THE NATIONAL PLAN
for
Civil Defense and Defense Mobilization

Annex 10
NATIONAL SHELTER PLAN

Executive Office of the President
OFFICE OF CIVIL AND DEFENSE MOBILIZATION

Preface

This annex supports and amplifies the National Plan for Civil Defense and Defense Mobilization, particularly Part V, Section C, **Reduction of Vulnerability,** Subsection 1, Public shelters and protective devices. It states the principles, responsibilities, requirements and broad courses of nonmilitary action incident to this subject.

Auxiliary documents will be issued as necessary and will be subordinate to and compatible with this annex and the National Plan.

The annex is published in looseleaf form in order that pages may be added or replaced easily whenever revisions are made.

Leo A. Hoegh
Director
Office of Civil and Defense Mobilization

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Contents

ANNEX 10
NATIONAL SHELTER PLAN
I. Definitions

For the purpose of this annex, "shelter" means any structure, facility or device intended to be used for shielding the civilian population from the effects of nuclear weapons, conventional weapons, biological and chemical agents, etc. Major types of shelter are:

A. Fallout Shelter

Intended to afford protection primarily from the effects of radioactive fallout and secondarily from biological and chemical agents, blast and heat.

B. Blast Shelter

Intended to afford protection primarily from the immediate effects of nuclear weapons (blast, heat and initial radiation) as well as protection from radioactive fallout and biological and chemical agents.

II. Assumptions[1]

A. Highest priority is to be given to providing for a national active military capability for retaliation and defense against attack. This is the chief deterrent to war since it may eventually have the capability of effectively preventing an enemy from striking intended targets.

[1]See Part I of the NATIONAL PLAN and Annex 1, PLANNING BASIS.

B. WITH ADEQUATE SHELTER PROTECTION A SUCCESSFUL ATTACK ON THE NATION WOULD BE MORE DIFFICULT AND THE TEMPTATION OF AN AGGRESSOR TO LAUNCH AN ATTACK WOULD BE SUBSTANTIALLY LESSENED.

C. IN EVENT OF NUCLEAR ATTACK, THE DANGER FROM RADIOACTIVE FALLOUT WOULD BE WIDESPREAD, LONG TERM AND INTENSE. THE EFFECTS OF FALLOUT CAN BE SIGNIFICANTLY REDUCED BY FALLOUT SHELTER.

III. General Responsibilities

A. In accordance with existing national policy the Federal Government will provide the stimulation, leadership, guidance and example necessary for the American people to make preparations for shelter protection and will work with State and local governments and with private organizations to expedite and facilitate their actions for its provision.

B. State and local governments will, in coordination with the shelter activities of Federal installations located within their jurisdictions, expedite and facilitate the provision of shelter both for their normal populations and for others estimated to be within their jurisdictions during the period when shelter will be required.

C. Each property owner has an obligation to provide protection on his own premises. Private organizations and individuals will expedite and facilitate the provision of shelter in accordance with the shelter activities of the jurisdictions in which their properties are located.

IV. Functions Regarding Provision of Fallout Shelter

A. Information and Education[2]

1. Objectives
   a. To explain the need for fallout shelter.
   b. To insure support of government programs regarding fallout shelter and to stimulate appropriate and effective public action.
2. Actions Required
   a. Expand civil defense programs of information and education to disseminate information pertinent to the need for and provision of fallout shelter, through
      (1) Support of adult education programs
      (2) Use of all appropriate public information media
      (3) Use of all organizations — national, State and local — to reach the community and neighborhood leaders.
   b. Prepare subject matter for the means listed above on the following broad subjects:
      (1) The place of individual preparedness in the total national security program

[2]See Part VII, Section B of the NATIONAL PLAN and Annex 37, TRAINING AND EDUCATION.

(2) Nuclear weapons effects on people, plants and animals
(3) How to provide fallout protection, including
  (a) How to construct a fallout shelter
  (b) How to improvise home and basement shelters
  (c) How to protect food and water
(4) What governments — Federal, State and local—are doing about fallout protection
(5) Radiological decontamination.

B. Survey of Existing Fallout Protection[3]

1. Objectives
   a. To provide a basis for national fallout shelter planning.
   b. To identify the quantity, quality and locations of fallout protection normally existing in the Nation.
   c. To determine which existing structures can and should be modified to afford fallout protection.
2. Actions Required
   a. Survey existing shelter, other than military, on a sampling basis—by the Federal Government in cooperation with State and local governments and private organizations.
   b. Survey existing shelter for State and local operational purposes — by the governments of States and their political subdivisions with the assistance of the Federal Government.

[3]See Part VII, Section A of the NATIONAL PLAN and Annex 36, RESEARCH AND DEVELOPMENT.

c. Translate and interpolate data on a continuing basis to make it useful for national planning.
d. Interpret data for public use.

C. Research, Development, Design and Prototype Construction[4]

1. Objectives
   a. To refine knowledge of shelter and of shelter occupancy.
   b. To develop more economical and efficient shelter designs.
2. Actions Required
   a. Field-test shelters, other structures and shelter equipment, including the instrumentation necessary to evaluate results.
   b. Develop and test experimental structures, facilities, equipment and material.
   c. Study physiological, psychological, emotional, educational and morale problems and determine tolerance limits under emergency conditions; medical, food and water requirements in shelter habitation, and sanitary controls to permit tolerable occupation.
   d. Develop architectural designs and specifications for new types of multiple-use shelters which shall be attractive as well as practical. Consideration will be given to the use of current authorities or the proposal of new authorities in order that grants may be made to

[4]See Part VII, Section A of the NATIONAL PLAN and Annex 36, RESEARCH AND DEVELOPMENT.

schools of architecture and engineering to stimulate curriculum development, training of new students, and new concepts of shelter design.

e. Design and construct shelter prototypes, including relatively small-capacity multiple-use fallout shelters, differing in design and type; adapt prototypes to differing geographic and climatic conditions, and after completion test by actual occupancy for realistic periods of time. This action would include construction or modification of prototype facilities such as
   (1) Underground parking garages
   (2) Understreet shelters
   (3) Subways
   (4) Highway patrol and maintenance facilities
   (5) Additions to existing schools and new schools, including such facilities as cafeterias, assembly space and classrooms
   (6) Additions to existing hospitals and new hospitals, including such facilities as cafeterias, visitors' and convalescent rooms and reserve areas
   (7) Industrial plants
   (8) Commercial buildings
   (9) Family residences and apartments, including such facilities as bathrooms, garages, basements and recreation rooms.

f. Design, construct and test shelter prototypes in existing Federal buildings.

D. Construction of Fallout Shelters

1. Objectives
   a. To provide, in accordance with current national policy, fallout shelter for persons likely to be exposed to radioactive fallout.
   b. To contribute to the national defense by decreasing the vulnerability of the people to nuclear attack.
2. Actions Required
   a. Incorporate fallout shelter in the construction of appropriate new Federal civilian buildings, of suitable size, and make such fallout shelter available to the public where practicable.
   b. Incorporate fallout shelter in new State and local public construction, adapt appropriate existing public facilities and make such fallout shelter available to the public where practicable.
   c. Incorporate fallout shelter in new private construction and adapt existing private facilities where practicable.

V. Functions Regarding Provision of Blast Shelter

There will be continuing research and development, on a limited scale, on the various factors affecting the provision and use of blast shelter.

VI. Execution

A. The National Shelter Plan shall be directed and coordinated by the Director, Office of Civil and Defense Mobilization as a function of "protection of life and property," in accordance with Part IV, Section A and Part V, Section C of the National Plan.

B. Execution of Federal responsibilities not reserved by the Director shall be in accordance with Part IV, Section A and Part V, Section C of the National Plan and Annex 5, "Federal Delegations and Assignments."

C. Execution of responsibilities of State and local governments, private organizations and individuals shall be in accordance with Part IV, Section B and Part V, Section C of the National Plan and in coordination with the authorities applicable to execution of Federal responsibilities.

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Appendix 1

(Annex 10—National Shelter Plan)

Fallout Shelter Surveys:

GUIDE FOR EXECUTIVES

NP–10–1

NATIONAL PLAN APPENDIX SERIES

Executive Office of the President

OFFICE OF CIVIL AND DEFENSE MOBILIZATION

October 1959

CONTENTS

INTRODUCTION

Ten years ago terms such as "nuclear radiation" and "roentgen" were pretty much confined to the scientist's laboratory.

Today they are on the executive's desk.

They are there by necessity because they are tied in with the promises and the problems of the new nuclear age—an age which demands informed leadership.

You will find these and other like terms in this manual because the manual deals with an important problem—radioactive fallout from nuclear attack—as it concerns a key executive: the man responsible for directing civil defense preparedness measures in government, industry, or other large facility.

The job this man faces is sometimes discouraging because of its size and newness. But it is far from an impossible job. There are more answers today, for example, to the problem of radiological defense than there were even as recently as 6 months ago.

The purpose of this manual is to describe one of today's answers—a fallout shelter survey.

Fallout shelter surveys are an essential part of the National Policy on Shelters issued by direction of the President on May 7, 1958. Since the policy announcement, there has been a growing recognition of the importance of these surveys. State Governors, for example, at their 51st annual meeting in August 1959, unanimously approved a resolution: "That each State initiate a survey of all State owned or operated facilities to determine both their adequacy as fallout shelters, and what steps are needed to provide fallout protection for their users, both regular and transient."

A fallout shelter survey has two immediate goals: (1) To discover what facilities already exist in a community in the way of fallout shelter, and (2) to determine the best ways of improving these facilities from the standpoint of fallout protection and shelter habitability. This information is vital to the development of any plan for shelter use.

Many methods could be used to achieve these goals in a given survey—some of them very expensive and time-consuming. The Office of Civil and Defense Mobilization, with the assistance of other governmental and private agencies, has developed survey methods that take into account these important matters of time and expense as well as other factors in shelter surveying. The methods are based upon considerable research, including pilot shelter surveys conducted in the spring of 1959 in Contra Costa County, Calif.; Milwaukee, Wis.; Montgomery, Ala.; and Tulsa, Okla.

This manual, prepared as background guidance for the executive responsible for planning and directing a fallout shelter survey, contains a brief description of the characteristics of radioactive fallout, radiation shielding, and shelter habitability, followed by a discussion of suggested survey planning, administrative, and field work procedures.

Architects or engineers who actually conduct fallout shelter surveys should be fully acquainted not only with the material in this manual but also with the technical procedures described in another OCDM manual, *Fallout Shelter Surveys: Guide for Architects and Engineers*.

THE PROBLEM—RADIOACTIVE FALLOUT

The detonation of a nuclear weapon near the ground causes large quantities of earth and debris to be forced up into the fireball and the resulting mushroom-shaped cloud—a cloud which may reach an altitude of 15 miles or more before leveling off. The earth and debris particles in the cloud vary in size from fine powder to large grains, and it is these particles which act as the sources of radiation that can damage living cells.

Most of the particles fall back to the earth's surface within 2 days—"early fallout"—but some remain aloft far longer—"delayed fallout." (See fig. 1.) In a nuclear attack the immediate and most serious danger would be from early fallout. Therefore, the term fallout as used in this manual refers to early fallout only.

FIGURE 1.—*Formation of fallout.*

Significant amounts of fallout do not arrive outside a blast area earlier than about 30 minutes after an explosion. From then on the fallout begins to cover an increasingly larger area, and may eventually blanket thousands of square miles.

The fallout pattern depends largely on the type, size, and detonation of the weapon involved, and the meteorological conditions for the first day or so after the explosion. Some idea of the effect that wind conditions have on fallout patterns from a single nuclear burst is illustrated in figure 2. In areas where the fallout patterns from two or more weapons overlap the hazard increases, and in a massive nuclear attack on the United States much of the country could be covered by dangerous radioactive contamination (fig. 3).

There are three different kinds of radiation associated with fallout—alpha and beta particles, and gamma rays. Alpha and beta emitters may be dangerous if they are ingested through contaminated food, water, or air, but from the shelter standpoint they present no problem. Alpha particles cannot penetrate the external layer of skin, and beta particles cannot penetrate heavy clothing. However, *gamma rays, like X-rays, are*

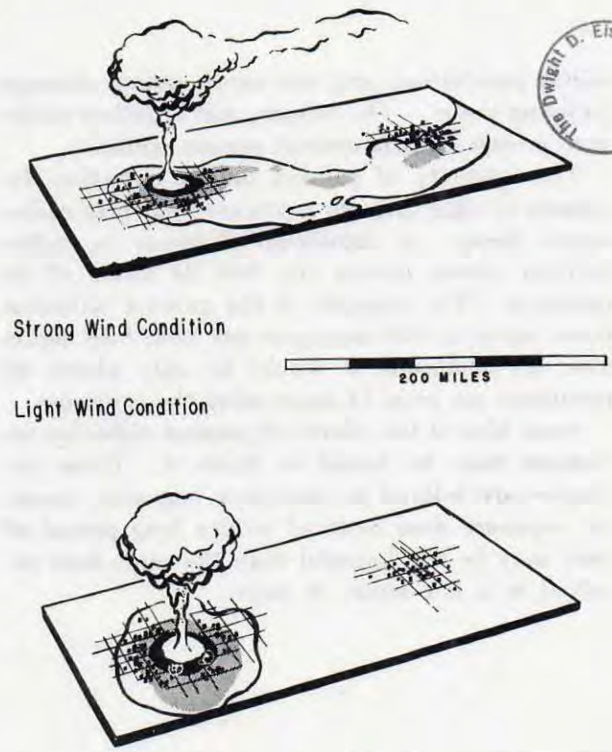

FIGURE 2.—*How wind conditions affect fallout distribution.*

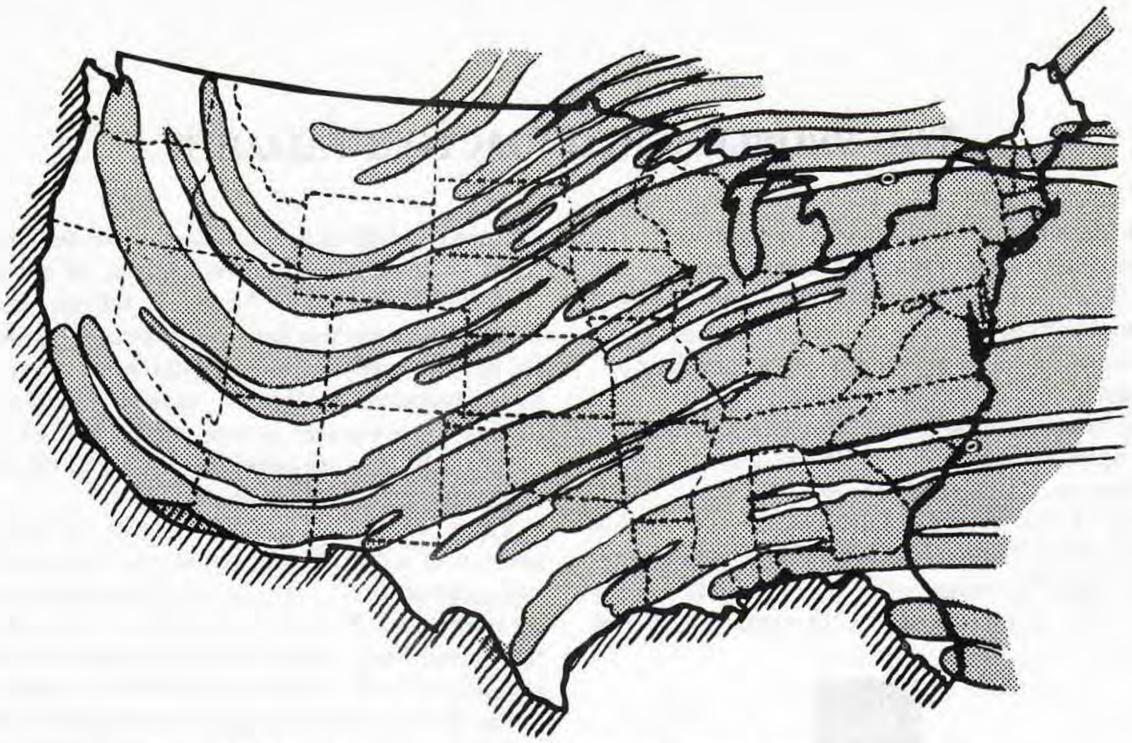

FIGURE 3.—*How fallout could cover the Nation following a massive nuclear attack.*

highly penetrating, and can cause serious damage to living tissue. *The primary aim of fallout shelter is to provide a shield against gamma radiation.*

The intensity of gamma fallout radiation decreases in time through a process known as radioactive decay. A significant decrease in radioactivity comes during the first 24 hours of its existence. For example, if the gamma radiation is measured as 800 roentgens per hour [1] 3½ hours after an explosion, it would be only about 80 roentgens per hour 24 hours after the explosion.

Some idea of the effects of gamma radiation on humans may be found in figure 4. These examples are related to *short-term* exposure doses. An exposure dose received over a long period of time may be less harmful than the same dose received in a few hours or days.

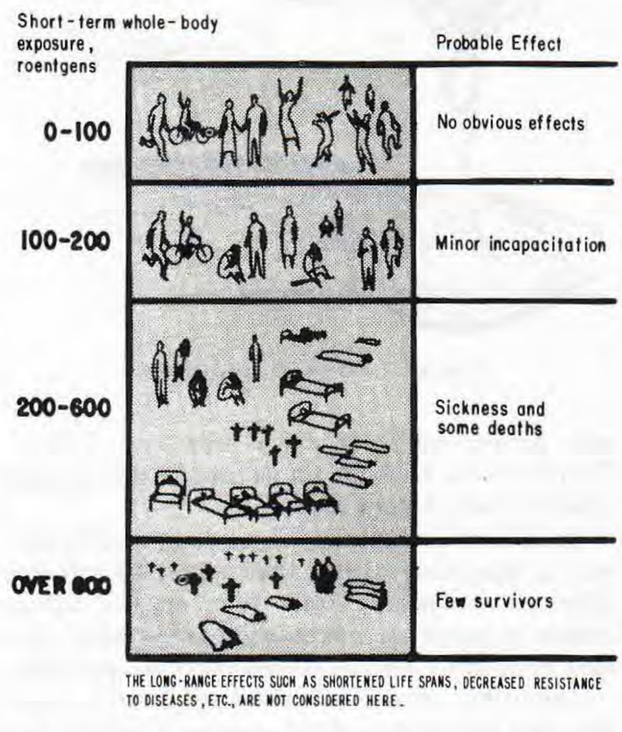

FIGURE 4.—*Probable acute effects of gamma radiation on humans.*

[1] A roentgen is the unit used to measure exposure dose of gamma radiation, and exposure dose rate is expressed in roentgens per hour (r/hr).

KEY SHELTER FACTORS

SHIELDING

There are two methods of shielding from fallout radiation: barrier shielding and geometry shielding.

In the first method, a barrier is placed between the fallout field and the individual. The heavier the protective barrier, the greater the barrier shielding effect. Examples of barriers in structures are walls, floors, and ceilings. (See fig. 5.)

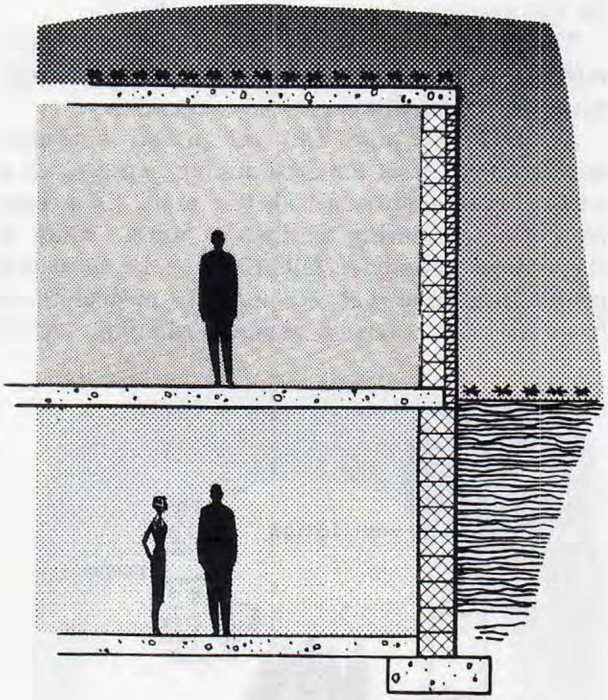

FIGURE 5.—*Barrier shielding.*

Geometry shielding is determined by the extent of the fallout field affecting an individual, and/or his distance from it.

Here is an example of the geometry shielding effect:

If two buildings are of the same height and similar construction, but of different area, the protection from ground contamination would be greater on the first floor in the building with the larger area.

On the other hand, if two buildings are of equal area and similar construction, but differ in height, protection from roof contamination would be greater on the first floor of the higher building. (See fig. 6.)

