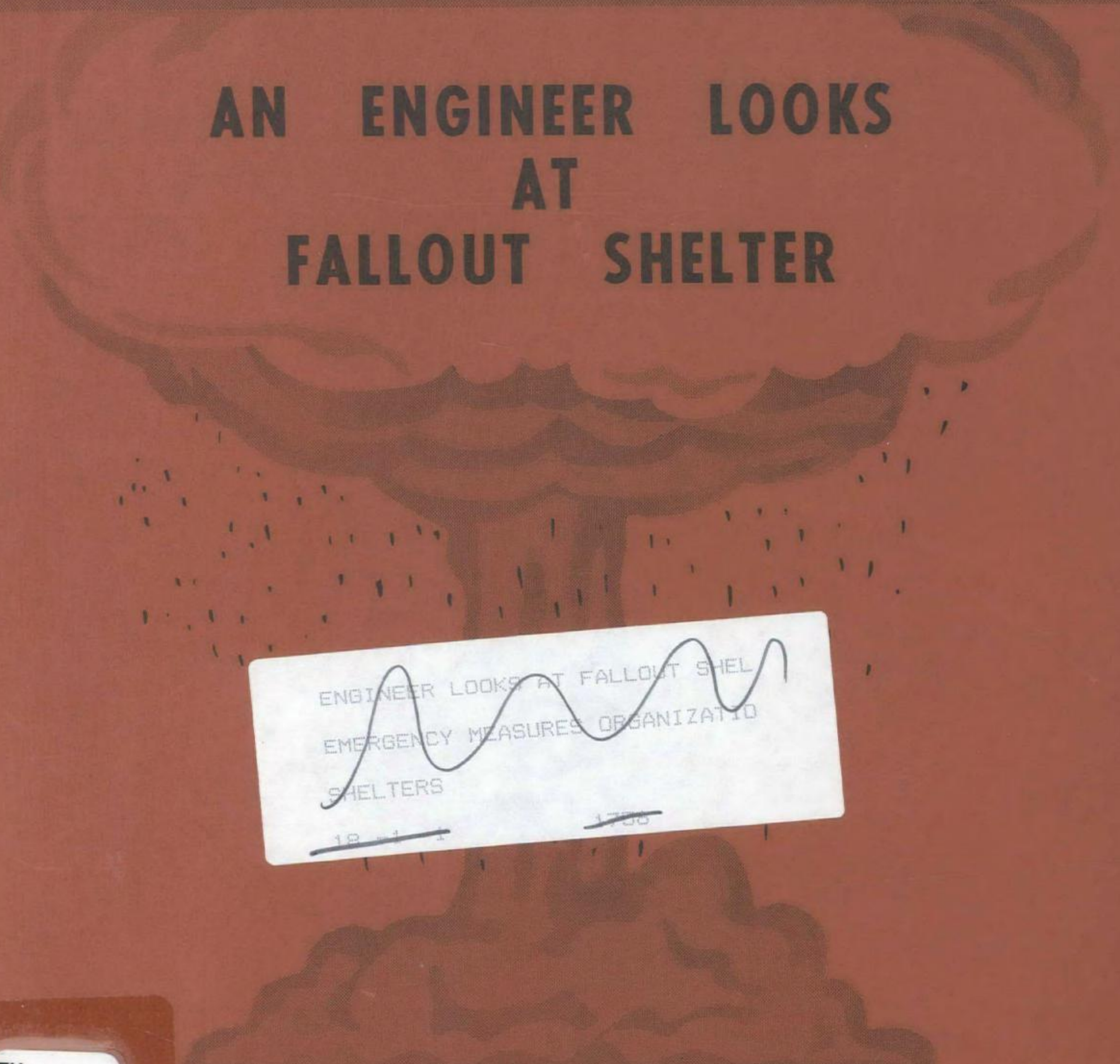
EMERGENCY MEASURES ORGANIZATION

AN ENGINEER LOOKS AT FALLOUT SHELTER



PRIVY COUNCIL OFFICE
OTTAWA

EMO MANUAL NO. 1

AN ENGINEER LOOKS AT FALLOUT SHELTER

A Manual for Architects and Engineers

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INTRODUCTION

The purpose of this manual is to outline certain procedures recommended for evaluating the fallout shelter potential of structures within a given area or municipality. Should any local government contemplate a survey to determine, within the area of its jurisdiction, the quantity and quality of accommodation capable of providing the population with protection against radioactive fallout, it is hoped that recourse to this guide will be of assistance. The text is planned for the use of the architect or engineer, whether he be employed in municipal, provincial or federal government.

Apart from a minimum of background information, little space is devoted to the theory of radiation shielding. All calculations involving protection against gamma radiation are based on a series of charts developed by the U.S. Office of Civil and Defense Mobilization. After extensive study, we are convinced that the O.C.D.M. methods of estimating fallout protection are the best available, and we have drawn liberally upon their publications.

Some of the practical problems used in these pages to illustrate protective improvements are based on improvisations, such as the sandbagging of exposed walls. While expedients of this nature would be essential in time of emergency, the reader will readily appreciate that under normal conditions, aesthetical considerations may dictate rather different treatment. This is a matter of local judgement; insofar as the calculations are concerned, both types may be derived with equal facility.

In some of the examples used to explain the various charts, our handling of significant figures may be open to question. Theoretical and experimental work carried out by O.C.D.M. indicates that protection and reduction factors should be rounded off to not more than two significant figures. Where we use more than this, it is for purposes of comparison only. The accuracy of this type of work is limited by the basic assumptions discussed in Chapter 3.

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LIST OF ABBREVIATIONS

A_b – area of basement floor
A_c – central roof area
A_c' – adjusted central roof area
A_f – area of floor
Ap% – percentage of apertures
A_r – total roof area
A_r' – adjusted total roof area
B – breadth or width
D – position of detector
E – east
F_a – aperture correction factor
F_h – height correction factor
F_m – mutual shielding factor
F_p – perimeter factor
F_s – skyshine correction factor
GC – ground contribution
H_c – height of detector above contaminated plane
H_r – height of roof deck above detector
L – length
M_b – mass thickness, basement walls
M_e – mass thickness, exterior ground floor walls
M_f – mass thickness, ground floor slab (basement ceiling)
M_f2 – mass thickness, second floor slab
M_p – mass thickness, interior partitions
M_r – mass thickness, roof slab
M_{to} – total overhead mass thickness
M_{tw} – total mass thickness of walls
N – north
RC – roof contribution
RF – reduction factor
P – perimeter
PF – protection factor
S – south
W – west
W_c – width of contaminated plane

CHAPTER 1

THE PROBLEM OF RADIOACTIVE FALLOUT

1.01 Effects of Nuclear Explosions

A nuclear explosion kills or injures people by blast, heat, or ionizing radiation. Modern nuclear weapons have the ability to devastate large areas to an extent undreamed of only a few years ago. Let us suppose that a direct hit is scored upon a target city by a 5 megaton bomb--one equal, in terms of total energy release, to five million tons of conventional explosives. This size of weapon is selected for discussion because it would effectively destroy any Canadian city, and from the enemy's point of view it would be uneconomical to use larger weapons. Figure 1 shows the ranges of the various types of damage that would result if such an explosion took place as a surface or ground burst. The effects of the explosion cover an area

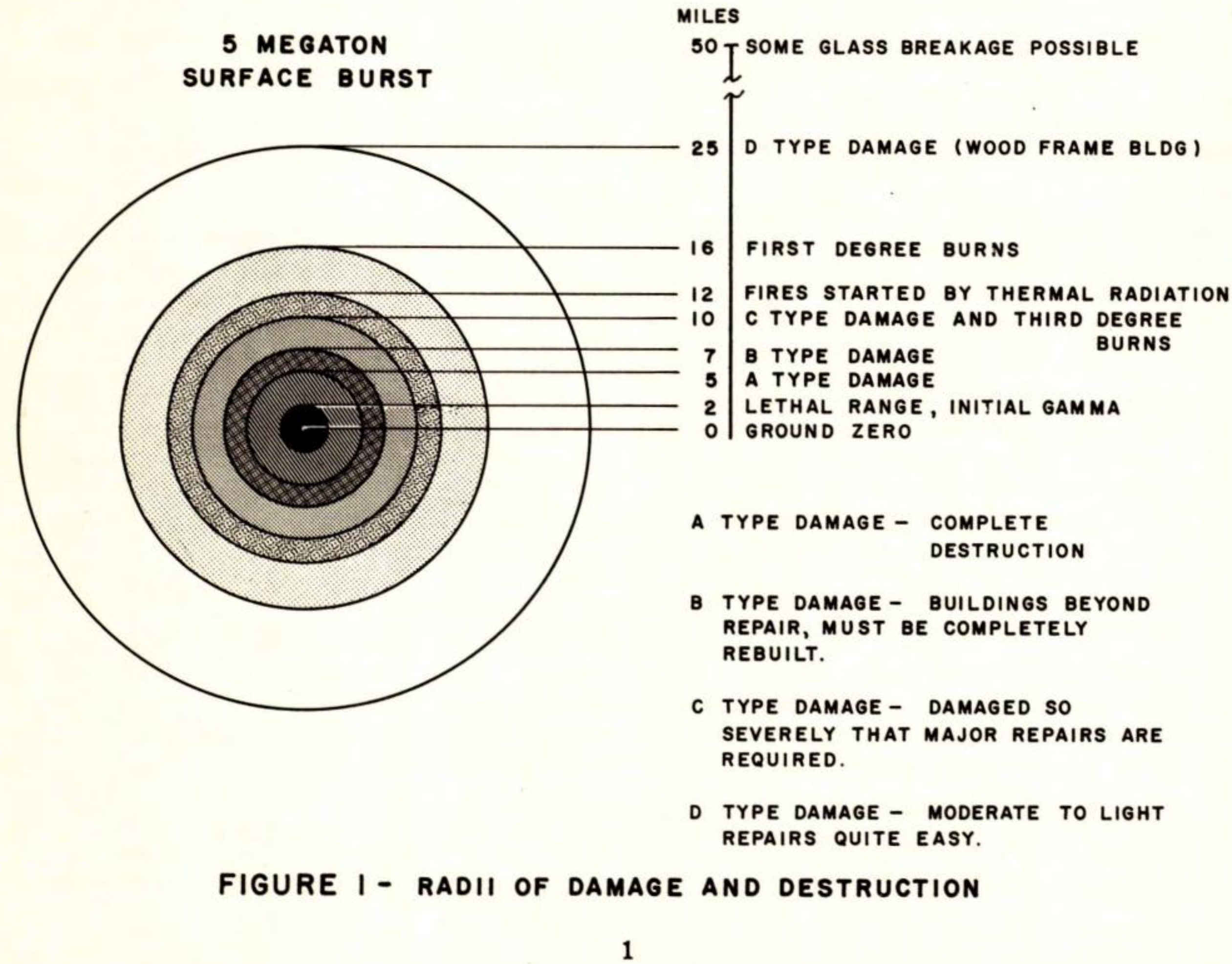


FIGURE 1 - RADII OF DAMAGE AND DESTRUCTION

which is roughly circular in shape, with its center, called ground zero, being the point of detonation. The radii shown in Figure 1 do not apply to high air burst explosions, which are not considered in this manual.

1.02 Blast Damage

Blast damage would extend outwards from the center point to a distance of approximately 25 miles. This means that some damage could be expected to all normal buildings throughout an area of nearly 2,000 square miles. It would vary from complete destruction, through severe and moderate damage, to broken plaster and window frames on the outer perimeter. Inconceivable as it may seem, the explosion of a single 5 megaton bomb could break windows up to 50 miles away--thus affecting a total area of 8,000 square miles.

1.03 Thermal Radiation

Thermal radiation or heat flash from the 5 MT surface burst would cause third degree skin burns to unprotected people up to 10 miles from the point of detonation. First degree burns would be experienced to a radius of 16 miles. The incendiary action of thermal radiation would initiate fires over a large area. Fortunately it is relatively easy for people to protect themselves against thermal radiation, and barring a surprise attack, casualties from this source could be sharply reduced.

1.04 Initial Nuclear Radiation

Radiation from gamma rays emitted during the fission and fusion processes, and also by the fission products in the fireball, would be lethal to unprotected people out to a distance of about two miles. In a limited area, it is possible that the occupants of anti-blast shelters would survive the blast effects of the explosion, only to become radiation casualties. However, for weapons in the megaton range, damage caused by the initial nuclear radiation is overshadowed by the blast and heat effects.

1.05 Immediate Effects on Target Area

The blast wave, the thermal flash and the initial gamma radiation will all have disappeared in about one minute after the detonation. Of course people will still be dying and receiving injuries after this time, due to secondary effects such as collapsing buildings and fires. The total number of casualties in the target area will depend on many factors such as population density, time of day, type of buildings, warning received and general public discipline. In the event of a surprise attack on an unprepared city, the toll would be staggering. If the attack had been expected and the city had a good civil defence plan, a large percentage of these casualties would be avoided.

1.06 A Delayed Effect

The prospects for people in a target area at the time of the explosion are grim. There is much that can be done to reduce the number of deaths and injuries, but it is not the intention here to describe in detail the necessary protective measures. This manual is concerned with a danger which, in terms of human lives, is potentially even greater than that which threatens the target area itself. The peril referred to is that of radioactive fallout.

1.07 The Atomic Cloud

When our 5 megaton bomb explodes on or near the ground in the target area, enormous quantities of earth and debris of all types will be drawn up into the fireball, which rises rapidly to form a so-called atomic cloud. Much of this extraneous material will, initially, be in vapour form, to reappear later as particulate matter, when condensation and solidification are caused by cooling. The total quantity of such debris in the atomic cloud will depend on the height of burst and the nature of the terrain. It will usually be in the order of thousands of tons.

1.08 Sources of Residual Radioactivity

Some of the particles in the cloud were made radioactive by the absorption of neutrons released by the explosion. For the most part however, the dirt particles are intimately mixed with fission products and other bomb residues, and in consequence become carriers of intensely radioactive substances. It is estimated that at one minute after the explosion of a 5 megaton bomb, the total radioactivity due to fission products is comparable to that of several million tons of radium.

1.09 Radioactive Fallout

The atomic cloud continues to rise and starts to spread out horizontally at heights from 10 to 15 miles. The top of the cloud may attain an elevation of up to 25 miles. Gradually the cloud begins to disperse in a downwind direction. The particulate matter falls back to earth over a period of time. The heavier particles, as one would expect, fall more quickly, while lighter particles settle to earth progressively farther downwind and at a later time.

The larger particles, which are 400-500 microns in diameter, a size similar to grains of medium sand, normally begin to reach the earth's surface about one half-hour after the explosion. Smaller particles, of silt size, may take as long as 48 hours to return to earth, and by this time they may have been carried a few hundred miles from ground zero. The material so deposited is referred to as early or close-in fallout, and it may contaminate an area of several thousand square miles. Meanwhile some of the very minute particles will have found their way into the troposphere and stratosphere, from which they fall back to earth over periods extending to several years, at very great distances from the explosion. This latter phenomenon is known as delayed, or world-wide fallout. While of little concern to civil defence, delayed fallout introduces long term biological hazards which represent a public health problem. Figure 2 shows the formation of fallout after a surface burst. Figure 3 is an idealized contamination pattern, showing the total dose caused by the close-in fallout up to 36 hours after a 15 megaton surface burst.

1.10 The Danger of Fallout

Close-in fallout affects an area which is several times the size of that subjected to blast, thermal and initial nuclear radiation. If the area is densely populated, and if its inhabitants are unprotected, it is quite conceivable that more casualties could result from fallout than from all the immediate effects of the explosion combined. Hence it is often stated that the principal danger to the largest number of people is radioactive fallout. Thousands of people, who completely escaped injury or death from blast and fire because of their distance from the explosion, might become radiation casualties hours, days, or even weeks later.

1.11 Protection of the Public

When contemplating the consequences of large-scale radioactive contamination in populated areas, it soon becomes apparent that here, at least, one does have a chance to protect oneself. Extensive studies have revealed that although radioactive fallout may be the greatest potential danger to the Canadian population, it is also one against which individual defensive measures are most likely to be effective. What is required? For the most part, information and guidance. The public must be told what the hazard is, and how to prepare for it. This is easier said than done. Although heavy fallout can be seen coming down, or on the ground after deposition, it is not possible to see, hear, taste, feel or smell radiation, and people are simply not accustomed to dealing with such intangibles. The pamphlet "Your Basement Fallout Shelter", published by the Emergency Measures Organization in May 1960 as Blueprint for Survival No. 1, offers a solution to a large number of citizens who are fortunate enough to occupy homes with basements. The pamphlet "11 Steps to Survival" offers excellent advice for speedy personal survival methods. Another pamphlet will be issued shortly with suggestions for shelters that can be built in a backyard. These publications are easy to read and understand. If they are acted on, a large percentage of the population will be able to provide itself with adequate protection against fallout. For the remainder of the public, those for whom household fallout shelters are not feasible, alternative planning in the form of larger shelters is required. In this category are those apartment dwellers for whom insufficient space is available to permit the construction of shelters for individual families. Also to be considered are office, factory, shop employees; school children, shoppers, travellers, or anyone who finds it impossible to get home to shelter within about 30 minutes after a nearby nuclear explosion.

1.12 Fallout Shelters

Large community or public fallout shelters can be designed as separate structures or may often be incorporated in existing buildings. It is obvious that, for reasons of economy, the latter solution will have to be applied in the majority of cases. Although certain basic principles apply to shelter construction regardless of size, it is evident that the problem becomes more complex as the number of people to be protected increases. In the following chapters procedures will be suggested which should enable municipal building authorities to evaluate the fallout shelter potential of existing structures. Guidance will also be offered for the improvement of such structures from the viewpoint of both radiation shielding and general habitability.

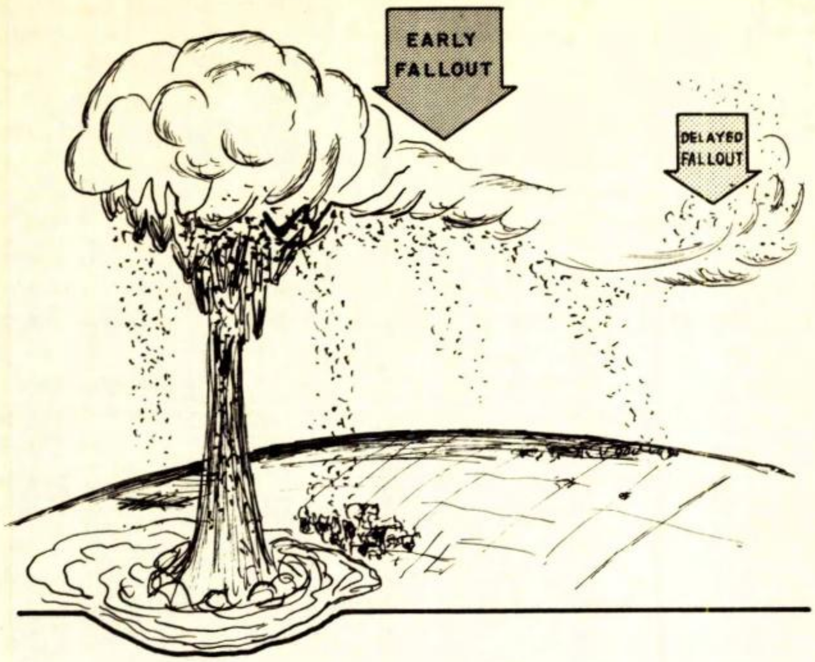
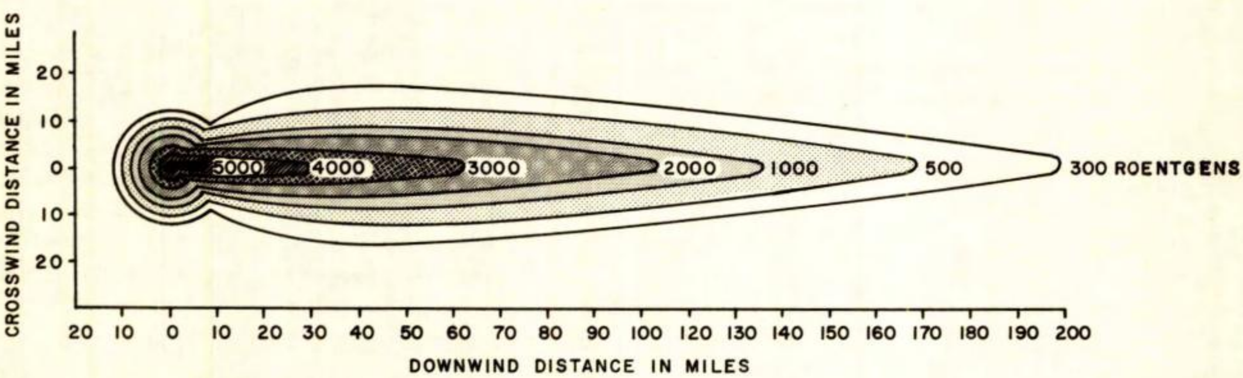


FIGURE 2 - FORMATION OF FALLOUT



ISODOSE CONTOURS, 36 HOURS AFTER EXPLOSION AT BIKINI ATOLL, 1 MARCH 1954

FIGURE 3 - IDEALIZED FALLOUT PATTERN

CHAPTER 2

PROTECTION AGAINST RADIATION

2.01 Effects of Ionizing Radiation

Before commencing the development of practical protective measures, it may pay us to examine briefly the nature of the danger with which we are confronted. Radio-active elements in fallout emit alpha, beta and gamma rays. Alpha and beta rays are physical particles having short ranges in air, and little penetrating power. Shielding against them presents no problem, and as long as fallout is kept off the clothing and skin and is not ingested, there is nothing more to worry about. Gamma rays on the other hand are electro-magnetic waves with the ability to penetrate all types of materials. The exposure of a human being to gamma radiation results in the ionization within the body of atoms of carbon, hydrogen, nitrogen and oxygen. Proteins, enzymes, and other substances making up the body cells, are injured or destroyed. If enough living tissue is thus damaged, the victim will become seriously ill or die. Exposure doses of gamma radiation

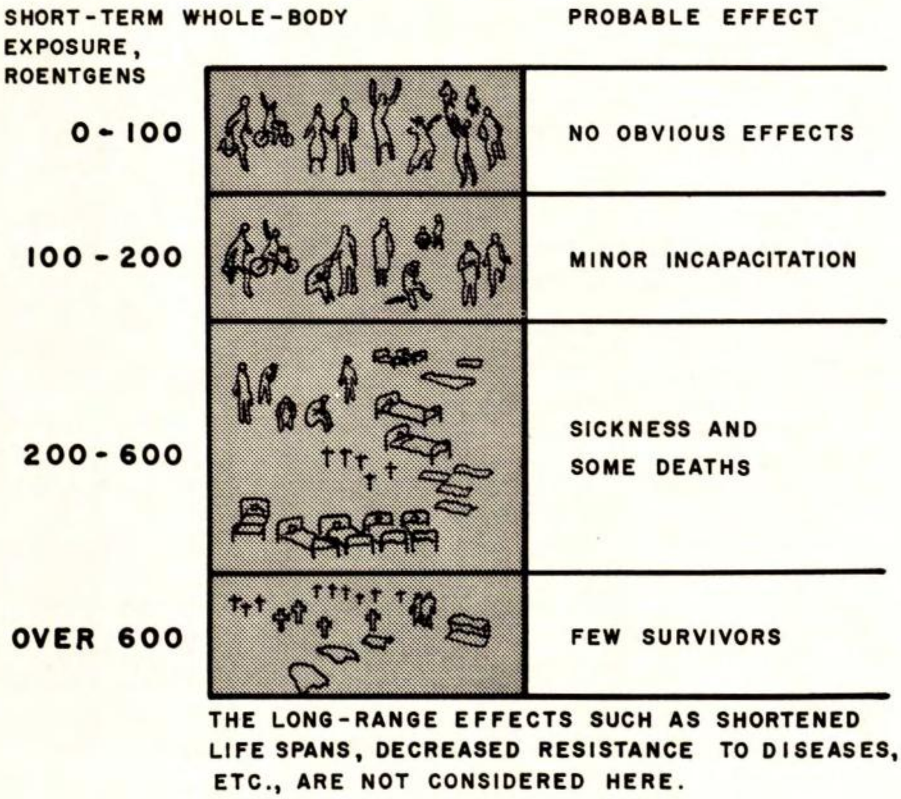


FIGURE 4 – EFFECTS OF GAMMA RADIATION

are measured in units called roentgens (r). Figure 4 is a table showing the effects on human beings of exposure to various doses of gamma radiation.

2.02 Theory of Protection

Let us now examine the ways in which it is possible to achieve protection against ionizing radiation. The first method is known as "barrier shielding" and involves the placing of a barrier, or mass of material, between the fallout field and the person or persons to be protected. Part of the gamma radiation is attenuated by the barrier, and the greater the density of the material, the smaller will be the percentage of radiation that gets through. Figure 5 illustrates the exponential manner in which radiation is attenuated by increasing thicknesses of material. Although this curve was drawn for monoenergetic gamma radiation from a point source, similar attenuation curves will be introduced for gamma radiation from fallout, which is considered as a polyenergetic plane isotropic source. The second way of obtaining protection against radioactive fallout is known as "geometry shielding" and this simply means increasing the distance between the individual and the source or sources of radioactivity. It will be seen in Chapter 3 that radiation shielding problems are normally solved by a combination of barrier and geometry shielding. Also on our side, when it comes to problems of protection against fallout, is the factor of time. Although it cannot be manipulated as readily as mass or distance, time has a place of great importance in the field of protection. This is due to the fact that the intensity of radiation from fallout decreases rapidly with the passage of time. Figure 6 illustrates the logarithmic rate of decay. It is obvious that the greater part of the individual's dosage will be required during the first few hours after the arrival of fallout.

This fact serves to emphasize the necessity of protection from the earliest possible moment.

FIGURE 5 - ABSORPTION OF RADIATION

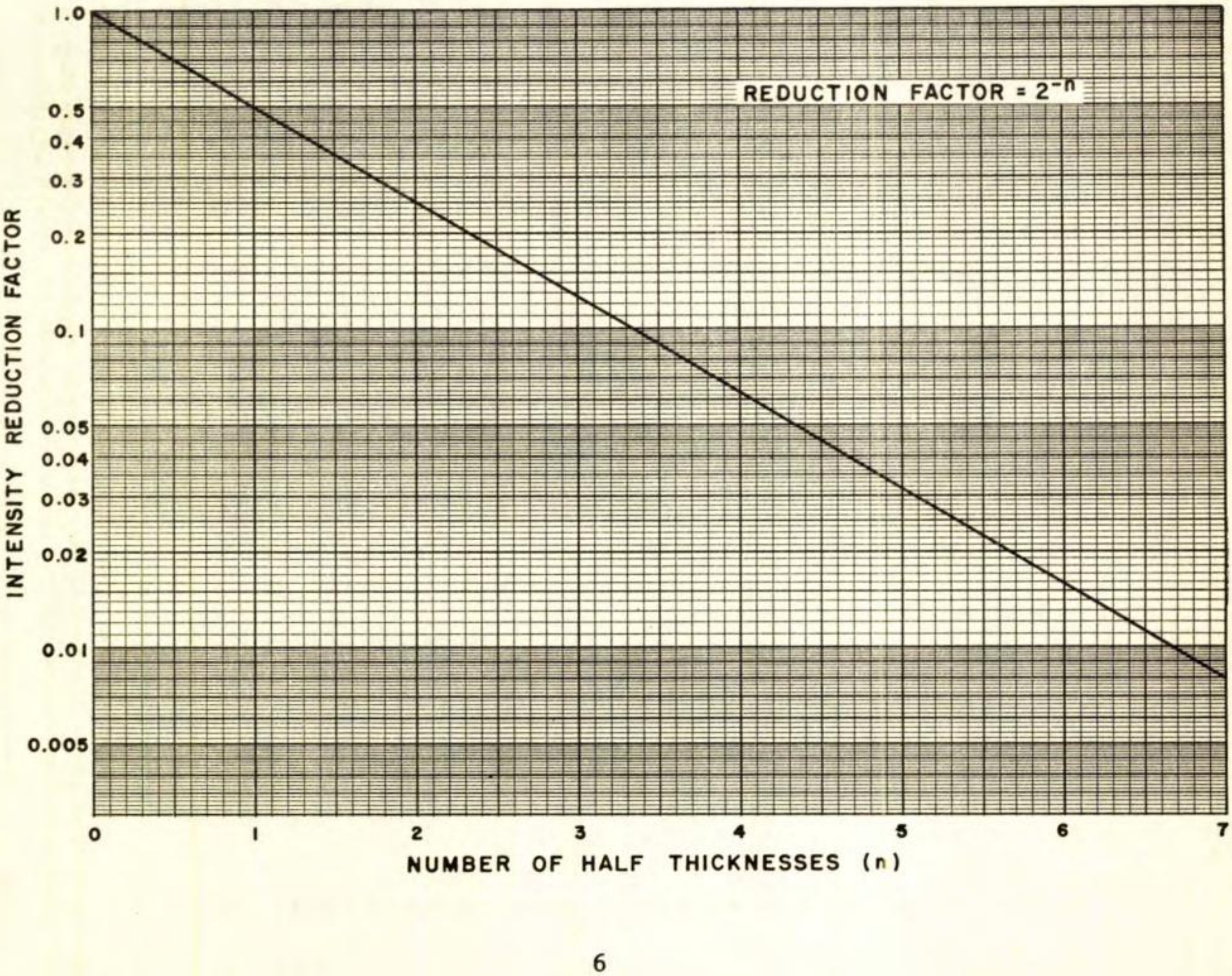
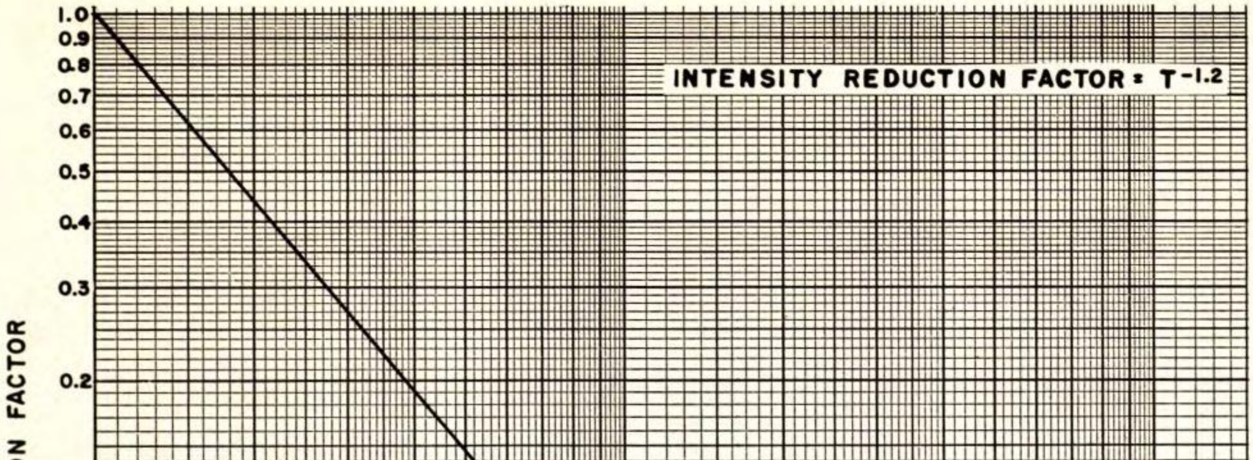


FIGURE 6 - DECAY RATE OF FISSION PRODUCTS



2.03 Degree of Protection

Having established the theoretical ways and means of obtaining protection from fallout, the next step involves their application to existing buildings and structures, or to the drawing board, with a view to providing suitable shelters. Immediately, however, a question arises--what degree of protection is desired? The logical answer--sufficient protection to avoid radiation casualties. Then what degree of protection is practical? Who can say what the intensity of radiation will be at point "A" after fallout arrives there? To calculate this accurately in advance, one would have to know exactly where the bomb or missile was going to explode, its size, its fission-fusion ratio, its efficiency, and what the meteorological conditions would be at the time. It is evident that by using this approach, the number of unknowns exceeds by far the number of equations, and the answer might appear to be that there is no answer. This is far from being true however, and as we shall soon see, it is quite feasible to design a fallout shelter for point "A" or anywhere else.

2.04 Protection Factor

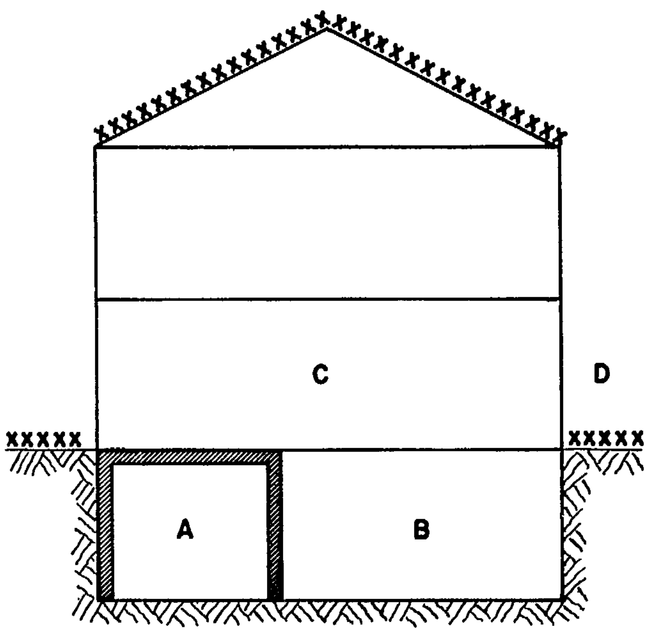
When designing fallout shelters, or assessing existing buildings in terms of their ability to provide radiation shielding, the concept of "protection factor" is used. This term expresses the factor by which the amount of radiation received by a person would be reduced in a protected site, as compared to an unprotected location in the same area. Figure 7 demonstrates the effect of the protection factor on the occupants of various parts of a house.

2.05 Shelter Categories

When fallout shelters are being designed, or when rooms in existing buildings are being assessed as potential shelters, there are two main considerations to be kept in mind. These are the protection factor, which rates the shelter in terms of radiation shielding, and the habitability factors, which determine the suitability of the shelter for occupancy by human beings. Habitability factors will be discussed at length in Chapter 4. Insofar as protection factors are concerned, the Federal Government's Panel on Research has stated that a Class A fallout shelter must have a protection factor of at least 500, while a Class B fallout shelter requires a minimum protection factor of 100. Class A shelters will be required for high priority installations such as emergency control centers and broadcasting stations, hospitals, etc. Class B shelters will be non-functional, in the sense that no work will be carried on in them. They will include all household and community shelters. Extensive study has revealed that people who remain in shelters having protection factors of 100 will, with a very few exceptions, escape radiation injury.

2.06 The Purpose of a Fallout Shelter

Before proceeding with detailed shielding calculations, it should be emphasized that the primary purpose of a fallout shelter is to protect people from gamma radiation. It is **not** intended to give protection against blast. Indeed, at the time of the actual explosion, there may be greater danger in the shelter than elsewhere, due to the danger of collapse. Fallout shelters are intended for use **after** an explosion by people in areas that have escaped devastation by blast and fire, but which are in the path of the fallout. How are they to know? Warnings of fallout will be broadcast by radio.



PROTECTION FACTORS

A = 100 C = 3
B = 30 D = 1

ASSUMING THAT INITIAL INTENSITY IN AREA AT (H+1)HRS WAS 1000 ROENTGENS/HR., TABLE GIVES DOSAGE ACQUIRED IN EACH LOCATION.

TIME	A	B	C	D
H + 2 hrs.	6.2	21	206 (sick)	620 (dying)
H + 7 hrs.	16	53	533 (dying)	
H + 2 days	27	90		
H + 2 weeks	33 (O.K.)	110 (slightly sick)	dead	dead

FIGURE 7 - PROTECTION FACTORS AND EFFECTS

CHAPTER 3

DETAILED SHIELDING CALCULATIONS

3.01 Basic Assumptions

(a) It is assumed that the radioactive fallout is uniformly deposited on the ground and on the roofs of buildings.

