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COMMUNAL AIR RAID SHELTERS



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INTRODUCTION

This pamphlet on Communal Air Raid Shelters has been prepared under the direction of the Chief of Engineers, U. S. Army, and published by the Office of Civilian Defense. Earlier pamphlets on protective construction are:

Protective Construction, (Revised Edition, 1942).

Glass and Glass Substitutes.

Report of Bomb Tests on Materials and Structures.

Air Raid Shelters in Buildings.

The term "communal air raid shelter," as used herein, designates a protective structure intended for construction out-of-doors and for groups of persons larger than individual families. They may be erected on public or private property, and the occupancy may be either definitely assigned to individuals and groups or open to the public in the immediate neighborhood. This definition of the term is derived from British usage which excludes from the meaning of the term group shelters constructed within buildings. This latter type of shelter is discussed in the pamphlet entitled "Air Raid Shelters in Buildings."

The selection of shelter types is closely associated with air raid shelter policy. Nothing in this publication establishes such policy, and the description of communal shelters herein in no way indicates that they should be selected to the exclusion of other types or, indeed, constructed at all.

The illustrative designs are based on the application of established design principles where possible; on knowledge of the behavior of various structures under bombing; on observations in England by representatives of the War Department; and on results of tests performed in England by the Ministry of Home Security and in the United States under the direction of the Chief of Engineers. Although considerable data are available on blast pressure-time relations, fragment velocity and distribution, earth shock and movement, this pamphlet includes only data or information directly applicable to the design of the shelter types discussed.

Prepared under the direction of the Chief of Engineers, U. S. Army, with suggestions of the Committee on Passive Protection Against Bombing of the National Research Council and the National Technological Civil Protection Committee.

COMMUNAL AIR RAID SHELTERS

I. THE AIR RAID SHELTER PROBLEM

A. Basic Considerations.

The psychology of sheltering from air raids is very difficult to evaluate. There is good evidence, observed during actual heavy air raids abroad, that in a raid, people like company. Some families will prefer to take refuge in small domestic shelters, which may be safer than their own homes, but will be less comfortable. Others will prefer more company than the family affords, and also will take account of the fact that the head of the family may not be at home. Therefore, they will prefer the joint comfort and moral support which is possible in the communal shelter, together with the possibility of more effective joint action in an emergency. Some people will prefer to be sheltered underground for purely psychological reasons, and others will, for similar reasons, prefer to be sheltered on the surface. In either case the preference will be emotional rather than logical.

Any air raid shelter construction which is undertaken, regardless of type, must appear to the layman as adequate for the purpose intended. Experience abroad has clearly demonstrated this necessity. A shelter program undertaken on the basis of structures which are actually or apparently weak will result in failure of the public to make full use of such shelters, avoiding them in favor of other protection which appears to be more adequate.

The more sparse the population, the less damage from bombs. In rural areas, for example, the probability of a given bomb causing casualties is very small, often so small that it is impossible to justify the construction of any shelters. In villages, suburbs, and towns, the probability of casualty increases, but is still small in comparison with cities. In any area

the possibility of casualty may be influenced by the presence of important industrial developments. In congested areas the probability of casualty is large. Thus, it is evident that there is a logical degree of protection which ought to be provided in any area and, therefore, the degree of protection justified may be regarded as a function of the density of population.

In areas of sparse population containing no military targets, not only is the chance of casualty per bomb reduced, but the chance of any bombs being dropped is also reduced. Rural areas which lie on routes to military targets may be assumed to be exceptions to this rule. Such areas might be subjected to occasional bombing by raiders unloading their bombs to lighten the aircraft in an attempt to escape when the defense prevents them from reaching the target area.

Fortunately, the foregoing probabilities are closely related to the kind of protection which can be afforded. In general, the larger the number of people who can be sheltered in a given edifice, the smaller the cost per person for the same degree of protection. It is obviously difficult to measure the cost of human shelter in dollars and, wherever possible, the cost should be measured in terms of the productive effort required for their construction.

Finally, if shelters are of the large type (maximum capacity limited only by space available but with limited accommodation per compartment), it is evident that they must be located in regions of sufficiently dense population to permit the number of people to be protected to reach and enter the shelter in a reasonably short space of time.

B. Types of Air Raid Shelters.

1. *General.*—At the present time experience has demonstrated that there are several broad classes of shelters that will provide reasonable protection. The degree of protection afforded by these classes of shelters under average conditions generally increases in the following order:

- a. Table shelters.
- b. Family-type shelters.
- c. Communal shelters.

d. Shelters in buildings (protection afforded according to the structural character of the building).