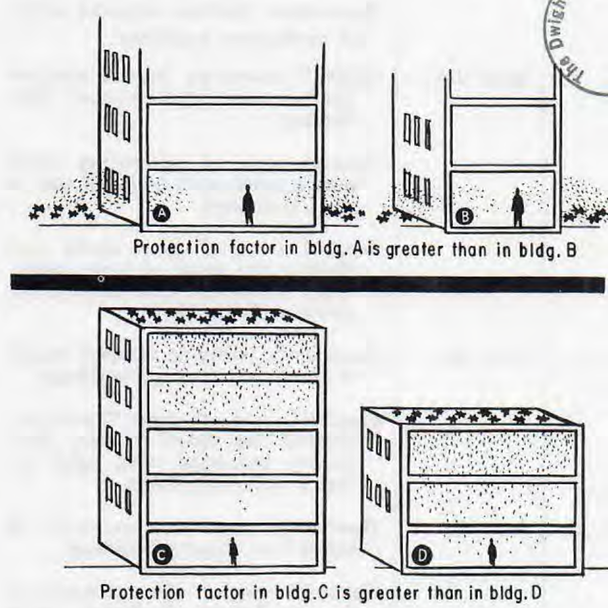

FIGURE 6.—*Geometry shielding.*

The combined effects of barrier shielding and geometry shielding result in a shelter "protection factor." This term is used by technicians to express the relative reduction in the amount of radiation that would be received by a person in a protected location, compared to the amount he would receive if he were unprotected. For example, if a shelter has a protection factor of 500, an unprotected person would be exposed to 500 times more radiation than someone inside the shelter.

For shelter survey purposes, structures should be classified according to their protection factor. Six categories of protection factors, "A" through "F," together with some examples of potential shelter areas to which they may be applied, are listed in table 1.

TABLE 1.—*Description of shelter categories*

Shelter category	Protection factor [1]	Shelter examples [2]
A	1,000 or greater.	OCDM underground shelters.
		Subbasements of multistory buildings.
		Underground installations (mines, tunnels, etc.).
B	250 to 1,000.	OCDM basement fallout shelters (heavy masonry residences).
		Basements (without exposed walls) of multistory buildings.
C	50 to 250	OCDM basement fallout shelters (frame and brick veneer residences).
		Central areas of basements (with partially exposed walls) of multistory buildings.
		Central areas of upper floors (excluding top floor) of large multistory buildings with heavy exterior walls and floors.
D	10 to 50	Basements (without exposed walls) of small 1- or 2-story buildings.
		Central areas of upper floors (excluding top floor) of large multistory buildings with light exterior walls and floors.
E	2 to 10	Basements (partially exposed) of small 1- or 2-story buildings.
		Central areas on ground floors in 1- or 2-story buildings with heavy masonry walls.
F	1½ to 2	Aboveground areas of low buildings, in general, including residences, stores, light industrial buildings.

[1] This term expresses the relative reduction in the amount of radiation that would be received by a person in a protected location, compared to the amount he would receive if he were unprotected.

[2] These examples refer to isolated structures only. The presence of other structures nearby could increase the protection factor of a given shelter area, perhaps enough to raise its category.

Some indication of the likelihood of survival from the effects of fallout radiation, as related to category of shelter, is given in table 2. It is important to note that even "E" category shelters afford "fair" protection from light fallout, and could save many lives.

TABLE 2.—*Chances of survival without severe illness from exposure to fallout radiation*

Shelter category	Fallout deposition		
	Heavy	Medium	Light
A	Excellent	Excellent	Excellent.
B	Good	Excellent	Excellent.
C	Fair	Good	Excellent.
D	Poor	Fair	Good.
E	Nil	Poor	Fair.
F	Nil	Nil	Poor.

HABITABILITY

Although a potential shelter area may provide excellent shielding from fallout radiation, its worth as a shelter is limited if it is poorly ventilated, deficient in sanitary facilities, or too small for the number of occupants. (See fig. 7.)

The term "capacity," as used in shelter surveys, refers to the number of persons that can be accommodated in a shelter.

At least 12 square feet per person is recommended as a basis for determining capacity of a well-ventilated potential shelter area. The best plan of action during the first 24 hours—which is the critical period for fallout—may be to crowd people into somewhat less space to protect them from the high levels of outside radiation. After

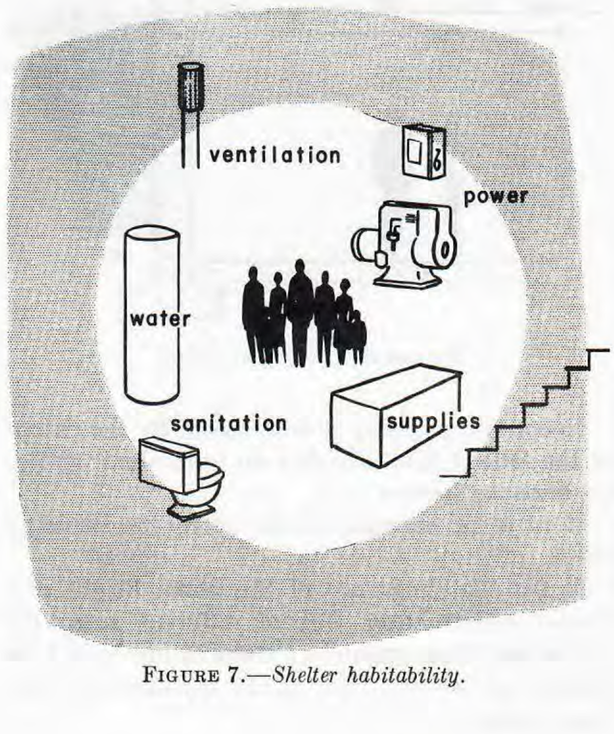

FIGURE 7.—*Shelter habitability.*

this time it may be feasible to transfer them to areas with lower protection factors but more space per person.

Adequate shelter ventilation is most important. A forced-air system with a fresh-air intake of at least 3 cubic feet per minute per person would allow full use of a shelter.

Many existing buildings have well-shielded rooms that are unventilated or poorly ventilated. In these cases, capacity is limited by the volume of the room, not its floor area. A rule of thumb for estimating capacity of unventilated basement shelter is that each occupant requires 500 cubic feet of volume.

Water available to a shelter area should not be less than one-half gallon of potable water per person per day. At least a 2-week supply should be assured. A dependable well in or supplying the shelter is preferred, but stored water is a suitable alternative—and could be less expensive if a well is not already in place.

Unsanitary conditions may develop in a relatively short time after a shelter is occupied unless proper provisions are made. Building codes normally require at least 1 toilet for every 35 occupants in barracks, dormitories, and similar structures. In shelter planning, this requirement may be lowered to as much as 1 toilet for every 70 occupants.

Garbage and trash disposal probably will not be a serious problem because it can be deposited outside the shelter area soon after it collects.

Each public shelter area should have electric power. Unless there is reasonable assurance that normal power supplies will be available during the emergency, engine-generator sets may be required.

IMPROVEMENT OF SHELTER AREAS

Two types of improvements should be considered for potential shelter areas. First, improvements to increase the protection factor, and second, to provide a tolerable environment.

Obviously, if enough money is available, any area can be improved to the highest shelter category, with a satisfactory environment. For shelter survey purposes, however, it is necessary to distinguish between a "reasonable improvement" of an existing area and virtual reconstruction.

The suggested approach in evaluating fallout shelter improvement potential is to define the limits of reasonable improvements by a fixed cost per occupant, excluding costs of bunks, bedding, food, and other supplies. Then match the per capita cost with the highest practicable category to which the structure can be improved.

As a general rule, the fixed cost selected should not be greater than the per capita cost of a new fallout shelter nor less than that required to meet minimum habitability standards.

PROGRAMING AND PLANNING

GENERAL

A fallout shelter survey should be considered an essential part, but not the only part, of a total shelter program for a community. The total program would consist ideally of at least five major projects:

1. Establishment of a working organization with the authority to develop a comprehensive community shelter program that is carefully integrated with the overall civil defense program.
2. Completion of a community fallout shelter survey.
3. Designation of temporary shelters in existing buildings for use if an emergency occurs before the shelter program is completed.
4. Modifying existing buildings and incorporating shelter areas into new buildings.
5. Construction of new shelters which can serve such dual purposes as youth centers, community halls, schools, hospitals, etc.

PROGRAMING THE SHELTER SURVEY

Fallout shelter survey programing may be divided into five major phases: (1) Initial funding and organizing; (2) collection and analysis of data on existing fallout shelter areas; (3) preparation of estimated costs for improving fallout shelter areas; (4) collection of data on population distribution; and (5) integration of phases 2, 3, and 4 into a report that shows the fallout shelter potential of the community.

Perhaps most important to the man responsible for managing the survey is the first phase, particularly the initial funding. He has to be able to answer the obvious question: "How much is it going to cost?"

Based on experience gained in its pilot shelter surveys, OCDM suggests the following cost-estimate formula:

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.

As an example of a specific case, the pilot shelter survey conducted in Montgomery, Ala., cost $33,100. However, Montgomery officials believe that with the procedures and techniques now available—many of them developed through the pilot study—they could do the same job today for about $21,000. The survey involved a total of about 8,000 man-hours. Survey officials believe that the total man-hours required for a similar survey could be reduced by about 50 percent, cutting about $12,000 off the cost.

This survey covered Montgomery County (population 177,000; 805 square miles), which includes the city of Montgomery (population 132,000; 30 square miles). There are a total of 43,185 structures in the County.

The cost breakdown for the Montgomery pilot survey was as follows:

Professional services	$27, 200
Consultant service	475
Travel expense	1, 800
Communication	375
Taxes and licenses	600
Insurance	200
Supplies	400
Office rent	700
Equipment rent	550
Reproduction of reports	800
Total	$33, 100

As a general rule survey costs will be kept to a minimum if (1) the architect or engineer conducting the survey thoroughly understands the nature of fallout radiation and how shielding factors relate to the problem, and has an efficient survey organization; (2) local records on existing buildings are complete, up-to-date, and readily available; and (3) a cooperative spirit exists within local government, among civic associations, and on the part of the public.

SHELTER SURVEY PLANNING

The overall management of a community shelter survey is the responsibility of the chief executive of the community or his designee, such as his civil defense director. However, it is desirable to have an experienced architect or engineer direct the details of the actual survey. Such a professional should be hired on a full-time basis. A model "General Scope of Work for Fallout Shelter Survey Contracts" is presented in supplement A, p. 11.

Although planning is largely determined by local conditions, some generalizations may be made. First, a cursory preliminary study may be worthwhile because it will indicate the variety of buildings to be analyzed and which buildings may be considered typical of a particular class. For example, every residence in a given subdivision may be so similar that a shelter analysis of one could be assumed to apply to all.

Second, shelter survey "districts" should be chosen to coincide with well-established areas such as census tracts, political precincts, or land utilization areas as determined by local planning commissions.

Third, it is important to collect information on critical structures, such as electrical power stations and waterworks, during the early phases of the survey. Also, information on public structures, such as schools and hospitals, may be collected as separate groups in addition to considering the structures as part of a given shelter district.

Finally, good public relations is essential to a successful survey. The survey will be "news" and local news media should be kept fully informed on the purpose of the survey, the manner in which it is to be conducted, and the results.

GENERAL GUIDANCE ON MAKING THE SURVEY

ORGANIZATION

The organizational setup required for a shelter survey project will depend upon time and money available, and size and nature of the area to be surveyed.

One example of organization is shown in figure 8.

In the pilot survey conducted in Montgomery, Ala., the survey team consisted of 11 persons, as follows: 3 supervisors, a secretary, and 7 others who functioned as clerks, computers, and inspectors.

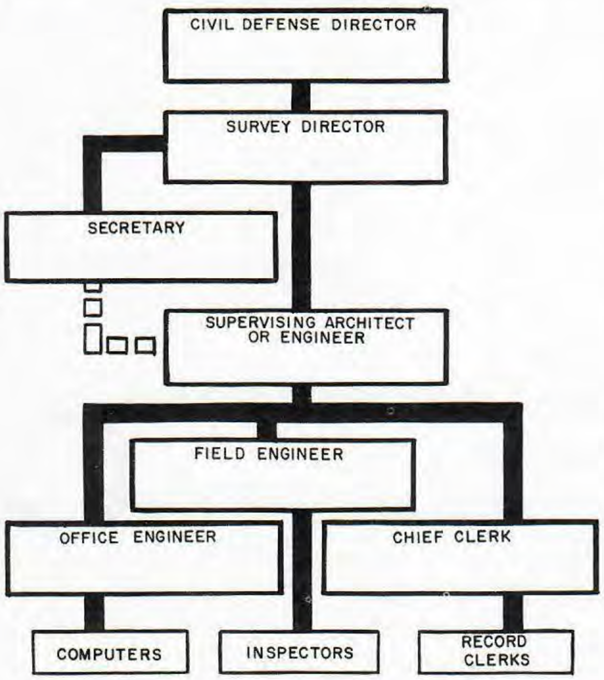

FIGURE 8.—*Shelter survey organization.*

"Task force" members must be versatile. For example, during the early stages of the project, computers may be required to work as field inspectors. Later, the reverse may be necessary.

OFFICE OPERATIONS

Principal office tasks will be calculations to determine category and capacity of existing shelter areas, preliminary cost estimates of modifications, and preparation of maps, tables, and summaries.

Sample data forms prepared by OCDM to expedite this work are shown in figure 9. Their use is detailed in the OCDM manual, *Fallout Shelter Surveys: Guide for Architects and Engineers.* Through use of six graphs included in that publication, simple arithmetic will provide all the answers necessary to fill in these forms.

Equipment and supplies ordinarily available in the office of an architect or engineer are required for office operations. In addition, use of a punch-card system for machine analysis would be particularly helpful in metropolitan areas where data is already on cards. Otherwise it may be too expensive. In some cases, however, information entered could be used later by local government on other projects, such as long-range urban planning.

Before extensive field work is started, a check should be made for pertinent records and other informational sources of local government, business, and industry. Table 3 lists some of the more important of these sources.

If good records are available, it may be advisable to have a separate group of clerical personnel spend full time transferring information from files to the data collection forms. If available records are poor, the need for higher salaried personnel will be greater because more care will be required in extracting desired information, and more field work will be necessary.

FIELD OPERATIONS

Full-scale field operations should be preceded by a "cruising" or "windshield" survey. This will familiarize inspectors with assigned territories, and will also provide valuable planning information.

As an example, visual inspection from a moving automobile often is sufficient basis for quickly designating an entire subdivision as "F" category for shelter purposes.

A cruising team is a driver and an inspector. As the team drives down a street, the inspector looks at the various structures and enters on

Fallout Shelter Survey
DATA COLLECTION FORM

(1) Survey No. ________ (2) By ____________________ (3) On ____________

(4) Location ____

(5) Description of Surroundings ______________________________

____

(6) Description of Structure:

a. General Dimensions ______________ b. Number of Floors __________

c. Floor Heights __________________ d. Sill Heights ______________

e. Basement Floor Level ____________ f. Ground Floor Level __________

g. % Basement Wall Exposed ________ h. % Areaways ________________

(7) Structural Information: Apertures

a. Roof ______________________________________ ______%

b. Ground Floor ______________________________ ______%

c. Higher Floors _____________________________ ______%

d. Exterior Walls ____________________________ ______%

e. Interior Walls ____________________________ ______%

f. Basement Walls ____________________________ ______%

(8) Non-Structural Information:

a. Occupancy __________ Business Hours __________ Other Times ________

b. Entrances & Exits ______________ c. Ventilation ______________

d. Sanitation ____________________ e. Water Supply _____________

f. Power Supply __________________ g. Hazards __________________

(9) Adaptability for Fallout Shelter ____________________________

(10) Remarks ____

____

Oct. 1959

Fallout Shelter Survey
DATA SUMMARY FORM

(1) Survey No. ________ (2) By ____________________ (3) On ____________

(4) Location ____

(5) Description of Shelter Area:

a. Location within Building ______________________________

b. General Dimensions __________________________________

c. Space Utilization ____________________________________

d. Unimproved Shelter Area*: Category ____________ Capacity ________

e. Improved Shelter Area: Category ____________ Capacity ________

(6) Required Improvements: Item Cost

a. Shielding............ ______________________ ______

b. Entrances and Exits... ______________________ ______

c. Ventilation.......... ______________________ ______

d. Sanitation........... ______________________ ______

e. Water Supply......... ______________________ ______

f. Power Supply......... ______________________ ______

g. Storage.............. ______________________ ______

h. Miscellaneous........ ______________________ ______

i. Total Cost.. ______

(7) Unit Costs:

a. Cost Per Occupant (Shielding)................. ________

b. Cost Per Occupant (Habitability).............. ________

c. Cost Per Occupant (Total)..................... ______

(8) Shelter Area Symbol............................ ______________

*Stay-time generally limited by habitability requirements.

Oct. 1959

FIGURE 9.—*Shelter survey forms.*

TABLE 3.—*Sources of information useful in fallout shelter surveys*

Sources	Remarks
Publications	
Operational Survival Plans	These plans have been completed for every State in the United States and contain much useful information for shelter surveys.
Sanborn maps	These maps can be obtained for almost every urban area in the United States with a population of 2,000 or more. They show location and construction characteristics of every building in a given area. Information on basements, type of occupancy, etc., is included.
Bureau of Census publications	Statistical abstracts, county and city data books, etc., contain detailed population information.
Topographic and geologic maps and air photos	Location of underground installations such as mines, tunnels, caves, etc.
Local government offices	
Building Department	Plans may be on file for each public building and most private buildings.
Tax Assessor's Office	Records may give summaries of construction type, size, and location of all types of buildings.
Planning Commission	Land-use maps, population studies, and general information on building types for certain areas may be available.
Department of Education	Information on schools, including student populations and possibly building plans.
Police and Fire Departments	Location and possibly building plans of all stations in the area.
Department of Public Health	Location and possibly building plans of medical facilities in the area.
Electric power, telephone, and gas companies	Location and possibly building plans of their office buildings, generating stations, etc.
Private business and associations	
Chamber of Commerce	Location and description of commercial and industrial establishments.
Architects, engineers, and building contractors	As-built drawings of buildings designed by their firms.
Building materials suppliers	Information on materials used in local building construction.
Trade associations	Information on buildings constructed using their products.
Individual building owners or managers	As-built drawings and up-to-date information on alterations.

previously prepared data sheets his estimate of a shelter category and capacity, according to street address.

Table 1 may be helpful for a quick estimate of shelter category.

Information obtained in full-scale field operations should be entered on a Fallout Shelter Survey Data Collection Form. (See example, fig. 9.)

The best way to get the facts about the fallout shelter potential of existing buildings is by specific examination of the individual structures. However, it may be possible to complete some of the survey form through use of "as-built" plans, Sanborn maps, and other pertinent records. (See table 3.)

Field personnel should carry identity cards and explanatory letters signed by the executive of local government. The letters should introduce the bearer, briefly explain the purpose of his work, and urge cooperation on the part of building owners or tenants.

D					SHELTER DISTRICT IX		
	SHELTER SPACES FOUND IN SHELTER CATEGORIES						
	EXISTING SPACES		IMPROVED SPACES BY COST OF IMPROVEMENT				
CATEGORY	NUMBER	%	a	b	c	d	TOTAL
A	276	4.4	416				416
B	298	4.6	400	8		368	776
C	191	2.9	232	140	236		608
D	385	5.9	516	232	586	20	1,354
E	5,340	82.2	8,846	44			8,890
TOTAL	6,490	100	10,410	424	822	388	12,044
	POPULATION - NIGHT TIME						28,831
	SURPLUS OR DEFICIENCY						-16,787
	DAY TIME						19,438
	SURPLUS OR DEFICIENCY						- 7,394

Tabulation of Survey District

Map of Survey District

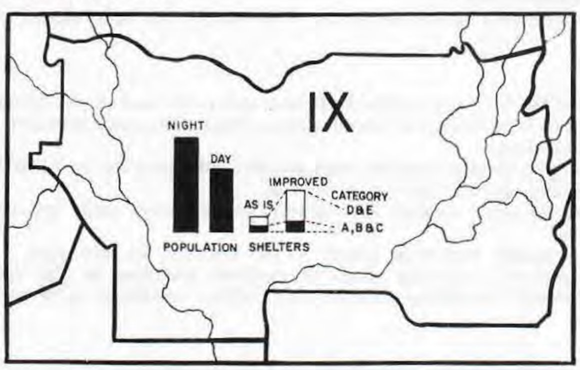

FIGURE 10.—*Sample data records.*

If an inspector finds no one available to admit him to a building, he should leave a "call-back" card. The card should give the inspector's name and survey office address and telephone number, tell the purpose of the visit, and ask that the inspector be called to arrange a convenient time for his return.

Although the primary duty of field inspectors is data collection, they are also responsible for maintaining their own files of information collected.

REPORTS

The following outline may be useful in preparing the final fallout shelter survey report:

1. Description of survey area.
2. Procedures used in the survey.
3. Summary of survey results.
4. Discussion of survey results.
5. Conclusions and recommendations.

The detailed tabulation sheets and supplementary maps should be included as appendixes or as companion publications.