(b) All roofs are considered to be flat and therefore to have areas equal to their horizontal projections. The average height of a sloping roof is normally taken to be above its eave by one half of the

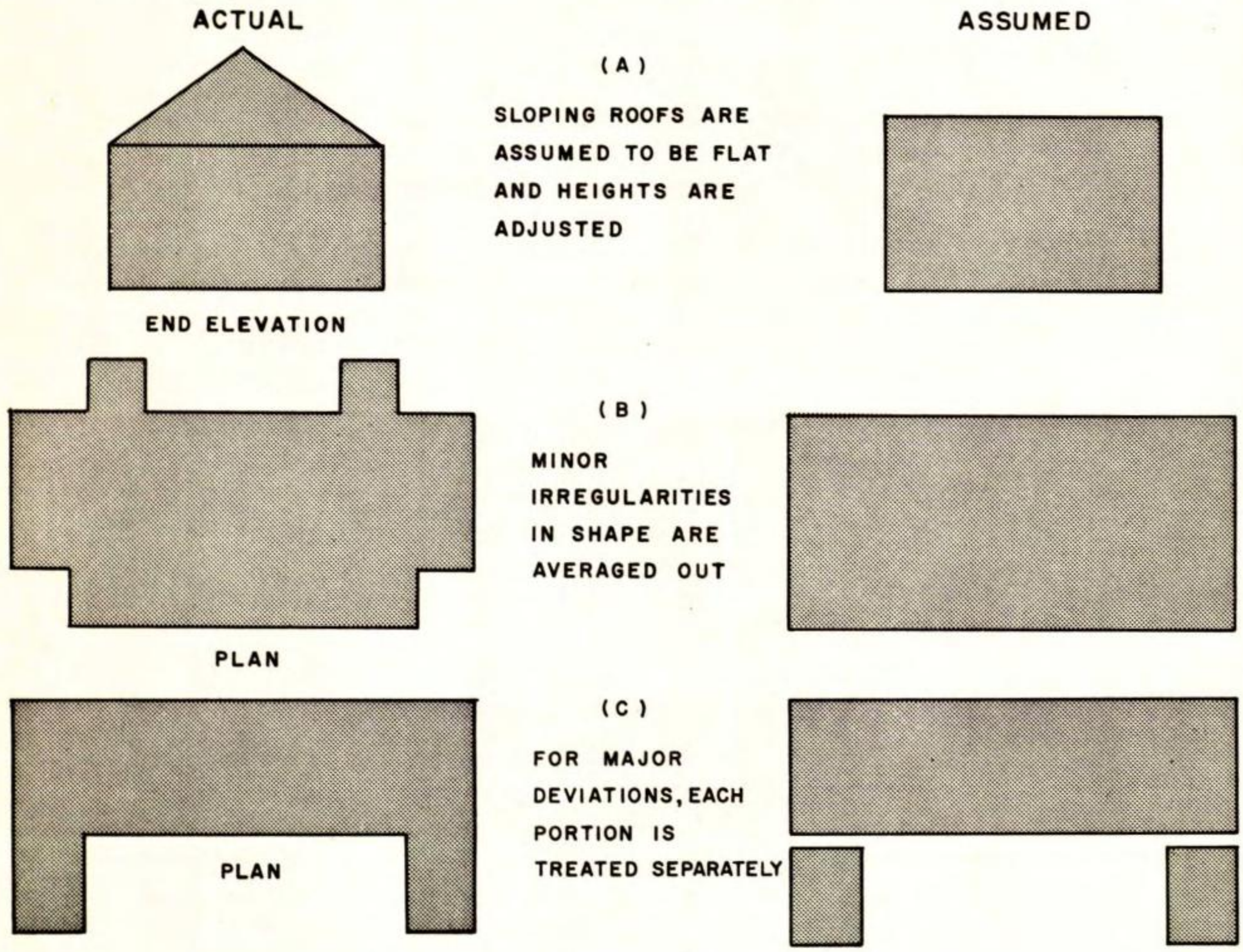


FIGURE 8 - ADJUSTMENT OF DIMENSIONS

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vertical distance from the eave to the ridge. For very low buildings with steep roofs, it is safer to assume a lower average height, above the eave by approximately one quarter of the vertical distance from eave to ridge. See Figure 8.

(c) Minor irregularities in the length and width of buildings are ignored and average dimensions are considered. Major deviations, such as annexes, are considered separately. This is illustrated in Figure 8.

(d) Fallout deposits on walls, window sills, or projections from walls are not considered.

(e) It is assumed that no radioactive material enters the building proper.

(f) The redistribution of fallout on the ground or on roofs by the action of weather is not taken into consideration.

(g) For any room, the protection factor is normally calculated for a point 3 ft. above the center of the floor. This height corresponds with the mid point of the body in a standing position.

(h) The effective energy of gamma radiation from fallout is assumed, for all attenuation problems, to be equal to that of mixed fission products at one hour after a nuclear explosion.

3.02 Mass Thickness

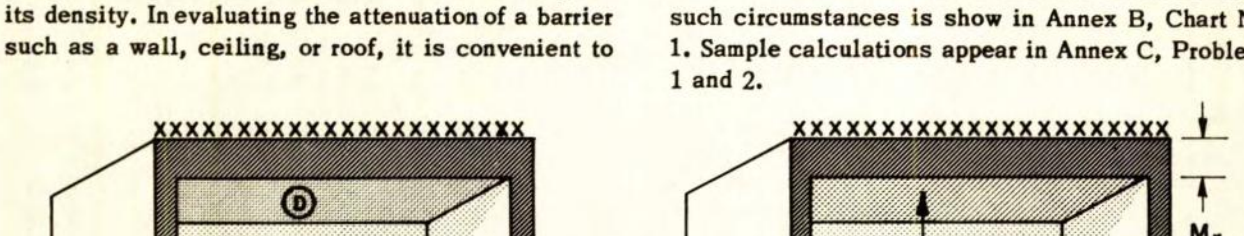
It was mentioned earlier that the ability of a substance to attenuate radiation varies directly as its density. In evaluating the attenuation of a barrier such as a wall, ceiling, or roof, it is convenient to consider its weight per unit of surface area. The term "mass thickness" is used for this purpose, and is normally expressed in pounds per square foot. A table giving the mass thickness of several common materials will be found at Annex A.

3.03 Adjusted Mass Thickness

In many cases the mass thickness of walls, floors, or roofs will not be uniform over the entire area. A wall may include apertures. It may be thicker in some places due to massive columns, pilasters, or chimneys. Floors are often supported by beams which may themselves contribute to the attenuation of radiation. As a general rule construction irregularities are averaged out over the area being considered, so that average mass thicknesses are normally used for purposes of calculation. In paragraphs 3.12 and 3.13, special attention is devoted to the problem of walls with large areas of glass.

3.04 Roof Contribution – Elementary Case

(a) *Barrier Shielding – Fallout on a Barrier.* Figure 9 (a) shows a simple case where the only source of radioactivity is fallout deposited on top of a flat roof. A radiation detector is located immediately underneath. The intensity of radiation recorded by the detector will be reduced by the roof slab. The greater the mass thickness of the roof, the lower will be the intensity of radiation or dosage rate. The mathematical relationship between mass thickness and radiation reduction factor under such circumstances is show in Annex B, Chart No. 1. Sample calculations appear in Annex C, Problems 1 and 2.



(A) BARRIER SHIELDING

(B) BARRIER AND GEOMETRIC SHIELDING

H_r = HEIGHT OF ROOF ABOVE DETECTOR

M_r = MASS THICKNESS OF ROOF

FIGURE 9 - FALLOUT ON A BARRIER

(b) *Effect of Height-Geometry Shielding.* Figure 9 (b) portrays exactly the same conditions as 9 (a) except that the detector has been moved to a location which is significantly below the roof. By thus placing distance between the fallout plane and the detector, additional shielding is achieved. The effect on the detector is analogous to a physical reduction in the size of the area of the contaminated roof – and this is the approach used in solving problems of this type. Chart No. 2 of Annex B makes possible the calculation of radiation reduction factors for roof contribution, taking into account both barrier and geometry shielding. It will be noted that Chart 2 assumes the detector to be 10 ft. below the roof. Before using this chart for heights other than 10 ft., it is first necessary to calculate an adjusted roof area. This is done by a simple formula based on the actual distance between the detector and the roof:-

$$\frac{\text{Adjusted Roof Area}}{\text{Actual Roof Area}} = \frac{A_r^1}{Ar} = \frac{(10)^2}{(Hr)^2}$$

where H_r is the distance, in feet, of the roof deck above the detector. Chart 2A contains a series of curves designed to simplify the use of this formula. See Problems 3, 4 and 5 of Annex C for examples of the use of Chart 2.

3.05 Roof Contribution

Multistory Buildings with Interior Wall Partitions

(a) In Figure 10 (a) is shown a three-story building having thin interior partitions (mass thickness less than 20 psf). Attenuation of the roof contribution by such light interior walls is negligible, and for the purpose of shielding calculations, their existence is ignored. Thus to use Chart 2 to calculate the protection factor of the room in which the detector is shown, one would require to know the total roof area, the distance from the detector to the roof, and the *total* mass thickness of the roof and all the floors above the detector.

(b) Figure 10 (b) shows a similar building in which the interior partitions are relatively heavy (mass thickness over 60 psf). In such cases it may safely be assumed that the only area of the roof contributing to the detector is that immediately over the four interior walls of the room in which the detector is located.

(c) Figure 10 (c) demonstrates the remaining possibility, in which the interior walls have a mass thickness *between* 20 and 60 psf. Here the detector will receive a contribution from the central roof area *plus*, from the remaining roof area, some radiation that must come through the interior walls as well as the roof and floor slabs. Such calculations are performed in the following manner:-

(i) Calculate the contribution from the central roof area as for Figure 10 (b).

(ii) Calculate the contribution from the *total* roof area using as a mass thickness the total overhead mass thicknesses plus that of the interior wall.

(iii) Calculate the contribution from the central roof area, using the increased mass thickness value as in (ii).

(iv) Subtract (iii) from (ii) to obtain the roof contribution from outside the central roof area.

(v) Add (i) and (iv) to get total reduction factor for roof contribution.

(d) Calculations of roof contribution for various multistory buildings appear at Annex C, Problems 6, 7 and 8.

3.06 Roof Contribution – Skyshine Effect

In a vacuum gamma rays travel in straight lines, but in the atmosphere they become scattered due to collisions with electrons, principally those of oxygen and nitrogen atoms. This phenomenon gives rise to the effect known as "skyshine". Even if all fallout is removed from a roof, there will still be a contribution from the roof due to the scattering of radiation originating on the ground. This is known as the skyshine contribution. If the overhead mass thickness is large, skyshine contribution may be practically negligible. For very thin roofs however, it may increase the roof contribution by as much as fifteen percent. Chart 3 of Annex B gives skyshine correction factors, for contaminated and decontaminated roofs, for a variety of overhead mass thicknesses. See Annex C, Problems 9 and 10 for examples of the use of these factors.

3.07 Ground Contribution – Aboveground Areas

(a) *Elementary Case – Fallout Adjacent to Vertical Barrier.* Figure 11 (a) shows a simple case where the only source of radioactivity is fallout deposited on one side of a vertical wall. A detector is located against the uncontaminated side of the wall. The thicker the wall, the lower will be the dosage rate recorded by the detector. Chart No. 4 of Annex B demonstrates the mathematical relationship between mass thickness and the radiation reduction factor for ground contribution under these

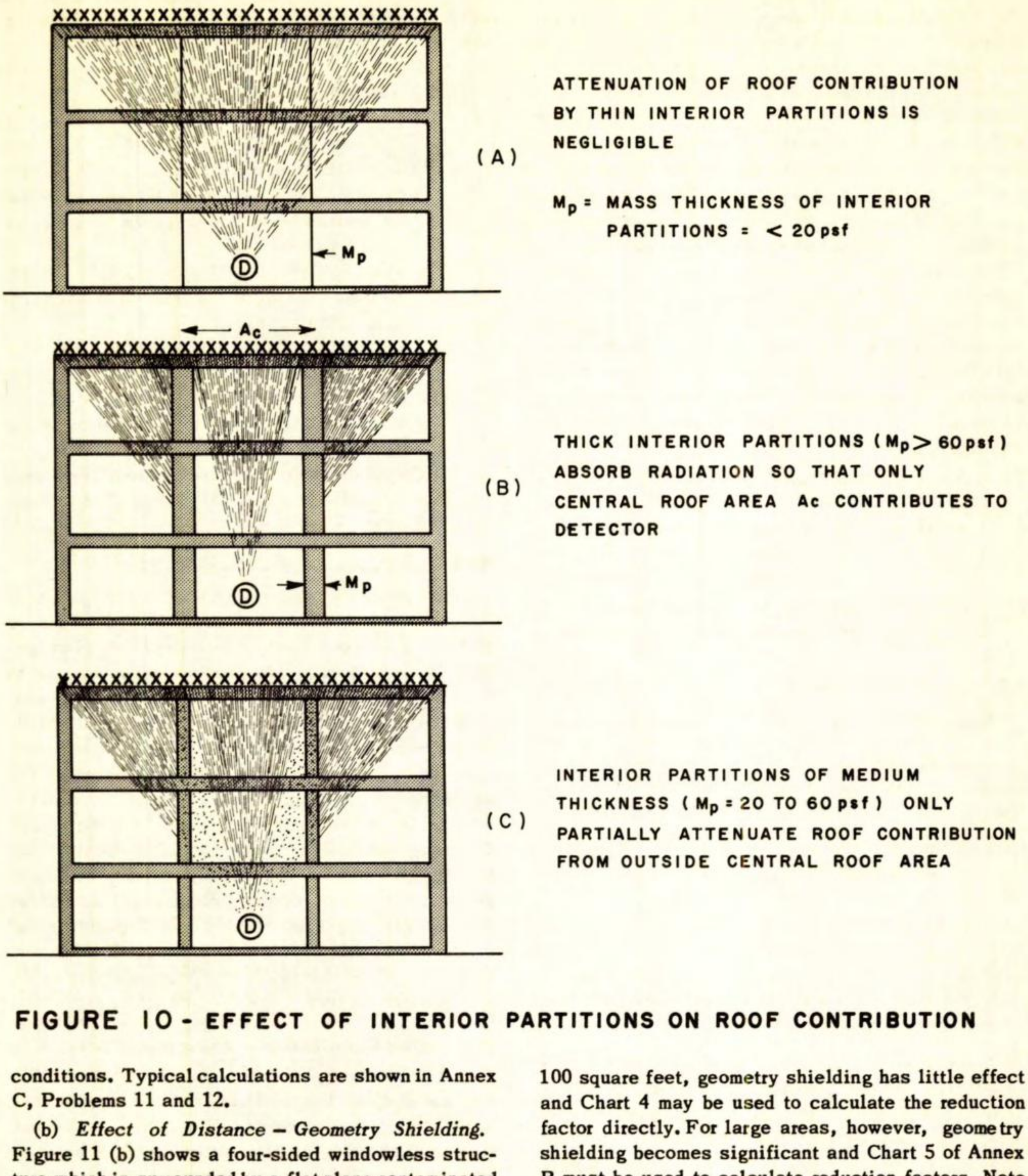
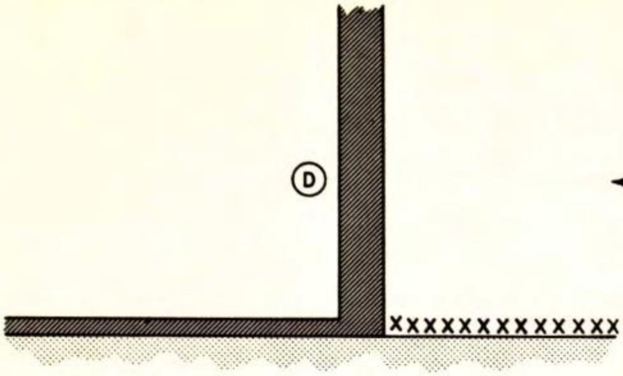


FIGURE 10 - EFFECT OF INTERIOR PARTITIONS ON ROOF CONTRIBUTION

conditions. Typical calculations are shown in Annex C, Problems 11 and 12.

(b) *Effect of Distance – Geometry Shielding.* Figure 11 (b) shows a four-sided windowless structure which is surrounded by a flat plane contaminated with radioactive fallout. As well as being shielded by the walls, the detector receives less radiation because it is at a significant distance from the contaminated planes. This distance is related to the floor area of the structure. If the area is less than 100 square feet, geometry shielding has little effect and Chart 4 may be used to calculate the reduction factor directly. For large areas, however, geometry shielding becomes significant and Chart 5 of Annex B must be used to calculate reduction factors. Note that if the building has interior partitions, their mass thicknesses are added to that of the exterior wall, and the total value is applied to the abscissa in Chart 5. For shielding calculations requiring the use of Chart 5, see Annex C, Problems 13 and 14.



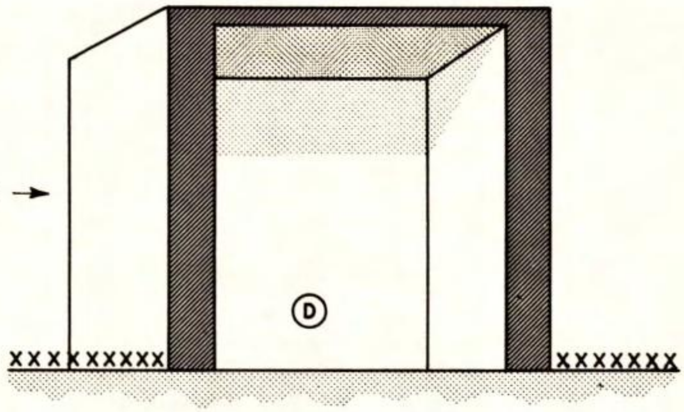


FIGURE 11 - FALLOUT ADJACENT TO A VERTICAL BARRIER

3.08 Perimeter Ratio

(a) It is sometimes desirable to calculate the ground contribution of each individual wall. If there is a significant difference in the type of wall construction, this procedure becomes mandatory. Wall-by-wall calculations make it possible to quickly pick out weaknesses from the standpoint of radiation shielding.

(b) Figure 12 shows a plan view of a building that is surrounded by fallout on the ground. Obviously the detector is shielded by all four walls. If the radiation reduction factor for ground contribution for any *one* of the walls is required, its mass thickness and the total floor area are used in Chart 5. As the contribution of only one wall is required, the factor thus obtained from Chart 5 must be multiplied by the perimeter ratio of the wall. For any one wall, this is merely its length, divided by the total perimeter of the building. Note that the sum of the perimeter ratios of all the walls is always unity.

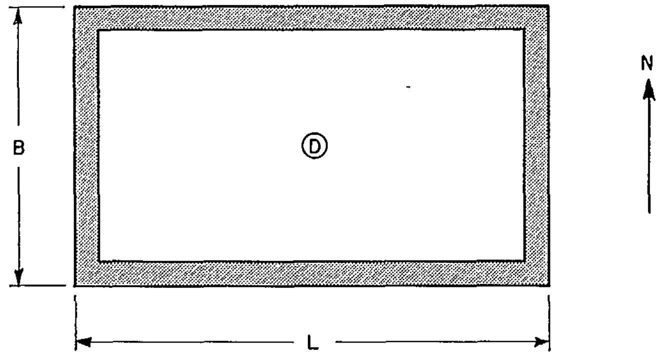
(c) If wall-by-wall calculations are used, all individual wall contributions must be added together to give the total reduction factor for ground contribution. Sample calculations will be found in Annex C, Problems 15 and 16.

3.09 Ground Contribution – Belowground Areas

(a) *Elementary Case – Fallout Adjacent to Horizontal Barrier.* Figure 13 (a) shows a simple case in which the barrier is in the same horizontal plane as the fallout. However, unlike Figure 9 (a), there is no fallout on the actual barrier. If a detector is placed underneath the barrier, it will receive less radiation as the barrier thickness increases. Chart 6 of Annex B shows the relationship between the mass thickness of the horizontal slab and the reduction factor. Note that this curve does not consider any attenuation of radiation by the exterior above-ground walls; i.e., their mass thicknesses are taken to be zero. See Problems 17 and 18 of Annex C.

(b) *Basement Areas – Completely Below Grade.*

(i) In the basement of the building shown in Figure 13 (b), the detector is located in the center of the room, five feet below grade. There is no ceiling over the basement, but the amount of radiation entering the basement area will be affected by the exterior



PLAN VIEW

NOTE – BUILDING IS SURROUNDED BY FALLOUT

1. IF L = LENGTH AND B = BREADTH THEN PERIMETER, P = 2(L+B)

2. TOTAL GROUND CONTRIBUTION AT DETECTOR = GC (TOTAL)
= GC (NORTH WALL) + GC (S) + GC (E) + GC (W)

3. IF WALLS ARE OF SIMILAR CONSTRUCTION, THEN
GC (N) = GC (S) = GC (TOTAL) X $\frac{L}{P}$
AND GC (E) = GC (W) = GC (TOTAL) X $\frac{B}{P}$

FIGURE 12 – PERIMETER RATIO, WALL-BY-WALL ANALYSIS

aboveground walls. Geometric shielding will vary with the size or area of the basement. Chart 7 of Annex B gives reduction factors for various basement areas and ground floor wall mass thicknesses. See Problem 19 of Annex C.

(ii) Figure 13 (c) portrays the same conditions as Figure 13 (b), with the exception that a basement ceiling has been introduced. To account for the additional attenuation of radiation by this slab, the reduction factor calculated from Chart 7 must be multiplied by that derived from Chart 6. The resultant product is the net reduction factor, and it takes into consideration geometric shielding, mass thickness of exterior ground floor walls, and mass thickness of the basement ceiling. For a sample calculation, see Annex C, Problem No. 20.

(c) *Basement Areas – Partly Above Grade.* It will be seen in Figure 13 (d) that part of the basement wall is above grade. The total ground contribution to the detector is made up of two parts; one coming through the basement ceiling and one coming through the exposed basement walls. To calculate the total ground contribution the following procedure is used:-

(i) Use Chart 5 to obtain the reduction factor due to the basement walls. Be sure to use the mass thickness of the basement walls for the abscissa value.

(ii) Multiply the factor obtained in (i) by a fraction representing the portion of the basement walls that is exposed, e.g. $\frac{20}{100}$ or 0.20 for 20% exposed.

(iii) Use Chart 7 to calculate the reduction factor for ground contribution coming through the exterior walls and the basement ceiling.

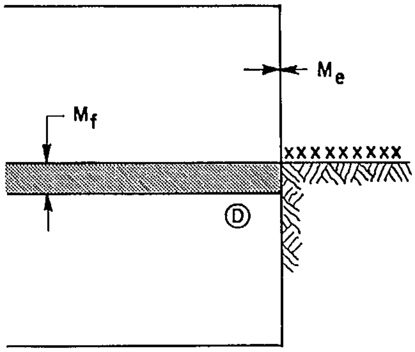
(iv) Use Chart 6 to obtain the reduction factor due to the attenuation by the basement ceiling.

(v) Multiply factor (iii) by factor (iv).

(vi) Add (ii) and (v) for total ground contribution. An example of such a calculation is given in Problem 21, Annex C.

3.10 Ground Contribution – Upper Floors of Multistory Buildings

(a) Under certain circumstances, it is conceivable that upper floors of multistory buildings may be considered for use as fallout shelters. The height of the floors above the contaminated ground plane makes it possible to take further advantage of geometric shielding from the ground contribution. Figure 14 (a) shows a simple case in which the detector is located on the fourth floor of a six story building. Considering ground contribution only, the reduction factor is first calculated from Chart 5 as if the detector was located on the ground floor. A

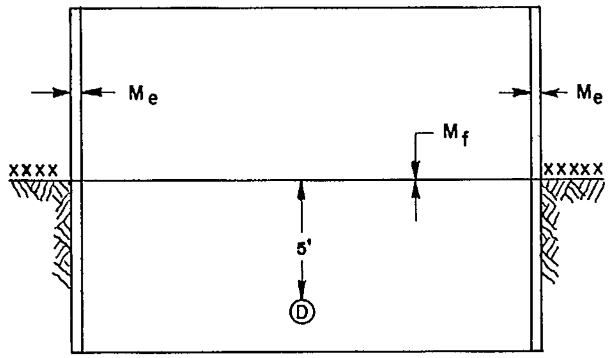


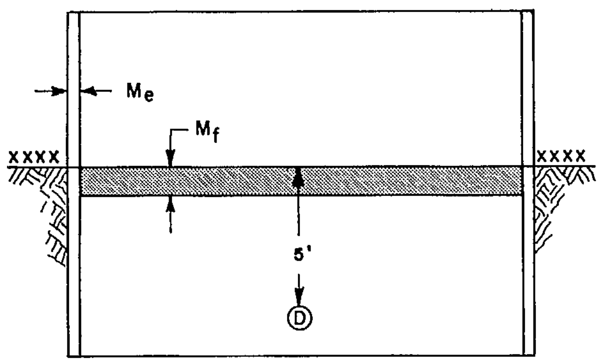
(A)

FALLOUT ADJACENT TO HORIZONTAL BARRIER
M_e = MASS THICKNESS OF EXTERIOR GROUND FLOOR WALL = 0
M_f = MASS THICKNESS, FLOOR SLAB
USE WITH CHART 6

(B)

DETECTOR SHIELDED DUE TO EXTERIOR GROUND FLOOR WALLS AND GEOMETRY
M_f = 0
USE WITH CHART 7





(C)

DETECTOR SHIELDED BY FLOOR SLAB, EXTERIOR GROUND FLOOR WALLS, AND DISTANCE.
USE WITH CHARTS 6 AND 7.

(D)

BASEMENT PARTLY ABOVE GRADE. GROUND CONTRIBUTION TO DETECTOR COMES THROUGH FLOOR SLAB AND EXPOSED BASEMENT WALLS.
USE WITH CHARTS 5, 6 AND 7.

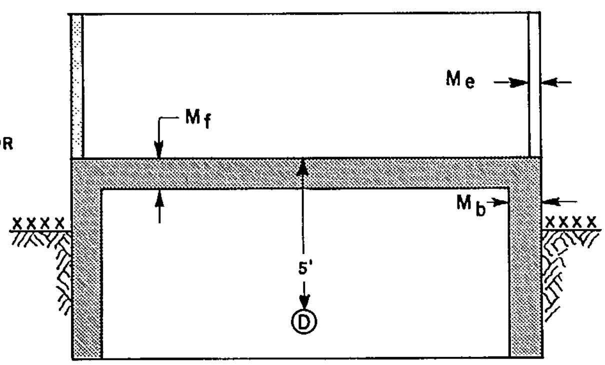
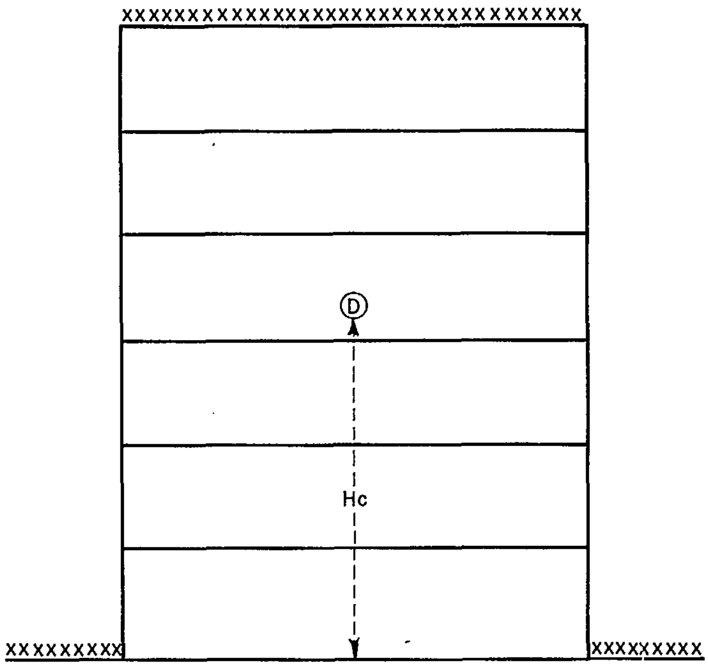
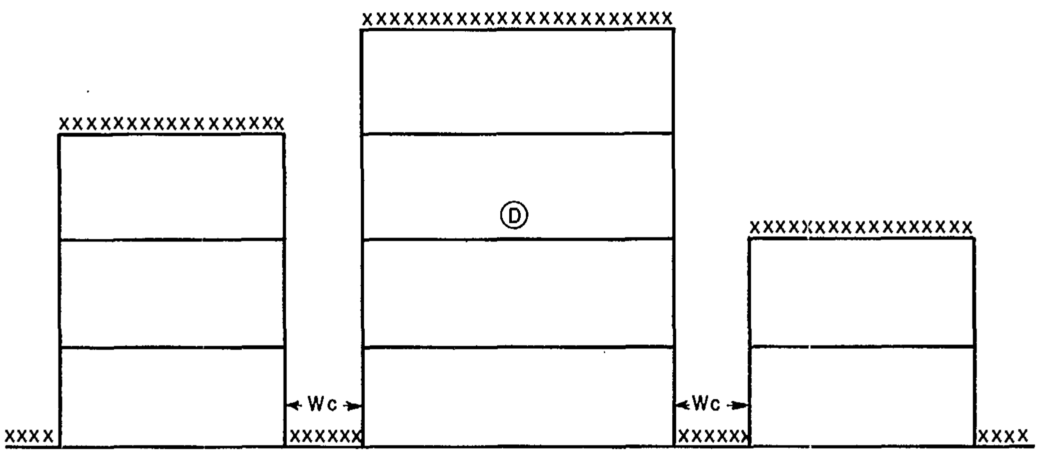


FIGURE 13 - GROUND CONTRIBUTION, BELOWGROUND AREAS



A. SHELTER AREA IN UPPER FLOOR
USE CHARTS 2, 5 AND 8



B. FALLOUT ON ADJACENT ROOFS MAY AFFECT DETECTOR IN UPPER FLOOR.

GROUND CONTRIBUTION WILL BE REDUCED DUE TO SHIELDING OF ADJACENT BUILDINGS.

Wc = WIDTH OF CONTAMINATED PLANE
Hc = HEIGHT OF DETECTOR ABOVE CONTAMINATED PLANE

USE CHARTS 2, 5, 8 AND 9.

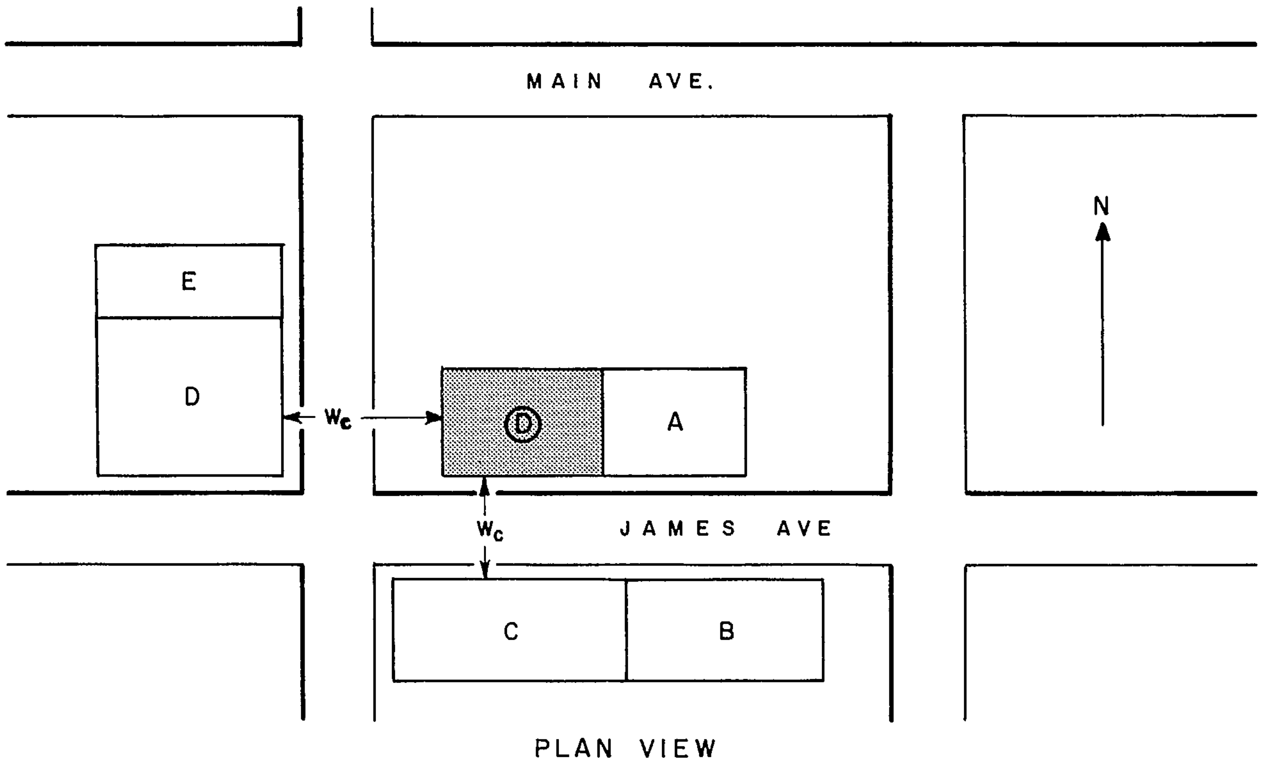
FIGURE 14 - HEIGHT EFFECTS, SHELTER IN UPPER FLOOR

height correction factor is then applied to the reduction factor so calculated. Chart 8 of Annex B gives height correction factors for various detector heights above the contaminated plane. Problem 22 of Annex C illustrates the use of Chart 8.

(b) Figure 14(b) shows a more complex situation, in which fallout on adjacent roofs will have a definite effect on the detector. It is also evident that the adjacent buildings will provide some shielding against radiation from the contaminated ground.

3.11 Shielding by Adjacent Buildings

Adjacent buildings may serve to reduce the amount of radiation reaching a detector from fallout on the ground. Figure 15 illustrates the effect of adjacent buildings on ground contribution. When performing shielding calculations of this type, the reduction factor for ground contribution, normally obtained from Chart 5 or 7, must be multiplied by a correction factor. Chart 9 of Annex B is used to select the appropriate correction factor, which is a function of the width of the contaminated ground between the building housing the detector, and the adjacent structure. Shielding buildings must be of substantial construction and height, and of a length sufficient to essentially close off the angle subtended at the detector by the ends of the shelter



ENTIRE AREA IS UNIFORMLY CONTAMINATED BY FALLOUT
DETECTOR IS LOCATED IN GROUND FLOOR OF SHADED BUILDING

EAST WALL WILL BE COMPLETELY SHIELDED BY BUILDING 'A'
SOUTH AND WEST WALLS WILL BE PARTLY SHIELDED
NORTH WALL IS NOT SHIELDED BY ADJACENT BUILDING

FIGURE 15 - GROUND CONTRIBUTION - EFFECT OF ADJACENT BUILDING

wall under consideration. A sample calculation appears in Problem 23, Annex C.

3.12 The Problem of Openings

(a) In the foregoing calculations, minor openings in walls or roofs have been accounted for by averaging them out across the entire area, and using adjusted mass thickness figures for the various charts in Annex B. In practice, this procedure is permissible if the openings are relatively small, or if the proposed shelter is screened from the apertures by heavy interior partitions. Similarly, if the shelter area being calculated is in a basement that is mostly below grade, openings in the exterior ground floor walls may normally be accounted for by using an average mass thickness figure for these walls.

(b) It may also be considered as self-evident that before any area is deemed to be suitable as a fallout shelter, steps would automatically be taken to close up apertures in the exterior walls with heavy materials, such as bricks, concrete blocks or sandbags.

(c) The above notwithstanding, many large modern buildings have walls that contain large glassed areas, and a requirement may arise to assess their protective potential "as is ". It would therefore appear to be desirable to investigate shielding calculations for structures of this type.

