

CANADIAN EMERGENCY MEASURES COLLEGE

RADIOLOGICAL DEFENCE OFFICERS

COURSE MANUAL

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CANADIAN EMERGENCY MEASURES COLLEGE

RADIOLOGICAL DEFENCE OFFICERS

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CANADIAN EMERGENCY MEASURES COLLEGERADIOLOGICAL DEFENCE OFFICERSCHAPTER 1EMERGENCY GOVERNMENT ORGANIZATION IN CANADA

This chapter reviews the structure and functions of the emergency government organization in Canada, emphasizing the municipal organization.

INTRODUCTION

1. Planning and preparations for national survival under conditions of nuclear war became a requirement when weapon delivery systems opened Canada to direct attack. The whole concept of major war changed and it became apparent that civil planning and preparations were of national importance and that government must provide the leadership and co-ordination required for national survival.

2. There are two principal areas in which preparations must be undertaken in order to ensure survival:

First The nation's resources, both human and material, must be protected and conserved.

Second The structure of government must be designed so that it will be able to continue to function in the face of the damage and dislocation that would occur.

NATIONAL OBJECTIVES

3. The overall aim of civil emergency planning is to develop, in peacetime, plans and facilities designed to contribute to the nation's ability to survive a nuclear war.

4. To achieve this aim, certain national objectives are essential. They are:

First To protect and preserve life and property, i.e., to take measures which will assist the population to survive the hazards of a nuclear war.

Second To maintain a structure of government, i.e., to ensure that all aspects of government can continue to provide leadership and direct their essential services.

Third To conserve resources, i.e., to take measures which, will ensure that surviving resources are managed properly in the early post-attack period and therefore, will help the nation to recover in a more rapid and orderly manner.

5. The Radiological Defence (RADEF) organization may be involved in the achievement of all of these objectives; its specific **role** and functions are discussed in subsequent chapters. This chapter discusses the second objective: "To maintain a structure of government".

#### CONCEPT OF EMERGENCY GOVERNMENT

6. Early planning studies revealed that the degree of damage to communications, transportation and other facilities could be severe enough to result in complete or partial disruption of a centrally-oriented government organization. Therefore, it was concluded that the basic approach to ensuring continuity of government operations in a war emergency should be decentralization. Decentralization would ensure that legally constituted civilian authority was in existence, and capable of providing the necessary direction and control in whatever circumstances might result from a nuclear attack.

7. Thus, in 1958 the Government announced the intention to establish a decentralized system of emergency government. The system would be made up of central, regional, zonal and municipal elements, with the latter three having the capability and the delegated authority to act independently should there be a loss of contact with the next higher level in the chain. There would of course be some limits placed on the degree of authority delegated to the elements of the structure. For example, the conduct of overall defence of the nation and international relations remain the prerogative of the central element.

#### EMERGENCY GOVERNMENT STRUCTURE

8. The result of the decision to adopt decentralization as a concept has been the development of an emergency government structure which would come into existence upon the proclamation of the War Measures Act.

9. The country has been divided into 10 Emergency Government Regions; their boundaries coincide with the present provincial boundaries. The Regions may be further subdivided into Zones. Within each Zone, municipal emergency government elements are formed, each consisting of a group of urban and rural municipalities.

10. A line of authority will then extend from the Central element through Regions and Zones to Municipalities, with each having the power and authority to control any situation, or resolve problems as they arise, in accordance with Orders and Regulations prepared under the authority of the War Measures Act.

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### CENTRAL ORGANIZATION

11. The central emergency government element will be made up of a **small** group of federal cabinet ministers and senior departmental officials. The primary function of this "core" of federal government will be to establish and direct national policy. In order to ensure that they can continue to function, they will operate from a protective facility outside of Ottawa, referred to as the Central Emergency Government Facility (CEGF).

12. The policy making core element will require the support of operating elements of each of the major government departments. The departmental groups will provide information and technical advice to the policy-makers and oversee the execution of policy directives. These small groups of departmental officials will operate from emergency government facilities referred to as departmental Relocation Units (RUs), in proximity to the CEGF, and linked by adequate communications.

### REGIONAL ORGANIZATION

13. Within each region a similar group of facilities have been or will be provided. Regional Emergency Government Headquarters (REGHQ) will **pro-**vide protection against fallout and will be located where the danger from direct damage is considered relatively low.

14. The REGHQ will be staffed by elements of the provincial government, including the premier, some cabinet ministers, and key departmental officials, as well as local sections of federal departments including Canadian Forces personnel. A Regional Commissioner will be appointed as the senior official. He will receive advice from the provincial and federal officials and ensure the co-ordination of all operations within the region. Both the provincial and federal elements in the REGHQ will be supported by somewhat larger groups at re-location sites similar to those planned for the central facility.

### ZONAL ORGANIZATION

15. Zone boundaries were determined by consideration of such factors as population, transportation, existing local or government boundaries, and communications. Zone Emergency Government Headquarters (ZEGHQ) are generally located in basements of existing buildings which have been modified to provide fallout protection and austere accommodation for about 70 people. Elements of both federal and provincial governments will be found in the ZEGHQ.

### MUNICIPAL ORGANIZATION

16. The base of the emergency government structure is the municipal level. The role of a municipal emergency government is somewhat different to that of the other three echelons. The Central, Regional and Zonal

echelons will be concerned with overall direction and control of activities within their respective jurisdictions. The Municipal emergency governments, on the other hand, will be directly involved in the actual conduct of operations, such as the processing and care of evacuees and casualties, and in the acquisition of basic intelligence data, such as measurement of radiation levels and actual observations of damage.

17. The situation resulting from any nuclear detonation will most certainly affect many municipalities; communities many miles away may **be** subjected to radioactive fallout; operational assistance and support will also involve many adjacent municipalities. Hence, the grouping of municipalities in order to pool resources and effect co-ordination of effort. Thus the term Municipal Emergency Government encompasses something more than just the immediate geographical area of individual cities, towns or villages; the term may apply to groups of municipalities, in which emergency councils are formed. These councils are composed of representatives of all of the municipal councils involved. Such an emergency council, in the event of an emergency, would provide the authority and control for operational activities within the area.

18. The primary function of a municipal emergency government would be to direct and control survival operations; its main aim being the restoration and rehabilitation of the community.

#### MUNICIPAL EMERGENCY GOVERNMENT HEADQUARTERS (MEGHQ)

19. The Municipal Emergency Government Headquarters organization will consist of four basic elements:

- a. Executive Control Committee - composed of elected officials, representative members of the municipal council or councils. Its composition is such that a legally constituted head of government is in charge at all times.
- b. Operations and Intelligence - provide the Executive Control with the information on which decisions can be based and orders issued, translates these orders into action, and co-ordinates the activities so generated.
- c. Emergency Services - the heads of the emergency services and their senior staffs are responsible for provision of specialized advice, as well as operational control of their respective emergency services.
- d. Administrative Staff - responsible for meeting the administrative and housekeeping needs of the headquarters.



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20. Two of these elements which are directly concerned with operational activities warrant more detailed consideration; particularly their composition, function, operational responsibilities and methods of operation. Some of these factors are now discussed.

#### OPERATIONS AND INTELLIGENCE ELEMENT

21. The Operations and Intelligence element would probably be headed by the Emergency Measures planning co-ordinator who, in his capacity as senior staff officer to the executive, would direct and co-ordinate the actual conduct of operations.

22. This element must obtain and analyse information from all pertinent sources, in order to provide the Executive Control with an accurate and up-to-date picture of the situation at all times. For this to be accomplished, it will be necessary for relevant data concerning the situation which applies to each emergency service to be channelled through this element. Operations and intelligence will also oversee the execution of orders and ensure that emergency service heads are kept abreast of any changes likely to affect their particular tasks.

23. In effect, this element acts as the hub of the whole organization. Piecemeal information is fed in, digested and analysed, then passed up the line in the form of clear and meaningful intelligence reports. Back down will come decisions and orders, which are then disseminated as required; the resultant activities are monitored in order to ensure their fulfilment.

#### EMERGENCY SERVICES ELEMENT

24. The various Municipal Emergency Services are the operating elements of the organization; they will actually carry out orders and conduct operations. As previously mentioned, information from them will be essential in the making of decisions and the issuance of orders. Therefore, representatives of each service, preferably service heads or department chiefs, will be required on the staff of the Municipal Emergency Government Headquarters.

#### THE OPERATING SERVICES

25. The essential functions of those emergency services that are simply expanded versions of normal municipal departments will not change greatly in an emergency. There will no doubt be an increase in responsibility and activity but the prime role of each service will remain essentially the same.

26. The following is a list of the emergency services which will likely be required by most municipalities, though the size of each and its specific organization will depend upon the size and role of the community.

Those listed in the left-hand column will probably already exist in some form in most communities, while those listed in the right-hand column will probably have to be established. The function of each is described briefly in the succeeding paragraphs.

|                |                    |
|----------------|--------------------|
| Engineer       | Supply             |
| Fire           | Personnel          |
| Police         | RADEF              |
| Health         | Rescue             |
| Welfare        | Warden             |
| Communications | Public Information |
| Transportation |                    |

27. Engineer Service. The principal functions of this service will be the maintenance of essential utilities and the provision of engineering support to other emergency services. These responsibilities will be met by using the existing engineering and utilities services, augmented by the resources of private contractors and engineering firms. Some of the general areas of responsibility will be repair and clearance of roads; serviceability of water, sewerage and power systems; light construction and possibly demolition of damaged buildings.

28. Fire Service. The functions of this service will be as in peacetime, firefighting and fire prevention. It will probably be necessary to augment existing forces by trained auxiliaries and by obtaining additional equipment. The need for fire prevention in reception areas will be even more important than usual during an emergency, due to overcrowding, and because the consequences of fire at this time would be very serious. In damaged areas, the firefighting problem will be made more difficult by lack of water and the dangers imposed by fallen power lines, ruptured gas mains and rubble-cluttered streets.

29. Police Service. This is another service whose basic functions will not change during an emergency, merely increase in magnitude. The police service will be concerned with traffic and movement control, enforcement of emergency regulations, security of vital installations, and assistance to other services.

30. Emergency Health Services (EHS). The specific tasks of municipal emergency health services will vary depending upon the size and role of the community. However, generally they will be responsible for the provision of medical/surgical care to casualties and for ensuring that adequate public health measures are enforced. Tasks therefore include:

- a. Supporting initial first aid to casualties, as provided at the site of rescue operations by the rescue workers.
- b. Operation of Advanced Treatment Centres (ATC) close to damaged areas, where casualties are sorted and provided with sufficient care to sustain them during transportation to hospitals.

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- c. Surgical/hospital care in existing hospitals or in 200-bed emergency hospitals set up in schools or similar buildings.
- d. Operation of emergency clinics for persons in need of medical care but not requiring hospitalization.
- e. Continuation of public health measures, including supervision of water supply and waste disposal operations and control of communicable diseases.

31. Emergency Welfare Services (EWS). The emergency welfare services are an extension of the regular services. These services will probably be headed by the municipal director of welfare, with a chief for each of the individual services: lodging, feeding, clothing, registration and inquiry, and personal services. The basic operating unit is the Welfare Centre, whose function will be to provide the five welfare services to people in a Welfare Centre Area, and to provide mobile welfare teams as required for assistance to other communities.

32. Communications. The function of this service will be to provide adequate and secure communications for the MEGHQ and the various services so that these elements of emergency government can continue to function throughout the emergency.

33. Transportation. During the early stages of an emergency, municipal governments will have the use of local road transport, subject to any over-riding emergency orders and priorities. There will be a need for the Road Transport Control Organization (RTCO) to establish priorities, and for the allocation of vehicles to essential users both before and during the emergency.

34. Supply. The function of the municipal supply service will be to control the allocation and distribution to the various emergency services of municipally owned supplies, and in conjunction with the War Supplies Agency (WSA) to assist in establishing priorities, processing requisitions and procuring supplies. The WSA has been assigned full responsibility for all aspects of control over the production, distribution, and pricing of supplies for both civilian and military use, except for some aspects of the agricultural and fishing industries.

35. Personnel. The functions of this service will be to assist in co-ordinating the use and allocation of municipal personnel and in the assessment of the manpower requirements of the various emergency services. The existing municipal personnel staff will carry out this task and during the emergency will maintain close liaison with the Canadian Emergency Manpower Service (CEMS), which is the federal authority concerned with co-ordinating the use of all manpower except medical personnel and the Canadian Forces.

36. Radiological Defence. The municipal RADEF organization will have the responsibility of collecting and analysing radiological data, and then making recommendations to municipal authorities concerning the necessary remedial measures.

37. Rescue. The rescue service is concerned with the removal of injured and uninjured people trapped in damaged buildings, the rendering of first aid and the evacuation of the injured to the nearest medical installation.

38. Warden. The function of the warden service is to provide local neighbourhood leadership during any operations and assist in the dissemination of instructions and information to the public.

39. Public Information. The role of the emergency public information service will be to acquaint the public with all aspects of emergency measures regulations, and to advise and instruct them during actual emergency operations, To be effective it is necessary that any information, advice or instructions be valid and meaningful, that the source be reliable and have the respect of the public, and that use be made of all available and appropriate media.

#### CONCLUSION

40. The prime purpose of the municipal emergency government organization will be to maintain authority, provide direction and control during the period of the war emergency. This chapter has reviewed the tasks and the organization that would enable the municipality to carry out its functions and perform its tasks.

41. A Municipal Emergency Government Headquarters (MEGHQ) would contain four principal elements:

- a. Executive Control - composed of elected officials.
- b. Operations and Intelligence - to oversee the conduct of actual operations.
- c. Emergency Services - made up of existing and additional municipal departments and agencies.
- d. Administrative Staff - consisting of those responsible for the administrative and physical requirements of the headquarters.

42.. The emergency government structure, on a national scale, consists of a CEGF, 10 regions with REGHQs divided into zones or districts with appropriate headquarters and, finally, municipal groupings with MEGHQs.

CANADIAN EMERGENCY MEASURES COLLEGERADIOLOGICAL DEFENCE OFFICERSCHAPTER 2RADIOLOGICAL DEFENCE

This chapter describes the organization and operations of a provincial/municipal RADEF system.

INTRODUCTION

1. A risk study, conducted by the Defence Research Board on behalf of Canada EMO, considered many different attack patterns on US and Canadian cities and on certain important military and industrial complexes. More than a hundred different wind patterns were used to evaluate the potential distribution of fallout on Canadian territory. The results of that study are shown on the following Risk Map:

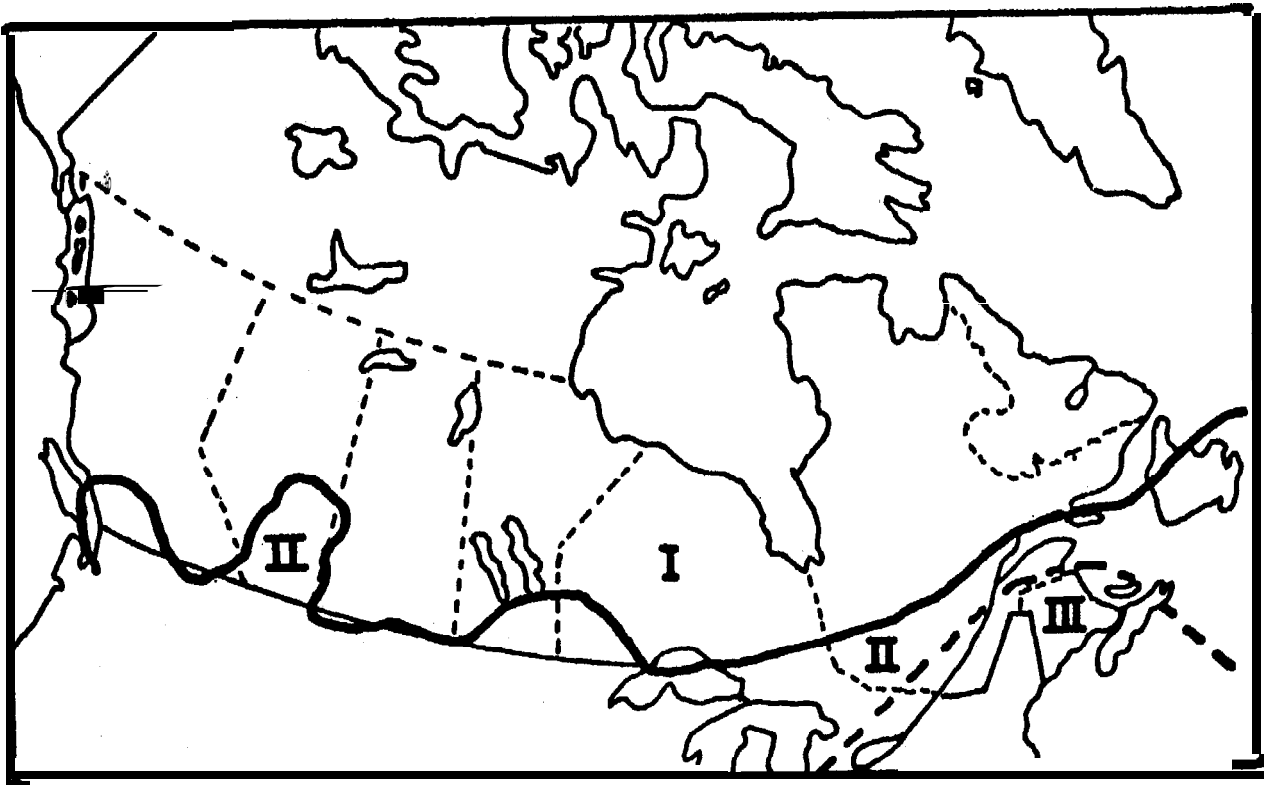


Figure 2.1 - Risk Map of Canada

2. In Risk Area III, South of the broken line, there is one chance in five that the total unprotected radiation doses would exceed 750 Roentgens (R) in six weeks, necessitating strict control of the entire population.

3. In Risk Area II, between the broken line and the solid line, there is one chance in five that some control of public activity would be required and that the 6-week dose would be less than 750 R but greater than 100 R.
4. In Risk Area I, North of the solid line, the probability of need for control of public activity is less than one in five. The total radiation dose should be less than 100 R in six weeks.
5. From these risk studies it becomes evident that most of the populated portions of Canada are likely to be subjected to fallout if North America is attacked. It is necessary, therefore, that a radiological defence system be developed which would be capable of identifying the radiation hazard and providing information to government authorities, so that they may make the decisions necessary to ensure the safety of the population.

#### ORGANIZATION

6. The facilities required to meet the needs of radiological defence are provided by a military component and a civilian component. As these two information-gathering agencies operate differently, it is convenient to discuss them separately up to the operational level at which they begin to function as a composite unit, that is at the REGHQ.
7. The Department of National Defence (DND) is assigned the responsibility for providing predicted and actual patterns of fallout, in Privy Council Order 1965-1041. In order to execute this responsibility, DND has taken action to obtain radiation measurements from all of their military bases and, also, to use aircraft to perform aerial radiation monitoring. All radiation measurements obtained by the military component will be relayed to the respective REGHQs via the Canadian Forces Communications System (CFCS). At the REGHQ this data plus the data obtained from civilian sources will be displayed and analysed by an integrated civilian and military staff.
8. The civilian component of the system, referred to as the Provincial/Municipal Radef System, is based on the municipal emergency measures organizations and will, in general, function as follows:
  - a. Approximately 12,000 monitoring posts will report radiation data to some 400 MEGHQs, which will analyse the local situation.
  - b. The MEGHQs will report to their next higher headquarters who in turn will provide analysed data to the REGHQs.

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MONITORING POSTS

9. The monitoring posts will be manned by civilian volunteers who will be trained in their duties by monitor instructors and radiological defence officers.

10. Monitoring posts will normally be approximately half a mile apart in urban cores, one mile apart in urban areas and ten miles apart in open country. The posts must provide good protection for the monitors, have communications to the MEGHQs and be provided with the necessary monitoring equipment. Monitoring procedures are described in the publication "A Guide for Provincial/Municipal Radiological Defence Systems".

HEADQUARTERS STAFFS

11. The RADEF staffs at MEGHQs will consist of Radiological Defence Officers (RDOs), analysts and plotters, and in the large Urban municipalities of Radiological Scientific Officers (RSOs). Reports from monitoring posts will be plotted, analysed and interpreted by these staffs and passed to the decision-making authority in their MEGHQs. Decisions made at this level would then be passed to the public via the broadcasting network. If conditions are such that decisions cannot be made at the local level, the problem will be relayed to the ZEGHQ for co-ordinated action.

12. Selected information about the local radiation situation will be passed up to the ZEGHQs by the RADEF staffs at the MEGHQs. This will enable the ZEGHQs to develop their own overall analyses of the situations throughout their zones. Each ZEGHQ will, therefore, be able to effectively oversee and co-ordinate operations affecting several municipalities at once.

13. Some data will also be passed to REGHQs by ZEGHQs. REGHQs will thereby receive consolidated reports from all municipalities and zones under their jurisdiction as well as reports from the military agencies located in their region. The collation of all this information at the REGHQ will be carried out by an integrated staff consisting of plotters and monitors from the DND component and analysts, RDOs and RSOs provided by the province. This staff will normally form part of the joint operations and information (OPINFO) staff, to which is added damage estimation and resource analysis personnel. This group provides briefings to governmental executives and maintains an up-to-date display of the situation.

14. Information collated at the REGHQs will then be passed to the CEGF, where an integrated staff also exists.

15. The training of the Monitors and Monitor Instructors is carried out within the municipalities to the number required locally. Three monitors per post are required, to ensure 24-hour coverage and spares. The Analyst will be trained locally by the RSO or RDO.