Because of the voluminous nature of collated shelter survey information, concise methods of presentation must be used. One method is a three-part sequence of symbols that denote shelter category, shelter capacity, and cost per person for required improvements. Shelter category letter symbols are given in Table 1. For cost-of-improvement symbols see Table 4.

As an example, in the concise, three-part presentation "C75b," "C" denotes shelter category (with a protection factor of 50 to 250); "75" indicates a shelter capacity of 75 persons; and "b" relates to a per capita cost estimate of $25 to $50 for improvement of category, habitability, or both.

These same symbols may also be used for entry of data on tabulation sheets or maps. (See fig. 10.)

TABLE 4.—*Cost symbols for improvement of shelters*

Symbol	Estimated cost per shelter occupant
	Dollars
a	Less than 25.
b	25 to 50.
c	50 to 75.
d	75 to 100.
e	More than 100.

GENERAL SCOPE OF WORK FOR FALLOUT SHELTER SURVEY CONTRACTS

A. The contractor, in consultation with the contracting authority, shall furnish the necessary personnel, services of others, facilities, and materials and shall use his best efforts to evaluate thoroughly the fallout shelter resources located in the ____________________ (Name of city or county), hereinafter referred to as the "area," and shall prepare a report on this evaluation as well as the methods and procedures used in performing the work and services under this contract.

B. The specific studies to be undertaken will include, but will not necessarily be limited to, the following:

1. Making a complete inventory, by individual buildings, of existing and potential fallout shelters located within the area in accordance with the OCDM manual, *Fallout Shelter Surveys: Guide for Architects and Engineers.*

2. Summarizing in tables and on maps the aforesaid inventory.

3. Using the latest data available, preparing separate maps and tables to show distribution of daytime and nighttime populations of the area.

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Appendix 2
(Annex 10—National Shelter Plan)

Fallout Shelter Surveys:

GUIDE FOR ARCHITECTS AND ENGINEERS

NP–10–2
National Plan Appendix Series

Executive Office of the President

OFFICE OF CIVIL AND DEFENSE MOBILIZATION

Appendix 2
(Annex 10—National Shelter Plan)

Fallout Shelter Surveys:

GUIDE FOR ARCHITECTS AND ENGINEERS

(NP–10–2 National Plan Appendix Series)

May 1960

Executive Office of the President

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CONTENTS

SUPPLEMENTS

INTRODUCTION

The purpose of this guide is to provide architects and engineers with procedures and standards for (1) evaluating the fallout shelter potential of existing structures, and (2) modifying structures from the standpoint of radiation shielding and habitability to improve their worth as fallout shelters. These same procedures and standards may be used for preliminary design to incorporate shelter into new structures.

The standards suggested in this guide are not meant to obviate the sound professional judgment that individual cases will require. However, it is important when considering fallout shelter standards to keep in mind that *survival* is the paramount issue and that comfort is secondary. Therefore, engineering practices that have been proved sound for peacetime purposes may be somewhat unrealistic if followed to the letter in designing fallout protection. For example, local building codes and zoning regulations may require overdesign of shelters as far as survival requirements are concerned. In such cases, exceptions to the local regulations should be sought.

Emphasis in this guide is on procedures for collecting, analyzing, and summarizing information on potential shelter areas. A suggested Data Collection Form and a Data Summary Form are shown in supplement A. Detailed analysis procedural forms, intended primarily for informational and instructional purposes, also are shown in supplement A. Condensed analysis forms are in supplement E.

Explanation of the various symbols used is given in the shielding analysis outlines, parts 2, 3, and 4, supplement A.

Six charts in supplement B are used in making shielding calculations.

The methods of evaluating radiation protection used in this guide were developed from radiation penetration studies sponsored by the Office of Civil and Defense Mobilization and the Department of Defense since 1956 at the National Bureau of Standards of the Department of Commerce. The Atomic Energy Commission cooperated with OCDM in testing the theories developed from these studies. In addition, members of a subcommittee on radiation shielding of the Committee on Civil Defense, National Academy of Sciences, aided in the development of procedures described in this guide.

Architects and engineers, to whom this guide is addressed, should also read the first publication in this OCDM series, NP–10–1, *Fallout Shelter Surveys: Guide for Executives*. NP–10–1 provides background guidance for the executive—in government, industry, or other large facility—responsible for planning and directing a fallout shelter survey.

I. SHIELDING FUNDAMENTALS

FALLOUT

The detonation of a nuclear weapon near the ground causes large quantities of earth and debris to be forced up into the fireball and the resulting mushroom-shaped cloud—a cloud which may reach an altitude of 15 miles or more before leveling off. The earth and debris particles in the cloud vary in size from fine powder to large grains, and it is these particles which act as the sources of radiation that can damage living cells.

Most of the particles fall back to the earth's surface within 2 days—"early fallout"—but some remain aloft far longer—"delayed fallout." (See fig. 1.) In a nuclear attack the immediate and most serious danger would be from early fallout. Therefore, the term fallout as used in this manual refers to early fallout only.

Significant amounts of fallout do not arrive outside the blast area earlier than about one-half hour after an explosion. From then on, it begins to cover an increasingly large area and may eventually blanket thousands of square miles. At any given location, however, the elapsed time between the arrival of fallout and the cessation of deposition may be a matter of hours.

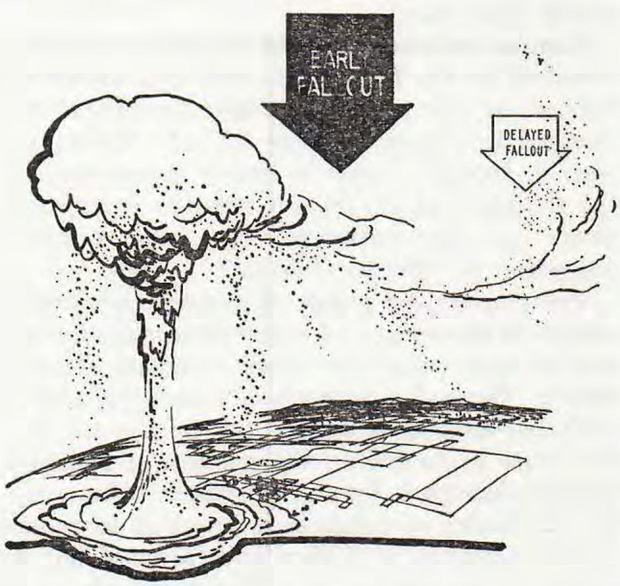

FIGURE 1.—Formation of fallout.

The distribution of fallout over large regions, and possible coverage of much of the Nation, is discussed in the first publication of this OCDM series, NP–10–1, *Fallout Shelter Surveys: Guide for Executives*.

In this guide, attention is given to the distribution of fallout particles around and on specific types of structures. It is probable that flat, builtup roofs with parapet walls would collect and retain more fallout than other roof types; and that smooth, sloping roofs without dormers or monitors would collect and retain the least. However, in the case of sloping roofs, fallout may collect in the eavestroughs and remain for some time. Effects of wind, rain, and snow on fallout deposition on various roof types are only qualitatively known. Therefore, except for special conditions indicated in part II of this guide, "Shielding Calculations," fallout will be assumed to cover roof surfaces uniformly—according to their horizontal projections (fig. 2). Further, it will be assumed that no significant amounts of fallout enter the structure itself.

Fallout deposition in the area around a structure may be of equal or greater importance than that on the structure itself. Among the factors affecting local distribution of fallout around a structure are the type, and relative location and height, of nearby buildings; position of the structure relative to geographic features, such as hills, depressions, and bodies of water; and the nature of surrounding surfaces and grounds, such as paved or unpaved, wooded or cleared. The effects of the more important factors will be discussed in part II of this guide. In general, it will be assumed that fallout covers the area surrounding the structure uniformly.

Once fallout is on the ground it may be further redistributed by the action of wind, rain, and snow. This is termed "weathering." The effects of weathering are so variable and complex they will not be considered in this guide.

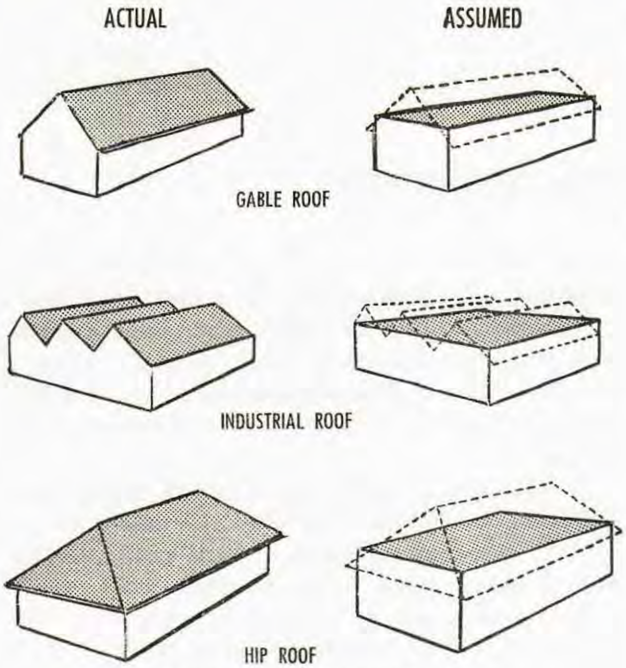

FIGURE 2.—Fallout on roofs.

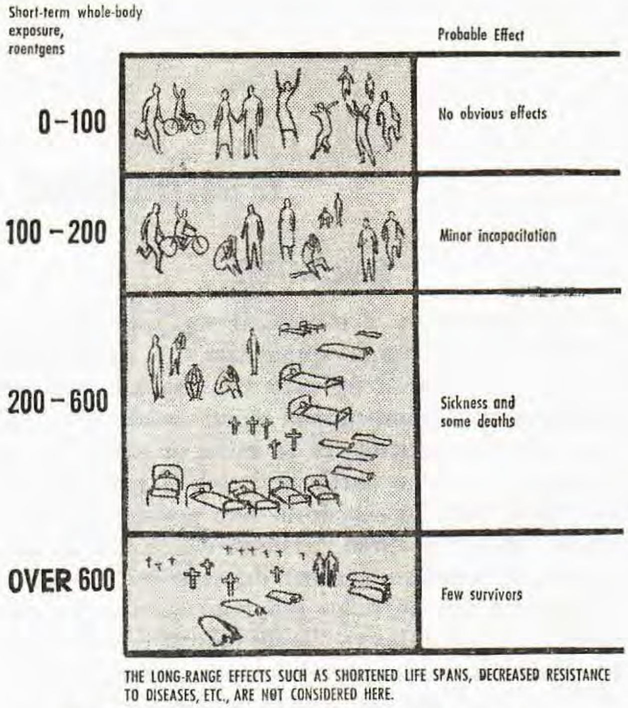

FIGURE 3.—Acute effects of gamma radiation.

Early fallout particles are generally assumed to be mostly within a range of 50 to 500 microns in size.

Three different kinds of radiation are associated with fallout—alpha and beta particles, and gamma rays. Radioactive materials that give off alpha and beta particles may be dangerous if they are ingested through contaminated food, water, or air, but from the shelter standpoint they present no problem. Alpha particles cannot penetrate the external layer of skin, and beta particles cannot penetrate heavy clothing. However, *gamma rays, like X-rays, are highly penetrating,* and can cause serious damage to living tissue. *The primary aim of fallout shelter is to provide a shield against gamma radiation.*

FALLOUT GAMMA RADIATION

Exposure doses of fallout gamma radiation are measured in units called roentgens (r). Indications of the physiological effects of various acute exposure doses are given in figure 3.

The radioactivity of fallout decreases with time—rather rapidly at first, but more slowly as time passes. A convenient rule to remember for this decay process is that for every sevenfold increase in time after detonation, the dose rate decreases by a factor of 10. For example, 3 hours after a nuclear explosion, measurements taken in an area where fallout is no longer accumulating on the ground indicate a dose rate of 50 roentgens per hour (r/hr). Assuming no weathering effects, the dose rate 18 hours later (21 hours after the explosion) would be 5 r/hr. (The quotient of the elapsed time ratio (21/3) is 7, and the predicted dose rate, 5 r/hr, is $\frac{1}{10}$th the 3-hour dose rate.)

Gamma radiation striking a barrier can be (1) absorbed by the barrier, (2) scattered within the barrier, or (3) passed through the barrier unchanged in direction. (See fig. 4.) What happens in any given case is largely determined by the thickness of the barrier and the penetrating power of the radiation. See page 4 for a discussion of "Barrier Effects."

The penetrating power of gamma radiation is related to its energy. A convenient unit of measure for this energy is "Mev" (million electron volts). Generally, the higher the energy of gamma radiation striking a barrier, the thicker the barrier must be to reduce the amount of radiation passing through it by a given factor. For example, 12 inches of concrete is required to reduce gamma radiation of ½ Mev by a factor of 100; 15 inches if the energy is 1 Mev; and about 20 inches if the energy is 2 Mev.

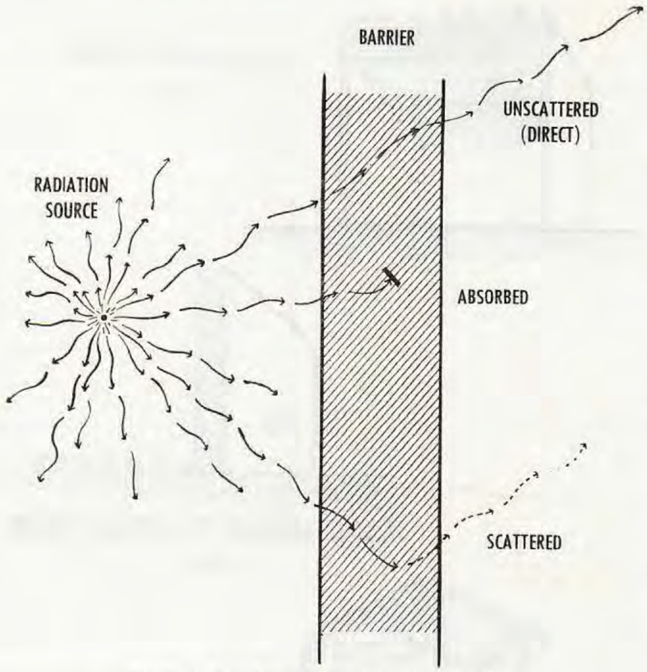

FIGURE 4.—Gamma radiation paths.

Gamma radiation from fallout consists of many energy components. These may vary up to about 3 Mev. All of the charts in this guide take into consideration the spectrum of energies associated with fission products about 1 hour after an assumed detonation. The net penetrating effect of this spectrum of energy is roughly equivalent to that of cobalt-60, for which the average energy is about 1¼ Mev.

SHIELDING TERMINOLOGY

Protection from the effects of fallout gamma radiation may be achieved in two ways. One method is to place a barrier between the fallout field and the individual. This is termed "barrier shielding." The second method is to increase the distance of the individual from the fallout field and/or reduce the extent of the fallout field contributing to the individual's dose. This is termed "geometry shielding."

In most analyses it is necessary to consider the effects of both barrier and geometry shielding. This is termed "combined shielding."

The location of the position in the structure to be analyzed for shelter is termed the "detector position" or simply the "detector."

The term "protection factor" expresses the relative reduction in the amount of radiation that would be received by a detector in a protected location compared to the amount it would receive if it were unprotected. For convenience of calculation, the reciprocal of the protection factor, called the "reduction factor," is used. Reduction factors, expressed as decimals, can be added when combining the effects of fallout on the roof over the detector (roof contribution) and fallout on the ground surrounding the detector (ground contribution). For example, the roof contribution at a given detector position may be 0.015, and the ground contribution at this point 0.010. The sum of these, 0.025, would be the total reduction factor. The protection factor in this case would be the reciprocal of 0.025, or 40.

Table 1 relates shelter categories to corresponding protection factors. It is intended to provide

TABLE 1.—*Description of shelter categories*

Shelter category	Protection factor [1]	Common examples [2]
A	1,000 or greater.	OCDM underground shelters. Subbasements of multistory buildings. Underground installations (mines, tunnels, etc.).
B	250 to 1,000.	OCDM basement fallout shelters (heavy masonry residences). Basements (without exposed walls) of multistory buildings. Central areas of upper floors (excluding top 3 floors) of high-rise buildings [3] with heavy floors and exterior walls.
C	50 to 250	OCDM basement fallout shelters (frame and brick veneer residences). Central areas of basements (with partially exposed walls) of multistory buildings. Central areas of upper floors (excluding top floor) of multistory buildings with heavy floors and exterior walls.
D	10 to 50	Basements (without exposed walls) of small 1- or 2-story buildings. Central areas of upper floors (excluding top floor) of multistory buildings with light floors and exterior walls.
E	2 to 10	Basements (partially exposed) of small 1- or 2-story buildings. Central areas on ground floors in 1- or 2-story buildings with heavy masonry walls.
F	2 or less	Aboveground areas of light residential structures.

[1] This term expresses the relative reduction in the amount of radiation that would be received by a person in a protected location, compared to the amount he would receive if he were unprotected.

[2] These examples refer to isolated structures.

[3] For the purposes of this example, "high-rise" buildings are those greater than about 10 stories; multistory buildings are those from 3 up to about 10 stories.

(1) a general idea of the relative amounts of protection offered by common types of buildings, and (2) a preliminary estimate of potential shelter areas for survey programing purposes. These protection factors may be conservative in many cases since they are based on isolated structures. For example, in the case of a building surrounded by taller buildings, the protection factor might be increased sufficiently to raise it to a higher category. In any case, on-site examination and practical judgment must be used before a protection factor is assigned to any given structure.

BARRIER EFFECTS

If a shield is placed between a radiation source and a detector, there will be a reduction in the detector reading. It is convenient to evaluate the attenuation of a given shield by its "mass thickness," which is expressed as the weight, in pounds per square foot (psf), of a solid barrier. A table of mass thicknesses for various common building materials is presented as supplement C. It may be assumed that the weights given for the various types of roof, floor, and wall construction, as found in standard engineering tables, are equivalent to the mass thickness of the construction.[1]

When analyzing the shielding effectiveness of a given barrier, it is essential to consider the relative positions of the barrier, the contamination, and the detector. For simplicity, this guide considers three cases, as follows:

1. In case 1 (fig. 5) the fallout is deposited on top of the barrier and the detector is located immediately under the barrier. This is termed "fallout on a barrier."

2. In case 2 (fig. 5) the barrier is perpendicular to the contaminated plane, which is located on one side of the barrier only, and the detector is located 3 feet above the contaminated plane on the opposite side of the barrier. This is termed "fallout adjacent to a vertical barrier."

3. In case 3 (fig. 5) the contamination and the barrier lie in the same plane. However, the fallout surrounds the barrier and does not lie directly on it. The detector is located just under the barrier. This is termed "fallout adjacent to a horizontal barrier."

Chart 1 [2] shows how reduction factors vary with mass thickness for the three cases cited above. (See also examples 1, 2, and 3 for chart 1, p. 32.)

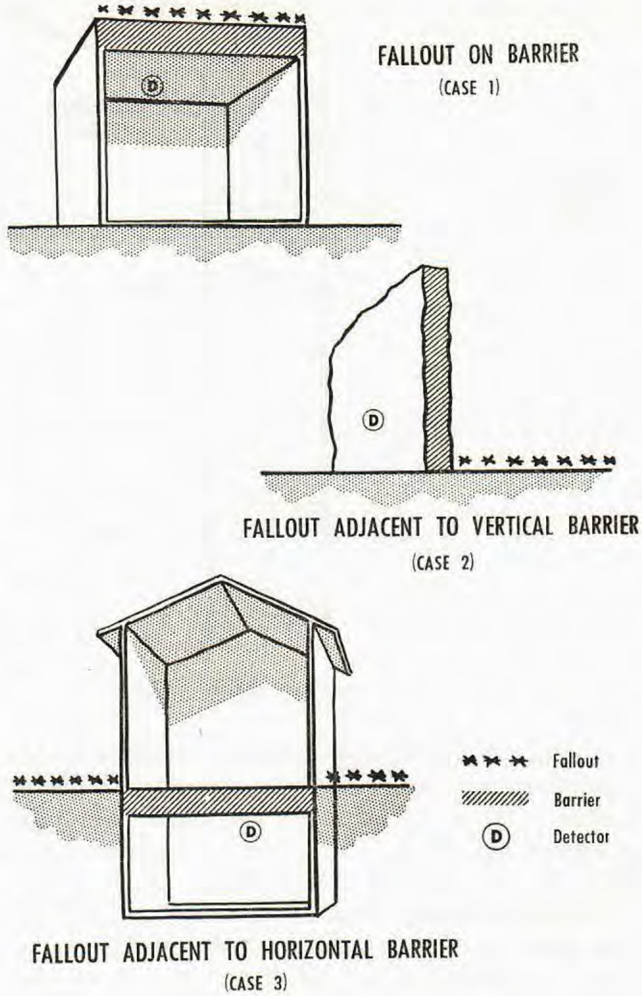

FIGURE 5.—Barrier shielding effects.