3.13 Aperture Calculations

(a) *Aperture Correction to Ground Contribution.*

(i) Figure 16 shows two buildings which are identical except for the height of the windows, or the window sills. In Figure 16 (a) the detector, when located on either the first or second floor, is below the sill. In these positions, it is partly shielded by the exterior wall against direct gamma radia-

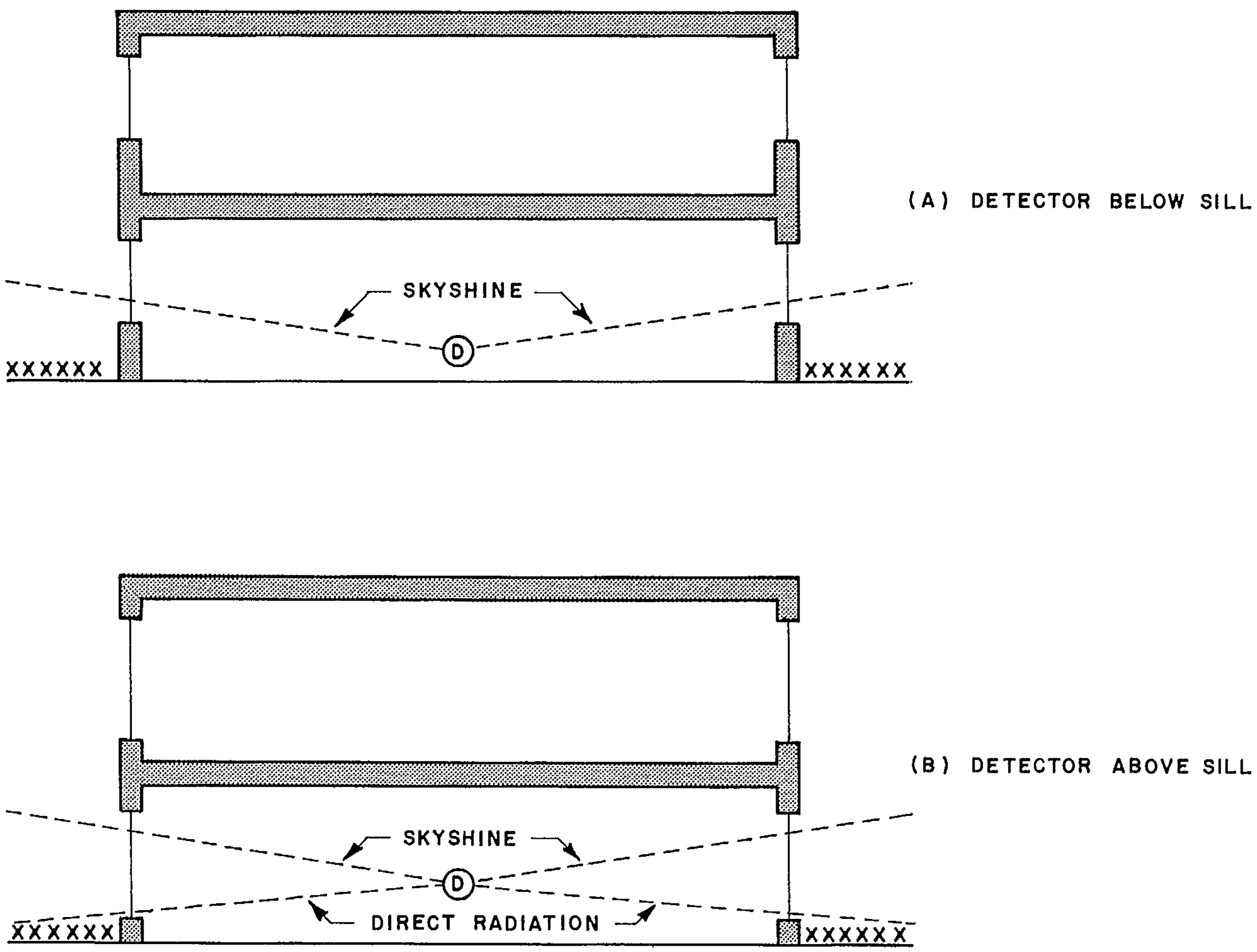


FIGURE 16 - APERTURE CALCULATIONS

tion from fallout deposited on the ground. It does, however, receive skyshine radiation through the windows. When located in the second (or higher) story, it will be noted that the detector is also shielded by the floor slab underneath it. In Figure 16 (b) the only difference is that the detector receives gamma radiation coming directly from the ground plane.

(ii) If the building floors are over 40 psf ("thick" floors), it is assumed that no radiation reaches the detector from below. If the floors are less than 40 psf, ("thin" floors), a significant amount of radiation will pass upwards through them. At Figure 17 is a Table of Aperture Correction Factors. The Table is actually divided into two parts, one for thick and one for thin floors. Each part in turn gives correction factors for two detector positions, i.e. above and below the window sill. The factors from this table are applied to ground contribution as calculated from Chart 5, using zero as the wall mass thickness for glass. The product is then further adjusted to allow for the actual percentage of openings in the wall. See Annex C, Problems 24 and 25.

Floor No.	Thick floors (M_f greater than 40 psf)		Thin floors (M_f less than 40 psf)	
	Above sill	Below sill	Above sill	Below sill
1	1.0	0.2	1.0	0.2
2	.7	.2	1.0	.7
3	.6	.2	1.0	.6
4	.5	.2	1.0	.5
5	.4	.2	1.0	.4
6	.3	.2	1.0	.3
6+	.2	.2	1.0	.2

FIGURE 17 – APERTURE CORRECTION FACTORS

(b) *Reduction Factor for Apertures – Ground Floor.* If a ground floor wall has a large glassed area that extends practically to the floor, Chart 10 of Annex B may be used to determine the ground contribution reduction factor at any distance from the window. To use Chart 10 it is only necessary to know the width of the opening and the distance of the detector from it. See Problem 26, Annex C.

3.14 Calculation of Shelter Protection Factors

(a) *Components of Reduction Factors*

(i) Roof contribution may be made up of one or more components. In certain buildings (see paragraph 3.05) it is necessary to consider separately contributions from the central roof area and the remainder of the roof. Skyshine forms part of the roof contribution, and in certain cases radiation from the roofs of adjacent buildings would have to be considered.

(ii) Ground contribution is normally calculated as the sum of the contributions through each wall. In the case of a shelter in a basement that is partly above grade, the ground contribution could have eight component parts, i.e. four ground floor walls and four basement walls.

(b) *Reduction and Protection Factors.* In the examples considered earlier in this chapter, roof contribution and ground contribution have been dealt with separately. In practice, of course, their effects will be apparent simultaneously. The total reduction factor calculated for roof contribution is simply added to that calculated for ground contribution. The reciprocal of this sum is the protection factor of the shelter.

(c) *Hypothetical Example*

Shielding Analysis – Basement Shelter

(1)	Roof Contribution		0.0022
(2)	Skyshine Correction..............		1.09
(3)	Reduction Factor (roof) (1) x (2)		0.0024
(4)	Ground Floor Wall Contribution		
	North Wall	0.0006	
	East Wall	0.0007	
	South Wall	0.0006	
	West Wall	0.0021	
	Total	0.0040	0.0040
(5)	Basement Wall Contribution		
	North Wall	0.0003	
	East Wall	0.0005	
	South Wall	0.0003	
	West Wall	0.0005	
	Total	0.0016	0.0016
(6)	Reduction Factor (ground) (4) + (5)		0.0056
(7)	Total Reduction Factor (3) + (6)		0.0080
(8)	Protection Factor		125

In this hypothetical case, it will be noted that the ground floor west wall is a comparatively weak feature. If it can be improved so that it has the same mass thickness as the east wall, the total reduction factor would be decreased to 0.0066, and the protection factor increased to 151. Such improvement may simply consist of the bricking up of windows. See Annex C Problems 27 and 28 for a practical example of a complete shielding analysis.

CHAPTER 4

BASIC REQUIREMENTS OF A FALLOUT SHELTER

4.01 Habitability Factors

(a) A fallout shelter must protect its occupants against gamma radiation from radioactive contamination. It must also provide sufficient living space and a minimum of facilities, so that the health of its occupants will not deteriorate appreciably in the event of a prolonged stay in the shelter. The factors to be considered are fairly obvious; sanitation, water and food supply, ventilation, cooking and sleeping arrangements, heat, light, furnishings, etc. Although the design of a shelter for a single family may be elementary, large public or community shelters require very careful planning if adequate protection is to be achieved. The various habitability factors will be discussed in detail in the remaining paragraphs of this chapter. It is pointed out that all recommendations as to space, power, water, etc. refer to Class B shelters only. The requirements for Class A shelters will be governed by the nature of the work to be carried out in them.

(b) The criteria set forth in the ensuing paragraphs are intended as a guide in the planning of austere shelter for a 14 day period of occupancy. If they are adhered to, the environmental conditions of shelter will be such as to ensure the survival of all persons in a reasonable state of health. On the other hand, in an emergency, a potential shelter should not be rejected because it fails to meet even these minimal specifications. Uncomfortable shelter for short periods of time, with good protection against radiation, is preferable to comfort in a house that provides inadequate shielding. People must have air, but most of them would still be alive after 48 hours under crowded conditions, without water, food, heat, light or sanitary conveniences. If the shelter protects its occupants against gamma radiation during these unpleasant but crucial two days, it may be well mean the difference between life and death. It must be appreciated, however, that skimping on habitability factors does involve risks which are incapable of predetermination.

4.02 The "Core" Concept

Figure 6 shows that fission products decay very rapidly during the first few hours after a nuclear explosion. It follows that most of an in-

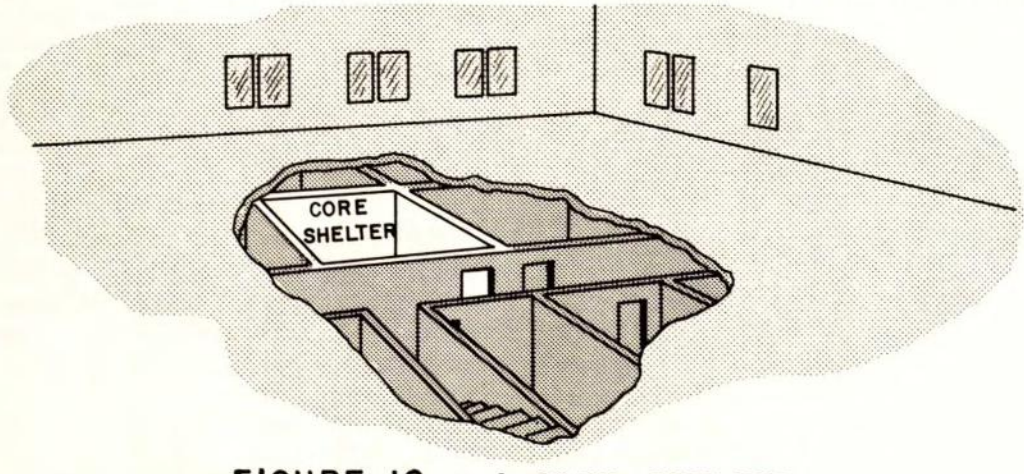


FIGURE 18 - A CORE SHELTER

dividual's dosage of radiation is acquired in a short period after the arrival of fallout. People in the shelter portrayed in Figure 7 received 27 roentgens during the first two days after the explosion. Their dosage after two weeks in the shelter was only 33 roentgens. This leads us to the "core" concept, which is based on the provision of a relatively small shelter area, having a high protection factor, and surrounded by or adjacent to a larger area that has a lower protection factor. During the time immediately after the arrival of fallout, when the dosage rate is highest, people would remain in the "core" or inner area. Later on, subject of course to advice from radiation monitors or other competent authorities, it might be possible to use the larger shelter area which would permit greater comfort for all concerned. Many buildings are constructed in such a way as to make this system quite practicable. Figure 18 shows a typical core shelter.

4.03 Space

In estimating the capacity of a shelter we begin by allowing 12 sq. ft. of floor space per occupant. This is a net figure, and excludes areas covered by cupboards, built-in equipment, columns, etc. Area alone is not sufficient to determine shelter capacity, and the figure of 12 sq. ft. per person is valid only if the shelter also provides 80 cu. ft. of free air space per person. This figure, in turn, is based on the assumption that ventilation and other arrangements will be adequate. Should this not be the case, a considerably larger area and volume will be required.

4.04 Ventilation

(a) If fresh air is not brought into a shelter continuously, the existing air supply will rapidly become foul. The oxygen content of the air will decrease, while the concentration of carbon dioxide will increase. Danger to the occupants first becomes apparent when the CO_2 content of the air exceeds two percent by volume. It has been established that 5 cfm per person of fresh air will maintain acceptable oxygen and carbon dioxide levels.

(b) All shelters should be designed on the assumption that they may be occupied for two weeks. It is therefore obvious that air changing arrangements will have to be provided. In household shelters, vent holes to the larger basement area will meet the requirement. Even in some larger shelters, natural air convection currents may replenish the supply of fresh air at a satisfactory rate. For the most part, however, mechanical ventilation will be necessary. The equipment will vary from hand-operated blowers in backyard shelters, to high-powered systems in large public shelters. Recirculation of air within the shelter will also be required in most cases.

(c) Depending on the time of year, forced ventilation may be essential to keep down the temperature and humidity in a shelter. This may involve a pumping rate considerably higher than 5 cfm per person. On the other hand, normal air replenishment during cold weather may create a heating problem in the shelter. The maximum effective temperature should not be allowed to exceed 85° Fahrenheit, and the minimum ET recommended is 50°F.

(d) Air intakes for the ventilation systems must be located and designed so as to be weatherproof. For domestic shelters with manually operated air pumps, simple hooded intakes are adequate. With powered ventilation equipment, however, the air intake velocity may be sufficiently high to suck fallout particles into the shelter itself. To avoid this possibility, air filters should be installed in the intake ducts, well away, and shielded from, the shelter itself. Conventional dust filters similar to those used in forced air heating systems are satisfactory for this purpose.

4.05 Lighting, Heating and Cooking

(a) It could happen that the public utilities serving many shelters would not be damaged by the nuclear explosion from which the fallout originated. This situation would, however, have to be regarded as something of a bonus, and all planning with regard to the occupation of shelter accommodation must be done on the assumption that normal building services would be disrupted. Therefore, whatever arrangements are considered for heat and light in shelters will have to be independent of the normal services. In household shelters, studies have revealed that by using kerosene as a fuel, the problems of light, heat and cooking could be solved in a satisfactory manner. Kerosene lanterns and cooking equipment produce considerable heat when operating. The fuel is relatively safe and lends itself readily to storage, in which it is quite stable. The gases of combustion must be expelled from the shelter, but simple fume hoods are adequate for this purpose in small shelters.

(b) The provision of heat in shelters may not be necessary at all in some areas. However, as many parts of Canada experience very low winter temperatures, the problem may not be disregarded in this country. The requirement of heat must, as far as possible, be minimized by the use of warm clothing and a generous supply of blankets or bedrolls. If there is any danger of the shelter temperature dropping below 50°F, emergency heating equipment must be brought into action. This may consist of simple coal, oil, or kerosene fired space heaters. Larger installations may have oil-fired forced hot air heating systems, the operation of which would require the availability of standby electrical power. It is not possible to specify the capacity of auxiliary heating equipment prior to the carrying out of normal heat loss calculations. However, a maximum figure would appear to be approximately 5 B.T.U. per hour per cubic foot of shelter volume. It must be borne in mind that no matter what method of heating is contemplated, there will be fuel storage problems.

(c) In larger shelters, electrical generators are desirable. They should be driven by diesel-powered motors, for which adequate fuel storage arrangements must be made. Generator capacity will be related to shelter size and function. The electrical energy generated will be used for emergency lighting systems, pumps, and for the operation of ventilation and possibly heating equipment. In Class A shelters, there will be several other requirements for electricity. In Class B shelters, it is estimated that a maximum of five kilowatts per hundred occupants would suffice.

(d) Cooking equipment will, for obvious reasons, be minimal. It must be capable of boiling water, but as a general rule, nothing more elaborate would be necessary.

4.06 Water Supply and Sanitation

(a) For planning purposes, it must be assumed that the normal water supply will be cut off. Provision should be made to store water for shelter occupants on the basis of one gallon per person per day. The main storage tank does not need to be located inside the shelter proper, but it should be in a protected location adjacent to the shelter. The supply should be piped to the shelter and should flow by gravity. In addition, one gallon per occupant should be stored at all times inside the actual shelter.

(b) In the pre-attack period, the entire water storage system should be designed so as to ensure frequent change, and consequent freshness of the entire supply. Subsequent to the attack, no additional water should be drawn from the public mains, even if these remain serviceable, until such time as municipal authorities confirm that the source remains free from radioactive contamination. In many buildings there are sufficient hot water, expansion and fire reserve tanks to provide the necessary storage volume. Steps must be taken to ensure that water thus stored does not drain back into the mains in the event of a pressure drop due to pipe rupture or failure of pumping equipment.

(c) In household shelters, it is recommended that sanitary toilets be installed and provided with a 14 day supply of polyethylene bags. These bags should, after use, be tied at the neck and stored in a metal container with a tight-fitting lid. In community or group shelters, the disposal of human waste becomes a very serious problem. If it is not done properly, the resultant odours can quickly undermind the morale of shelter occupants. Within the shelter area, chemical toilets should be provided on the scale of one per 70 occupants. Following the core concept, toilets should be moved to the outer shelter area as soon as the intensity of radiation will permit. In many cases, sewage lines will still be operative, and toilets can be connected to them quickly if the necessary outlets are prepared in advance. Flush type toilets may be used under these circumstances, and they could be operated with waste ablution water. In structures that were actually designed as fallout shelters, the problems with regard to sanitation would be well taken care of.

4.07 Food Supplies

For a family shelter, the pamphlet "Your Basement Fallout Shelter" suggests a list of canned and packaged food designed to sustain an individual for 14 days. The items should be used up and replaced every six months, and this imposes no hardship on the household. For multiple occupancy shelters, the problem is more difficult but by no means insurmountable. The stocking, turnover, and security of food would be the responsibility of the municipality or agency providing the shelter. The important aspect to the engineer or architect designing the shelter is that food storage facilities are, in fact, provided. Two cubic feet per occupant will be required to store food and medical supplies for a 14 day period.

4.08 Furnishings and Equipment

The list of equipment recommended for even a family shelter is a long one. (See "Your Basement

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Fallout Shelter"). Every item in the list is intended to contribute something to the improvement of shelter living conditions. Again, as the shelter size increases, the problem becomes more complex. In this manual we are largely concerned with the engineering work necessary to make a shelter as comfortable and functional as possible for the number of people for which it was designed. This would include the layout of the sleeping area; the rows and tiers of bunk beds and the aisles between them. Kitchen equipment must be properly laid out and tied in with the ventilation, water and waste disposal systems. As mentioned earlier, proper ablution and toilet areas are very important to the well-being of the occupants. If a new structure is being designed, these matters can be arranged with a minimum of difficulty. It is perhaps more perplexing to assess part of an existing building in terms of its suitability as a fallout shelter for a large group of people.

4.09 General Considerations

(a) It is always advisable to have two exists from a public shelter. One exit may become unusable because of fire, or structural failure due to enemy action.

(b) Accessibility affects the time required to fill a shelter. Many basement areas of high capacity are serviced chiefly by elevators which may be useless after an enemy attack.

(c) Areas which include hazards such as explosives, inflammable materials, exposed machinery or electrical equipment, should not be considered for shelter purposes.

CHAPTER 5

ASSESSMENT OF INDIVIDUAL BUILDINGS

5.01 Data Collection Form

(a) In examining a building to determine its suitability as a fallout shelter, some sort of aide-memoire is required so that every important item of information will be recorded. The Data Collection Form, which appears at Annex "D", has been developed with this in mind. This form does not have to be compiled by an architect or engineer. Normally it will be used by a team of two men who are inspecting and measuring up certain buildings in an area, as part of a shelter survey. If possible such teams should consist of technical personnel who can read blueprints and have some knowledge of building construction. Before commencing the task, they must be thoroughly briefed as to the purpose of their work. Appendix 1 to Annex D contains detailed instructions for completing the Data Collection Form.

(b) To save time, the information for the Data Collection Form is taken directly from building plans, if they are available. Experience has shown that apart from newer buildings, suitable plans are seldom to be found. Survey teams usually find that building maintenance personnel, due to their intimate knowledge of the structure, are of great value in producing the required data. It is often desirable, in the absence of building plans, to use the reverse side of the Data Collection Form for sketch drawings.

5.02 Shelter Analysis Form

(a) When a Data Collection Form has been completed for a building, the information it contains is used to assess the proposed shelter area in terms of its radiation protection factor, and capacity. At Annex "E" is a copy of a Shelter Analysis Form, which has been developed to facilitate the calculation of shelter assessments. These computations must be carried out by personnel who have received suitable training in the field of shelter analysis. Appendix 1 to Annex E contains detailed instructions regarding the use of the Form.

(b) Part one of the Shelter Analysis Form deals with radiation shielding, and is so designed that weaknesses from the point of view of gamma shielding are readily detectable. In many cases, relatively simple measures may be employed to improve the protection factor. The form provides space for the analyst to suggest the necessary improvements, and to recalculate the protection factor that would apply if they were carried out. The section of the form devoted to analysis of improvements will be completed only if the work proposed would result in a significant improvement of the protection factor, at a reasonable cost.

(c) In the Shelter Analysis Form, Part Two provides space for comments with regard to the various habitability factors. It is to be expected that when existing buildings are examined as potential shelters, there will be many deficiencies in evidence. For planning purposes however it may still be necessary to rate the capacities of the proposed shelter areas. In the appropriate spaces, the engineer preparing the analysis might merely remark "10 K.W. standby generator and electrical distribution system required" and "ventilating fans and ductwork 1000 cfm capacity should be installed". If he then rated the shelter capacity at say 200, it would be a qualified rating, subject to the execution of the work recommended.

(d) It will be noted that the Shelter Analysis Form in Annex "E" is designed for all types of shelters, i.e. upper story, ground floor, or basement. The vast majority of potential fallout shelters will undoubtedly be found in basements. However,

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shelters on other floors are by no means ruled out, and they may easily be calculated by using the procedures described in paragraph 3.10. Similarly, if large apertures or heavy interior partitions necessitate supplementary calculations, these are described in paragraph 3.05 and 3.13.

5.03 Basis of Assessment

(a) An individual building can only be assessed on its own particular merits. If its protection factor is below 100, and there is no economical way of making improvements to bring it up to this figure, then the building simply fails to qualify as Group B shelter. This means that the structure offers somewhat less than the amount of protection recommended, but it still may be useful in an emergency. Similarly, a building which provides satisfactory radiation shielding may have to be rejected because for one reason or another, it is not fit for people to live in.

(b) Whether or not financial expenditures will be authorized to improve the standards of various shelters is, of course, a matter to be settled at the policy-making level. For this reason, individual building assessments must be performed as accurately as possible, to facilitate comparison of their relative merits by appropriate authorities. A building which might have appeared to be a rather poor prospect to the original survey team, may well have to be included in the list of potential shelters, if there is a general shortage of suitable accommodation in the area.

5.04 Example of Shelter Analysis

Annex F contains a complete analysis of a hypothetical building, to determine the suitability of its basement as a fallout shelter. Note that the Data Collection Form includes sufficient sketches to clarify details of construction. A site plan is also provided, enabling account to be taken of the shielding effects of adjacent buildings.

5.05 Shelter Analysis – Short Form

The standard Shelter Analysis Form illustrated in Annex "E" is designed for wall-by-wall calculations. This form makes it possible to account for differences in the type of construction of the four exterior or basement walls. It also enables the shielding effects of adjacent buildings to be taken into consideration. There are many buildings, however, in which there are no significant differences in wall construction, and which do not enjoy any mutual shielding benefits. For such structures, a special form has been developed, in order to make shielding calculations less cumbersome. At Annex "G" will be found a copy of the "Shelter Analysis – Short Form". A quick inspection of the Data Collection Form will tell the engineer if he may dispense with the wall-by-wall calculation and use the abbreviated form. It should be noted that the short form does not allow for the shielding effects of interior partitions. However, it is often useful if one wishes to make a quick assessment of the protection factor of a potential shelter area.

CHAPTER 6

PROTECTIVE IMPROVEMENTS TO EXISTING BUILDINGS

6.01 Scope of Improvements

(a) In Chapter 5, certain forms were introduced for use in the assessment of individual buildings. Paragraph 5.02 (b) mentions that the Shelter Analysis Form provides space in which may be listed the engineer's recommendations as to methods of increasing the protection factor. The question arises as to how far one should go in suggesting improvements of this type. It is not possible to establish hard and fast rules, as what may apply in one municipality may be quite unsuitable in another. For the most part however, it would appear that shielding improvements should be devoted to the reinforcement of weak areas. If, for example, a wall of massive construction has several windows which sharply reduce its shielding value, it is simply a matter of common sense that such windows should be blocked up with brick or other heavy material. Some buildings may have three massive walls and a fourth one that is weak insofar as the attenuation of gamma rays is concerned. Under these circumstances, it may be quite logical to increase the mass thickness of the thin wall.

(b) Shielding improvements should be designed to avoid the overloading of building frames or structural components. While it may be technically feasible to increase the mass thicknesses of all walls, floors, and roofs, such action will seldom be economically justifiable. The funds required for such work might well be used to greater advantage in new construction.

(c) When recommending shielding improvements, the engineer must keep in mind exactly what he is trying to achieve. There is little point in recommending costly work that will increase the protection factor of a shelter from 40 to 60, if the policy is that all shelters must be Class B or better. On the other hand, if the existing protection factor is 150 and this can easily be increased to 200, the method should be explained by the analyst.

6.02 Typical Shielding Improvements

Figure 19 shows examples of shielding improvements that are suitable for existing buildings. It will be noted that elaborate and expensive methods are avoided. Improvisation is to be encouraged as long as safety regulations are not violated. The matter of aesthetics must be left to the discretion of local authorities. It is a problem that would vanish as soon as the first bomb exploded. The following list includes some of the things that can be done to improve shielding:—

1. Block up windows.
2. Raise window sill levels.
3. Block up non-essential doorways.
4. Erect baffle walls at exits.
5. Bank exposed basement walls.
6. Cover skylights with suitable material.
7. Shield air filtration equipment.
8. Increase mass thickness of basement ceiling.
9. Thicken individual weak walls with sandbags, etc.
10. Close over disused stairwells, elevator shafts.

6.03 Practical Example – Shielding Improvements

Annex H contains an example showing how protective improvements can be recommended on the basis of information available in a Shelter Analysis Form. The Data Collection Form has been omitted in this instance.

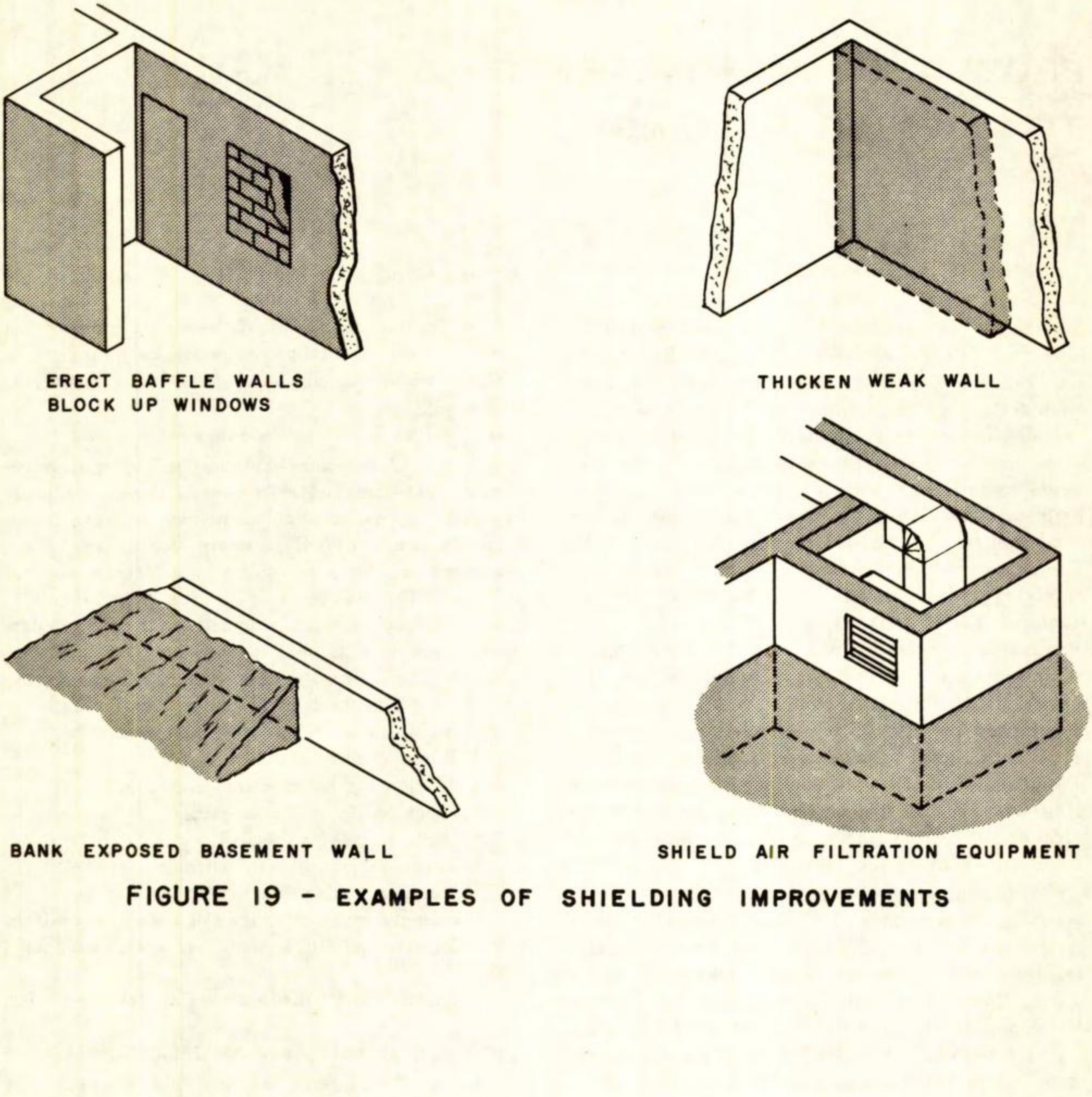


FIGURE 19 - EXAMPLES OF SHIELDING IMPROVEMENTS

CHAPTER 7

DESIGN OF FALLOUT PROTECTION

7.01 Classification of Fallout Shelters

(a) It is normal to classify shelters in accordance with their use, and in Chapter 2, Class A and B shelters were discussed. For Class A shelters the minimum protection factor is 500. Basic requirements such as space, utilities, etc., will vary with the nature of the work to be done. Non-functional or Class B shelters should have protection factors of at least 100. They are made up of three general groups, the last two of which may overlap to some extent:

1. Family, household or domestic shelters, intended for occupancy by one family.
2. Apartment, staff, employee, or school shelters, available for occupancy by people living or working in specific buildings.
3. Community or public shelters, usually larger structures, for the use of those among the general public who are not otherwise provided for.

(b) Shelters may also be classified according to the way they are built. Incorporated shelters are areas in existing structures. Before the outbreak of hostilities, such space will normally be used for other purposes. Individual shelters, on the other hand, are independent structures that are designed and built as shelters. Being more expensive, individual shelters will seldom be found, unless there is a shortage of suitable space in existing buildings.

7.02 General Design Considerations

(a) If the site of the proposed shelter is in a probable target area, consideration should definitely be given to blast-resistant construction, or at least to "hardening" in some form. Anti-blast shelters entail myriad new problems, and their design is beyond the scope of this particular manual.

(b) The best way to achieve protection against fallout is to go underground. This should always be considered in the construction of new individual shelters. Excavation costs may, in some cases, be offset by the fact that thinner wall and roof sections are permissible in underground shelters. It is appreciated that in some areas the nature of the ground may cause underground construction to be prohibitively expensive, in which case surface shelters will have to be used.

(c) It is more economical and much more satisfactory, to provide for shelter areas when new buildings are in the design stage, than it is to adapt areas in existing buildings as shelters. Figure 20 shows a few of the many possibilities in this regard. Should financial considerations preclude the allocation of additional space for shelters, the designer will usually be able to arrange for certain areas to serve a dual purpose. It is of interest to note the policy of the U.S. Government with regard to the construction of new federal buildings. It states that except in special cases, the total additional cost for incorporating a shelter into a new federal building shall not exceed 5% of the cost of the building without a shelter.

(d) If the architect is given a small amount of leeway, and keeps shelter requirements in mind during the design stage, it is feasible, at relatively small extra cost, to ensure:

1. Adequate horizontal and vertical shielding against gamma radiation.
2. Baffling of entrances and exits.
3. Elimination of apertures that would seriously affect shielding of the proposed shelter area.

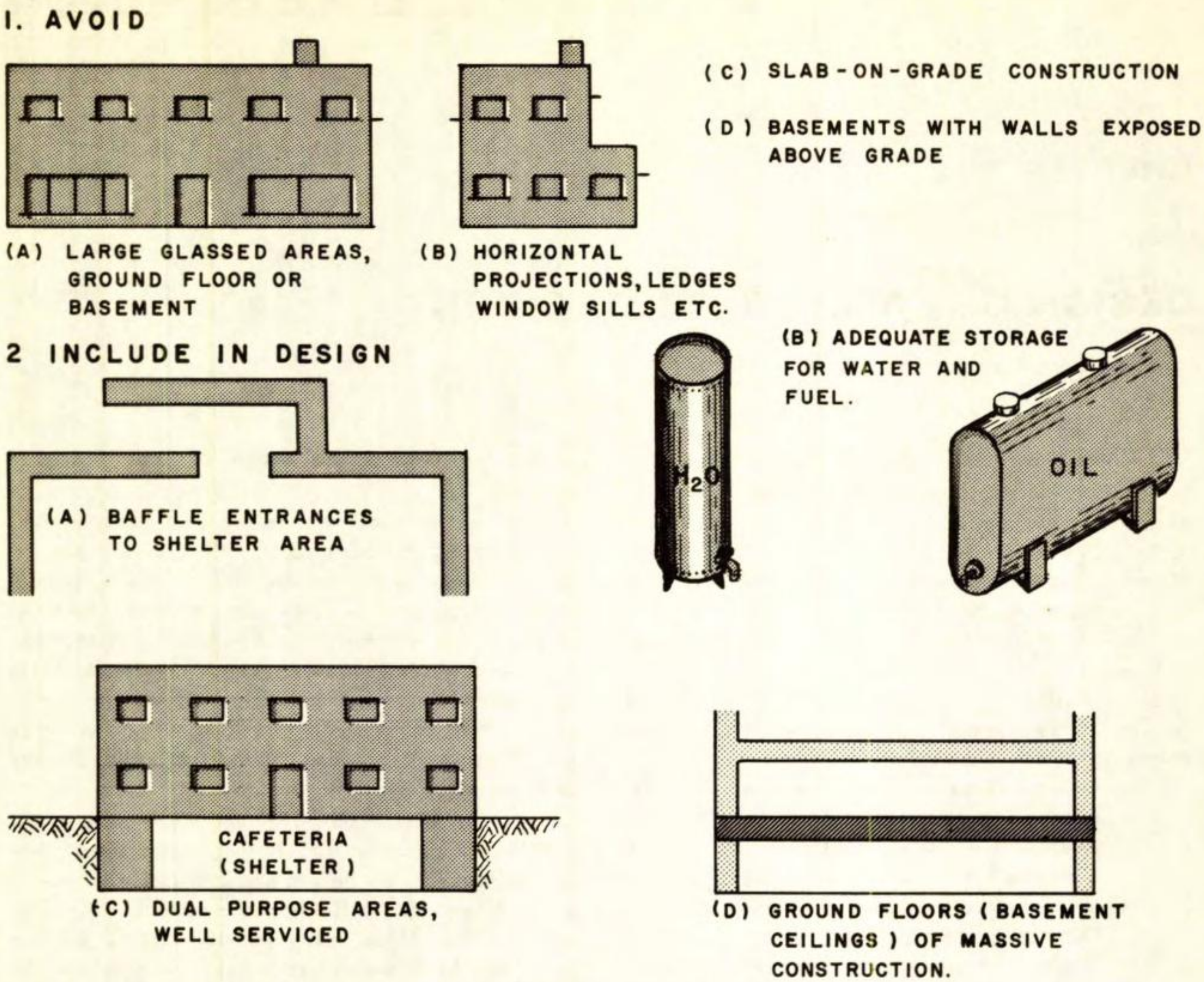


FIGURE 20 - SHELTERS IN NEW CONSTRUCTION

4. Adequate ventilation, power, water supply and storage, sanitary facilities etc.—all accessible to or controllable from the shelter area.
5. Elimination of exterior window sills, ledges, niches, grooves or any unnecessary flat surfaces that would tend to collect and retain fallout particles.
6. Sprinkler systems for flooding of flat roofs to permit their rapid decontamination.

(e) The normal use of dual purpose areas must be such as to permit of rapid conversion to fallout shelters. For example, rooms containing large amounts of fixed equipment or machinery, or those used for the storage of heavy merchandise, are unsuitable as most of the total floor space would not be available when needed. In general, the most suitable areas will be in basements, and their normal uses might be as rest rooms, cafeterias, sales rooms, dormitories, etc. One type of construction, sorely required by most cities, is underground parking facilities. Such structures, properly designed, would make excellent public shelters.

7.03 Design Criteria -- Habitability Factors

(a) The basic requirements for Class B shelters were discussed in Chapter 4. The criteria are summarized hereunder:

1. Area — 12 sq. ft. (net) per person, minimum.
2. Volume — 80 cu. ft. free air space per person, minimum.
3. Ventilation — 5 cfm fresh air per person, minimum. Recirculation of air within shelter. Maximum ET recommended is 85°F.
4. Air Filtration — Conventional dust filters required on all air intake ducts. Filters

must be shielded and intakes protected.

