DESIGNING SHELTER IN NEW BUILDINGS

A manual for Architects on the preliminary designing of shielding from fallout gamma radiation in normally functioning spaces in new buildings.

written for

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by
Albert Knott

Shelter Research and Study Program
Department of Architectural Engineering
The Pennsylvania State University
University Park, Pennsylvania

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ABSTRACT

This manual discusses radiation shielding as it applies to the preliminary desig of protection against fallout gamma radiation in new construction. The archit tural principles of shielding are discussed at length and designing examples ar given. Planning charts are presented whereby material weights can be selecte a preliminary basis to provide shielding which will satisfy the Office of Civil requirements for Community Shelters. Environmental control, shelter supply, management factors are not discussed as they are auxiliary to the problem of t provision of radiation protection.

It is anticipated that the preliminary architectural schemes developed through use of this manual will be verified by skilled analysts before final designs are pleted.

ACKNOWLEDGEMENT

The assistance of Mr. Larry O. Sinkey for development of the computer progra which were used to generate the data from which the planning charts were dra and of Mr. Thomas B. Brown for the presentation of the illustrations, is gratef acknowledged. Appreciation is also extended to Mr. Richard E. Kummer, Mr Robert Sprankle, and Mrs. Joan Brooks for editorial and production assistance

Sincere appreciation is extended to the architects and engineers who allowed buildings or competition entries to be used as examples in this manual. Their are listed with the examples.

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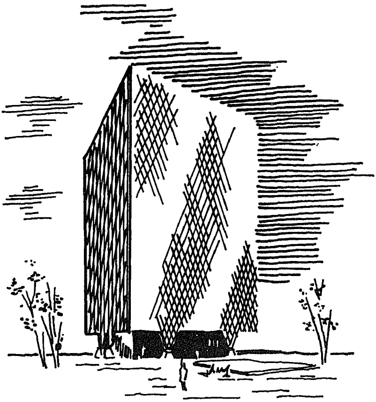
DESIGNING SHELTER IN NEW BUILDINGS

THE ARCHITECT

The architect can be defined as that designer who, through his specialized training and ability, can most efficiently and creatively determine the environment in which man can live and function. The definition is extended, for the purpose of this manual, to include the environment of fallout gamma radiation as well as the normal environments of wind, rain, and sun. This manual has been written to provide the architect with the information necessary to design radiation protection into buildings as he now designs protection from the elements. This manual discusses preliminary designing.

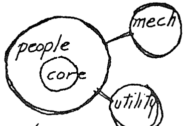
THE FALLOUT SHELTER



Architects have recognized that any building offers protection from fallout radiation. Some buildings provide adequate protection. Others provide protection which is less than adequate. The architect can use his creativity to provide adequate protection within all buildings. *

Protection must be incorporated without jeopardizing the appearance, the normal function of the building, or the cost. The judicious choice of building materials, and the special arrangement of the building spaces to enhance radiation protection, are the essence of the architectural design problem for fallout shelters.

The architect is to select the shape and materials of a building so that spaces are created in which people can find adequate protection from fallout radiation. Since, hopefully, the need for radiation protection will never arise, many clients may feel they cannot afford to incorporate high level shelter which will adversely affect the function or cost of the building. The architect is, therefore, challenged with the problem of providing adequate radiation protection, without sacrificing the normal design requirements. Shelter must be incorporated as integral, multi-use space satisfying fully the primary purpose of the building.



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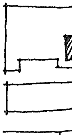

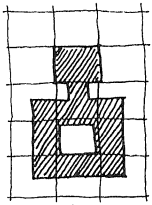

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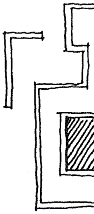


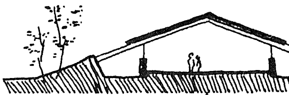
SHELTER DESIGN

Schematic architectural design is the development of an architectural concept, simultaneously considering the interrelated parts of the problem. It is the initial stage of any architectural design development.

Shelter design, a facet of architectural design, is the design of a building within which adequate protection from fallout radiation is to be provided. It is to be emphasized that if shelter is to be provided, without a significant increase in cost, and without adversely affecting the function or beauty of the building, it must be considered in the schematic design stage of the architectural design and must be an integral part of the building concept included as a program requirement. It must also be a secondary function, subservient to the primary function for which the space is intended.

section

It is the purpose of this presentation to discuss the concepts of shelter and the mechanics of shelter design for radiation protection. Guide lines and simplified procedures will be presented to enable architects to make proper basic decisions regarding shelter during the design stage.



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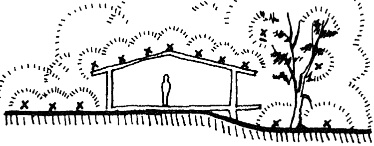
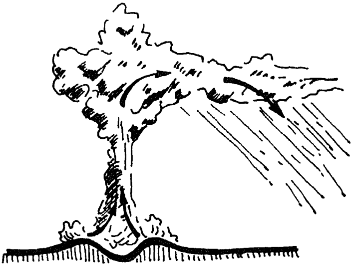
THE NATIONAL FALLOUT PROTECTION PROBLEM



The Nation must tackle its problems in the sequence of their importance and relative ease of solution. For example, if a nuclear attack should occur, the problem of fallout will be widespread. The provision of protection from fallout radiation is relatively simple and can be inexpensive as will be seen in the text that follows. The problem of protection from thermal radiation and blast destruction, however, may be extreme in targeted areas, and expensive and difficult to solve. Since millions of people in the United States will need only fallout protection, that can be obtained at relatively low cost, fallou radiation shielding is emphasized in national policy.

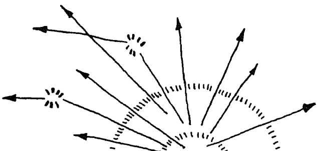
Fallout



If a nuclear device is detonated on or near the ground a great amount of earth and other materials will be vaporized in the extreme heat and will mix with the radioactive materials from the bomb. As this vapor mixture is carried into the cooler air of high altitudes, it condenses. Minute radioactive particles cling to the surfaces of the condensed debris. They soon become heavy enough to descend to earth, downwind, sometimes many miles from the point of explosion. Thus, radioactiv fallout is spread across the land.

The debris, fine to medium particles, will settle on exposed surfaces, on streets, roofs, lawns, farms, reservoirs. It will drift. It may be washed or wiped away, plowed under, tracked in, swept out.

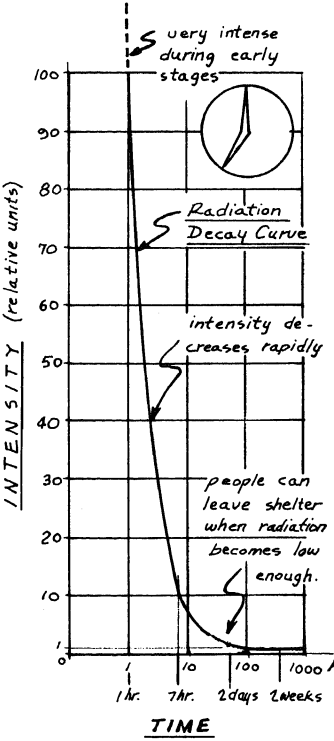
Radioactivity



Radioactivity is the spontaneous emission of energy from the bomb's unstable atoms which

These rays can damage living tissue. A person may become ill when exposed to sufficient radiation, because of the number of damaged cells in his body. An excessive amount of damaged tissue of the body may result in death after several days.

As time passes, radiation is emitted from the unstable or radioactive atoms, resulting in atoms of a stable or at least a more nearly stable form. Thus as the number of unstable atoms reduces, the radiation level of the field of fallout decreases. This decrease in intensity is at first quite rapid, later less rapid.

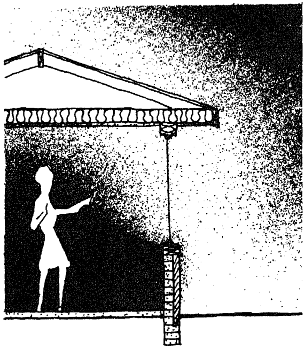


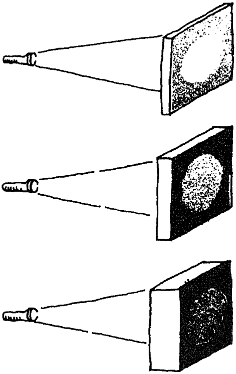
For every seven-fold increase in time, there is approximately a ten-fold decrease in radiation intensity. If the radiation intensity level one hour after the explosion is taken as the starting point, at the end of seven hours the intensity of radiation will have decreased ten-fold or to 10% of the original. In seven times seven hours or 49 hours (2 days) later it will be down another ten-fold or to 1% of the original, and in two weeks (7 times 2 days) the radiation will be one-tenth of 1% of its value at the starting point. Thus radiation decreases rapidly in the first two weeks; but as time goes on, the decrease is much slower.

Shelter occupants can emerge when the radiation intensity drops to biologically acceptable levels. Although some areas may receive little or no fallout, most required shelter occupancy periods will be from two days to two weeks in duration. Others may have to remain protected for extended periods of time.

RADIATION AND ARCHITECTURE

It has been indicated that the unstable atomic particles in fallout emit bundles of energy including gamma rays. These rays are the





A useful analogy in understanding radiation and the effect architectural facilities have upon it, is to say that each particle of fallout is a tiny but powerful flashing light. These tiny lights flash intermittantly, shining their tiny, piercing beams each time in a randomly different direction. Thus a field of fallout might appear to an observer as a vast city at night would appear to a passenger on a plane. The lights of this analogous city would each be blinking rapidly on and off, shooting darts of light off into the night air.

In relation to these fields of flashing light rays, all matter would be analogous to clouded glass. Lights can be seen through relatively thin clouded-glass sheets, analogous to the way radiation can be "seen" through lightweight partitions, roofs, and walls. As the wall (the panel of clouded glass) becomes thicker, less light is transmitted directly and more light is scattered and diffused. As the building envelope becomes massive, the light is nearly all absorbed, and the room becomes quite dark. This would correspond to a high degree of fallout radiation protection. It is to be noted that gamma radiation is actually not visible and that it can penetrate all materials, no matter how dense. Do not assume that if you cannot see the fallout you will not receive radiation. We assume only for the sake of our analogy that it can be seen.

Even the soil is clouded glass. Thus each analogous building may be envisioned as a full-sized, clouded-glass structure set on a plain of clouded glass. Sheets of tiny flashing lights would lie on the roof, window sills, and on the ground. As the wind blows, these tiny lights would move and drift, piling up against curbs as sand will drift across a road.

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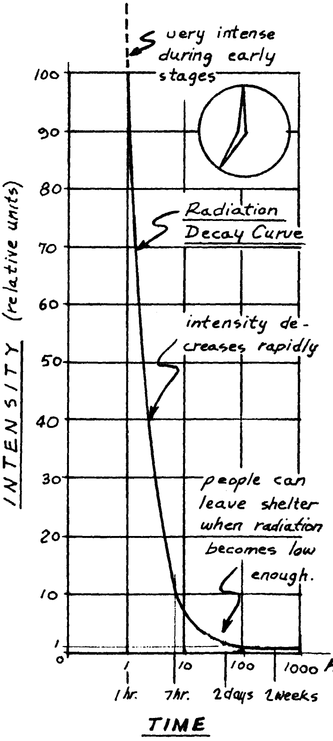

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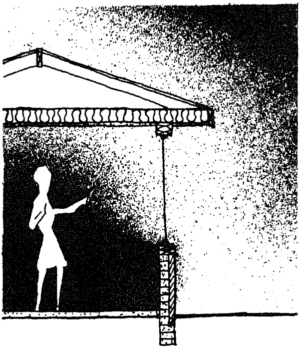

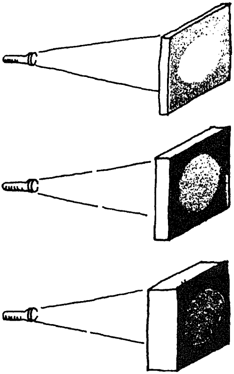

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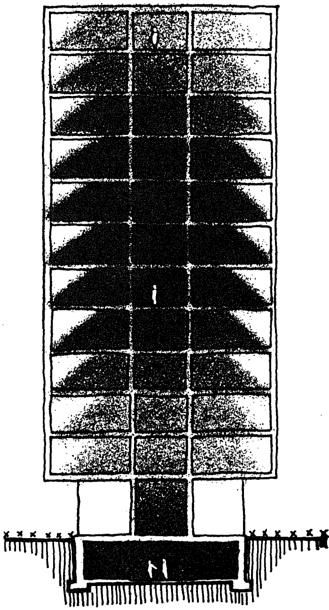
Although these lights are tiny, their darting rays are extremely penetrating. In the living room of a normal suburban home made of our clouded glass, the brightness would be still about half as great as it would be outside in the field of lights. We say the room has a "protection factor" of two (2), as the outside light intensity has been reduced by a factor of two by the materials of which the house is made.

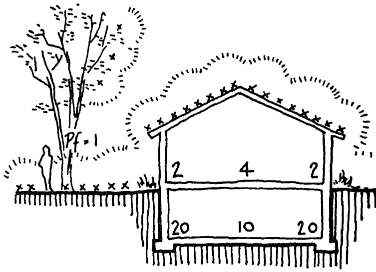


If we were in the central corridor on, say, the sixth floor of a twelve-story modern apartment house, the area would be relatively dark. The light intensity might be only about one fiftieth (1/50), of the light intensity down below on the street, or P_f 50.

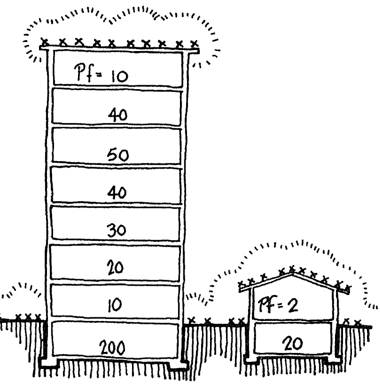
Note that if the observer were standing on the twelfth floor, it would be quite bright, due to the light shining down through the roof material from the fallout lying on the roof. Similarly the ground floor level would be well lit due to the fallout radiation shining through the walls, windows, and doors at street level.

Suffice it to say, the less "bright" the building space is, the greater protection it offers against fallout gamma radiation. Below ground basements under multistory buildings are usually excellent.

Protection Factor



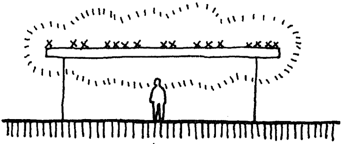
Any space within a building provides its occupants some measure of protection against fallout radiation. As building materials absorb and diffuse incoming rays of radiation, the level of exposure inside the building will be less than that outside. As the occupant is surrounded by building material, no matter how light weight it may be, he receives some protection.



It is convenient to discuss the exposure levels quantitatively. The degree of radiation reduction of architectural spaces is given by the single above-mentioned term "protection factor." If a building occupant receives one tenth (1/10) of the radiation which he would have received had he been standing on a smooth horizontal plane outside of the building with fallout evenly distributed everywhere around him, his protection factor is said to be ten (10). If the shape, size, and materials of a building reduce the level of exposure in one of its interior spaces to one part in one hundred (1/100), the protection factor of that space is said to be one hundred (100). Hence, the higher the protection factor, the better the shelter.

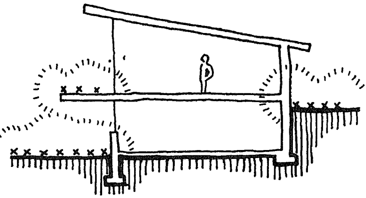
Representative values may be as shown in the sketches shown to the left. Protection factor is abbreviated as PF.

<u>Radiation Contributions</u>



Roof Contribution

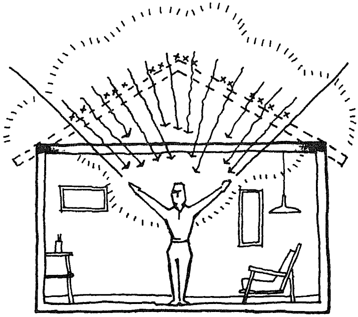
Protection factors are computed by trained analysts by calculating the "contributions" from the various sources of radiation. Radiation will come from the fallout lying on the roof. This radiation is called the roof contribution, its amount being dependent on the size, shape, and location of the roof and the weight of the materials used in its construction.



Ground Contribution

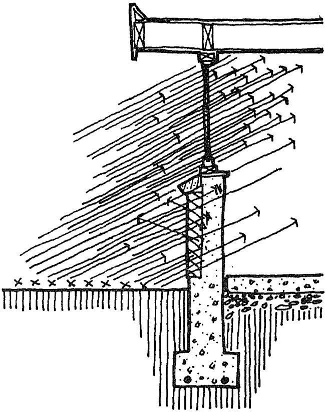
Ground contribution is the amount of radiation entering the shelter through the walls and openings, having come from the fallout lying on the ground. Together with the roof contribution it makes up the majority of the radiation received. Radiation contributions from fallout lying on foliage, on window sills, canopies and the like, together with that tracked in, or brought in through unprotected or unfiltered ventilation air intakes, make up the remainder of the radiation of concern to the architect.

These radiation contributions are expressed in per cent. For example, if a shelter occupant receives 20 per cent (1/5) of the total radiation outside the building, he has a protection factor of 5. Likewise, if he receives 2.5 per cent (1/40) of the total outside radiation, he has PF 40.



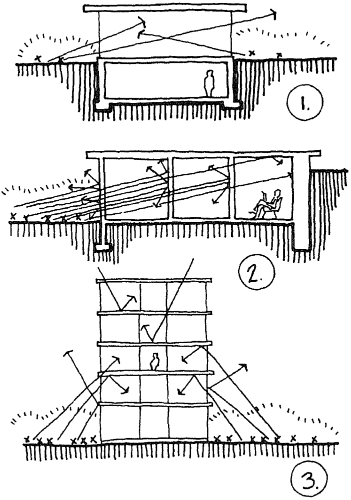
Roof Contribution. To continue the discussion of radiation, the writer will return to the clouded-glass analogy and the fields of tiny lights. Considering the roof construction as a sheet of clouded glass, it occupies the same area with respect to the sheltered space as does the field of tiny flashing lights it supports. The light diffuses down through the roof and bathes the room in a general glow. An observer looking upward would note that the roof surface directly overhead was considerably lighter than areas more distantly removed. If he held his arms extended over his head and encompassed the area of greatest brightness, his arms would be pointed about 45 degrees down from directly overhead. This is the area of greatest roof contribution and is of major concern to the designer.

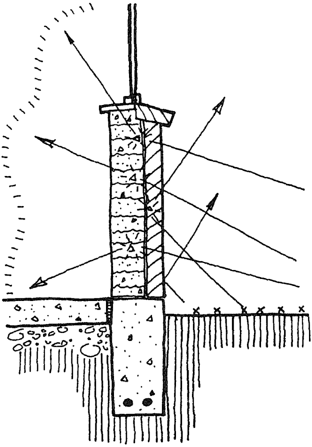
If the roof were increased in weight in this area directly overhead, the greatest reduction in radiation (light) would be made for the lowest increase in total weight of construction materials. This would probably result in the lowest possible construction cost.



It is to be noted that the light does not come from the peripheral areas of the roof as easily as from directly overhead. It has a greater slant thickness of roof material down through which to pass and greater distance to travel.

Ground Contributions. The second basic type of contribution mentioned above was





Wall Scattered Radiation

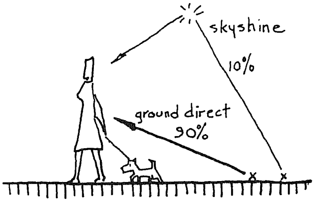
in turn will be broken up into three categorie direct radiation, wall scattered radiation, an skyshine.

Ground-Direct Radiation. In a clouded-glass house made analogous to normal masonry school or residential construction, the walls would be still transparent enough for some of the light to shine directly from the outside field of lights into the shelter space. This light would enter on a line-of-sight path from the fallout particles, through the walls and into the shelter. It would be reduced in inter sity due to the normal absorption of the wall material but would not be altered in its course This is ground direct radiation.

Ground-direct radiation can first be greatly reduced by placing the shelter spaces in the below-ground areas of building interiors, (1), thus "ducking under" the incoming gamma radiation. Second (2) and third (3) means of avoiding ground-direct radiation are to place the shelter in an inner core at ground level, or in the central areas of upper floors, several floors above the street. The first method, the basement location, requires the rays to pass down through the dense, clouded-glass soil to gain access to the shelter. The second requir the ground-direct radiation to come in horizontally through a series of walls and interior partitions, while the third method requires the harmful rays to come up through several floor layers, diminishing by natural absorption before gaining access to the designated shelte areas.

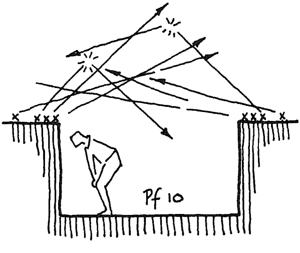
Wall-Scattered Radiation. The second form o ground contribution of concern to architects i wall-scattered radiation. As gamma rays ente the galaxy of atomic particles which make up the construction materials of a building, the opportunity for collision occurs. Just as the wall absorbs radiation by direct collision, so can radiation be scattered by near misses or by ricocheting.

The technical descriptions of the various forms of interaction between gamma radiation and the molecular particles of construction materials are not of concern to the architect. Since material can allow the passage of energy as ground-direct radiation, or absorb or scatter radiation as described by collision, we have a sufficient concept for the design of architectural shelter spaces. We will use the analogy that as diffused light providing a general glow will occur in our clouded-glass structure, so will scattered radiation enter an architectural shelter space. As diffused and scattered light will enter a room by devious routes, so will gamma radiation find its way through barrier after barrier and into sheltered spaces.