2. *Characteristics of shelters.*—The general characteristics of each kind of shelter and the manner in which it performs its function are described below.

a. *Table shelters.*—This type of shelter, as illustrated and described in the revised edition of the publication entitled "Protective Construction" is intended for use in individual dwellings. The shelter relies on the walls of the building to protect against blast and splinters and is itself designed only to support the debris load which may be imposed if the building, or a part of it, collapses under bombing. The table shelter offers the advantage of ready accessibility, thus keeping the family in the home, where the members can have light, heat, sanitation, and general comfort. Table shelters also require very little manpower to produce.

b. *Family-type shelters.*—These shelters are intended to be installed in the yards adjacent to dwellings and may be buried, semiburied, or on the ground surface. The buried and semiburied types rely on earth cover to stop splinters and on their relatively flexible construction to withstand blast pressure and earth shock from near misses. The surface shelter relies on the thickness of the walls (usually of reinforced concrete or masonry construction) to resist splinters, and on the rigidity of construction to resist blast and earth shock. For economic reasons these shelters cannot be large and are not apt to be provided with facilities for light, heat, sanitation, mechanical ventilation, or gasproofing. Therefore, they generally will not be comfortable for long periods of occupancy.

c. *Communal shelters* are separate structures designed for group occupancy where existing buildings are not suitable structurally or otherwise for shelters and where there is lack of sufficient space for domestic shelters in yards adjacent to dwellings. They may be either on the surface or semiburied. These shelters can be provided with heat, light, ventilation, sanitation and, if necessary, some degree of gasproofing as well. Sleeping accommodations may also be provided in these shelters. The communal shelter generally will afford protection from blast, splinters, aerial gun fire, and small incendiary bombs. Like the previously described types, they are not proof against a direct hit by even a small high explosive bomb.

d. *Shelters in buildings* are discussed at length in the pamphlet entitled "Air Raid Shelters in Buildings."

C. Choice of Shelter Types.

Localities where shelters may be required will present a variety of characteristics and a number of shelter schemes and arrangements will be needed from which to select suitable types for protection against air attack. The choice of shelter types is closely related to shelter construction policy. As stated in the introduction, nothing in this pamphlet is intended to determine policy. It is appropriate, however, to discuss some of the factors which must be considered in selecting shelter types for any particular area. In any extensive shelter program, it will be impracticable to provide complete protection by structural means. It is, therefore, important to follow the principle of dispersion, which has been demonstrated as an effective means of minimizing casualties.

Inasmuch as the purpose of any air raid shelter construction program is to reduce casualties while at the same time keep the morale of the sheltered populace at the high level necessary for successful prosecution of a war, those responsible for the determination of shelter policy will doubtless take account of the intangible factors previously discussed, where a choice of shelters is possible. Some practical considerations upon which shelter types will normally be selected are outlined below.

1. *Shelters in existing buildings.*—Effective shelters may be provided in existing buildings which are structurally suitable (see publication entitled "Air Raid Shelters in Buildings"). The suitability of existing buildings for shelter purposes will be established by the following criteria:

a. The building is of structural steel, reinforced concrete frame, or other construction which will afford protection.

b. Within the building there are areas which, either as they stand or by structural modification and addition, can afford suitable refuge.

c. The buildings are so located that full use

will be made of the protection afforded by them. Such full use of shelters in buildings may be expected when—

(1) Persons are likely to be in the building or on adjacent streets at times when raids occur.

(2) The raiding is likely to be of such long duration in the night that it is practicable for personnel not normally in the vicinity to seek overnight shelter in the building areas.

2. *Communal shelters.*—The construction of separate shelter structures would normally imply that local conditions are not favorable for the use of existing buildings for air raid protection.

II. COMMUNAL SURFACE SHELTERS

A. Surface Shelter Characteristics.

1. *Forces to be resisted.*—The forces which must be resisted by any air raid shelter are: Debris loads, earth shock, blast, fragments from bombs and antiaircraft shells, incendiary bombs, and aerial gunfire.

A well-armed stockade having thick walls to resist all splinters and blast, with roof thick enough only to defeat antiaircraft shell fragments, incendiary bombs, and debris loads, and construction capable of resisting earth shock, will be defeated only by a direct hit, the chances of which under the laws of probability are small. These considerations lead naturally to the selection of masonry construction. Other types of construction are possible, however, if protection is provided against all the forces enumerated above.

2. *Average protection warranted.*—The weapons which will probably be employed in any aerial attack must be assumed arbitrarily from a consideration of the broad economy of munitions in relation to objectives. The illustrative surface type communal shelters shown herein are designed to afford the maximum protection practicable for average conditions, determined principally on the basis of British experience.

The shelters are considered proof against a 500-pound demolition bomb detonating 25 feet or more from the shelter walls, with the exception of rare and "freak" fragmentation effects. The overhead detonation of a parachute mine or the ricochet on the shelter of any high explosive bomb from the walls of adjacent buildings must be regarded as direct hits and will be expected to defeat the shelter.

In addition to resistance to blast, splinters, and earth shock, the shelter must be designed for debris loads that may be imposed by the failure and demolition of nearby structures. Ordinarily, such designs will result in no increase in the suggested minimum thicknesses of walls, floors, and roofs, though the amount of reinforcement may be affected. If computations indicate that greater thicknesses are required for debris loads, the increased dimensions should, of course, be used.