5. Standby Power – 2 KW minimum to 5 KW maximum, per 100 persons. Generator engines should use fuel of low volatility. Storage for 14 days fuel required.
6. Illumination – minimum 5 foot-candles at table height.
7. Water Storage – Minimum of 14 gallons per person of which at least one gallon per person must be within the actual shelter area.
8. Sanitation – Chemical or flush toilets, minimum 1 per 70 occupants. Two urinals for each toilet if possible.
9. Auxiliary Heating System – Supply maximum of 5 B.T.U. per hour for each cubic foot of shelter volume. Depends on heat losses, humidity, air changing frequency. Less heat will be required for underground shelters, in which it is mainly required to deal with dampness and high humidity. Minimum ET recommended is 50°F. Provide fuel storage for 14 days.
10. Entrances and Exits – Minimum of 2, separated as widely as possible, (For certain family shelters, one exit may be acceptable). Check local fire codes regarding fill-time. Rule of thumb – one unit of access or egress (24" unrestricted width) per 200 persons.
11. Storage for Food, Medical Supplies – 2 cu. ft. per person.
12. Bunks, Furnishings, Cooking Equipment – scaled to number of occupants. Allow one bunk per two occupants in large shelters.

(b) The above criteria may be used as a starting point for the design of Class A shelters. Many factors will have to be increased, depending on the type of work to be done in such shelters.

7.04 Design Criteria – Protection Factor

(a) If a new individual shelter is to be constructed to provide a certain protection factor, a multiplicity of designs can be produced by adjusting the ground and roof contribution. The designer's problem is the reconciliation of such adjustments with economical construction methods. Examples of three simple types of shelters will be used to illustrate the methods used.

(b) In the design of a conventional structure, provision for fallout shelter space can be made at very low cost, if a few basic principles are followed by the architect. Annex I is an example of such design.

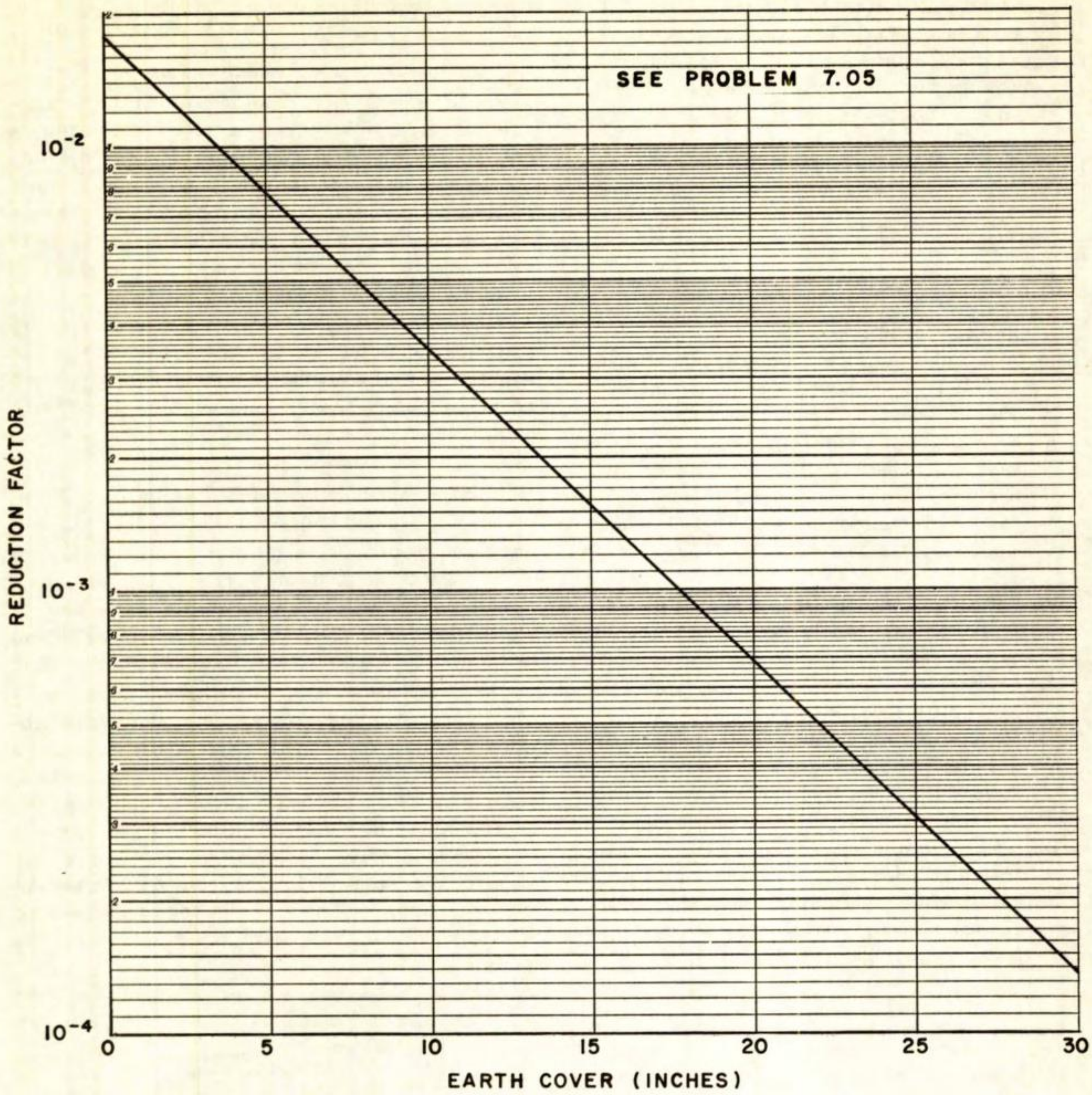
7.05 Underground Shelter for 50 People

(a) *Problem* – Calculate the thickness of packed dry earth cover required to give protection factors of 100, 250, 500, 1000, 2000, and 5000 in an underground shelter. Inside measurements of the shelter are 35' long, 20' wide, 10' high, and its walls and roof are of 8" reinforced concrete construction.

(b) *Solution* – Roof contribution is the only possibility here and the concrete roof alone provides a barrier of 100 psf. A graphical solution is attained by plotting the earth cover, in inches, against the reduction factor which is obtained from Chart 2, Annex B. If semi-logarithmic paper is used, the resultant curve becomes, for all intents and purposes, a straight line. Figure 21 shows the graphical solution. The co-ordinates of the various points used for the curve were calculated as follows:

1.	2.	3.	4.	5.	6.
Earth Cover (inches)	Hr (ft.)	Ar' (sq. ft.)	Earth Mass Thickness (psf)	Mto (psf) (4) + 100	Reduction Factor
0	7.67	1190	0	100	.018
4	8.0	1090	28	128	.0090
8	8.33	1000	56	156	.0045
10	8.5	970	70	170	.0033
12	8.67	930	84	184	.0025
16	9.0	860	112	212	.0013
18	9.17	830	126	226	.00090
22	9.5	770	154	254	.00050
24	9.67	750	168	268	.00037
28	10.0	700	196	296	.00018

FIGURE 21 – PROTECTION FACTOR – UNDERGROUND SHELTERS



(c) Referring to Figure 21, the answers are readily available:

Protection Factor Desired	Reduction Factor	Earth Cover Required (inches)
100	0.01	3.5"
250	0.004	9.0
500	0.002	13.3
1000	0.001	17.5
2000	0.0005	22.0
5000	0.0002	27.5

7.06 Aboveground Shelter for 100 People

(a) *Problem* – Suggest designs for the roof and walls of an aboveground shelter so that protection factors of 100 and 500 would result. Assume that the inside dimensions are to be 25' x 60', x 10' high.

(b) *Solution* – In this case there will be roof contribution, and ground contribution through the exterior walls. Taking each of the desired protection factors in turn, let us examine some of the possibilities.

(c) Protection Factor – 100
Reduction Factor – 0.01
That is, GC + RC must not exceed 0.01

Proposal	RC	GC	Roof psf*	Walls psf
1.	0	.01	**	180
2.	.003	.007	180	198
3.	.004	.006	167	206
4.	.005	.005	157	214
5.	.006	.004	150	225
6.	.007	.003	143	237
7.	.01	0	127	**

* – 2% allowed for skyshine
** – very high, impracticable.

Proposals 3, 4 or 5 represent the most economical combinations in terms of total mass, and any one of them would be acceptable. Probably No. 5 is best, as it is more economical to put mass thickness into walls rather than roofs. In this case a centre beam would be used to support the roof. A 6" concrete slab, reinforced one way, will then carry approximately 195 psf, including its own weight of 75 psf. Over the concrete roof it will be necessary to place 75 psf of dry gravel, or 8 inches. This would still leave about 45 psf for snow load. Arrangements would have to be made to retain the gravel and waterproof it by covering with a suitable asphalt membrane.

There are several ways of building the walls to the required 225 psf. An economical method would be to use a double wall, consisting of two courses of 8" hollow concrete block, spaced 12.5" apart, and well tied together. If the space between courses is then filled with packed dry gravel, the total mass thickness of the wall will be 55 + (12.5 x 9.5) + 55 = 229 psf.

(d) Protection Factor – 500
Reduction Factor – 0.002
GC plus RC must not exceed 0.002

Proposal	RC	GC	Roof psf	Walls psf
1.	.0002	.0018	293	264
2.	.0005	.0015	254	275
3.	.001	.001	224	292
4.	.0013	.0007	216	312

In this case, proposal 3 appears to be the most economical. Using a center beam carried by columns, a 7" roof slab with one-way reinforcing will carry 270 psf including its own weight. If 14.5 inches of dry gravel are placed over the roof slab, the roof barrier will then have a mass thickness of (7 x 12.5) + (14.5 x 9.5) = 225 psf. This leaves 45 psf for the snow load. The walls could be designed in a manner similar to that used in the previous example. The space between the concrete blocks would have to be 19.5" and the total mass thickness of the walls would then be 55 + (19.5 x 9.5) + 55 or 295 psf.

7.07 Protection Factor – Small Aboveground Shelters

Figure 22 contains a series of curves which make it possible, for any given protection factor, to rapidly determine the necessary mass thicknesses of the roofs and walls of small aboveground shelters. While perhaps slightly less accurate than Charts 2 and 5, Figure 22 has greater ranges in terms of protection factors and mass thickness. Moreover, as the designer usually tends to be on the safe side, the accuracy of Figure 22 will be sufficient for most purposes. It is suitable for small shelters, in which geometry shielding plays a minor role.

7.08 Protection Factor – Incorporated Shelters

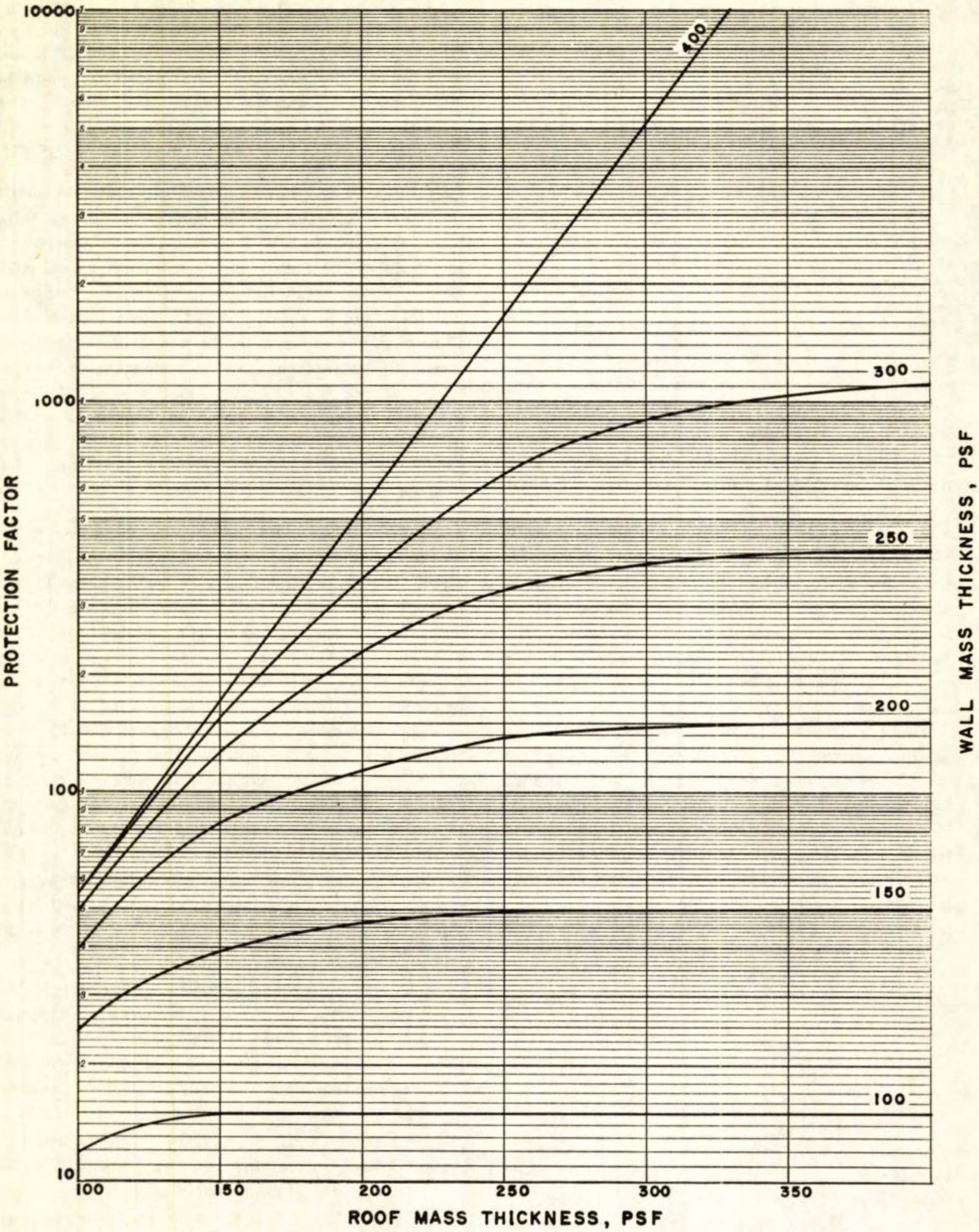
(a) In some buildings, there may be areas in which the protection factor is sufficiently high to obviate the necessity of construction for the purpose of improving shielding against radiation. Likewise, there will be a large number of buildings in which the protection factor falls short of the minimum requirement. If a shelter is to be constructed inside such a building, it should be so located as to make optimum use of the inherent shielding qualities of the structure. Almost invariably, this leads to a location in the basement—if there is a basement, and if it has suitable habitability factors.

(b) The design of an incorporated shelter, from the point of view of radiation shielding, will follow the pattern described in paragraph 7.06. There are two differences:

(i) For basement shelters, radiation coming through the exposed basement walls must be considered. If the protection factor is to be 500, then RC plus GC (exterior aboveground walls) plus GC (exposed basement walls) must not exceed 0.002.

(ii) The existing structure already provides some shielding in the horizontal and vertical planes. The designer must calculate the *additional* mass thickness required in the walls and roof of the shelter itself,

FIGURE 22 - PROTECTION FACTORS SMALL ABOVEGROUND SHELTERS



to provide the specified protection factor. These figures will determine the type of construction recommended.

7.09 Example of Design – Incorporated Shelter

(a) *Problem* – A staff shelter is to be constructed in the basement of Brown's Department Store, which is described in Annex "F". The shelter dimensions are set at 20' x 30' and it must be located in the center of the basement in order to take advantage of existing utilities. A protection factor of 500 is specified. Make recommendations as to the construction of the walls and roof of the shelter proper. No exterior work, such as sandbagging, is to be permitted.

(b) *Solution* –

Protection Factor – 500
Reduction Factor – 0.002
Existing Reduction Factor (Annex F) is 0.00684

From an inspection of the shelter analysis form, it will be seen that the RC and GC (exterior walls) are quite low in comparison to GC (basement walls). If a 4" reinforced concrete roof is used for the shelter, RC becomes 0.00026 and GC (exterior walls) is reduced to 0.00017 for a total of 0.00043. Therefore GC (basement walls) must not exceed 0.002 minus 0.00043 or 0.00157. From the analysis form, its present value is 0.00503. The GC calculated from Chart 5 (see paragraph 30 of the analysis) must be reduced from 0.037 to 0.037 x 0.00157 ÷ 0.00503 or 0.0116. Again referring to Chart 5, it will be seen that a reduction factor of 0.0116 results when Mb is 156 psf. This means that the shelter proper must have walls with mass thickness of 156 – 102 = 54 psf. From Annex A, 8" hollow concrete block will provide 55 psf. The answer then becomes:

Walls – 8" hollow concrete block, with entrances suitably baffled.
Roof – 4" reinforced concrete slab.

CHAPTER 8

MUNICIPAL FALLOUT SHELTER SURVEYS

8.01 Object of a Shelter Survey

(a) The primary purpose of a fallout shelter survey is to take stock of the accommodation that is suitable, and immediately available, to protect the population against residual gamma radiation. The survey will also provide information regarding other accommodation that, although unsuitable at present, can be quickly converted into satisfactory shelter space, provided that certain specified improvements are made. Furthermore, the completed survey will relate information on potential shelter capacity to population. Thus the sponsor of the survey will know how many people can be protected in existing facilities; how many more can be protected for the expenditure of $X; and how many will still remain without adequate protection.

(b) It must be clearly understood that a shelter survey is only part of a shelter programme, which in turn is but one of the many problems in the overall civil defence plan. The survey is, however, a necessary prerequisite to intelligent planning for shelter allocation, improvement, or construction.

8.02 Organization of a Shelter Survey

(a) Fallout shelter surveys will normally be made by, or on behalf of, towns, cities, townships or counties. The area covered by such a survey will usually correspond to that administered by the municipal government concerned. In a sparsely populated area, the work involved in a shelter survey may not be extensive. In a large city, the task may well assume prodigious proportions.

(b) Once it has been decided to conduct a shelter survey, sufficient manpower should be provided to ensure rapid completion of the project. Those involved should devote all their time to the survey. If it is treated as a part-time job, interest wanes and the end result will probably be of less value. The number of personnel required will increase for larger areas, but the basic organization remains constant.

(c) The survey may be carried out by municipal employees, or professional assistance may be enlisted, i.e. consulting engineers or architects. If at all possible, it is preferable to use employees of the local government. They are thoroughly familiar with the area and will tend to take a long-term interest in the subject of fallout protection. Moreover, if they perform the actual building inspections and the subsequent calculations, their detailed knowledge will continue to be available to the municipality. The work itself entails innumerable calculations and considerable typing and printing, for which municipal offices are properly equipped. If a consultant is engaged, the use of such facilities would add appreciably to the cost of the survey.

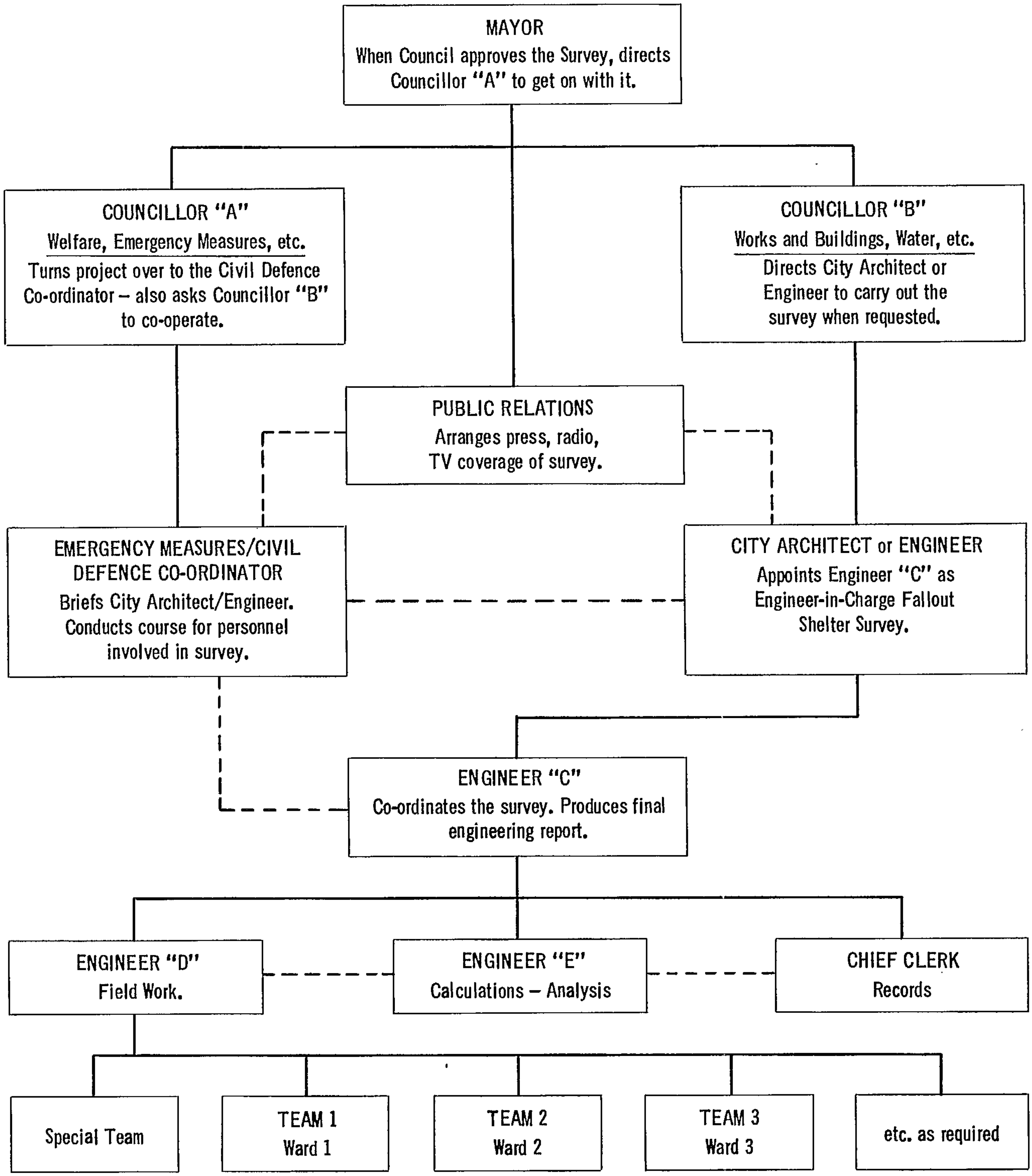
(d) Ground organization of a fallout shelter survey should follow the normal municipal system. The inspections might be divided into districts, wards, or sub-areas conforming to any other existing intermunicipal boundaries.

(e) Figure 23 is a suggested organization chart for a city, showing how various personnel might be employed in carrying out a shelter survey.

8.03 Public Relations

(a) Experience in the U.S.A. and Canada has served to emphasize the importance of public relations in shelter survey work. The public must, by all available news media, be acquainted with the object and nature of the survey. If this is not done, cooperation will not be forthcoming and the field teams will encounter aggravating delays in obtaining the necessary data. On the other hand,

FIGURE 23
ORGANIZATION OF A FALLOUT SHELTER SURVEY



Note:– a Field Team might consist of a Building Inspector with an assistant, or several sub-teams in large areas.

it has been found that a well-informed public is more than anxious to assist in every possible way. It is stressed, therefore, that a fallout shelter survey should be preceded by an intensive public relations programme. Only in this way will the inspectors be able to avoid difficulties in attaining access to private property. Needless to say, the surveying team must carry proper identification, which should include, if possible, a letter explaining briefly the purpose of the work, and signed by the head of the municipal government concerned.

(b) It has also been found that there is a tendency for inspectors to lose considerable time by becoming involved in long explanatory discussions with the occupants of the building being surveyed. Such dissertations have been known to wander from the subject at hand to the theory of atomic fusion and fission, or nuclear disarmament. It is not possible to establish hard and fast rules for this problem. Courtesy must be observed, and it is only natural that people will be curious as to what is going on, particularly when their property may be affected. At the preliminary briefing of survey personnel, the pitfalls leading to such loss of time will be made known. In the final analysis however, the tact and diplomacy of the individual surveyor will determine the speed of the project.

8.04 Fallout Shelter Survey Costs

(a) In Canada, very little information is available on survey costs. Pilot surveys have been carried out by federal government employees, assisted by civic employees and volunteers from Civil Defence organizations. In a municipal survey, although perhaps additional casual employees may be hired, the bulk of the work would devolve upon regular employees, whose pay would come from their own departments. With these hidden costs, it would not be fair to publish such cost data as may be available at the present time.

(b) In the U.S.A. there is much more knowledge with regard to survey costs, as several pilot studies have been carried out by consultants for various cities and counties. The cost-estimate formula suggested by OCDM is as follows: "Multiply the number of people in the community (daily peak population) by 10 cents. Multiply the number of structures in the community by 50 cents. The higher of the two figures will give a good indication of the minimum cost".

8.05 Preliminary Work *(Refer to Figure 23)*

(a) Once the manpower is available, work begins. The Emergency Measures Co-ordinator should arrange to give a short course on shelter analysis to all the professional members of the civic survey organization. If he has no personnel qualified to do this, the Regional Officer of the Federal Emergency Measures Organization will, on request, obtain expert assistance.

(b) Next the City Architect or City Engineer will call together every member of the staff to be employed on the survey. He, or his Assistant, will brief them as to the purpose of the survey and on the method of carrying it out. His instructions need not go into complete technical detail but every man should be given a clear understanding of what he is expected to do.

(c) Engineer "C", the key man in the survey, discusses the ground organization with Engineer "D", who is in charge of all the inspection teams. Agreement must be reached as to the utilization of available manpower among the various wards, some of which will contain more structures than others. A time schedule and reporting system will be established.

(d) Engineer "C" will give Engineer "E" detailed instructions as to the operation of the engineering office required for the survey. The amount of time "E" is to devote to protective improvements, habitability improvements and cost estimates, will be governed by the total time available for the survey. For instance, in the first phase, it is conceivable that protection factors only would be required – on the assumption that a preliminary plan for short-term shelter could be developed at very low cost. Another duty of Engineer "E" would be to obtain for Engineer "D" all the available building plans, by wards. Those not available as civic records might be obtained from Provincial or Federal Public Works Departments, or from private owners. Such plans would serve to alleviate the work-load of the field teams.

(e) The Chief Clerk, working directly under Engineer "C", will be responsible for the preparation of forms and the maintenance of records. For each ward he will prepare a package of Data Collection Forms. (See Annex "D"). These will contain the addresses of every public, commercial, industrial or multistory apartment building in the ward. This package, accompanied by the appropriate maps and plans from Engineer "E"'s staff, will form a basis of work for the survey team in that particular ward. Subsequently the Chief Clerk will assist Engineer "C" in the compilation of the final report, and he will also ensure that all records of the survey are suitably preserved for future reference.

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8.06 Collection of Data

(a) Once the actual ground survey begins, a special team will immediately set forth to examine all critical structures in the area, regardless of team boundaries. They will cover power stations, waterworks, sewage works, large central heating plants, gasworks, broadcasting stations, public telephone exchanges, etc. The blast effects of a nuclear explosion occurring at some distance from the municipality may not damage these structures, but they may well be in the path of the radioactive fallout. If the services they provide are essential to the community, then the protection of their operators against fallout must be given high priority.

(b) The survey team responsible for a district will probably drive around it first, to make a preliminary visual study, and to assist in the formulation of a plan of action. If of suitable calibre, teams may be authorized to forego the inspection of obviously unsuitable buildings, such as light wood-frame structures. Discretion in this matter will have to be exercised by the engineer in charge. Private residences will not normally be inspected. With these exceptions, all buildings in the district will be investigated. Using a standard Data Collection Form, the team must:

(i) Obtain complete information regarding structures for which no plans are available;
(ii) Verify, or obtain additional data, on buildings for which drawings are incomplete;
(iii) Note any conditions that cannot be determined from drawings, e.g. state of repair, dampness, flooding, location of equipment and fixtures;
(iv) For larger buildings, indicate *all* possible shelter areas.

(c) In collecting data, experience has shown that perhaps the greatest difficulty encountered will be in establishing the mass thicknesses of walls or roofs of buildings for which no detailed plans are available. Men with knowledge of the building trades are often able to estimate the type of construction. If it becomes necessary to guess at such things, the engineer must ensure that the guesswork is conservative. It is possible to measure mass thickness directly by using a radioactive source and Geiger counter, together with a set of calibration curves. This type of equipment has been used on Federal surveys and is quite accurate.

(d) Multistory apartment dwellings will normally be included in the list of buildings to be inspected by the survey team. These buildings often have large common areas or basements, which are potential shelters. However, the inspection of every private home is not contemplated, and there will be no Data Collection Forms for individual houses. Small residences may be considered in groups, according to whether or not they have basements. It may be argued that a 1½ story or 2 story home is a better potential shelter than a bungalow, or that a house with brick veneer walls offers more protection than a frame and stucco dwelling. This is all true, but no modern house, "as built", provides adequate shielding. Homes with basements do have a potential and can be equipped with fallout shelters; those with slab-on-grade construction are hopeless in this respect. It would appear therefore that the following information, if not available in municipal records, should be obtained by survey teams:

(i) Percentage of homes with, and without, basements;
(ii) The percentage of basementless homes having sufficient space to permit the construction of back-yard shelters.

The value of such information would vary with circumstances. In some municipalities, there may be sufficient accommodation for public shelters so that the construction of household shelters need not be encouraged. In others, an accommodation shortage may necessitate a large scale domestic shelter construction programme. In any case, municipal authorities must have these statistics, and relate them to the public shelter capacity, before they can intelligently advise people what to do.

(e) At the end of each working day, survey teams should turn in their completed Data Collection Forms to the engineer in charge of field work. He will screen them, request additional information in some cases, and pass them to his colleague for analysis.

8.07 Analysis of Data

(a) As Data Collection Forms are completed and checked, they are passed to the engineering office of the survey for analysis. In the organization shown at Figure 23, the flow of paper would be from Engineer "D" to "E". Using a Shelter Analysis Form similar to Annex E, the protection factor and capacity of each potential shelter area would then be calculated. It should be noted that some buildings may have two or more possible shelter areas, and each one must be calculated separately. In most cases, the analyst will make recommendations as to shielding or habitability improvements.

(b) Whether or not the engineering office is required to produce cost estimates for the necessary improvements is a matter of policy. To most municipalities, the matter of cost will be vital. The analyst, or his assistant, must be told if he is to produce detailed cost data, or if rough estimates will suffice. Information as to costs will be included on, or attached to, the Shelter Analysis Form.

(c) The cost of shielding improvements is usually quite low, provided that improvisations are acceptable. In peacetime these may not be well received, and costs will increase accordingly. There is no rule of thumb covering the cost of protective improvements, which will differ considerably from one building to another. For habitability improvements, however, it has been found that on the average, all the necessary work can be completed for a maximum of $25.00 per shelter occupant. This figure is for engineering work only and does not cover bunks, furnishings, food, or other supplies. Obviously, the per capita cost of improvements must be less than that of new shelter construction. The engineer must be given clearly defined terms of reference with regard to minimum protection and habitability factors, if he is expected to produce meaningful cost estimates.

(d) The engineering office attaches completed analysis forms to their corresponding data forms, and assembles the documents by wards or districts. For each ward there should be two groups of shelter analyses at this stage:

- (i) Shelters having existing protection factors which equal or exceed the specified minimum, or which can be brought up to this level if simple protective improvements are made;
- (ii) Those for which major reconstruction would be required to bring the protection factor up to the minimum established by the local government.

Under covering lists, the calculations are then passed to the Chief Clerk for the survey co-ordinator.

8.08 Summary of Results

(a) The engineer in charge of the survey, on receiving completed shelter analysis forms for each ward, is now in a position to relate the information on shelter capacity to the daytime and nighttime populations. This may be done in a variety of ways, but it is essential that sufficient information be included to give the local government a complete and lucid picture of the overall problem.

(b) Using a small hypothetical city as an example, Annex "J" contains a typical report that might be prepared by the engineer in charge of the survey. This report summarizes all the information that was gathered on the survey, and presents it in a manner that enables subsequent users to see the problem at a glance. Normally, the engineer will not be required to make recommendations as to construction programmes for household or public shelters. He will, however, have provided sufficient basic information to enable his local government to quickly appreciate the requirement. For example, Appendix 7 to Annex J may well be prepared by the Emergency Measures/Civil Defence Co-ordinator to summarize the measures necessary for the maximum protection of the public against radioactive fallout.

(c) The survey in Annex "J" is based on a minimum protection factor of 100, and on the habitability criteria described in Chapter 4. Financial considerations may necessitate lowering these standards, in which case the complete shelter programme could be accomplished at a decreased capital cost. This approach is certainly preferable to ignoring the problem, but it is again stressed that an indeterminate risk is introduced when the recommended standards are reduced.