16. The RSOs and RDOs are trained at the Canadian Emergency Measures College. Course material and training standards are available to provinces by Canada EMO, to enable them to carry out their own RDO training programs. The duties and responsibilities of RDOs and RSOs are described in "A Guide for Provincial/Municipal Radiological Defence".

17. The RADEF sections in the various headquarters will require facilities for the receipt, display and analysis of all radiological information. For this purpose they will require maps, charts, display areas, communications facilities and work rooms in the MEGHQs, ZEGHQs, REGHQs, RUs and the CEGF.

18. From time to time the provinces will test their local, zone or district and regional organizations by means of exercises in order to evaluate their organizational and operational procedures and their communications systems. Periodically, US/Canada exercises are also held, to test cross-border information exchange procedures.



CANADIAN EMERGENCY MEASURES COLLEGERADIOLOGICAL DEFENCE OFFICERSCHAPTER 3RADIOLOGICAL EFFECTS OF NUCLEAR WEAPONS

This chapter describes the characteristics of nuclear radiations: the origin, distribution and characteristics of radioactive fallout from nuclear weapons; and the principles of protection against the radiation hazards resulting from radioactive fallout.

ORIGIN OF NUCLEAR RADIATIONS

1. All matter consists of combinations of a limited number of chemical elements, such as Hydrogen, Oxygen, Carbon, etc. The smallest particle of an element which exhibits its chemical properties is called an *ATOM*. Atoms in turn, are made up of sub-atomic particles called protons, neutrons and electrons. The number of protons in the nucleus is equal to the number of orbital electrons.

2. With the single exception of hydrogen in its simplest form, all atomic nuclei contain neutrons as well as protons. The lighter elements tend to have approximately equal numbers of neutrons and protons; the heavier elements have more neutrons than protons. The number of neutrons in the nucleus may range from zero to almost 150.

3. Isotopes. In certain elements it is found that different atoms of the same element have the same number of protons but vary in the number of neutrons. These variants are called *ISOTOPES*. To the nuclear physicist and the physical chemist, these are different forms of the same element differing only in the number of neutrons in the nucleus. Many of the isotopes are stable. Some of the isotopes are unstable, and therefore *RADIOACTIVE*.

4. The ratio of neutrons to protons within the nucleus of the atom largely determines the stability of the atom. The protons being positively charged tend to repel each other. The repulsive force is counteracted however, by a nuclear attractive force.

5. Very little is known about this force. However, it is known that for elements which have relatively low atomic weights, nuclear stability occurs when the number of protons and neutrons are nearly equal. For example, Hydrogen, the simplest of all atoms, is found in three forms (isotopes). They are usually referred to as Hydrogen, Deuterium and Tritium. From Table 3.1, we find that tritium, which has 2 neutrons to 1 proton, is unstable, i.e., radioactive.

| TABLE 3.1 - ISOTOPES OF HYDROGEN                  |         |          |           |                           |
|---|---------|----------|-----------|---------------------------|
|   | Protons | Neutrons | Electrons | State                     |
| Hydrogen ${}_1\text{H}^1$                         | 1       |          | 1         | Stable                    |
| Deuterium<br>${}_1\text{H}^2$ or ${}_1\text{D}^2$ | 1       | 1        | 1         | Stable                    |
| Tritium<br>${}_1\text{H}^3$ or ${}_1\text{T}^3$   | 1       | 2        | 1         | Unstable<br>(Radioactive) |

6. Radioactivity. An unstable atom will eventually achieve stability by spontaneous emission of energy and/or particles from its nucleus. This process is known as *RADIOACTIVITY*. It may be the natural decay of unstable isotopes which occur in nature or it may be as the result of artificial radioactivity caused by man. In each case the nucleus is in the unstable or excited state, having an excess of energy which will be *radiated* allowing the nucleus to achieve a stable state.

*RADIOACTIVITY is the spontaneous disintegration of unstable nuclei with the resulting emission of NUCLEAR RADIATION.*

7. Radiation. Radiation is the conveyance of energy through space. Everyone is familiar with the radiation of heat from stoves, light from electric lights and the sun, and the fact that some kind of energy is received by our radio and television sets. The radiation of energy from radioactive materials is comparable to these familiar forms.

#### NATURE OF NUCLEAR RADIATIONS

8. The principal nuclear radiations are *Alpha Particles, Beta Particles, Gamma Radiation, and Neutrons.*

9. Alpha Particles. *Alpha* particles are comparatively large, heavy particles of matter which have been ejected from the nucleus with high velocity. They consist of two neutrons and two protons (i.e., a helium nucleus stripped of its electrons) and carry a net positive charge of two.

Because of its relatively high mass, the *alpha* particle has a very short range and little penetrating power. *Alpha* particles are completely absorbed in an inch or two of air and do not penetrate the unbroken skin.

10. Beta Particles. *Beta* particles are identical to high speed electrons. They carry a negative charge of one and are extremely light. *Beta* particles have a maximum range of a few yards in air and will just penetrate the skin.

11. Gamma Radiation. *Gamma* rays, like X-rays, are a type of electromagnetic radiation (pure energy). They have no measureable mass or electrical charge. *Gamma* radiation can travel great distances (hundreds of feet) in air and penetrate considerable thicknesses of material.

12. Neutrons. *Neutrons* are not encountered in natural radioactive decay but are released by the fission and fusion reactions. They have no electrical charge, but can induce radioactivity in other atoms. They have considerable powers of penetration and a fairly great range in air.

TABLE 3.2 - COMPARISON OF NUCLEAR RADIATIONS

|          | Type     | Relative Mass | Charge | Range In Air     | Penetrating Power                           |
|----------|----------|---------------|--------|------------------|---|
| Alpha    | particle | 4             | ++     | 1 or 2 inches    | slight, stopped by a sheet of paper         |
| Beta     | particle | 0.000549      | -      | few feet         | moderate, stopped by thin sheet of aluminum |
| Gamma    | energy   | 0             | 0      | hundreds of feet | highly penetrating                          |
| Neutrons | particle | 1             | 0      | hundreds of feet | highly penetrating                          |

13. The unit used in measuring gamma and X-radiation is called the Roentgen (R). It is an expression of the ability of gamma or X-radiations to ionize air.

14. Some instruments measure the *total* amount of radiation, in R, received during a period of exposure. Others are designed to give the *dose-rate*, in Roentgens per hour (R/hr), at which radiation is being received. The two types of information must not be confused. They are analogous to the two types of information furnished by the speedometer in a car, *distance* (miles) and *speed* (miles per hour).

#### NUCLEAR RADIATIONS FROM WEAPONS

15. Nuclear radiations from nuclear weapons are described in two categories:

- a. *Initial Radiation*: the radiations emitted within the first minute after the detonation.
- b. *Residual Radiation*: the radiations emitted over the succeeding minutes, hours, days, weeks and years.

16. Initial Radiation. The significant components of initial radiation are gamma radiation and neutrons. Alpha and beta particles, because of their very short range in air, do not contribute to initial radiation. Most of the neutrons and part of the gamma rays are emitted in the actual fission process, that is, simultaneously with the explosion. The remainder of the gammas are produced in various secondary nuclear processes, including decay of the fission products.

17. The line of demarcation between initial and residual radiation, i.e. 1 minute after the explosion, is based upon the assumption that by this time the fireball will have risen high enough that the distance will exceed the effective range of the radiations.

18. The effective range of the initial radiation is only about 2 or 3 miles. As this is well within the range of severe blast and thermal damage for yields of 1 megaton and more, *THE EFFECTS OF INITIAL RADIATION, ARE CONSIDERED INSIGNIFICANT FOR HIGH YIELD WEAPONS*. The remainder of this chapter is, therefore, devoted exclusively to discussion of the residual radiation problem.

19. Residual Radiation. Sources of residual radiation are:

- a. *Unfissioned weapon fuel* (uranium or plutonium); emits alpha particles.
- b. *Substances made radioactive by neutron capture*; emit beta particles and gamma radiation.
- c. *Mixed fission products*, emit beta particles and gamma radiation.

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20. Fission products are the greatest contributors to residual radiation. For practical purposes residual radiation can be considered to be due entirely to fission products.

21. The residual radiations become a hazard to man when the mixed fission products (the source of the residual radiations) are deposited on the earth's surface in significant amounts, i.e. when they contaminate man's environment. This deposition of radioactive material upon the earth's surface is referred to as *RADIOACTIVE FALLOUT*.

#### ORIGIN AND DISTRIBUTION OF RADIOACTIVE FALLOUT

22. The story of radioactive fallout begins in the fireball, right after the moment of the detonation. While the fireball is still luminous, the temperature, in the interior at least, is so high that all the weapon materials are in the form of vapour. This includes the radioactive fission products, unfissioned bomb fuel, the weapon casing, etc. As the fireball increases in size and cools the vapours condense to form a cloud containing solid particles of weapon debris.

23. Quite early in the ascent of the fireball, cooling of the outside and the drag of the air through which it rises brings about a change in shape. The roughly spherical f&m becomes a toroid (or doughnut) although this shape and its motion are often hidden very quickly by the cloud.

24. Depending on the height of burst and the nature of the terrain, a strong updraft with inflowing winds, called *after-winds*, is produced in the immediate vicinity. These after-winds can cause dirt and debris to be sucked up from the earth's surface into the radioactive cloud.

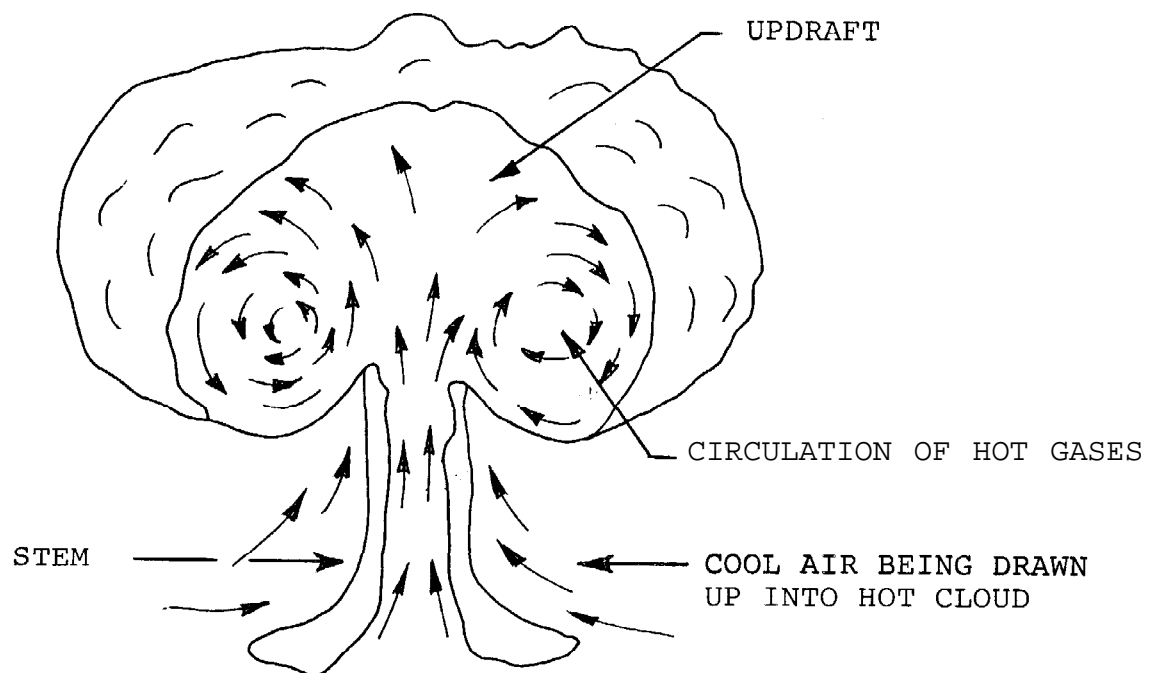


Figure 3.1 - Cutaway of Circulation Within Cloud

25. In a *high air burst*, little surface material is drawn up into the cloud. In *lower air bursts*, although the after-winds may draw up dirt and surface debris, only a relatively small proportion of the dirt particles become contaminated with radioactivity, as they do not mix with the fission products while they are still vaporized.

26. In the case of a surface *burst*, however, large quantities of earth or water enter the fireball at an early stage and are fused or vaporized. When sufficient cooling has occurred, the fission products and other radioactive residues become incorporated with earth particles as a result of the condensation of vaporized fission products onto fused particles of earth, etc.

#### EARLY AND DELAYED FALLOUT

27. As the rising fireball cools and stabilizes as the typical mushroom cloud, the condensed particles begin to respond to gravity and the winds. Large particles *fall* out of the cloud and descend rapidly back to earth, while the smaller particles are carried by the winds, settling very slowly to the ground.

28. It is convenient to consider radioactive fallout in two parts: *early* and *delayed*. *EARLY FALLOUT* is defined as that which reaches the ground during the first 24 hours following a nuclear detonation. It consists of large particles of visible size and is capable of producing radioactive contamination over large areas with intensities great enough to represent an immediate biological hazard. From land surface bursts, early fallout may bring down from 50 to 70% of the total residual radioactivity. Early fallout is sometimes referred to as *local* fallout.

29. *DELAYED FALLOUT*, which is that arriving after the first day, consists of very fine, invisible particles which settle in low concentrations over a considerable portion of the earth's surface. It is sometimes referred to as *global* or *world-wide* fallout. In delayed fallout, the radiation from the fission products and other substances is greatly reduced in intensity as a result of radioactive decay during the relatively long time the fallout remains suspended in the atmosphere. Because of these characteristics, the radiations from delayed fallout generally pose no immediate danger to health, although there may be a long term hazard.

30. Any burst which injects fission products into the atmosphere, i.e. high altitude, air, surface, and shallow subsurface bursts, may contribute to delayed fallout. However, only surface burst (or near surface burst) will result in early radioactive fallout. Only early fallout will result in high radiation intensities sufficient to cause an immediate hazard to man and other living things.

31. The differences between early and delayed fallout are summarized in the following table:

| TABLE 3.3 - COMPARISON OF EARLY AND DELAYED FALLOUT                  |  |
|--|--|
| Early Fallout  | Delayed Fallout  |
| Arrives within 24 hours after explosion.                             | May take days, weeks or months.  |
| Within a few hundred miles of Ground Zero.                           | Diffused over large fraction of earth's surface.   |
| From landburst mostly visible particles.                             | Submicroscopic particles.  |
| Radioactivity very high.   | Most of activity has decayed before arrival.   |
| An acute survival problem.   | A long term problem.   |
| Mainly an external hazard, from whole body <i>gamma</i> irradiation. | Hazard results mainly from ingestion and subsequent internal beta irradiation from elements fixed in the body. |
| May prohibit access to an area.                                      | Will not prohibit access to any areas.   |
| Contaminated articles may be unsafe to handle.                       | Contaminated articles safe to handle with minimal precautions.   |

#### METEOROLOGY AND EARLY FALLOUT

32. The height of the nuclear cloud and its dimensions at the time of stabilization are mainly functions of the total energy yield of the weapon. The amount of radioactivity is related to the fission yield. Physical size of the fallout particles is governed by the height of burst. The subsequent distribution of the fallout on the ground is determined by the meteorological conditions (i.e. direction and speed of the winds) prevailing at the time.

33. Discussion of the fallout distribution requires reference to three particular layers of the earth's atmosphere:

- a. The *TROPOSPHERE*, the turbulent layer closest to the earth.

- b. The *STRATOSPHERE*, the next, more stable layer.
- b. The *TROPOPAUSE*, a boundary layer between the troposphere and stratosphere.

34. The tropopause, in our latitudes, occurs at about 35,000 feet, somewhat higher in summer and lower in winter. All weather, as we know it on the earth's surface, occurs within the troposphere, below the tropopause. Clouds from kiloton (**Kt**) range weapons will tend to be confined within the troposphere, whereas megaton (Mt) range clouds, being much more buoyant, will punch through the tropopause into the stratosphere. The stronger, more consistent winds of the stratosphere, then, will exert the first and most significant influence on the distribution of fallout from high yield weapons.

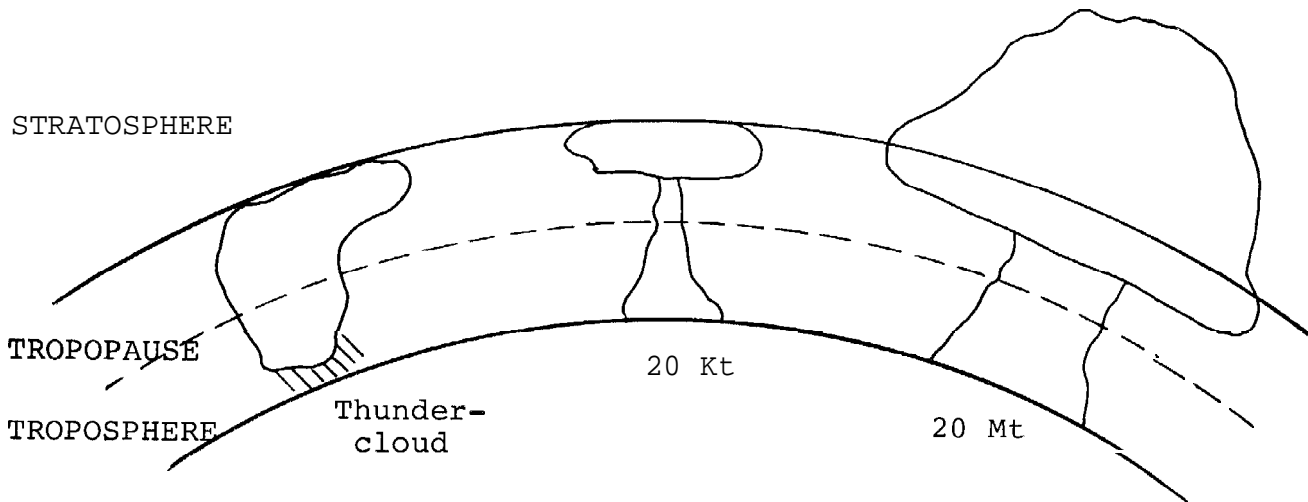


Figure 3.2

35. The effect of particle size, height and winds on fallout distribution are illustrated in Figures 3.3 and 3.4.



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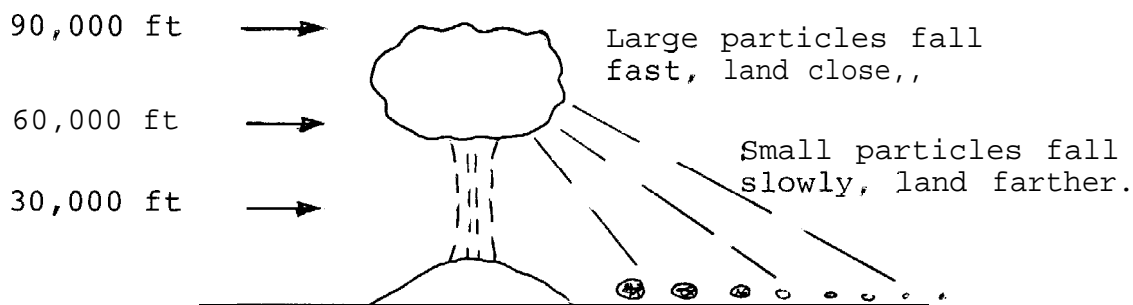


Figure 3.3 - EFFECT OF PARTICLE SIZE (Wind & Initial height assumed constant)

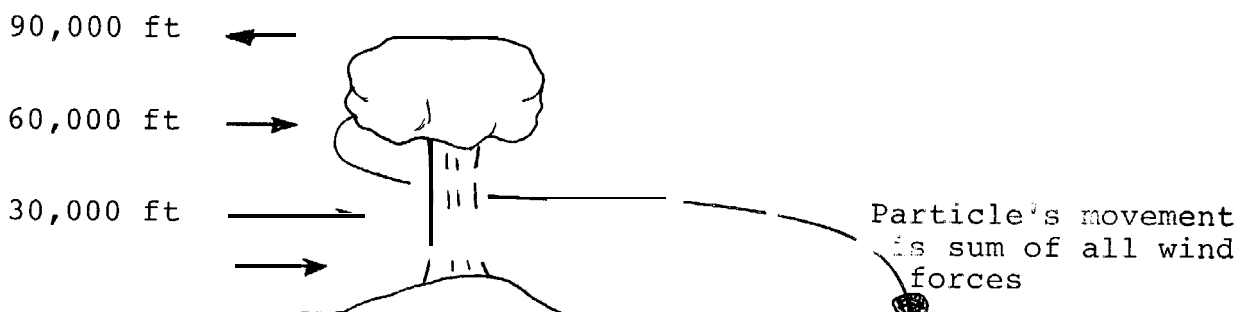


Figure 3.4 - EFFECT OF VARIABLE WIND (Particle size & initial height assumed constant)

36. As may be seen in Figure 3.4, a particle falling from a given height will be affected by the directions and speeds of all the winds from that height down to the surface. The fallout pattern which is ultimately produced on the ground following a burst, then, is the net result of particles of various sizes, originating at various heights within the nuclear cloud, having been affected by the winds at the various levels on their way down to the surface. The process is very complex but, generally, if the winds at the various levels are strong one could expect a long narrow fallout pattern, whereas, a short broad pattern would result if the winds were light or if wind directions at the various altitudes differed widely.

37. Actual fallout patterns tend to be very irregular, however, the general shape and dimensions can be illustrated by idealized patterns, as in Figure 3.5.

