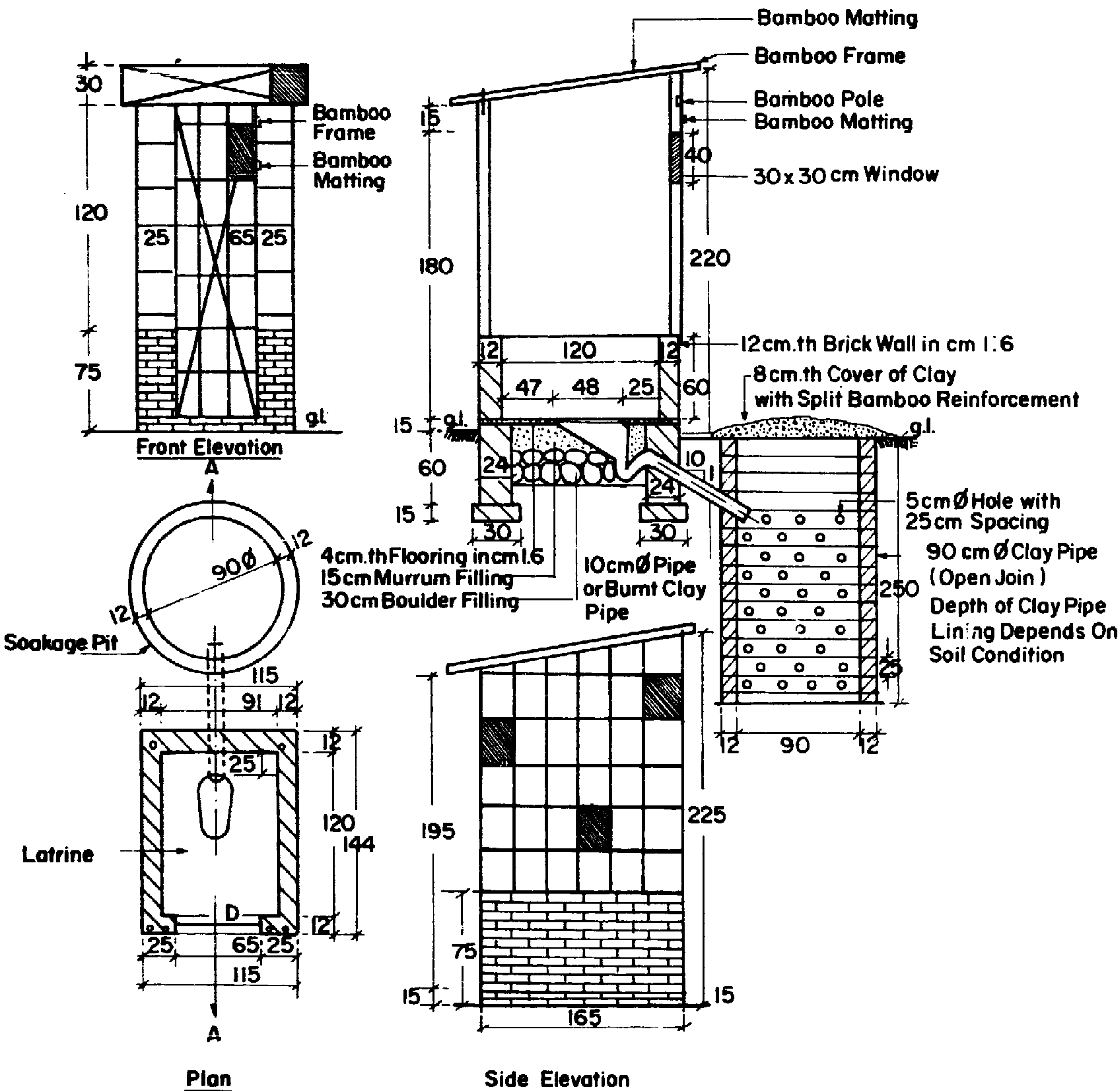


Details of Squatting Plate



Section A-A

LATRINE BLOCK FOR RURAL HOUSING (6)



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