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Annex A

TABLE OF MASS THICKNESSES

Annex A

TABLE OF MASS THICKNESSES

Item	Thickness (inches)	Mass Thickness (psf)
Aluminum	1"	14
Asbestos board	3/16	2
Asbestos, corrugated	5/16	4
Asbestos shingles	5/32	2
Asphalt, for paving	1"	8.5
Brick, common	1"	8 to 10
Brick, fire	1"	12.5
Concrete, stone or gravel	1"	12
Concrete, stone, reinforced	1"	12.5
Concrete, cinder	1"	8.5
Concrete, cinder, reinforced	1"	9
Concrete Block, stone, hollow	4"	30
	6	42
	8	55
	12	85
Concrete Block, cinder, hollow	4	22
	6	30
	8	39
	12	61
Earth, dry, packed	1"	7 to 8
Floor, typical wooden:		
3/4" hardwood on 1" subfloor carried by 2" × 10" at 16" centers		10
1/8" tile on 3/4" subfloor carried by 2" × 8" at 16" centers		7.5
Glass, sheets	1/8	2
	1/4	3.5
	3/8	5
Granite	1	14
Gravel (dry)	1	9.5
Ice	1	4.5
Iron, cast	1	37.5
Lead, sheet	1	59
Plaster	1/2 – 3/4	5 to 6
Plaster ceiling on suspended metal lath		10
Plywood sheathing	3/8	1
	3/4	2
Roofing, 3 ply		1
4 ply pitch and gravel		6
5 ply pitch and gravel		7

Item	Thickness (inches)	Mass Thickness (psf)
Sand, dry	1	8
Sand, wet	1	10
Skylights, 3/8" wire glass and frame		7.5
Steel, plate	1	40
panels	18 ga.	3
corrugated sheet	20 ga.	2
Stone Masonry	1	10 to 14
Stucco	3/4	5
Terra Cotta, hollow	1	5
solid	1	10
Terrazo, mosaic	3/4	9
Tile, clay, partitions	3	18
	4	20
	6	25
	8	32
	10	40
Tile, structural	8	42
	12	58
Tile, roofing		10 to 20
Wallboard, asbestos	3/16	2
Fibreboard	1/2	1
gypsum	1/2	2
Wood, dry, maple	1	4
oak	1	4
pine	1	2
poplar	1	2.5
spruce	1	2

Annex B

CHARTS OF REPRODUCTION FACTORS

CHART I - FALLOUT ON A HORIZONTAL BARRIER

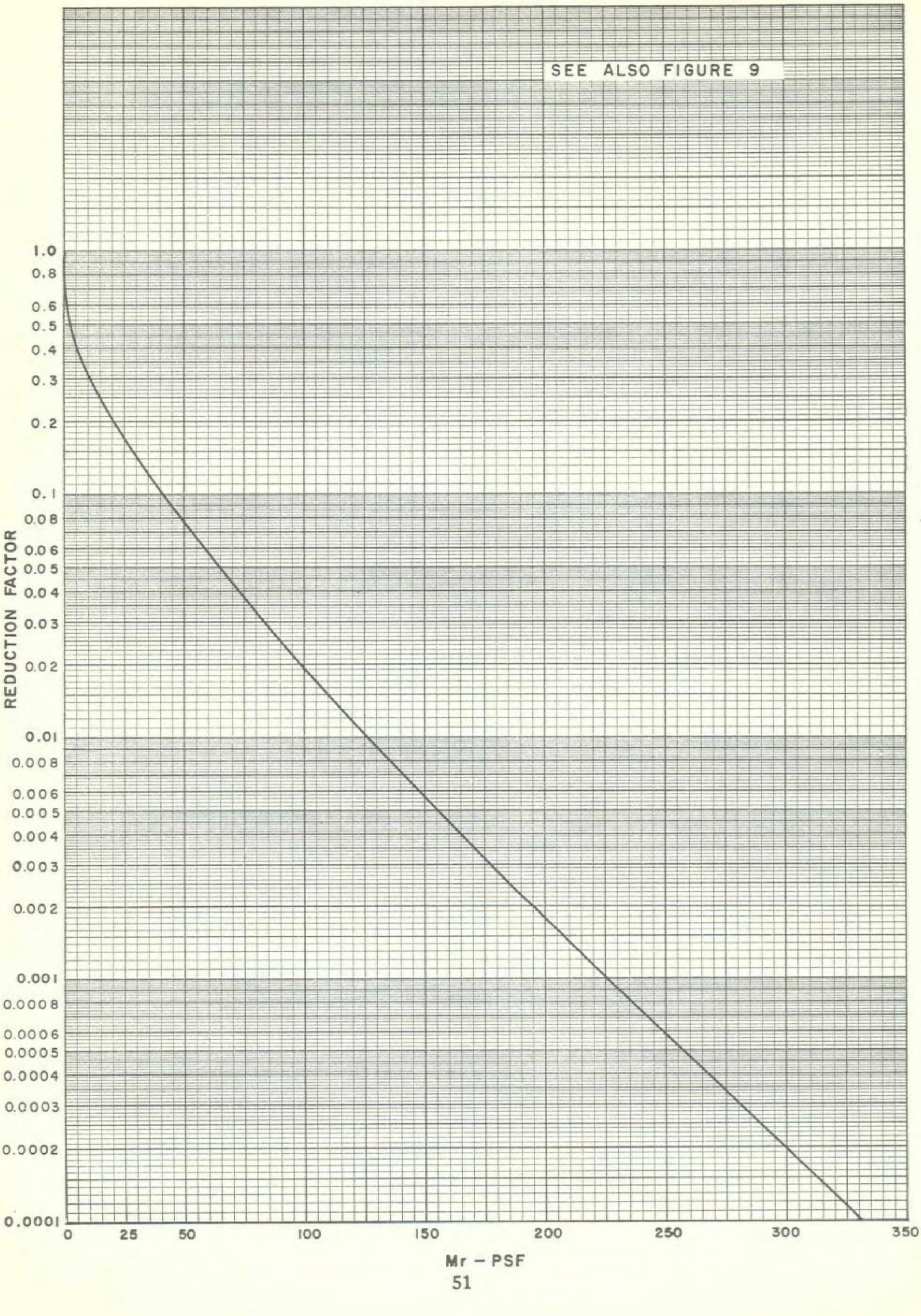

CHART 2 - REDUCTION FACTORS - ROOF CONTRIBUTION

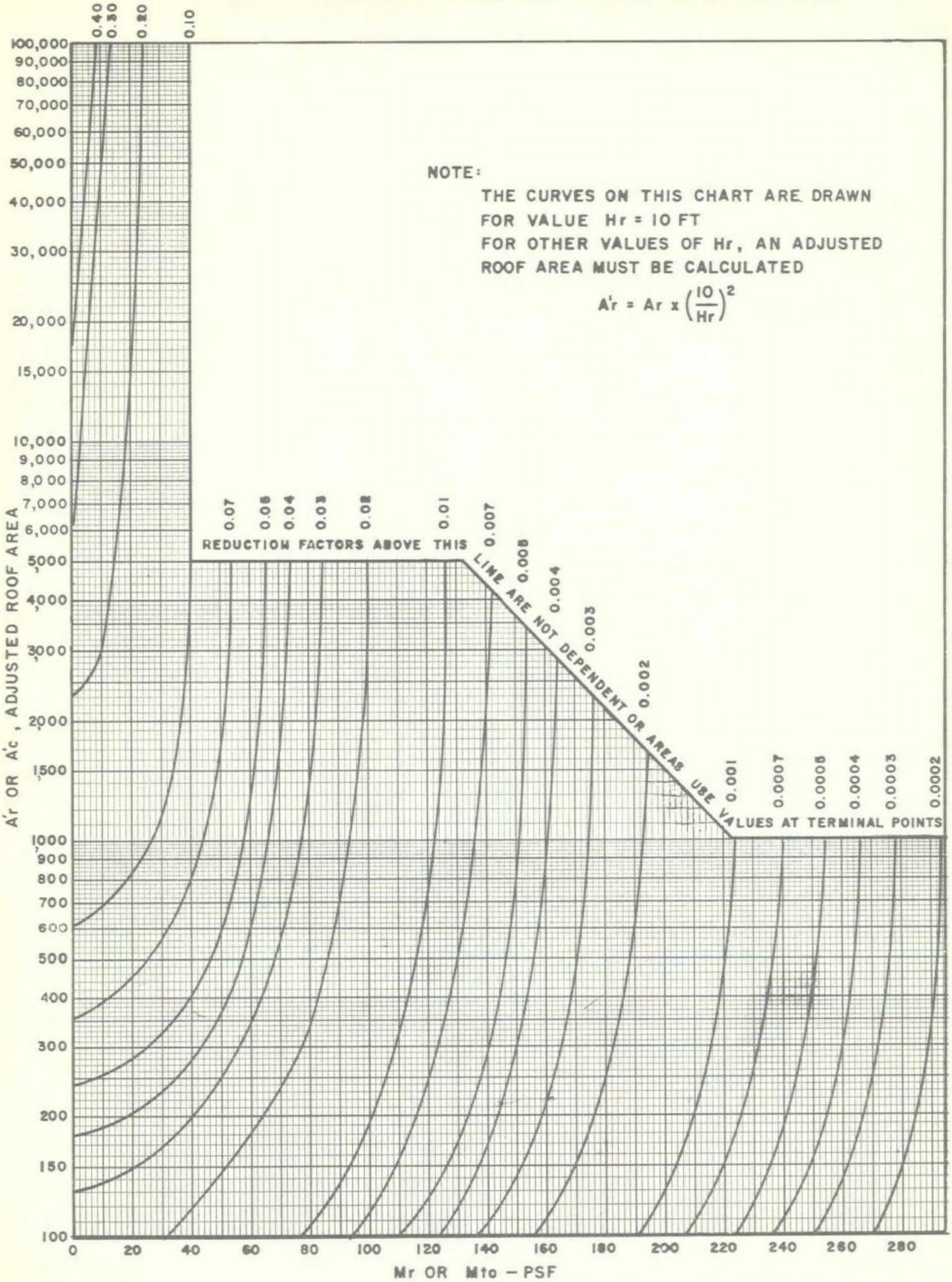

CHART 2A - CALCULATION OF ADJUSTED ROOF AREA

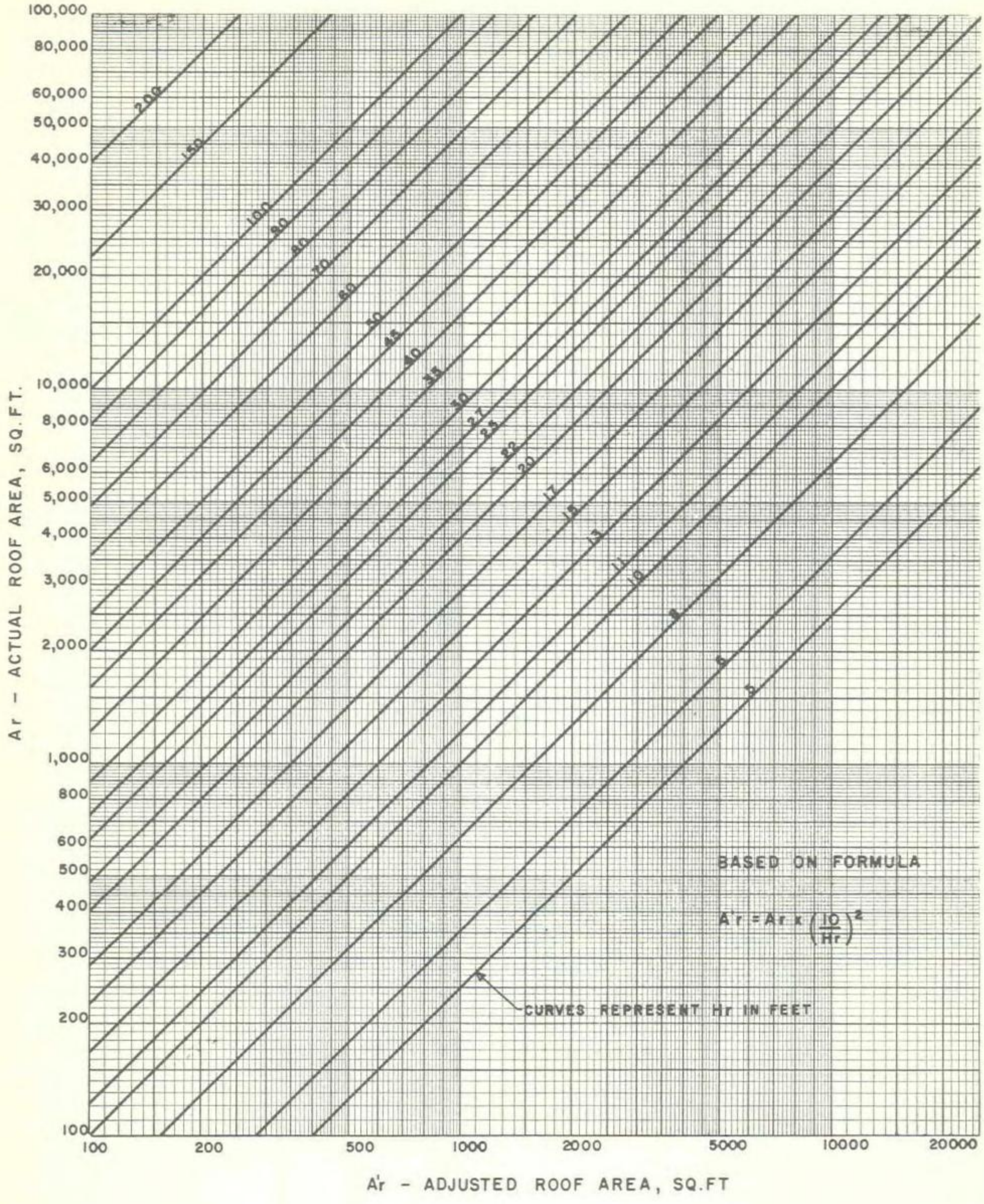

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CHART 3- SKYSHINE CORRECTION - ROOF CONTRIBUTION

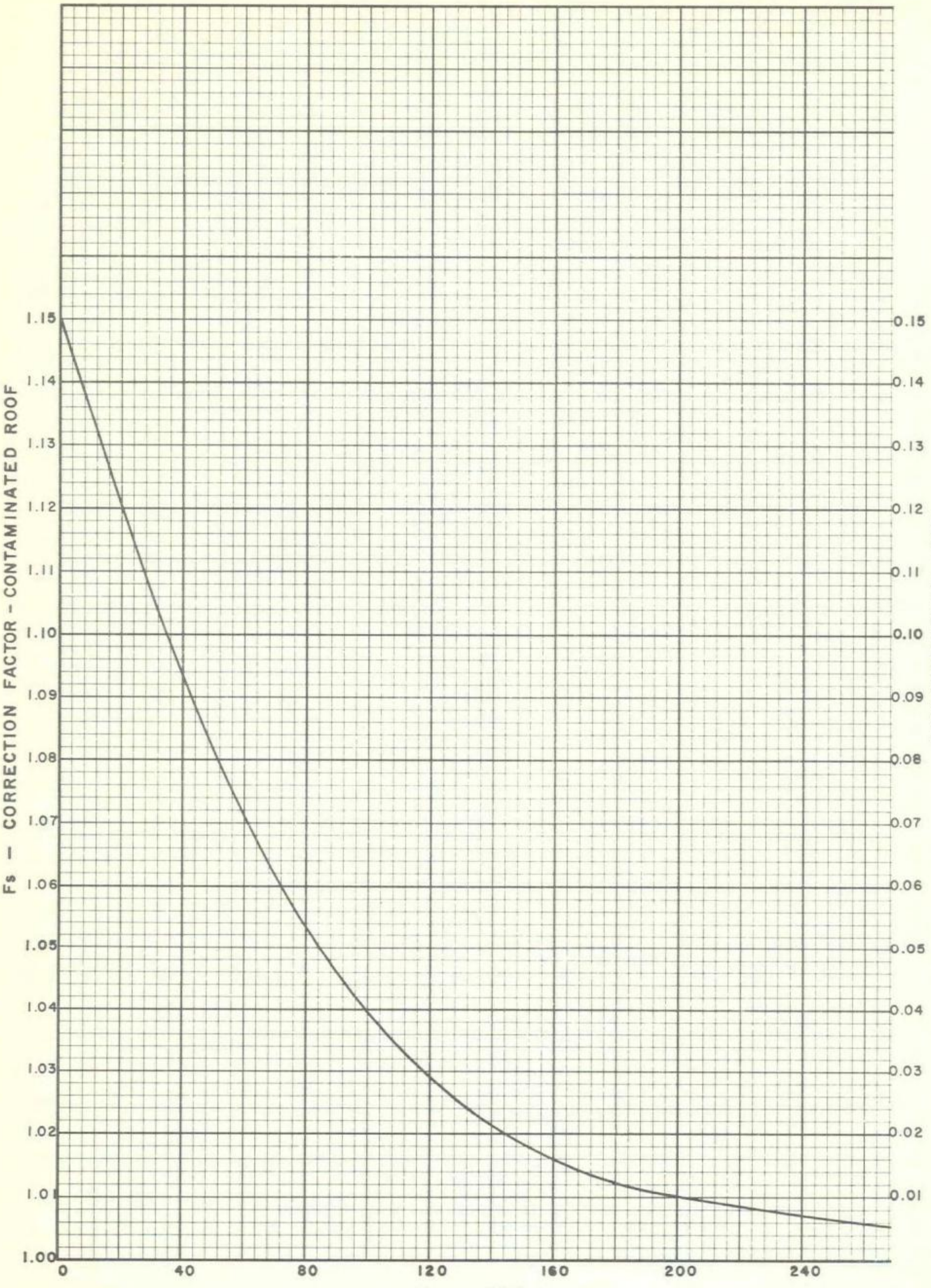

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CHART 4 - FALLOUT ADJACENT TO A VERTICAL BARRIER

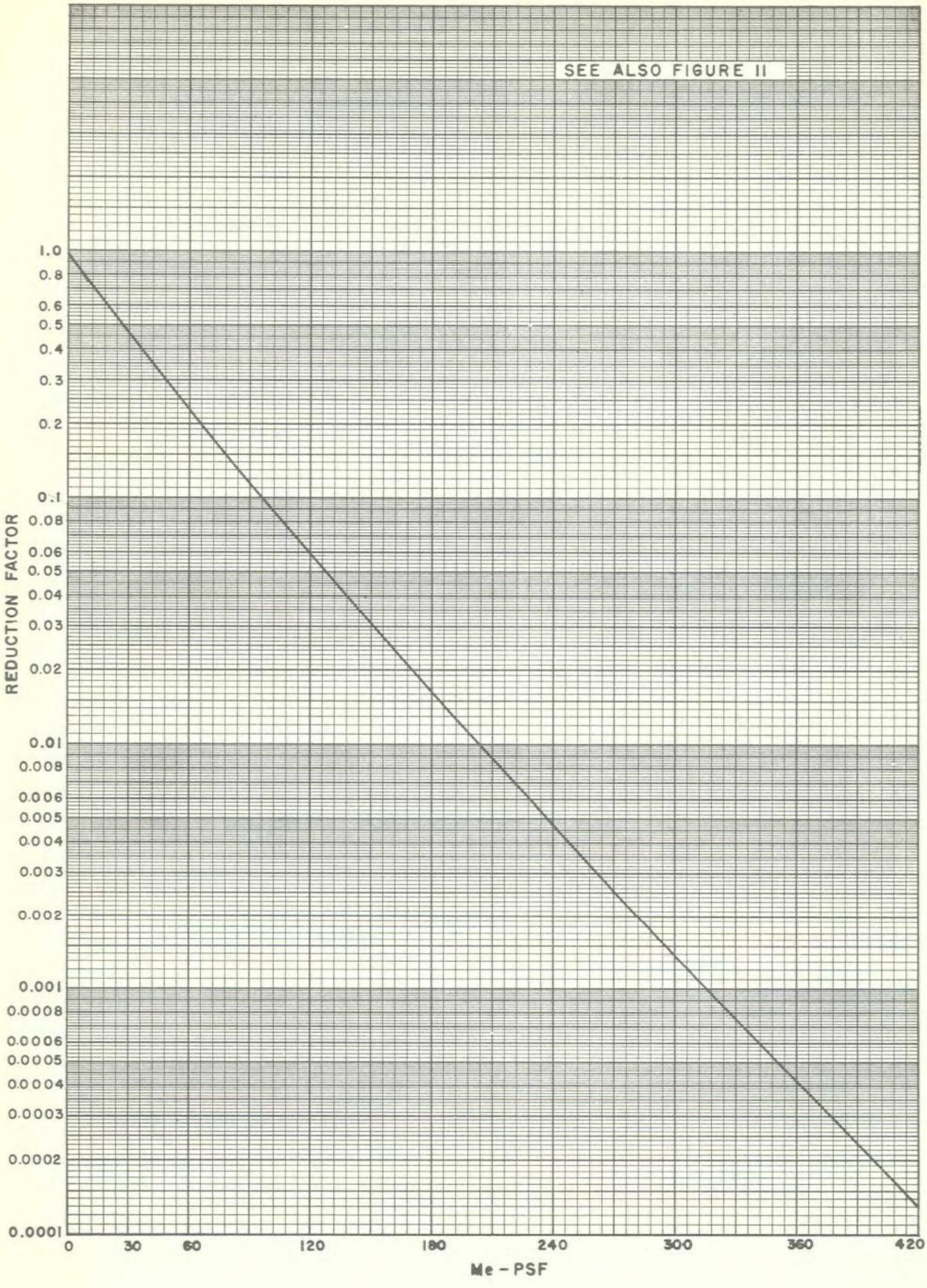


CHART 5 - GROUND CONTRIBUTION - ABOVEGROUND AREAS

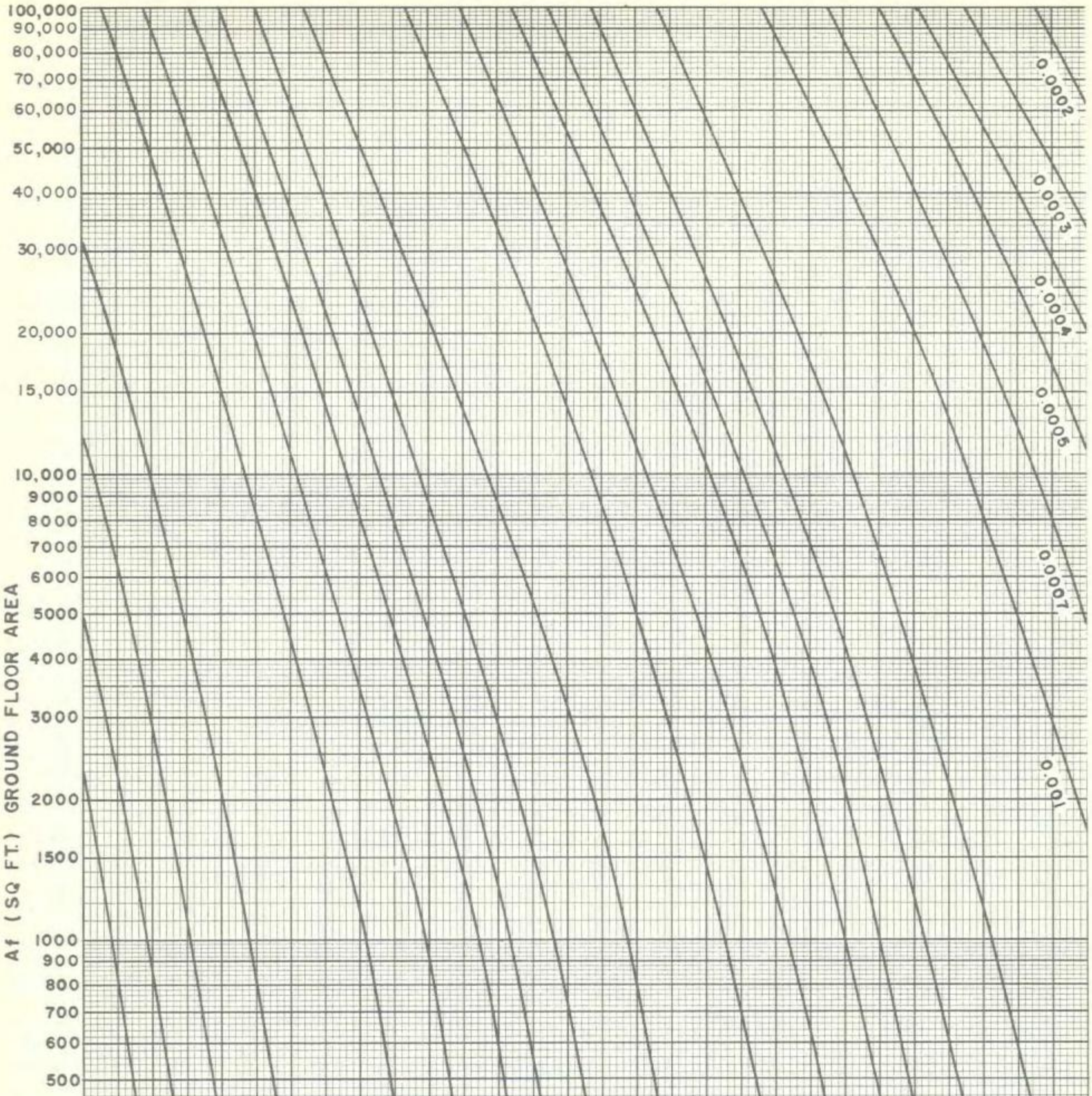


CHART 6 - FALLOUT ADJACENT TO A HORIZONTAL BARRIER

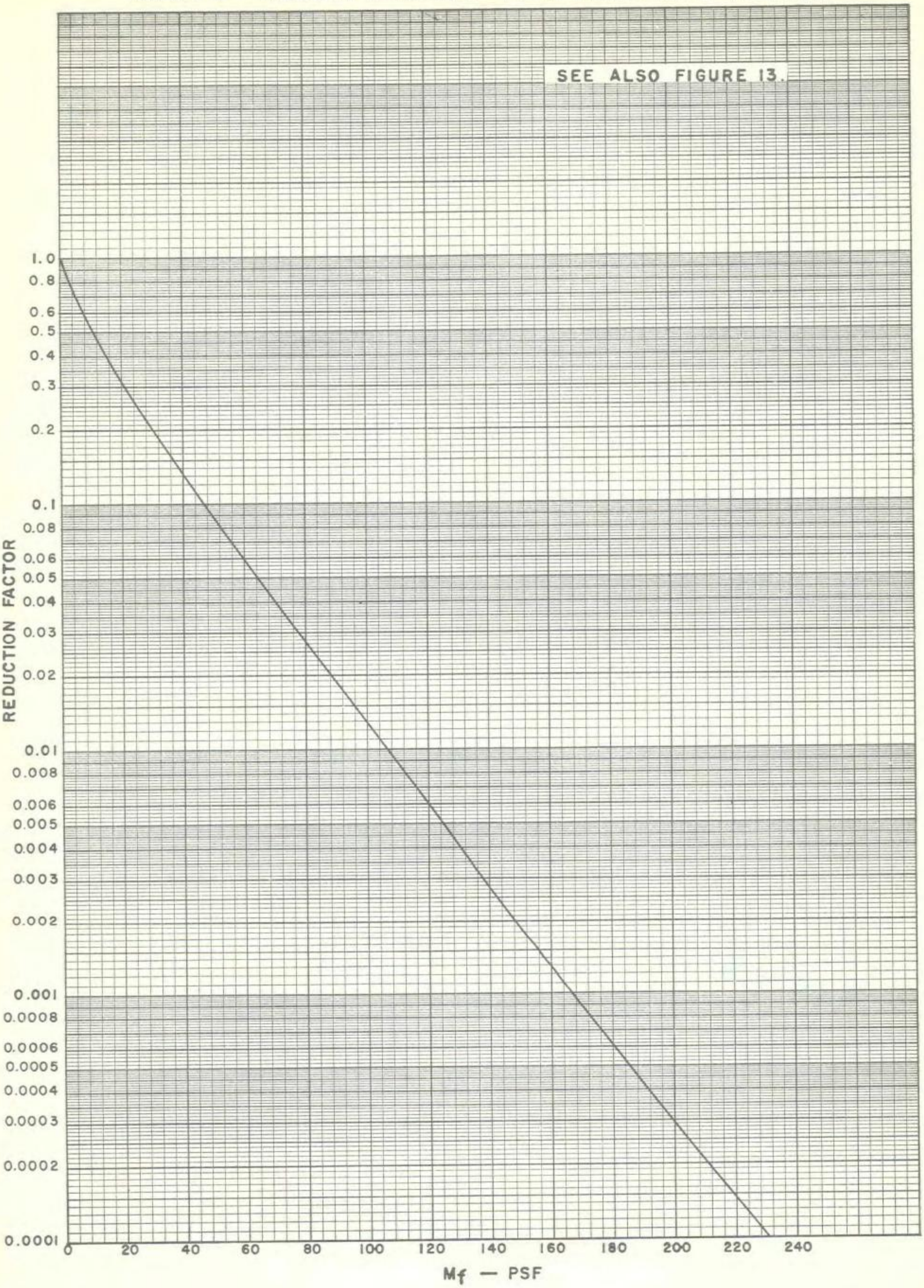


CHART 7 - GROUND CONTRIBUTION - BELOWGROUND AREAS

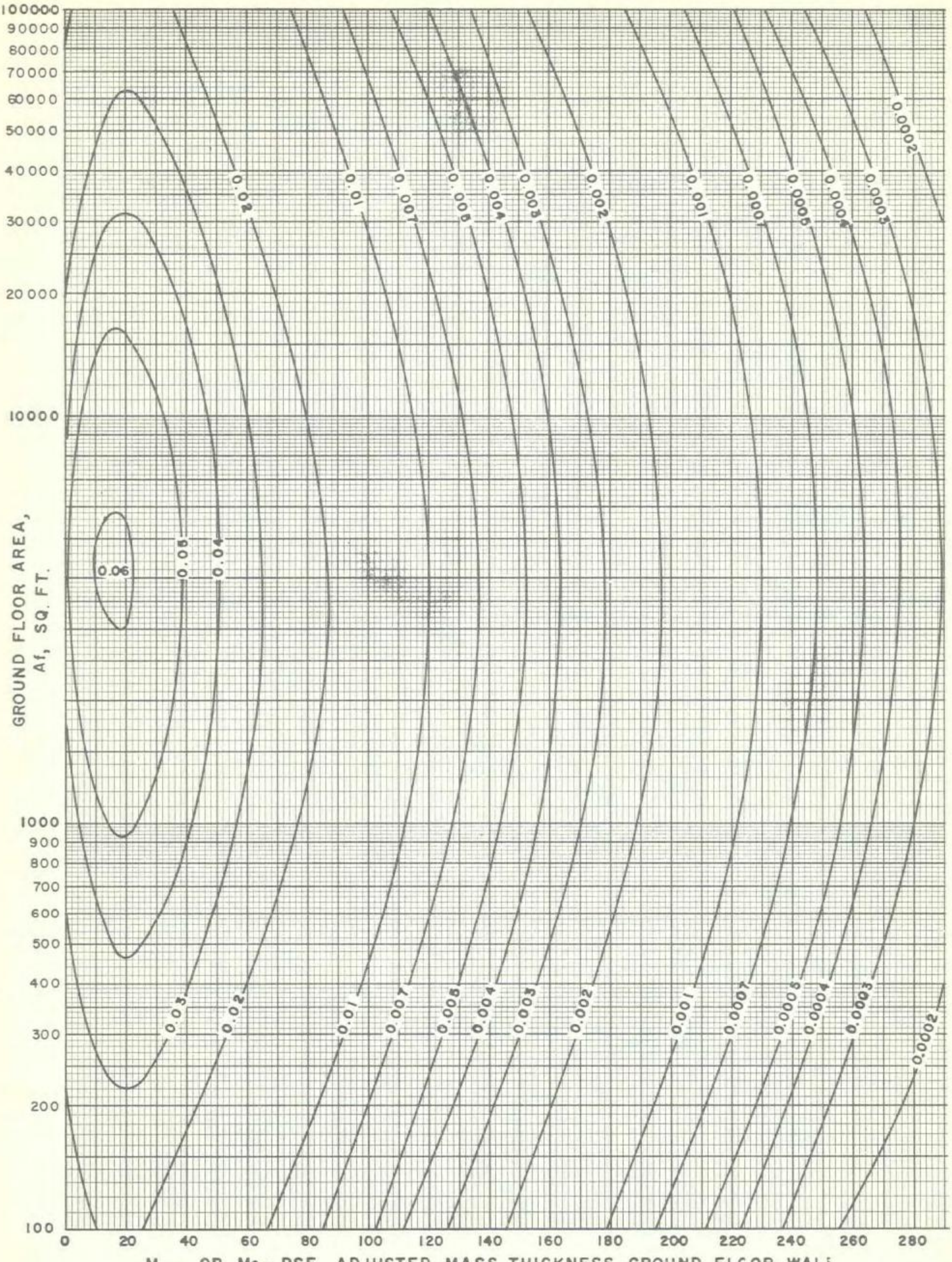


CHART 8 - SHIELDING EFFECTS OF HEIGHT

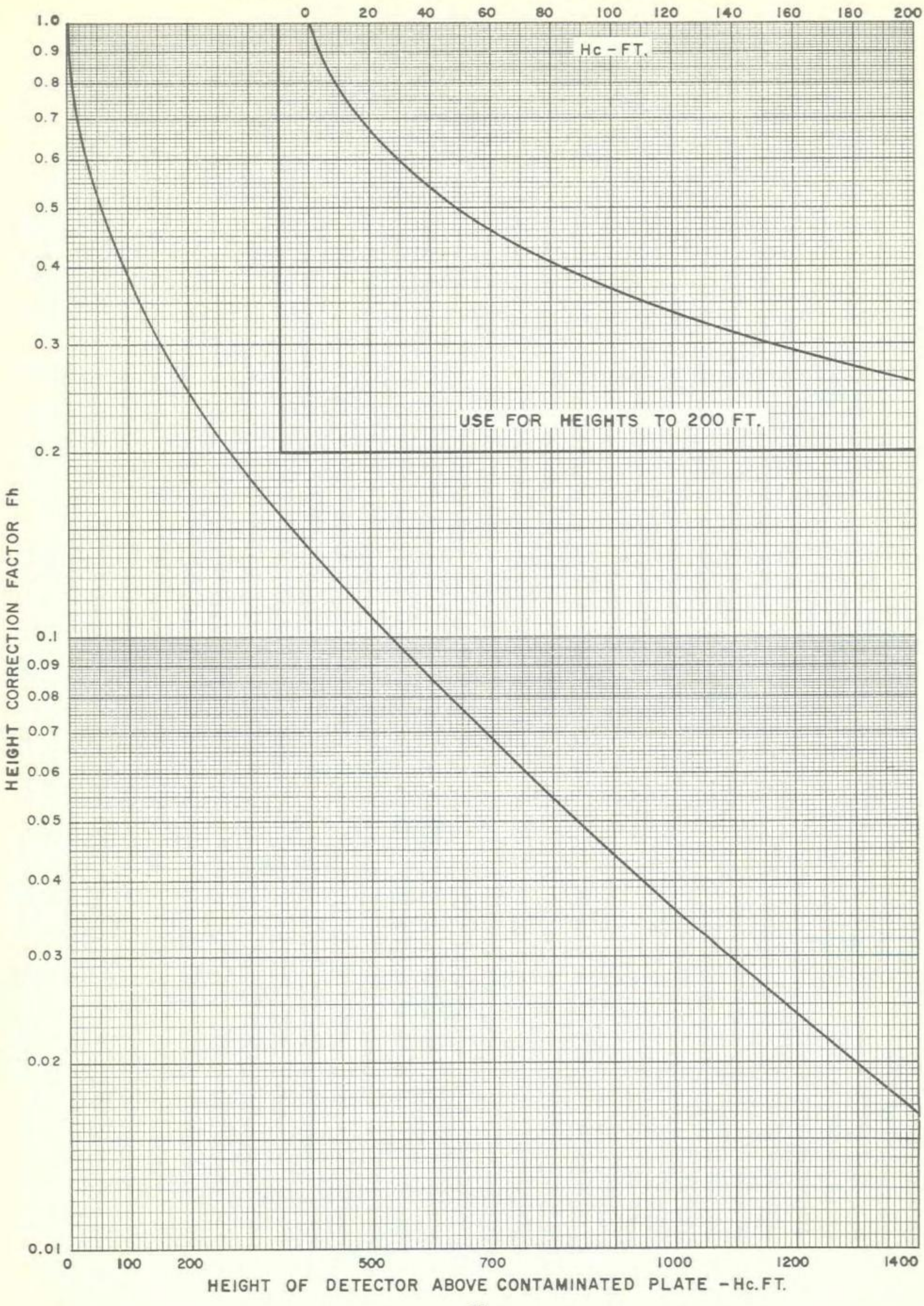


CHART 9 - CORRECTION FACTOR - MUTUAL SHIELDING

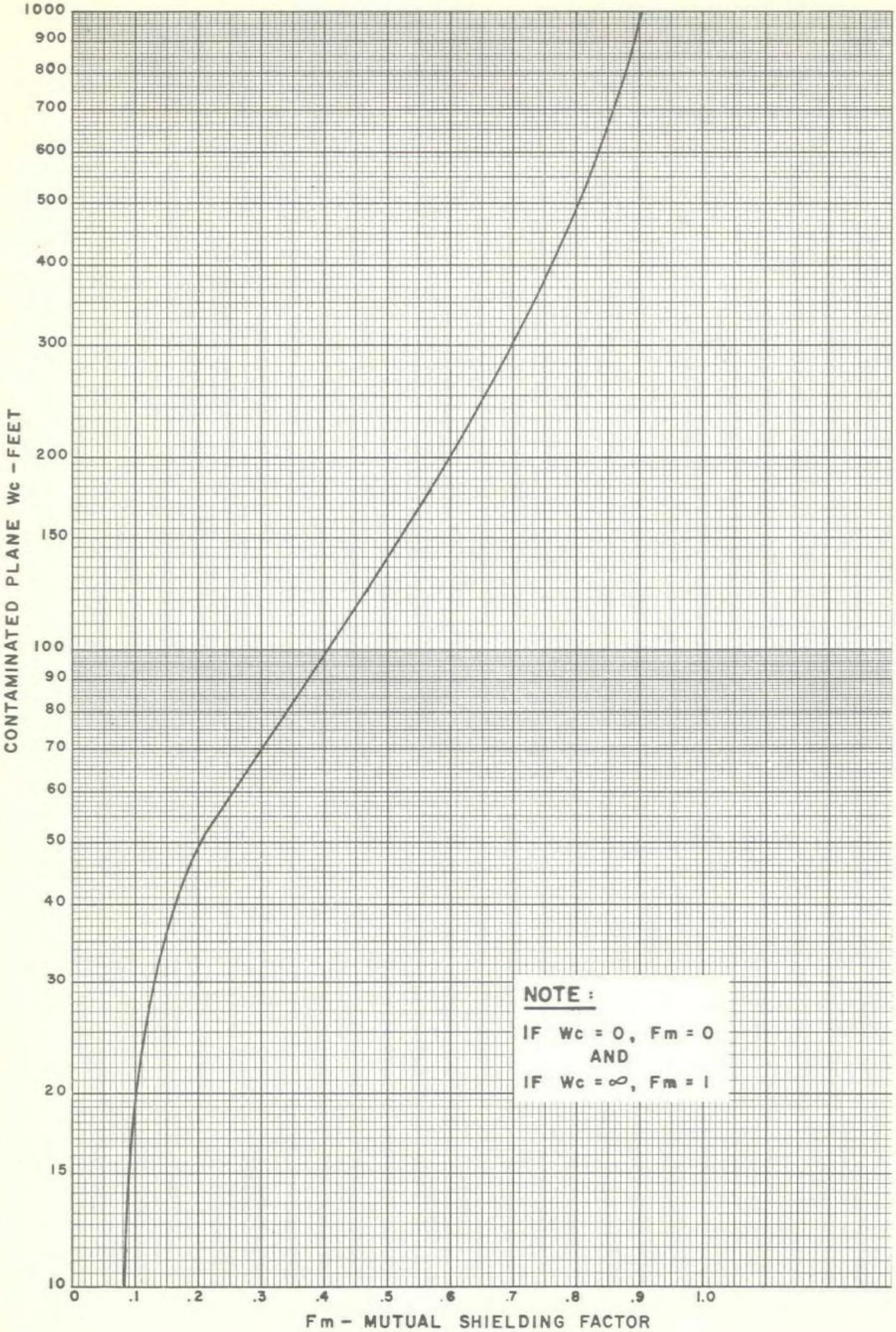
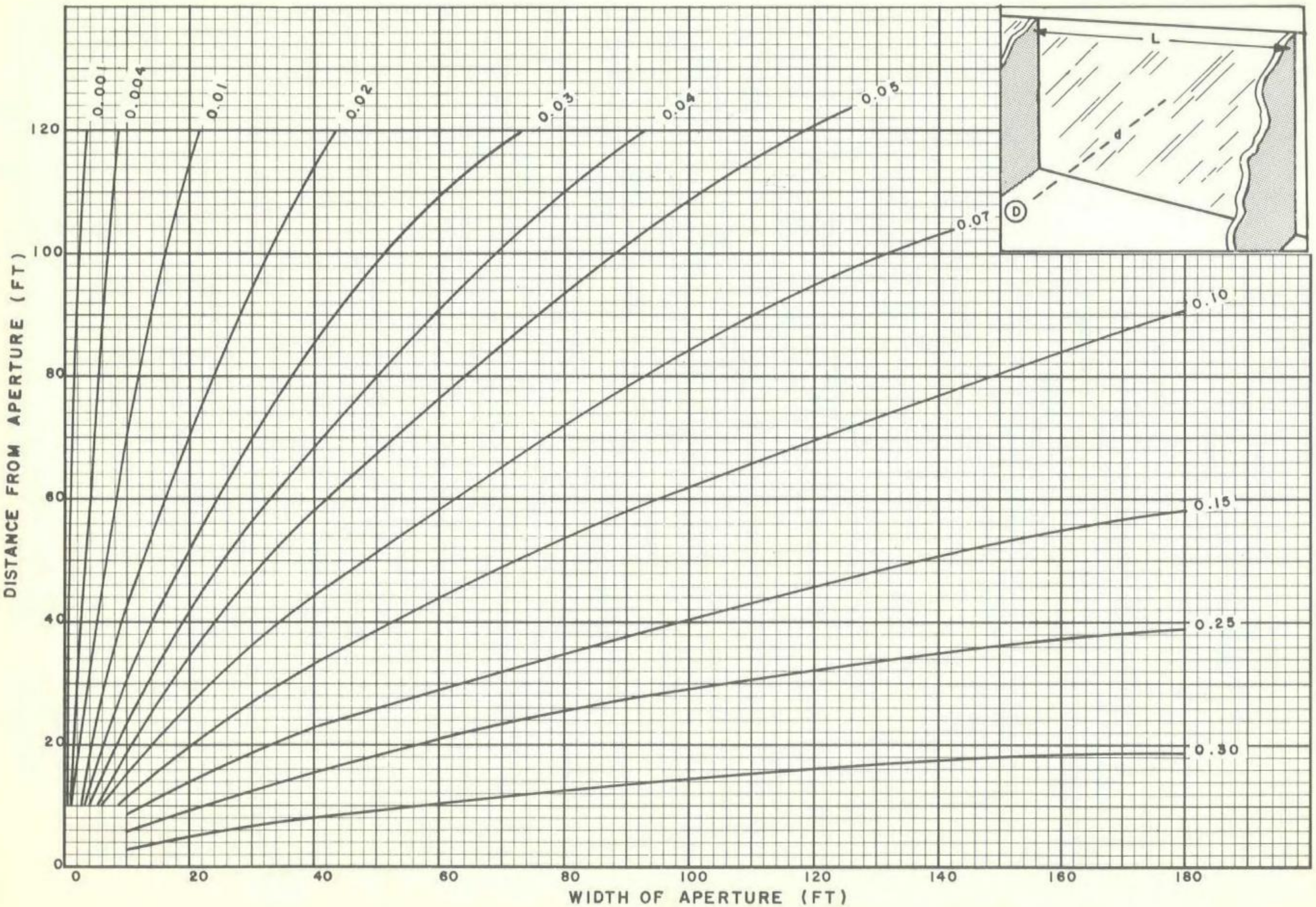


CHART 10 REDUCTION FACTORS FOR APERTURES - GROUND FLOOR



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Annex C

PRACTICAL SHIELDING PROBLEMS

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Annex C

PRACTICAL SHEILDING PROBLEMS

PROBLEM 1 In Figure 9(a) what will be the reduction factor if the roof has a mass thickness of 180 psf?