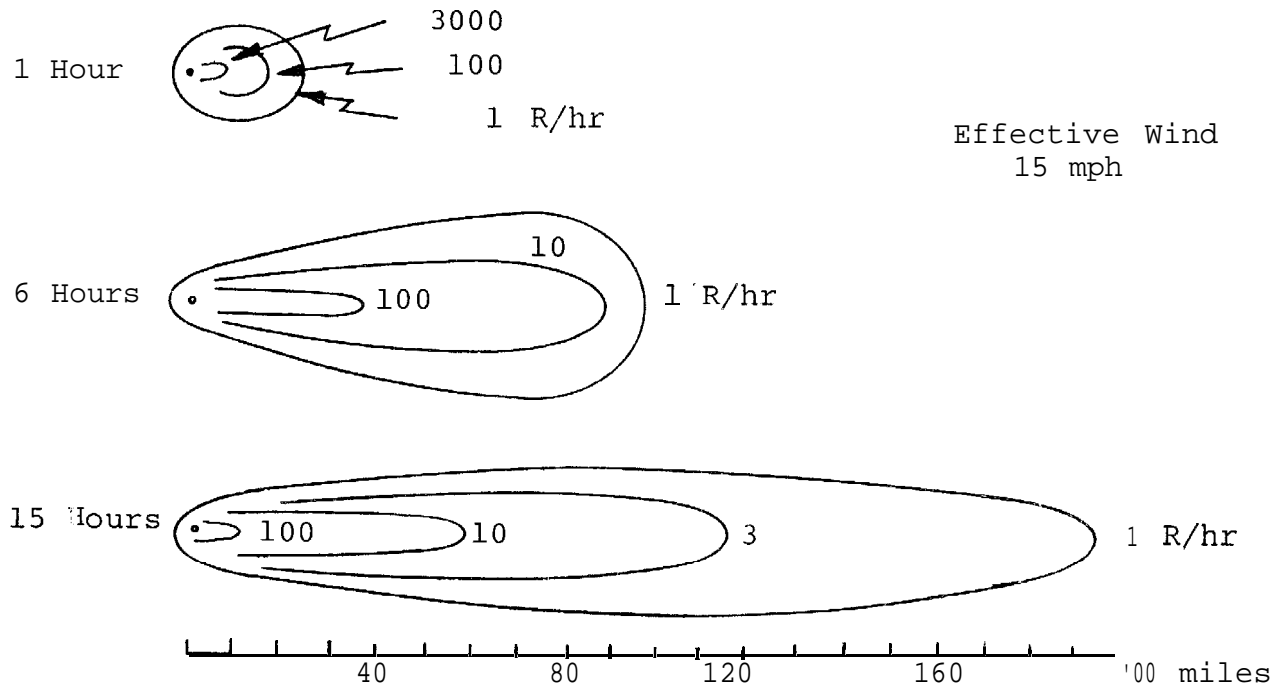


Figure 3.5 - Idealized dose-rate contours from early fallout at 1, 6, and 18 hours after a surface burst with 1 Mt fission yield (15 mph wind).

38. Because so many variables bear upon the whole process of fallout production and distribution, precise prediction of exact radiation levels from a given burst is not feasible. However, the general process is understood and it is possible, if the approximate yield and the general location of a burst are known and pertinent meteorological data is available, to predict the area in which fallout will likely occur. This type of prediction is necessary for fallout warning purposes. The technique of fallout prediction is discussed separately.

#### PARTICLE CHARACTERISTICS

39. The processes which lead to the production of radioactive fallout and its subsequent deposition on the ground have been discussed. Attention is now directed to the characteristics of the particles themselves, the radiation hazards which result, and the principles of protection.

40. Depending on the time of day and the condition of the atmosphere (rain, fog or haze), the early fallout would probably be seen as it approached, much in the manner of a rain, snow or dust storm. If sufficient fallout were deposited for it to be dangerous, anyone looking for it would see it either as it came down or as it accumulated on such surfaces as automobiles, sidewalks, streets or window ledges. *Although the radiations emitted by the fallout are invisible, the fallout itself is not; it is made up of real, tangible particles that would be very difficult to ignore, especially if enough were around to be dangerous.*

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41. Early fallout can be visualized as being like sand (particle sizes range from powdered sugar to coarse sand). Sand in the proper size range is considered so close a physical approximation that it is used as a fallout simulant in research studies. Fallout from Pacific tests has been white. Nevada fallout was generally darker. War-produced fallout, like weapon-test fallout, would probably be a mixture of sharp-edged irregular particles and spherical particles with smooth surfaces; its colour would be derived from the material over which the burst had occurred, probably in the brown-grey-black categories.

42. To produce a radiation intensity of 3000 R/hr at one hour after detonation, a layer of fallout averaging 1/64 to 1/16 inch thick would be required. It would weigh about 1.5 tons per acre or about 1000 tons per square mile.

43. After fallout has been deposited it is subject to natural forces which may cause it to migrate. Winds sweeping over relatively smooth surfaces redistribute the fallout against curbs, buildings and other obstructions. This accumulation of material against surface irregularities should make the presence of fallout apparent to any observer.

#### RADIOACTIVITY AND DECAY OF EARLY FALLOUT

44. The fallout particles, as stated earlier, consist of a mixture of surface materials and mixed fission products (the principle source of residual radiation). These *mixed fission products* constitute a very complex mixture of over 200 isotopes (forms) of 36 elements. Most of these isotopes are radioactive, decaying by the spontaneous emission of beta particles and *gamma* rays.

45. The emission of radiation from radioactive substances, such as the fission products, is a gradual process. It takes place over a period of time, at a rate depending upon the nature of the material. Because of the continuous decay, the quantity of the radioactive material and the rate of emission of radiation decrease steadily. The total radioactivity of the fission products initially is extremely high but falls off at a fairly rapid rate as the result of radioactive decay.

46. The rate of decay of individual isotopes is described in terms of *half-life*, the time required for the isotope to lose half of its activity through radioactive decay. Half-lives vary widely, from a fraction of a second to hundreds of years. Because the fission products consist of such a complex mixture of isotopes, with a wide range of individual half-lives, the term *half-life* is not used to describe the total decay. A simple rule is used to describe the rate at which the intensity (or dose-rate) of the radiation emitted by the fission products decreases with time. This rule is known as the *7:10 RULE* and is stated as follows:

FOR EVERY SEVEN-FOLD INCREASE IN TIME THERE WILL BE A TEN-FOLD DECREASE IN THE RADIATION INTENSITY.

47. For example, if the radiation dose-rate at one hour after an explosion (H + 1 hr) was 1000 R/hr, according to the 7:10 rule, the subsequent dose-rates would be in accordance with the following table:

| TABLE 3.4 - EXAMPLES OF APPLICATION OF 7:10 RULE |                      |
|--|----------------------|
| Time After Burst                                 | Radiation Dose-rate  |
| H + 1 hr   | 1000 R/hr            |
| H + 7 hrs (7 x 1)                                | 100 R/hr (1000 ÷ 10) |
| H + 2 days (7 x 7 hrs = 49 hrs)                  | 10 R/hr (100 ÷ 10)   |
| H + 2 wks (7 x 2 days = 14 days)                 | 1 R/hr (10 ÷ 10)     |
| H + 3 mos (7 x 2 wks = 14 wks)                   | 0.1 R/hr (1 ÷ 10)    |

48. The fact that the radiation intensities decrease with time, and the additional fact that the decrease is very rapid during the first few hours and days, can be applied in a very useful manner in actions designed to minimize radiation exposure, as will be seen later in this chapter in the section about "protection".

#### HAZARDS OF EARLY FALLOUT

49. It is convenient to consider the radiation hazards arising from early fallout in 3 categories:

- a. *External.* Whole body irradiation by *gamma* radiation emitted by sources (fallout particles) outside the body. Radiation sickness or even death may result.
- b. *Contact.* Irradiation (mainly by *beta*) of the skin and other outer body tissues as a result of direct contamination of exposed skin surfaces. Skin lesions (beta burns) may result.
- c. *Internal.* Direct irradiation of internal body tissues by sources inside the body, as a result of ingestion of radioactive material.

50. Of the three, the *external gamma hazard* is by far the most significant, as the whole body is involved and the results can be sickness or death if the exposure is great. *Contact* injury by beta is not instantaneous; brushing or washing off the fallout particles will easily

reduce or eliminate the hazard. For the *internal* hazard to be significant a person would have to build up a body burden of radioactive material by consuming significant quantities over an extended period of time; the present feeling is that this is unlikely to occur.

51. These hazards and their biological effects will be discussed separately. The remainder of this paper is devoted to discussion of the principles of protection against the external gamma hazard.

#### PROTECTION FROM EXTERNAL RADIATION

52. Protection against the gamma radiation from early fallout involves the application of three factors:

- a. *Distance*
- b. *Shielding*
- c. *Time*

53. Each of these is discussed separately here but in actual application the factors are usually used in combination.

54. *Distance*. It is a known fact of physics that radiations emitted from a point *source* (e.g. a single fallout particle) are radiated uniformly in straight lines in all directions, diverging with distance, as illustrated in Figure 3.6.

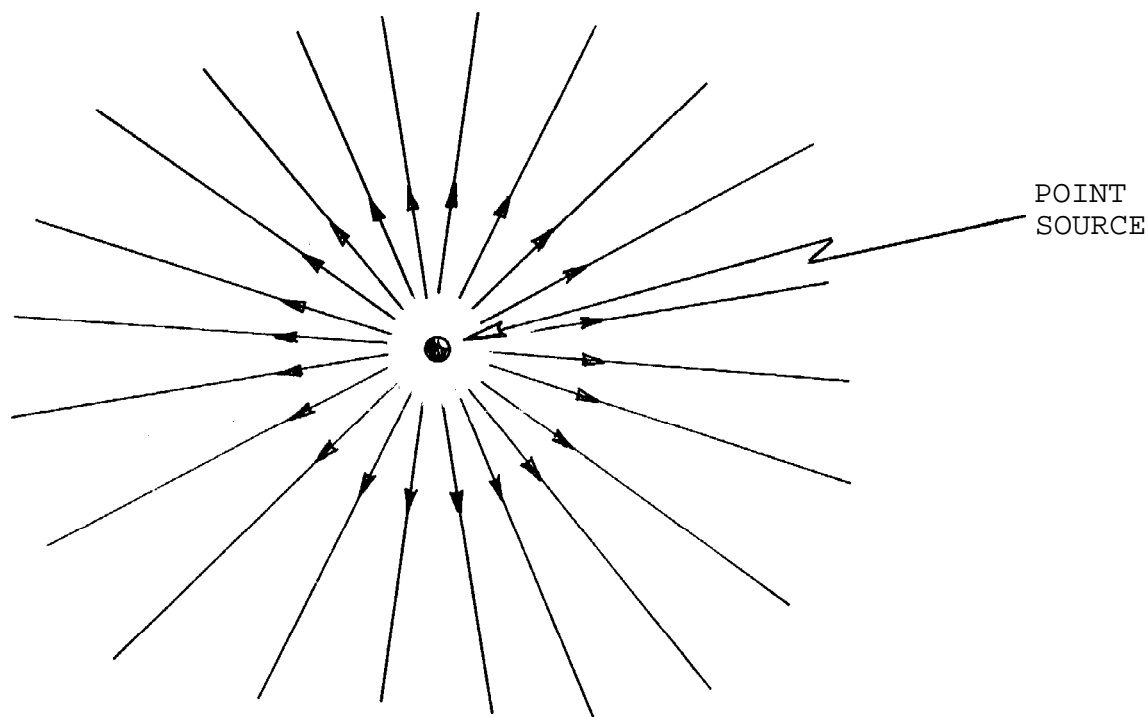


Figure 3.6 - Emission of radiation from a point source.

55. As a result, the number of rays incident upon a given surface decreases with distance.

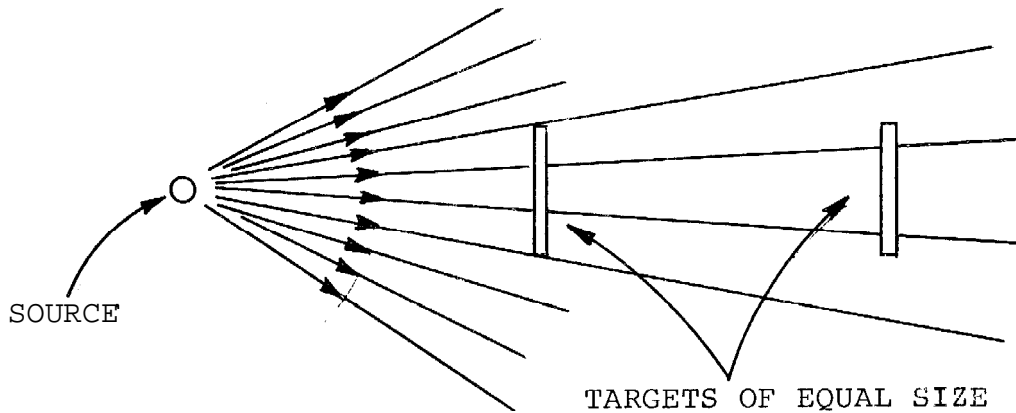


Figure 3.7 - Decrease of radiation with distance from a point source.

56. This decrease of radiation intensity with distance is in accordance with an inverse square law.

57. In the case of radioactive fallout, however, millions of individual point sources are involved. They become distributed upon horizontal surfaces, such as the ground, roofs, etc., creating a series of *CONTAMINATED PLANES*.

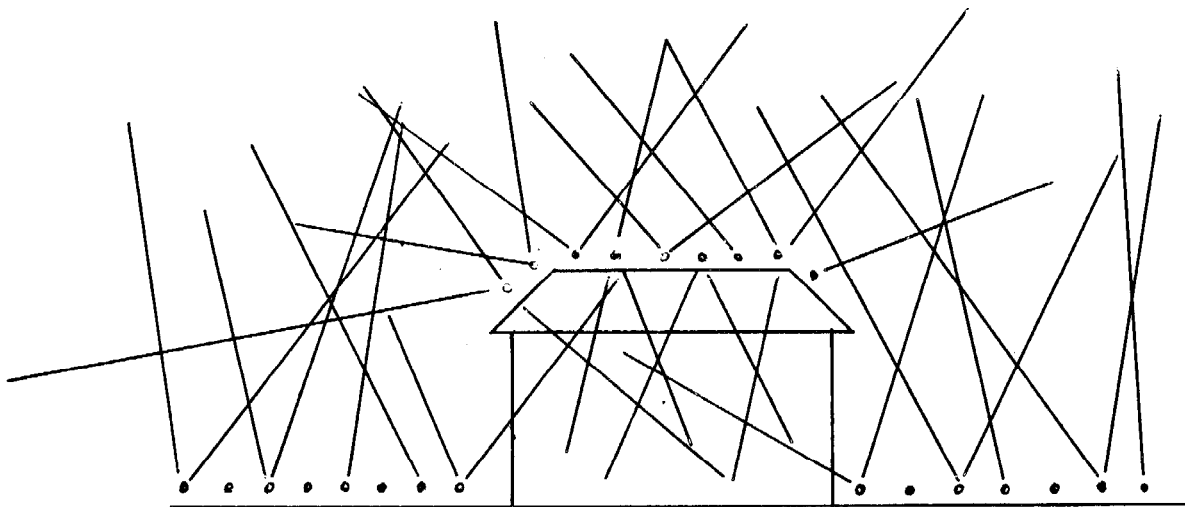


Figure 3.8 - Deposition of fallout on horizontal surfaces.

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58. The decrease of radiation intensity with distance from a contaminated plane is not as simple a relationship as that of a point source, but there is a decrease and it *is* significant.

59. The relationship between radiation intensity and distance for a contaminated plane may be clarified by consideration of the following situation:

- a. A man stands in the centre of a uniformly contaminated plane of infinite dimensions.
- b. The radiation dose he receives will be the sum of the contributions from all of the individual sources distributed across the contaminated plane.
- c. As the intensity of radiation is highest close to a single source and decreases with distance (as per para 55 above), the sources closest to him will contribute more to his radiation dose than those farther away.
- d. Figure 3.9 shows that 50% of his dose comes from the sources lying within 50 feet, a further 25% comes from sources in the wider belt extending on out to 200 feet, and the remaining 25% from sources more than 200 feet away.

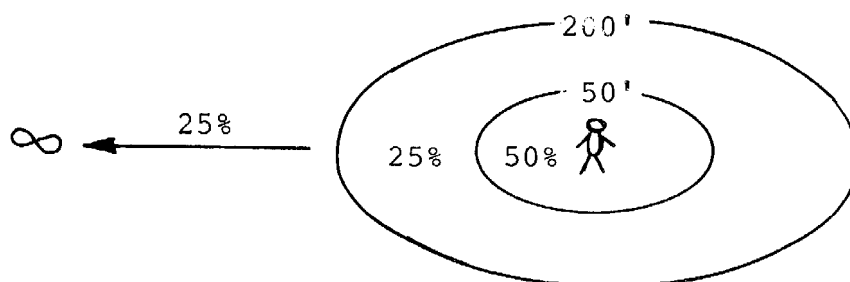


Figure 3.9 - Dose contributions from an infinite plane.

60. A corollary of this (i.e., that the closest sources contribute most significantly to the total radiation dose) is that, if an uncontaminated strip can be created around an individual, a significant portion of his potential dose can be prevented.

61. Similar results can be obtained by moving the individual some distance from the contaminated plane, e.g., upstairs in a multistorey building where he is some distance above the contaminated plane.

62. *Shielding*, As a beam of gamma radiation passes through a slab of any material, some of it will be attenuated or absorbed within the material. This results from interactions between some of the gamma rays and the atoms of matter of which the slab is composed.

63. The amount of gamma absorbed by a given shielding material depends upon:

- a. *The density of the material*, i.e., the number and size of the atoms of which it is composed.
- b. *The thickness of the material*, i.e. the number of atoms placed in the path of the gamma.

64. Figure 3.10 shows the relative efficiency of certain shielding materials. These materials are efficient in about the proportions shown in stopping the same amount of gamma.

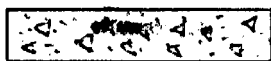
LEAD



STEEL



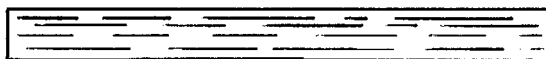
CONCRETE



EARTH



WATER



WOOD

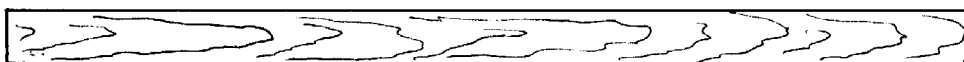


Figure 3.10 - Relative efficiencies of shielding materials



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65. Various shielding materials are used in various applications, depending upon the purpose to be served. Lead, for instance, is quite compact and is most suitable where space requirements are a factor. On the other hand, it is quite expensive and where space is not a critical factor, greater thicknesses or another more common material such as concrete may be more economical.

66. *Time.* Disregard, for a moment, the decay of the radioactive materials in fallout and consider a case where an individual stays in an area where the dose-rate remains constant at 10 R/hr. In one hour, he would be exposed to 10 R of radiation, If he stayed 2 hours he would accumulate a dose of 20 R ; 30 R for a 3 hour period: 40 R for a 4 hour exposure, and so on. Thus, time could be used as a protective measure - by keeping the exposure time to a minimum, the radiation dose would be minimized. For instance, if a job must be done in a high radiation area, the work should be carefully planned so that *stay time* in the contaminated area is minimized.

67. As discussed earlier in this paper, the decay of the radioactive materials will cause the radiation levels from fallout to decrease with time. In the early periods after detonation, the decrease in dose-rates is very rapid. At later times, the decrease is not as rapid because the longer lived fission products make the major contribution to the dose-rate. Knowledge of the general decay pattern of radioactive fallout suggests an additional way in which time is important. All activities in contaminated areas should be postponed as long as practicable in order to permit the radiation levels to decrease.

68. The time factor, then, may be applied in two ways:

- a. By limiting exposure time.
- b. By delaying commencement of exposure.

#### FALLOUT SHELTER

69. The simplest application of the three factors: distance, shielding and time is the *fallout shelter*. In a fallout shelter, protection is achieved by placing a barrier between the fallout field and the individual and secondly by increasing the distance between the fallout field and the individual.

70. The heavier the barrier between the fallout and the individual, the greater the protection effect.

71. The protection afforded by the principle of distance depends on:

- a. *The size of Contaminated Plane.* If the size of the contaminated area around a building was restricted, say by the presence of other buildings, the radiation levels inside the building would be less than one would expect from an infinite plane.
- b. *The distance from Contaminated Plane.* In a multistory building, one would receive less radiation from ground contamination on upper floors than at street level. However, increased radiation from roof contamination would be experienced as one moves higher in the building.

72. The effect of shielding and distance are combined into a term very useful for considering the effectiveness of various types of shelters. This term is *PROTECTION FACTOR (PF)*. The precise definition is: *the relative reduction in the amount of radiation that would be received by a person in a protected location, compared to the amount he would receive if he were unprotected.*

73. If a shelter has a PF of 100, an unprotected person would be exposed to 100 times more radiation than someone inside the shelter.

#### DELAYED FALLOUT

74. This subject is not discussed in detail in this paper as the problems which may arise are not really within the purview of the RADEF system. The hazards arising from *delayed fallout* are mainly associated with the possible introduction of certain long-lived radioisotopes into the food chain.

75. Certain of these isotopes may be metabolized by the body and concentrate in certain parts of the body. For instance, Strontium-90 behaves like Calcium and may become fixed in the bones. Long-term consumption of contaminated foods could lead to the build-up of a body burden of one or more such isotopes and some form of hazard may result.