GEOMETRY EFFECTS

The concepts involved in geometry shielding may be visualized by considering a cleared circular area in a smooth contaminated plane, with a detector located over its center (fig. 6a). The dose rate measured at the detector will decrease as the size of the cleared area increases. Likewise, as the detector is raised vertically above the center of the cleared area, the dose rate decreases.

If, as in figure 6b, the contamination covers the circular area and the rest of the area is clear, the dose rate would decrease as the detector is raised or lowered vertically from the center of the contaminated circle.

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[1] A convenient reference is *Minimum Design Loads in Buildings and Other Structures* (A 58.1-1955), published by the American Standards Association, Inc., 70 East 45th St., New York 17, N.Y.: Price $1.50.

[2] "Barrier Shielding Effects." (See p. 33, supp. B.)

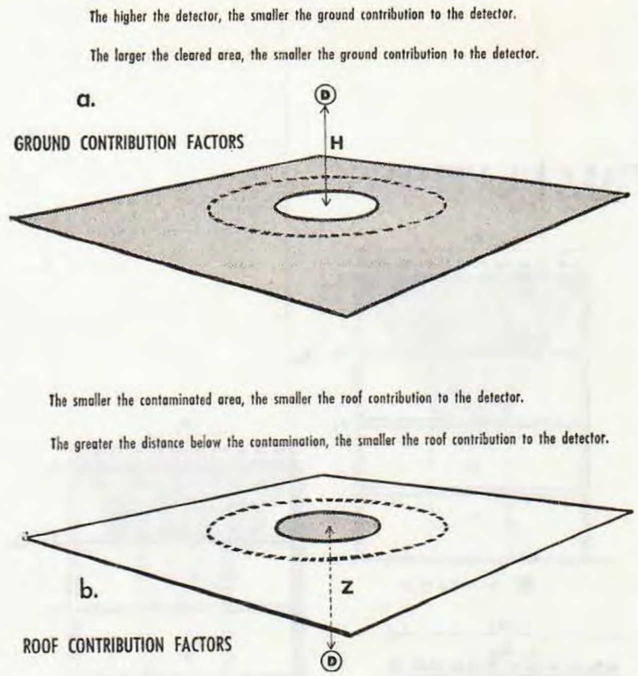

FIGURE 6.—Geometry shielding effects.

Two examples may be given from these generalizations:

1. First, if two buildings are of the same height and similar construction, but of different area, the dose rate measured at the center of the ground floor would be less in the larger building, provided the contamination of the roof is not considered. Thus, the larger the area of a structure, the less the ground contribution at the center of the ground floor.

2. In the second example, if two buildings are of equal area and similar construction, but differ in height, the dose rate measured at the center of the ground floor would be less for the higher building provided the contamination on the ground is not considered. Thus, the higher the structure, the less the roof contribution at the center of the ground floor.

The interrelationship of barrier and geometry shielding may be seen in the fact that in both of the above cases the mass thicknesses of the walls, floors, etc., also affect the dose rate at the detector.

II. SHIELDING CALCULATIONS

ROOF CONTRIBUTION

As stated earlier (p. 1), for the purposes of this guide, fallout is generally assumed to cover roof surfaces uniformly—according to their horizontal projections (fig. 2).

In a building that has relatively thin interior wall partitions (X_1 less than about 20 psf), only three factors are necessary to determine the combined shielding effects for the roof contribution (fig. 7a). First, it is necessary to know the total mass thickness (X_o) of the roof and all the floors between the contamination and the detector; second, the total area of the roof (A_r) over the detector; and third, the distance from the detector to the roof.[3] The combined shielding effect for the roof contribution, expressed as a reduction factor, is found from chart 2.[4] (See example 1 for chart 2, p. 34.)

When interior wall partitions are relatively thick (X_1 greater than about 60 psf), the actual area of the roof contamination contributing to the detector is that enclosed by the interior walls (fig. 7b). In finding the reduction factor from chart 2, the central roof area (A_c) is used instead of total roof area (A_r). (See example 2 for chart 2, p. 34.)

For buildings (fig. 7c) with interior wall partitions of intermediate thicknesses (X_1 20 to 60 psf), the contribution from the central roof area and the contribution from the remainder of the roof must be added.[5] This is done as follows:

1. Calculate the contribution from the central roof area.
2. Calculate the contribution from the total roof area, but use as a mass thickness the total overhead mass thickness (X_o) and that of the interior wall (X_1).
3. Repeat calculation 2, but use the central roof area (A_c) instead of the total roof area (A_r).
4. By subtracting the result of calculation 3 from that of 2, the roof contribution from outside the central area is obtained.

[3] For convenience, chart 2, p. 35, assumes the detector is 10 ft. below the roof (Z=10 ft.). For other Z's, the roof area is adjusted by a K factor on the same chart.

[4] "Reduction Factors for Combined Shielding Effects: Roof Contribution." (See p. 35, supp. B.)

[5] See example 3 for chart 2, p. 34.

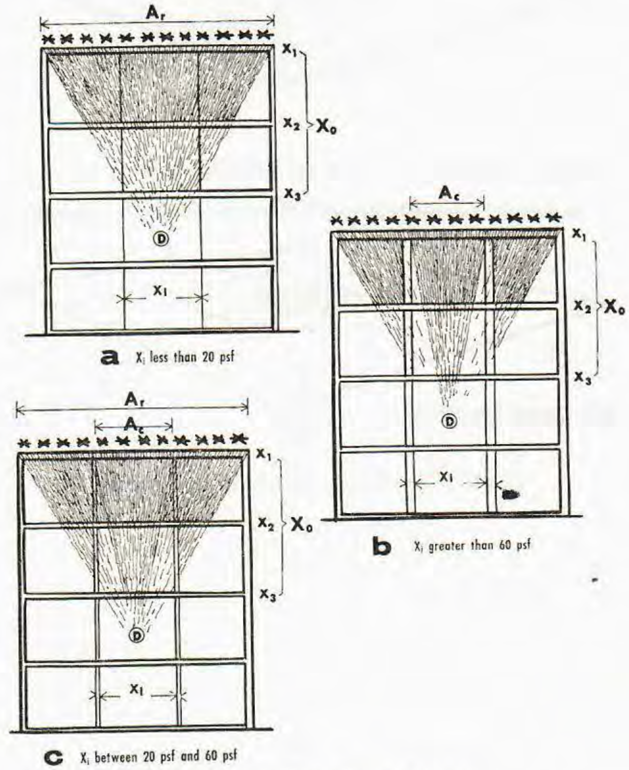

FIGURE 7.—Roof contribution.

5. The total roof contribution is the sum of items 1 and 4.

Skyshine Contribution

"Skyshine"—an effect produced by scattering of radiation by the air—is another factor that should be considered in relation to roof contribution. The effect is roughly analogous to the "sky glow" caused by scattering of light over cities on misty nights.

To account for skyshine, use is made of table CF–2 (p. 44). As will be noted, if X_o is very large, the skyshine contribution is negligible. (See example 4 for chart 2, p. 34.)

Even if a roof is decontaminated, either by weathering or by a washdown system, skyshine might still be a factor to be considered.

For skyshine correction to roof contribution—with comparisons for a contaminated and a decontaminated roof—see table CF–2 in supplement B (p. 44). Also see examples 4 and 5 for chart 2 (p. 34).

GROUND CONTRIBUTION
(Aboveground Areas)

Radiation from the ground surrounding a building must reach the detector inside by penetrating walls, windows, and doors. (See fig. 8.) Generally, a distinction is made between the radiation passing through walls and that passing through apertures. The latter case is discussed under Apertures, page 8.

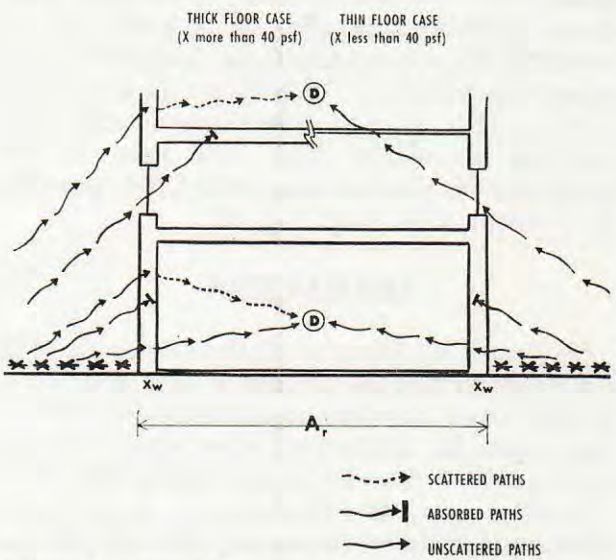

FIGURE 8.—Ground contribution (aboveground areas).

In a windowless structure, radiation reaches the detector both directly and by scattering from within the walls. These barrier effects are accounted for in the wall mass thickness (X_w) factor in chart 3.[6] The geometry effects are related to the cleared area around the detector, which is given as the ordinate on this same chart. (See example 1 for chart 3, p. 36.) If the building has no interior partitions, the wall mass thickness (X_w) equals the exterior wall mass thickness (X_e); however, when interior partitions exist, the wall mass thickness used as the abscissa in chart 3 should be the sum of the exterior and interior walls, i.e., $X_w = X_e + X_i$. (See example 2 for chart 3, p. 36.)

[6] "Reduction Factors for Combined Shielding Effects: Ground Contribution—Aboveground Areas." (See p. 37, supp. B.)

Note that for very small areas (less than 100 sq. ft.) geometry effects are no longer important, and the curve for wall barriers (case 2, chart 1), may be used to obtain the reduction factor directly.

GROUND CONTRIBUTION
(Belowground Areas)

In basement areas with virtually none of their walls exposed above grade (fig. 9), the only radiation reaching a detector from ground contamination would be that scattered by the walls on the ground floor, or skyshine through openings in these walls. All of this radiation must pass through the floor slab located immediately above the basement.

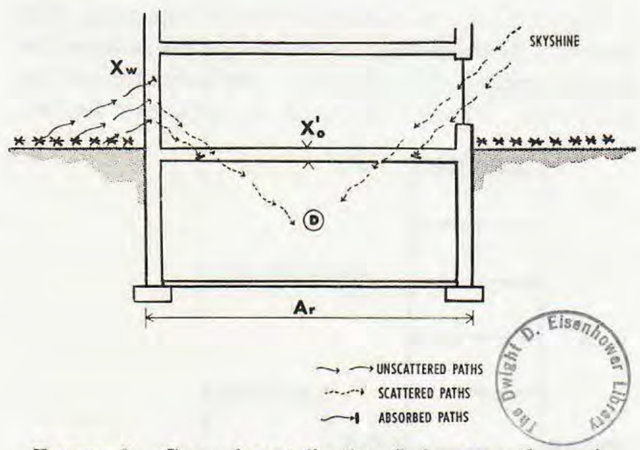

FIGURE 9.—Ground contribution (belowground areas).

For the simplest case, with windowless walls on the ground floor, chart 4[7] gives the reduction factor for radiation scattered into a detector at the center of a basement, 5 feet below the ground floor slab. To account for the mass thickness of the overhead floor slab, X'_o, it is necessary to multiply the reduction factor from chart 4 by the one obtained from the case 3 curve in chart 1. (See examples 1, 2, and 3 for chart 4, p. 38.)

Exposed portions of basement walls are computed as aboveground areas and adjusted by the percentage exposed. This adjusted ground contribution is added to ground contribution as calculated with the assumption of no exposed walls. When making the exposed-wall calculation from chart 3, the mass thickness of the basement wall, X_b, is used in lieu of X_w. (See example 4 for chart 4, p. 38.) Partitions in the basement are added

[7] "Reduction Factors for Combined Shielding Effects: Ground Contribution—Belowground Areas." (See p. 39, supp. B.)

to the basement wall, and this total mass thickness is the X_b to be used in chart 3.

To simplify belowground calculations, use is made of an "adjusted" mass thickness for the wall on the ground floor, X'_w. This is merely the product of the mass thickness of the ground floor wall and the percentage of wall without apertures. For example, if X_w equals 60 psf and windows cover 25 percent of the wall area, the proportion of wall without apertures would be 75 percent and X'_w would equal 60 psf times 0.75, or 45 psf. This last number would be the one to use in making the belowground calculation from chart 4. (See example 2 for chart 4, p. 38.)

HEIGHT EFFECTS

Upper floors of multistory buildings may offer substantial shielding and should be considered for shelter areas. (See fig. 10.) An indication of the protection afforded by such an area can be calculated by applying a height correction (chart 5 [8]) to the reduction factor for ground contribution as calculated with the assumption that the floor under consideration is a ground floor. (See example 1 for chart 5, p. 40.)

Discretion must be used when selecting the appropriate height of the detector above the contamination, because adjacent roofs can complicate matters (fig. 10b and c). The shielding effects of adjacent buildings must also be considered (fig. 10c).

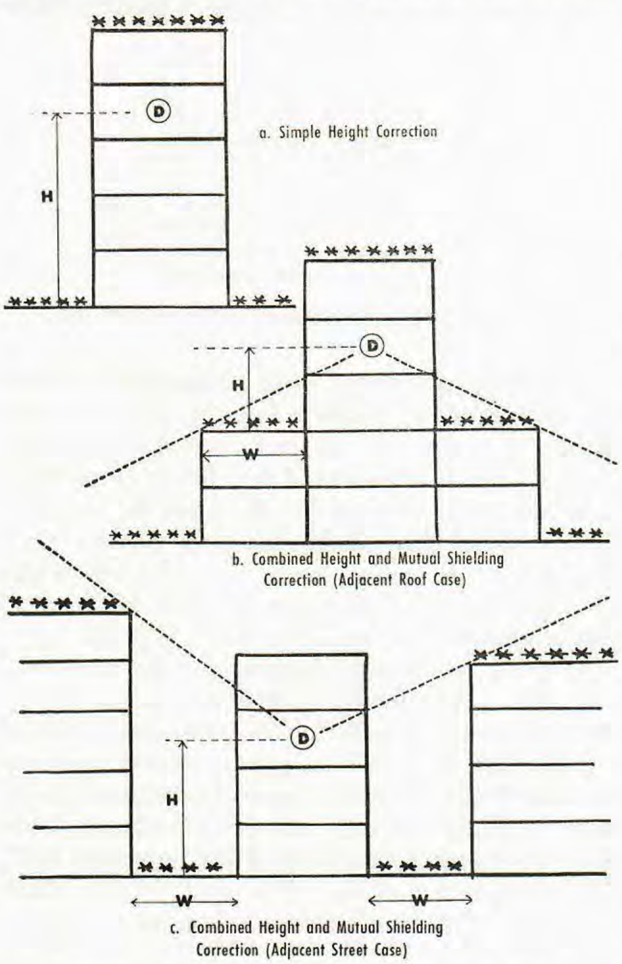

FIGURE 10.—Height and mutual-shielding effects.

MUTUAL SHIELDING

Adjacent buildings may effectively reduce the amount of radiation reaching a detector from ground contamination (fig. 10b and c). To account for this, a correction factor is applied to the ground contribution. This factor is a function of the width of the contaminated strip surrounding the shelter area. The value of the factor may be obtained from table CF–3, page 44. (See example 2 for chart 6, p. 42.)

APERTURES

Condensed shielding calculations are made with a detector located at the center of a floor area. In these cases, aperture computations are of two types: those for a detector located above sill level and those for a detector located below (fig. 11a).

In either case, the calculation for ground contribution is made on the assumption that the exterior wall has no mass thickness ($X_w = X_e = 0$ psf); or when appropriate, the windows are assumed to be shielded by the interior partitions ($X_w = X_i$) and the applicable aperture correction from table CF–1, page 44, is applied to the value obtained from chart 3. Further adjustment is made for the actual percentage of openings in the wall. (See example 3 for chart 3, p. 36.)

Note that table CF–1 is divided into a "thick floor" case and a "thin floor" case. With thick floors, it is assumed that no radiation from below reaches the detector. With thin floors, some of the radiation passing through the windows of the story below may reach the detector, because thin floors provide virtually no shielding (fig. 8).

For practical purposes, a floor of mass thickness greater than 40 psf may be assumed to be "thick", and less than that, "thin". Normally, this means

[8] "Shielding Effects of Height." (See p. 41, supp. B.)

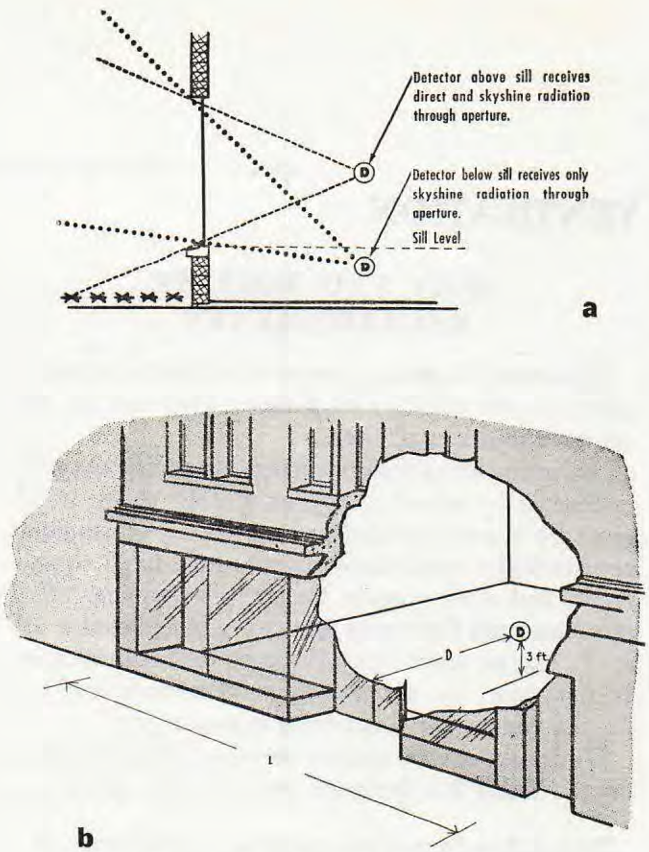

FIGURE 11.—Aperture contribution.

that concrete floor slabs are considered to be thick floors and wooden floors are considered to be thin.

An illustration of an aperture calculation is given in example 2 for chart 5, p. 40.

Many large buildings, which are otherwise rather massive, have windows extending entirely across one wall (fig. 11b). To determine the reduction factor at a given distance from an aperture that extends virtually to the ground, use chart 6.[9] It is necessary to know only the length of the aperture and the distance from it. (See examples 1 and 2 for chart 6, p. 42.) Chart 6 should be used only when considering areas on the ground floor.

To calculate the ground contribution through apertures in a basement wall, it is necessary either to assume that (1) the exposure is large enough to warrant a separate "aboveground" calculation or (2) the exposure is small enough to follow the "belowground" analysis. In general, a basement wall exposure of up to about 3 feet can be reasonably calculated using the belowground analysis.

[9] "Reduction Factors for Apertures, Ground Floor." (See p. 43, supp. B.)

PERIMETER RATIO

Reduction factors for ground contribution may be calculated on a wall-by-wall basis, providing adjustments are made for the relative length of the sides. In general, the ground contribution is calculated as if all the walls of a building are of the same construction as the wall under consideration. The final reduction factor from this computation is multiplied by the perimeter ratio of this wall. The perimeter ratio for a given wall is the quotient of its length and the total perimeter of the building. (See fig. 12.)

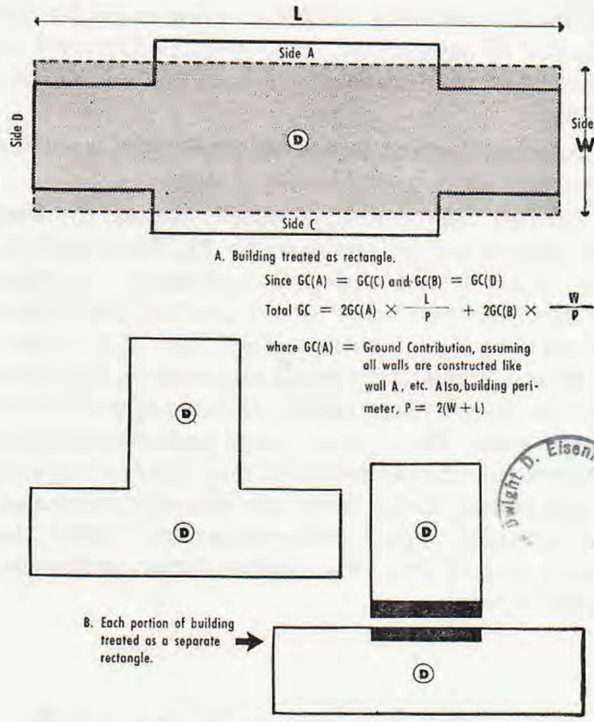

FIGURE 12.—Perimeter effects.

To find the total reduction factor for ground contribution, it is necessary to add the contribution from each wall. The wall-by-wall shielding analysis forms on pages 51 and 52 provide space for calculations for a building in which each of four walls have different shielding characteristics. (Note: The sum of all the perimeter ratios is 1.0.)