Solution – using Chart 1 Annex B

Reduction factor = <u>0.0029</u>

PROBLEM 2 In Figure 9(a) assume that the roof slab consists of 6 inches of reinforced concrete. What is the reduction factor?

Solution

From Annex A, mass thickness = $6 \times 12.5 = 75$ psf

Using Chart 1, Annex B,

Reduction factor = <u>0.038</u>

PROBLEM 3 Using Figure 9(b), assume that the roof area is 3600 sq. ft., mass thickness of roof is 150 psf, and detector is 20 ft. below roof. Calculate the reduction factor.

Solution

Adjusted Roof Area = $3600 \times \frac{(10)^2}{(20)} = 900$ sq. ft.

Using Chart 2, Annex B

Reduction factor = <u>0.005</u>

PROBLEM 4 Using Figure 9(b) calculate the reduction factor, if:–

A_r = 50,000 sq. ft.

M_r = 100 psf

H_r = 30 ft.

Solution

Adjusted roof area = $50{,}000 \times \frac{(10)^2}{(30)} = 5555$ sq. ft.

Using Chart 2,

Reduction factor = <u>0.02</u>

PROBLEM 5 Using Figure 9(b) calculate the reduction factor, assuming:–

A_r = 2030 sq. ft.

M_r = 30 psf

H_r = 13 ft.

Solution

Adjusted roof area = $2030 \times \frac{(10)^2}{(13)} = 1200$ sq. ft.

Using Chart 2,

Reduction factor = <u>0.10</u>

PROBLEM 6 Using Figure 10(a), calculate the reduction factor, assuming that the roof area is 6000 sq. ft., mass thickness of roof 60 psf, each floor 50 psf, interior partitions 15 psf, height of roof above detector 36 ft.

Solution

Total Overhead Mass Thickness = 60 + 50 + 50 = 160 psf

Mass Thickness, Interior Partitions = 15 psf (ignored)

Adjusted Roof Area = $6000 \times \frac{(10)^2}{(36)} = 463$ sq. ft.

Using Chart 2,

Reduction Factor = <u>0.0037</u>

PROBLEM 7 What is the reduction factor at the detector in Figure 10(b), assuming:—

A_r = 8500 sq. ft.
A_c = 2400 sq. ft.
M_r = 70 psf
M_f = 100 psf (all floors)
M_p = 120 psf
H_r = 40 ft.

Solution

Due to the mass thickness of the interior partitions ($M_p > 60$ psf) only the central roof area will contribute to the detector.

Adjusted Central Roof Area = $A_c' = 2400 \times \left(\frac{10}{40}\right)^2$

$= 150$ sq. ft.

Total Overhead Mass Thickness = $M_{to} = (70+100+100)$

$= 270$ psf.

Using Chart 2,

Reduction Factor = <u>0.00025</u>

PROBLEM 8 In a building similar to Figure 10(c) the total roof area is 12500 sq. ft. The roof consists of a 6 inch slab of reinforced stone concrete covered with built up roofing, i.e. five ply pitch and gravel. All floors are constructed of reinforced cinder concrete in 4 inch slabs. On the floors is a wearing surface of terrazo mosaic ¾ inches thick. All ceilings consist of suspended metal lath and plaster. Interior partitions are constructed of 8 inch structural clay tile, plastered on both sides. The area enclosed by the interior partitions is 5000 sq. ft. The vertical distance from the ground floor to the roof is 53 ft. Calculate the reduction factor for roof contribution, assuming the detector location to be as shown in Figure 10(c).

Solution

Step 1 – Calculate mass thicknesses

$M_r = (6 \times 12.5) + 7 + 10 = 90$ psf*
$M_f = (4 \times 9) + 9 + 10 = 55$ psf
$M_p = 32 + 5 + 5 = 40$ psf*
$M_{to} = M_r + 2\,M_f = 90 + 110 = 200$ psf

* figures rounded off

Step 2 – Calculate adjusted roof areas.

(a) $A_r' = A_r \times \left(\frac{10}{H_r}\right)^2$

$= 12500 \times \left(\frac{10}{53-3}\right)^2 = 500$ sq. ft.

(b) $A_c' = A_c \times \left(\frac{10}{H_r}\right)^2$

$= 5000 \times \left(\frac{10}{50}\right)^2 = 200$ sq. ft.

Step 3 – Calculate contribution from central roof area using Chart 2.

A_c' = 200 sq. ft. M_{to} = 200 psf

Reduction Factor = 0.0013

Step 4 – Calculate contribution from total roof area.

A_r' = 500 sq. ft. $M_{to} + M_p$ = 240 psf

Reduction Factor = 0.00066

Step 5 – Calculate contribution from central roof area.

A_c' = 200 sq. ft. $M_{to} + M_p$ = 240 psf

Reduction Factor = 0.00051

Step 6 – Subtract result Step 5 from Step 4.

0.00066 – 0.00051 = 0.00015

Step 7 – Add results, Steps 3 and 6.

0.0013 + 0.00015

Total reduction factor = 0.00145 (for roof contribution)

PROBLEM 9 Using data from Problem No. 5, recalculate the reduction factor, allowing for skyshine.

Solution

From Problem 5, reduction factor = 0.10

From Chart 3, skyshine factor = F_s = 1.107 (for 30 psf)

Corrected reduction factor = 0.10 × 1.107 = 0.11

PROBLEM 10 Recalculate Problem No. 7, taking skyshine into consideration.

Solution

From Problem 7, reduction factor = 0.00025

M_{to} = 270 psf

From Chart 3, F_s = 1.005

Corrected reduction factor = 0.00025 × 1.005 = 0.00025

N.B.: In other words, skyshine may be ignored for such large mass thicknesses.

PROBLEM 11 In Figure 11(a) what will be the reduction factor if the wall has a mass thickness of 140 psf?

Solution Using Chart 4,

Reduction Factor = 0.04

PROBLEM 12 In Figure 11(a), what will be the reduction factor if the wall consists of a steel plate 1" thick?

Solution

From Annex A, M_e = 40 psf

Using Chart 4,

Reduction Factor = 0.36

PROBLEM 13 Calculate the reduction factor for ground contribution, using Figure 11(b) with the following data:–

Floor Area = A_f = 3500 sq. ft.

M_e = 80 psf

Solution Using Chart 5,

Reduction Factor = 0.07

PROBLEM 14 A building similar to Figure 11(b) is 80' long, 50' wide and has exterior walls of 8" concrete block (hollow block, gravel concrete). Calculate the reduction factor.

Solution

From Annex A, M_e = 55 psf

Floor Area, A_f = 4000 sq. ft.

Using Chart 5,

Reduction Factor = 0.12

PROBLEM 15 Considering the building described in Problem 14, what is the reduction factor of each wall?

Solution

Width = 50' Length = 80' Perimeter = 260'

$\frac{B}{P} = \frac{50}{260} = 0.192$

$\frac{L}{P} = \frac{80}{260} = 0.308$

From Problem 14, total reduction factor = 0.12

Reduction factor for one wide wall = 0.12 × 0.308
= <u>0.037</u>

Reduction factor for one narrow wall = 0.12 × 0.192
= <u>0.023</u>

Note: (2 × 0.037) + (2 × 0.023) = 0.12

PROBLEM 16 Perform a wall-by-wall calculation to determine the total reduction factor for ground contribution for a building similar to Figure 12, having the following description:—

Length = L = 150'
Width = B = 50'
Mass thickness north wall = $M_e(N)$ = 100 psf
$M_e(W)$ = 20 psf
$M_e(S)$ = 80 psf
$M_e(E)$ = 50 psf

Solution (a) Area = 7500 sq. ft.

(b) Calculate perimeter ratios.

$\frac{B}{P} = \frac{50}{400} = 0.125 = F_p(E) = F_p(W)$

$\frac{L}{P} = \frac{150}{400} = 0.375 = F_p(N) = F_p(S)$

(c) North Wall.

Assuming $M_e(N)$ applies to entire building, using Chart 5, reduction factor = 0.033
$F_p(N)$ = 0.375 (7500 sq. ft. and 100 psf)
Wall contribution = 0.033 × 0.375
= <u>0.0124</u>

(d) West Wall.

Chart 5 (7500 sq. ft. and 20 psf) reduction factor = 0.22
$F_p(W)$ = 0.125
Wall contribution = 0.22 × 0.125
= <u>0.0275</u>

(e) South Wall.

Chart 5 (7500 sq. ft. and 80 psf) reduction factor = 0.052
Wall contribution = 0.052 × 0.375
= <u>0.0195</u>

(f) East Wall.

Chart 5 (7500 sq. ft. and 50 psf)
Reduction Factor = 0.11
Wall Contribution = 0.11 × 0.125 = <u>0.0138</u>

(g) Total Reduction Factor (for ground contribution)
= 0.0124 + 0.0275 + 0.0195 + 0.0138 = <u>0.073</u>

PROBLEM 17 In Figure 13(a) what will be the reduction factor if the ground floor slab has a mass thickness of 180 psf?

Solution

Using Chart 6 of Annex B

Reduction Factor = <u>0.00062</u>

PROBLEM 18 In Figure 13(a) assume that the floor consists of 6 inches of reinforced concrete. What is the reduction factor?

Solution

From Annex A, $M_f = 6 \times 12.5 = 75$ psf

Using Chart 6,

Reduction Factor = <u>0.032</u>

PROBLEM 19 A building similar to Figure 13(b) has a floor area of 4000 sq. ft. The exterior ground floor walls weigh 50 psf. What is the reduction factor at the detector in the basement?

Solution

Using Chart 7 (4000 sq. ft. and 50 psf)

Reduction Factor = <u>0.04</u>

PROBLEM 20 Calculate the reduction factor for ground contribution in the basement of a building similar to Figure 13(c), given the following data:–

Dimensions – 30' × 50'

Exterior Walls – 12" brick

Openings in Exterior Walls – 10%

Ground Floor – ¾" oak flooring on 1" spruce subfloor, carried by 2" × 10" spruce joists at 16" centers.

Solution

(a) Area of ground floor = 1500 sq. ft.

(b) $M_e = 12 \times 8 \times 0.9 = 86$ psf

(c) $M_f = 10$ psf (Annex A)

(d) Using Chart 7, (1500 sq. ft. and 86 psf)

Reduction Factor = 0.019

(e) Using Chart 6,

Reduction factor due to basement ceiling = 0.5

(f) Total Reduction Factor = 0.019×0.5

= <u>0.0095</u>

PROBLEM 21 Calculate the reduction factor for ground contribution in the basement of a building similar to Figure 13(d), given the following data:–

$A_f = A_b = 3000$ sq. ft.

$M_e = 60$ psf

$M_b = 125$ psf

$M_f = 15$ psf

25% of basement walls above grade.

Solution

Step 1 – Use Chart 5 to calculate reduction factor for basement walls.

$A_b = 3000$ sq. ft. $M_b = 125$ psf

Reduction Factor = 0.026

Step 2 – Correct factor calculated in Step 1 to account for percentage of basement walls above grade.

Corrected reduction factor = $0.026 \times 0.25 = 0.0065$

Step 3 – Use Chart 7 to calculate reduction factor for radiation coming through exterior ground floor walls.

$A_f = 3000$ sq. ft. $M_e = 60$ psf

Reduction Factor = 0.033

Step 4 – From Chart 6, obtain reduction factor due to attenuation by basement ceiling.

$M_f = 15$ psf

Reduction Factor = 0.40

Step 5 – Corrected reduction factor calculated in Step 3 to account for attenuation by basement ceiling.

Corrected factor = 0.033 × 0.4 = 0.0132

Step 6 – Add values, steps 2 and 5

Total reduction factor for ground contribution = 0.0065 + 0.0132
= <u>0.0197</u>

PROBLEM 22 A building similar to Figure 14(a) has a floor area of 10,000 sq. ft. Its exterior walls weigh 85 psf. Calculate reduction factors for ground contribution for the following detector positions:–

(a) Fourth floor – – – $H_c = 50$ ft.

(b) Second floor – – – $H_c = 19$ ft.

Solution (a)

Using Chart 5, considering detector on ground floor

Reduction factor = 0.040

From Chart 8 of Annex B, for $H_c = 50'$

Height Correction Factor – $F_h = 0.5$

Corrected reduction factor = 0.040 × 0.5
= <u>0.020</u>

Solution (b)

As for (a) reduction factor = 0.040 (before correction)

From Chart 8, for $H_c = 19'$

$F_h = 0.68$

Corrected reduction factor = 0.040 × 0.68
= <u>0.027</u>

PROBLEM 23 Refer to Figure 15. Detector is at center of ground floor. Calculate the reduction factor for ground contribution, given the following data:–

L = 125'

B = 64'

M_e (North Wall) = 140 psf

$M_e(E) = 120$ psf

$M_e(S) = M_e(W) = 40$ psf

W_c = width of contaminated plane

$W_c(N) = \infty$

$W_c(E) = 0$

$W_c(S) = 200'$

$W_c(W) = 100'$

Solution

(a) $A_f = 125 \times 64 = 8000$ sq. ft.

$$F_p(N) = F_p(S) = \frac{L}{P} = \frac{125}{378} = 0.331$$

$$F_p(E) = F_p(W) = \frac{B}{P} = \frac{64}{378} = 0.169$$

(b) *North Wall*

Using Chart 5 (8000 sq. ft. and 140 psf)

Reduction factor = 0.014

From Chart 9 of Annex B, if $W_c = \infty$

$F_m = 1$ (mutual shielding factor)

Ground Contribution = 0.014 × 1 × 0.331
= 0.0046

(c) *East Wall*

From Chart 9, if $W_c = 0$

$F_m = 0$

Ground Contribution = 0

(d) *South Wall*

Using Chart 5 (8000 sq. ft. and 40 psf)

Reduction factor = 0.14

From Chart 9, if $W_c = 200'$

$F_m = 0.6$

Ground Contribution = $0.14 \times 0.6 \times 0.331$

= 0.0278

(e) *West Wall*

Reduction Factor = 0.14 (as for south wall)

From Chart 9, if $W_c = 100'$

$F_m = 0.4$

Ground Contribution = $0.14 \times 0.4 \times 0.169$

= 0.0095

(f) Total reduction factor for ground contribution

= 0.0046 + 0 + 0.0278 + 0.0095

= <u>0.042</u>

PROBLEM 24 Consider a multistory building of construction similar to Figure 16(a). Calculate the total ground contribution on the fifth floor, given the following data:–

A_f = 5000 sq. ft.

M_f = 80 psf

M_e = 80 psf (solid portion)

M_e = 0 (glassed portion)

$A_p\%$ = 45%

H_c = 60 ft.

Solution

(a) Calculate ground contribution through apertures.

(i) Using Chart 5 (5000 sq. ft. and 0 psf)

Reduction factor = 0.40

(ii) Using Chart 8 ($H_c = 60'$)

$F_h = 0.46$

(iii) Using Figure 17 (floor no. 5, below sill, $M_f > 40$ psf)

$F_a = 0.2$

(iv) $A_p\% = 45\%$

(v) GC (Apertures) = $0.40 \times 0.46 \times 0.2 \times 0.45$

= 0.0166

(b) Calculate GC through solid wall

(i) Using Chart 5 (5000 sq. ft. and 80 psf)

Reduction factor – 0.060

(ii) As above, $F_h = 0.46$

(iii) Solid walls comprise (100–45) = 55% of area

(iv) GC (solid walls) = $0.060 \times 0.46 \times 0.55$

= 0.0152

(c) GC (total) = (a) + (b) = 0.0166 + 0.0152

= <u>0.032</u>

PROBLEM 25 Calculate the total ground contribution on the third floor of a building, given the following data:—

A_f = 2000 sq. ft.
M_f = 20 psf
M_e = 60 psf (solid portion)
M_e = 0 psf (glassed portion)
A_p% = 70%
H_c = 30 ft.
Detector is above sill.

Solution

(a) *GC (apertures)*

(i) From Chart 5,
Reduction factor = 0.51

(ii) From Chart 8,
F_h = 0.59

(iii) From Figure 17 (floor no. 3, above sill,
$M_f < 40$)
F_a = 1

(iv) Ap% = 70%

(v) GC (apertures) = 0.51 × 0.59 × 1 × 0.7
= 0.211

(b) GC (Solid Walls)

(i) From Chart 5,
Reduction factor = 0.14

(ii) As above, F_h = 0.59

(iii) Solid walls comprise 30% of wall area

(iv) GC (Solid Walls) = 0.14 × 0.59 × 0.3
= 0.025

(c) GC (total) = 0.211 + 0.025
= <u>0.236</u>

PROBLEM 26 Using Chart 10, calculate reduction factors for apertures on the ground floor for the following cases:

	Width of Opening	*Distance to Detector*
(a)	60 ft.	60 ft.
(b)	20 ft.	80 ft.
(c)	80 ft.	20 ft.

Solution

Reading Chart 10 directly

(a) Reduction factor = 0.069
(b) 0.017
(c) 0.24

PROBLEM 27 Calculate the protection factor for the basement of the COMMERCIAL STORES building, which is described in the sketch drawings on the following page.

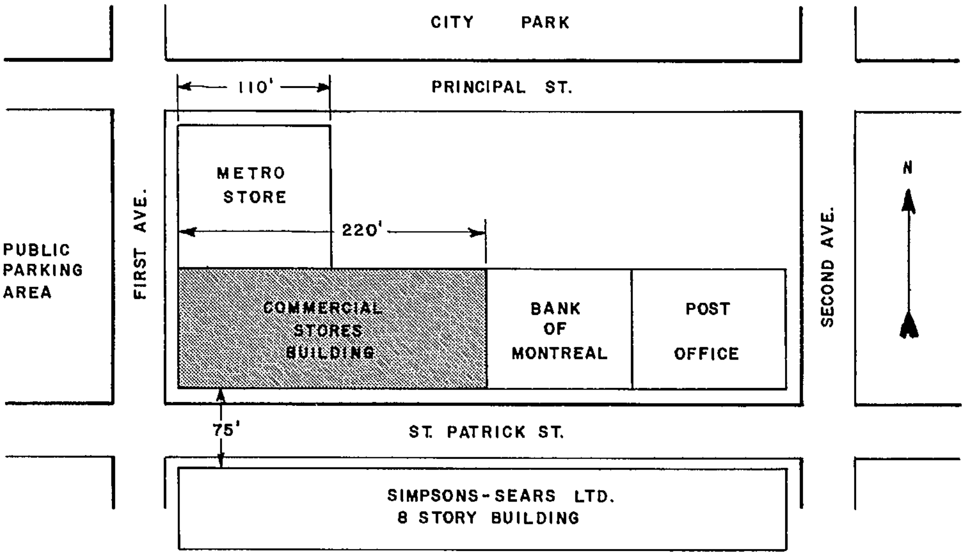
Solution

Step 1 — Assemble all data.

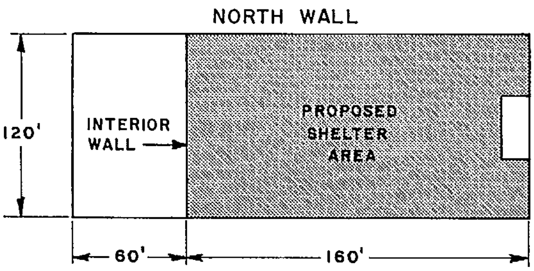
L = 220'
B = 120'
A_r = 26,400 sq. ft.
A_b = 19,200 sq. ft.
H_r = 68 ft.
M_r = (5 × 12.5) + 7 + 10 = 79 psf

COMMERCIAL STORES BUILDING

PROBLEM NO 27



SITE PLAN



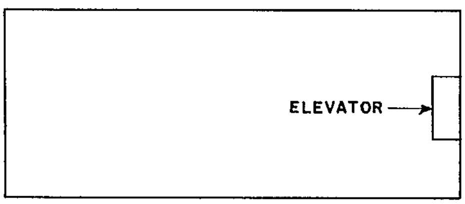
BASEMENT PLAN

EXTERIOR WALLS (BASEMENT)

NORTH, EAST - 18" STONE MASONRY
WEST, SOUTH - 12" CONCRETE

INTERIOR WALL (BASEMENT)

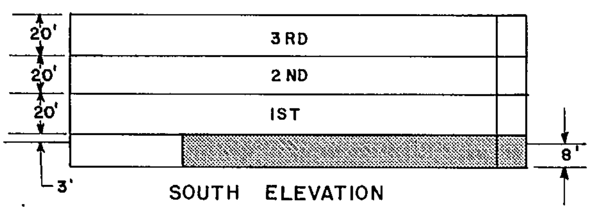
8" CINDER BLOCK



GROUND FLOOR PLAN

EXTERIOR WALLS

NORTH - 12" BRICK, 1" PLASTER (10 PSF)
EAST - 16" BRICK
WEST, SOUTH - 8" CONCRETE BLOCK STUCCO AND $\frac{5}{8}$" PLASTER (6 PSF)



SOUTH ELEVATION

ROOF

5" REINFORCED STONE CONCRETE, 5 PLY PITCH AND GRAVEL

ALL FLOORS

4" REINFORCED CINDER CONCRETE $\frac{3}{4}$" TERRAZO

CEILINGS

METAL LATH AND PLASTER

FLOOR OPENING - 10% FOR STAIRWELLS, ELEVATORS ETC.

WALL APERTURES - NORTH 5% EAST - NIL SOUTH AND WEST - 60%

BASEMENT - 40% WINDOWS IN EXPOSED PORTION OF SOUTH SIDE

M_f = 90% (to allow for floor openings)
of $(4 \times 9) + 9 + 10 = 50$ psf (all floors)
M_{to} = $(3 \times 50) + 79 = 229$ psf
M_e (N) = 0.95 (96 + 10) = 100 psf
M_e (E) = (16 × 8) = 128 psf
M_e (S) = 0.4 (55 + 5 + 6) = 26 psf
M_e (W) = 26 psf
M_b (N) = (18 × 10) = 180 psf
M_b (E) = 180 psf
M_b (S) = 0.6 (12 × 12) = 86 psf
M_b (W) = 144 psf
M_p (W) basement = 39 psf
M_b (W) (net) = 144 + 39 = 183 psf
W_c (N) = ∞ (for 110' of shelter wall)
W_c (N) = 0 (for 50' of shelter wall)
W_c (E) = 0
W_c (S) = 75'
W_c (W) = ∞
Portion of Basement Walls Above Grade =
$\frac{3}{11} = 0.273$

Step 2 – Calculate Perimeter Factors (based on shelter dimensions)
P = 2 (160 + 120) = 560'
F_p (N) = 110 ÷ 560 = 0.197 (for unshielded wall)
F_p (N) = 50 ÷ 560 = 0.089 (for shielded wall)
F_p (E) = 120 ÷ 560 = 0.214
F_p (S) = 160 ÷ 560 = 0.286
F_p (W) = 120 ÷ 560 = 0.214
Total = 1.000

Step 3 – Determine Mutual Shielding Factors (Chart 9)
F_m (N) = 1 (Unshielded Wall)
F_m (N) = 0 (completely shielded wall)
F_m (E) = 0
F_m (S) = 0.32
F_m (W) = 1

Step 4 – Calculate Roof Contribution
Adjusted Roof Area = 570 sq. ft. (from Chart 2A)
M_{to} = 229 psf
From Chart 2,
RC = 0.0009
From Chart 3,
F_s = 1.008 (negligible)
Corrected RC = 0.0009

Step 5 – Calculate ground contribution through basement ceiling.
(i) *Unshielded North Wall*
From Chart 7 (26,400 sq. ft. and 100 psf)
RF = 0.010
From Chart 6 (M_f = 50 psf)
RF = 0.090
F_p = 0.197 (Step 2)
F_m = 1 (Step 3)
GC (N) (unshielded wall)
= .01 × .09 × .197 × 1 = 0.00018

(ii) *Shielded North Wall*

As $F_m = 0$,

GC (N) (shielded wall) = 0

(iii) *East Wall*

As F_m (E) = 0,

GC (E) = 0

(iv) *South Wall*

From Chart 7 (26400 sq. ft. and 26 psf)

RF = 0.041

From Chart 6,

RF = 0.090

F_p (S) = 0.286

F_m (S) = 0.32

GC (S) = .041 × .09 × .286 × .32

= 0.00034

(v) *West Wall*

From Chart 7 (26400 sq. ft. and 26 psf)

RF = 0.041

From Chart 6,

RF = 0.090

F_p (W) = 0.214

F_m (W) = 1

GC (W) = .041 × .09 × .214 × 1 = 0.00079

(vi) Total, Step 5

= .00018 + .00034 + .00079

= 0.0013

Step 6 – Calculate GC through exposed basement walls.

(i) *Unshielded North Wall*

From Chart 5 (26400 sq. ft. and 180 psf)

RF = 0.0030

Applying corrections for F_m, F_p, and % exposed

GC (N) = 0.0030 × 1 × 0.197 × 0.273

= 0.00016

(ii) *Shielded North Wall and East Wall*

GC = 0

(iii) *South Wall*

From Chart 5 (26400 sq. ft. and 86 psf)

RF = 0.025

Applying corrections for F_m, F_p, and % exposed

GC (S) = 0.025 × 0.32 × 0.286 × 0.273

= 0.00062

(iv) *West Wall*

From Chart 5 (26400 sq. ft. and 183 psf)

RF = 0.0029

Applying corrections for F_m, F_p and % exposed

GC (W) = 0.0029 × 1 × 0.214 × 0.273

= 0.00017

(v) Total, Step 6

= .00016 + .00062 + .00017

= 0.00095

Step 7

Total Contribution

= Step 4 + Step 5 + Step 6

= 0.0032

$$\text{Protection Factor} = \frac{1}{0.0032} = 310$$

PROBLEM 28 Referring to Problem 27, how would the protection factor be affected if the basement windows in the south wall were closed up with 12" solid concrete blocks (stone concrete)?

Solution

(a) The change would come in Step 6 (iii) of the solution to Problem 27.

(b) Mass thickness of 12" stone concrete blocks (solid) is 144 psf.

(c) Calculate mass thickness for south basement wall (when blocks are in place)

M_b (S) = (12 × 12) = 144 psf

(d) From Chart 5 (26400 sq. ft. and 144 psf)

Reduction Factor = 0.0066

Apply corrections for F_p, F_m, % exposed

GC (S) (Basement Walls)

= 0.0066 × 0.286 × 0.32 × 0.273

= 0.00017

(e) Change in Reduction Factor

= 0.00062 − 0.00017

= 0.00045 (decrease)

Revised Total Reduction Factor

= 0.00315 − 0.00045 = 0.0027

(f) New Protection Factor

$$= \frac{1}{0.0027} = 370$$

N.B.: Blocking up of windows in the shelter proper should be regarded as mandatory. If this is not done, circumstances might arise whereby occupants could be exposed to direct radiation from the contaminated ground.

Annex D

DATA COLLECTION FORM

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Serial No. ________

FALLOUT SHELTER SURVEYS

DATA COLLECTION FORM

(1) Survey No. ____________ (2) Completed By ____________ (3) Date ____________

(4) Name and Address of Building ____________

(5) Type of Building ____________

(6) Owner ____________

(7) Description of Surroundings ____________

____

(8) Description of Structure
(a) Length ________ ft. (b) Width ________ ft. (c) Height ________ ft.
(d) No. of Stories ____________ (e) Height of Stories ____________
(f) Basement Dimensions ____________

	N.	E.	S.	W.
(g) Ground Floor Level, ft.				
(h) Basement Floor Level, ft.				
(j) % Basement Wall Exposed				
(k) Width of Contaminated Plane, ft.				

(9) Structural Information		% Openings
(a) Roof	____________	______
(b) Ground Floor	____________	______
(c) Second Floor	____________	______
(d) Third Floor	____________	______
(e) Other Floors	____________	______
(f) Exterior Wall (N)	____________	______
(g) " " (E)	____________	______
(h) " " (S)	____________	______
(j) " " (W)	____________	______
(k) Interior Partitions	____________	______
(l) Basement Wall (N)	____________	______
(m) " " (E)	____________	______
(n) " " (S)	____________	______
(o) " " (W)	____________	______

(10) Non-Structural Information
(a) Number of Occupants. Business Hours ____________ Other Times ____________
(b) Proposed Shelter Area ____________
(c) Net Area sq. ft. (d) Net Volume ____________ cu. ft.
(e) No. of Exits ____________ (f) Details of Exits ____________
(g) Ventilation ____________
(h) Power Supply ____________
(j) Panel Location ____________
(k) Illumination ____________
(l) Water Supply ____________
(m) Water Storage Capacity ____________
(n) Sanitation ____________

(11) Remarks ____________

____

INSTRUCTIONS FOR USE – DATA COLLECTION FORM

1. This number will be allotted by the co-ordinating authority.
2. Name of individual doing the actual survey.
3. Date of inspection.
4. For example, PARKDALE SCHOOL, Main St., Podunk.
5. Normal use, e.g. office building, garage, retail clothing store, etc.
6. This information will be of value if it is decided to develop the shelter.
7. General description of adjacent buildings and surrounding terrain.
8. (a) (b) (c) Average dimensions. If building has major irregularities in shape, draw sketch on reverse side.
8. (d) Above grade.
8. (e) If multistory, use (1) 15', (2) 12', all above 10', etc.
8. (f) Describe only if basement plan differs from ground floor plan.
8. (g) Above grade level.
8. (h) Below grade level.
8. (j) Percentage of basement wall that is above grade level.
8. (k) Distance from building wall to adjacent structure that provides radiation shielding.
9. (a) to (e) Describe the components found in a typical vertical section, and their dimensions. Openings include skylights, stairwells, etc.
9. (f) to (j) Describe a typical horizontal section and provide dimensions. Openings include windows, doors, etc.
9. (k) As for 9 (f). If interior partitions are apt to affect the shielding of the proposed shelter area, their locations should be shown in sketches on the reverse side of the form.
9. (1) to (o) As for 9 (f). Here the percentage of openings will apply only to the portion above grade.
10. (a) This information is required to determine who will use the shelter if it is developed.
10. (b) Describe the part of the building recommended for a fallout shelter, e.g. "east half of basement", "rooms 36 and 38 on the third floor", etc. Illustrate by sketch on reverse side if necessary.
10. (c) Exclude space taken by columns, closets, built in equipment, etc.
10. (d) Free air space.
10. (e) and (f) Mention any points that might affect the fill-rate.
10. (g) Describe any existing equipment or assess extent of natural ventilation.
10. (h) Indicate source, characteristics, installed capacity, standby equipment if any.
10. (j) Location of control panel with respect to proposed shelter.
10. (k) Existing intensity of illumination in proposed shelter, in foot-candles (at desk or table level).
10. (1) Indicate source, alternative supply if any, location of piping with respect to shelter area.
10. (m) Volume of tanks in which it would be feasible to store water.
10. (n) Information re sewage lines and drains, septic tank (if any), garbage disposal facilities.
11. Include any information not covered in the above.