76. The hazards which accrue, however, are not immediate hazards to health. Rather, they are late physical or genetic hazards, i.e., they may result in shortened lifespan or affect future generations.

77. The present official attitude regarding the use of food and water during the emergency period is as follows:

- a. As a general rule, if an area is safe for human habitation (that is, if the external gamma radiation levels are tolerable!) then food and water can be used.

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- b. If normal hygienic practices are followed in food preparation, this should eliminate any gross contamination. (Seriously contaminated foods would probably be gritty, and one would tend to reject them on these grounds.)

78. The hazards from delayed fallout are of a long-term nature, in contrast with those from early fallout. Delayed fallout and its associated hazards will be of possible concern to food production and health agencies, not directly to RADEF.

#### SUMMARY

79. a. Two types of radiation effects may result from nuclear detonations: *initial radiation* and *residual radiation*.
- b. *Initial radiation* from high yield weapons is not considered significant, because of its limited range in relation to blast and heat.
- c. The *residual radiation* problem, in the form of radioactive fallout, may be serious.
- d. Two forms of radiation result, beta and *gamma*.
- e. *Gamma*, which has considerable range in air and is highly penetrating, constitutes the principal threat to health.
- f. It will constitute a threat if large amounts of the radioactive material are brought down to earth within a few hours after the burst, i.e., as *early fallout*.
- g. Knowledge of the mechanics of fallout production and distribution will allow us to predict generally when and where early fallout will occur, i.e., *fallout prediction is, to a certain extent, possible*.
- h. By application of the three factors: *distance, shielding* and *time*, protection from the gamma radiation threat can be obtained.



CANADIAN EMERGENCY MEASURES COLLEGERADIOLOGICAL DEFENCE OFFICERSCHAPTER 4FALLOUT PREDICTION

This chapter gives a general description of the method of fallout prediction used by the federal and provincial warning centres, and details the procedure for decoding the fallout warning message and preparing the associated plots.

INTRODUCTION

1. DND is responsible for fallout prediction and dissemination of fallout warnings. It will exercise these functions through the National Survival Attack Warning System (NSAWS).

2. Fallout warnings will be disseminated by the Federal Warning Centre (FWC) and Provincial Warning Centres (PWCs) of the NSAWS in two ways:

- a. As *fallout warning broadcasts* to the general public, through the facilities of the Canadian Emergency Broadcasting System (CEBS).
- b. As coded Fallout Warning (FALLWARN) messages, through emergency communications channels, to certain civil emergency government headquarters and military organizations. When these are decoded, they can be reproduced as plots on the operational maps in the various headquarters.

3. As mentioned in the preceding chapter, because of the number of variables affecting the processes of fallout production and distribution, prediction of exact radiation levels is not feasible. The fallout prediction method used in Canada is a *danger sector* method; that is, it endeavours only to give a qualitative picture of the general fallout area and indicates likely arrival times.

DEVELOPMENT OF THE FALLOUT PREDICTION

4. Twice each day, the Meteorological Branch of the Department of Transport (DOT) provides special upper level wind forecasts for all of Canada and the northern United States to the NSAWS. These forecasts indicate wind speed and direction for specified altitude layers from ground level up to about 80,000 feet.

5. As each upper level wind forecast is received, each Warning Centre prepared special wind vector plots for a number of locations within its area of operations. Actual or assumed data regarding height of burst, location of ground zero and weapon yield are then applied to each wind vector plot and a fallout prediction is produced for each location. A sketch of a fallout prediction plot is shown in Figure 4.1.

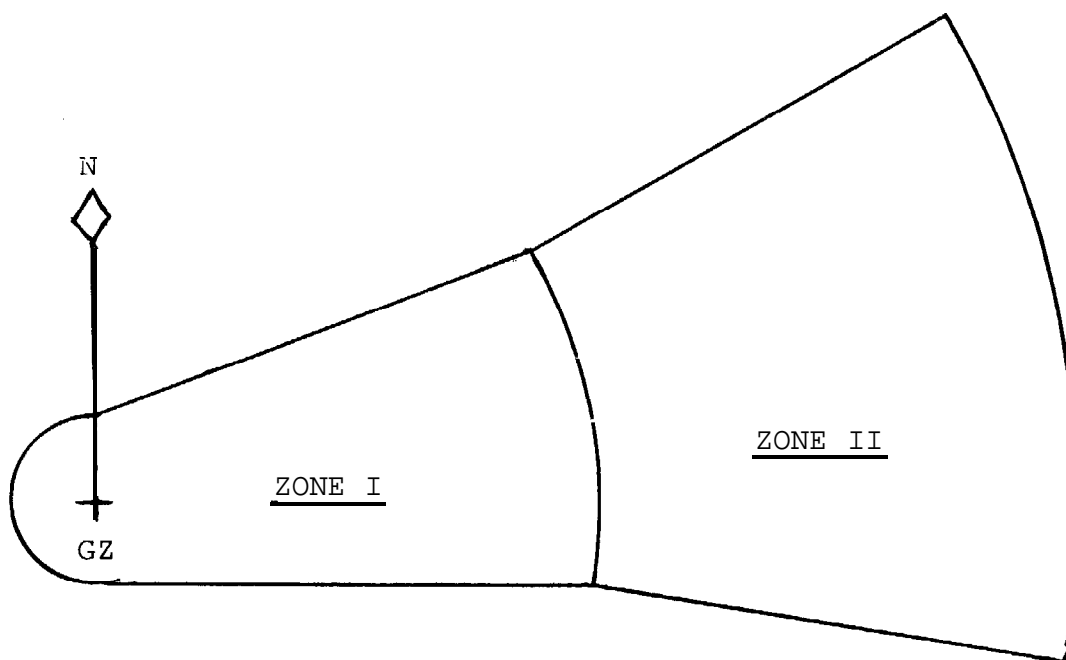


Figure 4.1

#### DEFINITION OF ZONES

6. As may be seen in Figure 4.1, the fallout prediction is divided into two zones of different relative risk.

- a. Zone I is an area of *immediate concern*. In it, there will be areas where exposed persons may receive doses greater than 100 R within 4 hours after the arrival of fallout. Major disruption of activities and casualties among exposed persons may occur within this zone. The areas of major disruption are likely to be smaller than the zone, but their exact location within the zone cannot be predicted.
- b. Zone II is an area of *moderate risk*. In it, exposed persons are unlikely to receive a dose of more than 100 R within 4 hours after the arrival of fallout. While this is the maximum 4-hour dose to be expected, only a small percentage of exposed persons will receive this much. Previously

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unexposed personnel may be permitted to continue critical missions for as much as 4 hours after the arrival of fallout, without incurring casualty-producing doses.

- c. Outside these two zones, unprotected personnel should not receive a dose of over 20 R within the first 6 hours after arrival of fallout, and the total dose for an infinite stay should not exceed 150 R. Therefore, outside Zones I and II, no serious disruption of operations is predicted for personnel previously unexposed to nuclear radiation.

7. The predicted zones are considerably larger than the actual area of ground likely to be significantly contaminated with radioactive fallout.

#### FALLWARN MESSAGE

8. The dimensions necessary for other headquarters to reproduce the fallout prediction plot are transmitted in the form of coded *FALLWARN Messages*. The format of the *FALLWARN* message text is as follows:

|                      |  |
|----------------------|--|
| TOB DDtttt           | - Date/Time of burst in Greenwich Mean Time (GMT)  |
| GZ LLLLLL Urbanville | - Location of burst (given as a Universal Transverse Mercator (UTM) Grid reference)        |
| AZ bbbbbb            | - Bearings of the two radial arms.   |
| PLOT sszzzrr         | - Effective wind speed (ss), down-wind distance of Zone I (zzz), and radius of cloud (rr). |

9. An example message text would look something like this:

|                     |   |
|---------------------|---|
| TOB 111915 z        | - Burst occurred on the 11th day of the month, at 7:15 PM (GMT)   |
| GZ 228447 - TORONTO | - Ground Zero was in the Toronto area.  |
| AZ 060100           | - Bearings of the radial arms are 60 and 100 degrees, respectively. (Bearings are always given as 3 figures). |
| PLOT 3514019        | - Effective Wind speed is 35 mph, Zone I is 140 miles long, and the cloud radius is 19 miles.                 |

PLOTTING PROCEDURE

10. The usual procedure is to construct the plot on a piece of transparent overlay material, to the scale of the operations map, and then apply the completed overlay to the map. The steps in this procedure are detailed below, using the data from the example message in paragraph 9.

11. Step 1

Mark a GZ reference point and a North reference line.



Figure 4.2

12. Step

Draw the two radial arms, at bearings of 60 and 100 degrees (using AZ 060100).

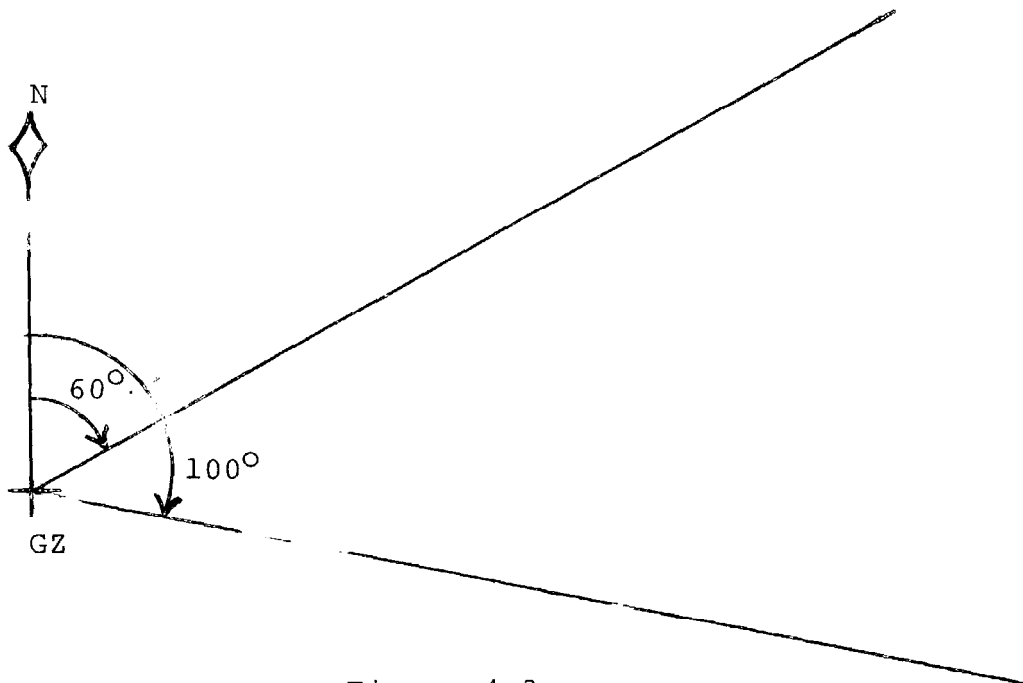


Figure 4.3



13. Step

Inscribe an arc between the two radial arms, having a radius equal to the Zone I distance (using PLOT ssl40rr).

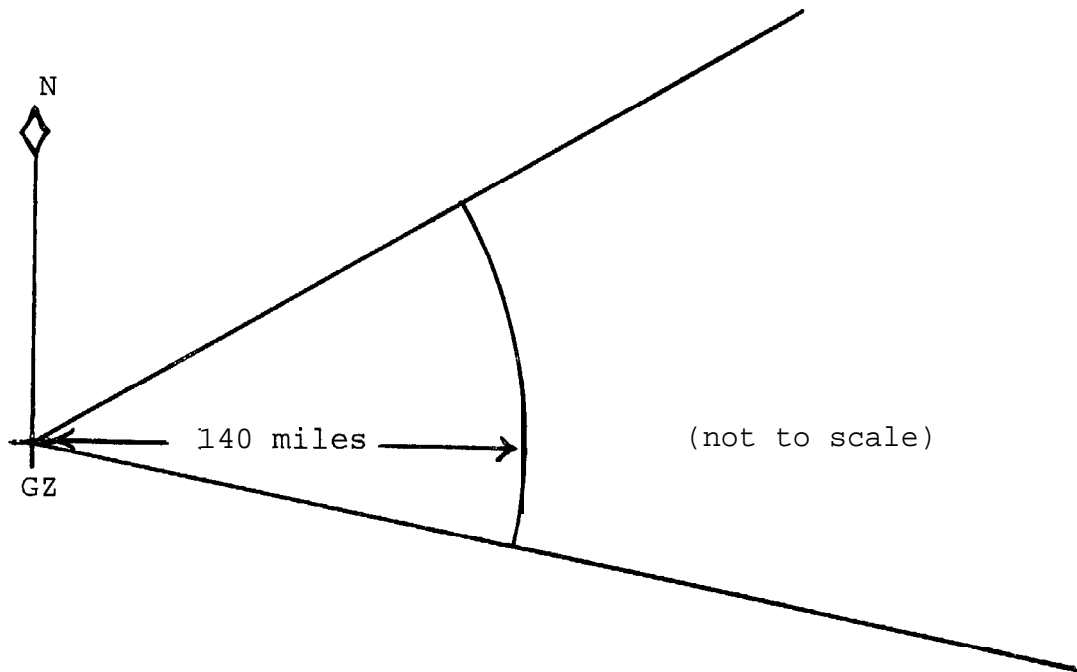


Figure 4.4

14. Step 4

Double the Zone I distance and inscribe another arc to represent the Zone II distance. ( $2 \times 140 = 280$ ).

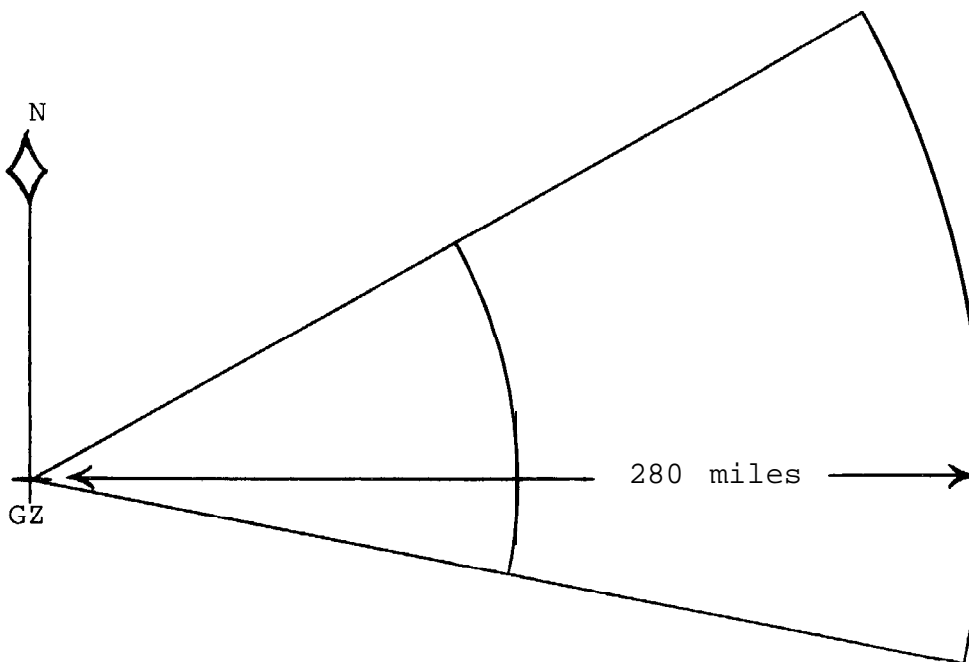
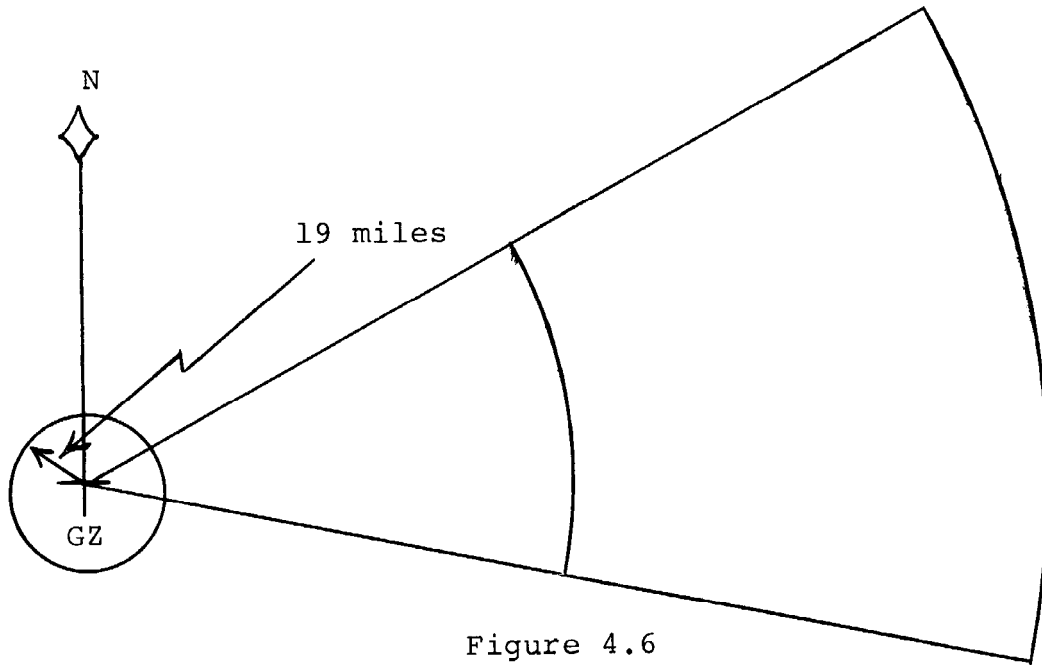


Figure 4.5

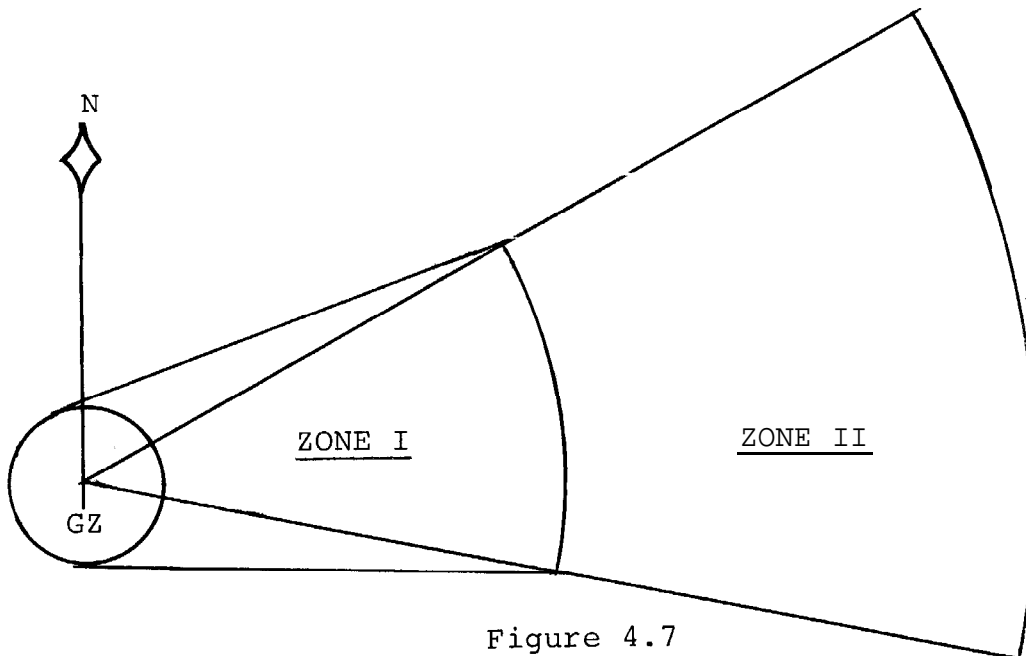
15. Step

Draw a circle around ground zero, equivalent to the cloud radius (using PLOT `sszzz19`).



16. Step

Draw tangential lines from the circle to the points where the Zone I arc intersects the radial arms.



17. Step

Using the effective wind speed of 35 mph (PLOT 35zzzrr), inscribe time of arrival arcs across the plot at 35 mile increments from the downwind edge of the cloud radius circle, and label them  $H + 1$ ,  $H + 2$ , etc.

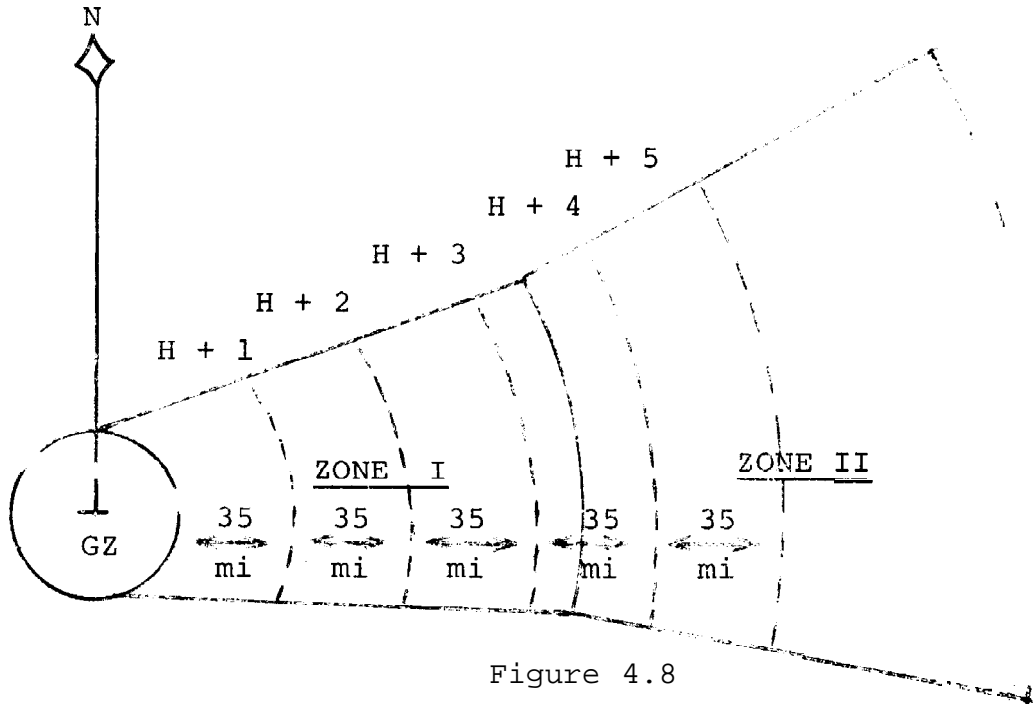


Figure 4.8

18. Step 7 may be omitted when it is not necessary to show the predicted arrival times. The completed plot would then look like the one shown in Figure 4.1 or Figure 4.8, depending whether Step 7 has been omitted or not.