Care must be taken in applying the perimeter ratio technique to irregularly shaped buildings. Small irregularities generally can be overlooked, but simple adjustments are sometimes necessary, as in figure 12a.

Major irregularities, as exemplified by buildings of T, U, L, or H design, require handling of each wing as a separate building.

III. SPACE AND VENTILATION

GENERAL

Although a potential shelter area may provide excellent shielding from fallout radiation, its worth as a shelter is limited if it is poorly ventilated, deficient in sanitary facilities, or too small for the number of occupants. Sanitation is discussed in connection with water supplies, in part IV of this guide.

Another limiting factor on capacity of a shelter area is the anticipated length of stay.

Because fallout decays rapidly during the first few days after the explosion (p. 2), this would be the critical period of shelter occupancy. In view of this, there are many structures that lend themselves to a "core" concept (fig. 13). The "core" shelter is a relatively small area with a high protection factor, surrounded by or adjacent to a larger area that has a lower protection factor. During the critical period of stay-time, occupants would remain in the "core" shelter, with minimum, or "survival", space and ventilation. Later, the larger shelter area, with better living conditions, could be used.

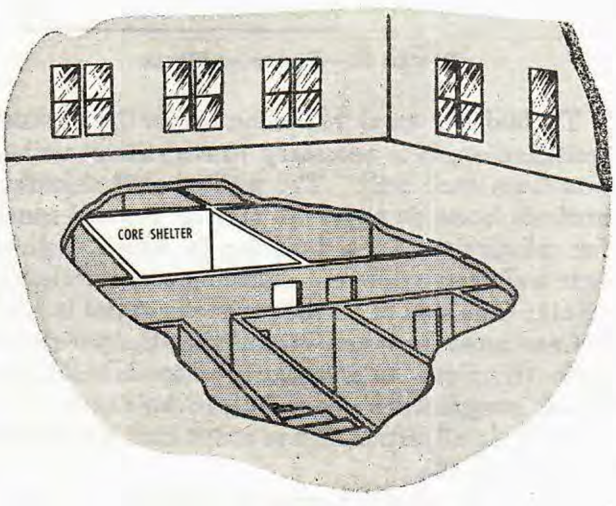

FIGURE 13.—"Core" concept.

AREA AND VOLUME REQUIREMENTS

The term "capacity", as used in shelter surveys, refers to the number of persons that can be accommodated in a shelter.

Assuming dual-purpose usage, capacity may be estimated by allowing approximately 15 sq. ft. of gross floor area per shelter occupant. Gross floor area includes such items as columns, fixed equipment, and storage space for shelter supplies. The minimum net floor area allowance per person is 10 sq. ft. except when using the core shelter principle. In that case, the net area may be reduced to 8 sq. ft. per person for short-term occupancy.

Optimum use of shelter requires detailed planning. Table 2 is designed to aid in this planning.

TABLE 2.—*Factors for shelter capacity planning*

Activity	Floor space required	Remarks
	Sq. ft.	
Sleeping in cots	30	Includes aisle space.
Sleeping in double bunks.	15	Includes aisle space.
Sleeping in triple bunks.[1]	10	Includes aisle space.
Sitting	8	Includes aisle space.
Walking		Use aisle space.
Storage	2	Includes space for food, bunks, etc.
Fixed equipment	As required	

[1] Specially constructed emergency bunks.

In general, it may be assumed that at any given time one-half of the occupants are in bunks and the other half are sitting, standing, or walking. When evaluating or designing shelters based on the "core" concept, it may be desirable to consider all occupants as sitting, and therefore allocate 8 sq. ft. per person.

Shelter capacity or occupancy time may be limited by the volume of the room and not by its area. This is particularly true if mechanical ventilation is inadequate. For rough estimating, each shelter occupant should be allowed at least 500 cu. ft., where no mechanical ventilation is available. This would permit shelter occupancy for about a day before conditions become intolerable. In many cases, however, interior stairwells, shafts, and ducts would create enough natural ventilation to extend stay-time markedly.

VENTILATION REQUIREMENTS

The basic requirement for a shelter ventilation system is that it provide a safe and tolerable environment for a specified shelter occupancy time. In areas of very light fallout, occupancy time may be as little as one day. In areas of heavy fallout, it may be as much as 2 weeks or more, but occupants probably could spend some time outside the shelter after the first few days.

The following are important considerations in the ventilation of shelters:

1. Oxygen supply is generally not a critical factor. Carbon dioxide is. The carbon dioxide concentration should not exceed 3 percent by volume, and preferably should be maintained below 2 percent by volume. Three cfm per person of fresh air will maintain acceptable concentrations of both oxygen and carbon dioxide.

2. A combination of high temperature and high humidity in a shelter may be hazardous. An effective temperature of 85° F. should not be exceeded.

3. If recommended sanitation and ventilation standards are followed, odors within a shelter should not be unacceptable under the short-term emergency situation.

Based upon the above factors, the following minimum standards for ventilation may be used as guidance in making shelter surveys and for preliminary design purposes:

1. If no mechanical ventilation is available, a net volume of 500 cu. ft. per person may be used for estimating shelter capacity.

2. If mechanical ventilation is used, at least 3 cfm of fresh air per person should be provided to permit full shelter occupancy. If there is no provision for cooling the air, provision should be made for increasing the fresh air supply during hot or humid weather.

3. If equipment is available for mechanical ventilation at rates of less than 3 cfm of fresh air per person, with occupancy estimated on the basis of floor area, the net volume of space required per person may be determined from table 3.

4. The installation of equipment for the artificial cooling of air for shelter purposes only should be avoided if possible.

5. A heating system generally is not essential. Use of blankets, heavy clothing, etc., for warmth usually will suffice when outside air temperatures are low.

TABLE 3.—*Relation of space requirements to ventilation*

Rate of air change (minutes) [1]	Volume of space required per person
	Cu. ft.
1,000+	500
600	450
400	400
200	300
100	200
60	150
35	100
22	65

[1] Computed as the ratio, $\frac{\text{Net volume of space (cu. ft.)}}{\text{Fresh air supply (cfm)}}$

EXAMPLE for table 3, "Relation of Space Requirements to Ventilation"

Given:

A potential shelter area with clear floor dimensions of 60 by 90 ft., and a ceiling height of 10 ft.

Find:

1. The capacity: based upon adequate ventilation (3 cfm or more of fresh air per person), at least 15 sq. ft. of floor area per person, and at least 65 cu. ft. of space per person.
2. The capacity: based upon no ventilation (½ cfm or less of fresh air per person) and 500 cu. ft. of space per person.
3. The capacity: based upon ventilation with 270 cfm of fresh air supplied by a blower.

Solution:

1. Floor area $=60\times90=5{,}400$ sq. ft.
   Volume $=5{,}400\times10=54{,}000$ cu. ft.
   Capacity $=\frac{5{,}400}{15}=\underline{360}$ persons
   or
   Capacity $=\frac{54{,}000}{65}=\underline{830}$ persons
   (The smaller capacity, 360 persons, governs.)
2. Volume $=54{,}000$ cu. ft.
   Capacity $=\frac{54{,}000}{500}=\underline{108}$ persons
3. Volume, $V=54{,}000$ cu. ft.
   Fresh air, $Q=270$ cfm
   Ratio, $\frac{V}{Q}=200$ min. for air change
   From table 3, when $\frac{V}{Q}=200$, the required space per person $=300$ cu. ft.
   Capacity $=\frac{54{,}000}{300}=\underline{180}$ persons

FILTER REQUIREMENTS

Weatherproof air intakes should be provided for the ventilation systems of all shelters to keep out rain and fallout particles. For home shelters with hand-operated blowers, a simple hooded intake is considered sufficient. For larger shelters, however, fresh-air intake velocities of mechanical ventilation systems may be high enough to draw fallout particles into the shelters. Therefore, good quality commercial air filters should be installed. High-efficiency filters that would remove submicron sizes of particles are not required for fallout shelter.

If filters or plenum chambers where radioactive particles can accumulate are in or adjacent to a shelter area, they should be shielded. The following is a guide for sizing the filter shields, which may be walls, or floors above or below the filter:

Intake (cfm)	*Mass thickness (psf)*
100	40– 60
1,000	80–120
10,000	160–240

IV. WATER SUPPLY AND SANITATION

GENERAL

As in the case of space and ventilation, shelter occupancy time is an important factor in water supply and sanitary requirements. However, a distinction should be made between occupancy time within the designated shelter area and within the building itself. (See discussion of the "core" concept on page 10.)

This means that water sources and sanitary facilities available to the entire building—both inside and outside the main shelter area—should be considered in evaluating a structure for shelter.

WATER SUPPLY REQUIREMENTS

A supply of potable water is essential. At least one-half gallon per day must be readily available to each occupant. In addition, it is highly desirable to have another one-half gallon of water per day per person for hygienic purposes.

Of the available water supply, at least 1 gallon per person should be stored *inside the shelter* (e.g., 100 gallons for a 100-person shelter). A storage tank connected to an existing waterline in regular use would insure that the stored water would be fresh when needed.

A reliable well in or adjacent to the shelter area is the best source of supply. However, if it can be assumed that the normal public water supply will be available under war-emergency conditions, consideration may be given to its use. Before relying on this source for drinking water, it should be ascertained that the water would be uncontaminated and that the treatment and pumping plant would be in operation. This requires fallout shelter for the operators and an auxiliary power source if there is likelihood that normal power would be disrupted. If the public water supply is from wells, there would be less danger of contamination by radioactive particles.

Colloidal and soluble radioactive isotopes could be hazardous if sufficient quantities of fallout contaminate a water source. Exposed surface sources such as reservoirs of public water systems are the most vulnerable to this type of contamination. Use of water from these sources may be dangerous for drinking, but not dangerous for such uses as washing or flushing.

To determine the overall water supply available to a shelter area, both outside sources and those within the building should be considered. A most desirable type of outside source would be a large covered water tower or reservoir which is connected to the building by a gravity piping system. To determine actually how much water would be available to a given shelter area, a general analysis must be made of all potential users that would be dependent upon this outside source during an emergency.

In larger buildings, water in hot water tanks, fire reserve tanks, house storage tanks, or in the piping systems, may be a good resource. However, water from each source should be checked to see if it is potable. In residences, hot water tanks are excellent sources of potable water; and if ample warning is received, bathtubs and sinks could be filled before the arrival of fallout.

SANITARY REQUIREMENTS

Because of the confined and crowded living conditions that sheltering might require, sanitation could be a major problem.

Personal cleanliness would have to be encouraged. Metal or plastic hand basins, with buckets for water distribution, would be adequate.

In family shelters, human waste may be disposed of through use of newspapers, plastic bags, or other disposable containers. These would then be deposited in tightly covered containers. A suitable type of chemical toilet may also be used.

In the larger group shelters, regular or austere flush-type toilets, or chemical toilets, should be available on the basis of 1 per 70 occupants. Half of these may be outside the shelter area if readily available in other parts of the building.

A suggestion for austere demountable manual flush-type toilet facilities is the use of long, wall-hung galvanized sheet metal urinals, and long, wall-hung and leg-supported galvanized sheet metal toilets with smooth board edge seats. The urinals and toilets should be provided with outlets designed for quick coupling to Y's and traps in the soil stacks. Water supply should be available at the flushing end of the urinals and toilets. Tapped wall inserts and bolts should be provided for quick fastening of the urinals and toilets. Fixtures of this type would be stored in a manner similar to that for bunks and bedding, for installation immediately upon occupation of the area for shelter purposes.

In-shelter storage of wastes would take up valuable space. Therefore, for long stay-times, installation of sewage pumps or ejectors should be considered—for use with either chemical or flush-type toilets.

Trash and garbage should not be allowed to accumulate. While inside the shelter, it should be kept in tightly covered containers; and it should be deposited outside the shelter area as often as necessary.

V. POWER SUPPLY AND OTHER FACTORS

ELECTRIC POWER REQUIREMENTS

In all but family and small group shelters, electric power will be needed to operate motors and to provide light. The greatest load probably would be for the ventilation system. If a special emergency ventilation system is installed, fan motor power requirements may be kept to a minimum. In many cases, it may be more desirable to modify an existing ventilation system. In this case, the minimum power requirement must be determined by the size of the existing fan motors. This may be far more than the basic emergency system requirements.

Other electrical motors that may be required for larger group shelters include those for a water well pump and a sewage ejector pump.

Lighting is not a critical factor in electrical power requirements. A minimum illumination level of only 5 foot-candles should be sufficient for most of the shelter area. Higher levels may be needed in "activity" areas, but power required for light should still constitute only a small part of the total electric load.

The best source of emergency electric power is an engine-generator set with an adequate supply of fuel—preferably a 2-week supply. The relative merits of gasoline, diesel, and liquefied petroleum gas engines should be carefully considered. Initial cost is important, but so are local code requirements, ease of maintenance, dependability, safety of operation, and storage characteristics of fuels.

The capacity of emergency engine-generator sets may range from 1 to 10 kilowatts per 100 shelter occupants, depending upon lighting and equipment requirements, and dependability of outside power. Normally, the requirement would be in the lower half of this range.

If the power station has fallout protection, and operational plans provide for the continued operation of the station under fallout conditions, it may be assumed that electric power would be available. Under such circumstances the capacity of the shelter emergency generator set may be limited to the lighting and ventilation loads, or to the lighting load alone, if such a calculated risk is acceptable.

ENTRANCES AND EXITS

Entrances, exits, and other openings can markedly affect shelter category and capacity—for example, large garage-type doors in the basement walls of many commercial buildings. Doors of this type, used for belowground shipping service and parking areas, have low mass thicknesses and are in exposed positions. This can result in a low protection factor for basement areas where the factor might otherwise be high.

Baffle walls can be used to shield entryways and other openings (fig. 14). In any given instance the baffle wall should be of a mass thickness that will provide the category of protection desired for the shelter. In most cases this mass thickness should be equivalent to X_w or X_b, whichever is appropriate. Exceptions to this will be those cases where the mass thickness of X_w or X_b is extremely high (e.g., a granite wall 3 feet thick).

In some cases, stairwells entering shelter areas have open sides and it may be necessary to provide shielding walls to enclose them. In general, the mass thickness of these walls need not be greater than 100 psf.

Accessibility may affect fill-time of a shelter. As an example, the basements of some large buildings may in themselves have high capacity. However, these same areas may be served chiefly by elevators and may have only one or two narrow stairways for entry. In an emergency, the elevators may not function, and fill-time would be lengthened appreciably.

Local fire codes may be useful in determining accessibility and fill-time. In regard to these two factors, however, it should be kept in mind that a heavy concentration of fallout is not likely to occur immediately following the explosion of a nuclear weapon some distance away.

HAZARDS

Sometimes areas that offer good protection from radiation are used for storage of dangerous materials or have other dangerous conditions.

Architects and engineers should carefully consider all types of hazards before designating areas as suitable for use as shelters.

Some of the hazards to look for are storage of explosives, or highly combustible materials such as paints, varnishes, and cleaning fluids; or exposed high-voltage equipment.

If the amount of dangerous material in storage is small and readily movable, or the hazard can be isolated, the capacity rating of the shelter should not be affected.

Local fire codes should be consulted to determine which materials are hazardous.

VI. COMMUNITY SURVEY PROCEDURES

Administrative information on programing and planning a community fallout shelter survey, and general guidance on making the survey, is presented in the first of this OCDM series, NP–10–1, *Fallout Shelter Surveys: Guide for Executives.*

As pointed out in that guide, the overall management of a community shelter survey is the responsibility of the chief executive of the community or his designee, such as his civil defense director. However, a professional architect or engineer, preferably from local government, should direct the details of the actual survey, on a full-time basis.

It is important that the survey director thoroughly understand the nature of fallout radiation and how shielding factors relate to the problem. This, and an efficient survey organization, will help keep survey costs at a minimum. Other factors that will help keep costs down are: Complete, up-to-date, and readily available local records on existing buildings; and a cooperative spirit within local government, among civic associations, and on the part of the public.

Good public relations is essential to a successful survey. This point should be emphasized to all those who take part in the work. Another thing to remember is that the survey will be news. It is important that the survey director and the local chief executive who is administering the project be in agreement on procedures for keeping local news media fully informed on the purpose of the survey, on progress, and on results.

The survey director should be thoroughly familiar with the objectives of the survey and the benefits to be expected. He should know that fallout shelter surveys implement the *National Policy on Shelters,*[10] and broaden the base of information used to make policy decisions at local, State, and national level. Locally, this information is a prerequisite to: A shelter utilization program, a shelter improvement program, or a shelter construction program. Such information is useful also in progressive city planning.

[10] Announced May 7, 1958, by Leo A. Hoegh, Director, OCDM, at the direction of the President.

The survey director will need to determine the probable cost of the survey; the time, skills, and manpower required; the best available sources of information; and the type of task force organization best suited to the local situation. Following are some guidelines concerning these factors:

1. From experience on pilot surveys, an estimate of cost may be obtained by multiplying the peak population of an area by 10 cents, multiplying the number of individual structures in the area by 50 cents, and taking the higher of these two figures as the estimate.

2. Generally three-fourths of the total estimated cost may be allocated for salaries. Sufficient personnel should then be obtained to complete the project in the shortest period of time consistent with the available manpower.

3. Personnel with the required skills, such as engineers, inspectors, computers, draftsmen, and clerks, are usually available within local government. Such personnel may often be obtained on a loan basis to establish a short-term task force to conduct the fallout shelter survey. This staff might be augmented by temporary personnel obtained through established local civil service rosters. Local government may also be able to provide office space, equipment, and furnishings, and administrative, accounting, and printing or other reproduction services. Use of regular personnel, facilities, and services of local government has other important advantages; for example, indoctrination and retention of "know-how" within the local government organization.

4. Before extensive field work is started, a check should be made for pertinent records and other informational sources of local government, business, and industry. Table 4 lists some of the more important of these sources.

5. The type of organization to be used in any given survey is largely dependent upon the size and nature of the area to be surveyed, the manpower available, and the method of collecting and recording pertinent data.

Engineers and inspectors should be trained in the methods and techniques to be used in the

TABLE 4.—*Sources of information useful in fallout shelter surveys*

Sources	Remarks
Publications, maps, and photos	
Operational Survival Plans	These plans have been completed for every State in the United States and contain much useful information for shelter surveys.
Sanborn maps	These maps can be obtained for almost every urban area in the United States with a population of 2,000 or more. They show location and construction characteristics of every building in a given area. Information on basements, type of occupancy, etc., is included.
Bureau of Census publications	Statistical abstracts, county and city data books, etc., contain detailed population information.
Topographic and geologic maps and air photos	Location of underground installations such as mines, tunnels, caves, etc.
Local government offices	
Building Department	Plans may be on file for each public building and most private buildings.
Tax Assessor's Office	Records may give summaries of construction type, size, and location of all types of buildings.
Planning Commission	Land-use maps, population studies, and general information on building types for certain areas may be available.
Department of Education	Information on schools, including student populations and possibly building plans.
Police and Fire Departments	Location and possibly building plans of all stations in the area.
Department of Public Health	Location and possibly building plans of medical facilities in the area.
Private businesses and associations	
Electric power, telephone, and gas companies	Location and possibly building plans of their office buildings, generating stations, etc.
Chamber of Commerce	Location and description of commercial and industrial establishments.
Architects, engineers, and building contractors	As-built drawings of buildings designed by their firms.
Building materials suppliers	Information on materials used in local building construction.
Trade associations	Information on buildings constructed using their products.
Individual building owners or managers	As-built drawings and up-to-date information on alterations.

particular survey area before field operations are undertaken. These personnel should be given a short course on general use of this guide, and they should practice by making sample calculations on the various types of dwellings and other structures common to the particular area under consideration.

DATA COLLECTION

Where accurate and complete data is available from existing records such as may be found in a tax assessor's office, or from sources such as "as-built" plans or Sanborn maps, it may be possible to have clerical personnel or draftsmen transfer or copy this information onto the data collection form. (See part 1, supp. A.)

In most metropolitan areas, the above procedure should be confined to structures other than dwellings, because the category of dwellings usually can be determined in cruising (windshield) surveys.

In this type of survey, a preliminary analysis can be made of the various types of dwellings in the entire survey area to determine which dwellings may be considered typical of each class. For example, every residence in a given subdivision may be so similar that an analysis of one could reasonably be assumed to apply to all.

A cruising (windshield) survey team is a driver and an inspector. As they go down a street, the inspector looks at the various dwellings and enters on previously prepared data sheets his estimates of the shelter category and capacity, according to street address. Visual inspection in this manner is sufficient to classify each dwelling. Often a cruising team can readily designate an entire slab-on-grade subdivision as "F" category for shelter purposes.

Where records are not available, up-to-date, or reliable, inspectors would then make on-site inspections to obtain the basic data required to analyze the major structures.

In any case, it usually is necessary to survey each major structure individually. This is because of structural complexities, and because the best of plans will not show the disposition and nature of many items, such as equipment, stored goods, and furniture; nor do they usually indicate the state of repair or other factors that may have a marked effect on the area's worth as shelter, or on the cost of improvement.