Skyshine Radiation. Air is composed of molecules of gas, particles of haze, droplets of moisture, and dust. Radiation will scatter by collision with these particles. Radiation entering the shelter, after having scattered in air, is called "skyshine."

As an example of the relative intensity of this air-scattered radiation, skyshine, a person standing alone in a vast plain of fallout would receive about 90% of the radiation from the ground as ground-direct, and about 10% from above as skyshine.



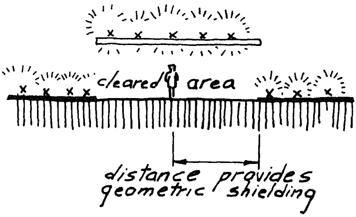
It is also interesting to note that if he were standing in an open excavation, ducking down below the field of fallout, he would receive only skyshine, and that being a contribution of 10% or one part in ten, his protection factor would be 10. As the Civil Defense requirement is PF 40, he is well on his way to protection before the architect has an opportunity to place him in a building. It is for such reasons as this that the statement is made, that all construction, no matter how simple, offers some degree of radiation protection.

PROTECTION FROM RADIATION

Protection is obtained by geometry and barrier

Geometric Shielding

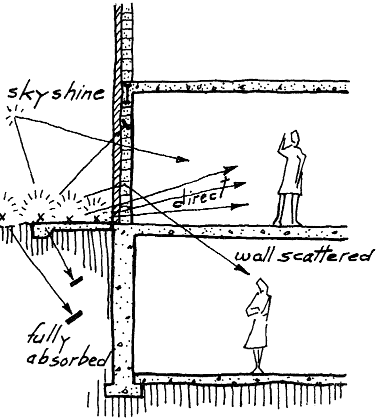
Radiation intensity reduces with distance; this is one of the characteristics which validates the clouded-glass structure analogy. The farther away the source of radiation is, the less radiation the shelter occupant will receive.



Thus, a house or a building provides a "cleare area" in which the shelter occupant can stand, and holds a layer of fallout at a distance overhead. As the fields of fallout lie at some distance from the person, some radiation protectio is afforded. The overall level of radiation exposure may be cut down in this fashion by as much as a factor or two or more.

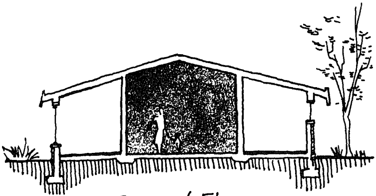
Barrier Shielding

The second means of obtaining protection is by placing mass (dense material) between the fall out and shelterees.



As indicated by the clouded-glass analogy, construction material (matter) will interfere with the passage of radiation. The "light" in the analogy will be reduced in intensity by absorption, and by diffusion or scattering. Thus construction material will (1) allow some radiation to pass on through (direct), (2) cause some radiation to change direction (wall-scatter), and (3) absorb some radiation completely. Thus, the atomic particles of which the material is made will either allow the rays of energy to pass among them, will lie in the path causing collision and scattering, or will block the path causing collision and complete absorption. The heavier the material the great the probability of absorption.

It is with these two characteristics, geometry and barrier, that the architect must create protection in new construction.

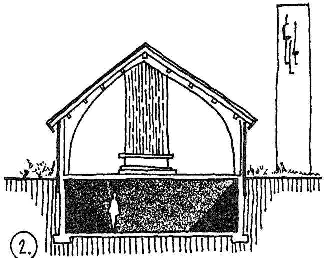


1. Ground Floor

NORMAL SHELTER CONFIGURATIONS

Three architectural configurations of common occurrence lend themselves to radiation shielding. It will be convenient to consider each separately. For reference the writer chooses to title them:

The Ground Floor Case
The Basement Case
The Multistory Case

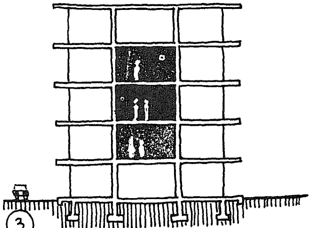


2. Basement

Other configurations using normal construction are developed by creative designers using such concepts as enclosed courtyards, areaways, ground sculpture, and so forth. Examples will be treated later in the text. The variety of possibilities has no limit. Shelter of course can be obtained by merely increasing the material weights (and hence the cost) of buildings, but such solutions should only be adopted when other restrictions are insurmountable.

The Ground Floor Case

The single story building is represented by many homes, schools, churches, and small shops and office buildings throughout the nation. Due to the short structural spans and large glass areas, these buildings are often fairly lightweight and open. For this reason, the radiation protection afforded is usually inadequate (considerably less than PF 40).

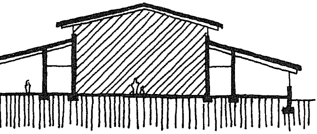


3. Multi-story

The greatest protection found in such buildings lies in the central areas such as the interior corridors and those below the plane of the sills of the windows. Thus, the greatest amount of construction material lies between the person and the outside field(s) of fallout.

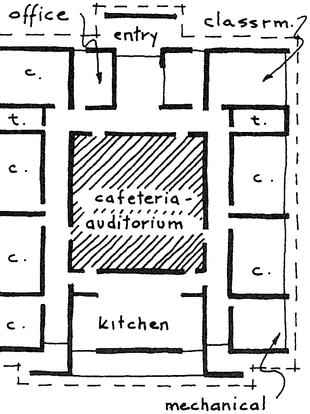
interior corridor occupant must pass through the exterior walls, through such furniture, book cases, and normal furnishings as may have been in the way, and through the interior partitions. This series of barriers is thus instrumental in reducing the radiation exposure.

To utilize this shielding characteristic of modern building, locate normal building functions usable by shelter occupants (and hence which facilitate shelter occupancy) in the central areas. Large rooms house the most people. Toilets, food preparation facilities, school libraries, and public utility control areas support shelter occupancy. A building, square in plan, is a more effective shield than a long thin building. Thus large rooms placed in the "core" or central areas of square buildings and surrounded by such service functions as toilets and kitchens provide the best shelter in one-story buildings.



Section

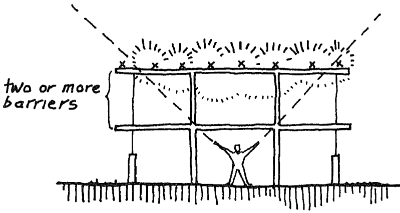
A narrow interior corridor with a heavy wall provides the greatest protection from roof contribution because a comparatively large amount of the radiation must pass obliquely down through the corridor walls before entering the shelter. Thus a weakness of our previous solution of large core area shelters comes to light. The larger the interior core space, the larger the roof contribution. Locate the shelter centrally to minimize ground contribution, then make the room large enough to house large numbers of people.



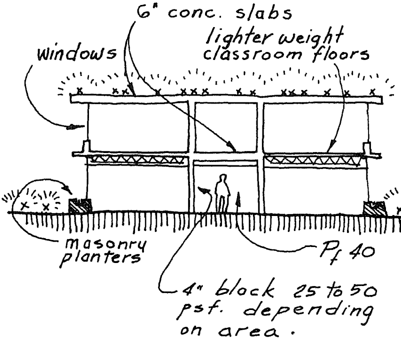
Plan

This centrally located shelter is thus placed in the most disadvantageous location as far as roof contribution is concerned, and the walls are pushed back allowing roof radiation to enter without passing through the interior partitions.

It is to be noted that a large interior room has very little more roof radiation than does a medium-large room. Recall that most of the roof radiation reaches us from almost directly overhead. Therefore unless the walls are quite close to us, they will not interfere with this major contribution. An interior auditorium or gymnasium in a school will not allow very much more radiation to enter than will a classroom. To reduce roof contribution appreciably, the walls must be as near as, say, those found in the corridors between classrooms. Recall that, if we hold our hands up at 45 degrees pointing to the ceiling, most of the roof radiation comes from within this cone.

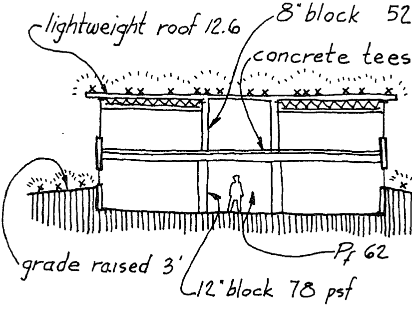


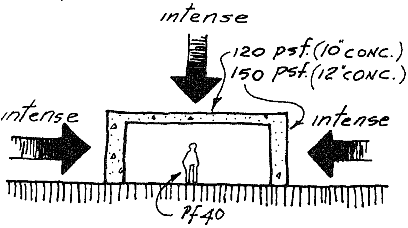
The roof radiation problem leads to the next logical change in shelter configuration. As a single story building must have a relatively heavy roof (see the charts shown later in this text), it is often more economical to use construction of two or more stories. Hence, rather than titling this discussion "The Single Story Case," it is called the "Ground Floor Case." By placing several overhead floor and roof barriers between the shelter occupant and the fallout lying on the roof, the radiation entering the shelter from above is appreciably reduced.



Thus a shelter in, say a two-story school, can be located in the first floor corridors with some degree of success. Normal construction, if judiciously selected as to material weight and location, can provide a protection factor of forty.

It has been noted that radiation exposure is greatest to shelter occupants when the shelter is located in single-story buildings of normal construction. To provide a protection factor of forty, both the roof construction and wall construction must be heavy and hence seldom normal. In almost all cases, fairly massive construction will have to be used. With reference to our clouded-glass structure analogy, the weights of the walls will have to be increased to cut down on the intense light



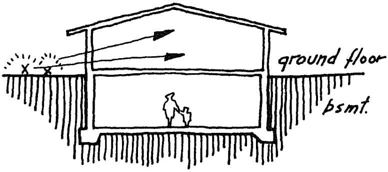


FULLY EXPOSED SHELTER

coming from the ground, and either a heavy roof or a series of light floors and a roof will have to be placed overhead to cut down on the roof radiation. When our space becomes quite gloomy, we have eliminated enough light. When our structure becomes quite heavy or quite complex, utilizing a series of barriers, we have eliminated enough fallout radiation.

In summary, a shelter on the ground floor must have an appreciably greater amount of material (mass) between it and the fields of radiation. This may consist of either single, heavy walls and a heavy roof, or a series of lighter encompassing walls and overhead roofs, totaling the same weight as the single barriers.

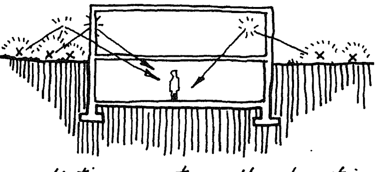
The actual weights required can be found in the planning charts starting on page 41, and will be discussed later in the text.



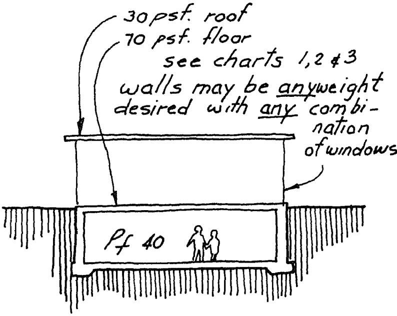
ducking under line of fire

The Basement Case

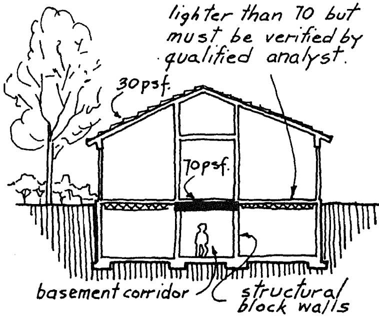
The second, simplest, most effective, and usually lowest cost configuration for providing shelter in modern construction is the basement. The shelter occupant has been placed under the "line of fire" of radiation from fallout lying on the ground outside, and beneath at least one overhead floor and roof. Thus ground radiation must enter the shelter after having scattered at least once (in the air outside or in the ground floor exterior wall) and after having passed through two barriers (the outside wall and the overhead floor). The radiation contribution from the roof will have passed through the roof and the overhead floor(s).


radiation must scatter to get in

The weight of material between the shelter occupant and the fallout on the roof must be 90 pounds per square foot if no radiation is received from the ground. It will be seen from the charts that, if the overhead floor weighs 70 pounds per square foot (psf) and the roof weighs 30 pounds per square foot, the designer may make the ground floor walls, partitions, and windows of any weight and size he wishes and still have a PF 40 shelter in the basement. Seventy pounds per square foot is equivalent to five and one-half inches of concrete. Note should be taken that the required weights are considerably below those for a ground floor shelter.

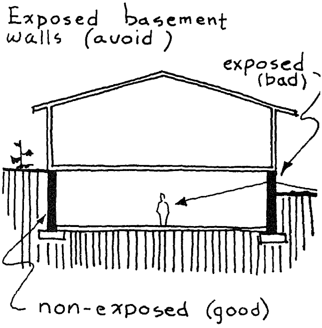


Shelter can also be developed in basements by placing the occupants in basement corridors and using an overhead barrier weighing less than 70 psf. The corridor walls intercept not only the ground radiation coming in after having scattered in the exterior walls above, but also intercept some of the radiation coming from the roof. Thus, although the corridor ceiling must still weigh 70 psf, the remaining portions of the basement ceiling may be reduced in weight. A reasonable decision would be to reduce the required basement ceiling weight by an amount equal to the weight (psf) of the added corridor walls.



It is interesting to note that one of the standard Civil Defense home shelter, made by constructing a brick box in the corner of the basement, is merely a variation of the basement corridor concept.

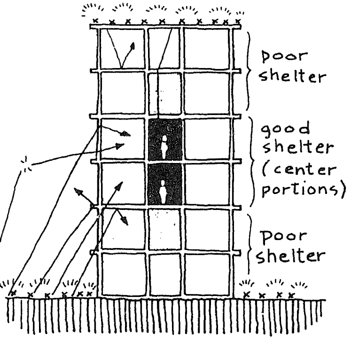
Exposed basements, in which a portion of the basement wall extends above the surface of the ground, are common. In such designs, protection is reduced and compensation must be provided by increasing the walls of the shelter. As radiation can enter the shelter with a minimum amount of scattering, its energy is not effectively dissipated, and heavy walls must be used.



In situations where it becomes necessary to utilize exposed basement walls in shelter planning, the ground floor chart values may be used to determine the required wall weight of the exposed portions.

The Aboveground Shelter (The Multistory Case)

The third and final type of shelter to be considered is the protected space found in the interior portions of the upper floors of multistory buildings. These spaces are in full view of the fields of radiation, but are surrounded by many natural barriers. Several floors normally lie between the shelter occupant and the fallout on the ground outside. Several overhead barriers lie between the occupant and the roof. Partitions shield the spaces from fallout scattering from the exterior walls, from skyshine, or from that coming directly in from the distant ground.



Multistory case

It will be noted from the planning charts that the most exposed aboveground shelters are those which are located either near the ground or immediately below the roof. This is logical. As in the clouded-glass structure analogy, these would be the well-lit spaces. The most protected areas are the interior spaces of the middle stories. It will be noted from the planning charts that normal construction is usually adequate.

USE OF THE PLANNING CHARTS

The charts are designed to read alike. The arrows on the diagrams on page 18 indicate the sequences permissible. Any three values of the variables will indicate the fourth required to give a protection factor of forty (40).

On the Ground Floor Shelter and Aboveground Shelter charts, the four characteristics which are necessary to specify the degree of radiation protection are given. These are (1) the per cent of the exterior wall perimeter occupied by doors and windows, (2) the weight of the exterior wall in pounds per square foot (psf), (3) the total weight of the overhead construction through which radiation from the fallout on the roof must pass, again in pounds per square foot (psf), and (4) the total weight (psf) of interior partitions through which the ground contribution must pass. These are arranged so that if any three are given, the fourth may be determined. The combinations are such that the protection factor anywhere within the shelter is at least forty.

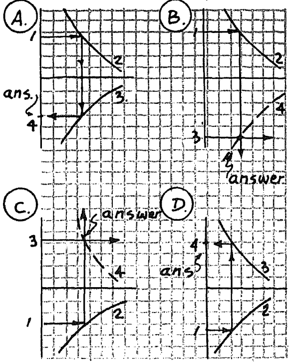
To work an example, assume a multistory building of, say, 8 stories, each floor of which is a 2 1/2 inch concrete slab on corrugated steel decking. Each floor (and roof) weighs 40 pounds per square foot. Protection in the fourth floor corridors is requested.

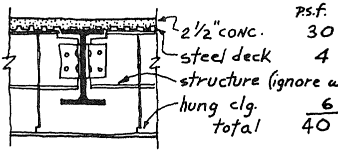
The total overhead weight is five barriers at 40 psf each, or 200 psf. If the area of each floor is approximately 10,000 square feet there is sufficient information with which to enter chart 14. Turn to chart 14 on page 64. Note that it is for a fourth floor, interior shelter in a 10,000 square foot building.

The windows (chosen for architectural reasons) start 36 inches above the floor level and extend to the 7-foot level. The charts were developed assuming that the windows start at the three foot level and extend to the ceiling. The difference will have a negligible effect on our solution. Fifty per cent of the perimeter of the building at the fourth floor level is window, the remainder being composed of precast concrete panels weighing 30 pounds per square foot.

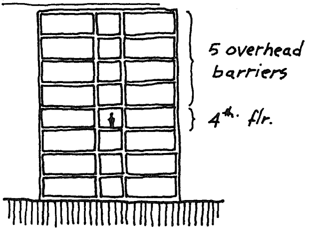
Enter the chart and read in accordance with the sketched directions shown on the next page. The answer found is that an interior partition weighing at least 42 pounds per square foot is necessary all around the shelter to meet the Civil Defense requirement for minimum radiation protection, PF 40. A 4-inch hollow block wall, plastered both sides, will satisfy the requirement.

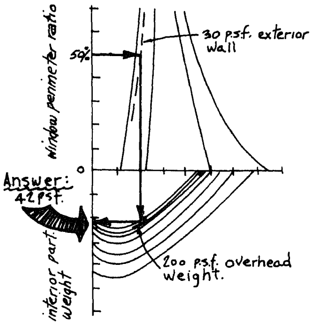
Reading the charts (choose any 3 variables and look up the fourth).



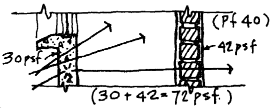


the fourth floor

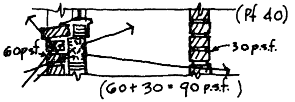




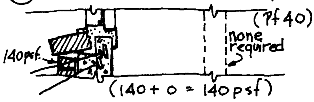
(1.) Pre-cast wall + plastered partition



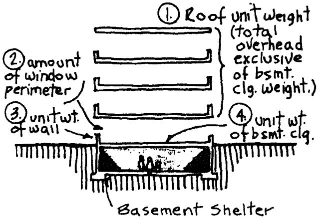
(2.) Masonry wall + unplastered partition



(3.) 4" Brick on 8" concrete with plaster



Variables for Basement Shelter Charts



Note that if an unplastered 4-inch block wall is desired for architectural reasons (4-inch block weighs 30 psf), an exterior wall weighing from 55 to 60 pounds per square foot is required.

Note also that the original choice of a 30 psf exterior wall and a 42 psf interior partition totals 72 pounds per square foot, while the second choice totals 60 plus 30, or 90 pounds per square foot. In multistory buildings, lightweight exterior walls reduce the amount of radiation scattering in, hence reduce the total amount of wall barrier required to meet the criterion.

The radiation absorption characteristics of the wall also enter in. Note that if the wall weighs 140 psf, no interior partition is required.

Thus it is seen that the use of the charts is quite simple. The architect chooses three of the four variables and looks up the fourth, which will give him a PF of 40.

In the Basement Shelter Case the four variables are different, although the mechanics of chart reading are the same. The four variables are the wall unit weight, the window perimeter ratio for the floor above, the total overhead weight (exclusive of the weight of the floor immediately over the basement), and finally, the unit weight of the basement ceiling construction itself.

CHART LIMITATIONS

The charts are intended to provide quantitative data for preliminary design only. They will enable the architect to make reasonable, preliminary choices which must later be verified or refined by a staff member trained in shelter analysis.

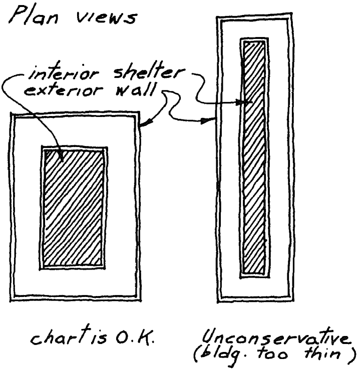
The charts give exact answers for conditions which duplicate the design chart assumptions. These are as follows:

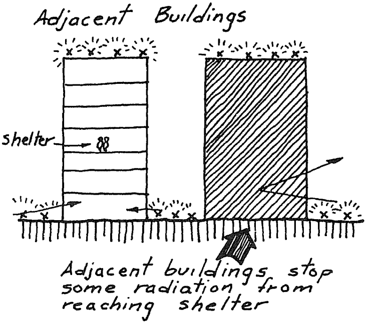
1. The shelter is centrally located within the building and occupies one third of the floor area. (The charts will give reasonably close answers for any size of shelter located anywhere within the building. If a wall of the shelter is also an exterior wall that wall should be the weight indicated by the chart using an interior partition weight of zero).