19. The completed overlay is then placed over the appropriate ground zero on the operations map, oriented to the correct bearing, and fastened in place.



CANADIAN EMERGENCY MEASURES COLLEGERADIOLOGICAL DEFENCE OFFICERSCHAPTER 5SURVEY RESULTS - FALLOUT PROTECTIONSURVEY OF CANADA

This paper describes and explains the information contained in the printout listings of Survey Results for the Fallout Protection Survey of Canada.

INTRODUCTION

1. It was recognized several years ago that a knowledge of fallout protection in existing structures (an inventory of what is on hand, so to speak) would be one of the essential ingredients of any fallout protection program which might be adopted by the Government of Canada,
2. For more than ten years Canada, the United States and other NATO countries have been engaged in the development of engineering methods for analyzing the fallout protection capability of structures, Concurrent studies have been directed toward the development of survey procedures,
3. Early surveys included the Brockville Pilot Study in 1959, a survey of basements of federally-owned buildings in 1961, and a survey of mines and underground works in 1962.
4. In 1964, the Federal Government conducted a full scale pilot survey of the Province of Alberta to determine the amount of fallout protection available in that province and to perfect survey techniques for a complete national survey,
5. In February 1965, the Government approved the start of a complete Fallout Protection Survey of Canada,. The Canada Emergency Measures Organization and the Department of Public Works of Canada began the survey that year; it was completed in 1969. The aim of the survey was to determine the amount of existing fallout protection which might be made available to the public.. Already a modest program of updating has begun: a program to delete information about buildings which have been demolished and to add information about new construction,

SCOPE OF SURVEY

6. The Fallout Protection Survey of Canada included:
  - a, All categories of buildings and structures having a minimum protection factor of 10 and a minimum floor area of 1000 square feet, except
    - (1) DND-owned and -operated buildings and structures.

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(2) Residential buildings of the following types:  
detached, semi-detached or double; town and  
row-housing: duplex, triplex and fourplex; and  
apartments with less than 7 units.

- b. All essential services buildings, such as utility stations, relay stations and generator buildings, including those that did not meet the basic criteria, (These buildings are recorded separately on shelter analysis cards and were not processed through the computer.)

7. All above-ground and below-ground space was considered and environmental factors recorded for each building surveyed,

#### FIELD SURVEY

8. Each building was inspected by a field survey team of engineers and technicians who recorded information about each building's identify; location; utility services; size; shape; wall, floor and roof mass; and surroundings. This information was then keypunched and transferred to tape file for computer input, The taped data was computed and results were then printed out and bound in booklets by subzones. All told some 70,000 structures were surveyed, approximately 115,000 data sheets were compiled, each containing a potential of 465 pieces of data - over 53,000 bits of information. In processing this data the computer rejected about 5,000 structures because they had protection factors of less than 10. All told about 5% of the buildings were rejected for one reason or another,

9. The analyzed data which were finally printed out in the "Survey Results" booklets are in partially coded form, requiring some interpretation by the user. Some also require additional background explanation. Much of the information which follows in this paper may be found in the booklet entitled INTERPRETATION GUIDE FOR SURVEY RESULTS, EMO IM100-2, which was provided to the provinces along with the printout booklets themselves,

#### PRINTOUT LISTING BOOKLETS

10. For survey purposes the country was divided and subdivided into small manageable sections. Existing boundaries such as province and zone were used and, where necessary, zones were further divided into subzones, Each province, zone and subzone was identified by a number and a name. Results of the survey were compiled on a subzone basis, and each booklet has a title page which indicates the number and name of the province, zone and subzone and the date of the printout, as illustrated in Figure 5.1.

```

* * * * *
*          PROVINCE          4/ONTARIO
*
*          ZONE              5/OTTAWA
*
*          SUBZONE          508/RENFREW
*
*          DATE              MAR 1968
*
* * * * *

```

Figure 5.1 - Title page of Printout Listing

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11. In the printout listing every building or building part surveyed in the particular zone is listed, in the order surveyed, starting at BUILDING NO. 1 and going right through to BUILDING NO. 206, or whatever it happens to be. Herein lie two facts of importance to those who may attempt to make use of the data:

- a. FIRST, the order of listing in the printout is in accordance with the order that the field data sheets were completed, not building by building, street by street. For example, the buildings at Numbers 2, 4, 6, and 8 Main Street might be listed consecutively, but if the survey team could not contact the owner of No. 10 on the first visit and did not complete that data sheet until several days later, Number 10 Main Street might be listed somewhere else in the data book,
- b. SECOND, what the computer considered to be a building and listed as a building may not be a building at all, but only a part of one.

#### BUILDING SHAPE ASSUMPTIONS

12. For computation purposes building dimensions had to be averaged to provide simple shapes which were rectangular or square in plan. Certain assumptions were used, for example, roofs were assumed to be flat. As may be seen in Figure 5.2, a pitched roof structure would be described to the computer as if it had a flat roof at a height somewhere between the actual height of the eaves and the roof peak.

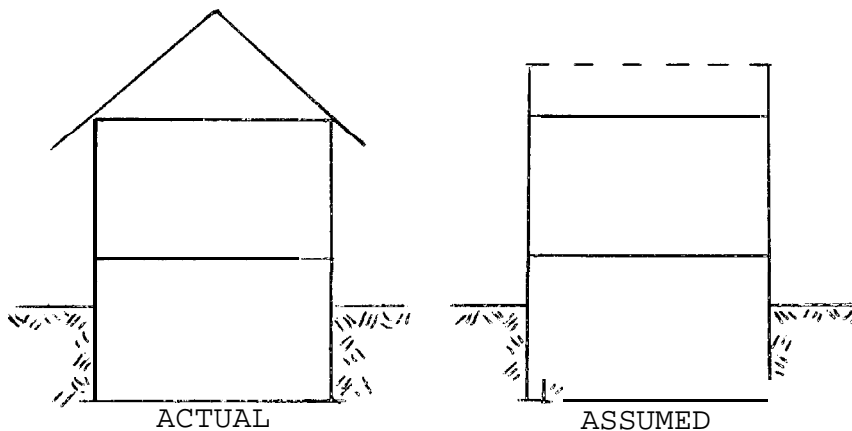


Figure 5.2 - Roof Assumed to be Flat

#### DATA SHEETS

13. Each printout listing contains a number of pages or data sheets. Each data sheet has a heading which identifies the printout listing to which it belongs, and printout data relating to one or more "buildings" (most sheets contain data for three "buildings").

14. The section describing identity, location, occupancy and services appears on the first two lines of the printout data,

AGENCY OR OWNER

15" The Agency or Owner classification system used in the survey classifies buildings as:

- 1 Federal
- 2 Provincial
- 3 Municipal
- 4 School, Collegiate and other Boards
- 5 Religious Organizations
- 6 Public Utility Undertakings
- 7 All Others,

TYPE

16, The Type category used in the survey classifies buildings in accordance with the National Building Code, 1965, as:

- 1 Assembly
- 2 Institutional
- 3 Residential
- 4 Business and Personal Services
- 5 Commercial and Industrial - High fire hazard
- 6 Commercial and Industrial - Moderate fire hazard
- 7 Commercial and Industrial - All others
- 8 Hospitals and Nursing Homes.

PEAK OCCUPATION

17, The second line of the printout listing gives environmental information about the building, starting with peak occupation, The number of peak occupants indicates the normal as opposed to transient population of the building, For example, the number shown for a store would probably be the number of employees, not the peak number of shoppers; schools and hospitals include the number of students and patients as well as the staff; and the auditoria and churches normally do not include audience or congregation. The number given for a part building applies to that part only, not the whole structure.

GAS

18, If gas facilities exist in the building or gas lines are laid to the building, the word GAS will appear. Otherwise NO GAS will be indicated.



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POWER

19. The word HYDRO is used to indicate availability of electric power from an outside distribution system. The abbreviation AUX relates to auxiliary power. It will be followed by either a zero, indicating no auxiliary power, or by an indication of the capacity of the auxiliary system. If a building lacks power in any form all of this section will be left blank.

WATER

20. Where a building has no water supply this section is left blank. If a building is connected to a municipal water supply the word CITY will be inserted here. If a building has its own or other non-public water supply the word SEPARATE will appear. If a building has both its own water supply and a connection to a municipal system the entry will be CITY/SEP.

SANITATION

21. The entries following this heading will be similar to the entries described for the heading WATER, i.e., blank, CITY, SEPARATE OR CITY/SEP.

VENTILATION

22. Where a building is ventiated by natural flow through doors and windows the entry here will be NATURAL. If all or part of the building has a mechanical ventilation system the entry will be MECHANICAL. If both types of system are available the entry will appear as NAT & MECH.

REDUCTION FACTOR

23. Before the numerical data of the printout sheets can be understood, it is necessary first to understand one more term,

24. Most people are familiar with the term Protection Factor or PF, the term which has been used for several years to describe the relative protection afforded by a fallout shelter,

25. Protection Factor has been described as "the relative reduction in the amount of Gamma radiation that would be received by an individual in a protected location, compared with the amount he would receive if unprotected," If, for example, a shelter had a Protection Factor of 100, in this shelter a person would only receive 1/100 of the radiation dose that he would receive at the same location, with no protection,

26. There is another way of expressing this relative reduction. If one takes the reciprocal of a Protection Factor, one gets a decimal fraction. For example, using the PF of 100 which was referred to above:

The reciprocal of a number is 1 divided by that number, or in this case  $1 \div 100$ , dividing 1 by 100, we obtain a value of 0.01.

We may put a name to this value which we obtained - we will call it a "Reduction Factor", and we will abbreviate it as "RF".

27. An RF (Reduction Factor) is the reciprocal of a PF (Protection Factor). For a PF of 100 we obtained an RF of 1/100 or 0.01.

28. It follows mathematically that if Reduction Factor is the reciprocal of Protection Factor, then Protection Factor is also the reciprocal of Reduction Factor. That is, if we were given a Reduction Factor of 0.01, we could calculate the Protection Factor by dividing 1 by 0.01 - which would give us a value of 100. In actual fact that is how Protection Factors are obtained. . . . A building is analyzed, its RF determined, and then the PF obtained from the RF,

#### PROTECTION FACTOR CATEGORY (PC)

29. Many people encountering the printout listings for the first time are surprised that they do not show the Protection Factor for each storey. This is understandable when one considers that we have been describing relative effectiveness of shelters in terms of Protection Factor for several years. Actually the information is there, it is merely expressed in another form. Total Reduction Factors are given for each storey, and the Protection Factor for the storey can be calculated by finding the reciprocal of the Reduction Factor.

30. Although individual Protection Factors are not shown in the printouts, a PROTECTION FACTOR CATEGORY is shown for each storey of each building. This value is indicated in the column headed PC.

31. The Protection Factor Categories are shown in Figure 5.3 with the corresponding Protection Factor Range and Reduction Factor Range.

| <u>PC</u> | <u>PF RANGE</u>   | <u>RF RANGE</u> |           |
|-----------|-------------------|-----------------|-----------|
| 1         | 2 - 9             | 0.5             | 0,111     |
| 2         | 10 - 19           | 0.1             | 0,053     |
| 3         | 20 - 49           | 0.05            | - 0.0234  |
| 4         | 50 - 99           | 0.02            | - 0.0101  |
| 5         | 100 - 199         | 0.01            | - 0.00503 |
| 6         | 200 - 499         | 0.005           | - 0.00201 |
| 7         | 500 - 1000        | 0.002           | - 0.001   |
| 8         | Greater than 1000 | Less than       | 0,001     |

Figure 5.3 - Protection Factor Category

#### AREA AND VOLUME

32. The Analysis of Fallout Protection Characteristics Section of the data, then, gives the actual diagnosis of the building's protection characteristics. Data are given on a storey by storey basis about the

- 7 -

various radiation contributions, the total Reduction Factor, and the Protection Factor Category, The next section of the printout listings deals with Area and Volume and includes the data listed in the next four columns in the printout listing.

### AREA

33. Area is the total floor area in square feet, In the case of basements the figure given is useable floor area.

### S-AREA

34. S-area is "shelter area", the floor area in square feet where the Protection Factor does not drop significantly below that computed for the geometric center of the floor. For PC's of 6, 7 and 8 (i.e. PF's greater than 200) it is assumed that there will be no significant difference in relative protection between the perimeter of the floor and its center, The S-area figure is therefore equal to the total floor area.

35. For PC's 2 to 5, it is assumed that the perimeter areas will have Protection Factors that are significantly lower, and the S-area is taken to be  $\frac{1}{2}$  of the total floor area. (PC 1's are shown for some buildings but should not be used because they have a PF less than 10). The suggested minimum requirement for a shelter space on a floor area basis is 12 square feet.

### VOLUME

36. This is the total volume of the shelter space, in cubic feet. It is obtained by multiplying S-area by storey height. The suggested minimum requirements for shelter space on a volume basis are five hundred cubic feet per person for unventilated space and eighty cubic feet per person for ventilated space.

### CONCLUSION

37. This brief expose of the survey results was designed to give you some idea of what was accomplished here in Canada in the field of Public Protection against radioactive fallout.



CANADIAN EMERGENCY MEASURES COLLEGERADIOLOGICAL DEFENCE OFFICERSCHAPTER 6DECONTAMINATION

This chapter discusses radiological decontamination, i.e., the radiological recovery of facilities and areas, and the relative effectiveness of various methods. This is optional reading material, no lecture will be given.

DEFINITION

1. Radiological decontamination is defined as *the reduction or removal of contaminating radioactive material from a structure, area, object, or person.*

INTRODUCTION

2. Radioactivity cannot be destroyed, but the fallout radiation hazard could be reduced by:

- a. Removing radioactive particles from a contaminated surface and safely disposing of them.
- b. Covering the contaminated surface with shielding material, such as earth.
- c. Isolating a contaminated object and waiting for the radiation from it to decrease through the natural process of radioactive decay.

3. As far as early radioactive fallout is concerned, decontamination is essentially the removal of quantities of dust and dirt. Although the *radiations* emitted by fallout are invisible, the *early fallout* itself is a very real, tangible substance: a seriously contaminated person would have visible quantities of dust on him; contaminated food would probably be gritty; and the physical quantities of material associated with seriously contaminated areas would be apparent under most circumstances.

4. Generally, as implied in Chapter 3, decontamination of personnel, food and water would not be required as a special, large scale activity. Good hygienic practices and maintenance of usual food handling and water treatment activities would sufficiently reduce any hazard. Therefore, these aspects of decontamination are not discussed any further at this time.

## RECOVERY OF FACILITIES AND AREAS

5. Generally, decontamination would be applied to vital areas and facilities to allow early use of important resources such as public utilities, food distribution and processing facilities, medical facilities, vital industries, etc., and to allow earlier emergence from shelter.

6. Decontamination of whole towns or cities might be **engineering** tasks of impossible magnitude, but decontamination of hospital complexes, etc., could be quite feasible. Decontamination operations, in other words, should be useful, feasible recovery activities, if executed on a selective basis. As general criteria, an area or facility must be essential to some vital post-attack function and must be needed at a time when serious contamination would result in unacceptable radiation exposure. If these criteria are met, and if resources are available, decontamination operations could be considered.

7. Decontamination may be partial or complete. For example, priority work at a vital facility might be possible with reasonable safety following a rapid partial removal (or covering) of contamination. Complete decontamination might then be accomplished later, to further reduce the radiation hazard.

## METHODS AND EQUIPMENT

8. The types of equipment and skills needed for this type of decontamination are not new. Ordinary equipment now available such as firehoses, street sweepers and bulldozers, and the skills normally used to operate them, are the basic requirements. The choice of method will depend upon:

- a. The type and extent of contamination.
- b. The type of surface.
- c. The weather conditions.
- d. The availability of personnel, equipment and materials.

9. The efficiency of each method is expressed as a *decontamination factor* (DF), which is defined as:

THE DECIMAL FRACTION OF THE CONTAMINATE, OR THE RADIATION FROM IT, THAT REMAINS AFTER DECONTAMINATION.

The more effective the decontamination, the smaller the DF. Thus, whereas the protection afforded by a shelter increases as the *protection factor* increases, the advantages of decontamination increase as the *decontamination factor* decreases.

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10. But there are certain problems associated with the use of the decontamination factor. Recall the example, in Chapter 3, of the man who stood in the centre of an infinite contaminated plane, and the relative contributions to his dose which would have come from sources at various distances from him. It was mentioned that 50% of his dose would come from the sources lying within a 50-foot radius of him. What would be the net result of the decontamination of this circular area of 50-foot radius? Suppose that a DF of .1 is realized in decontaminating a 50-foot circle around the man. The result would be 50% + (.1 x 50%) = 55% of the initial dose-rate; where the first 50% is the contribution from beyond 50 ft and the remaining 5% is the contribution from within 50 ft, modified by the DF.

11. In a similar fashion, decontamination of the roof of a building (or of any other contaminated plane contributing to the dose in a shelter) would only result in a reduction in the contribution from that particular plane. For this reason, it is necessary to study the situation carefully, when undertaking the radiological recovery of a facility, to determine the particular contaminated plane(s) making the principal contribution to the dose-rate at the location of interest, and then decontaminate these planes. There is no point in decontaminating the roof of a structure, if the principal contribution to the dose in a shelter area within it is from sources on the ground.

#### PAVED AREAS AND EXTERIOR SURFACE OF STRUCTURES

12. In warm weather, decontamination of paved areas and the exterior surface of structures requires two principal actions:

- a. Loosening the fallout material from the surface.
- b. Removing the material from the surface to a place of disposal.

13. Decontamination methods for paved areas include street sweeping, motorized flushing, and firehosing. Firehosing may be used for paved areas and the roofs of structures.

14. Street Sweepers. Most commercial street sweepers have similar operating characteristics. A powered rotary broom is used to dislodge the debris from streets into a conveyor system which transports it into a hopper. Thus, a removal and bulk transport system is inherent in the design.

15. Normally, a single operator is required for most street sweepers. However, because fallout material would be concentrated in the hopper, the operator may be subjected to a high radiation dose. This may make it necessary to rotate personnel often.

16. Sweepers are efficient, have high rates of operation, have low man-power requirements, and have application in both warm and cold weather. In decontaminating paved areas, decontamination factors from 0.15 to 0.04 can be realized, depending upon the rate of operation and the amount of fallout material.

17. Street Flushers. Conventional street flushers which generally use two forward nozzles and one side nozzle under a pressure of about 55 psi, are also satisfactory for decontaminating paved areas. The flushing or sweeping action of the water moves the fallout further toward the drainage facilities with each successive pass. Because the push of the water spray is limited, flushers are better adapted for use on long narrow paved areas, such as streets, than on larger areas such as parking lots. Decontamination factors of 0.04 to 0.02 can be realized by motorized flushing, depending upon the rate of operation and the type and roughness of the surface.

18. Firehosing. Firehosing is a good decontamination method for both paved areas and the roofs of buildings. It is particularly useful because of its adaptability to large paved areas, roofs, irregular and limited access areas, and equipment. Equipment and personnel are readily available for this method but it is dependent upon an adequate post-attack water supply.

19. Decontamination factors between 0.12 and 0.01 can be realized by firehosing tar and gravel roofs with very little slope, and 0.08 to 0.03 in decontaminating composition shingle roofs that slope 1 ft in every 2½ ft. DFs of 0.07 or better can be realized in firehosing of pavements.

#### UNPAVED LAND AREAS

20. Decontamination of unpaved land areas can be accomplished by:

- a. Removing the top layer of soil.
- b. Covering the area with uncontaminated soil.
- c. Turning the contaminated surface into the soil by plowing.

The latter two methods employ soil as the shielding material. The effectiveness of any of the methods is dependent on the thoroughness with which they are carried out. Spills or misses and failure to overlap adjoining passes should be avoided.

21. Motorized Scrapers. Motorized scrapers are used in large scale operations to cut off the top layer of contaminated soil, and carry the soil to suitable dumping grounds. Effectiveness of the procedure depends upon the surface conditions. Decontamination factors over 0.02 can be realized if all spills and misses are cleaned up. One operator and sometimes a shovel man are required with a scraper.