Field personnel should carry identity cards and explanatory letters signed by an executive of the local government. The letters should introduce the bearer, briefly explain the purpose of his work, and urge cooperation on the part of building owners or tenants.

If an inspector finds no one available to admit him to a building, he should leave a "call-back" card. The card should give the inspector's name and survey office address and telephone number, tell the purpose of the visit, and ask that the inspector be called to arrange a convenient time for his return.

For shelter survey purposes, "districts" should be chosen to coincide with well-established areas such as census tracts, political precincts, or land-use areas as determined by local planning commissions.

Several engineer-inspector teams may be assigned to one supervising engineer to do a particular district of a city or to specialize by type of structure, such as public, commercial, or industrial buildings. There will be fewer correlation problems if assignments are made by districts.

Critical structures, such as electric power stations and waterworks, should be analyzed first to determine whether or not they may be operable in a war emergency. Special attention should be given to public structures, such as schools, hospitals, and government buildings. These structures usually are strategically located in respect to population distribution, and often offer good shelter areas.

Information obtained on individual structures should be entered on the fallout shelter survey data collection form. (See part 1, supp. A.)

The latest available data on the population and its distribution may be obtained from updated census data which should be available from either the Bureau of the Census, the local Chamber of Commerce, or some other reliable source.

DATA ANALYSIS

The data and information collected in fallout shelter surveys is used to (1) analyze each structure and determine the existing protection afforded (protection factor and category) against fallout radiation; (2) determine the number of persons that can be sheltered in a structure; (3) estimate the possible shielding improvements that could be made at reasonable cost to belowground areas to raise the category of protection; (4) estimate the possible habitability improvements (ventilation, sanitation, and water supplies) that could be made at reasonable cost to increase the number of shelter spaces; and (5) estimate the total cost.

Comprehensive step-by-step shielding analysis procedures are outlined in supplement A for three general cases; that is, Roof Contribution (part 2), Ground Contribution—Aboveground Areas (part 3), and Ground Contribution—Belowground Areas (part 4). Roof and ground contributions are combined in a separate outline (part 5), which also compares existing and modified protection factors. These shielding analysis outlines are intended for instructional purposes.

To facilitate the survey analysis procedure, several steps have been combined and the outlines simplified so that aboveground or belowground areas may be analyzed on a single page.

For community fallout shelter surveys, single-family residences and one-story buildings with light interior partitions should be analyzed through use of the "condensed" forms shown in parts 1 and 2 of supplement E. For analysis of other structures, the comprehensive wall-by-wall procedures shown in parts 3 and 4 of supplement E should be used. Many structures have several potential shelter areas. Because each area may have a different protection factor, each should be analyzed separately.

A summary form for recording the results of an analysis is presented as part 6 of supplement A.

After an architect, engineer, or inspector has analyzed a few structures, he will find that once the "input" data is assembled, even a complex structure can be analyzed in a short time.

Charts 1 through 6 and tables of correction factors are provided in supplement B for use in shielding analysis. For reference, a "Brief Table of Mass Thicknesses" is included as supplement C.

For planning purposes in shelter surveys, shelter habitability standards may be based on a maximum floor-space requirement of 15 sq. ft. per person, and a maximum shelter-occupancy time of 2 weeks.[11] It may be assumed that basement windows of dwellings would be filled in by the occupants with readily available materials.

Analysis of the ventilation problem should be confined initially to a comparison of the capacity of the existing equipment, if any, and the number of persons this equipment can accommodate.

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[11] See par. 1, "Ventilation Requirements," p. 11.

Pilot surveys indicate that $25 per occupant of improved shelter may be used in estimating the cost of habitability improvements—ventilation, sanitation, water supply, and power supply—in order to develop the full shelter capacity. A more detailed cost analysis should be made when improvements are actually contemplated.

Standard items selected for shielding improvements should be costed according to local prices for materials and labor. Examples of these standard items are shown in figure 14.

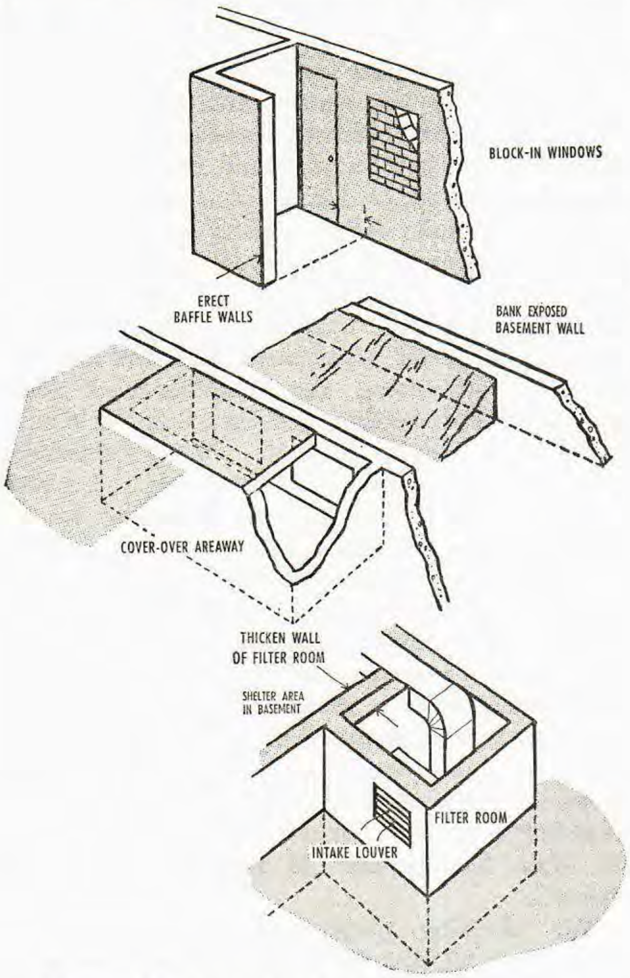


FIGURE 14.—Examples of shielding improvements.

Following are some of the things that can be done to improve shielding:

1. Block-in windows or raise sill level.
2. Cover areaways.
3. Erect baffle walls at entrances and exits.

(NOTE.—4, 5, and 6 are generally not feasible for above-ground areas.)

4. Increase mass thickness of wall construction.
5. Increase mass thickness of roof construction.
6. Increase mass thickness of floor construction.
7. Reduce exposure of basement walls.
8. Shield filter room or plenum chamber. (See p. 12.)

REPORTS

The following outline may be useful in preparing the final fallout shelter survey report:

1. Description of survey area.
2. Procedures used in the survey.
3. Summary of survey results.
4. Discussion of survey results.
5. Conclusions and recommendations.

The detailed tabulation sheets and supplementary maps should be included as appendixes or as companion publications.

Because of the voluminous nature of the collated shelter survey information, concise methods of presentation must be used. (See fig. 15.) One method is a three-part sequence of symbols that denote shelter category, shelter capacity, and cost

D					SHELTER DISTRICT IX		
	SHELTER SPACES FOUND IN SHELTER CATEGORIES						
	EXISTING SPACES		IMPROVED SPACES BY COST OF IMPROVEMENT				
CATEGORY	NUMBER	%	a	b	c	d	TOTAL
A	276	4.4	416				416
B	298	4.6	400	8		368	776
C	191	2.9	232	140	236		608
D	385	5.9	516	232	586	20	1,354
E	5,340	82.2	8,846	44			8,890
TOTAL	6,490	100	10,410	424	822	388	12,044
	POPULATION - NIGHT TIME						28,831
	SURPLUS OR DEFICIENCY						-16,787
	DAY TIME						19,438
	SURPLUS OR DEFICIENCY						- 7,394

Tabulation of Survey District

Map of Survey District

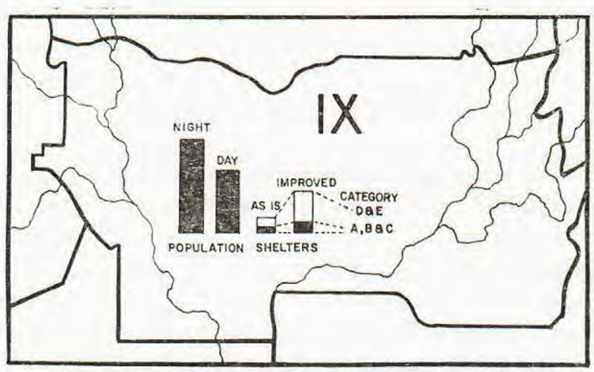


FIGURE 15.—Sample data records.

per person for required improvements. Shelter category letter symbols are given in table 1, and the cost of improvements (exclusive of supplies) may be reported using the symbols given in table 5.

TABLE 5.—*Cost symbols for improvement of shelters*

Symbol	Estimated cost per shelter occupant
	Dollars
a	Less than 25.
b	25 to 50.
c	50 to 75.
d	75 to 100.
e	More than 100.

As an example, in the concise, three-part presentation "C75b." "C" denotes shelter category (with a protection factor of 50 to 250); "75" indicates a shelter capacity of 75 persons; and "b" relates to a per capita cost estimate of $25 to $50 for improvement of category, habitability, or both.

These same symbols may also be used for entry of data on tabulation sheets or maps.

DATA COLLECTION FORM [1]

(1) Survey No. ______________ (2) By ______________________ (3) Date __________

(4) Location ____

(5) Description of surroundings ____

____

(6) Description of structure:

a. General dimensions ______________________ b. Number of floors ______________

c. Floor heights ___________________________ d. Sill heights __________________

e. Basement floor level _____________________ f. Ground floor level ______________

g. % basement wall exposed _________________ h. % areaways __________________

(7) Structural information: *Apertures*

a. Roof ____ ________%

b. Ground floor ____ ________%

c. Higher floors ____ ________%

d. Exterior walls ____ ________%

e. Interior walls ____ ________%

f. Basement walls ____ ________%

(8) Nonstructural information:

a. Occupancy ____________ Business hours ____________ Other times ____________

b. Entrances, exits _______________________ c. Ventilation ___________________

d. Sanitation ____________________________ e. Water supply _________________

f. Power supply __________________________ g. Hazards _____________________

(9) Adaptability for fallout shelter ____

(10) Remarks ____

____

[1] See Part 1-A, following, for instructions on filling out this form.

Instructions for Completing the Fallout Shelter Survey Data Collection Form [1]

1. Appropriate file number. This may be keyed to shelter district number, census tract number, etc.
2. Name of inspector.
3. Date data was collected.
4. Street address and shelter district, or name of subdivision, tract, precinct, etc.
5. Land use (industrial, commercial, residential, etc.). Height and general description of adjacent buildings; e.g., four-story brick loft building and two-story brick residence. In urban areas, include distances to adjacent buildings.

6a. Overall length, width, and height; L-shaped, T-shaped, U-shaped, etc. Make sketch on graph paper on reverse side of Data Collection Form.
6b. Self-explanatory.
6c. Give basement floor height as, e.g., B10½ ft.; ground floor height as, e.g., G15 ft.; and upper floor heights as, e.g., U9½ ft.
6d. Self-explanatory.
6e. Distance from basement floor to average ground line outside (level lot). Distance from basement floor to highest and lowest ground line (sloping lot).
6f. Distance from ground floor to average ground line outside.
6g. Estimate percent of basement wall above grade.
6h. Estimate percent of basement wall in areaways.
7a. State type of roof construction and estimate percent of roof area with skylights, hatches, etc.
7b and 7c. State type of floor construction and estimate percent of floor area with stairwells, elevator shafts, etc.
7d, 7e, and 7f. State type of wall construction and estimate percent of wall area with windows, doors, or duct openings.
8a. After "Occupancy" state whether residential, commercial, industrial, storage, public building, etc. After "Business hours," state number of employees and transients normally in building. After "Other times," state number of employees and transients in building after the normal business hours of the community.
8b, 8c, 8d, 8e, 8f, and 8g. To explain these conditions, use the graph paper on reverse side of the Data Collection Form for notes and sketches.

9. Indicate area(s) in building with fallout shelter potential.
10. Sources of information may be noted here.

NOTE.—Photographs may be useful in identifying a particular problem or structure. Attach to form.

---

[1] See Part 1, preceding.

Shielding Analysis Outline

ROOF CONTRIBUTION

(1) Total roof area, A_r ____________

(2) Central roof area, A_c ____________

(3) Distance, roof to detector, Z ____________

(4) Distance correction factor, K (chart 2) ____________

(5) Adjusted total area, $A'_r = A_r \times K$ ____________

(6) Adjusted central area, $A'_c = A_c \times K$ ____________

(7) Total overhead mass thickness, X_o ____________

(8) Interior wall mass thickness, X_i ____________

(9) Combined overhead mass thickness, $X_c = X_o + X_i$ ____________

---

(10)[1] Chart 2, [(5) or (6)] and (7) ____________

(11) Chart 2, (5) and (9) ____________

(12) Chart 2, (6) and (9) ____________

(13) Subtract (12) from (11) ____________

(14) Roof contribution, (10)+(13) ____________

(15) Skyshine correction (table CF–2, p. 44) ____________

(16) Total roof contribution (14)×(15) ____________

[1] When X_i is less than 20 psf, use items (5) and (7); and delete steps (11), (12), and (13). When X_i is greater than 60 psf, use items (6) and (7); and delete steps (11), (12), and (13). When X_i is greater than 20 psf, but less than 60 psf, use items (6) and (7); and also complete steps (11), (12), and (13).

Shielding Analysis Outline

GROUND CONTRIBUTION

(Aboveground Areas)

(1) Ground floor area, A_r ____

(2) Exterior wall mass thickness, X_e ____

(3) Interior wall mass thickness, X_i ____

(4) Total wall mass thickness, $X_w = X_e + X_i$ ____

(5) Percent apertures in wall, $Ap\%$ ____

(6) Percent of wall which is solid, $100 - Ap\%$ ____

(7) Aperture correction (table CF–1, p. 44) ____

(8) Height of detector above contamination, H ____

(9) Height correction: H_e (chart 5, p. 41) ____

(10) Width of contaminated plane, W_c ____

(11) Mutual shielding correction: M_s (table CF–3, p. 44) ____

(12) Perimeter, $P = 2\ (W + L)$ ____

(13) Length of wall, W or L ____

(14) Perimeter ratio, $P_r = W/P$ or L/P ____

---

(15) Chart 3, (1) and (4) ____

(16) Chart 3, (1) and (3) ____

(17) $(15) \times (6)$ ____

(18) $(16) \times (5) \times (7)$ ____

(19) Uncorrected ground contribution $[(17) + (18)]$ or (15) ____

(20) Corrected ground contribution $(19) \times (9) \times (11) \times (14)$ ____

Shielding Analysis Outline

GROUND CONTRIBUTION

(Belowground Areas)

(1) Ground floor area, A_r ____________

(2) Ground floor exterior wall mass thickness, X_e ____________

(3) Percent apertures in ground floor wall, Ap% ____________

(4) Adjusted wall mass thickness, $X'_w = X_e \times (100\% - Ap\%)$ ____________

(5) Immediate overhead mass thickness, X'_o ____________

(6) Basement wall mass thickness, X_b ____________

(7) Percent of basement wall exposed, Ex% ____________

(8) Width of contaminated plane, W_c ____________

(9) Mutual shielding correction: M_s (table CF–3, p. 44) ____________

(10) Perimeter, $P = 2\ (W + L)$ ____________

(11) Length of wall, W or L ____________

(12) Perimeter ratio, $P_r = W/P$ or L/P ____________

---

(13) Chart 4, (1) and (4) ____________

(14) Chart 1, case 3, (5) ____________

(15) Ground contribution through overhead, $(13) \times (14)$ ____________

(16) Chart 3, (1) and (6) ____________

(17) Ground contribution through basement walls, $(16) \times (7)$ ____________

(18) Uncorrected ground contribution $(15) + (17)$ ____________

(19) Corrected ground contribution, $(18) \times (9) \times (12)$ ____________

Shielding Analysis Outline

SUMMARY

Existing Structure

(1) Total roof contribution ____________
(2) Total ground contribution ____________
(3) Total reduction factor, (1)+(2) ____________
(4) Protection factor, reciprocal of (3) ____________
(5) Category (table 1, p. 3) ____________

Modified Structure

(1) Total roof contribution ____________
(2) Total ground contribution ____________
(3) Total reduction factor, (1)+(2) ____________
(4) Protection factor, reciprocal of (3) ____________
(5) Category (table 1, p. 3) ____________

Summary of modifications: ____________

DATA SUMMARY FORM

(1) Survey No. ______ (2) By ______ (3) On ______

(4) Location ______

(5) Description of shelter area:

a. Location within building ______

b. General dimensions ______

c. Space use ______

d. Unimproved shelter area:[1] Category ______ Capacity ______

e. Improved shelter area: Category ______ Capacity ______

(6) Required improvements:

	Item	*Cost*
a. Shielding	______	______
b. Entrances, exits	______	______
c. Ventilation	______	______
d. Sanitation	______	______
e. Water supply	______	______
f. Power supply	______	______
g. Storage	______	______
h. Miscellaneous	______	______
i. Total cost		______

(7) Unit costs:

a. Cost per occupant (shielding) ______

b. Cost per occupant (habitability) ______

c. Cost per occupant (total) ______

(8) Shelter area symbol ______

[1] Stay-time generally limited by habitability requirements.

Examples for Chart 1, "Barrier Shielding Effects"[1]

1. From the standpoint of roof contamination, when A'_r is very large (greater than 5,000 sq. ft.), and/or X_o is very large, geometry shielding effects are unimportant. In these situations, reduction factors for roof contribution can be taken directly from the curve for case 1.

   Example: If total overhead mass thickness $(X_o)=300$ psf, then
   Roof contribution=$\underline{\underline{0.00019}}$

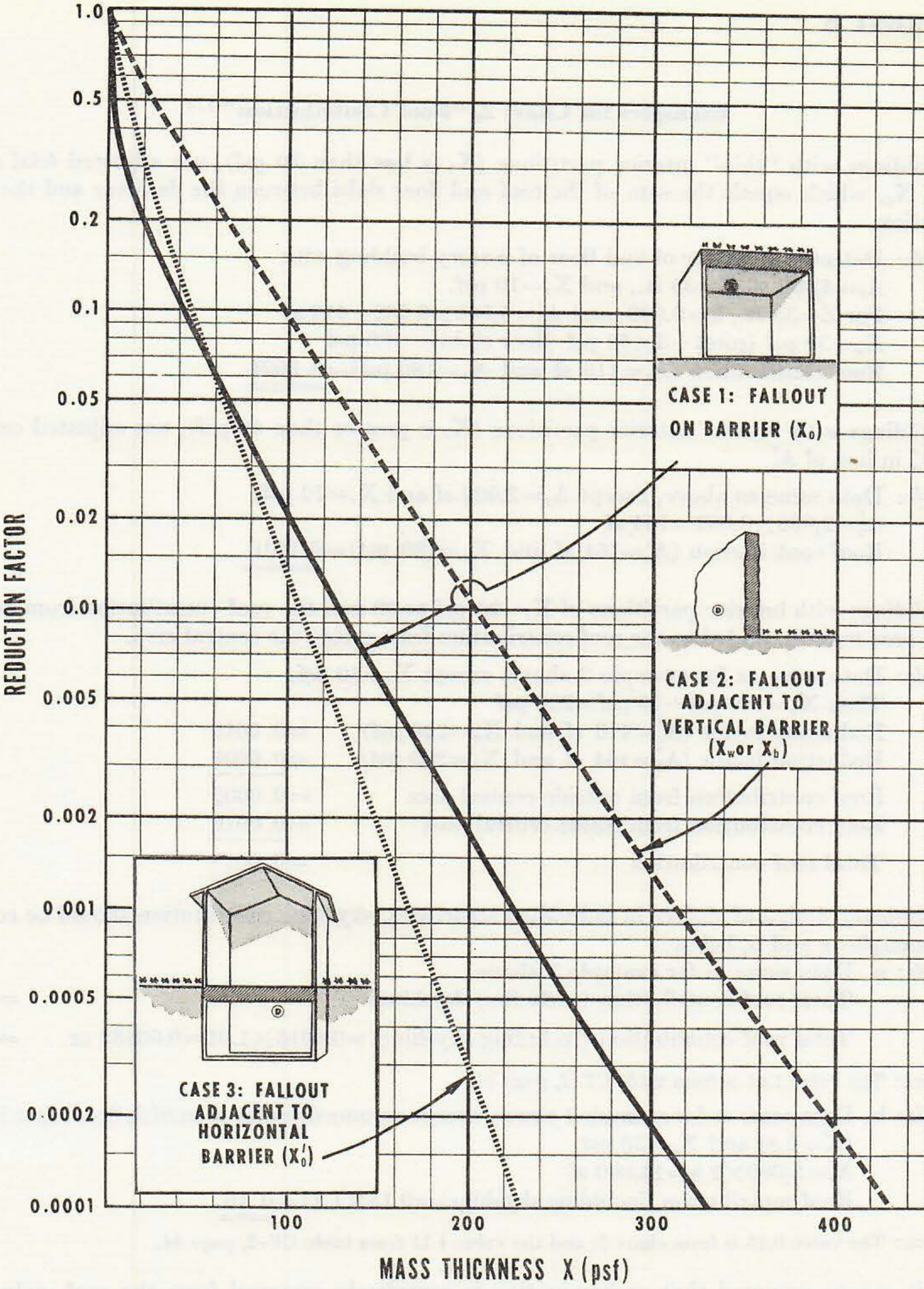
2. From the standpoint of ground contamination, when A_r is very small (less than 100 sq. ft.), geometry shielding effects are unimportant. In these situations, reduction factors for ground contribution can be taken directly from the curve for case 2.