Annex E

SHELTER ANALYSIS FORM

ANNEX "E"
EMO 17

Serial No. ______

FALLOUT SHELTER SURVEYS

SHELTER ANALYSIS – STANDARD FORM

PART I – PROTECTION FACTOR

(a) Summary of Data

1. Totsl Roof Area, Ar sq. ft.	
2. Height of Roof above Detector, Hr ft.	
3. Mass Thickness of Roof, Mr psf	
4. Mass Thickness, Basement Ceiling, Mf psf	
5. Total Overhead Mass Thickness, Mto psf	

	N.	E.	S.	W.
6. Height of Detector above Contaminated Plane, Hc ft. (Upper Story Shelters only)				
7. Mass Thickness Exterior Wslls, Me psf				
8. Mass Thicknsss, Interior Psrtitions, Mp psf				
9. Mass Thickness, Basement Walls, Mb psf				
10. Mass Thickness, Basement Partitions, Mp psf				
11. Perimeter Factor, Fp				
12. Width of Contaminated Plane, Wc ft.				
13. Mutual Shislding Factor, Fm, Chart 9 (12)				
14. % Openings, Exterior Wall ÷ 100				
15. % Basement Walls Above Grade ÷ 100				
16. % Openings, Exposed Basement Wall ÷ 100				
17. Totsl Mass Thickness, Exterior Walls Mtw = (7) plus (8) minus product (7) × (14)				
18. Adjusted Mass Thickness, Basement Walls Mb = (9) plus (10) minus product (9) × (16)				

(b) Roof Contribution

19. Adjusted Roof Area, $A'_r = \frac{(1) \times 100}{(2) \times (2)}$ sq. ft.	
20. Roof Contribution, Chart 2, (5) and (19)	
21. Skyshine Correction Factor, Fs, Chart 3 (5)	
22. Total Roof Contribution = (20) × (21)	

(c) Ground Contribution – Basement Shelters Only

	N.	E.	S.	W.
23. GC (Exterior Walls) Chart 7, (1) and (17)				
24. Attenuation of Basement Ceiling, Chart 6 and (4)				
25. Corrected GC (Exterior Walls) = (23) × (24) × (11) × (13)				
26. Total GC (Exterior Walls) = (25) N+E+S+W				
27. GC (Bassment Walls) Chart 5, (1) and (18)				
28. Corrected GC (Basement Walls) = (27) × (11) × (13) × (15)				
29. Total GC (Basement Walls) = (28) N+E+S+W				

(d) Ground Contribution
Ground Floor Shelters Only

	N.	E.	S.	W.
30. GC from Chart 5, (1) and (17)				
31. Corrected GC = (30) × (11) × (13)				
32. Total GC = (31) N+E+S+W				

(e) Ground Contribution
Upper Story Shelters Only

	N.	E.	S.	W.
33. GC from Chart 5, (1) and (17)				
34. Height Correction Factor, Fh, Chart 8 (6)				
35. Corrected GC = (33) × (34) × (11) × (13)				
36. Total GC = (35) N+E+S+W				

(f) Total Reduction Factor and Protection Factor

	R.F.	P.F.
37. Basement Shelter. Total Contribution = (22) + (26) + (29)		
38. Ground Floor Shelter. Total Contribution = (22) + (32)		
39. Upper Story Shelter. Total Contribution = (22) + (36)		

(g) Recommended Shielding Improvements

40. Roof Contribution (see 22) Work Proposed on Roof – Work Proposed on Floors – Revised Reduction Factor	
41. GC Exterior Walls (see 26, 32 or 36) Work Proposed on Walls – Work Proposed on Basament Ceiling – Revised Reduction Factor	
42. GC Basement Walls (see 29) Work Proposed on Walls Revised Reduction Factor	
43. Revised Total Contribution Basement Shelter (40) + (41) + (42)	
44. Revised Total Contribution Ground Floor or Upper Story Shelter (40) + (41)	
45. Revised Protection Factor	

PART II – ASSESSMENT OF HABITABILITY FACTORS

46. Capacity Limitations	(a) Area	(b) Volume	
47. Entrances and/or Exits			
48. Power Supply			
49. Ventilation			
50. Water Supply			
51. Sanitation			
52. Heating			
53. Recommended Maximum Capacity			
54. Remarks			

55. Completed By:

56. Appointment:

57. Date:

INSTRUCTIONS FOR USE – STANDARD ANALYSIS FORM

1	Normally L x B.
2	Detector position is normally taken at the centre of the shelter area, 3 ft. above the floor. Use average height if there is more than one roof level.
3, 4, 5	From information on Data Collection Form. Use average mass thicknesses.
6	The contaminated plane in this case is normally grade, but it may also be the roof of an adjacent building.
7 to 10	From Data Collection Form.
11	Calculated as L ÷ P or B ÷ P
12	As for 7.
13	Self-explanatory.
14 to 16	As for 7.
17 to 22	Self-explanatory.
23 to 29	Use only if the shelter area is in a basement.
30 to 32	Use for ground floor shelters only.
33 to 36	Use for upper story shelters only.
37 to 39	Self-explanatory.
40 to 42	Outline briefly the work proposed, and recalculate the reduction factor that would result if such work was done. Note that work on the ground floor slab (basement ceiling) affects both 40 and 41.
43 to 45	Self-explanatory.
46	Arrived at as follows: (a) net area ÷ 12 (b) free air space ÷ 80.
47	Note number of exits, width, requirement for baffling, access problems if any.
48 to 52	Describe briefly the existing facilities and outline work required to improve them or to provide additional or standby equipment.
53	Normally the lower of the two figures from para 46, often further reduced by limitations imposed by paras 47-52.
54	Include any pertinent information not covered above. May also be used for cost estimates.
55 to 57	Self-explanatory.

Annex F

EXAMPLE OF A SHELTER ANALYSIS

Serial No. F23

FALLOUT SHELTER SURVEYS

DATA COLLECTION FORM

(1) Survey No. 2 (2) Completed By J. Jones (3) Date 15 May 61

(4) Name and Address of Building BROWN'S DEPARTMENT STORE, Main St., Lardville

(5) Type of Building Retail Store

(6) Owner Mr. B. Brown, 16 Glenora Crescent, Lardville

(7) Description of Surroundings See attached sketch

(8) Description of Structure
(a) Length 100 ft. (b) Width 50 ft. (c) Height 36 ft.
(d) No. of Stories 3 (e) Height of Stories (1) 14' (2) and (3) 10'
(f) Basement Dimensions Full basement 5000 sq. ft. gross

	N.	E.	S.	W.
(g) Ground Floor Level, ft.	2	2	2	2
(h) Basement Floor Level, ft.	8	8	8	8
(j) % Basement Wall Exposed	20	20	20	20
(k) Width of Contaminated Plane, ft. (see sketch)	∞	80	100	∞

(9) Structural Information

		% Openings
(a) Roof	5 ply tar and gravel, 3" R.C., 3/4" plaster	10
(b) Ground Floor	3/4" terrazo, 4" R.C., 3/4" plaster	5
(c) Second Floor	as for (b)	5
(d) Third Floor	as for (b)	5
(e) Other Floors	Nil	
(f) Exterior Wall (N)	8" brick, stuccoed, 3/4" plaster inside	25
(g) " " (E)	as for (f)	20
(h) " " (S)	as for (f)	35
(j) " " (W)	as for (f)	20
(k) Interior Partitions	None affecting shelter	
(l) Basement Wall (N)	8" R.C., 3/4" plaster	0
(m) " " (E)	as for (l)	0
(n) " " (S)	as for (l)	0
(o) " " (W)	as for (l)	0

(10) Non-Structural Information
(a) Number of Occupants. Business Hours 120 Other Times 1 (watchman)
(b) Proposed Shelter Area Entire Basement Area
(c) Net Area 3000 sq. ft. (d) Net Volume 30000 cu. ft.
(e) No. of Exits 2 (f) Details of Exits 72" stairway at each end
(g) Ventilation 8 exhaust fans each 1/8 H.P. Total capacity 7200 cfm
(h) Power Supply Hydro - no standby
(j) Panel Location Near centre of basement
(k) Illumination 30 FC fluorescent lighting
(l) Water Supply Lardville P.U.C. 3" main 60 psi
(m) Water Storage Capacity 4000 gallons
(n) Sanitation 2 washrooms each with 2 basins and toilets

(11) Remarks Basement is used as a sales floor and available area is reduced by display counters. Boiler room contains 1000 gal. oil storage tank. Heated by hot water radiators. Boiler oil fired.

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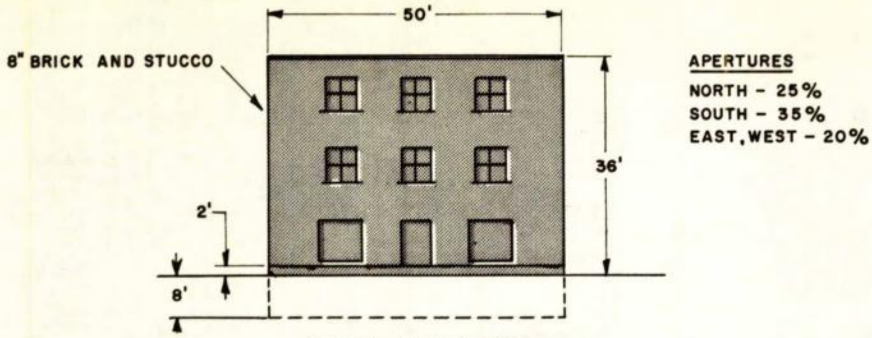
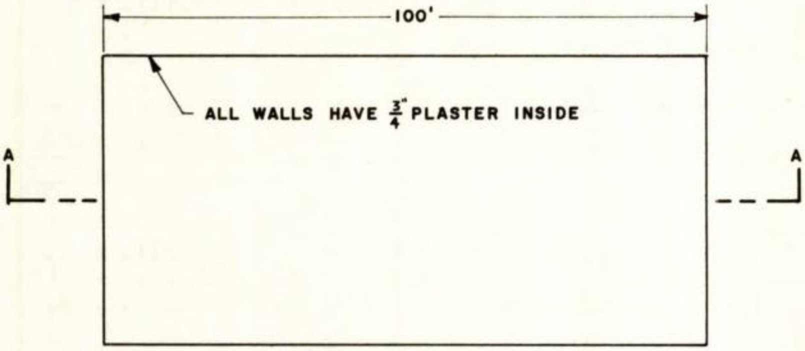
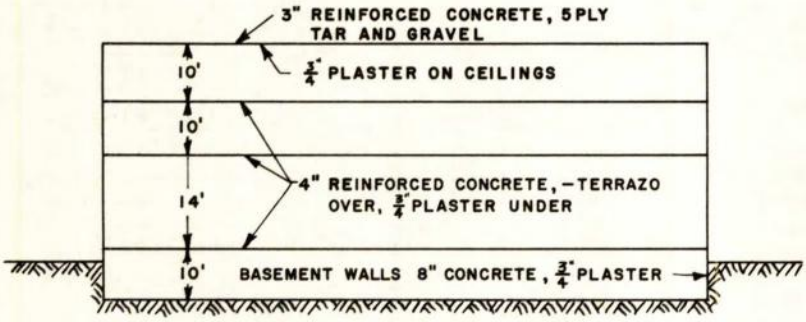
BROWN'S DEPARTMENT STORE



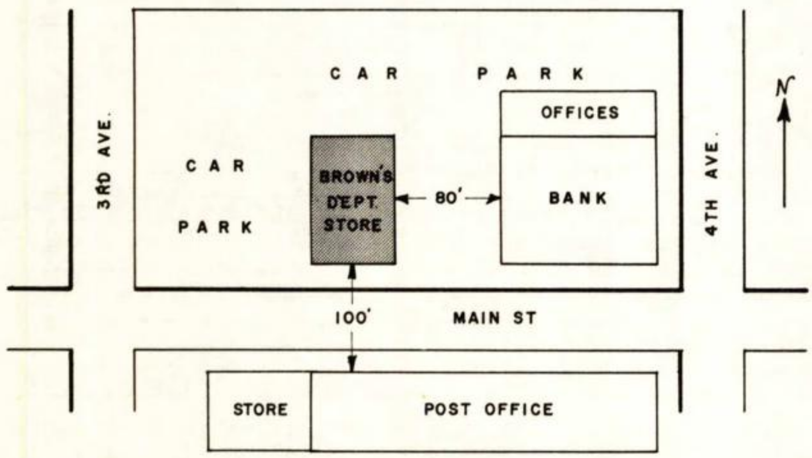
SOUTH ELEVATION



PLAN



SECTION AA



KEY PLAN

Serial No. F23

FALLOUT SHELTER SURVEYS

SHELTER ANALYSIS – STANDARD FORM

PART I – PROTECTION FACTOR

(a) Summary of Data

1. Total Roof Area, Ar sq. ft.	5000			
2. Height of Roof above Detector, Hr ft.	41			
3. Mass Thickness of Roof, Mr psf	45			
4. Mass Thickness, Basement Ceiling, Mf psf	62			
5. Total Overhead Mass Thickness, Mto psf	230			
	N.	E.	S.	W.
6. Height of Detector above Contaminated Plane, Hc ft. (Upper Story Shelters only)				
7. Mass Thickness Exterior Walls, Me psf	83	83	83	83
8. Mass Thickness, Interior Partitions, Mp psf				
9. Mass Thickness, Basement Walls, Mb psf	106	106	106	106
10. Mass Thickness, Basement Partitions, Mp psf				
11. Perimeter Factor, Fp	.167	.333	.167	.333
12. Width of Contaminated Plane, Wc ft.	∞	80	100	∞
13. Mutual Shielding Factor, Fm, Chart 9 (12)	1	.34	.40	1
14. % Openings, Exterior Wall ÷ 100	.25	.2	.35	.2
15. % Basement Walls Above Grade ÷ 100	.2	.2	.2	.2
16. % Openings, Exposed Basement Wall ÷ 100	0	0	0	0
17. Total Mass Thickness, Exterior Walls Mtw = (7) plus (8) minus product (7) × (14)	62	66	54	66
18. Adjusted Mass Thickness, Basement Walls Mb = (9) plus (10) minus product (9) × (16)	106	106	106	106

(b) Roof Contribution

19. Adjusted Roof Area, $A_r' = \frac{(1) \times 100}{(2) \times (2)}$ sq. ft.	300
20. Roof Contribution, Chart 2, (5) and (19)	.00074
21. Skyshine Correction Factor, Fs, Chart 3 (5)	1.008
22. Total Roof Contribution = (20) × (21)	.00075

(c) Ground Contribution – Basement Shelters Only

	N.	E.	S.	W.
23. GC (Exterior Walls) Chart 7, (1) and (17)	.032	.029	.038	.029
24. Attenuation of Basement Ceiling, Chart 6 and (4)	.055	.055	.055	.055
25. Corrected GC (Exterior Walls) = (23) × (24) × (11) × (13)	.00029	.00018	.00014	.00053
26. Total GC (Exterior Walls) = (25) N+E+S+W	.00114			
27. GC (Basement Walls) Chart 5, (1) and (18)	.034	.034	.034	.034
28. Corrected GC (Basement Walls) = (27) × (11) × (13) × (15)	.00113	.00077	.00045	.00226
29. Total GC (Basement Walls) = (28) N+E+S+W	.00461			

(d) Ground Contribution Ground Floor Shelters Only

	N.	E.	S.	W.
30. GC from Chart 5, (1) and (17)				
31. Corrected GC = (30) × (11) × (13)				
32. Total GC = (31) N+E+S+W				

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(e) Ground Contribution
Upper Story Shelters Only

	N.	E.	S.	W.
33. GC from Chart 5, (1) and (17)				
34. Height Correction Factor, Fh, Chart 8 (6)				
35. Corrected GC = (33) × (34) × (11) × (13)				
36. Total GC = (35) N+E+S+W				

(f) Total Reduction Factor and Protection Factor

	R.F.	P.F.
37. Basement Shelter. Total Contribution = (22) + (26) + (29)	.0065	150
38. Ground Floor Shelter. Total Contribution = (22) + (32)		
39. Upper Story Shelter. Total Contribution = (22) + (36)		

(g) Recommended Shielding Improvements

40. Roof Contribution (see 22) Work Proposed on Roof – Work Proposed on Floors – Nil Revised Reduction Factor	.00075
41. GC Exterior Walls (see 26, 32 or 36) Work Proposed on Walls – Work Proposed on Basement Ceiling – Nil Revised Reduction Factor	.00114
42. GC Basement Walls (see 29) Work Proposed on Walls Surround exposed basement walls with two courses sandbags (20 inches) Revised Reduction Factor	.00015
43. Revised Total Contribution Basement Shelter (40) + (41) + (42)	.00204
44. Revised Total Contribution Ground Floor or Upper Story Shelter (40) + (41)	
45. Revised Protection Factor	490

PART II – ASSESSMENT OF HABITABILITY FACTORS

46. Capacity Limitations	(a) Area 250 (b) Volume 375
47. Entrances and/or Exits	Satisfactory
48. Power Supply	Standby generator 5 KW 115/230 volt 60 cycle AC should be installed and wired in to panel
49. Ventilation	Existing fans adequate - can be driven by generator
50. Water Supply	Storage capacity is adequate for 285 people. Install check valve in delivery main.
51. Sanitation	Existing facilities will handle 280 people if water available. Recommend 4 chemical closets.
52. Heating	Recommend 4 oil fired space heaters each 60,000 BTU per hour. Oil storage facilities are adequate.
53. Recommended Maximum Capacity	250
54. Remarks	Estimated total cost of work recommended is $4000 or $16.00 per occupant.

55. Completed By: T. Square

56. Appointment: Assistant Town Engineer, Lardville

57. Date: 16 May 1961

Annex G

SHELTER ANALYSIS—SHORT FORM

Serial No. ______

FALLOUT SHELTER SURVEYS

SHELTER ANALYSIS – SHORT FORM

(a) Summary of Data

1. Total Roof Area, Ar sq. ft.	
2. Height of Roof above Detector, Hr ft.	
3. Mass Thickness, Basement Ceiling, Mf psf	
4. Total Overhead Mass Thickness, Mto psf	
5. Mass Thickness, Exterior Walls, Me psf	
6. % Openings Exterior Walls, Ap% ÷ 100	
7. Adjusted Me = (5) minus (5) × (6) psf	
8. Mass Thickness, Basement Walls, Mb psf	
9. % Basement Walls above Grade ÷ 100	
10. % Openings in Exposed Basement Wall ÷ 100	
11. Adjusted Mb = (8) minus (8) × (10) psf	

(b) Roof Contribution

12. Adjusted Roof Area = $A_r' = Ar \times \frac{100}{(Hr)^2}$ sq. ft.	
13. Roof Contribution, Chart 2, (4) and (12)	
14. Skyshine Correction Factor, Fs, Chart 3, and (4)	
15. Corrected Roof Contribution, RC = (13) × (14)	

(c) Ground Contribution
Basement Shelters Only

16. GC (Exterior Walls) Chart 7, (1) and (7)	
17. Attenuation, Basement Ceiling, Chart 6 and (3)	
18. Corrected GC (exterior walls) = (16) × (17)	
19. GC (Basement Walls) Chart 5, (1) and (11)	
20. Corrected GC (basement walls) = (19) × (9)	
21. Total GC = (18) plus (20)	

(d) Ground Contribution
Ground Floor Shelters Only

22. Total GC, Chart 5, (1) and (7)	

(e) Ground Contribution
Upper Story Shelters Only

23. Height of Detector Above Grade, Hc ft.	
24. Height Correction Factor, Fh, Chart 8, (23)	
25. GC, Chart 5, (1) and (7)	
26. Total GC = (25) × (24)	

(f) Protection Factor

BASEMENT SHELTER	27. Reduction Factor = (15) + (21)	
	28. Protection Factor = 1 ÷ (27)	
GROUND FLOOR SHELTER	29. Reduction Factor = (15) + (22)	
	30. Protection Factor = 1 ÷ (29)	
UPPER STORY SHELTER	31. Reduction Factor = (15 + (26)	
	32. Protection Factor = 1 ÷ (31)	

Annex H

EXAMPLE OF PROTECTIVE IMPROVEMENTS

Serial No. H-7

FALLOUT SHELTER SURVEYS

SHELTER ANALYSIS – STANDARD FORM

PART I – PROTECTION FACTOR

(a) Summary of Data

1. Total Roof Area, Ar sq. ft. 40' x 60'	2400			
2. Height of Roof above Detector, Hr ft.	40			
3. Mass Thickness of Roof, Mr psf	80			
4. Mass Thickness, Basement Ceiling, Mf psf	80			
5. Total Overhead Mass Thickness, Mto psf	240			
	N.	E.	S.	W.
6. Height of Detector above Contaminated Plane, Hc ft. (Upper Story Shelters only)				
7. Mass Thickness Exterior Walls, Me psf	120	120	120	120
8. Mass Thickness, Interior Partitions, Mp psf				
9. Mass Thickness, Basement Walls, Mb psf	150	150	150	150
10. Mass Thickness, Basement Partitions, Mp psf				
11. Perimeter Factor, Fp	.2	.3	.2	.3
12. Width of Contaminated Plane, Wc ft.	∞	0	∞	0
13. Mutual Shielding Factor, Fm, Chart 9 (12)	1		1	
14. % Openings, Exterior Wall ÷ 100	.6		.3	
15. % Basement Walls Above Grade ÷ 100	.2		.2	
16. % Openings, Exposed Basement Wall ÷ 100	.5		.3	
17. Total Mass Thickness, Exterior Walls Mtw = (7) plus (8) minus product (7) × (14)	48		84	
18. Adjusted Mass Thickness, Basement Walls Mb = (9) plus (10) minus product (9) × (16)	75		105	

(b) Roof Contribution

19. Adjusted Roof Area, $A'_r = \frac{(1) \times 100}{(2) \times (2)}$ sq. ft.	150
20. Roof Contribution, Chart 2, (5) and (19)	.00047
21. Skyshine Correction Factor, Fs, Chart 3 (5)	1.0007
22. Total Roof Contribution = (20) × (21)	.00047

(c) Ground Contribution – Basement Shelters Only

	N.	E.	S.	W.
23. GC (Exterior Walls) Chart 7, (1) and (17)	.041		.021	
24. Attenuation of Basement Ceiling, Chart 6 and (4)	.027		.027	
25. Corrected GC (Exterior Walls) = (23) × (24) × (11) × (13)	.00022		.00011	
26. Total GC (Exterior Walls) = (25) N+E+S+W	.00033			
27. GC (Basement Walls) Chart 5, (1) and (18)	.09		.046	
28. Corrected GC (Basement Walls) = (27) × (11) × (13) × (15)	.0036		.0018	
29. Total GC (Basement Walls) = (28) N+E+S+W	.0054			

(d) Ground Contribution
Ground Floor Shelters Only

	N.	E.	S.	W.
30. GC from Chart 5, (1) and (17)				
31. Corrected GC = (30) × (11) × (13)				
32. Total GC = (31) N+E+S+W				

(e) Ground Contribution
Upper Story Shelters Only

	N.	E.	S.	W.
33. GC from Chart 5, (1) and (17)				
34. Height Correction Factor, Fh, Chart 8 (6)				
35. Corrected GC = (33) × (34) × (11) × (13)				
36. Total GC = (35) N+E+S+W				

(f) Total Reduction Factor and Protection Factor

	R.F.	P.F.
37. Basement Shelter, Total Contribution = (22) + (26) + (29)	.0062	160
38. Ground Floor Shelter, Total Contribution = (22) + (32)		
39. Upper Story Shelter, Total Contribution = (22) + (36)		

(g) Recommended Shielding Improvements

40. Roof Contribution (see 22) Work Proposed on Roof – Work Proposed on Floors – Nil Revised Reduction Factor	0.00047
41. GC Exterior Walls (see 26, 32 or 36) Work Proposed on Walls – Work Proposed on Basement Ceiling – Nil Revised Reduction Factor	0.00033
42. GC Basement Walls (see 29) (North and South walls only) Work Proposed on Walls Close up all openings with 12" solid concrete blocks. Thicken portion of wall above grade by adding layer of 8" solid concrete blocks Revised Reduction Factor	0.00020
43. Revised Total Contribution Basement Shelter (40) + (41) + (42)	0.0010
44. Revised Total Contribution Ground Floor or Upper Story Shelter (40) + (41)	
45. Revised Protection Factor	1000

PART II – ASSESSMENT OF HABITABILITY FACTORS

46. Capacity Limitations	(a) Area	(b) Volume
47. Entrances and/or Exits		
48. Power Supply		
49. Ventilation		
50. Water Supply		
51. Sanitation		
52. Heating		
53. Recommended Maximum Capacity		
54. Remarks		

55. Completed By:

56. Appointment:

57. Date:

Annex I

EXAMPLE OF ELEMENTARY DESIGN

Annex I

EXAMPLE OF ELEMENTARY DESIGN

PROBLEM

A one-story building, with full basement is to be designed as a restaurant, to the dimensions shown in the outline drawing at Appendix 1. The design is to be such that the basement will have a dual purpose, i.e. cafeteria or fallout shelter.

(a) Specify roof, floor and wall design required to provide a protection factor of 100.

(b) Ditto, for a protection factor of 500.

(c) What other factors should be considered to ensure that the basement will be suitable as a fallout shelter?

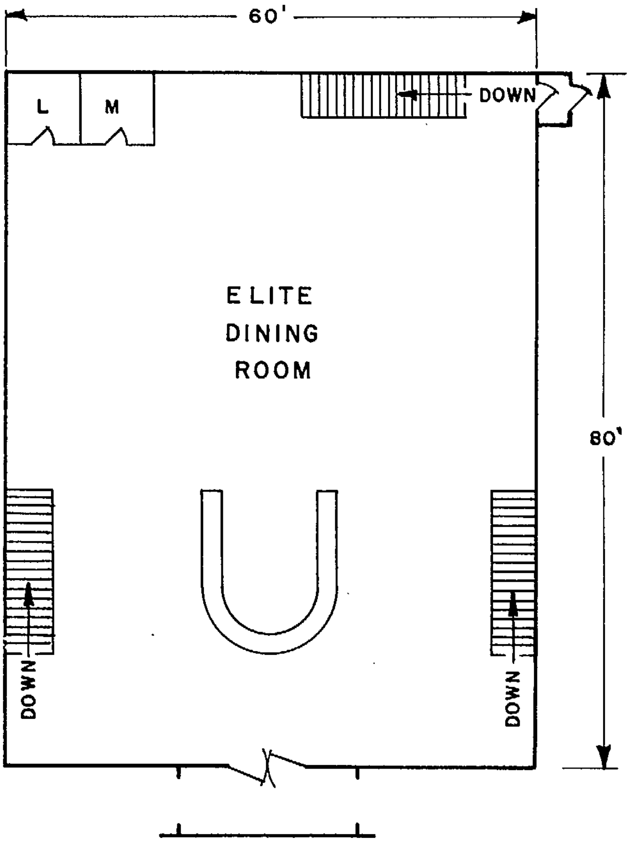
SOLUTION

(a) See Appendix 2

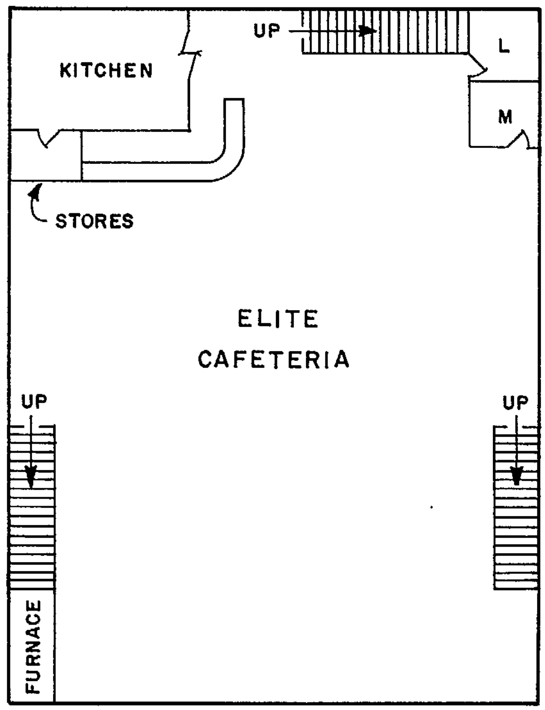
(b) See Appendix 3

(c) See Appendix 4

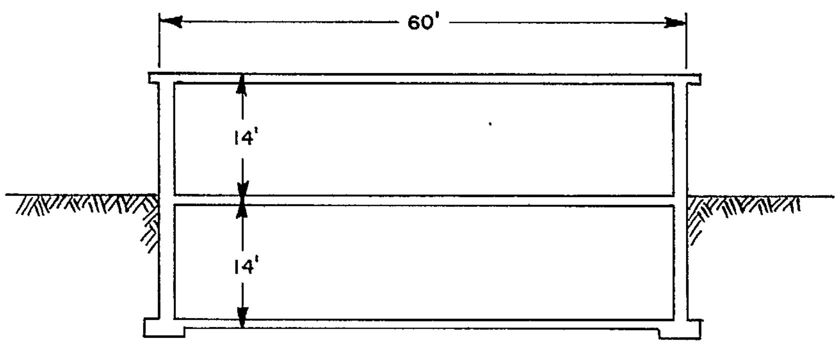
OUTLINE DRAWING – ELITE RESTAURANT



GROUND FLOOR PLAN



BASEMENT PLAN



SECTION

98751—9

FALLOUT SHELTER SURVEYS

SHELTER ANALYSIS – SHORT FORM

Design Calculations - Protection Factor of 100

(a) Summary of Data

1. Total Roof Area, Ar sq. ft.	4800
2. Height of Roof above Detector, Hr ft.	25
3. Mass Thickness, Basement Ceiling, Mf psf *	82
4. Total Overhead Mass Thickness, Mto psf **	127
5. Mass Thickness, Exterior Walls, Me psf ***	65
6. % Openings Exterior Walls, Ap% ÷ 100 Assume 40% apertures	.4
7. Adjusted Me = (5) minus (5) × (6) psf	39
8. Mass Thickness, Basement Walls, Mb psf 10" reinforced concrete	125) No
9. % Basement Walls above Grade ÷ 100	0) shielding
10. % Openings in Exposed Basement Wall ÷ 100	0) implications
11. Adjusted Mb = (8) minus (8) × (10) psf	125)

* 5" Reinforced Concrete, 3/4" terrazo over, plaster ceiling on suspended metal lath.

(b) Roof Contribution

12. Adjusted Roof Area = $A_r' = Ar \times \frac{100}{(Hr)^2}$ sq. ft.	768
13. Roof Contribution, Chart 2, (4) and (12)	.0085
14. Skyshine Correction Factor, Fs, Chart 3, and (4)	1.026
15. Corrected Roof Contribution, RC = (13) × (14)	.0087

** Roof = 127 - 82 = 45 psf. Use 3" reinforced concrete, 5 ply built-up roof, suspended ceiling of acoustic tile.

(c) Ground Contribution
Basement Shelters Only

16. GC (Exterior Walls) Chart 7, (1) and (7)	.050
17. Attenuation, Basement Ceiling, Chart 6 and (3)	.026
18. Corrected GC (exterior walls) = (16) × (17)	.0013
19. GC (Basement Walls) Chart 5, (1) and (11)	--
20. Corrected GC (basement walls) = (19) × (9)	nil
21. Total GC = (18) plus (20)	.0013

*** Exterior Walls - 8" hollow concrete block, stucco outside, ½" plaster inside.

(d) Ground Contribution
Ground Floor Shelters Only

22. Total GC, Chart 5, (1) and (7)	

(e) Ground Contribution
Upper Story Shelters Only

23. Height of Detector Above Grade, Hc ft.	
24. Height Correction Factor, Fh, Chart 8, (23)	
25. GC, Chart 5, (1) and (7)	
26. Total GC = (25) × (24)	

(f) Protection Factor

BASEMENT SHELTER	27. Reduction Factor = (15) + (21)	.01
	28. Protection Factor = 1 ÷ (27)	100
GROUND FLOOR SHELTER	29. Reduction Factor = (15) + (22)	
	30. Protection Factor = 1 ÷ (29)	
UPPER STORY SHELTER	31. Reduction Factor = (15 + (26)	
	32. Protection Factor = 1 ÷ (31)	

98751—9½

FALLOUT SHELTER SURVEYS

SHELTER ANALYSIS – SHORT FORM

Design Calculations - Protection Factor of 500

(a) Summary of Data

1. Total Roof Area, Ar sq. ft.	4800
2. Height of Roof above Detector, Hr ft.	25
3. Mass Thickness, Basement Ceiling, Mf psf *	131
4. Total Overhead Mass Thickness, Mto psf **	204
5. Mass Thickness, Exterior Walls, Me psf ***	65
6. % Openings Exterior Walls, Ap% ÷ 100 Assume 40% apertures	.4
7. Adjusted Me = (5) minus (5) × (6) psf	39
8. Mass Thickness, Basement Walls, Mb psf 12" reinforced concrete	150) No
9. % Basement Walls above Grade ÷ 100	0) shielding
10. % Openings in Exposed Basement Wall ÷ 100	0) implications
11. Adjusted Mb = (8) minus (8) × (10) psf	150)

* 9" Reinforced concrete, 3/4" terrazo over, plaster ceiling on suspended metal lath

(b) Roof Contribution

12. Adjusted Roof Area = $A_r' = Ar \times \frac{100}{(Hr)^2}$ sq. ft.	768
13. Roof Contribution, Chart 2, (4) and (12)	.0016
14. Skyshine Correction Factor, Fa, Chart 3, and (4)	1.01
15. Corrected Roof Contribution, RC = (13) × (14)	.00162

** Roof = 204 - 131 = 73 psf. Use 4½" reinforced concrete, 5 ply built-up roofing, plaster ceiling on suspended metal lath.

(c) Ground Contribution
Basement Shelters Only

16. GC (Exterior Walls) Chart 7, (1) and (7)	.050
17. Attenuation, Basement Ceiling, Chart 6 and (3)	.004
18. Corrected GC (exterior walls) = (16) × (17)	.00020
19. GC (Basement Walls) Chart 5, (1) and (11)	--
20. Corrected GC (basement walls) = (19) × (9)	nil
21. Total GC = (18) plus (20)	.00020

*** Exterior Walls - 8" hollow concrete block, stucco outside, ½" plaster inside.

(d) Ground Contribution
Ground Floor Shelters Only

22. Total GC, Chart 5, (1) and (7)	

(e) Ground Contribution
Upper Story Shelters Only

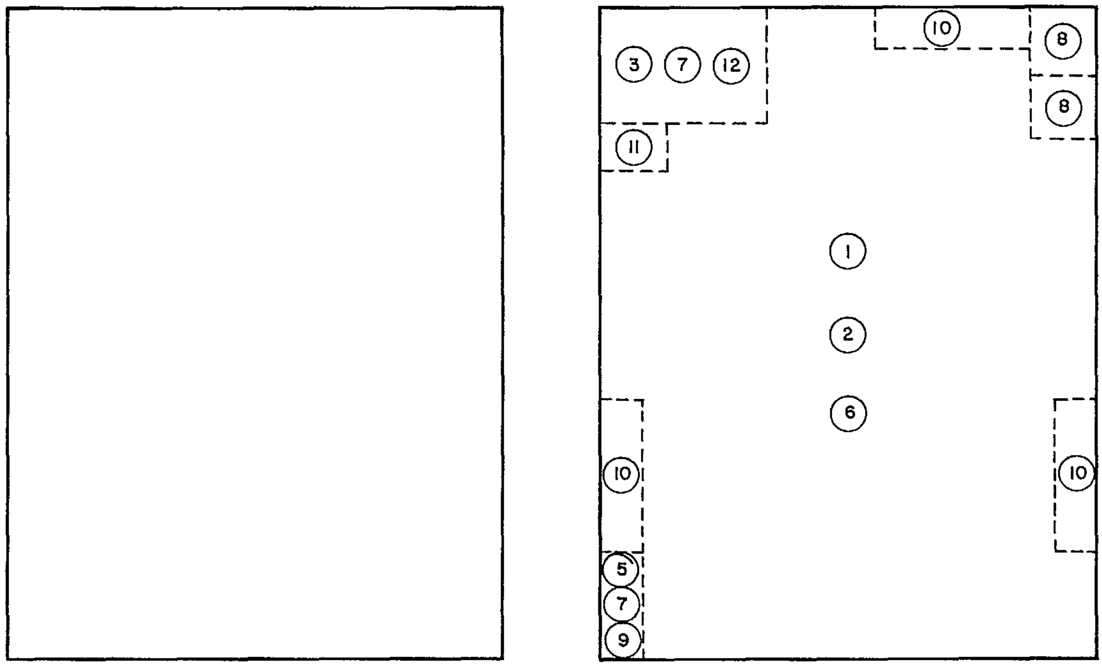
23. Height of Detector Above Grade, Hc ft.	
24. Height Correction Factor, Fh, Chart 8, (23)	
25. GC, Chart 5, (1) and (7)	
26. Total GC = (25) × (24)	

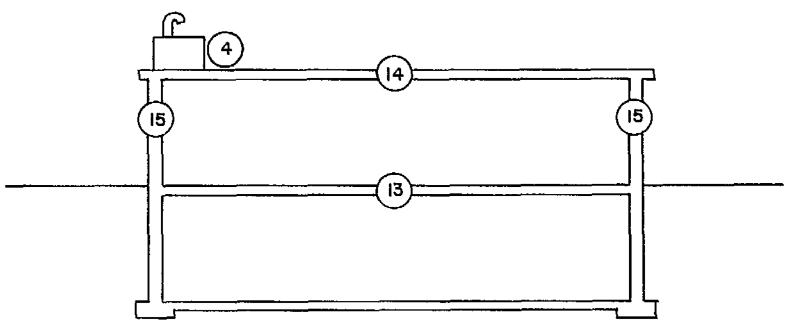
(f) Protection Factor

BASEMENT SHELTER	27. Reduction Factor = (15) + (21)	.00182
	28. Protection Factor = 1 ÷ (27)	550
GROUND FLOOR SHELTER	29. Reduction Factor = (15) + (22)	
	30. Protection Factor = 1 ÷ (29)	
UPPER STORY SHELTER	31. Reduction Factor = (15 + (26)	
	32. Protection Factor = 1 ÷ (31)	

Note: As the ground floor slab is so massive, the exterior wall construction is of little consequence. Roof contribution is far more important in this example.