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22. Motor Graders. A motor grader can be used effectively on any long narrow area where contaminated soil can be dumped along the edge of the cleared area. Usually, only an operator is required with the grader although a shovel man may be needed if conditions are such that missed areas are frequent. DFs of 0.07 can be achieved with a grader.
23. Bulldozers. A bulldozer can be useful in scraping small contaminated areas, burying materials, digging sumps for contaminated drainage, and in backfilling sumps. The bulldozer is generally limited in scraping operations to a horizontal push of about 70 ft. DFs of 0.07 can be achieved. Usually, only an operator is required.
24. Earth Filling. Filling may offer no advantage over scraping, either in effectiveness or speed. Its principal use would be where scraping procedures could not be used, either because of rocky ground or because of permanent obstructions. A 6-inch fill of earth can produce a decontamination factor of 0.15, and a 12-inch fill can produce a DF of 0.02.
25. Plowing. Plowing provides earth shielding from radiation by turning the contaminated soil under. In decontaminating unpaved land areas by plowing, DFs of 0.2 can be realized if the depth of plowing is from 8 to 10 inches. Plowing is particularly suited for buffer zones and has the distinct advantage of no waste disposal problems. Only one operator is needed.

#### COLD WEATHER DECONTAMINATION METHODS

26. Cold weather decontamination methods will depend upon the weather conditions prior to and after the arrival of fallout. Various problems, such as fallout on various depths of snow, on frozen ground or pavement, mixed with snow or freezing rain, and under various depths of snow could occur after a contaminating attack. The presence of snow or ice would complicate the situation since large quantities of these materials would have to be moved along with the fallout material. In addition, snow and ice could cause loss of mobility to men and equipment.
27. The principle cold-weather decontamination methods are:
- a. Snow loading
  - b. Sweeping
  - c. Snow plowing
  - d. Firehosing.
28. Snow Loading. Snow loading is accomplished with a front-end loader and a dump truck. Decontamination factors of about 0.10 can be realized, depending on the amount of spillage.

29. Sweepers. Sweepers can remove fallout from dry pavement, traffic-packed snow, or reasonably level frozen soil or ice. DFs are approximately 0.10.

30. Snow Plowing. Snow plowing is applicable for all depths of contaminated snow. Decontamination factors of 0.03 can be achieved.

31. Firehosing. Firehosing is possible and can be used on paved areas and exteriors of structures slightly below freezing temperatures. DFs will vary from 0.5 to 0.05.

#### SUMMARY

32. Under some circumstances, it is possible to reduce the level of a radiation field by removing, or covering, all or part of the material emitting the radiation. This activity is called decontamination.

33. The primary form of decontamination would be that associated with reduction of the radiation levels at vital facilities, during the recovery phase.

34. Generally, decontamination of personnel, food and water would not be required as a special, large scale activity. Good hygienic practices and maintenance of usual food handling would sufficiently reduce any hazard,

CANADIAN EMERGENCY MEASURES COLLEGERADIOLOGICAL DEFENCE OFFICERSCHAPTER 7REVIEW OF RADEF ANALYSIS

This chapter describes the types of analysis tasks likely to be required of the RADEF section in a headquarters and outlines the basis for the procedures which are detailed in subsequent chapters.

INTRODUCTION

1. The RADEF section in a municipal headquarters will be responsible for advising the head of government, the operations staff and the heads of the emergency services regarding:

- a. The current radiation situation.
- b. The future radiation situation and the likely radiation doses.
- c. The areas where public and operational activity must be controlled in order to minimize radiation doses.
- d. The areas where operational activities may be performed and the areas where the public may be permitted to move about freely.
- e. The length of time people in various locations must remain in shelter, when they can emerge, for how long, etc.
- f. When outdoor operations can be conducted, where, and for what lengths of time.
- g. The types of controls and remedial measures required in the more seriously affected areas, including such questions as when evacuation should be undertaken.

2. The execution of these responsibilities will involve the collection and collation of radiological information (i.e., the reports from the monitoring posts) into an intelligent picture of the radiation situation, and the subsequent, interpretation of the situation and its consequences. To perform his tasks, as a leader of the RADEF section, the RDO must be familiar with the operation of certain basic *tools* and be able to perform a number of simple analytical operations, such as:

- a. Forecast future dose-rates.
- b. Calculate and predict doses.

- c. Calculate "entry time" and "stay time".
- d. Determine shelter release times, etc.

3. The remaining chapters in this manual are designed to equip the RDO with the necessary skills to perform these duties and tasks.

#### DECAY CURVES

4. Each radioactive isotope has a characteristic half-life. These range from a few millionths of a second to millions of years. However, when many radioisotopes contribute to the radiation dose-rate, as in the case of the fission products from a nuclear weapon, no one half-life applies for the composite.

5. With fission products, there is a predominance of short-lived radioisotopes in the period immediately following the burst, hence the radiation dose-rate decreases rapidly. As these short-lived radioisotopes expend themselves, the longer half-life isotopes dominate and the decay rate of the fission products decreases.

6. The multiple radioactive decay of the fission products can be represented by the general equation:

$$I = I_1 t^{-n}$$

Where

$I$  equals the dose-rate at any time ( $t$ )

$I_1$  equals the dose-rate at unit time

and  $n$  is the decay exponent.

7. For this function, a plot, on ordinary graph paper, of dose-rate versus time after burst yields a curved line.

8. But the same function plotted on log-log graph paper yields a straight line since  $n$  is constant. This fact forms the basis for the dose-rate forecasting technique which is discussed in Chapter 9.

9. The decay of reactor-produced fission products from the slow fission of U-235 follows a  $t^{-1.2}$  curve for about the first 100 days. This 1.2 value for  $n$  is usually used in research work, in training, and in planning, when an estimate of the decrease in fallout radiation levels with time is required. " $t^{-1.2}$  decay" is so frequently used that it is referred to as standard decay.

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10. For planning purposes, the value of  $n = 1.2$  is quite satisfactory. It also has limited use for operational purposes. In fact, "tools" such as the Radiac Calculator are based upon this form of *standard decay*. Calculations limited to short periods of time into the future should not be grossly in error. However, for longer term predictions, other techniques which account for *non-standard* decay must be used.

11. The decision not to depend upon *standard decay* for operational purposes is supported by observations of the decay characteristics of actual fallout from weapon tests. Attempts to fit observed decay of the fallout with a general equation of the form  $I = I_1 t^{-n}$  have required values of "n" ranging from about 0.9 to 2.2. Therefore, attempts to forecast the decay of actual fallout fields on the basis of any particular value of "n" are almost certain to be grossly inaccurate.

12. To illustrate how some of these factors affect the decay characteristics of fallout, consider the influence of:

- a. Induced activity.
- b. Fractionation.
- c. Weathering.
- d. Different age fission products, and
- e. Decontamination.

#### THE BASIC TOOL: THE DOSE-RATE/TIME GRAPH

13. Because there are so many factors which may cause the decay characteristics of fallout to vary, it is important that a RADEF analyst use an analyst tool which is not dependent upon one single rate of decay, such as the " $t^{-1.2}$  law" is. The most practical approach, therefore, appears to be the use of techniques based upon the plotting of *observed dose-rates versus time after detonation* on log-log graph paper.



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CHAPTER 8

THE DOSE-RATE VERSUS TIME GRAPH

This chapter introduces the basic RADEF analysis tool: the *log-log* graph on which observed dose-rates are plotted against time. The procedures for forecasting dose-rates and the method of determining the value of the decay exponent "n" are described.

PLOTTING THE DOSE-RATE VERSUS TIME GRAPH

1. In this first section we will explain why the dose-rate/time graph should be plotted on log-log graph paper rather than on the ordinary type of graph paper.

2. Let us consider the following hypothetical example, Suppose that a nuclear weapon was detonated 30 miles upwind and fallout is now being deposited at our location. At 1 hour after the burst the intensity is 200 R/hr. The dose-rate then increases until the fallout is completely deposited. This happens at H + 2 hrs, say. Then, radioactive decay will cause the intensity to decrease, and if all of the above data is plotted on ordinary graph paper, a curve such as Fig. 8.1 will result.

3. But if the same data is plotted on log-log graph paper, a straight line will result for the decay. A straight line will also represent the fallout deposition, and a "smooth hump" the cessation of deposition. The complete curve is depicted in Fig. 8.2.

EXTRAPOLATION OF THE DOSE-RATE VERSUS TIME GRAPH

4. Now, the fact that we have obtained a straight line for the decay portion of our dose-rate versus time graph means that we can easily extrapolate this straight line portion to predict any future dose-rate that we wish to. There is obviously a certain amount of "danger" involved in extrapolating this curve, i.e. what tells us that the decay will continue at this rate? For example, weathering. The wind blowing the fallout from one area to another could change the "shape" of the curve significantly and our extrapolation would not be valid. Nevertheless the policy is we must take a risk and extrapolate our curve since we are interested in predicting future dose-rates.

5. While fallout is still coming down there is no suitable way of forecasting what the radiation might be in the future but once deposition has ceased, and some sort of fairly regular pattern of decay is apparent, forecasting is possible.

6. As we mentioned, to forecast a future dose-rate on a graph all we need to do is to extrapolate, i.e. to extend the curve, to a certain point. This is simple to do on log-log graph paper where the decay curve is approximately a straight line. Any substantial increase in radiation intensities after straight line decay has been observed for a time, would indicate the arrival of a significant amount of additional fallout,

### DOSE-RATE VERSUS TIME

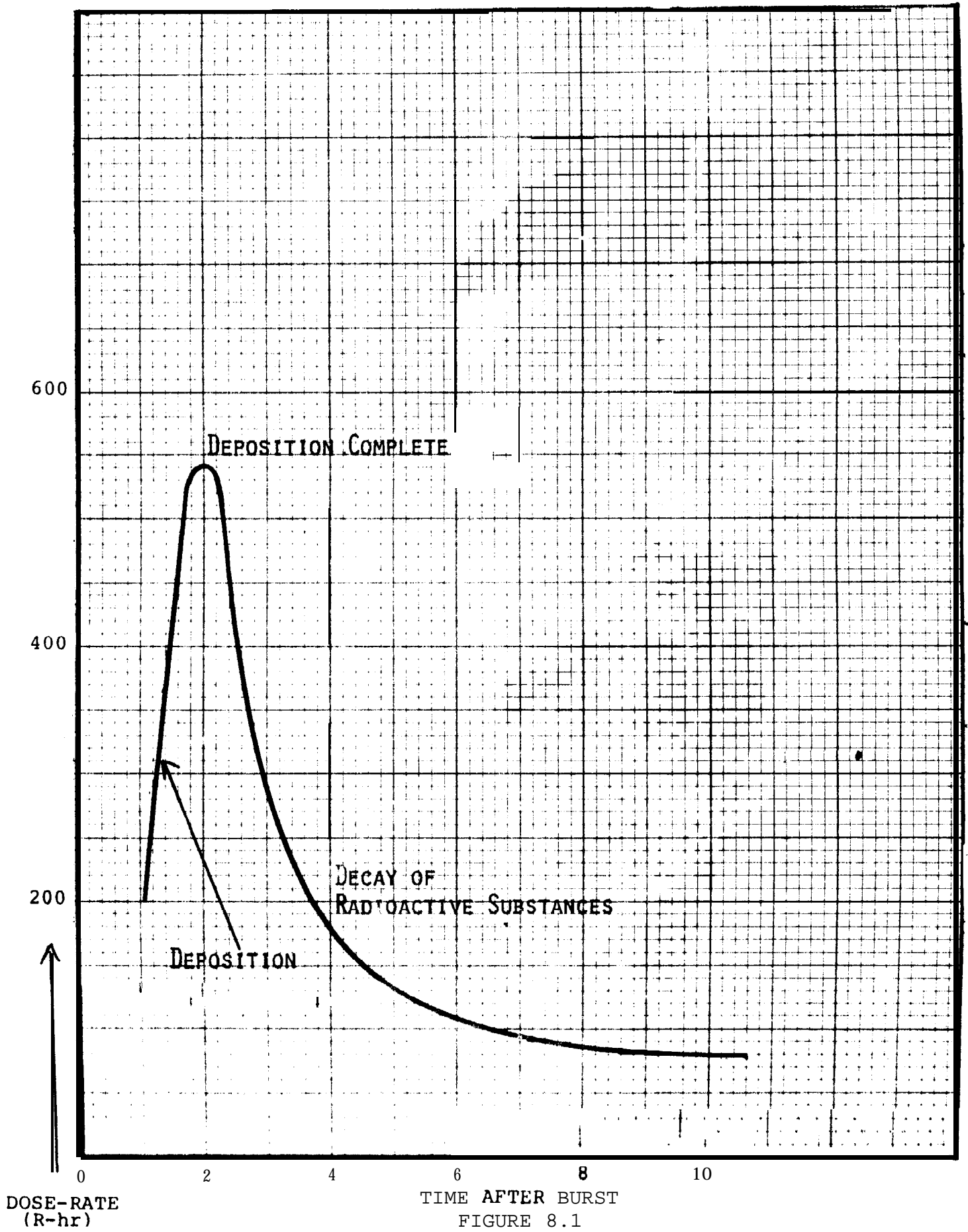


FIGURE 8.1



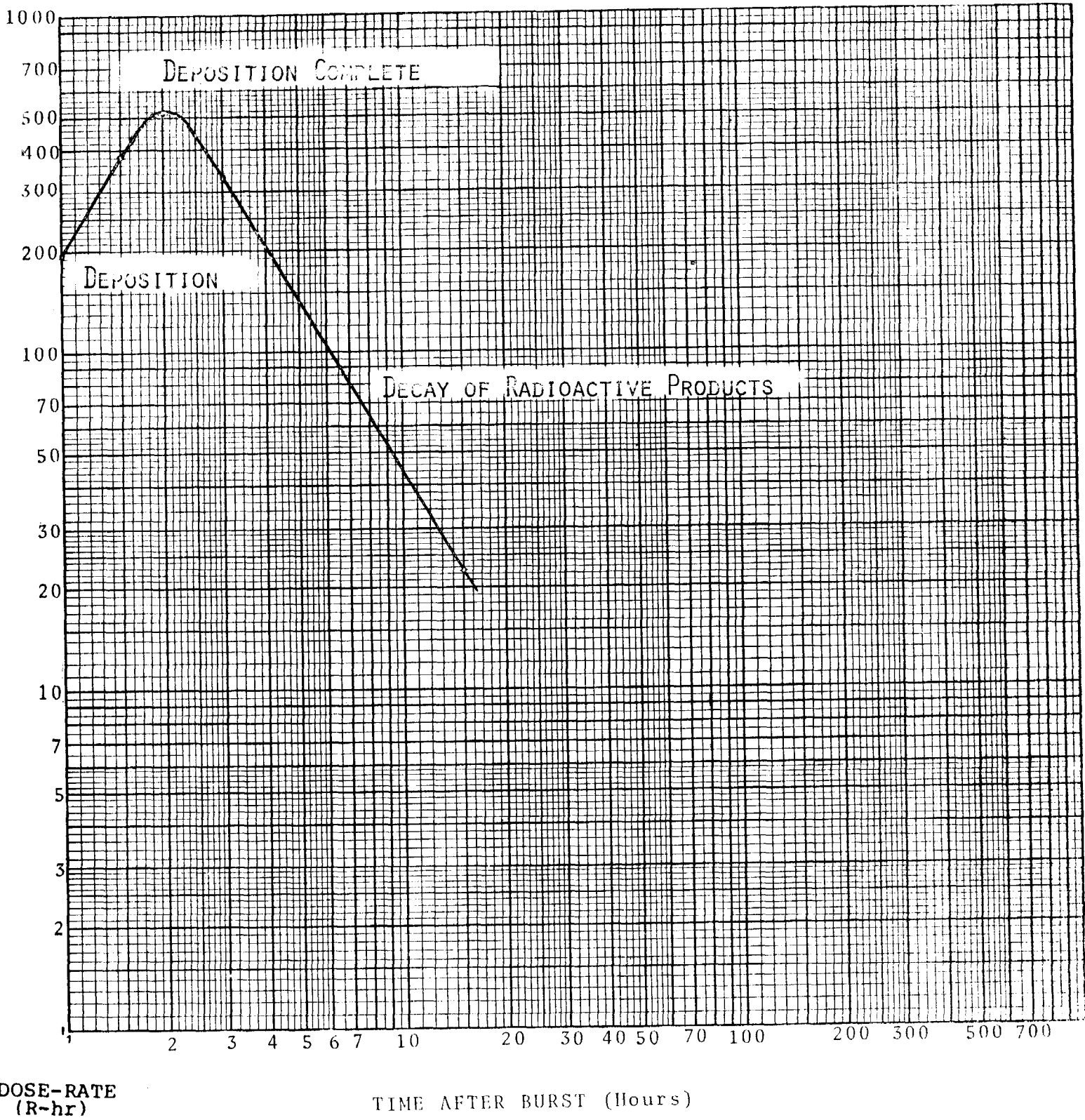


FIGURE 8.2

7, The following point is very important. If considerable time has elapsed since the first burst and the increase in dose-rate was greater than the earlier maximum, a new graph should be started using the estimated H-hour of the latest burst as the reference time.

8. After the plot indicates once again an orderly decrease, i.e. when it is reasonably a straight line again, then an extrapolation of the curve will again provide a reasonable basis for estimating future dose-rates.

#### DETERMINING THE VALUE OF THE EXPONENT "n"

9. There may be an advantage to knowing the value of the fallout decay exponent "n".

- a, If the exponent does approximate 1.2, the Radiac Calculator and tables based upon this value can then be used..
- b. It is possible to employ the general equation:

$$I = I_t t^{-n}$$

for the calculation of future dose-rates.

10. The fallout decay exponent "n" can be computed directly from the plotted curve. "n" is numerically equal to the slope of the curve and is therefore, constant only when the plotted line is straight. Determine "n" from the graph by-dividing the *measured* distance  $\Delta Y$  by the *measured* distance  $\Delta X$  as indicated in the following sketch,

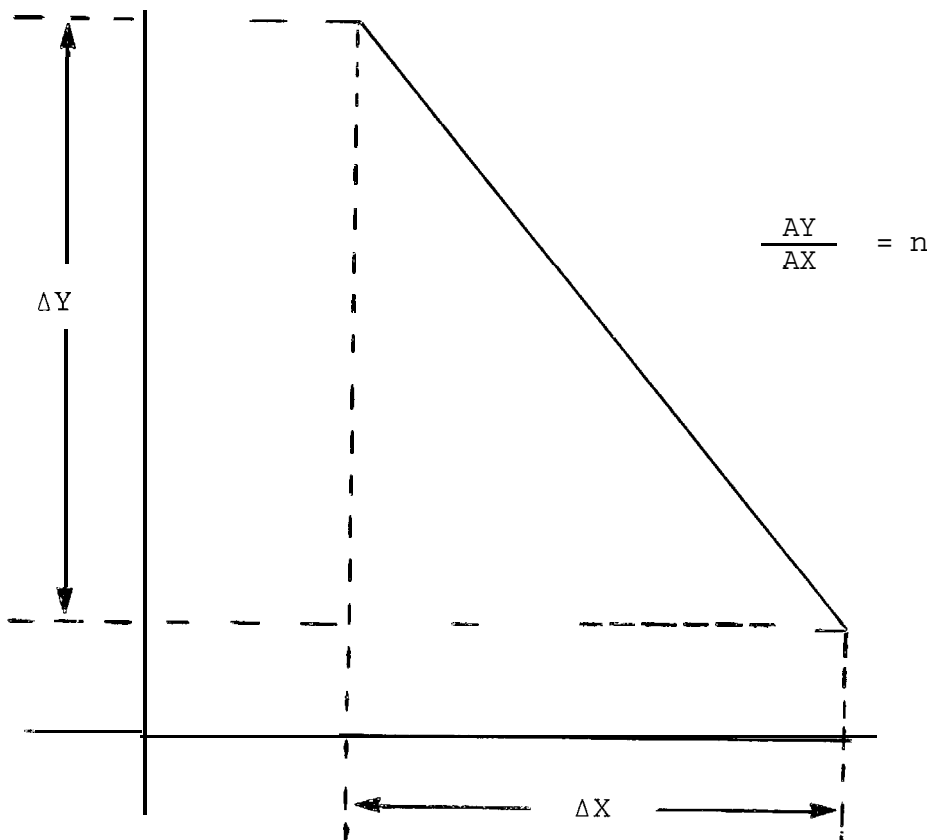


FIGURE 8.3

- 5 -

11. When the exponent "n" is equal to the value 1.2 we say that the decay rate is "normal". That is the decay rate follows the theoretical decay pattern of  $U^{235}$ .

12. The decay rate for a fission - fusion - fission weapon, one for which the bomb's outer casing is constructed of  $U^{238}$  would not follow this 1.2 law, The decay exponent, in this case, would actually be greater than 1.2, e.g. the Castle Bravo Detonation - the high yield weapon detonated on March 1, 1954 on the Island of Bikini,

### CLASSROOM PROBLEMS

#### REQUIREMENT NO, 1

#### SITUATION

Data from one of your monitoring posts is tabulated below. For convenience, times have been converted to *time after burst*. Normally, you would be required to make the conversion from clock time to time after burst,

| <u>TIME AFTER BURST (hours)</u> | <u>DOSE-RATE (R/hr)</u> | <u>TIME AFTER BURST (hours)</u> | <u>DOSE-RATE (R/hr)</u> |
|---------------------------------|-------------------------|---------------------------------|-------------------------|
| H + 3                           | 1                       | H + 13                          | 120                     |
| H + 4                           | 6                       | H + 14                          | 100                     |
| H + 5                           | 25                      | H + 15                          | 90                      |
| H + 6                           | 80                      | H + 17                          | 75                      |
| H + 7                           | 190                     | H + 20                          | 60                      |
| H + 8                           | 200                     | H + 23                          | 50                      |
| H + 9                           | 190                     | H + 26                          | 40                      |
| H + 10                          | 170                     | H + 32                          | 30                      |
| H + 11                          | 150                     | H • 38                          | 23                      |
| H + 12                          | 130                     | H + 44                          | 19                      |

#### PROBLEM

- a. Plot the data on log-log graph paper and draw a smooth curve through the plotted points.
- b. Calculate the decay exponent "n" for the portion of the curve which is a straight line.