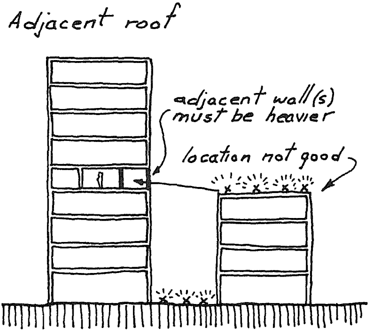
2. The buildings are assumed to be rectangular. (The charts give reasonably correct answers up to a length to width ratio of 5 to 1. The values given would be unconservative for very thin buildings, as the radiation coming in through the longer walls would be too great to meet the protection standards set.)

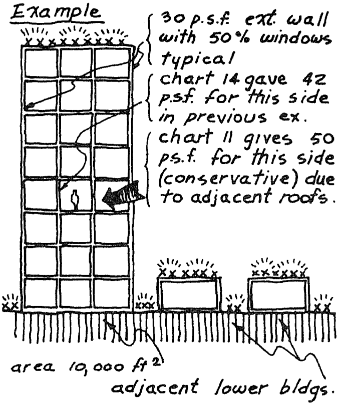
3. No consideration is given to adjacent buildings. (This is normally conservative. Note that an adjacent building will block off some radiation by acting as a barrier against radiation coming from the ground beyond.)

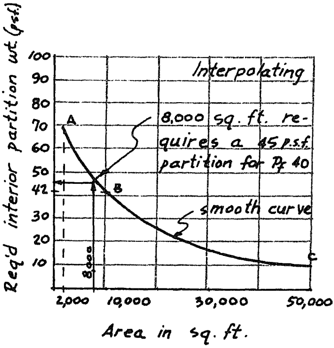
An unconservative condition would exist when a shelter on an upper level of a multistory building has the roof of an adjacent building along side of it. A reasonable solution would be to provide an exterior wall and interior partition combination on that side obtained by assuming the ground level to be raised to the elevation of the adjacent roof. If, for example, the adjacent roof were two stories (say 20 feet) below the shelter, the solution for the wall on that side

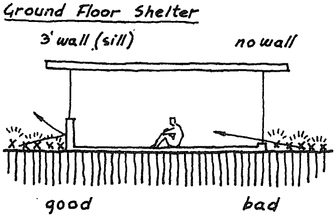












would be found on charts 10, 11, or 12. Study the example shown to the left.

4. The areas chosen for charting are 2,000 square feet, 10,000 square feet, and 50,000 square feet. These are representative of residences, commercial and school buildings, and large storage or industrial buildings. Solutions for intermediate areas may be found by interpolating between charts. For example, a fourth floor shelter with the same conditions of wall (30 psf) and overhead construction (200 psf) given in the earlier example may be in a building of 8,000 square feet. Chart 13 (2,000 square feet) gives a required interior partition weight of 70 psf. Chart 14 (10,000 square feet) gives 42 psf and Chart 15 (50,000 square feet) gives 10 psf. These values are plotted against area on the graph shown to the left.

It is seen by interpolation that the shelter would need a 45 pound per square foot partition. Note also that a simple straight line interpolation from point A to point B would have given the conservative answer of about 48 pounds per square foot.

5. A fifth basic assumption is that all window sills are three feet above the floor. If the windows start at floor level, the multistory charts will vary from slightly conservative for lightweight exterior walls to slightly unconservative for heavy exterior walls. The ground floor shelter charts will be dangerously inadequate, but almost no difference will occur in the basement

shelter charts. Do not rely on the charts if the design calls for a ground floor shelter and a sill height of less than three feet in the exterior walls. Use the charts freely for all other conditions.

Note that the windows, considered in the basement charts, occur in the walls of the floor above. As long as the outside ground level is at or above the level of the basement ceiling, windows (window wells) into the basement will not have too great a detrimental effect on the level of radiation protection. They should not, however, occupy more than, say, 10 to 20 per cent of the building perimeter. The charts do not cover window wells.

6. The charts are designed to give a protection factor of at least 40 in all parts of the shelter.

7. The story height was arbitrarily set at 12 feet to generate the data for the charts. This is reasonable, as radiation level is not greatly dependent on minor variations in story height. Note that the average height to sloping roofs on residences is similar to the floor-to-floor height used on most multistory buildings.

8. A final assumption, of concern to the architect, is that the building geometry is simple. The shelter is a simple rectangle within a rectangular building.

Radiationwise, an L-shaped building will provide the same protection as a rectangular building, if the length of the rectangular building

Basement Shelter

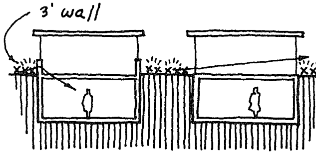
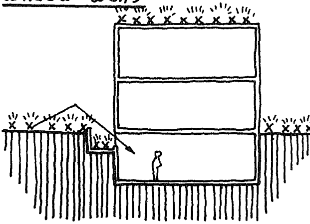


chart assumption

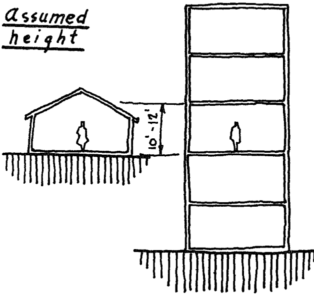
better without wall as no radiation is scattered into the basement

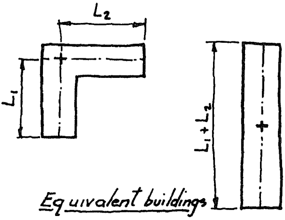
Window Wells

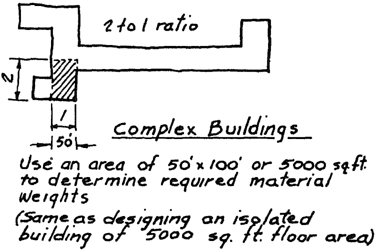


not too bad, but charts don't cover this condition.

Assumed height





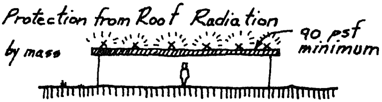


is equal to the sum of lengths of the two legs of the L-shaped building.

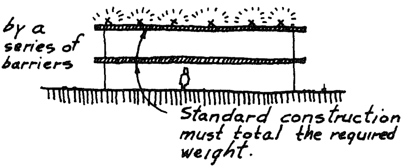
It is difficult to give general rules for the planning of shelters in buildings of complex layout. A reasonable approach, however, is to design any portion or leg of a building as if its length were twice its width (a 2 to 1 ratio), without regard to the actual length of the building. This of course is merely a matter of judgment, but it allows the architect to select a reasonable (and normally conservative) area with which to enter the charts.

THE PRINCIPLES OF SHELTER DESIGN

The purpose of fallout shelter is to enable the largest possible number of people to survive the effects of fallout radiation in the event of a nuclear attack. Hence considerations such as supply, communications, health, and management must enter the design problem to be considered by the architect. However, the single consideration of radiation shielding must be fully exploited before these others have meaning.



A radiation shield, like the structural system of a building, must be basically sound before attention is turned to its details. The creative architect should visualize the radiation condition in terms of the blankets of tiny, piercing lights at night, lighting up a hazy sky.



Protection from the blanket of fallout on the roof can only be obtained by a heavy overhead barrier or a series of lighter floors and roofs.*

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* Dependence should not be placed on washdown and other fallout removal methods. These methods should be reserved for the post-attack recovery period, after the shelterees have survived the early effects.

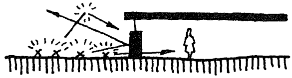
The overhead weight must be at least 90 pounds per square foot, and that only if no radiation is received from the ground. If ground radiation is received, the overhead barrier must be proportionately heavier to maintain the level of protection required.

Protection from the blanket of fallout on the ground must be obtained by: (1) walls, either a single envelope or a series of envelopes, (2) sinking the building into the ground to "duck under" the blanket, or (3) ground sculpture or adjacent construction in combination with one or more of the above. It is imperative that a sound, basic system of shielding against ground radiation be chosen during the preliminary stage.

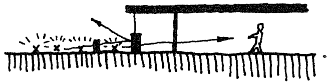
To illustrate several means of attaining protection as listed above, three example floor plans were chosen from the National School Fallout Shelter Design Competition, 1963, conducted by the American Institute of Architects for the Office of Civil Defense.* The designers of the examples are credited below each plan.

Protection from Ground Radiation

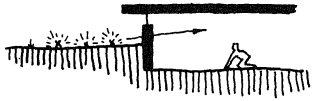
(1a) by a heavy wall (envelope)



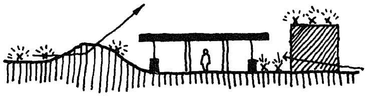
(1b) by a series of normal walls or envelopes



(2) by lowering the building partially or fully



(3) by ground sculpture or adjacent construction



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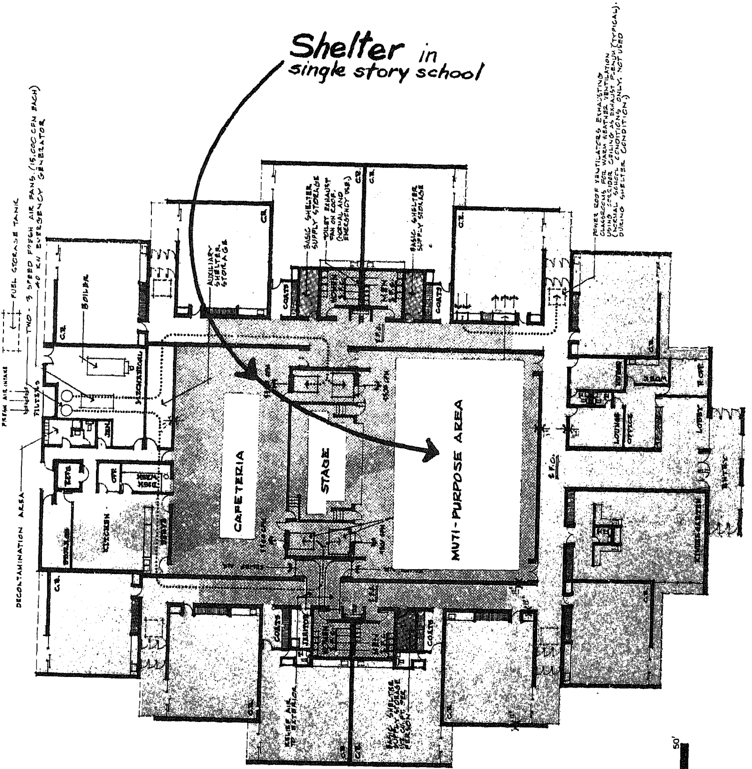
* See item 1 in the bibliography for complete details. Copies were distributed to all members of the AIA in 1963. Anyone wishing a copy may obtain it by writing to the Office of Civil Defense, Pentagon Building, Washington, D.C. 30210.

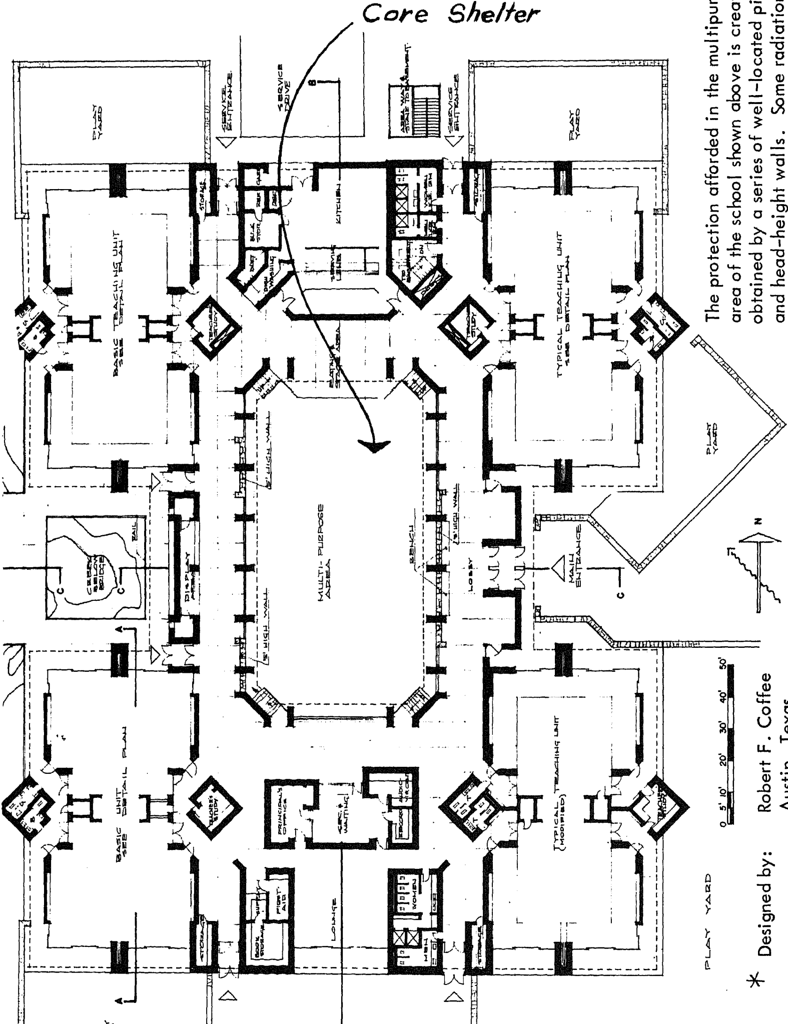
A Series of Walls or Envelopes *



Radiation must pass thru three normal walls to enter the shelter area.

* School designed by: M. Dwight Brown, AIA
Marshall and Brown
Kansas City, Missouri

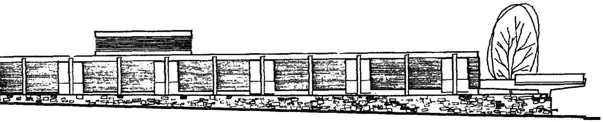
A series of well-placed intermittant walls *



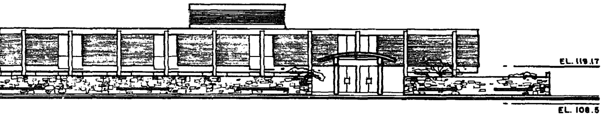
The protection afforded in the multipurpose area of the school shown above is creatively obtained by a series of well-located piers and head-height walls. Some radiation leaks still exist. Where are they?

* Designed by: Robert F. Coffee
Austin, Texas

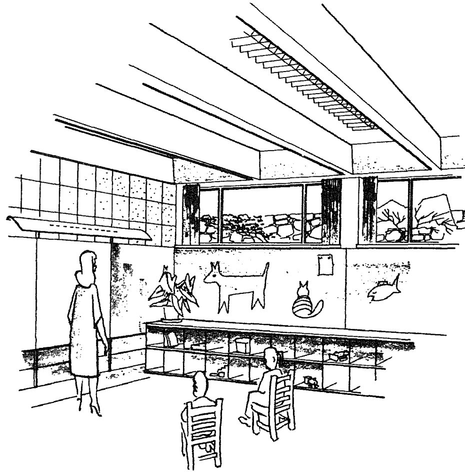
ower the building to duck under the
adiation from the ground. *



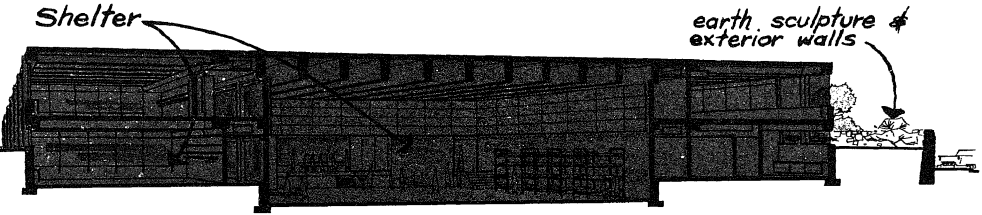
Elevation



Elevation



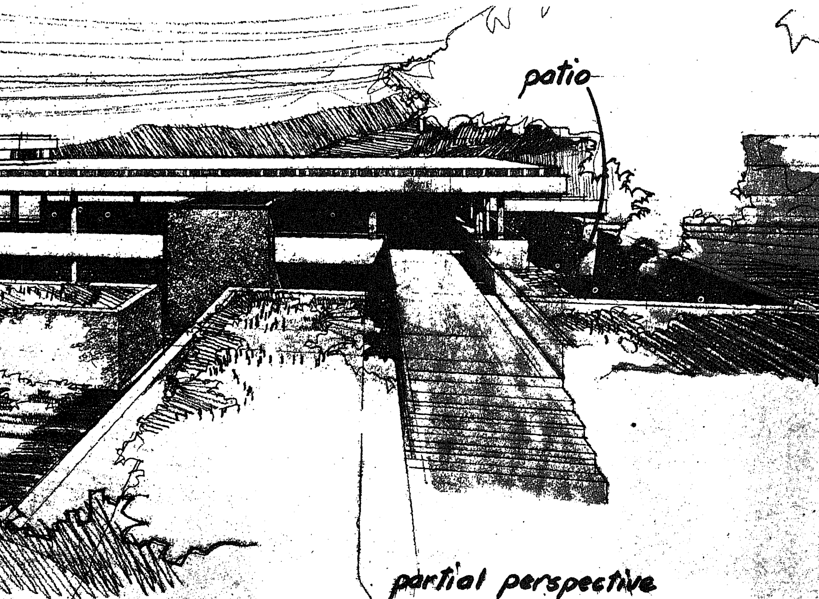
Typical Classroom



or Perspective

* Designed by: James S. Minges, James S. Minges & Associates, Farmington, Connecticut

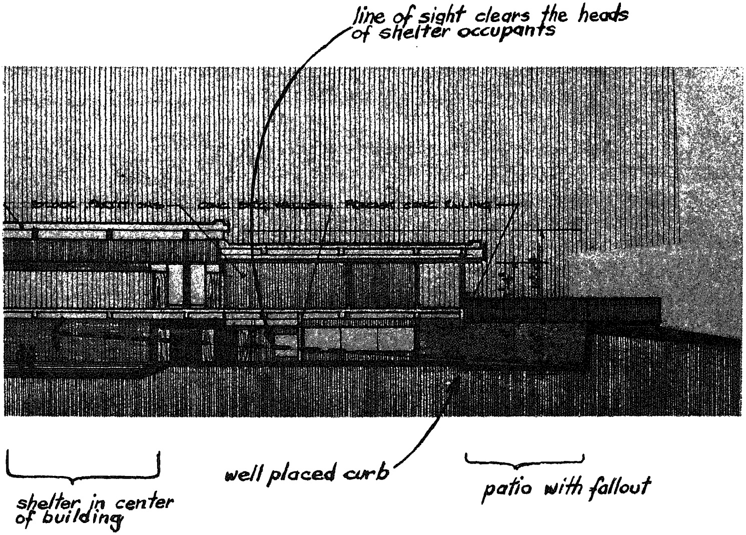
Radiation protection obtained by ground sculpture in combination with other techniques.



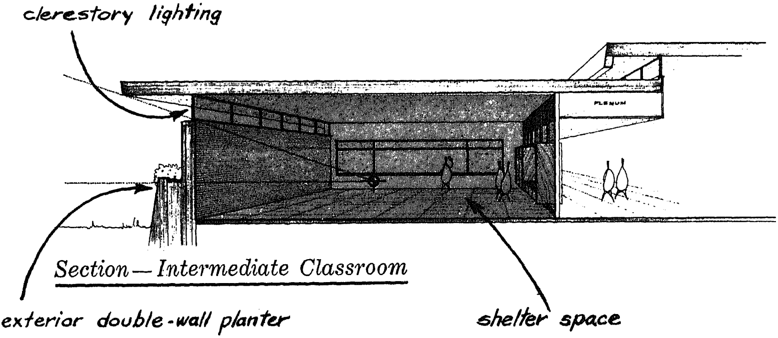
DETAILS

Details often exhibit the real ingenuity of the architect. For example, Ellery C. Green, AIA, of Tuscon, Arizona eliminated the "patio" direct radiation from the shelter area in his prize winning entry in the American Institute of Architects' National School Fallout Shelter Design Competition by providing a simple curb. The partial perspective shown on the previous page gives the general character of the building. The section shown below shows the patio, the curb and the fact that the curb requires the direct radiation from the patio to pass over the heads of the shelter occupants.

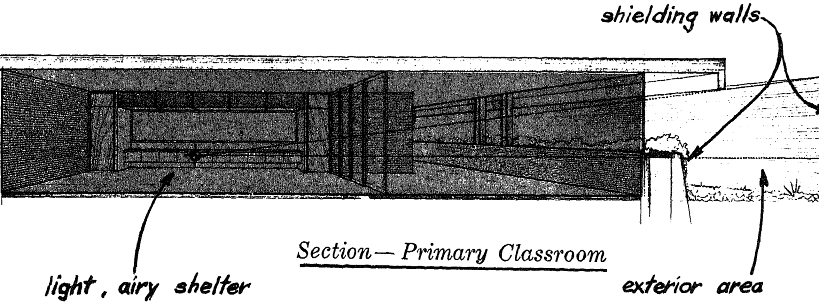
The radiation reaching the occupants fro the patio enters after scattering from the exterior walls or the lip of the curb. Th scattering causes the radiation to lose a considerable amount of energy and hence allows the architect to use lighter shelte walls. The planning charts will give approximations for the required weights c the interior partitions if the curb is consi ered to be an exterior wall and a unit weight is arbitrarily assigned to it.



A second example of good detailing is the choice of exterior walls shown below. Mr. Francis Telesca, AIA, of Miami, Florida, utilized them in his prize-winning presentation in the AIA competition just cited. The distribution of wall mass is proportioned to the intensity of radiation. The most intense radiation enters through the lower parts of the wall as ground-direct radiation. The upper portions predominantly shield against the less intense scattered radiation.