   Example: If wall mass thickness $(X_w)=60$ psf, then
   Ground contribution=$\underline{\underline{0.22}}$

3. The curve for case 3 is used in conjunction with chart 4, page 39, to determine ground contribution into basement areas.

   Example: From chart 4, a value of 0.03 has been determined as the ground contribution into a basement area with a "weightless" floor overhead. If the actual floor slab has $X'_o=40$ psf, then the reduction factor derived from the overhead slab is 0.14, and
   Ground contribution=$0.03\times0.14=\underline{\underline{0.0042}}$

[1] Chart 1 follows.



BARRIER SHIELDING EFFECTS

CHART 1

Examples for Chart 2, "Roof Contribution"[1,2]

1. For buildings with "thin" interior partitions (X_i is less than 20 psf), use adjusted *total* roof area, A'_r and X_o, which equals the sum of the roof and floor slabs between the detector and the roof contamination.

   Example: Detector at center of 2nd floor of 5-story building with
   A_r=5,000 sf, Z=35 ft., and X_i=10 psf.
   For Z=35 ft., k=0.082; and A'_r=5,000×0.082=410 sf
   X_o=30 psf (roof)+3×50 psf (floor slabs)=180 psf
   Roof contribution (A'_r=410 sf and X_o=180 psf)=<u>0. 0024</u>

2. For buildings with "thick" interior partitions (X_i is greater than 60 psf), use adjusted central roof area, A'_c in lieu of A'_r

   Example: Data same as above, except A_c=2,000 sf and X_i=70 psf.
   A'_c=2,000×0.082=164 sf
   Roof contribution (A'_c=164 sf and X_o=180 psf)=<u>0. 0016</u>

3. For buildings with interior partitions of X_i=20 psf to 60 psf, the roof contribution from outside the central area must be added to the roof contribution from inside the central area.

   Example: Data same as for example 2 above, except X_i=40 psf.
   Then X_c=180 psf+40 psf=220 psf

Reduction factor (A'_r=410 sf and X_c=220 psf)	=0. 0010
Reduction factor (A'_c=164 sf and X_c=220 psf)	=0. 0008
Roof contribution from outside central area	=0. 0002
Roof contribution from inside central area	=0. 0016
Total roof contribution	=0. 0018

4. In preliminary design of shelter in individual structures, skyshine contribution should be considered, as in examples a and b, below.

   Example: a. Data same as for example 3 above.
   Total roof contribution (excluding skyshine) =<u>0. 0018</u>
   Total roof contribution (including skyshine)=0.0018×1.01=0.00182 or =<u>0. 0018</u>

   NOTE: The value 1.01 is from table CF–2, page 44.

   Example: b. Data same as for example 1 above, except assume detector is on fifth floor: that is, Z=6 ft. (K=2.8) and X_o=30 psf
   A'_r=5,000×2.8=14,000 sf
   Roof contribution (including skyshine)=0.15×1.11=<u>0. 16</u>

   NOTE: The value 0.15 is from chart 2; and the value 1.11 from table CF–2, page 44.

5. When it can be assumed that contamination is completely removed from the roof, only skyshine need be considered as roof contribution.

   Example: Same data as for example 4b above, except contamination is completely removed from roof.
   Roof contribution (skyshine only)=0.15×0.11=<u>0. 016</u>

   NOTE: The value 0.11 is from table CF–2, page 44.

---
[1] Chart 2 follows.
[2] See "Shielding Analysis Outline, Roof Contribution" (p. 26).

Reduction Factors for Combined Shielding Effects

ROOF CONTRIBUTION

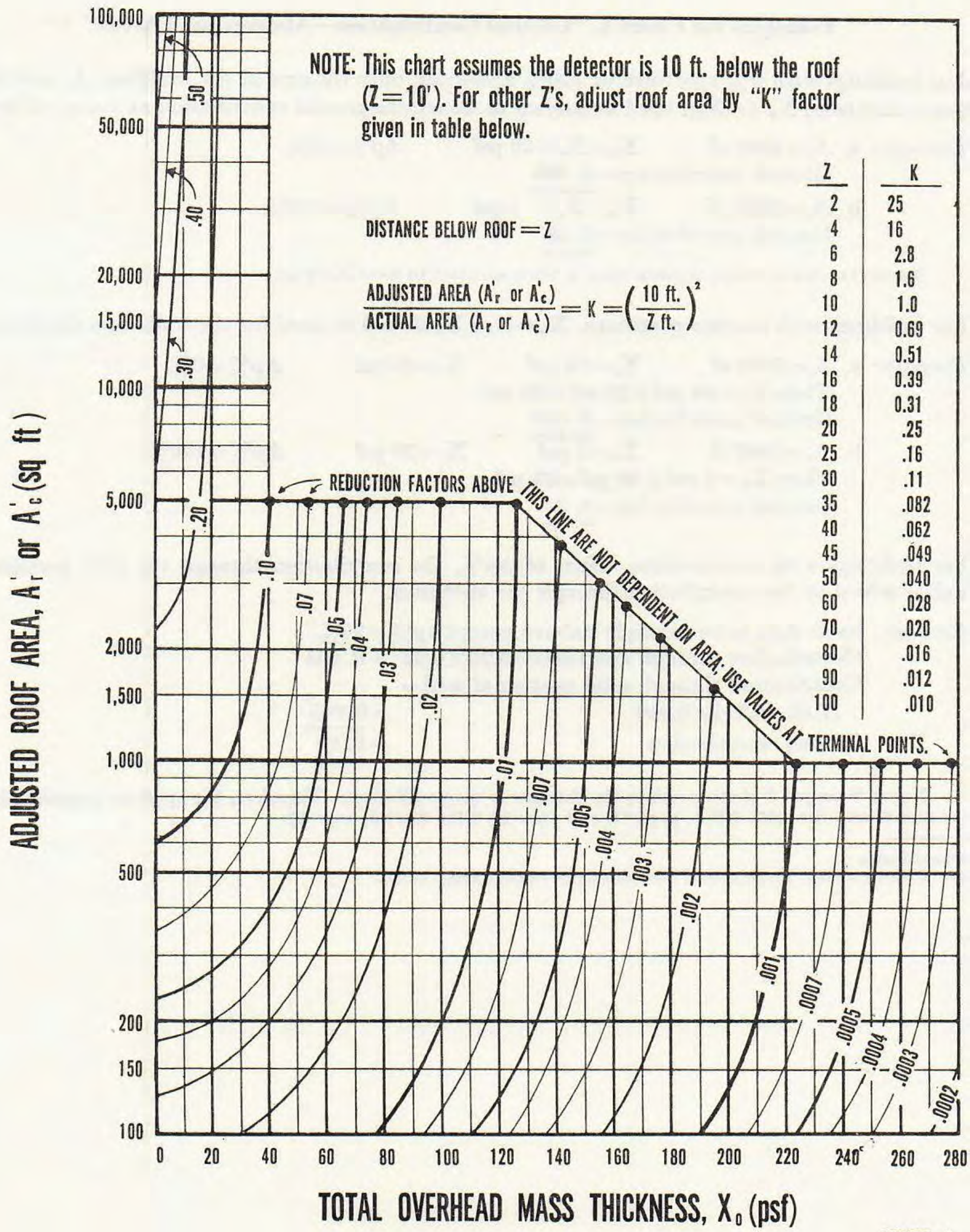


CHART 2

Examples for Chart 3, "Ground Contribution—Aboveground Areas" [1,2]

1. For buildings with 0% apertures or 100% apertures, only the area of the building, A_r, and the wall mass thickness, X_w ($=X_e$), need be known to determine ground contribution at center of first floor.

Example: a. $A_r=5000$ sf $X_w=X_e=60$ psf Ap%=0%
Ground contribution$=\underline{\underline{0.096}}$
b. $A_r=5000$ sf $X_w=X_e=3$ psf Ap%=100%
Ground contribution$=\underline{\underline{0.39}}$

NOTE: For convenience, window glass is often assumed to have $X=0$ psf.

2. For buildings with interior partitions, $X_w=X_i+X_e$ should be used for the wall mass thickness.

Example: a. $A_r=5000$ sf $X_e=60$ psf $X_i=20$ psf Ap%=0%
Then $X_w=60$ psf$+20$ psf$=80$ psf
Ground contribution$=\underline{\underline{0.060}}$
b. $A_r=5000$ sf $X_e=3$ psf $X_i=20$ psf Ap%=100%
Then $X_w=3$ psf$+20$ psf$=23$ psf
Ground contribution$=\underline{\underline{0.22}}$

3. For buildings with intermediate values of Ap%, the contribution through the solid portion of the wall is added to the contribution through the apertures.

Example: Same data as for example 2 above, except Ap%=25%.
Contribution through apertures$=0.25\times0.22$ $=0.055$
Contribution through solid portion of wall$=$
$(1.00-0.25)\times0.060$ $=0.045$
Ground contribution $=\underline{\underline{0.10}}$

NOTE: Example 3 above assumes the detector is above sill level. Therefore, the aperture correction is 1.0 for the first floor. See table CF–1, page 44, and example 2 for chart 5, page 40.

[1] Chart 3 follows.
[2] See "Shielding Analysis Outline, Ground Contribution (Aboveground Areas)" (p. 27).

Reduction Factors for Combined Shielding Effects

GROUND CONTRIBUTION - ABOVEGROUND AREAS

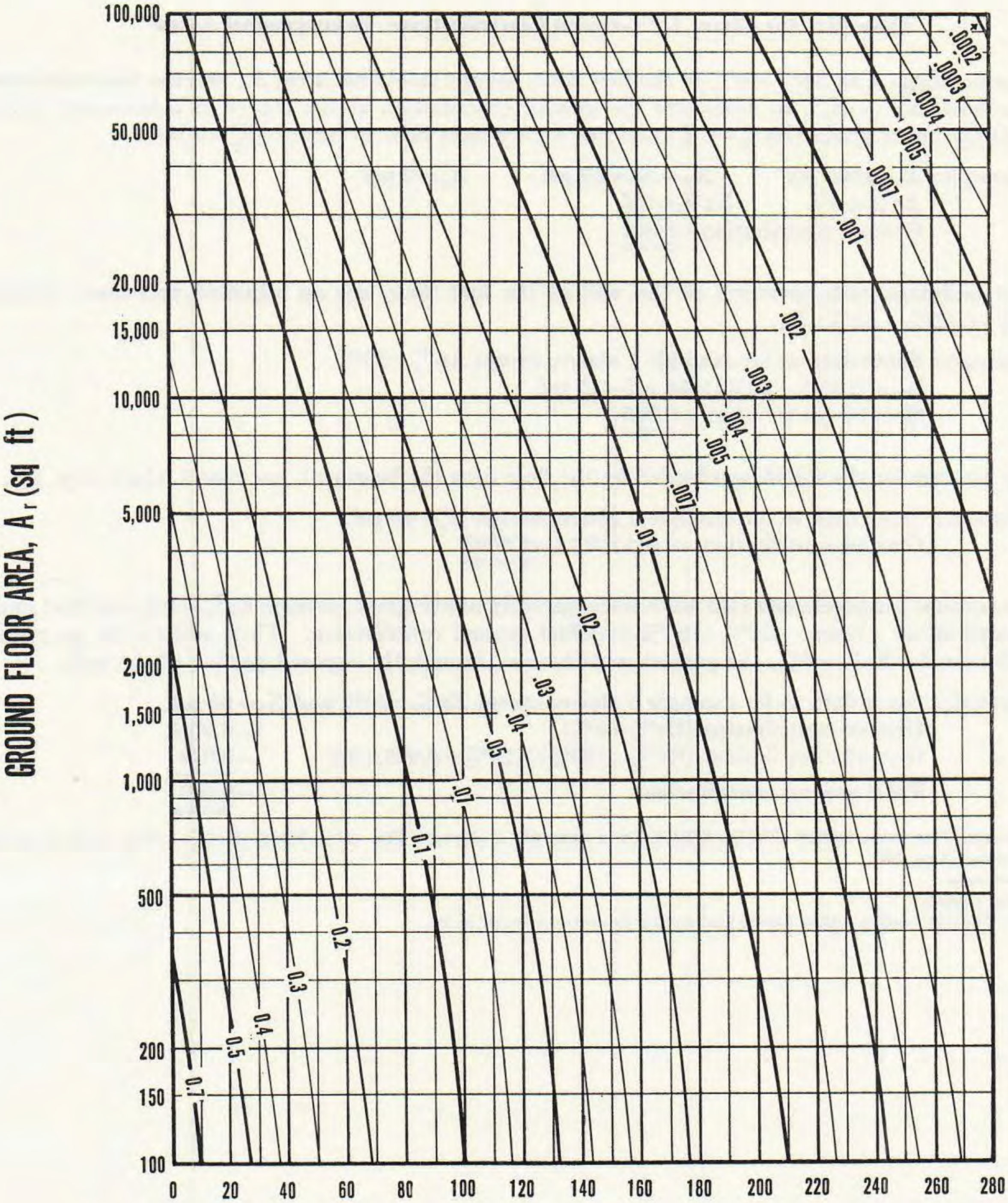


CHART 3

Examples for Chart 4, "Ground Contribution—Belowground Areas" [1, 2]

1. For buildings with Ap%=0% on the first floor, use the total floor area, A_r, and the mass thickness of the wall, X_w $(=X_e)$, to determine the ground contribution at the center of a basement which is entirely below grade (Ex%=0%) and has a very light floor overhead (X'_o=0 psf).

   Example: A_r=5000 psf $X_w=X_e$=60 psf X'_o=0 psf
   Ap%=0%   Ex%=0%
   Ground contribution=$\underline{\underline{0.034}}$

2. For buildings with apertures in the wall of the first floor, use an adjusted wall mass thickness, $X'_w=(100\%-\text{Ap}\%)\ X_w$.

   Example: Same data as for example 1 above, except Ap%=25%.
   $X'_w=(100\%-25\%)\times 60$ psf=45 psf
   Ground contribution=$\underline{\underline{0.045}}$

3. To account for the shielding afforded by the floor over the basement, use case 3, chart 1 (p. 33).

   Example: Same data as for example 2 above, except X'_o=40 psf.
   Ground contribution=0.045×0.14=$\underline{\underline{0.0063}}$

4. To account for basements that have walls partially above grade, assume Ex%=0% and find ground contribution. Assume Ex%=100% and find ground contribution. Then add to the ground contribution for Ex%=0%, the ground contribution through the exposed portion of the wall.

   Example: Same data as for example 3 above, except Ex%=20% and X_b=60 psf.

Ground contribution (Ex%=0%)	=0.0063
Ground contribution (Ex%=100%)×20%=0.096×0.2	=0.019
Total ground contribution	=$\underline{\underline{0.025}}$

NOTE: The value 0.0063 (Ex%=0%) is from example 3 above. The value 0.096 (Ex%=100%) is from example 1a for chart 3 (p. 36).

[1] Chart 4 follows.
[2] See "Shielding Analysis Outline, Ground Contribution (Belowground Areas)" (p. 28).

Reduction Factors for Combined Shielding Effects

GROUND CONTRIBUTION- BELOWGROUND AREAS

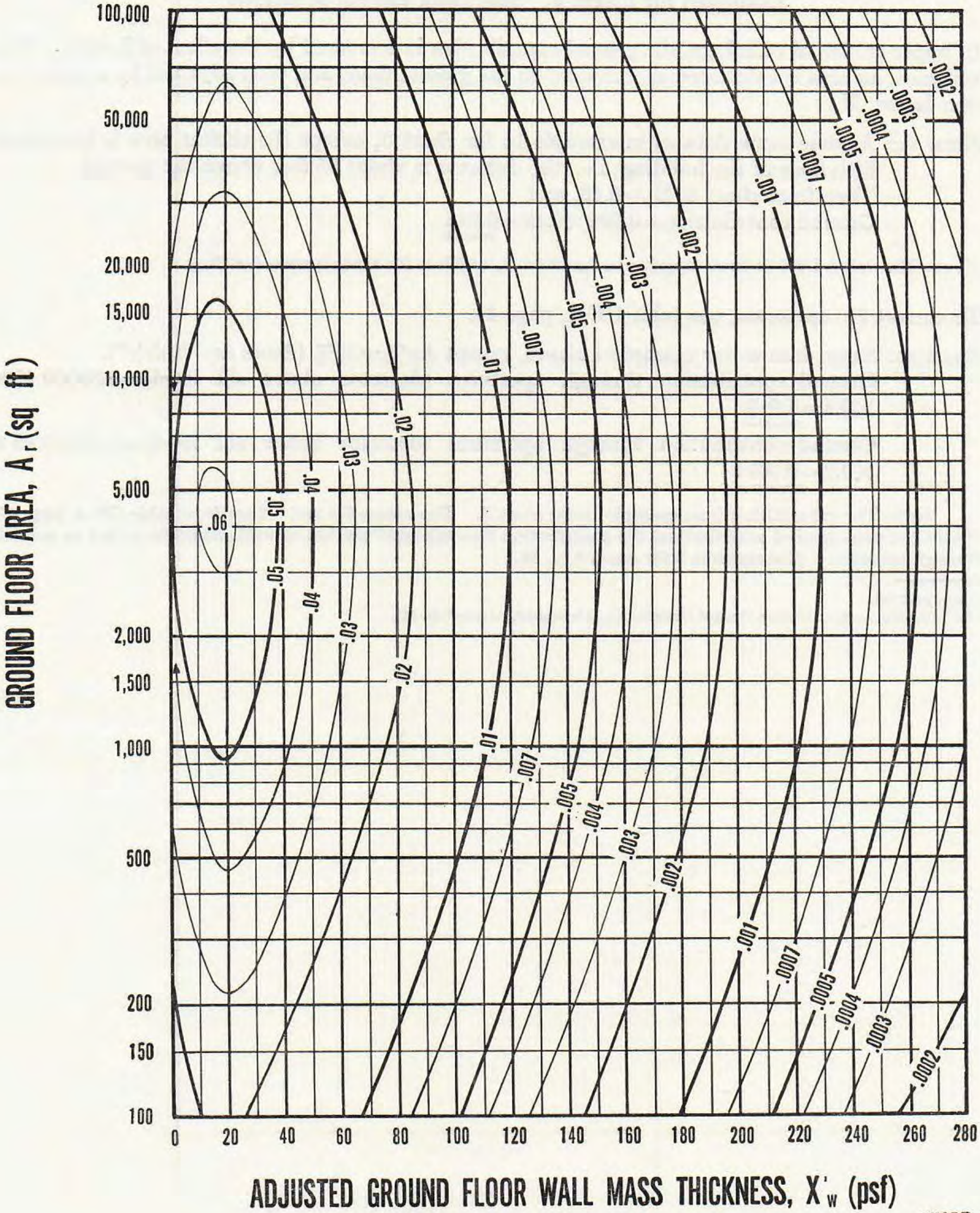


CHART 4

Examples for Chart 5, "Shielding Effects of Height" [1,2]

1. In upper stories of buildings, the ground contribution is decreased by the effect of height. For convenience, an area is calculated as if it were on the ground floor, and then adjusted by a height correction factor, H_c.

   Example: Assume same data as in example 1a for chart 3, except the shelter area is located on the fifth floor of the building; i.e., the detector is about 55 feet above the ground.
   Then from chart 5, $H_c=0.48$, and
   Ground contribution $=0.096\times0.48=\underline{\underline{0.046}}$

   NOTE: The value 0.096 is from example 1a for chart 3, which is for a windowless building.

2. To correct for apertures, use table CF–1, page 44.

   Example: Same data as for example 1 above, except Ap% $=25\%$ (floors are "thick").
   Ground contribution through apertures (detector above sill level) $=0.39\times0.48\times0.25\times0.4=\underline{\underline{0.019}}$

   Ground contribution through apertures (detector below sill level) $=0.39\times0.48\times0.25\times0.2=\underline{\underline{0.0094}}$

   NOTE: The value 0.39 is from example 1b for chart 3. The values 0.4 and 0.2 are from table CF–1, page 44. To obtain the total ground contribution, the contribution through solid portion of wall should be added to contribution through aperture. (See example 3 for chart 3, p. 36.)

---

[1] Chart 5 follows.
[2] See "Shielding Analysis Outline, Ground Contribution (Aboveground Areas)" (p. 27).