- c. Forecast the dose-rate at H + 60 and at H + 80 hours,  
 d. Plot the following additional data:

| <u>Time After Burst</u><br>(Hours) | <u>Dose-Rate</u><br>(R/hr) |
|------------------------------------|----------------------------|
| H + 55                             | 19                         |
| H + 60                             | 20                         |
| H + 70                             | 25                         |
| H + 90                             | 30                         |
| H + 120                            | 55                         |

- e. Can you forecast the dose-rate at H + 100 hrs using this data?  
 f. How would you interpret this last portion of the curve?  
 g. At another location in the same community, the dose-rate at H + 10 hrs was 15 R/hr.
- (1) How could you forecast what the dose-rate would be at H + 25 hours at that location?
  - (2) What would the dose-rate be at H + 65 hours?

## REQUIREMENT NO. 2

### SITUATION

The following data has been received from one of your monitoring posts. All times have been converted to "time after burst".

| <u>TIME AFTER BURST</u><br>(hours) | <u>DOSE-RATE</u><br>(R/hr) | <u>TIME AFTER BURST</u><br>(hours) | <u>DOSE-RATE</u><br>(R/hr) |
|------------------------------------|----------------------------|------------------------------------|----------------------------|
| H + 2                              | 1                          | H + 9                              | 65                         |
| H + 3                              | 20                         | H + 10                             | 60                         |
| H + 4                              | 80                         | H + 11                             | 54                         |
| H + 5                              | 70                         | H + 12                             | 50                         |
| H + 6                              | 60                         | H + 13                             | 46                         |
| H + 7                              | 65                         | H + 16                             | 38                         |
| H + 8                              | 70                         | H + 19                             | 31                         |

- 7 -

PROBLEM

- a. Plot the data on log-log graph paper.
- b. Calculate the value of the decay exponent "n" at H + 10 hours.
- c. What is the dose-rate at H + 30 hours? Do you think your extrapolation is very justifiable?
- d. Plot the following additional data:

| <u>TIME AFTER BURST (hours)</u> | <u>DOSE-RATE (R/hr)</u> | <u>TIME AFTER BURST (hours)</u> | <u>DOSE-RATE (R/hr)</u> |
|---------------------------------|-------------------------|---------------------------------|-------------------------|
| H + 22                          | 27                      | H + 69                          | 20                      |
| H + 25                          | 24                      | H + 72                          | 20                      |
| H + 31                          | 19                      | H + 75                          | 19                      |
| H + 38                          | 15                      | H + 81                          | 18                      |
| H + 44                          | 13                      | H + 87                          | 17                      |
| H + 54                          | 12                      | H + 93                          | 15                      |
| H + 57                          | 13                      | H + 99                          | 14                      |
| H + 60                          | 15                      | H + 120                         | 11                      |
| H + 63                          | 18                      | H + 144                         | 9                       |
| H + 66                          | 19                      |                                 |                         |

- e. Plot the above additional data and draw a smooth curve through the points.
- f. Calculate the decay exponent "n" at H + 20 hours and at H + 100 hours.
- g. Is there a difference between the two above decay exponents? Interpret your answer.
- h. Could you safely forecast the dose-rate at H + 200 hours?

REQUIREMENT NO, 3SITUATION

The dose-rate at H + 6 was 72 R/hr and decreasing.

PROBLEM

If  $n = 1, 3$ , forecast the dose-rate at  $H + 45$ .

CANADIAN EMERGENCY MEASURES COLLEGERADIOLOGICAL DEFENCE OFFICERSCHAPTER 9RADIAC CALCULATOR (PART 1)

This chapter describes the procedures for solving dose-rate/time problems on the Radiac Calculator.

INTRODUCTION

1. For most peacetime RADEF activities, such as planning, exercises, studies, etc., it is convenient to simply assume that *standard*  $t^{-1.2}$  decay pertains. There are a number of graphs, nomograms and simple calculators which are based upon this rate of decay and which can speed up and simplify calculations considerably. One such *tool* is the RADIAC CALCULATOR.
2. The Radiac Calculator is a simple pocket-size computer which consists of 3 concentric movable discs. The inner and intermediate discs can be reversed; one side is marked *LAND* and the other *SEA*. Theoretically, one would use the *SEA* scales for bursts which occurred on or in seawater, in order to account for a slightly more rapid rate of decay which may result from induced radioactivity in seawater constituents. However, in practice, as most of the bursts we might be concerned with will be *LAND* bursts, we will use the *LAND* scales for all of our calculations.
3. One should note that:
  - a. The Radiac Calculator is based upon *standard*  $t^{-1.2}$  decay.
  - b. For any calculation, one requires a dose-rate observation and knowledge of when it was made.
  - c. All times shown on this calculator are expressed in "*time after burst*".

PROCEDURE

4. The steps for solving dose-rate/time problems are:
  - a. Set the observed dose-rate on the outer scale opposite the time of observation on the intermediate scale.
  - b. Locate the time of interest on the intermediate scale.
  - c. Read answer off the outer scale.

PROBLEM 1

One hour after a nuclear detonation, the dose-rate is 1000 R/hr. What will the dose-rate be 7 hours after the explosion?

SOLUTION:

Locate 1000 R/hr on OUTER scale. Rotate the INTERMEDIATE disc and set 1 hr opposite the 1000 R/hr mark. Holding discs firmly to prevent further rotation, locate 7 hrs on INTERMEDIATE scale. Read answer from OUTER scale.

Answer:    about 98 R/hr

PROBLEM 2

Using the same original dose-rate and time as for Problem 1, find the dose-rate 2 days after the detonation.

SOLUTION:

With calculator set as for Problem 1, locate 2 day mark on INTERMEDIATE scale. Read answer from OUTER scale.

Answer:    about 9.7 R/hr

PROBLEM 3

Again using the dose-rate and time from Problem 1, find the dose-rate 2 weeks after the burst.

SOLUTION:

Similarly, locate 2 week mark on INTERMEDIATE scale and read answer from OUTER scale.

Answer:    about 0.94 R/hr

PROBLEM 4

Using same data, find the dose-rate 14 weeks after burst.

SOLUTION:

Proceed as before.

Answer:    about 0.09 R/hr



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RECALCULATE PROBLEMS 1 TO 4, USING  
THE 7:10 LAW, AND COMPARE RESULTS.

PROBLEM 5

Two hours after a nuclear detonation, the dose-rate was 300 R/hr. What was the dose-rate 1 hour after the explosion?

SOLUTION:

Set 2 hrs on INTERMEDIATE scale opposite 300 R/hr on OUTER scale. Locate 1 hr mark on INTERMEDIATE scale and read answer from OUTER scale.

Answer:     about 690 R/hr

PROBLEM 6

The dose-rate is 600 R/hr, 6 hours after burst. What will the dose-rate be at H + 15 hrs?

SOLUTION:

Set 6 hrs opposite 600 R/hr. Locate 15 hour mark and read answer from OUTER disc.

Answer:     about 200 R/hr

PROBLEM 7

At H + 6 hrs the dose-rate was 600 R/hr. When will the dose-rate be 50 R/hr?

SOLUTION:

As for Problem 6, set 600 R/hr opposite 6 hrs. Locate 50 R/hr on OUTER scale and read answer from INTERMEDIATE scale.

Answer:     about 2 days after detonation

PROBLEM 8

At  $H + 3$  hrs, the dose-rate was 4 R/hr. What was the dose-rate at  $H + 1$  hr?

SOLUTION:

Set 3 hrs opposite 4 R/hr. Locate 1 hour on INTERMEDIATE disc and read answer from OUTER disc.

Answer:     about 15 R/hr

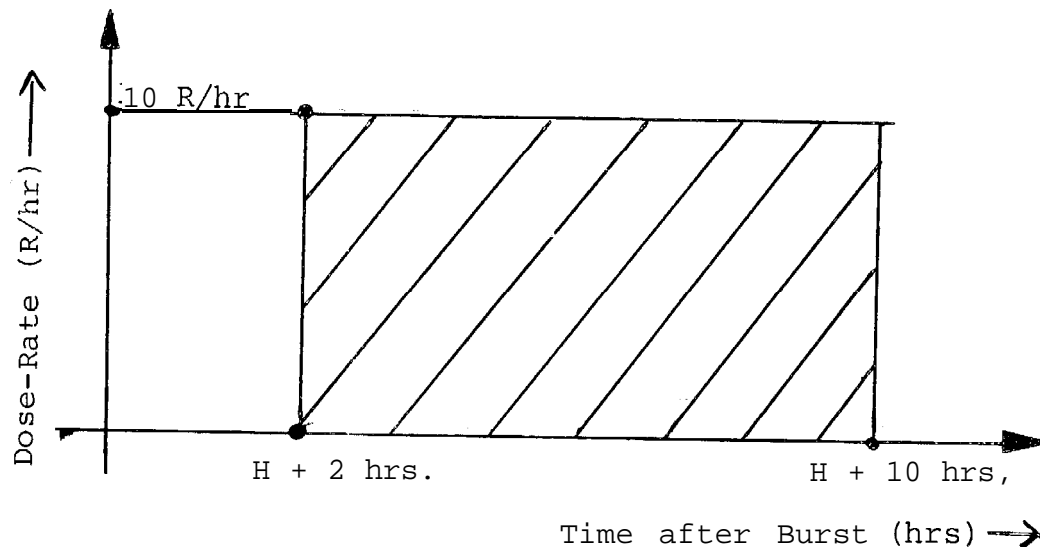
CANADIAN EMERGENCY MEASURES COLLEGERADIOLOGICAL DEFENCE OFFICERSCHAPTER 10THE DOSE-RATE/TIME GRAPH: DOSE ESTIMATES

This chapter explains the procedure for estimating total radiation dose by integration of a log-log graph of dose-rate vs time.

INTRODUCTION

1. Previous chapters have discussed methods of forecasting future dose-rates by extrapolation of a log-log graph and by manipulation of the Radiac Calculator. This chapter now introduces the subject of dose estimates,
2. The simplest, most direct method of determining total exposure dose is by measurement with a dosimeter, Dosimeters "integrate" exposure over a period of time and account automatically for variations in dose-rate due to decay, fallout deposition, or movement from one radiation level to another,
3. RADEF operating procedures call for periodic dose reports from monitoring posts (based upon dosimeter readings), but RADEF officers must also be prepared to estimate doses from the regular series of dose-rate reports and they must be prepared to forecast doses for future periods.
4. To estimate the total dose from a dose-rate/time graph, one must find the total area under the curve. This is the principle that will be exploited throughout the following chapter. Consider a simple example

The dose-rate was 10 R/hr from H + 2 hours to H + 10 hours.  
How many Roentgens would an individual have accumulated during this time interval? Let us draw a graph to describe the situation:



The dose-rate is constant and equal to 10 Roentgens per hour in this problem. Thus, if an individual receives 10 Roentgens every hour, during 8 hours, from  $H + 2$  to  $H + 10$ , he will receive

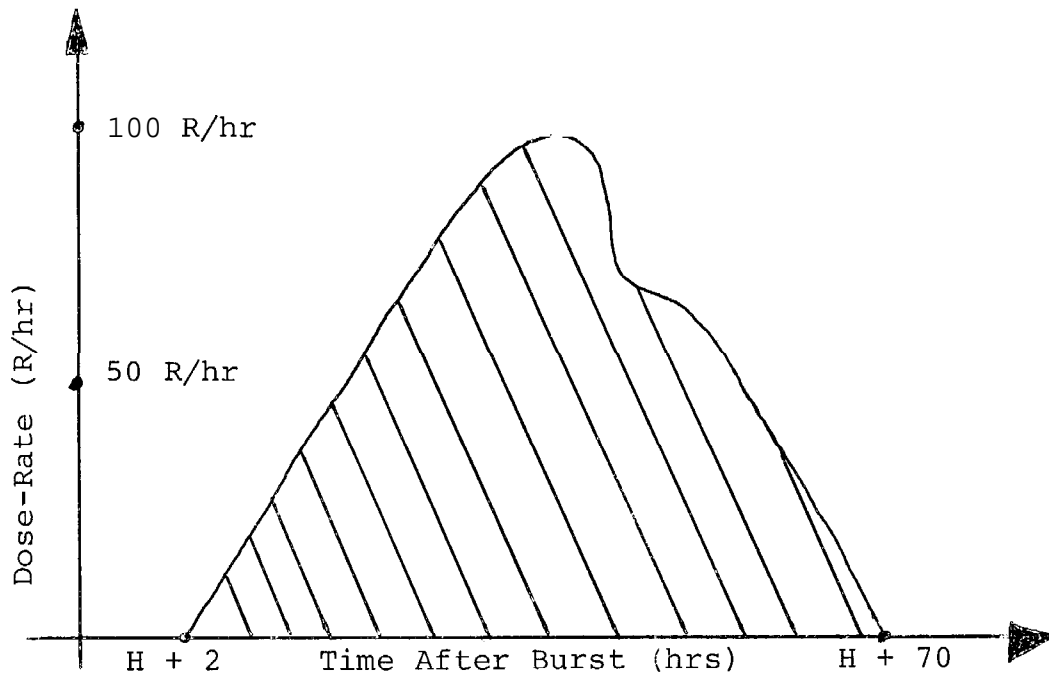
$$10 \times 8 = 80 \text{ Roentgens}$$

In other words, what we have done here is to multiply the dose-rate by the total elapsed time, i.e. we have found the area under the curve, which is a straight line in this case.

The general principle can therefore be enunciated as follows:

$$\text{Area under the curve} = \text{Total Dose}$$

For example, if we had the following dose-rate versus time graph



we would find the total dose simply by determining the total area under the curve. This procedure will now be discussed for a general curve.

#### PROCEDURE

5. The procedure is:
  - a. Divide the whole period of interest into small increments.
  - b. Establish an average dose-rate for each time increment.
  - c. Multiply each by the duration of the increment to determine the dose for that increment.

- 3 -

- d. Calculate the total dose for the full period by adding the incremental doses.

### TIME INCREMENTS

6. On a hump, when the curve does not degenerate into a straight line, the time increments should be small. When the slope is relatively straight over the exposure period, the increments may be larger. The increments need not be equal in size,

7. The general rule is: an increment should not exceed one-half of the time from detonation to the beginning of the increment. For example, if the increment begins at H + 10, it should not be longer than 5 hours. However, if the curve forms a hump during this time, it may be necessary to use smaller increments. During the initial periods of fallout deposition, the increments should be no longer than one hour,

### EXAMPLE PROBLEMS

#### REQUIREMENT NO. 1

From the graph of page 5 find:

- a, The total dose for the period from H + 7 to H + 15.

#### SOLUTION:

We will divide the period from H + 7 to H + 15 hours into small increments of time. The area for each increment equals the average dose-rate x elapsed time. To obtain the total dose from H + 7 to H + 15 we add the small incremental doses as shown below.

$$\text{Dose from H + 7 to 8} = \left( \frac{1 + 10}{2} \right) \times 1 = 5.5 \times 1 = 5.5$$

$$\text{Dose from H + 8 to 9} = \left( \frac{10 + 100}{2} \right) \times 1 = 55 \times 1 = 55$$

$$\text{Dose from H + 9 to 10} = \left( \frac{100 + 120}{2} \right) \times 1 = 110 \times 1 = 110$$

$$\text{Dose from H + 10 to 15} = \left( \frac{120 + 90}{2} \right) \times 5 = 105 \times 5 = 525$$

TOTAL DOSE: 695.5 or  
700 R

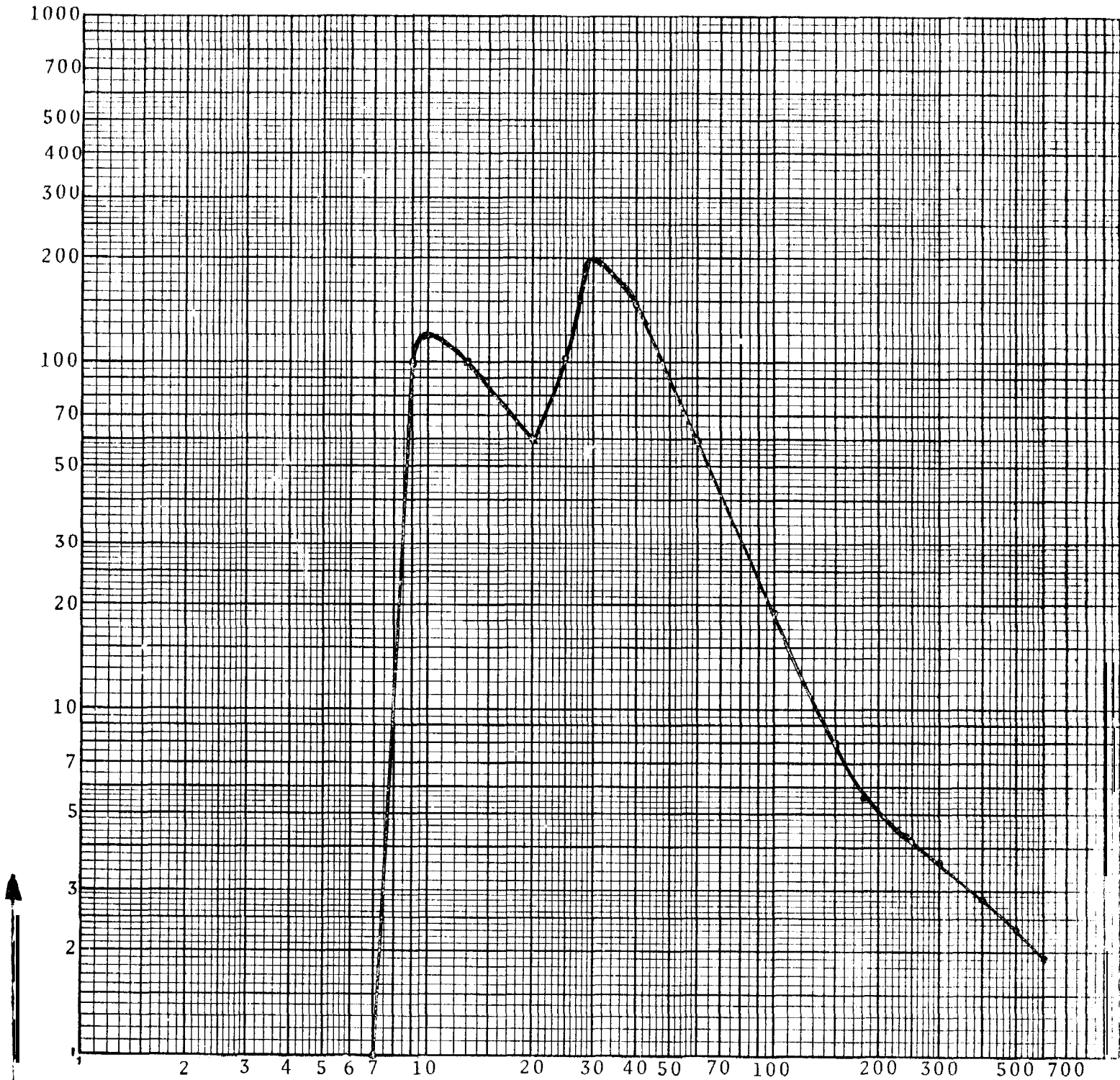
b. Now using the same graph as in part a. find the total dose for the period from  $H + 15$  to  $H + 40$ .

c. Now find the total dose for the period from  $H + 40$  to  $H + 600$ .

d. Add up the answers from parts a., b. and c. and thus obtain the total dose from fallout commence to  $H + 600$ .

REQUIREMENT NO. 2

Assume that a group of people were in a shelter with a PF of 20 from fallout arrival through  $H + 15$ , at which time they transferred to a shelter with a PF of 100. What would their dose be at  $H + 40$ , if the transfer took them 10 minutes and their exposure during transfer was 15 R? (Use the graph and your computed answers from Requirement No. 1).



DOSE-RATE  
(R/hr)

TIME AFTER BURST (Hours)

January, 1974





CANADIAN EMERGENCY MEASURES COLLEGERADIOLOGICAL DEFENCE OFFICERSCHAPTER 11RADIAC CALCULATOR (PART 2)

This chapter describes the procedures for solving total dose, entry time and stay time problems on the Radiac Calculator.

INTRODUCTION

1. Within the same limitations which applied to the use of the Radiac Calculator for dose-rate computations, the calculator may also be used for dose calculations. Given an observed dose-rate and time, and any two of the following, one can determine the third:

- a. Total dose
- b. Entry time
- c. Stay time.

2. Examples of problems of each type, and descriptions of the procedures for solving them, are contained in the following sections.

SECTION A - TOTAL DOSE PROBLEMSPROBLEM 1

The dose-rate at a post was 10 R/hr at H + 1. A person took up a position there and remained until H + 10 hrs. To what total dose was he exposed during this period?

SOLUTION:

Locate the 10 R/hr mark on the OUTER scale. Set the 1 hr mark of the INTERMEDIATE scale opposite the 10 R/hr mark. Hold these discs firmly together. The start exposure time for that person was H + 1, therefore set the 1 hour mark of the INNER scale at the START EXPOSURE arrow. Hold the three discs firmly in position. The person remained there until H + 10 hours, therefore locate the 10 hr mark on the INNER scale. The period between the START EXPOSURE arrow and the 10 hr mark represents the time of stay. Note that the 10 hr mark of the INNER scale is almost at the 35 minute line on the INTERMEDIATE disc. Follow this curved line to the OUTER disc. The point at which it meets the OUTER scale indicates the total dose

Answer:      about 19 R

PROBLEM 2

The dose-rate at a point was 10 R/hr at H + 1 hr. Estimate the dose to a person at this point for a 4 hour period starting at H + 3 **hours**.