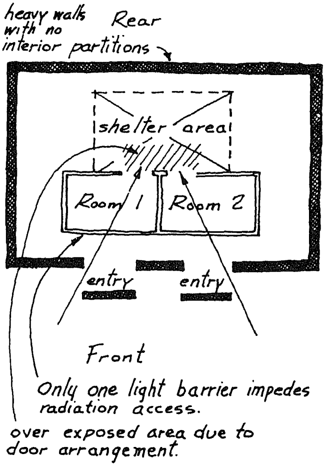
Section — Intermediate Classroom



Section — Primary Classroom

* Designed by Francis E. Telesca, A.I.A., Greenleaf/Telesca, Miami, Florida.

DEFICIENCIES IN DESIGN



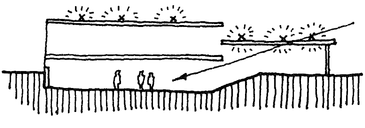
Probably the most common mistake made by shelter planners is leaving holes or leaks in the protective envelope encompassing the shelter. Doorways often will not be offset so that radiation from the fallout lying on the ground has relatively unrestricted access. In the simplified floor plan shown to the left the exterior door lines up on an interior door such that only a light partition impedes radiation access. This creates a "hot spot" located in a highly trafficked area, thus increasing the general level of radiation exposure to the group of occupants.

Note that in all other directions from the front of the building the radiation must pass through at least two walls, the sum of the weights of which is adequate.

Another common mistake is failure to consider the radiation problem in three dimensions.

The two-story wing of an actual school is shown to the left. The section is taken longitudinally through the corridor-shelter. The double overhead barrier provides adequate roof protection. The exterior walls have been designed to minimize ground contribution. The two-story section has been lowered, with respect to the ground outside, to allow the shelter occupants to begin to "duck under" the direct ground radiation.

The mistake occurs in not recognizing that the shelter occupants can see the ceiling of the adjacent one-story portion of the school, and hence be "seen" in return by the radiation from fallout lying on this roof. Since the corridor lines up on this roof it constitutes a major breach in the protective envelope.

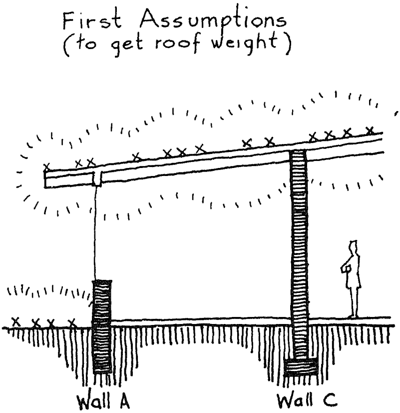


section through corridor

EXAMPLES OF DESIGN USING THE CHARTS

To present design examples illustrating the use of the charts, the writer has chosen two additional designs submitted by practicing architects for national AIA competition. With the architects permission, revisions have been made where considered advantageous to improve the clarity of the point being discussed.

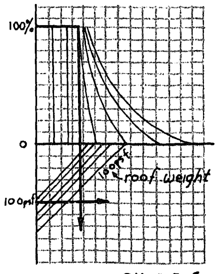
Case 1, A One-Story School



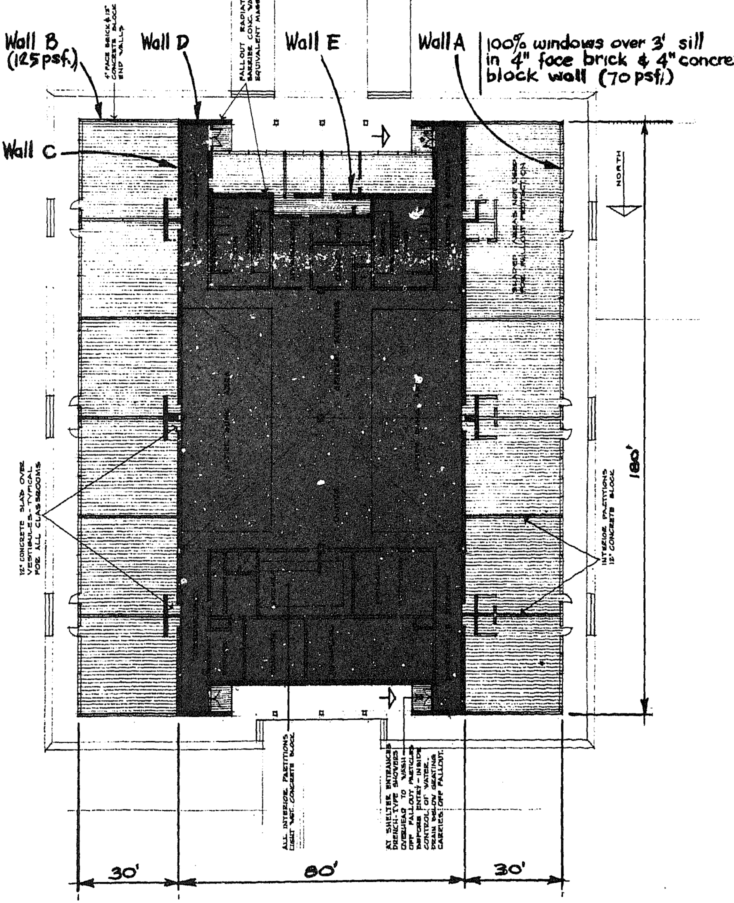
The building, the floor plan of which is shown to the right, is the preliminary design of a single story school. The middle portion of 80' x 180' is to be shelter. It is assumed that no material weights have been chosen except those shown. The remaining weights of the walls and partitions, and the roof weight are desired.

The roof weight is logically the one to choose first. It should be as light as practical to be low cost and devoid of supporting columns in the multi-purpose area if possible. The building has an area of 140' x 180' or approximately 25,000 square feet. The shelter is on the ground floor.

Arbitrarily assuming that walls A and C are typical all around the building, and that wall C tentatively weighs 100 pounds per square foot, reference to Chart 5 (10,000 square feet) indicates that the roof weight should be about 105 psf. Chart 6 (50,000 square feet) indicates a value less than 100 psf. One hundred pounds per square foot is the lightest roof that can be used to provide PF 40.



At this time, it should be noted that lines which intersect as these did on Chart 6 below and to the right of the 100 psf overhead weight curve, indicate an impossible condition. This chart says that the overhead



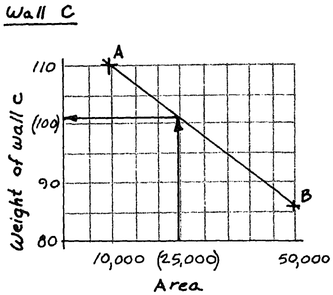
Joseph Baker, Architect, AIA
Joseph Baker and Associates
Newark, Ohio

weight cannot be less than 100 psf to give a PF 40 in a 50,000 square foot building. The roof contribution is too great no matter what the wall contribution may be. Therefore 100 psf is the minimum allowable roof weight for a 50,000 square foot building.

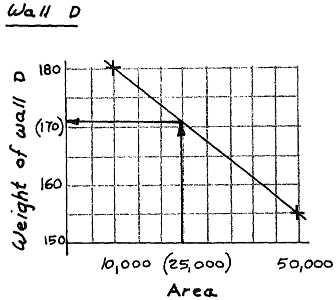
For a 25,000 square foot shelter use 100 psf (equivalent to an 8" concrete slab).

Assuming that the school board is willing to accept the 100 psf roof, let us continue to determine the remaining weights.

With a 100 psf roof, a wall A weighing 70 psf up to the 3-foot sill, and all glass above, Chart 6 indicates that wall C should be 86 psf. Chart 5 indicates that wall C should weigh 110 psf. Simple interpolation as shown to the right indicates that the tentative choice of 100 pounds for the unit weight of wall C is a good one. Use 100 pounds per square foot for wall C.



The condition of wall D is such that no interior partitions occur. Chart 5, for no windows and a 100 psf roof, gives a wall weight of 180 psf. Chart 6 gives 155 psf. Interpolation gives 170 psf as the required value.

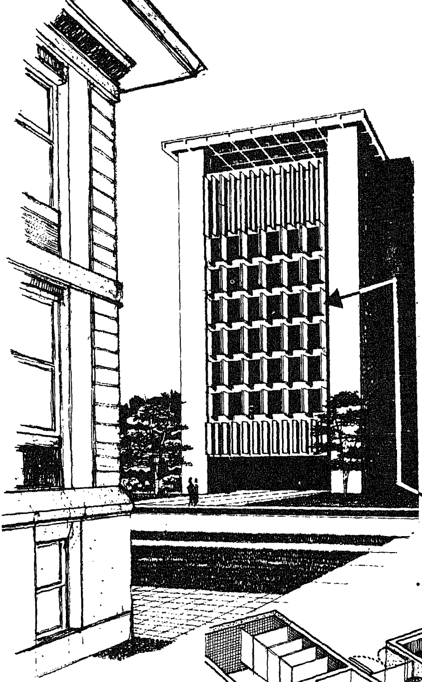


Wall E, assuming arbitrary average of 1 1/2 partitions (45 psf) yields 125 psf (Chart 5), and 100 psf (Chart 6), which interpolate to a 115 psf required weight.

The single story school shelter with these weights will have a protection factor of at least 40. The school will satisfy the minimum Office of Civil Defense requirements. *

With a little practice and familiarity with shielding design, the interpolation may be done by simple guess work. As most designs

* See Appendix.

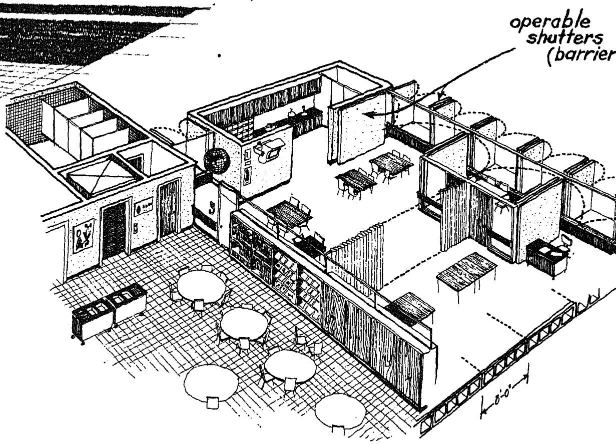


will be approximations of the design assumptions used in the development of the charts, the answers obtained from the charts cannot be assumed to be overly precise. The charts were designed to get the shelter planner into the ball park quickly.

It will become apparent, after using the charts, that a ground floor shelter is the most difficult type to design using normal construction. Both the walls and the roof will be heavier than required by normal architectural considerations unless creativity is rampant.

Case 2, A Multistory Building *

Assume the architect is checking the necessity of utilizing the inner and outer folding radiation barriers on the sixth floor, as shown



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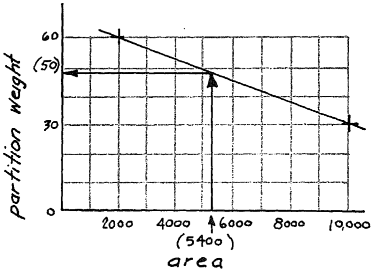
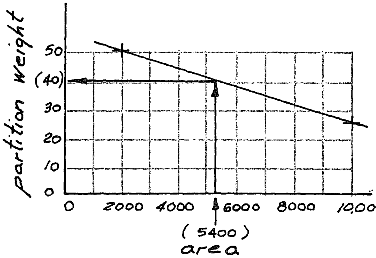
* Designed by Charles William Brubaker, Edward C. Colin, Hem C. Gupta, John F. Janiga, and James Allyn Steward, for the A.I.A. National School Fallout Shelter Design Competition 1963.



in the drawings on the preceding page. The floor weighs 80 pounds per square foot. There are five such barriers overhead, hence the total overhead weight is 400 pounds per square foot. (Note that the charts only go up to 240 psf. At that weight, virtually all of the roof contribution is eliminated.)

The school area is approximately 5,400 square feet per floor. The exterior wall weighs 30 pounds per square foot and windows occupy 40 per cent of the perimeter at the sixth floor level. Chart 19 (2,000 square feet), and a roof weight of 400 psf (use 240), indicate that an interior partition of 60 psf is required. Chart 20 (10,000 square feet) shows 30 psf. Interpolation gives 47 pounds per square foot for an area of 5,400. Therefore, if no exterior shutters are used, the interior folding partitions must weigh 50 pounds per square foot.



As an alternative let the exterior shutters and wall weigh 50 pounds per square foot. With the sutters closed, no windows will be considered.

Chart 19 indicates a 50 psf interior partition required. Chart 20 indicates 24 psf. The 5,400 square foot building area will require a 40 psf partition weight.

The choice is either zero and 50, or 50 and 40 pounds per square foot for exterior and interior shutters. Not much of a choice. Leave off the outer shutters. (Changing the design to allow the interior shutters to be permanent walls is also suggested, thus removing the dependence on the operability of the shutters or the memory of the teachers.).

The purpose of this example is not to suggest that designers use operable shutters, sliding panels, washdown procedures, and other human and mechanical response-dependent systems to gain protection. Such approaches should be avoided.

The purpose is rather to illustrate the uses to which the charts may be put and to discuss the characteristics of radiation which influence design. Note that the first solution (Alternate 1) requires less total mass than the second by almost a factor of two.

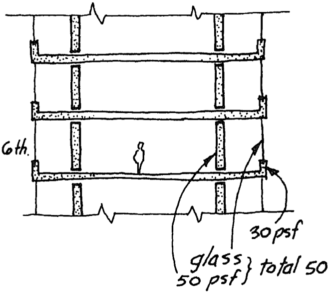
Why is this? The answer is that the most intense radiation, that coming from the first hundred yards around the building, is below the line of sight of the shelter occupant. Since it travels in relatively straight lines, it must pass through a floor barrier to get into the shelter. If a light wall, say 50 psf or less, is placed on the outside of the building this radiation can "see" it and hence scatter from it.

In Alternate 1, skyshine is coming through the windows, requiring a 50 pound interior partition. In Alternate 2, the skyshine has been virtually eliminated by the outer shutters, but radiation now scattering from these shutters and into the shelter has replaced it. It has been replaced to the extent that now a 40 pound per square foot interior partition is required.

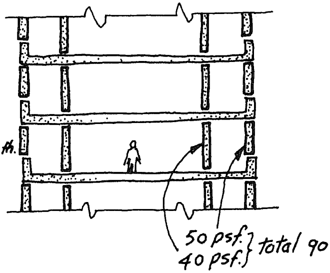
The phenomenon occurs, as was previously discussed, in the basement shelters. A basement shelter offers better protection when the walls on the floor above have negligible weight (say, glass), than when a lightweight wall (10 to 50 psf) is used. Recall from the discussion on page 15 that radiation had to scatter to enter the shelter.

Use a heavy wall or a wall of negligible weight. Avoid the use of walls between the 10 and 50 pound per square foot weights to minimize the scattering-in of radiation.

Alternate 1.

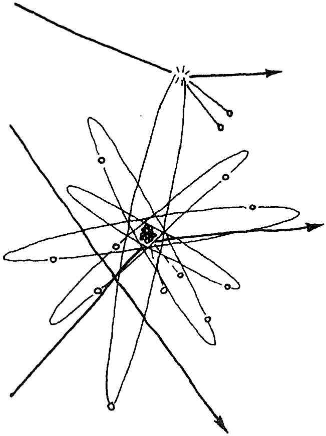


Alternate 2.



SHELTER PLANNING DISCUSSION AND SUMMARY

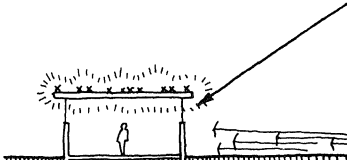
The Analogy



The greatest freedom for design can be had if the architect fully understands the analogy of the clouded-glass structure. The sheets of tiny flashing lights represent the fields of fall-out. All construction is translucent to this light in a manner proportional to the mass and density of the materials of construction.

Light will reflect from a surface. A polished sheet of metal or a mirror will reflect light. Gamma radiation, however, does not see a wall surface. A wall, to radiation photons, is like a galaxy of stars into which the photons are traveling.

Collision between gamma photons and atomic particles of matter in a wall is random. Scattering or ricocheting occurs in random directions and at differing depths into the galaxy. Thus, a stream of radiation striking a wall will not reflect with an angle of reflection equal to its angle of incidence. Radiation scatter will occur somewhat like a stream of water trained upon a heavy metal sieve. The readers' concept of the clouded-glass structure should include this understanding.



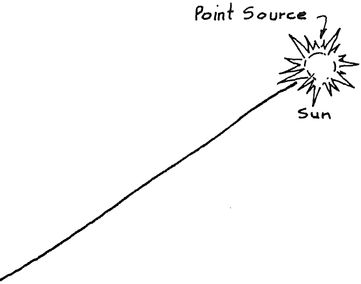
It must not be concluded from the analogy that the darker or more gloomy the space becomes (with respect to natural light), the better the radiation shielding. Neither must it be assumed that all spaces in a building which offer good shelter must be dark and gloomy. Most decidedly not! The space, unless it is bright and cheerful, will not be fully usable during peace time.

A space is dark if sunlight or artificial illumination does not reach it. During a disaster electric power may not be available, so the previous sentence may be shortened to: "A space is dark if sunlight does not reach it."

Sunlight and fallout gamma radiation are different. The sun is a point source of light. In our analogy the blankets of light (fallout) are field sources.

The sun is in the sky and follows a particular path well known to the designer and utilized daily in his considerations. Fallout is on the roof and ground. It is stationary. It is quite possible for the creative designer to get sunlight into radiation-shielded areas.

The creative architect can develop bright, airy, pleasant spaces which offer excellent radiation protection. As the architect ponders the relations in his hypothetical clouded-glass structure, he must clearly remember the difference between sunlight and fallout gamma radiation.



The Design Charts

It is impossible to plan properly without quantitative information upon which to base decisions. The graphs are for quick, reasonable, "ball-park", numerical values. They are an aid to judgment. They are not a source of creativity or even of good design.

Designing is the development of proper, general solutions to problems encompassing many variables. In the development of shielded areas within a building or building complex, decisions will be made concerning other areas which have nothing to do with shelter. Hence, shelter is a compromise, and the designing must be done in the mind and not in the manua

Field Source

Proper, well-thought-out concepts of radiation shielding can be developed using the clouded-glass structure analogy. The planning graphs will then yield the preliminary material weights required to develop the minimum protection factor of 40. Use the charts freely and without concern. Shelter analysts should verify and refine the weights. The variations found will be more often conceptual than numerical.

Summary

Fallout resembles sand, dust, or ash. The radioactive bomb fragments attached to it emit radiation which may damage or destroy living tissue. In a large attack about 75 per cent of the land area of the United States could be affected by fallout. Since less than 10 per cent may be affected by blast and heat, radiation protection is worth considering. It is the basis for the civil defense shelter system.

Radiation protection is relatively simple to design. Basements and interior portions of the upper floors of multistory buildings can easily offer adequate protection using normal materials of construction. Ground floor shelters are usually more difficult, heavier, and more expensive. However, creative solutions have been developed by architects which satisfy all requirements.

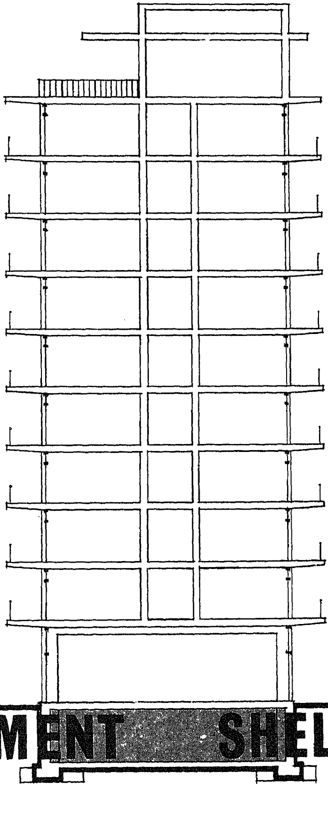
The two major sources of radiation are the fallout fields on the roof and the ground. Radiation enters a shelter by direct line of sight, by scattering from atoms of the building materials and by scattering from atoms in the atmosphere. These three types are called direct radiation, wall-scattered radiation, and skyshine. Skyshine is normally of minor importance. Hence, clerestory lighting is permissible in fallout shelters.

The three basic types of shelters have been discussed. The below ground, at ground level, and aboveground shelters, have intense ground radiation, leaving only the roof radiation and radiation scattering down from the walls above to be considered. The ground floor shelter or shelter at ground level in a single story building is fully exposed to ground radiation as well as roof radiation. Creativity is required to bring down the cost.

The shelter in the multistory building has the advantage of being moved up and away from the ground radiation and is several floors below the roof. Hence, as barriers are naturally located between the fallout and the shelter occupant, normal construction and normal costs are usually encountered. Adequate radiation protection is inherent in normal design. Of course not all multistory buildings provide adequate protection, but normally only minor design changes are encountered. Look for shelter first in below-ground areas, then in multistory areas, then gird yourself with ingenuity and design it on the ground floor.