GENERAL DESIGN FACTORS - ELITE RESTAURANT





LEGEND ON NEXT PAGE

GENERAL DESIGN FACTORS – ELITE RESTAURANT BASEMENT TO BE PREPARED AS A GROUP "B" SHELTER

(1) Net area of basement exceeds 3000 sq. ft. – sufficient shelter space for 250 people or more.
(2) Free air space well above minimum requirement.
(3) Normal ventilation system will be more than adequate.
(4) Air intake should be protected. Filter room should be well shielded from roof.
(5) Standby diesel generator (5 to 10 KW) should be wired to main electrical service.
(6) Adequate illumination, using only a portion of the lighting circuits.
(7) Total water storage facilities should handle 3500 gallons.
(8) Minimum of four toilets required.
(9) Normal heating system more than adequate. Fuel for 14 days to be stored on site.
(10) Ample exits.
(11) Normal food storage facilities adequate.
(12) Only part of kitchen equipment would be used for shelter occupants.
(13) (14) Design in accordance with Appendix 2.
(15) Wall design, including percentage of windows, is quite flexible.

Annex J

HYPOTHETICAL SHELTER SURVEY REPORT

Annex J

HYPOTHETICAL SHELTER SURVEY REPORT

City of Brightville

Appendix 1 – Map of City, Showing Ward Boundaries

Appendix 2 – Statistics, City of Brightville

Appendix 3 – List of Potential Public Shelters

Appendix 4 – Location Plan, Public Shelters

Appendix 5 – Summary of Cost, Fallout Protection

Appendix 6 – Fallout Shelter Situation Report

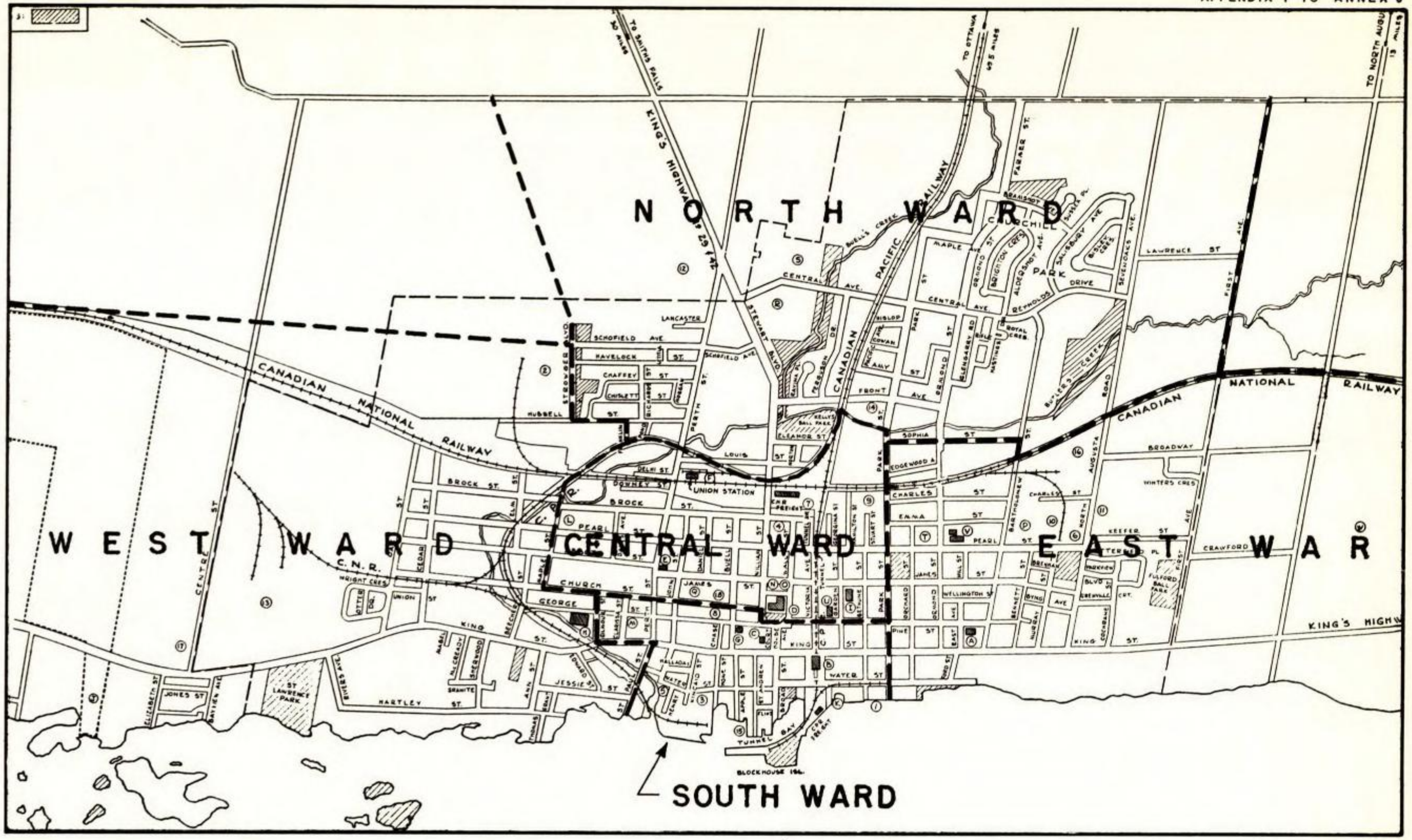
Appendix 7 – Recommendations re Construction

Survey Commenced – 16 Jan 61
Survey Completed – 21 Jan 61
Man-Hours, professional – 192
technical – 480
clerical – 240

Submitted by: R.S.J. Steel
Appointment: Assistant City Engineer
Date: 24 Jan 61

BRIGHTVILLE

APPENDIX I TO ANNEX J



APPENDIX 1
to
ANNEX "J"

STATISTICS – CITY OF BRIGHTVILLE

1. Population – 26,513 (census 1960)

	Average Population Distribution	
	By Night	By Day
North Ward	4720	3550
East Ward	4280	3050
South Ward	5870	8800
West Ward	3110	2300
Central Ward	8520	11100
	26500*	28800

* This figure also approximates the Sunday population.

2. Average Family

4.2 persons.

3. Buildings – (total 4,165)

	Miscellaneous Structures	Total Houses	Houses with Basements	Basementless Houses with Backyards
North Ward	43	835	763	52
East Ward	49	783	675	84
South Ward	123	624	401	73
West Ward	35	598	540	23
Central Ward	146	929	665	164
Total	396	3769	3044	396

4. Critical Structures

North Ward 1.– 1. Powerhouse. Coal fired. Six men on shift at all times

East Ward – 2. Sewage Disposal Plant. Three men on each shift.
3. Broadcasting Station. Three men per shift.

West Ward – 4. Waterworks. Seven men per shift.
5. Hospital. 200 beds and 2 operating rooms.

Central Ward – 6. City Telephone Exchange (automatic). Minimum staff of 3 required to operate.

APPENDIX 3
to
ANNEX "J"

LIST OF POTENTIAL PUBLIC FALLOUT SHELTERS

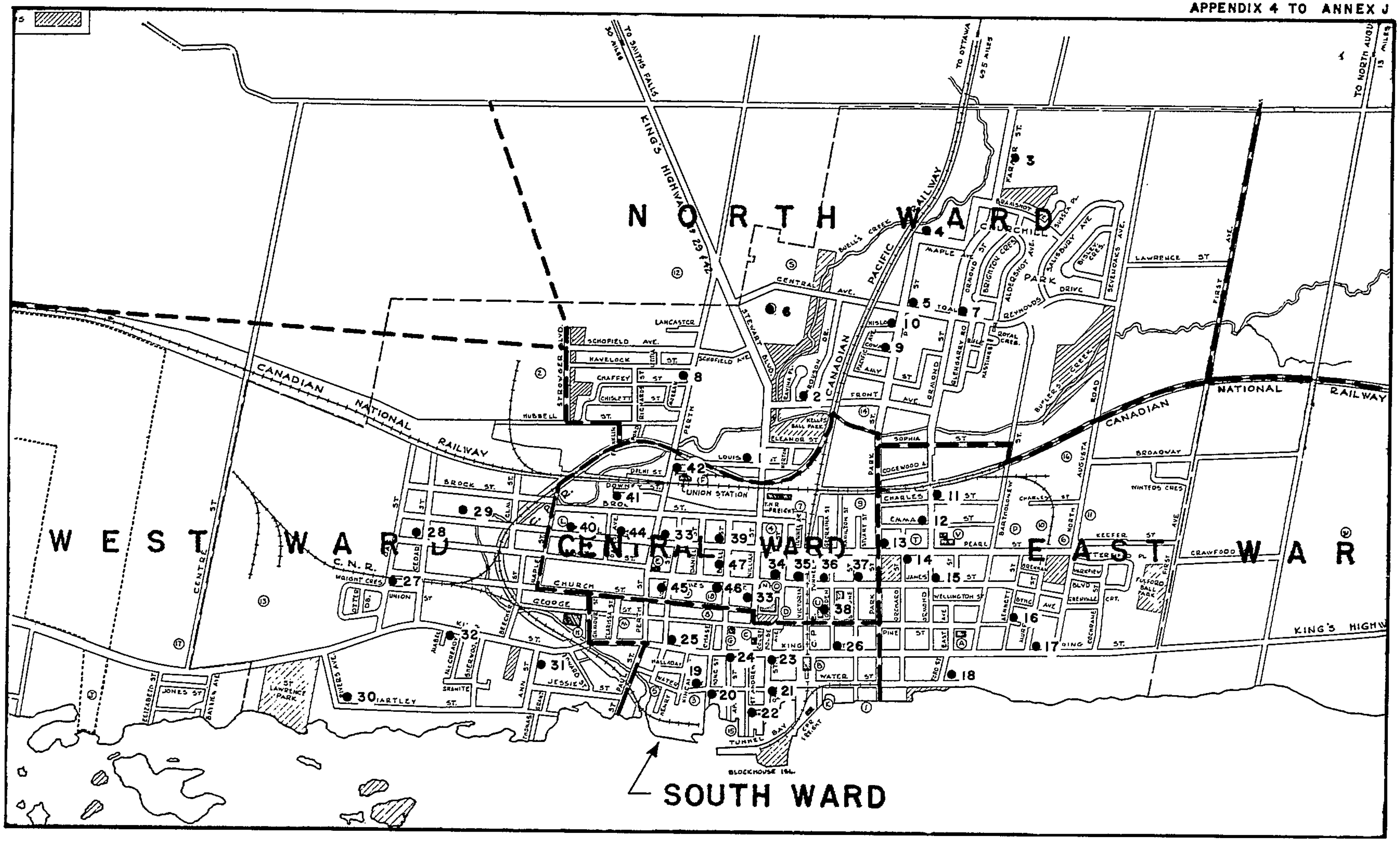
CITY OF BRIGHTVILLE

No.	Ward	Shelter Analysis Serial No.	Building	Protection Factor		Capacity
				Existing	Potential *	*
1	North	N-2	Apartment, 106 Louis St.	40	150	50
2	"	N-7	Church, 49 Front Ave.	40	120	100
3	"	N-14	Factory, 390 Farmer St.	140	450	150
4	"	N-17	School, 76 Maple Ave.	60	200	200
5	"	N-20	Library, 204 Central Ave.	50	200	150
6	"	N-26	School, 110 Stewart Blvd.	30	100	250
7	"	N-29	Church, 107 Central Ave.	120	400	250
8	"	N-33	Apartment, 618 Perth St.	25	100	250
9	"	N-38	Retail Store, 185 Park St.	40	120	250
10	"	N-43	Apartment, 270 Park St.	30	120	150
11	East	E-5	YMCA – 84 Charles St.	60	200	150
12	"	E-11	Church, 16 Emma St.	180	500	200
13	"	E-20	Apartment, 74 Pearl St.	140	500	100
14	"	E-29	Apartment, 88 Pearl St.	40	200	200
15	"	E-34	School, 104 James St.	120	300	250
16	"	E-36	School, 96 Church St.	30	120	300
17	"	E-41	Armoury, 308 King St.	80	300	250
18	"	E-47	Church, 204 First Ave.	65	250	250
19	South	S-1	Factory, 16 Water St.	100	400	500
20	"	S-17	Warehouse, 34 Water St.	80	350	400
21	"	S-26	Underground Parking, Water St.	150	500	600
22	"	S-39	Hotel, 86 Geary St.	120	500	400
23	"	S-52	Warehouse – 45 Broad St.	60	200	800
24	"	S-74	Garage, 32 Apple St.	40	150	600
25	"	S-98	Bank, 206 King St.	100	300	300
26	"	S-117	Hotel, 267 King St.	85	300	400
27	West	W-3	Church, 14 Union St.	60	220	150
28	"	W-9	Apartment, 192 Cedar St.	40	180	200
29	"	W-14	School, 60 Pearl St.	120	400	150
30	"	W-23	Clubhouse, Rivers Ave.	60	300	200
31	"	W-28	School, 35 Ann St.	80	320	200
32	"	W-35	Church, 41 Mabel St.	30	120	100
33	Central	C-4	Govt. Offices, 24 William St.	90	400	800
34	"	C-21	Church, 36 Wall St.	100	300	600
35	"	C-22	Retail Store, 86 Victoria Ave.	35	100	50
36	"	C-47	Post Office, 302 James St.	150	500	600
37	"	C-52	Cdn. Legion, 416 James St.	140	500	400
38	"	C-56	Apartment, 38 Garden St.	40	120	350
39	"	C-63	Office Bldg., 62 Buell St.	50	180	350
40	"	C-71	Bank, 120 Pearl St.	110	400	400
41	"	C-76	YWCA, 16 Downey St.	50	200	250
42	"	C-84	Station, 8 Louis St.	100	300	150
43	"	C-91	Retail Store, 216 Pearl St.	45	130	300
44	"	C-103	Retail Store, 185 Pearl St.	60	180	200
45	"	C-108	Bank, 64 John St.	180	500	450
46	"	C-117	Office Bldg. 180 Buell St.	90	300	350
47	"	C-139	Dept. Store, 214 Buell St.	200	1000	600
					TOTAL	14500

* These figures apply after completion of the work recommended on the shelter analysis forms.

BRIGHTVILLE

APPENDIX 4 TO ANNEX J



APPENDIX 4 to ANNEX "J"

98751-10

SUMMARY OF COST – DEVELOPMENT OF EXISTING FALLOUT PROTECTION
CITY OF BRIGHTVILLE

Group	Category	Item	North Ward	East Ward	South Ward	West Ward	Central Ward	Total	Remarks
1.	Critical Structures-protection factor to be 500.	Number of Structures	1	2	0	2	1	6	Proposals include protection in working and living areas. Total cost $30,800
		Cost, Protective Improvements	5500	7500	—	9800	1800	24600	
		Cost, Habitability Improvements	1500	1000	—	2500	1200	6200	
2.	Public Shelters. Existing protection factor 100 or over.	Number of Shelters	2	3	4	1	7	17	
		Number of Spaces	400	550	1800	150	3200	6100	From Shelter Analyses
		Cost, Simple Protective Improvements	300	700	2000	50	2800	5850	Bricking up windows etc.
		Cost, Habitability Improvements	3700	8100	34000	850	67600	114250	
		Total Cost by Wards	4000	8800	36000	900	70400	120100	
		Cost per Occupant, by Wards	$10.00	$16.00	$20.00	$ 6.00	$22.00	$19.70	City Average
3.	Public Shelters. Existing protection factors to be increased to 100 or over.	Number of Shelters	8	5	4	5	8	30	
		Number of Spaces	0	1150	2200	850	2800	8400	See Shelter Analyses
		Cost, Protective Improvements	7200	5000	8900	4500	13000	38600	
		Cost, Habitability Improvements	27800	18000	48300	9100	43000	146200	
		Total Cost, by Wards	35000	23000	57200	13600	56000	184800	
		Cost per Occupant, by Wards	$25.00	$20.00	$26.00	$16.00	$20.00	$22.00	City Average
4.	Public Shelters, Summary. (2) + (3)	Number of Shelters	10	8	8	6	15	47	See Appendix 3
		Number of Spaces	1800	1700	4000	1000	6000	14500	
		Total Cost, by Wards	39000	31800	93200	14500	126400	304900	
		Cost per Occupant	$21.60	$18.70	$23.30	$14.50	$21.00	$21.00	

APPENDIX 6
to
ANNEX "J"

FALLOUT SHELTER SITUATION REPORT

CITY OF BRIGHTVILLE

	PRESENT STATUS SHELTERS vs. POPULATION					SITUATION IF PROPOSED WORK IS CARRIED OUT		
				Deficiencies			Deficiencies	
WARD	Night Pop.	Day Pop.	Shelter Spaces	Night	Day	Shelter Spaces	Night	Day
North	4720	3550	400	4320	3150	1800	2920	1750
East	4280	3050	550	3730	2500	1700	2580	1350
South	5870	8800	1800	4070	7000	4000	1870	4800
West	3110	2300	150	2960	2150	1000	2110	1300
Central	8520	11100	3200	5320	7900	6000	2520	5100
Total	26500	28800	6100	20400	22700	14500	12000	14300
	At night there is shelter accommodation for 23% of the population. By day, this is reduced to 21%.					Night -- 55% could be protected. Day -- 50% only.		

RECOMMENDATIONS RE CONSTRUCTION

1. PHASE 1 – Preparation of critical structures in accordance with Appendix 5 Group 1.
2. PHASE 2 – Improve the most suitable existing buildings to provide public shelters in accordance with Appendix 5 Group 2.
3. PHASE 3 – Improve remainder of existing buildings that are potential shelters, as per Appendix 5 Group 3.
4. PHASE 4

(a) Construct basement fallout shelters in all houses having suitable basement areas.

Ward	Basement Shelters Proposed	Spaces Gained	Net Deficiency or Surplus	
			Night	Day
N	763	3200	+280	+1450
E	675	2840	+260	+1490
S	401	1680	−190	−3120
W	540	2260	+150	+ 960
C	665	2790	+270	−2310
Total	3044	Above figures brought forward from Appendix 6		

(b) Construct 45 backyard shelters in South Ward.

N.B. On completion of Phase 4 the community will have enough shelter accommodation to completely house the population in the event of an attack by night.

5. PHASE 5 – Construct new public shelters as follows:

South Ward – 850 spaces
Central Ward – 650 spaces
Total – 1500 spaces

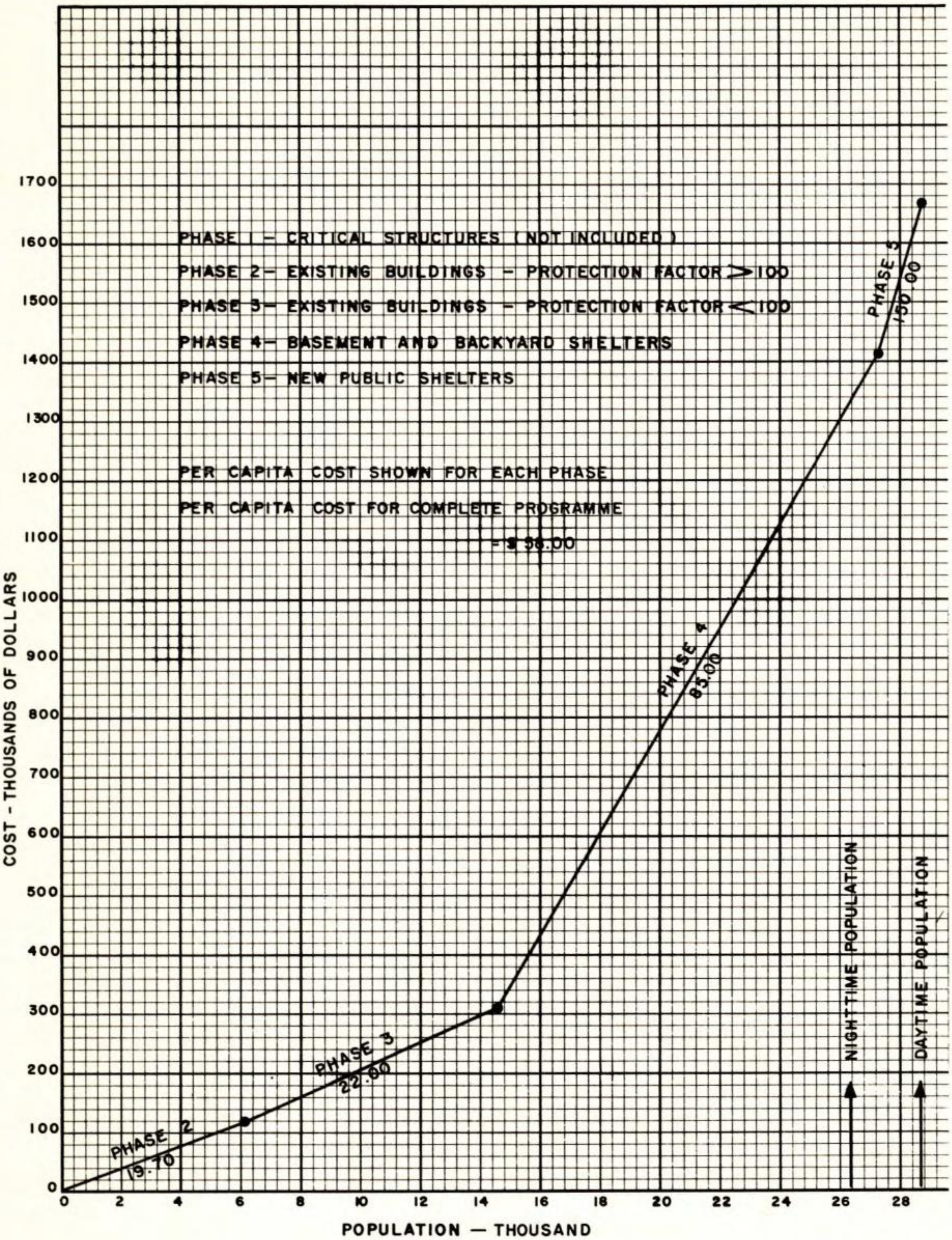
N.B. Although in daytime there will be about 5430 people without shelter in the downtown wards, (Central and South) it is estimated that some 3800 of them live in the residential wards (North, East, West). When the warning is given they will have time to proceed to their homes and shelters. A few will also leave the city for their homes in nearby communities. It is estimated that 1500 will remain unprotected, hence Phase 5.

6. *Summary of Cost (in round figures)*

Phase 1 – $ 31,000
Phase 2 – 120,000
Phase 3 – 185,000
Phase 4 – 1,110,000
Phase 5 – 225,000
Total $1,671,000

98751—10½

COST OF FALLOUT SHELTER ACCOMODATION
CITY OF BRIGHTVILLE



GLOSSARY OF TERMS

ABSORPTION: The transformation of radiant energy into other forms of energy when passing through a material substance.

ABSORPTION COEFFICIENT: A number characterizing the ability of a given material to absorb radiations of a specified energy. The linear absorption coefficient expresses this ability per unit thickness and is stated in units of reciprocal length (or thickness).

AIR BURST: The explosion of a nuclear weapon at such a height that the expanding ball of fire does not touch the earth's surface when the luminosity is a maximum.

ALPHA PARTICLE: A particle, identical with a helium nucleus, that is emitted from the nuclei of certain radioactive elements during the decay process. It consists of two protons and two neutrons, and carries a double positive charge.

ANODE: Positive electrode.

ATOM: The smallest (or ultimate) particle of an element that still retains the characteristics of that element. Every atom consists of a positively charged central nucleus, which carries nearly all the mass of the atom, surrounded by a number of negatively charged electrons, so that the whole system is electrically neutral.

ATOMIC BOMB: A term usually applied to a weapon that utilizes fission energy only.

ATOMIC NUMBER: The number of protons in the nucleus, hence in a neutral atom, also the number of orbital electrons.

BARRIER SHIELDING: The achievement of (partial) protection against gamma radiation from fallout, by the placing of mass (i.e. a barrier) between the fallout field and the individual(s) to be protected.

BETA PARTICLE: A charged particle of very small mass emitted spontaneously from the nuclei of certain radioactive elements. Most (if not all) of the fission fragments emit (negative) beta particles. Physically, the beta particle is identical with an electron moving at high velocity.

BINDING ENERGY: The energy represented by the difference in mass between the sum of the component parts, and the actual mass of the nucleus.

CATHODE: Negative electrode.

CHAIN REACTION: A nuclear (or chemical) process in which some of the products of the process are instrumental in its continuation or magnification.

COMPTON EFFECT: An interaction of gamma rays with matter, in which a gamma photon collides with an atomic electron, and as a result some of the energy of the photon is transferred to the electron, which is stripped from its atom. The photon, with decreased energy, then moves off at an angle to its original direction.

CONTAMINATION: The deposit of radioactive material on the surfaces of structures, areas, objects, or personnel, following a nuclear (or atomic) explosion. This material generally consists of fallout in which fission products and other bomb debris have become incorporated with particles of dirt, etc. Contamination can also arise from the radioactivity induced in certain substances by the action of bomb neutrons.

CRITICAL MASS: For a fissionable material, the minimum mass of a material that will support a chain reaction. For an explosion to occur, the system must be supercritical.

CURIE: Standard measure of rate of radioactive decay; 3.7×10^{10} disintegrations per second.

DECAY: Radioactive decay means the disintegration of the nucleus of an unstable element by the spontaneous emission of charged particles and/or gamma photons.

DEUTERIUM: A heavy isotope of hydrogen having in its nucleus one proton and one neutron.

DEUTERON: The nucleus of a deuterium atom.

DIFFRACTION: The bending of waves around the edges of objects. In connection with a blast wave impinging on a structure, diffraction refers to the passage around and envelopment of the structure by the blast wave. Diffraction loading is the force (or loading) on the structure during the envelopment process.

DOSE: A (total or accumulated) quantity of ionizing (or nuclear) radiation. The term dose is often used in the sense of the exposure dose, expressed in roentgens, which is a measure of the total amount of ionization that the quantity of radiation could produce in air. This should be distinguished from the absorbed dose, given in reps or rads, which represents the energy absorbed from the radiation per gram of specified body tissue. Further, the biological dose, in rems, is a measure of the biological effectiveness of the radiation exposure.

DOSE RATE: As a general rule, the amount of ionizing (or nuclear) radiation to which an individual would be exposed per unit of time. It is usually expressed as roentgens per hour or in multiples or submultiples of these units, such as milliroentgens per hour. The dose rate is commonly used to indicate the level of radioactivity in a contaminated area.

DOSIMETER: An instrument used to detect and measure an accumulated dose of radiation.

DRAG LOADING: The force on an object or structure due to the transient winds accompanying the passage of a blast wave. The drag pressure is the product of the dynamic pressure and a coefficient which is dependent upon the shape (or geometry) of the structure or object.

ELECTRON: A particle of very small mass which carries a negative or positive charge of 4.8×10^{-10} electrostatic units. Negatively charged electrons are present in all atoms. Positive electrons are usually called positrons. They each weigh 0.000548 mass units.

ELECTRON VOLT: The amount of energy gained by an electron in passing through a potential difference of 1 volt. Abbreviation: ev

FALLOUT: The process or phenomenon of the fall back to the earth's surface of particles contaminated with radioactive material from the atomic cloud. The term is also applied in a collective sense to the contaminated particulate matter itself.

FISSION: The process whereby the nucleus of a particular heavy element splits into (generally) two nuclei of lighter elements, with the release of substantial amounts of energy. The most important fissionable materials are uranium-235 and plutonium-239.

FISSION PRODUCTS: A general term for the complex mixture of substances produced by nuclear fission.

FUSION: The process whereby the nuclei of light elements, especially those of the isotopes of hydrogen, namely deuterium and tritium, combine to form the nucleus of a heavier element with the release of substantial amounts of energy.

GAMMA RAY: A high-frequency electromagnetic radiation emitted from the nuclei of certain unstable atoms. Its wave length may vary from 10^{-9} to 10^{-12} centimeters.

GEOMETRY SHIELDING: The achievement of (partial) protection against gamma radiation from fallout, by increasing the distance of the individual from the fallout field. In practice, it means taking advantage of the protection made possible by the physical dimensions (length, width, height) of structures.

GROUND ZERO: The point on the surface of land or water vertically below or above the center of a burst of nuclear (or atomic) weapon; frequently abbreviated to GZ.

HALF-LIFE: The time required for the activity of a given radioactive species to decrease to half of its initial value due to radioactive decay. The half-life is a characteristic property of each radioactive species and is independent of its amount or condition. The biological half-life is the time required for the amount of a specified element which has entered the body (or a particular organ) to be decreased to half of its initial value as a result of natural, biological elimination processes. The effective half-life of a given isotope is the time in which the quantity in the body will decrease to half as a result of both radioactive decay and biological elimination.

HALF-VALUE LAYER THICKNESS: (sometimes referred to as half-thickness). The thickness of a given material which will absorb half the gamma radiation incident upon it. This thickness depends on the nature of the material—it is roughly inversely proportional to its density—and also on the energy of the gamma rays.

HYDROGEN BOMB: A term sometimes applied to nuclear weapons in which part of the explosive energy is obtained from nuclear fusion (or thermonuclear) reactions.

INDUCED RADIOACTIVITY: Radioactivity produced in certain materials as a result of nuclear reactions, particularly the capture of neutrons, which are accompanied by the formation of unstable (radioactive) nuclei. The activity induced by neutrons from a nuclear (or atomic) explosion in materials containing the elements sodium, manganese, silicon, or aluminum may be significant.

INITIAL NUCLEAR RADIATION: Nuclear radiation (essentially neutrons and gamma rays) emitted from the ball of fire and the cloud column during the first minute after a nuclear (or atomic) explosion. The time limit of one minute is set, somewhat arbitrarily, as that required for the source of the radiations (fission products in the atomic cloud) to attain such a height that only insignificant amounts reach the earth's surface.

INTENSITY: The amount of radiant energy emitted in a specified direction per unit time and per unit surface area. Sometimes used, rather loosely, to express the dose rate (e.g. in roentgens per hour).

ION: An atomic particle, atom, or chemical radical bearing an electric charge, either positive or negative, due to an excess or deficiency of electrons.

IONIZATION: The result of any process by which a neutral atom or molecule acquires either a positive or a negative charge.

IONIZING RADIATION: Electromagnetic or particulate radiation capable of producing ions, either directly or indirectly, in its passage through matter.

ISOBARS: Elements having the same mass number, but different atomic numbers.

ISOTOPES: Elements having the same atomic number, but different mass numbers. All the isotopes of any one element are identical in chemical behaviour.

KILOTON ENERGY: The energy of a nuclear (or atomic) explosion which is equivalent to that produced by the explosion of 1 kiloton (i.e., 1,000 tons) of TNT, i.e., 10^{12} calories or 4.2×10^{19} ergs.

MASS NUMBER: The number of nucleons (protons plus neutrons) in the nucleus of an atom.

MASS UNIT: A unit of mass based upon one sixteenth of the weight of an oxygen atom, which is taken to be 16.00000. Abbreviation: m.u.

MEDIAN LETHAL DOSE: The amount of ionizing (or nuclear) radiation exposure over the whole body which it is expected would be fatal to 50 percent of a large group of living creatures or organisms. It is commonly (although not universally) accepted, at the present time, that a dose of about 450 roentgens, received over the whole body in the course of a few hours or less, is the median lethal dose for human beings.

MEGATON ENERGY: The energy of a nuclear (or atomic) explosion which is equivalent to 1,000,000 tons (or 1,000 kilotons) of TNT, i.e., 10^{15} calories or 4.2×10^{22} ergs.

NEUTRON: An elementary nuclear particle with a mass approximately the same of that of a hydrogen atom, and which is electrically neutral. Neutrons are present in all atomic nuclei, with the exception of ordinary hydrogen.

NUCLEON: A constituent part of the nucleus, commonly applied to protons and neutrons.

NUCLEUS: The heavy central part of an atom in which most of the mass and the total positive charge are concentrated. The nucleus of an ordinary hydrogen atom is a single proton, but all other nuclei contain protons and neutrons.

NUCLIDE: A general term referring to all nuclear species, both stable and unstable, of the chemical elements.

OVERPRESSURE: The transient pressure, usually expressed in pounds per square inch, exceeding the ambient pressure, manifested in the shock (or blast) wave from an explosion. The variation of the overpressure with time depends on the energy yield of the explosion, the distance from the point of burst, and the medium in which the weapon is detonated. The peak overpressure is the maximum value of the overpressure at a given location and is generally experienced at the instant shock (or blast) wave reaches that location.

PHOTOELECTRIC EFFECT: The process by which a photon ejects an electron from its atom. All the energy of the photon is absorbed in ejecting the electron and in imparting kinetic energy to it.

PROTECTION FACTOR: The relative reduction in the amount of gamma radiation that would be received by an individual in a protected location, compared to the amount he would receive if unprotected.

PHOTON: A quantity or packet of energy emitted in the form of electromagnetic radiation.

POSITRON: See ELECTRON

PROTON: A nuclear particle with a positive electric charge equal numerically to the charge of the electron. The proton has a mass of 1.007575 m.u.

RAD: A unit of absorbed dose of radiation; it represents the absorption of 100 ergs of nuclear (or ionizing) radiation per gram of the absorbing material or tissue.

RADIOACTIVITY: The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nuclei of an (unstable) isotope. As a result of this emission the radioactive isotope is converted (or decays) into the isotope of a different element which may (or may not) also be radioactive. Ultimately, as a result of one or more stages of radioactive decay, a stable (nonradioactive) end product is formed.

REM: A unit of biological dose of radiation; the name is derived from the initial letters of the term "roentgen equivalent man (or mammal)". The number of rems of radiation is equal to the number of rads absorbed multiplied by the RBE of the given radiation (for a specified effect).

REP: A unit of absorbed dose of radiation; the name is derived from the initial letters of the term "roentgen equivalent physical". Basically, the rep is intended to express the amount of energy absorbed per gram of soft tissue as a result of exposure to 1 roentgen of gamma (or X) radiation. This is estimated to be about 97 ergs, although the actual value depends on certain experimental data which are not precisely known. The rep is thus defined, in general, as the dose of any ionizing radiation which results in the absorption of 97 ergs of energy per gram of soft tissue. For soft tissue, the rep and the rad are essentially the same.

RESIDUAL NUCLEAR RADIATION: Nuclear radiation, chiefly beta particles and gamma rays, which persists for some time following a nuclear (or atomic) explosion. The radiation is emitted mainly by the fission products and other bomb residues in the fallout, and to some extent by earth and water constituents, and other materials, in which radioactivity has been induced by the capture of neutrons.

ROENTGEN: A unit of exposure dose of gamma (or X) radiation. It is defined precisely as the quantity of gamma (or X) radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying one electrostatic unit quantity of electricity of either sign. From the accepted value for the energy lost by an electron in producing a positive-negative ion pair in air, it is estimated that 1 roentgen of gamma (or X) radiation, would result in the absorption of 87 ergs of energy per gram of air.

SCATTERING: The diversion of radiation, either thermal or nuclear, from its original path as a result of interactions (or collisions) with atoms, molecules, or larger particles in the atmosphere or other medium between the source of the radiations, e.g., a nuclear (or atomic) explosion, and a point at some distance away. As a result of scattering, radiations (especially gamma rays and neutrons) will be received at such a point from many directions instead of only from the direction of the source.

SHIELDING: Any material or obstruction which absorbs radiation and thus tends to protect personnel or materials from the effects of a nuclear (or atomic) explosion. A moderately thick layer of any opaque material will provide satisfactory shielding from thermal radiation, but a considerable thickness of material of high density may be needed for nuclear radiation shielding.

SKYSHINE: A term used to describe the scattering by the atmosphere of gamma radiation from residual nuclear radiation in the fallout.

SURFACE BURST: The explosion of a nuclear (or atomic) weapon at the surface of the land or water or at a height above the surface less than the radius of the fireball at maximum luminosity (in the second thermal pulse). An explosion in which the bomb is detonated actually on the surface is called a contact surface burst or a true surface burst.

SURVEY METER: A portable instrument, such as a Geiger counter or ionization chamber, used to detect nuclear radiation and to measure the dose rate.

THERMAL RADIATION: Electromagnetic radiation emitted (in two pulses) from the ball of fire as a consequence of its very high temperature; it consists essentially of ultraviolet, visible, and infrared radiations. In the early stages (first pulse), when the temperature of the fireball is extremely high, the ultraviolet radiation predominates; in the second pulse, the temperatures are lower and most of the thermal radiation lies in the visible and infrared regions of the spectrum.

THERMONUCLEAR: An adjective referring to the process (or processes) in which very high temperatures are used to bring about the fusion of light nuclei, such as those of the hydrogen isotopes, deuterium and tritium, with the accompanying liberation of energy. A thermonuclear bomb is a weapon in which part of the explosion energy results from thermonuclear fusion reactions. The high temperatures required are obtained by means of a fission explosion.

TRITIUM: A heavy, radioactive isotope of hydrogen, having in its nucleus one proton and two neutrons.

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