SOLUTION:

Set 10 R/hr opposite 1 hr on outer two discs and hold them firmly. Rotate INNER disc until entry time (H + 3 hrs) is set opposite START EXPOSURE arrow. Hold all three discs to prevent rotation. For a 4 hour stay time, starting at H + 3, exposure ends at H + 7 hrs. Locate H + 7 hrs on INNER scale. It falls opposite the curved 1.5 hr line on INTERMEDIATE disc. Follow this curved line out to OUTER scale and read answer.

Answer:      about 6 R

PROBLEM 3

Three hours after a nuclear detonation, the dose-rate in an area was 8 R/hr. To what total dose would a person be subjected if he remained in that area until H + 50 years, starting exposure at 1 day after explosion?

SOLUTION:

Locate 8 R/hr on the OUTER scale and set opposite 3 hr mark on INTERMEDIATE scale. Set 1 day on INNER scale at the START EXPOSURE arrow. Locate the 50 year mark on the INNER scale. Note that it lies opposite the 30 min line. Follow this curved line to the OUTER scale and read answer.

Answer:      about 70 R

PROBLEM 4

Six hours after a nuclear detonation, the dose-rate at a damaged bridge was 30 R/hr. Nine hours later, a crew moved in to carry out repairs. Their job was completed at H + 1 day. To what total dose was this crew subjected while repairing the bridge?

SOLUTION:

Set 6 hours opposite the 30 R/hr mark. Start exposure was 9 hrs later or 15 hrs after explosion. Set 15 hr mark of INNER scale opposite START EXPOSURE arrow. The job was completed at H + 1 day, therefore locate 1 day mark on INNER scale. It meets the INTERMEDIATE disc at the 3 hr line. Follow this curved line to the OUTER scale and read answer.

Answer:      about 70 R

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SECTION B - STAY TIME PROBLEMSPROBLEM 5

The dose-rate at a point was 150 R/hr at H + 30 mins. If a group of workers arrived at this point at H + 3 hours, how long could they remain and not exceed a dose of 40 R?

SOLUTION:

Set H + 30 min opposite 150 R/hr on outer two discs. Set 3 hrs on INNER scale opposite START EXPOSURE arrow. Locate 40 R on OUTER scale. It lies opposite the curved 1.5 hr line of INTERMEDIATE disc. Follow this curved line to INNER disc and read answer from INNER scale.

Answer: until about H + 7 hrs  
(or for a period of 4 hrs)

PROBLEM 6

Two hours after burst, the dose-rate in an area is 300 R/hr. How long may a group occupy this area and not exceed a dose of 80 R, if they start their exposure at H + 1½ days?

SOLUTION:

Set 300 R/hr opposite 2 hrs. Set 1½ days (INNER scale) opposite START EXPOSURE arrow. Locate 80 R on OUTER scale. Follow curved broken line (6 hr) through INTERMEDIATE disc. Read answer from INNER scale.

Answer: until H + 2 days  
(or for a period of about 12 hours)

SECTION C - ENTRY TIME PROBLEMSPROBLEM 7

A rescue team has a job to do in an area in which the dose-rate was 80 R/hr at H + 50 minutes. They require 4 hours in the area to complete the job and must not exceed a 40 R total dose. When may they enter the area, remain for 4 hours and not be exposed to more than 40 R?

SOLUTION:

Set the 50 minute mark of the INTERMEDIATE scale opposite the 80 R/hr mark of the OUTER scale. Hold these discs firmly together. The second step in solving this problem is the reverse of that of an earlier problem. The information available is that the team must not exceed 40 R during a stay of 4 hrs. Therefore, locate 40 R on the OUTER scale and carry this to the INNER scale by following the curved line on the INTERMEDIATE disc. Note that 40 R is opposite the  $1\frac{1}{2}$  hr mark of the INTERMEDIATE disc. Mark this point. By trial and error, a 4-hour period must be fitted (on the INNER scale) between the START EXPOSURE arrow and the point you have marked. Thus, by starting exposure at 1 hr, the team could stay less than one hour. Starting exposure at H + 2 hrs would permit a stay of  $2\frac{1}{3}$  hrs. However, by starting exposure at H + 3 hrs, the team may stay for a period of 4 hrs and not be exposed to more than 40 R total dose.

Answer:      at about H + 3 hrs.

PROBLEM 8

Ten hours after a nuclear detonation, the dose-rate in an area is 7 R/hr. When may a group enter the area, stay for a period of 9 hrs and not be exposed to more than 30 R total dose?

SOLUTION:

Set the 10 hr mark of the INTERMEDIATE scale opposite the 7 R/hr mark of the OUTER scale. Hold these discs firmly together. Locate the 30 R mark on the OUTER scale. Note that it is opposite the 3 hr mark of the INTERMEDIATE scale. Follow the 3 hr line through the INTERMEDIATE disc and rotate the INNER disc until a period of nine hours is between this line and the START EXPOSURE arrow. By setting the 15 hr mark of the INNER scale opposite the START EXPOSURE arrow a period of nine hours will fit. Therefore, the group may enter 15 hrs after the explosion, leave at H + 1 day, and not exceed a dose of 30 R.

Answer:      at H + 15 hrs.

PROBLEM 9

At H + 2, the dose-rate in an area is 300 R/hr. When may this area be occupied for a period of 12 hours and the occupants not be subjected to a dose in excess of 80 R?

- 5 -

SOLUTION:

Set 300 R/hr opposite 2 hrs. Locate the 80 R mark on the OUTER scale. Follow the six hour line of the INTERMEDIATE disc to the INNER disc. Rotate the INNER disc until an interval of 12 hours is fitted between the 6 hr line and the START EXPOSURE arrow. It will be found that by starting exposure at no sooner than  $1\frac{1}{2}$  days after the explosion, a group could occupy the area for 12 hrs and not be exposed to more than 80 R.

Answer:      not before H +  $1\frac{1}{2}$  days



CANADIAN EMERGENCY MEASURES COLLEGERADIOLOGICAL DEFENCE OFFICERSCHAPTER 12MISCELLANEOUS RADEF CALCULATIONS

This chapter covers the following topics:

- a. A method for calculating the six-week dose.
- b. A method for calculating the dose and dose-rate when H-hr is unknown, and
- c. A procedure for computing shelter release times.

A METHOD FOR CALCULATING THE SIX-WEEK DOSE

1. Table 12.1 provides us with fast estimates for calculating the dose from a given time to the end of the six-week period, when the decay rate approximates  $t^{-1.2}$ .

| DOSE ESTIMATION TABLE   |        |
|---|--------|
| Multiplication Factors to determine dose received during the interval H + t to H + 6 weeks, given the dose-rate at H + t. |        |
| H + t   | FACTOR |
| H + 6 hours   | 20     |
| H + 8   | 25     |
| H + 12  | 35     |
| H + 18  | 45     |
| H + 24  | 60     |
| H + 36  | 80     |
| H + 48  | 100    |
| H + 3 days  | 140    |
| H + 4   | 180    |
| H + 5   | 200    |
| H + 7   | 240    |
| H + 2 weeks   | 300    |

Table 12.1

2. The dose from any time ( $H + t$ ) to  $H + 6$  weeks will be the product of the dose-rate at  $H + t$  and the multiplication factor, For example:

a, Suppose that the dose-rate at  $H + 8$  hrs. was 10 R/hr. To find the dose from  $H + 8$  to  $H + 6$  weeks:

(1) Find the Multiplication Factor for  $H + 8$  hrs. Line 2 of Table 12.1 shows the multiplication factor is 25.

(2) Multiply the dose-rate at  $H + 8$  (10 R/hr) by the Multiplication Factor

$$10 \times 25 = 250 \text{ R approx.}$$

b. Similarly, if the dose-rate at  $H + 48$  hrs. was 5 R/hr, the dose from  $H + 48$  to  $H + 6$  weeks would be

$$5 \times 100 \text{ or about } 500 \text{ R}$$

3. It is important to remember that the dose computed by this method is the dose from a particular time ( $H + t$ ) to  $H + 6$  weeks, *not* the *total* 6-week dose. The total 6-week dose will be the sum of the dose from  $H + t$  to  $H + 6$  weeks, as determined from the Table, and any dose received prior to  $H + t$ .

#### CALCULATIONS WHEN H-HR IS UNKNOWN

4. All of the forecasting procedures discussed so far are predicted upon the analyst having a reasonably accurate idea of when the weapons detonated. We do recognize, however, that there may well be occasions when all an analyst may have will be a series of dose-rate reports, with little or no idea of when the weapon was detonated. The following method has been developed, utilizing the Radiac Calculator, to solve such problems. Let us consider the following examples:

##### Problem 1

At a certain post, the dose-rate 2 hours ago was 70 R/hr. It has now decreased to a level of 50 R/hr. What will be the dose-rate 2 hours from now?

##### Solution:

Between the 70 R/hr and 50 R/hr marks, which appear on the outer disc,, try to squeeze in a time interval of 2 hours (the hours appear on the intermediary disc) . Once one of your attempts has been successful, you have found the H-hour in the sense that, in this problem,  $H + 6$  appears in front of 70 R/hr. Thus, **you** know that "at  $H + 6$  hours, the radiation intensity is (or was) 70 R/hr. The problem is therefore essentially solved,"

Now, if you want to find out what the dose-rate will be 2 hours later, i.e. 2 hours after  $H + 8$ , i.e. at  $H + 10$ , you simply move your finger along the intermediary disc to  $H + 10$  hours, and you will find on the outer disc, the value of 38 R/hr (appwox.). This is the answer,



The following problems are suggested for practice.

Problem 2

Given an initial reading of 50 R/hr and a reading 2 hours later of 30 R/hr, find the dose-rate 24 hours after the initial reading,

The answer is approx. 6 R/hr.

Problem 3

The dose-rate at 0600 hrs was 100 R/hr and at 0700 hrs it was 90 R/hr. Estimate the dose-rates at 0800 hrs. and at 1000 hrs.

(Answer: At 0800 hrs. dose-rate = 80 R/hr, and  
at 1000 hrs. dose-rate = 70 R/hr (approx))

Now that you have the dose-rates at 0600 hrs, 0700 hrs, 0800 hrs, and 1000 hrs, calculate the Total Dose accumulated between 0600 hrs and 1000 hrs.

Remark: These H-hour unknown problems do not have a unique solution in the sense that the logarithmic scale appearing on the Radiac Calculator repeats itself approximately 4 times.

SHELTER RELEASE TIME

5. The principal countermeasure against potential injury from fallout radiations is the use of fallout shelter. The desirable goal would be to limit the whole population to a dose of less than 25 R. However, where control measures are required and this general criteria cannot be met, we can apply a higher criterion of 100 R in 6 weeks,

6. Where in-shelter doses will be less than 100 R in 6 weeks some time may be spent out of shelter, A relatively simple technique for determining shelter release times in such a case has been devised. There are two steps to the procedure:

- a. First, determine *Average Time Out of Shelter*, that is, the average time one could spend out per day for the remainder of the 6-week period.
- b. In order to use the *average time* most effectively, apply it proportionately so that less time is allowed outdoors at early times when the dose-rate is high and gradually increasing times allowed and the dose-rate decreases.

7. The *tools* for doing this consist of a simple formula for determining *Average Time Out of Shelter* and a nomogram (Figure 12.2) for prorating the daily release times,

AVERAGE TIME OUT OF SHELTER

8. The formula for determining the average time out of shelter is:

$$T = \frac{24 (P-E)}{E (P-1)}$$

where T = average daily time out of shelter after H + 48 hours

P = Protection Factor of shelter

E = Effective Factor =  $\frac{\text{(predicted 6-week unprotected dose)}}{100 \text{ R}}$

Note that the system assumes no shelter release during the first 48 hours.

PROBLEM 1

A shelter has a PF of 50 and the predicted 6-week outdoor dose is 500 R. Determine the "average time out of shelter".

SOLUTION:

(1) Determine the Effective Factor (E):

$$E = \frac{500}{100} = 5$$

(2) Substitute in formula:

$$\begin{aligned} T &= \frac{24 (P-E)}{E (P-1)} \\ &= \frac{24 (50-5)}{5 (50-1)} \\ &= \frac{24 \times 45}{5 \times 49} \\ &= 4.4 \text{ Answer} \end{aligned}$$

Therefore, after H + 48, a person could spend an average of 4.4 hours out of shelter per day and not exceed 100 R in 6 weeks.

USE OF TIME OUT OF SHELTER NOMOGRAM

9. Having determined the average daily time out of shelter we can now establish a daily release schedule by using the nomogram of Figure 12.2. To use the nomogram lay a straight-edge from the day of interest (Scale 1) through the T factor (Scale 2) and read off the permissible release time on Scale 3.

TIME OUT OF SHELTER

NOMOGRAM

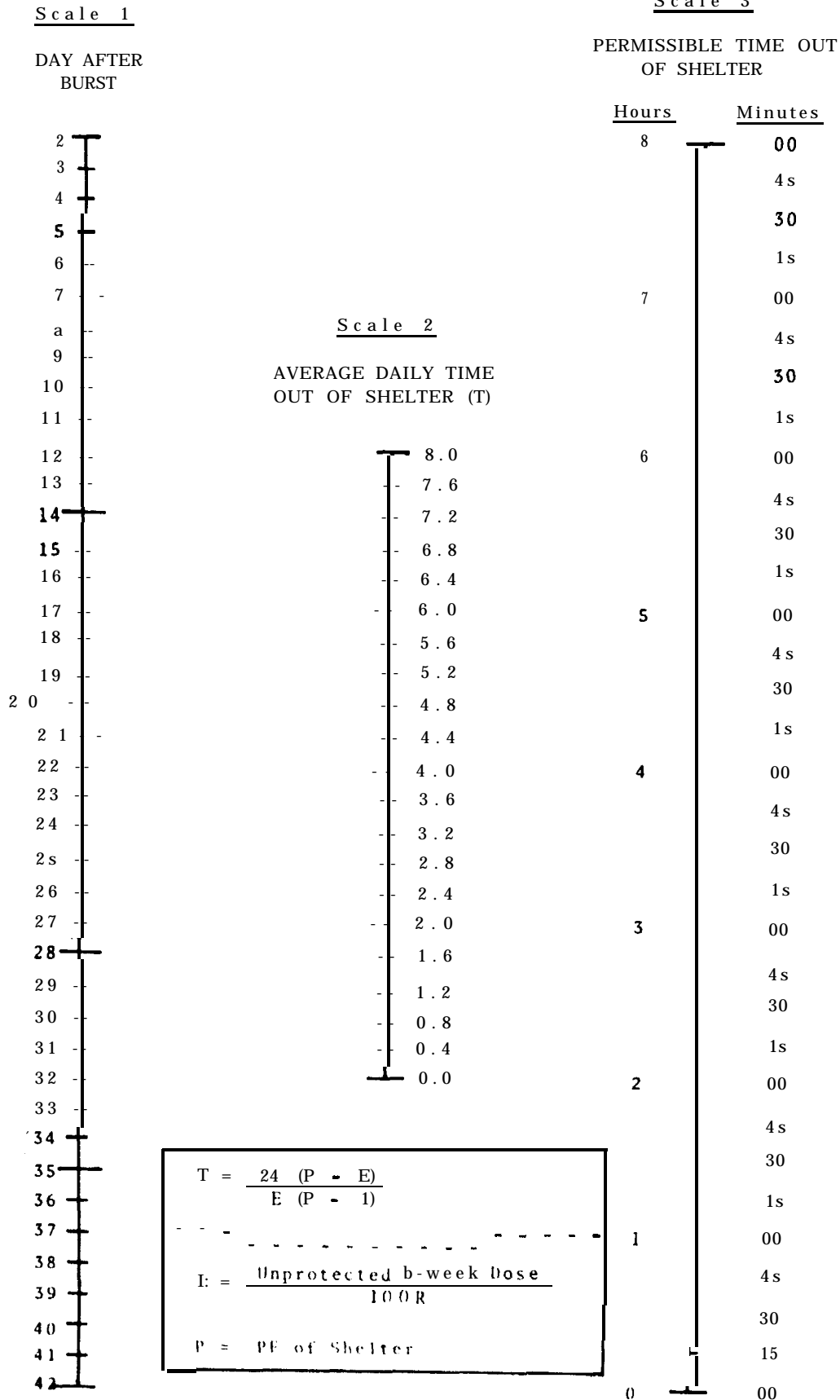


Figure 12.2 - Time Out of Shelter Nomogram

PROBLEM 2

Set a release schedule for the previous example ( $T = 4.4$ )

SOLUTION:

Locate the T factor value (4.4), on Scale 2 of the nomogram. Using a ruler (preferably of clear plastic) line up 4.4 on Scale 2 with appropriate days after burst on Scale 1 and read off the values in hours and minutes on Scale 3.

Examples:

|             |              |
|-------------|--------------|
| H + 3 days  | 30 mins      |
| H + 12 days | 2 hrs 25 min |
| H + 32 days | 6 hrs 25 min |

PRACTICE PROBLEMS

The following problems are for personal study.

PROBLEM 3

The following dose-rate reports were received from a monitoring post:

|       |          |
|-------|----------|
| H + 2 | 0.5 R/hr |
| H + 3 | 50 R/hr  |
| H + 4 | 100 R/hr |
| H + 5 | 84 R/hr  |
| H + 6 | 67 R/hr  |

Compute the estimated radiation dose to a person in a PF 10 shelter for the period from fallout arrival to H + 6 weeks.

METHOD:

- Compute the dose from fallout arrival to H + 6 hours by the "average dose-rate x time" method.
- Compute the dose from H + 6 hrs to H + 6 weeks by multiplying the H + 6 dose-rate by a multiplication factor from Table.
- Add the two doses to determine the total 6-week unprotected dose.
- Divide by PF of shelter to determine the dose inside the shelter.

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SOLUTION:a. Dose to H + 6 hrs.

$$H + 2 \text{ to } H + 3: \frac{.5 + 50}{2} \times 1 = 25.5 \text{ R}$$

$$H + 3 \text{ to } H + 4: \frac{50 + 100}{2} \times 1 = 75 \text{ R}$$

$$H + 4 \text{ to } H + 5: \frac{100 + 84}{2} \times 1 = 92 \text{ R}$$

$$H + 5 \text{ to } H + 6: \frac{84 + 67}{2} \times 1 = 75.5 \text{ R}$$

$$\text{TOTAL (H + 2 to H + 6)} \qquad \qquad \qquad 268 \text{ R}$$

b. Dose (H + 6 hrs to H + 6 weeks):

From Table, multiplication factor is 20. Hence,

$$67 \text{ R/hr} \times 20 = 1340 \text{ R}$$

c. Total Unprotected Dose:

$$268 + 1340 = 1608 \text{ R}$$

d. Dose in Shelter:

$$\frac{\text{Unprotected dose}}{\text{PF}} = \frac{1608}{10} = 160 \text{ R}$$

PROBLEM 4

A shelter has a protection factor of 110, The unprotected 6-week dose in the vicinity is estimated to be 500 R.

a. When can shelter release commence?

b. Estimate the number of hours of release from shelter on 7th, 14th, 28th, and 35th days after burst.

METHOD:a. Calculate Average Time out of Shelter (T):

Determine Effective Factor (E) where,

$$E = \frac{(\text{unprotected dose})}{100 \text{ R}}$$

Then, determine T, using:

$$T = \frac{24 (P-E)}{E (P-1)}$$

PROBLEM 5

From the nomogram of Figure 12.2 determine when shelter release should commence, and the release times for the 7th, 14th, 21st, 28th, 35th and 42nd days after the burst, for the following values of T.

- a. 1.6
- b. 3.6
- c. 7.2
- d. 11.0

SOLUTION:

|          | RELEASE TIME (hours:minutes) |            |                                   |          |   |
|----------|------------------------------|------------|-----------------------------------|----------|---|
|          | T = 1.6                      | T = 3.6    | T = 7.2                           | T = 11.0 |   |
| Commence | On 15th day                  | On 6th day | On 3rd day                        |          | NO<br><br>RESTRICTIONS<br><br>NECESSARY |
| 7th day  | 0                            | 0:35       | 4:10                              |          |   |
| 14th day | 0                            | 2:00       | 5:35                              |          |   |
| 21st day | 1:20                         | 3:20       | 7:00                              |          |   |
| 28th day | 2:50                         | 4:50       | FULL<br>8 HOURS<br>ON<br>26th DAY |          |   |
| 35th day | 4:10                         | 6:15       |                                   |          |   |
| 42nd day | 5:35                         | 7:40       |                                   |          |   |

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where

T = Average time out of shelter

P = Protection factor of shelter

E = Effective factor

Thus we have:

$$E = \frac{500}{100} = 5$$

and

$$T = \frac{24(110-5)}{5(110-1)}$$

$$= \frac{24 \times 105}{5 \times 109}$$

$$= 4.6$$

b. Daily Release Times:

(1) From Figure 12.2 - release can commence after H + 48  
(Table assumes no release for the first two days) .  
Initial release would be 45 minutes on H + 3 days.

(2) From Figure 12.2 release on the given days could be  
as follows (using T = 5):

|             |                         |
|-------------|-------------------------|
| H + 7 days  | 1 hour and 30 minutes   |
| H + 14 days | 3 hours                 |
| H + 28 days | 5 hours and 45 minutes  |
| H + 35 days | 7 hours and 15 minutes. |