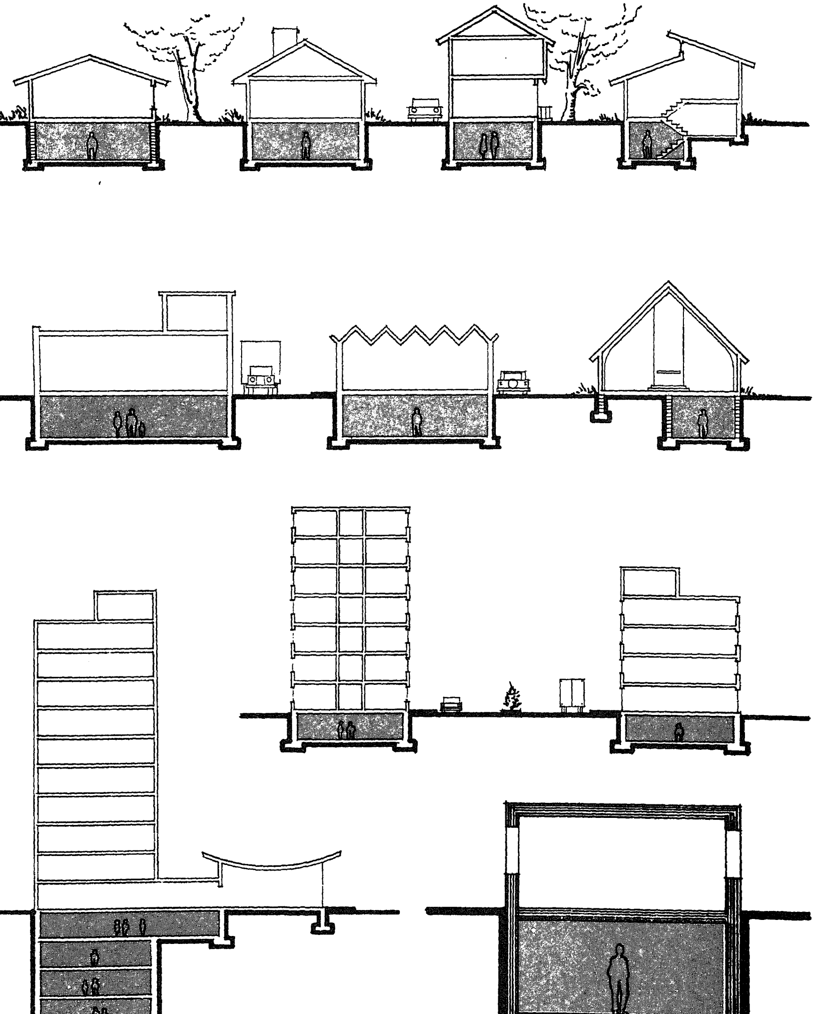
THE DESIGN CHARTS

The following charts are designed to give approximate numerical values for material weights of exterior walls, interior partitions, and overhead construction for simple shelters. These charts are developed to provide those combinations which will yield a minimum protection factor of forty (40) within the shelter. It is expected that designs developed through the use of these charts will be verified by qualified shelter analysts before being finalized.



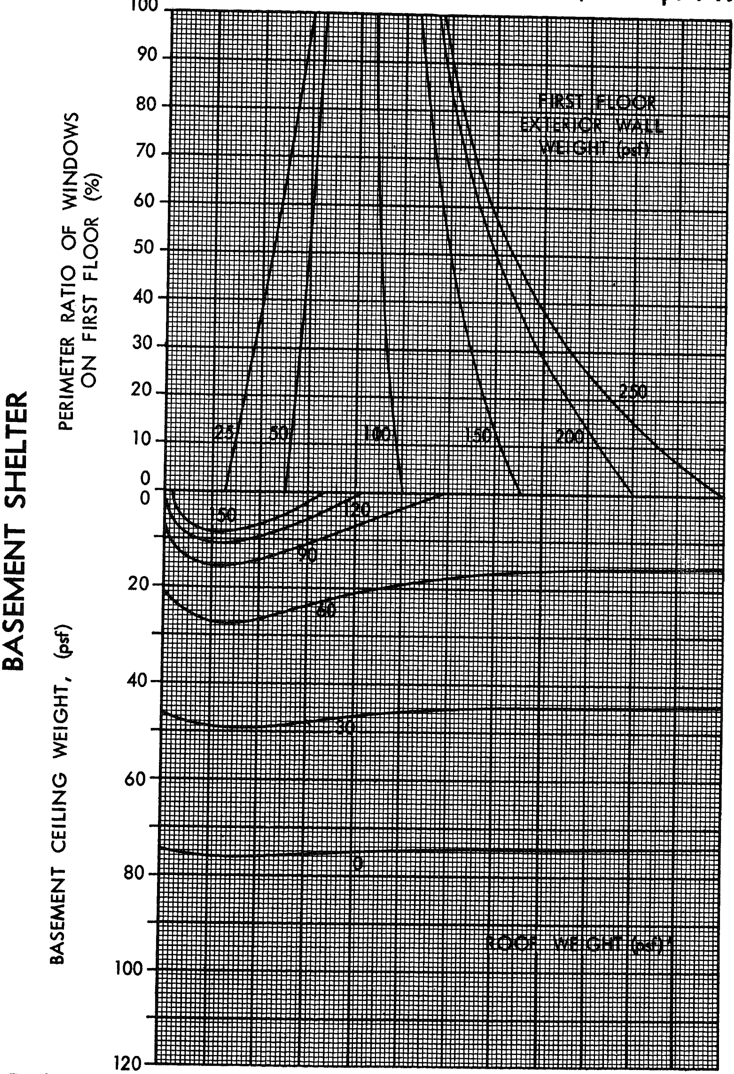
BASEMENT SHELT

BASEMENT SHELTER



BUILDING AREA 2,000 SQ. FT.

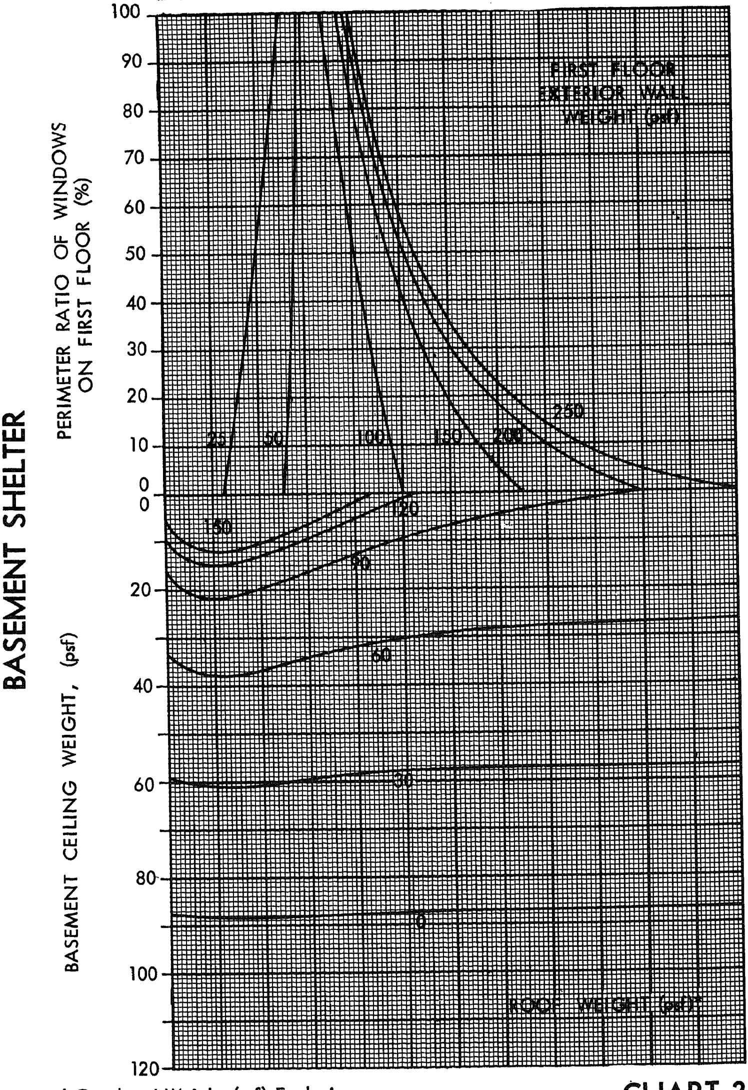
BASEMENT SHELTER



* Total Overhead Weight (psf) Exclusive Of Basement Ceiling

CHART I

BUILDING AREA 10,000 SQ. FT.

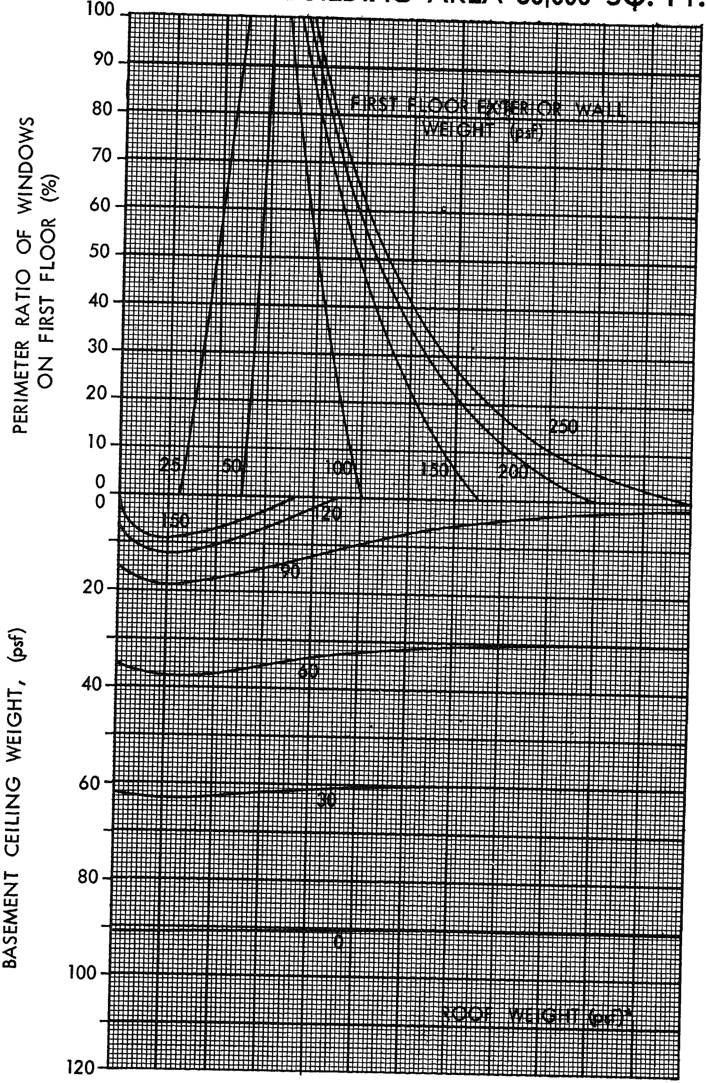


* Total Overhead Weight (psf) Exclusive

CHART 2

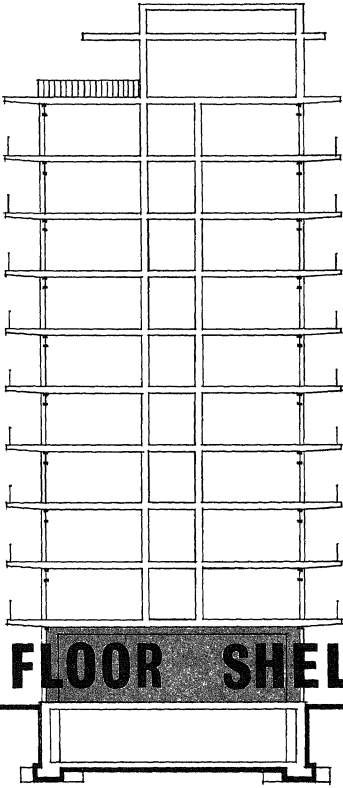
BUILDING AREA 50,000 SQ. FT.

BASEMENT SHELTER



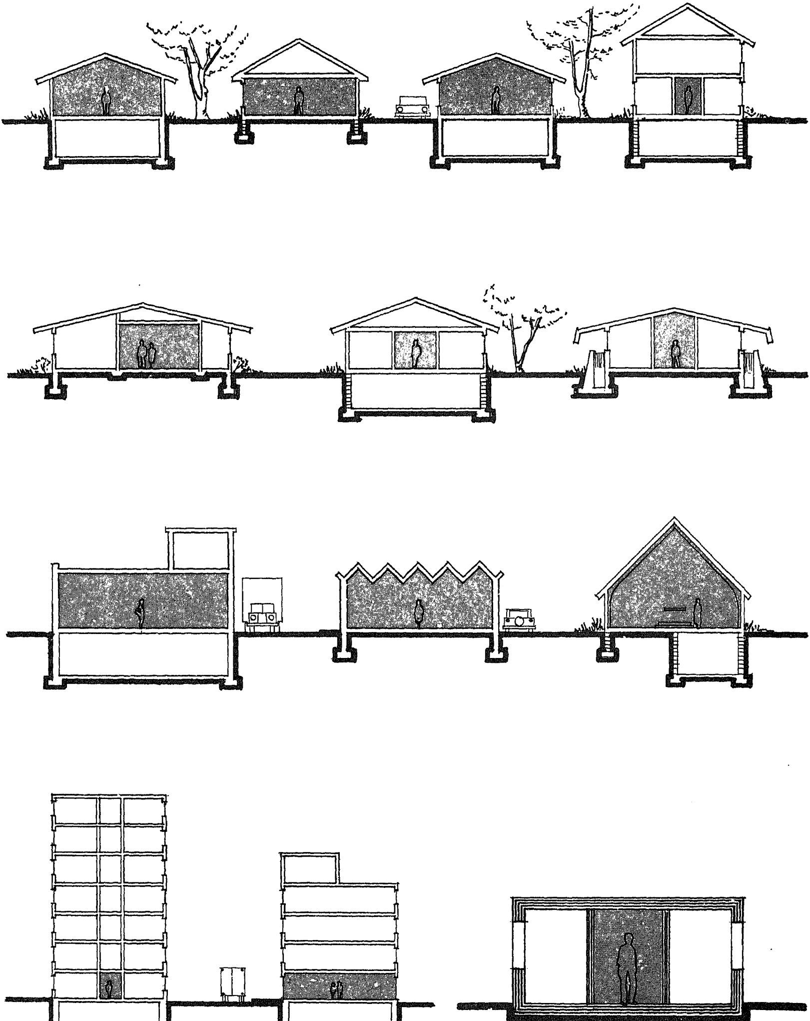
* Total Overhead Weight (psf) Exclusive

CHART 3



GROUND FLOOR SHELT

GROUND FLOOR SHELTER



DESIGN SECTION

BUILDING AREA 2,000 SQ. FT.

GROUND FLOOR SHELTER

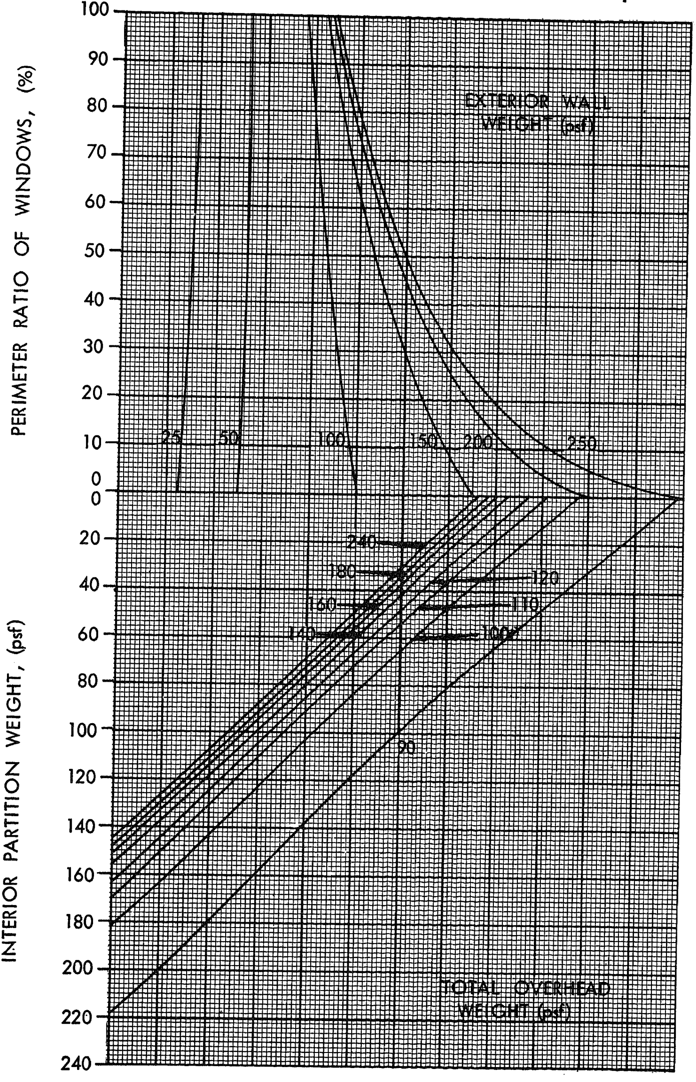


CHART 4

BUILDING AREA 10,000 SQ. FT.

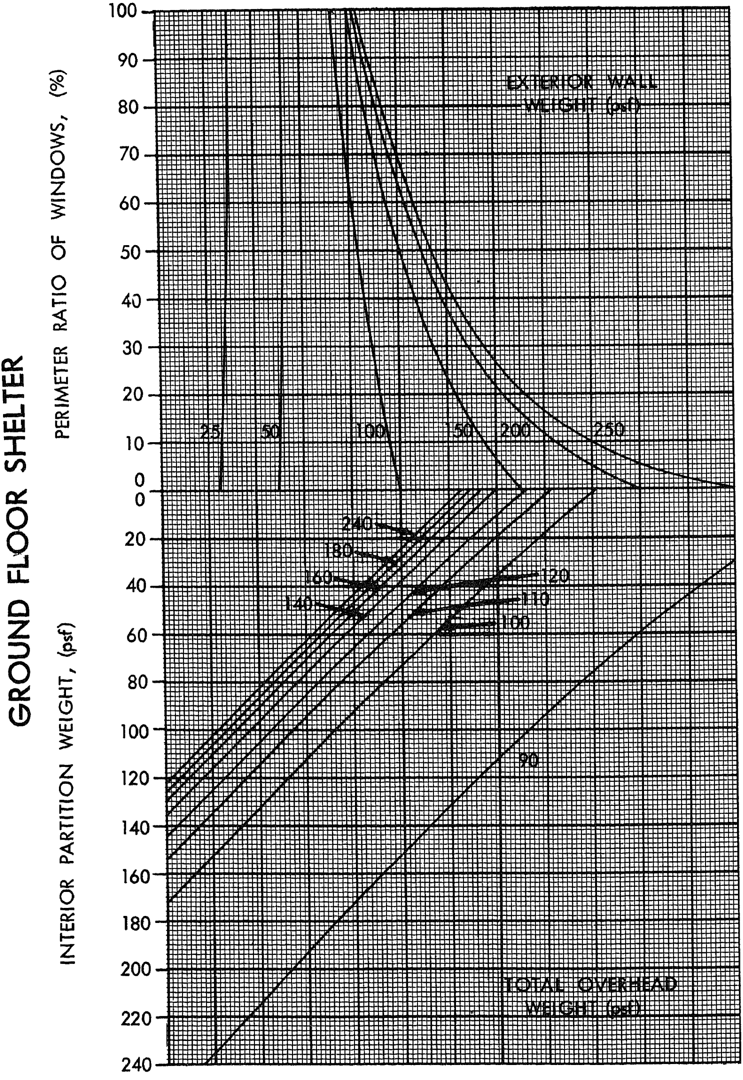
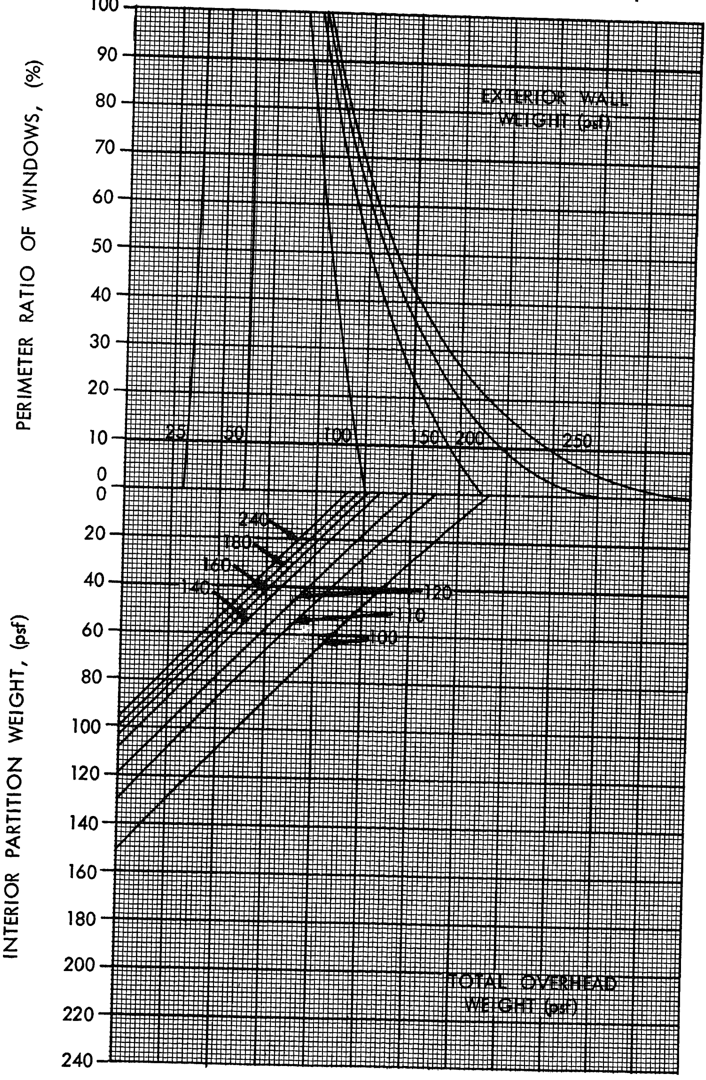


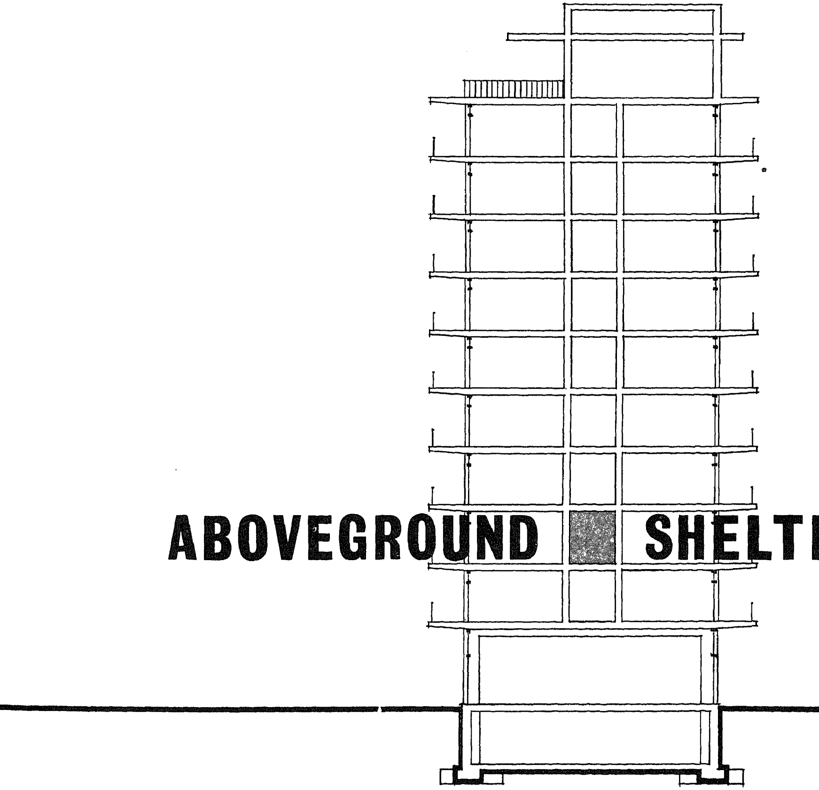
CHART 5

BUILDING AREA 50,000 SQ. FT.