SHIELDING EFFECTS OF HEIGHT

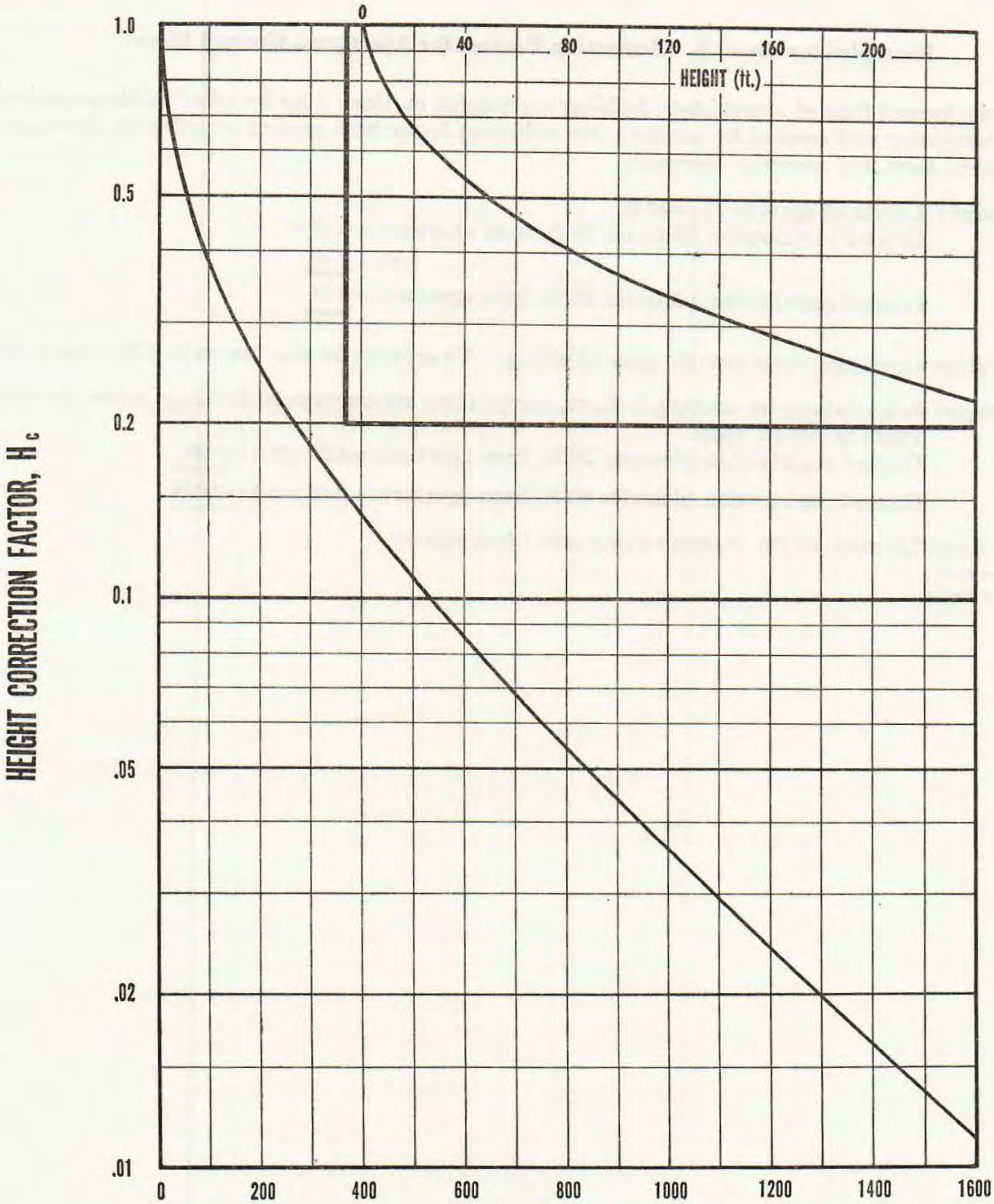


CHART 5

Examples for Chart 6, "Reduction Factors for Apertures, Ground Floor" [1]

1. On the ground floor of a multistory building surrounded on three sides by other buildings and with the remaining wall covered by windows, the reduction factor from ground contribution decreases as distance from the aperture increases.

Example: Length of aperture, L=50 ft.
Ground contribution (detector 20 ft. from aperture)=0.19+
or, 0.20
Ground contribution (detector 60 ft. from aperture)=0.06

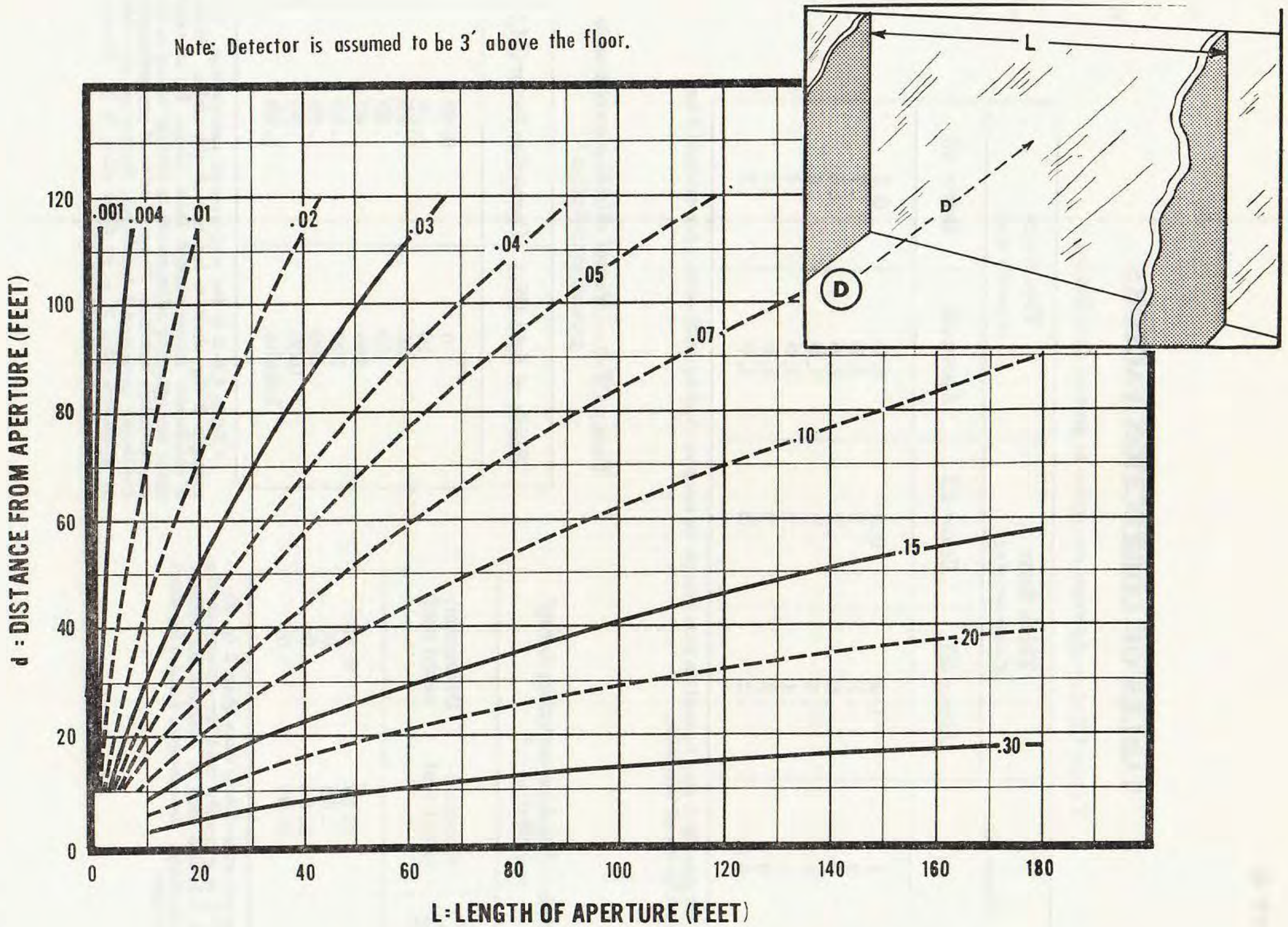
2. Buildings across the street provide some shielding. To account for this, use table CF–3, page 44.

Example: Same data as for example 1 above, except there are commercial buildings across the street, which is 100 ft. wide.
Ground contribution (detector 20 ft. from aperture)=$0.20 \times 0.4 = 0.08$
Ground contribution (detector 60 ft. from aperture)=$0.06 \times 0.4 = 0.024$

NOTE: The value 0.4 (W_o =100 ft.) is from table CF–3, page 44.

[1] Chart 6 follows.

Note: Detector is assumed to be 3′ above the floor.



REDUCTION FACTORS FOR APERTURES, GROUND FLOOR

CHART 6

TABLES OF CORRECTION FACTORS

TABLE CF–1.—*Aperture correction to ground contribution* [1]

Floor No.	Thick floors (*X greater than 40 psf*)		Thin floors (*X 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

[1] Table CF–1 may be used for either simple or complex (wall-by-wall) cases. See example 2 for chart 5 for use of this table.

TABLE CF–2.—*Skyshine correction to roof contribution* [1, 2]

Total overhead mass thickness, X_o	Contaminated roof	Decontaminated roof
0	1. 15	0. 15
50	1. 08	. 08
100	1. 04	. 04
200	1. 01	. 01

[1] Applied to reduction factor from chart 2 (p. 35).
[2] Table CF–2 is generally used for cursory checks only. However, it is also used to evaluate the efficacy of roof decontamination. See examples 4 and 5 for chart 2 for use of this table.

TABLE CF–3.—*Mutual shielding correction to ground contribution* [1]

Width of field (W_c)	Correction factor (M_s)
feet	
0	0. 00
10	. 08
20	. 10
50	. 20
100	. 40
200	. 60
500	. 80
1000	. 90
Infinite	1. 00

[1] Table CF–3 is for wall-by-wall calculations. See example 2 for chart 6 for use of this table. When a condensed computational form (supp. E) is used, make the following adjustments in tabular values in the case of urban buildings (those in areas of predominantly multistory commercial buildings): Streets on one side, × ¼; on two sides, × ½; on three sides, × ¾. (Streets on all sides, use values "as is.")

BRIEF TABLE OF MASS THICKNESSES

This brief table of mass thicknesses is presented as guidance only. In general, it may be assumed that the weights given for the various types of roof, floor, and wall construction as found in standard engineering tables are equivalent to the mass thickness of the construction. Publications of the American Standards Association, the American Institute of Steel Construction, the American Concrete Institute, and others may be used for this purpose.

Item	Thickness	Weight (mass thickness)
Asbestos:	*Inches*	*lb./sq. ft.*
Board	3/16	2
Corrugated		4
Shingles	5/32	2
Asphalt:		
Roofing (3 ply)		1
Roofing (4 ply and gravel)		6
Roofing (5 ply and gravel)		7
Shingles		2
Clay:		
Brick	1	8–10
Tile:		
Facing	2	15
Facing	4	25
Facing	6	38
Partition	4	18
Partition	6	28
Partition	8	34
Partition	10	40
Shingles		10–20
Structural	8	42
Structural	12	58
Concrete:		
Cinder	1	9
Haydite	1	8
Lightweight	1	6–8
Reinforced	1	12½
Slag	1	10–11
Stone or gravel (std. wt.)	1	12–12½
Block (hollow)		
Stone or gravel (std. wt)	4	30
	6	42
	8	55
	12	85

Item	Thickness	Weight (mass thickness)
Concrete—Continued	*Inches*	*lb./sq. ft.*
Cinder	4	22
	6	30
	8	39
	12	61
Lightweight	4	20
	6	28
	8	39
	12	61
Fiberboard or sheathing	½	1
Glass panes	¼	3½
Gypsum:		
Block	2	8–10
Block	4	10–12
Board or sheathing	½	2
Plaster:		
Applied directly or on lath	½–¾	5–6
Solid	1	8–10
Plywood sheathing	3/8	1
Slate	3/16	7
Soil:		
Clay	1	6–8
Loam	1	7–9
Sand and gravel	1	8–10
Steel:		
Plate	1	41
Corrugated sheet	20 Ga.	2
Panels	18 Ga.	3
Stone masonry	1	10–14
Stucco	¾	5
Terra cotta	1	5
Wood:		
Sheathing	1	2½
Shingles		2½
Siding	1	1–2½

Assumptions Used in Development of Procedures for Shielding Calculations

FALLOUT DISTRIBUTION

Fallout is assumed to be uniformly distributed over exposed surfaces according to their horizontal projections. Fallout on vertical surfaces is not considered.

ENERGY OF GAMMA RADIATION

The energy spectrum of gamma radiation is assumed to be that from fission products at one hour after weapon burst.

BARRIER ATTENUATION

It is assumed that the amount of attenuation by a given barrier depends only on its mass thickness and not on the chemical composition of the barrier material.

SCHEMATIZATION

The basic schematization consists of replacing a structure by another with the same height but with a square cross-sectional area equal to that of the original structure. The roof is replaced by a circular disk with area equal to that of the building.

CONTRIBUTION FROM SOURCES ON THE ROOF

Barrier Effect

Calculations are for the attenuation of radiation from an infinite plane isotropic source through an overhead barrier, using the moments method.

Geometry Effect

This factor gives the ratio of dose rate from a finite disk source to that from an infinite plane source. The barrier is assumed to be uniformly distributed between source and detector. The geometry factor depends on the source geometry and the angular distribution of radiation at the detector. Since the angular distribution is dependent on the barrier thickness, the geometry factor is also dependent on barrier thickness.

Reduction Factor from Roof Contribution

The product of the reduction factor from the roof barrier effect and the roof geometry effect is the reduction factor for the roof contribution.

CONTRIBUTION FROM SOURCES ON THE GROUND

Barrier Effect

Calculations are for the penetration of radiation from a semi-infinite plane isotropic source on one side of a vertical wall to a detector on the other side. Solutions were obtained by the moments method.

Geometry Effect

Thin walls (mass thickness much less than 40 psf).—This factor gives the ratio of the dose rate above a cleared circular area to the dose rate at the same height above an infinite plane source.

Thick walls (mass thickness much greater than 40 psf).—This factor, which depends upon the angular distribution of the radiation emerging from the inner surfaces of the wall, gives the ratio of the dose rate inside a square building of finite height to that between two infinitely long and infinitely high vertical slabs of the same wall mass thickness.

Walls of intermediate thickness.—A weighted average of the thin wall and thick wall geometry factors is used. The weighting factors are determined by the relative amounts of scattered and unscattered radiation emerging from the inner surface of the walls. The weighting factors vary with wall thickness.

Reduction Factor from Ground Contribution

The product of the reduction factors from the wall barrier effect and the ground geometry effect gives the reduction factor for the ground contribution.

CONTRIBUTION FROM RADIATION SCATTERED FROM AIR AND GROUND

A correction for scattered radiation, which varies with the mass thickness of the walls, is included in the ground geometry factors for detector position below grade. A fraction of 20 percent, scattered to total radiation, is assumed at 3 feet above an infinite plane isotropic source

NORMALIZATION OF REDUCTION FACTORS

The *total reduction factor* is the ratio of the dose rate at the detector to that 3 feet above an infinite smooth plane. It is the sum of roof and ground reduction factors.

CORRECTION FACTORS

The correction factors presented in the tables on page 44 are intended to correct for several effects in a qualitative way. More accurate estimates would involve a complicated dependence on other variables.

DETECTOR POSITIONS

For ground floor areas, the detector position is assumed to be 3 feet *above* ground level at the geometric center of the structure. For basement areas, the detector position is assumed to be 5 feet *below* the level of the ground floor at the geometric center of the structure.

CONDENSED SHIELDING ANALYSIS

(Aboveground Areas) [1]

Survey No. ________ By ______________________ Date ________

(1) Roof area ________ sf (2) Distance, roof to detector ________ ft.

(3) Total overhead mass thickness ________ psf

(4) Wall mass thickness ________ psf (5) Apertures ________ %

(6) Roof contribution: (1), (2), and (3), chart 2 ________

(7) (1) and (4), chart 3 ________

(8) (1) and 0 psf, chart 3 ________

(9) (7)×(100%−(5)) ________

(10) (8)×(5) ________

(11) (9)+(10) ________

(12) Ground contribution: (11)×table CF–3 ________

(13) Reduction factor: (6)+(12) ________

(14) Protection factor: reciprocal of (13) ________

(15) Category of shelter area ________

[1] This form should be used only for analyses of ground floor areas of buildings with light interior partitions.

CONDENSED SHIELDING ANALYSIS

(Belowground Areas) [1]

Survey No. ______________ By ________________________________ Date ______________

---

(1) Roof area ______________ sf (2) Distance, roof to detector ________ ft.

(3) Total overhead mass thickness ______________ psf

(4) Wall mass thickness ______________ psf (5) Apertures ________ %

(6) Ceiling mass thickness ______________ psf

(7) Basement wall mass thickness ______________ psf (8) Exposure ________ %

---

(9) Roof contribution: (1), (2), and (3), chart 2 ____________________

(10) (4) × (100% − (5)) ____________

(11) (1) and (10), chart 4 ____________

(12) (6), case 3, chart 1 ____________

(13) (11) × (12) ____________

(14) (1) and (7), chart 3 ____________

(15) (14) × (8) ____________

(16) (13) + (15) ____________

(17) Ground contribution: (16) × table CF-3 ____________________

(18) Reduction factor: (9) + (17) ____________________

(19) Protection factor: reciprocal of (18) ____________________

(20) Category of shelter area ____________________

[1] This form should be used only for analyses of basement areas of buildings with light interior partitions.

WALL-BY-WALL SHIELDING ANALYSIS
(Aboveground Areas)

Survey No. ______________ By ______________ Date ______________

Item	ROOF CONTRIBUTION		GROUND CONTRIBUTION (Aboveground)					Item
(1)	A_r		A_r					(1)
(2)	A_c		X_e					(2)
(3)	Z		X_i					(3)
(4)	Chart 2, K		X_w					(4)
(5)	A_r'		Ap%					(5)
(6)	A_c'		100% - A_p%					(6)
(7)	X_o		Table CF-1					(7)
(8)	X_i		H					(8)
(9)	X_c		Chart 5, H					(9)
(10)	Chart 2, See note		W_c					(10)
(11)	Chart 2, (5) and (9)		Table CF-3 W_c					(11)
(12)	Chart 2, (6) and (9)		P					(12)
(13)	(11) - (12)		W or L					(13)
(14)	(10) or [(10) + (13)]		P_r					(14)
(15)	Table CF-2		Chart 3, (1) and (4)					(15)
(16)	(14) x (15)		Chart 3, (1) and (3)					(16)
			(15) x (6)					(17)
			(16) x (5) x (7)					(18)
			(17) + (18) or (15)					(19)
			(19) x (9) x (11) x (14)					(20)

Note:

When X_i is less than 20 psf, use items (5) and (7); and delete steps (11), (12) and (13).

When X_i is greater than 60 psf, use items (6) and (7); and delete steps (11), (12) and (13).

When X_i is greater than 20 psf, but less than 60 psf, use items (6) and (7); and also complete steps (11), (12) and (13).

Total Ground Contribution		(21)
Total Roof Contribution	+	(22)
Total Reduction Factor		(23)
Protection Factor		(24)
Category		(25)

Shelter Sketches

SUPPLEMENT E
(Part 4)

WALL-BY-WALL SHIELDING ANALYSIS
(Belowground Areas)

Survey No. ____________ By ____________ Date ____________

Item	ROOF CONTRIBUTION		GROUND CONTRIBUTION (Belowground)					Item
(1)	A_r		A_r					(1)
(2)	A_c		X_e					(2)
	Z		Ap%					(3)
(4)	Chart 2: K		X_e'					(4)
(5)	A_r'		X_o'					(5)
(6)	A_c'		X_b					(6)
(7)	X_o		Ex%					(7)
(8)	X_i		W_c					(8)
(9)	X_c		Table CF-3					(9)
(10)	Chart 2: See note		P					(10)
(11)	Chart 2: (5) & (9)		W or L					(11)
(12)	Chart 2: (6) & (9)		P_r					(12)
(13)	(11) - (12)		Chart 4, (1) and (4)					(13)
(14)	(10) or [(10) + (13)]		Chart 1, case 3, (5)					(14)
(15)	Table CF-2		(13) x (14)					(15)
(16)	(14) x (15)		Chart 3, (1) and (6)					(16)
			(16) x (7)					(17)
			(15) + (17)					(18)
			(18) x (9) x (12)					(19)

Note:

When X_i is less than 20 psf, use items (5) and (7); and delete steps (11), (12) and (13)

When X_i is greater than 60 psf, use items (6) and (7); and delete steps (11), (12) and (13).

When X_i is greater than 20 psf, but less than 60 psf, use items (6) and (7); and also complete steps (11), (12) and (13)

Total Ground Contribution		(20)
Total Roof Contribution	+	(21)
Total Reduction Factor		(22)
Protection Factor		(23)
Category		(24)

Shelter Sketches

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