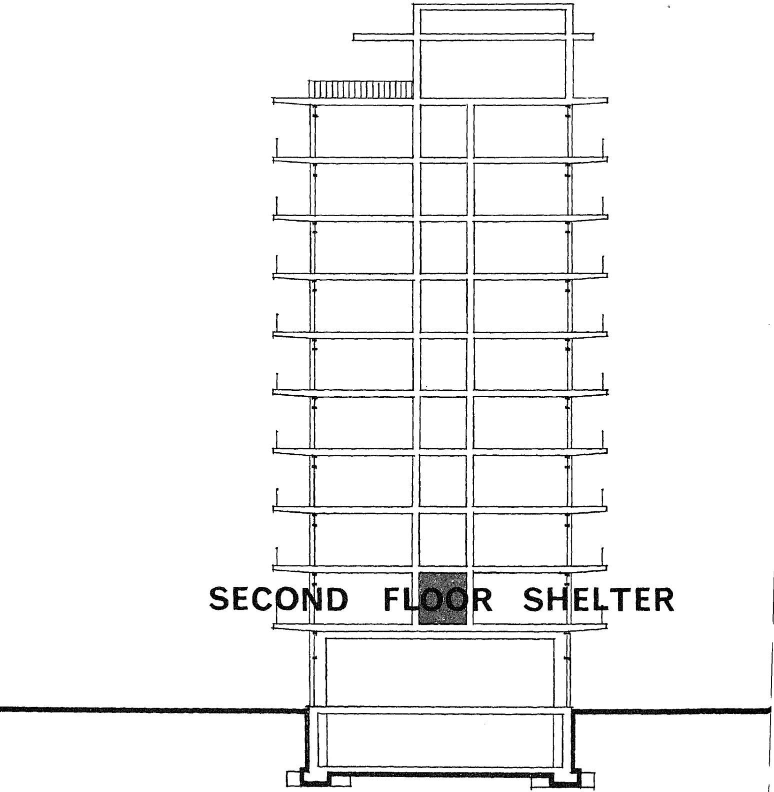
GROUND FLOOR SHELTER



ABOVEGROUND SHELT



ABOVEGROUND SHELTER



BUILDING AREA 2,000 SQ. FT.

SECOND FLOOR SHELTER

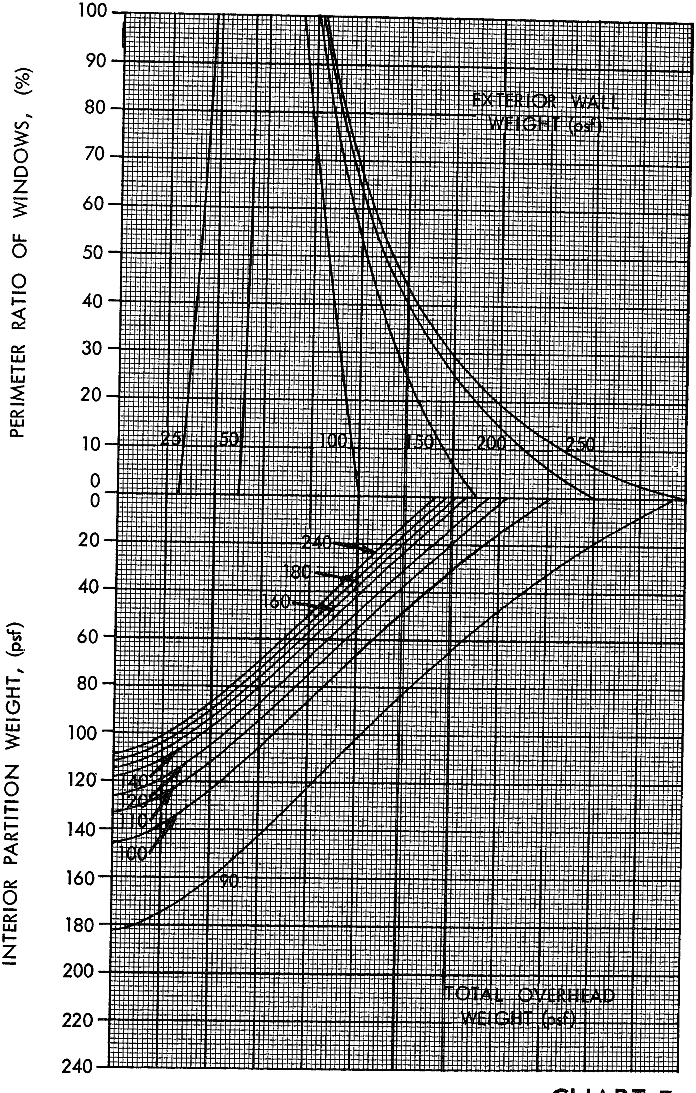


CHART 7

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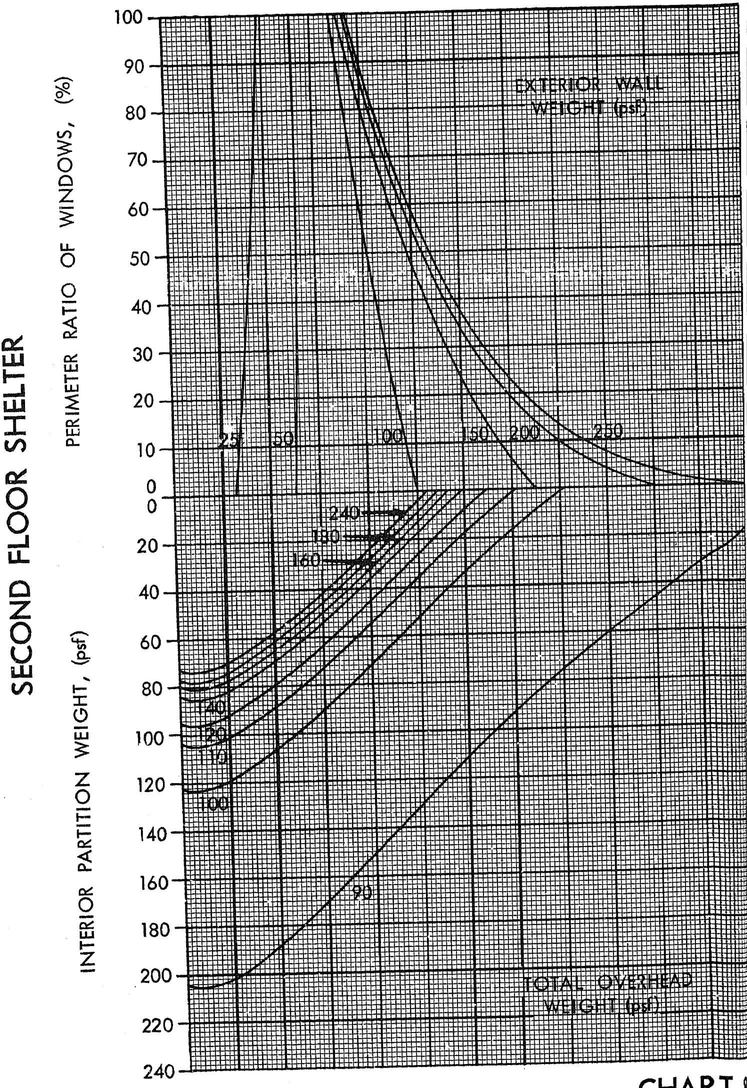


CHART

BUILDING AREA 50,000 SQ. FT.

SECOND FLOOR SHELTER

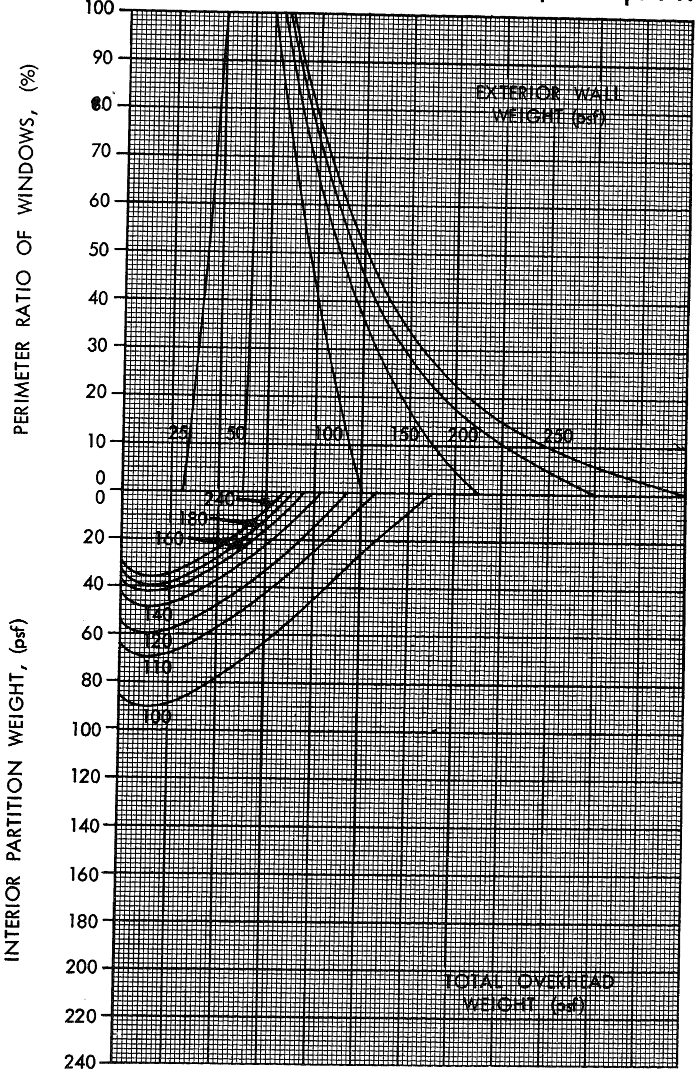
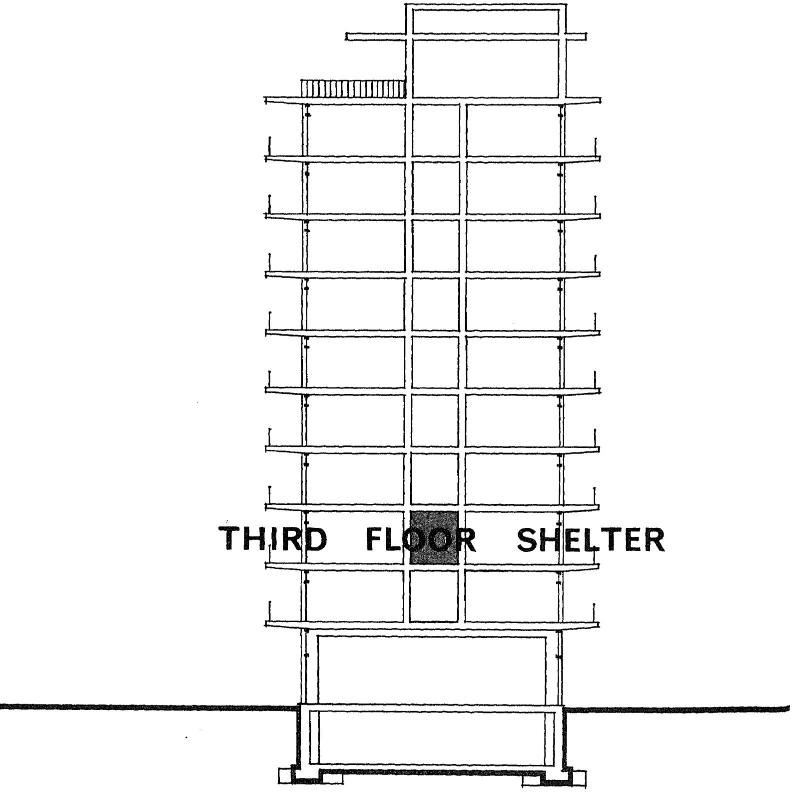


CHART 9

ABOVEGROUND SHELTER



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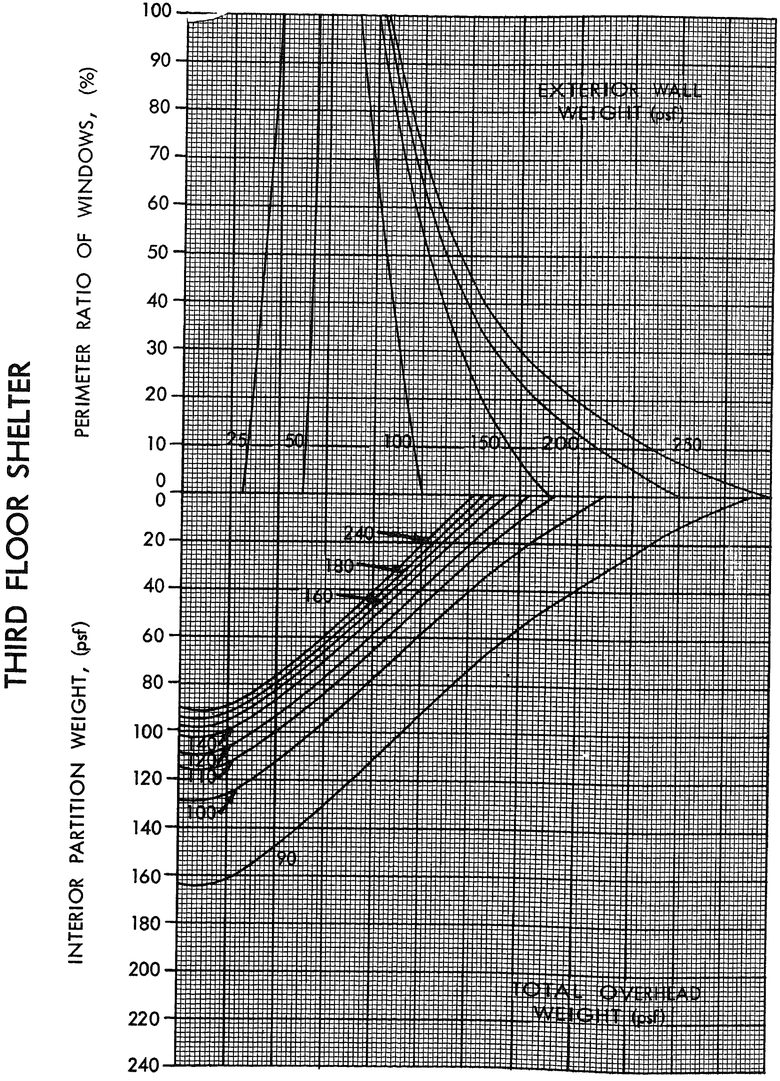

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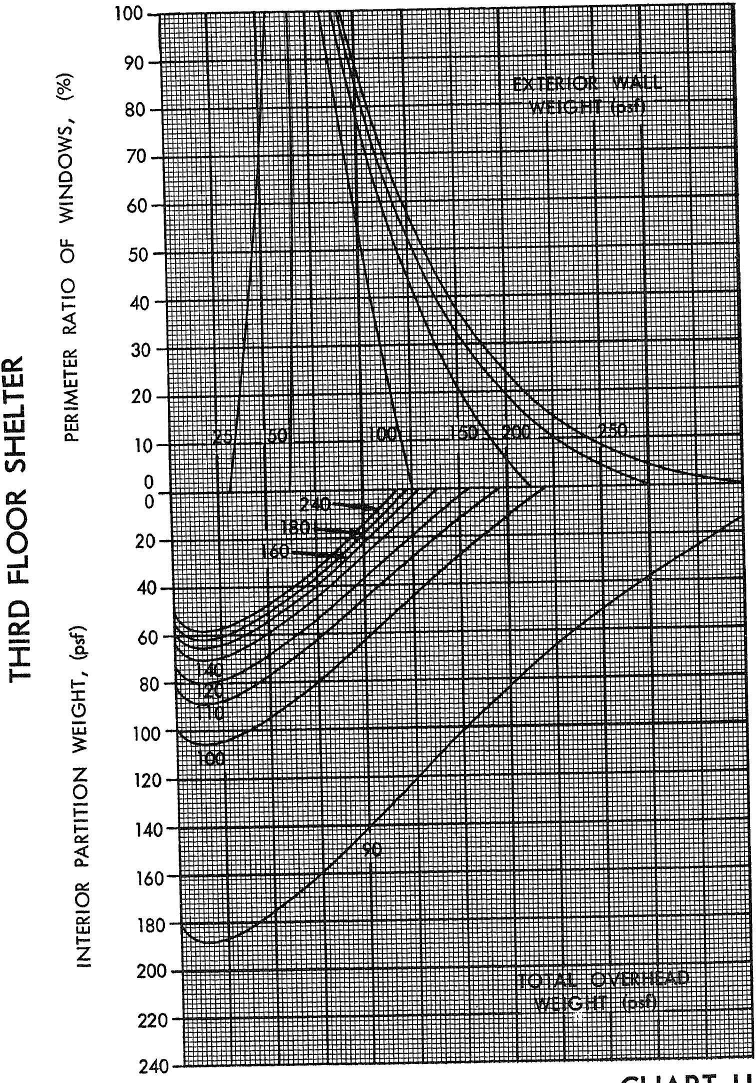
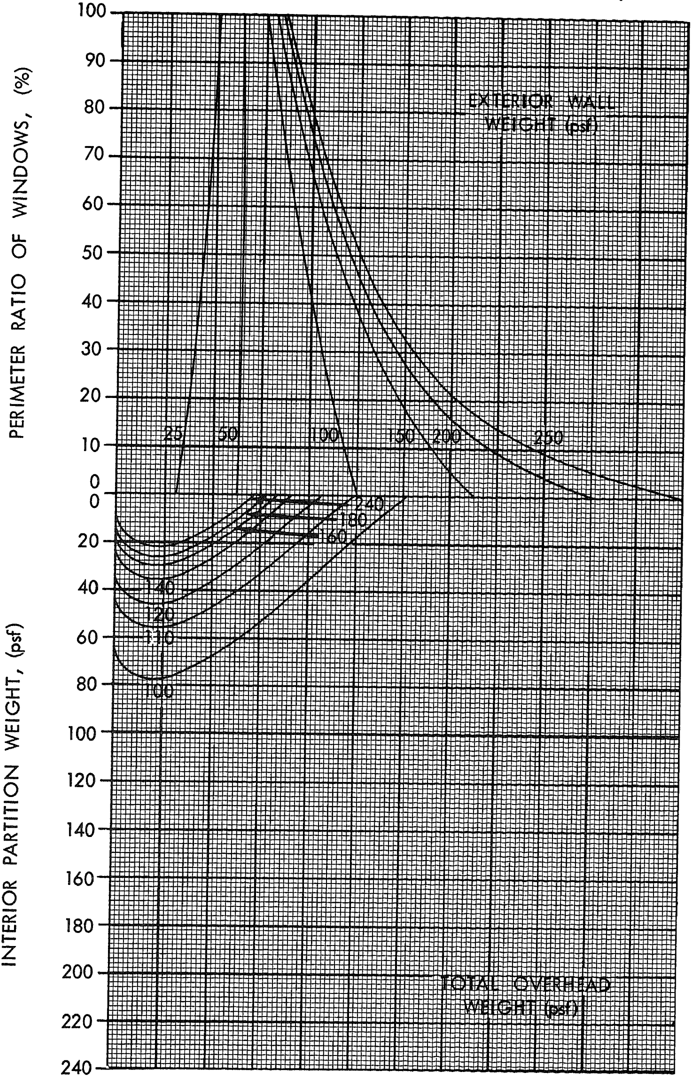


CHART 11

BUILDING AREA 50,000 SQ. FT.

THIRD FLOOR SHELTER



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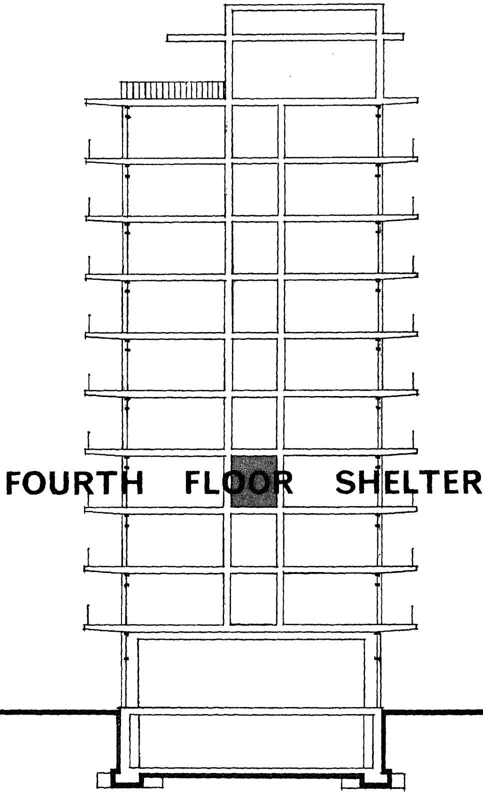


FOURTH FLOOR SHELTER

BUILDING AREA 2,000 SQ. FT.

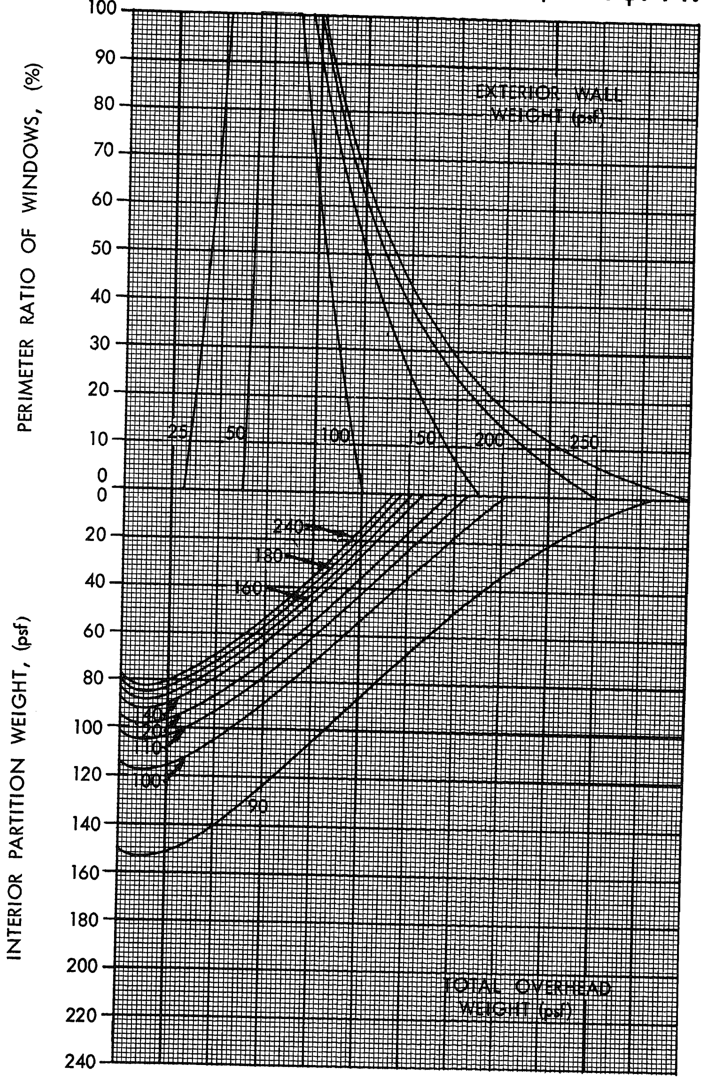
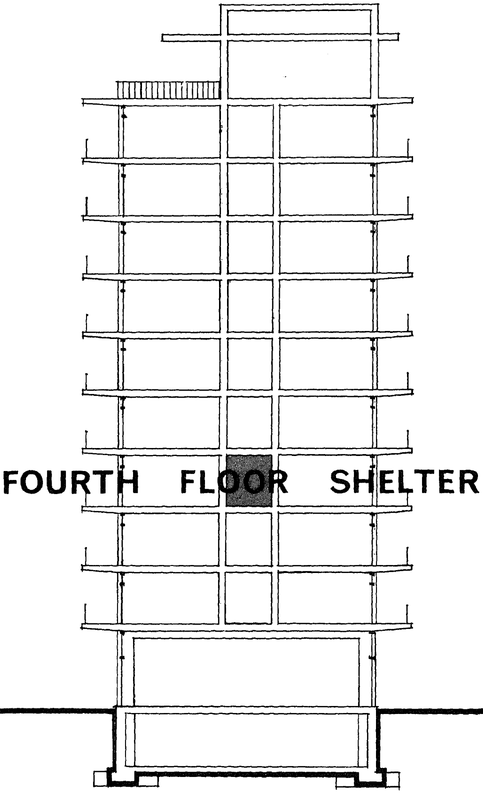


CHART 13

ABOVEGROUND SHELTER



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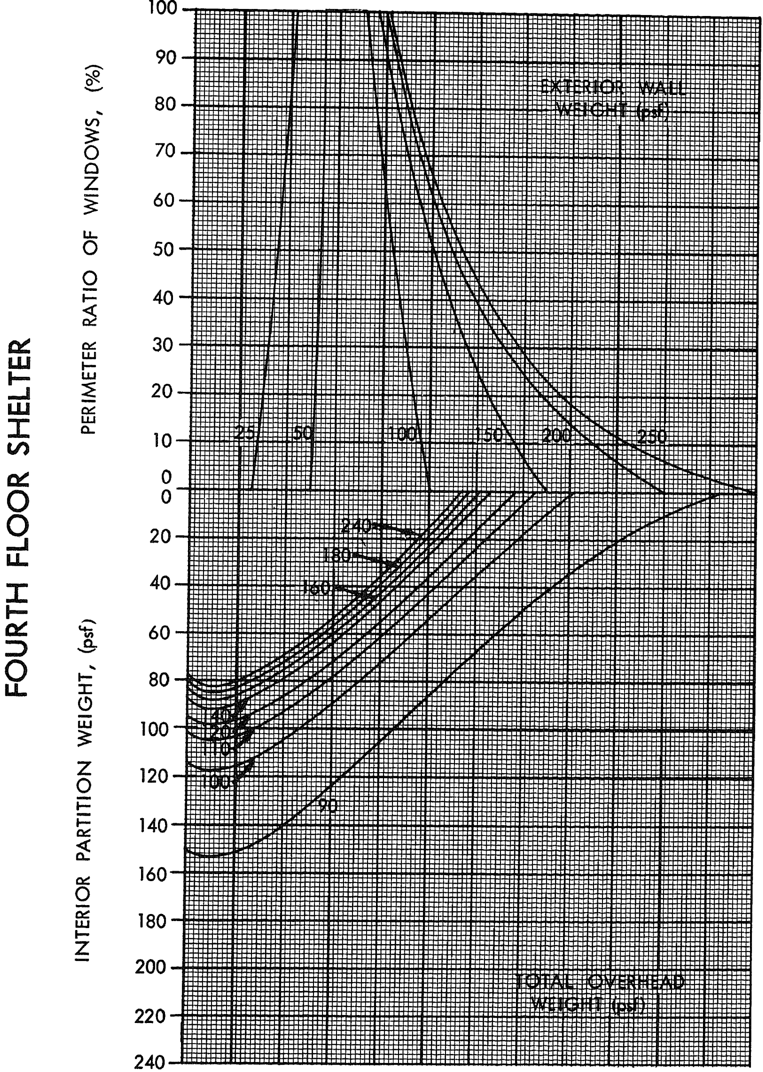

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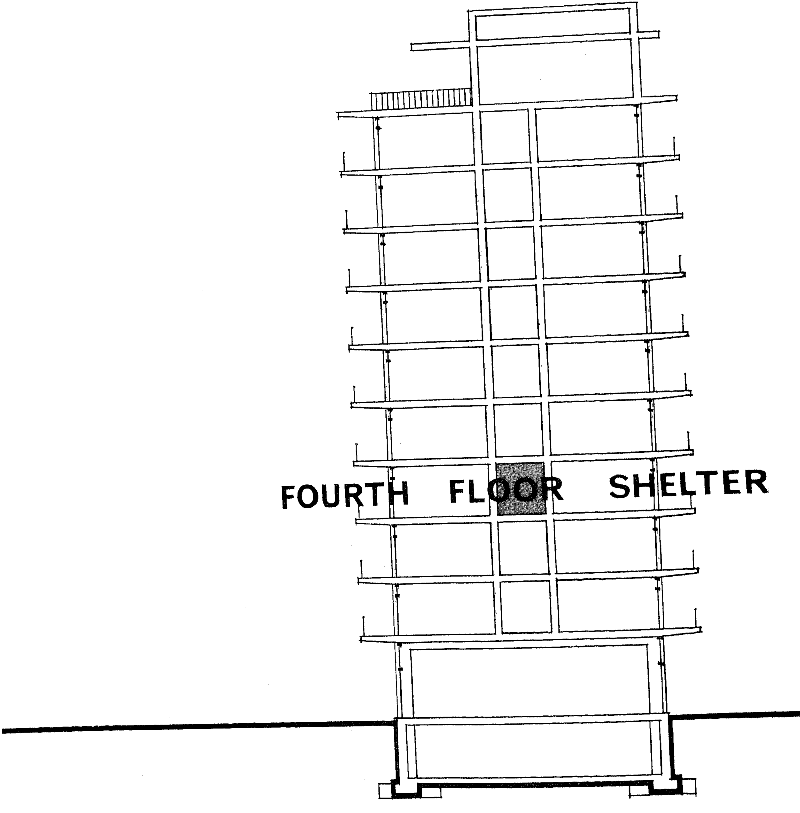

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FOURTH FLOOR SHELTER

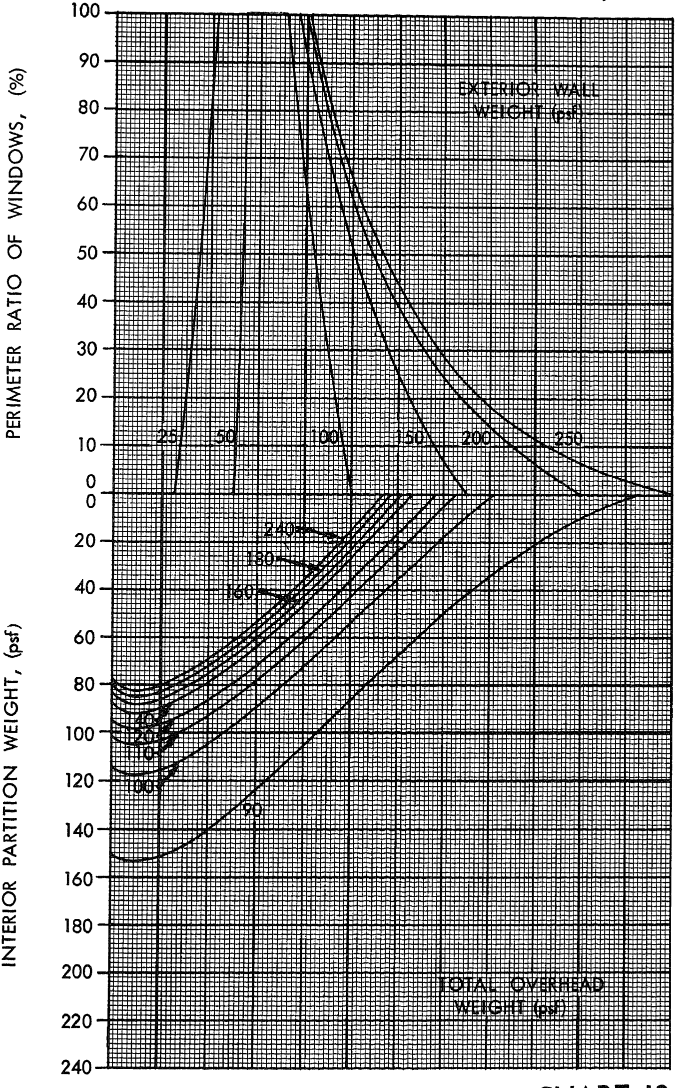


CHART 13

BUILDING AREA 10,000 SQ. FT.

FOURTH FLOOR SHELTER

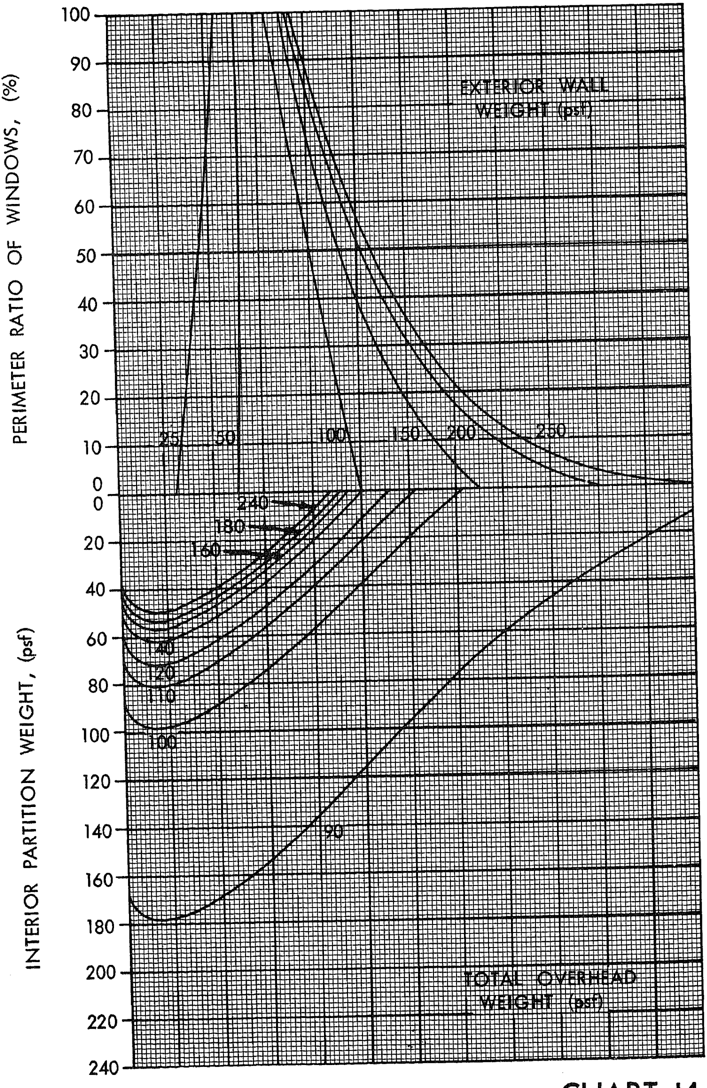


CHART 14

BUILDING AREA 50,000 SQ. FT.

FOURTH FLOOR SHELTER

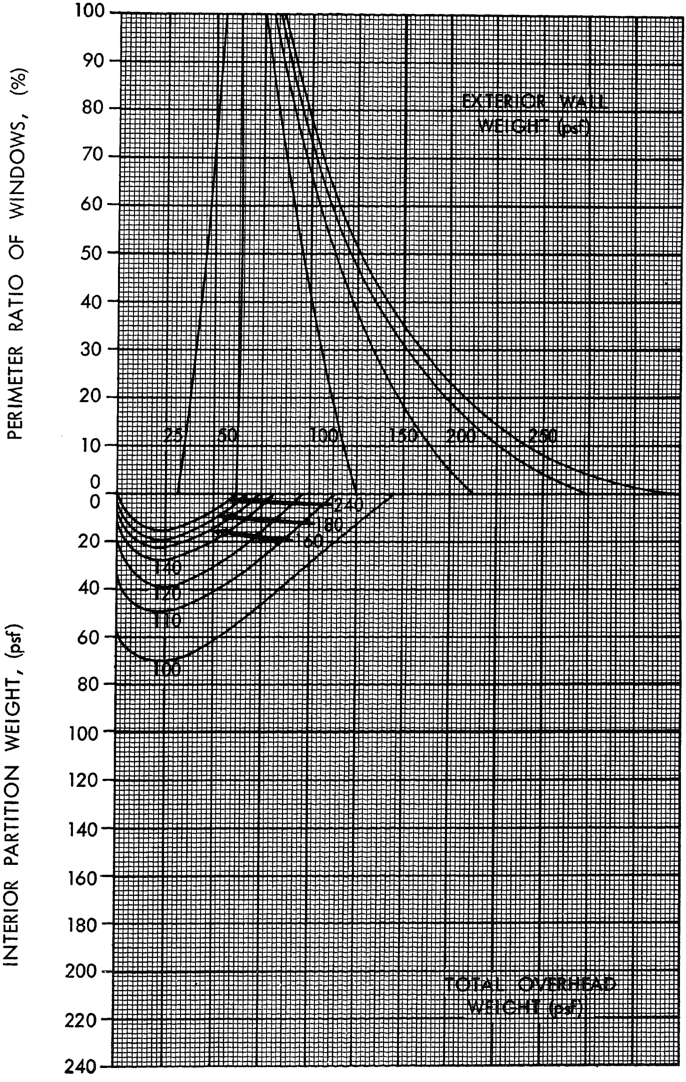
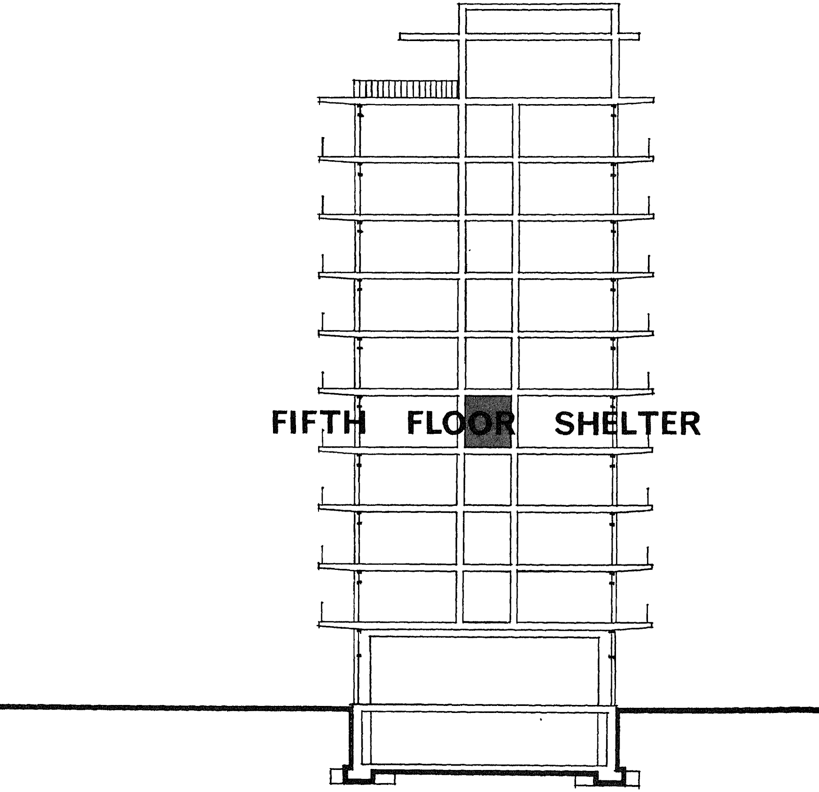


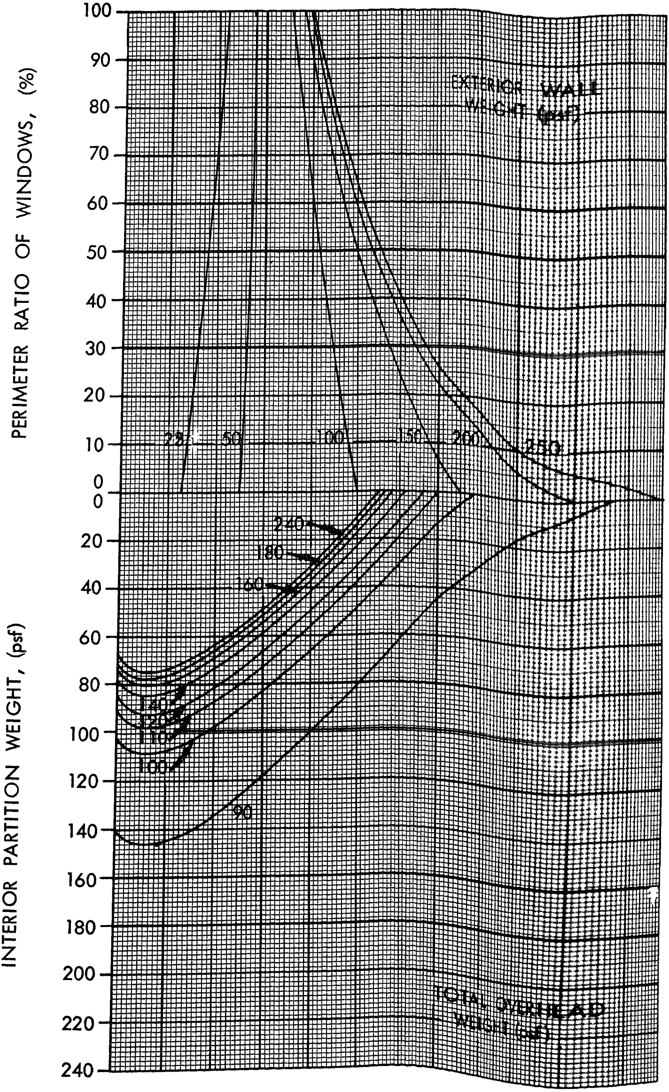
CHART 15

ABOVEGROUND SHELTER



BUILDING AREA 2,000 SQ. FT.

FIFTH FLOOR SHELTER



BUILDING AREA 10,000 SQ. FT.

FIFTH FLOOR SHELTER

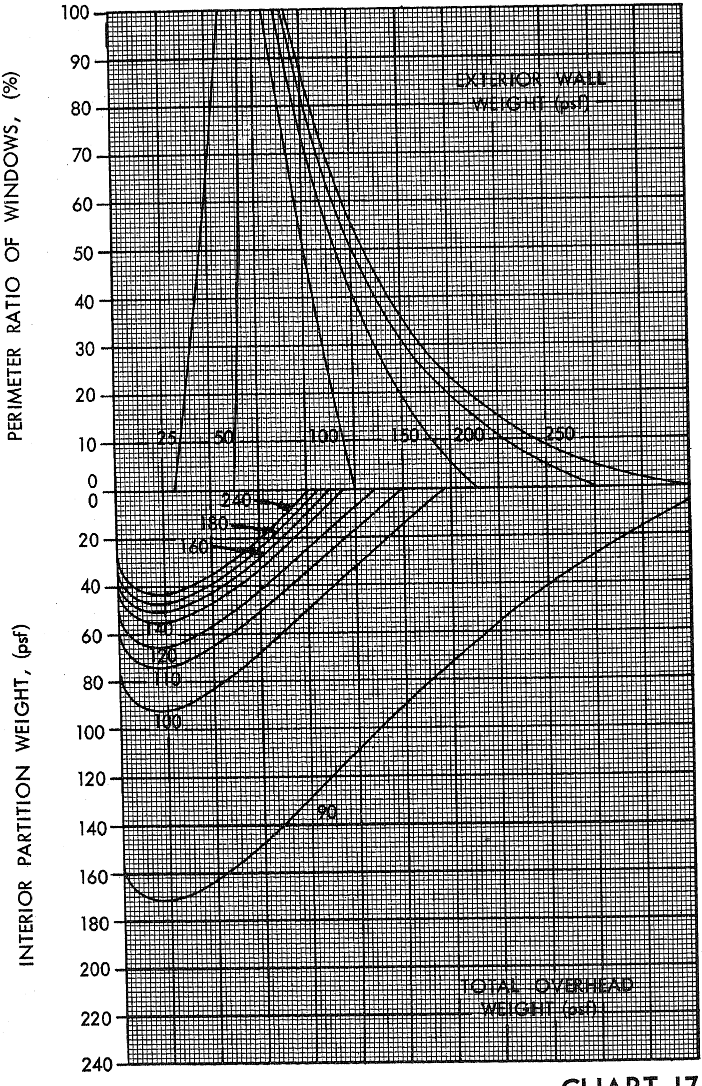
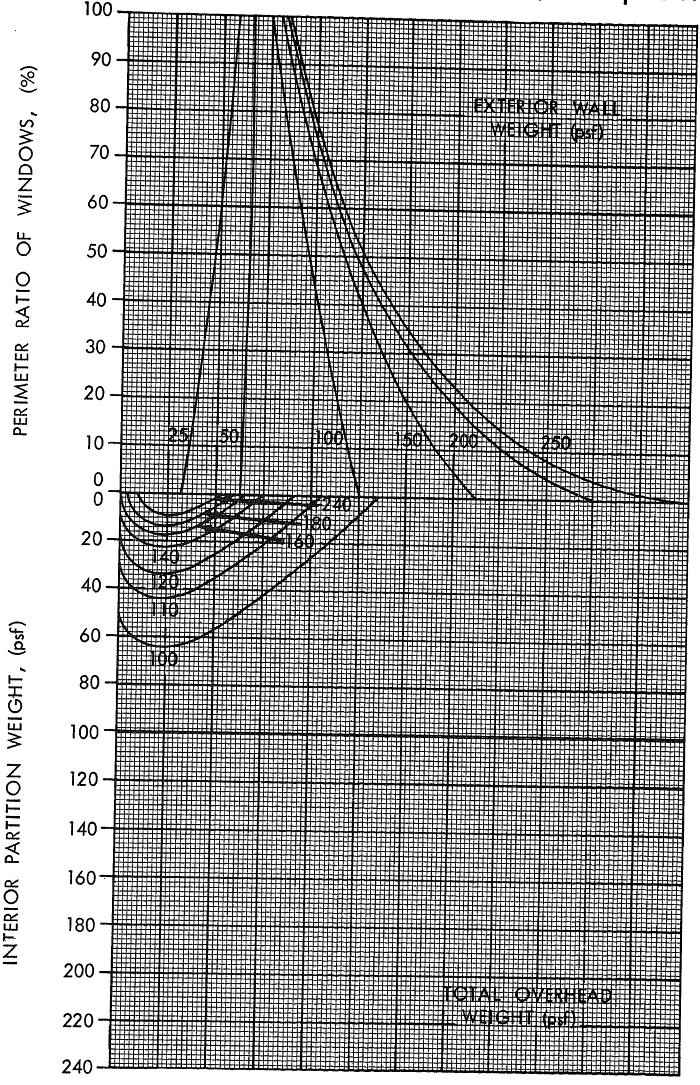


CHART 17

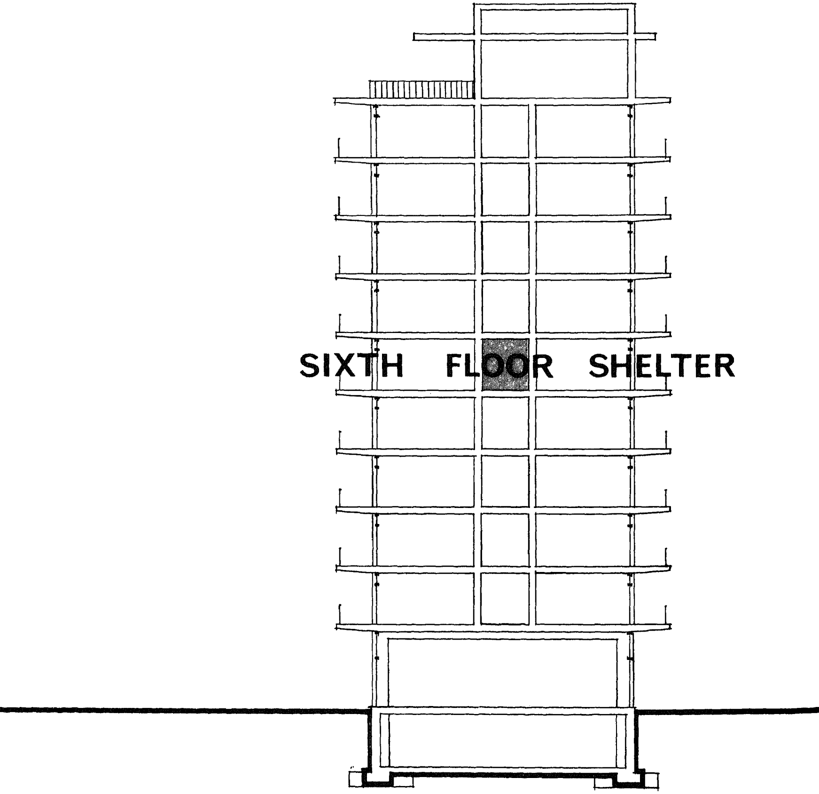
BUILDING AREA 50,000 SQ. FT.

FIFTH FLOOR SHELTER



CHART

ABOVEGROUND SHELTER



BUILDING AREA 2,000 SQ. FT.

SIXTH FLOOR SHELTER

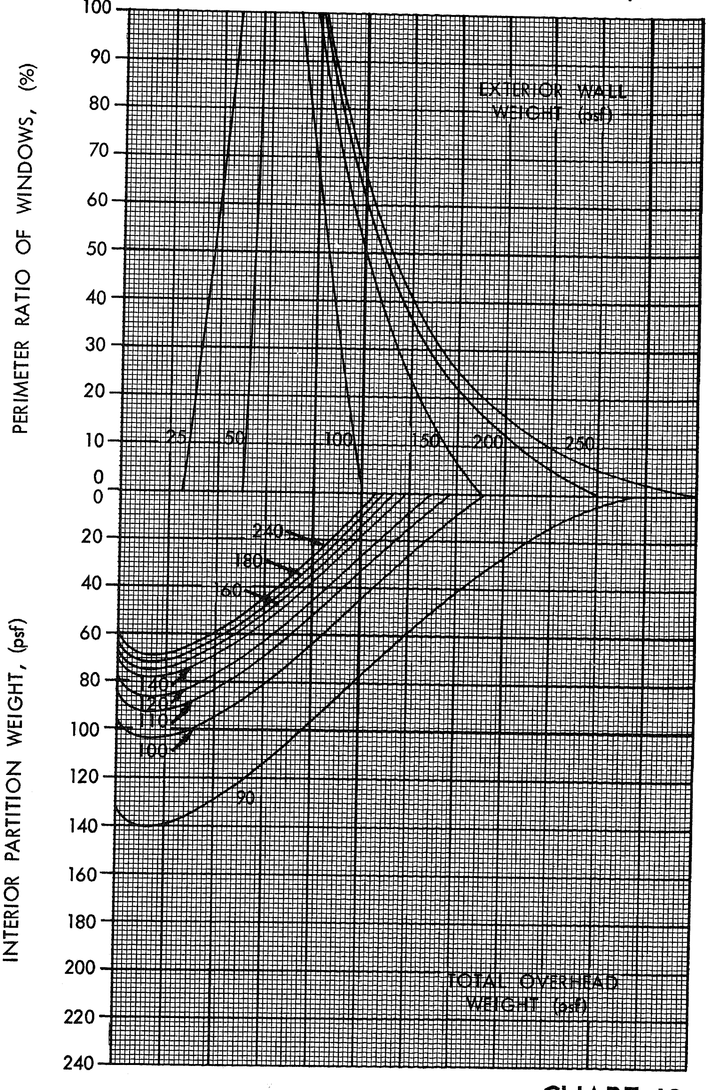


CHART 19

BUILDING AREA 10,000 SQ. FT.

SIXTH FLOOR SHELTER

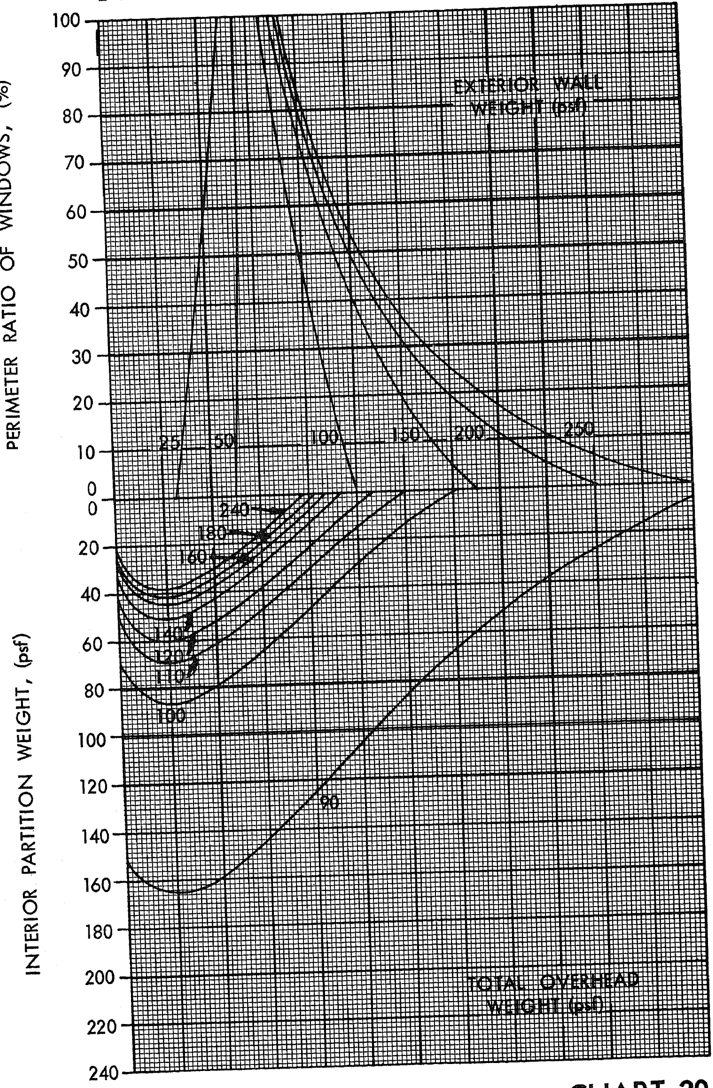


CHART 20

BUILDING AREA 50,000 SQ. FT.

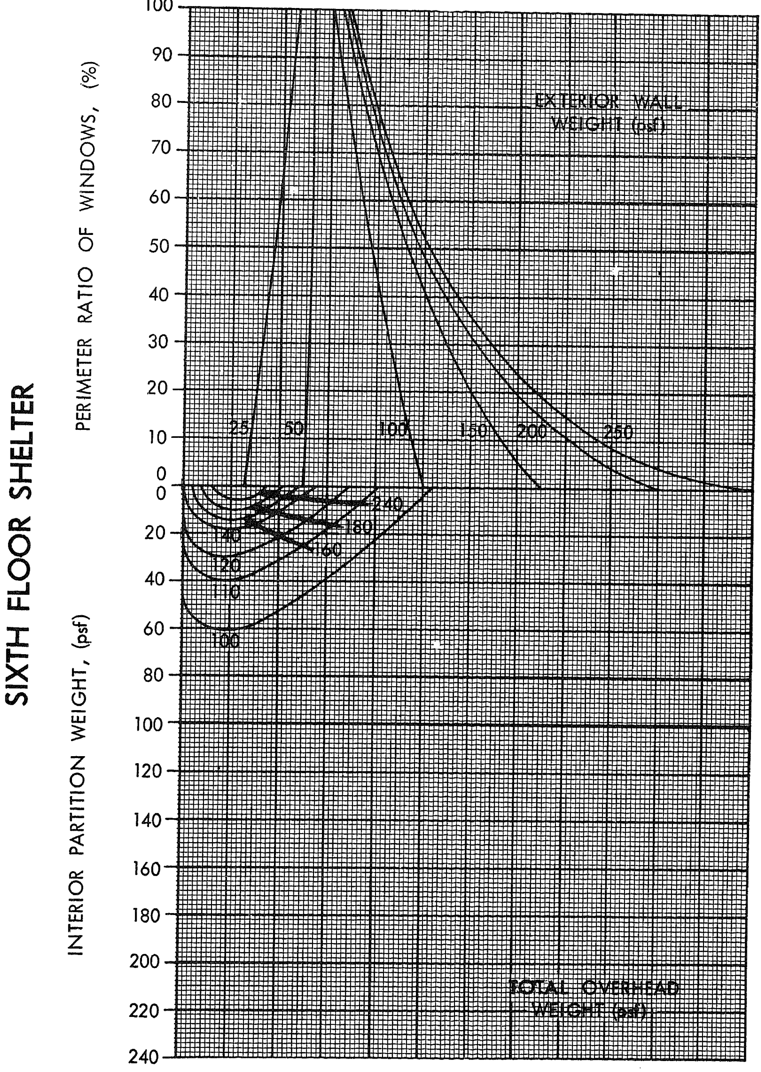


CHART 21

APPENDIX

DEPARTMENT OF THE ARMY
OFFICE OF THE SECRETARY OF THE ARMY
WASHINGTON, D.C. 20310

DIRECTOR
Office of Civil Defense

Technical Memorandum 61-3 (Revised)
March 1965*

TECHNICAL REQUIREMENTS FOR FALLOUT SHELTERS

I. General

The purpose of this technical memorandum is to establish official standards for fallout shelters.

II. Terminology

A. Protection Factor. A factor used to express the relation between the amount of fallout gamma radiation that would be received by an unprotected person and the amount that would be received by one in a shelter. For example, an occupant of a shelter with a PF of 40 would be exposed to a dose rate 1/40 (or 2½%) of the rate to which he would be exposed if his location were unprotected.

B. Fallout Shelter. A structure, room or space that protects its occupants from fallout gamma radiation, with a protection factor of at least 40.

III. Radiation Shielding

A. Computation of protection factors shall be made by methods acceptable to the Office of Civil Defense.

B. In the calculation of the protection factor, the radiation dose contribution to the shelter occupants coming from the entranceways, ventilation ducts or other openings in the shelter's barriers shall be considered.

IV. Shielding Requirements

Detailed DoD studies of the lifesaving potential of fallout shelters indicate that for the current time-frame and for the foreseeable future, shelters with a protection factor of 40 could save over 90% of those persons who would otherwise die if unprotected against potential lethal radiation levels. Therefore, design and construction objectives are:

A. Shelters for the General Population. In modifications to existing buildings and in new construction, protection factors and shelter areas should be maximized to the extent possible, at nominal or no cost, using slanting techniques (See TM 64-2). Although minimum protection for a shelter area should be at least PF 40, the objective is to obtain the best protection factor possible. Computations indicate that decreasing returns in added lives saved per added dollar invested are obtained as PF's are increased significantly above 40. On a nationwide basis, therefore, it would provide better life-saving potential per dollar, for the same dollar expenditure, to obtain more shelter space of lower PF than only a few shelter spaces with very high PF.

*Supersedes TM 61-3, August 1964.

B. Shelters for Emergency Operational Personnel. As it is anticipated that personnel with emergency functions may have to expose themselves to dangerous radiation levels during the performance of their duties, it is desirable to obtain the best possible protection factors for emergency operating centers or shelters housing emergency operational personnel, with an acceptable minimum objective of at least 100 PF.

C. Recognizing that in many design and construction projects it may be physically difficult or expensive to attain these minimum shielding objectives, it is still a worthwhile objective to increase protection factors to any level. Under many potential levels of radiation exposure, even these lower protection factors will save lives or minimize illness.

V. Space and Ventilation Requirements

A. Ten square feet of shelter floor area per person shall be provided.

B. At least 65 cubic feet of space per person shall be provided.

C. If the shelter capacity is based on minimum space requirements, then at least 3 cubic feet of fresh air per minute per person are required.

D. 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. When ventilation is limited, the following table can be used for determining the relation of space requirements to ventilation:

Time for one complete air change (minutes)*	Volume of Space required per person (Cu. Ft.)
1,000 or more	500
600	450
400	400
200	300
100	200
60	150
35	100
22	65

* Computed as a ratio: $\frac{\text{Net volume of space (cu. ft.)}}{\text{Fresh air supply (cfm)}}$

E. No filters are required on mechanical ventilation systems other than those necessary for the normal daily use of the space.

F. In general, incremental costs of fixed ventilation equipment to meet shelter requirements shall not exceed $2.50 per shelter space, the estimated cost of ventilating the shelter with packaged ventilation equipment approved by the Office of Civil Defense.

VI. Construction Requirements

A. In general, conventional methods of design and construction for concrete, wood, steel, brick, structural tile and other products will be followed. Allowable stresses and/or load factors as defined in the applicable codes shall be used.

B. The structure shall be designed for a useful life of at least 10 years.

C. At least one unit of access and egress width should be provided for every 200 shelter occupants (a unit width is 22 inches, the space required for free travel of one aisle of persons). In no case shall a single passage width be less than 24 inches; nor shall there be less than two widely separated means of egress from each building. Emergency-type hatchways may be used as a means of egress. They shall be designed so that any normal-size adult can readily enter or leave the main shelter chamber.

D. In areas subject to high-ground water conditions, provisions shall be made to prevent flotation of underground shelters.

E. Provisions shall be made to insure the shelter interior will remain reasonably dry.

F. To the extent practicable, hazardous utility lines such as steam, gas, etc., should not be located in or near the shelter area unless provision is made to control such hazards before the shelter is occupied.

G. All shelters shall be constructed to minimize the danger of fire from both external and internal sources.

VII. Services

A. Provisions shall be made for the storage of basic shelter supplies by allotting $1\frac{1}{2}$ cubic feet per person. This volume may be reduced to 0.6 cubic feet per person if the standard OCD $17\frac{1}{2}$ gallon water drums are not utilized. The live load attributable to placing these supplies should be considered. Fallout shelters with a capacity of 50 or more persons, which have been made available to the public should be stocked with:

1. Water - to provide each person with a minimum of $3\frac{1}{2}$ gallons of water.

2. Food - special crackers, biscuits, or wafers, etc., to provide 10,000 calories per person, deducting comparable food already available in the building.

3. Medical care kits.

4. Sanitation kits which include toilet tissue, sanitary napkins, toilet seat and commode chemicals. Empty water containers convert to commodes.

5. Radiation detection instruments.

B. Water Supply. An adequate supply of water from a suitable well, water trapped in the piping of the facility, or water storage tanks should be substituted, wherever feasible, for storage of drinking water in the standard OCD $17\frac{1}{2}$ gallon water drums.

C. Sanitation. Toilets may be provided on the basis of one per 50 occupants. In lieu of VII A 4 above, other austere provisions, based on economic considerations may be made for the disposal of garbage, trash, and human waste. Fifty percent of the toilets may be outside the shelter area, in other parts of the building, provided they are readily accessible without hazardous exposure to fallout gamma radiation.

D. Electrical power. It is assumed that normal electrical power will be available, therefore emergency generators are not required. No special lighting levels are required in fallout shelters. The following levels are deemed adequate for emergency occupancies:

1. Sleeping areas - 2-foot candles at floor level.

2. Activity areas - 5-foot candles at floor level.

3. Administrative and medical areas - 20-foot candles at desk level.

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BIBLIOGRAPHY

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