Debris load computations can be made on the basis of equivalent uniform live loads. Under ordinary conditions these loads can be taken as equal to 200 pounds per square foot. If, however, the shelter is adjacent to a building greater than 30 feet in height and at a distance from the

building less than half the height of the building, these loads should be increased to 400 pounds per square foot.

3. *Aerial weapons.*—Previous publications have described in some detail the various effects of bombs and aerial weapons in general. A summary of this information is given below, from which it may be realized that persons not engaged in active duties should take protective cover during an aerial attack in order to avoid unnecessary casualties.

a. *High explosive bombs.*—It will be recalled that the explosion will set up blast pressure having positive and negative pulses which will demolish structures not offering adequate resistance. Also, the explosion will propel fragments of the bomb case over a wide area at very high velocities. If the detonation takes place below ground level, severe earth movement and shock will be produced which may destroy or seriously damage nearby buildings and utilities.

(1) *Blast.*—Characteristically, a 500-pound demolition bomb detonated above ground will produce a blast pressure wave having a maximum positive pressure of the order of 23.5 pounds per square inch at a distance of 25 feet and of 5.8 milli-seconds duration. The positive pressure will be immediately followed by a negative pressure of the order of 4.5 pounds per square inch and of about 30 milli-seconds duration. This sets up an impulsive loading on the walls of a shelter which can be analyzed for any given situation with the aid of some simplifying assumptions in the manner described in the pamphlet, "Protective Construction," revised edition, 1942. Walls of the thickness required for splinter protection will resist this positive blast pressure without failure, provided the walls are not excessively long and are properly reinforced and well bonded to cross and end walls and to floors and roofs, as indicated in the illustrative designs.

The blast wave will injure unprotected persons in varying degrees not yet clearly understood. The positive pulse is the more injurious because of its greater intensity. The blast wave can be diffracted, however, by suitable baffle walls, reduced openings and doors, such as are shown at the entrances of the illustrative designs, to

the extent that it will not injure persons within the structure. The damping or throttling action of door openings in blastproof structures is great, even where no closure is provided. If several shelter units are combined, the possibility of minimizing the effect of the blast pressure on occupants of compartments adjacent to one which may suffer a direct hit should be considered. This can be accomplished in considerable measure by planning details such as those shown in the drawings (Figures 7, 8, and 9). Alternate arrangements of baffle walls should not be undertaken by persons who are not familiar with the principles involved in providing for the diffraction of blast. The suction pulse cannot be diffracted as can the pressure pulse but is not generally harmful to personnel.

(2) *Fragments.*—Parts of the bomb case are propelled at great velocities from the explosion starting at a velocity which may be as high as 10,000 feet per second. At 25 feet from the bomb they will still have great penetrative power. Walls of various thicknesses have been subjected to fragmentation attack, and the dimensions suggested in this publication have proved to be adequate. When properly reinforced, such walls have proved to be adequate to resist the other forms of attack also. The roof and floor are not usually exposed to fragments and consequently need not be as thick as the walls.

(3) *Earth shock.*—When a bomb detonates underground it sets up a shock wave and also causes a substantial movement of earth which itself imposes an impulsive load on the shelter structure. Near a detonation, vertical earth movement from the shock wave may reach the shelter before the horizontal movement is equally strong. If the roof is not firmly attached to the walls the upward acceleration may cause the roof to leave the walls and to fall back on them while they are in motion due to the horizontal acceleration, with possible complete destruction of the shelter and death to the occupants. It is earth shock which necessitates bonding the floor and roof of the structure thoroughly to the walls as indicated in the typical details.

b. *Aerial mines* are generally attached to parachutes. They contain a higher percentage

of explosive than other types of bombs. These weapons detonate by contact and their effects are due mainly to blast rather than splinters. They may explode in the air after contact with trees or overhead wires, causing severe blast from overhead.

c. *Incendiary bombs.*—This type of missile weighs from two to one hundred pounds and causes destruction by fire. In general the bomb is nonexplosive but the practice of the enemy has been to insert a small charge in one bomb of a group of about fifty. Thus when being dealt with, an occasional bomb will explode and scatter dangerously. The purpose of this is to cause uncertainty among personnel engaged in dealing with incendiary bombs. Fires caused by incendiary bombs can spread over a wide area and may also serve as directional guides for subsequent air attacks.

d. *Antiaircraft fragments.*—During a heavy barrage there is considerable danger from falling shell fragments which vary from the size of a coin to large jagged splinters and shell caps.

e. *Gas.*—The use of gas has not as yet constituted a major weapon in this war. However, consideration must be given to the preparation of protective measures in anticipation of its possible use.

B. Structural Considerations.

1. *Properties of shelter construction materials.*—Concrete for communal air raid shelter should be of a quality capable of developing 3,000 pounds or more per square inch in compression at 28 days. Though concretes of greater strength have somewhat greater resistance to penetration, it generally will not be desirable to develop concretes of greater strengths for shelters of this type. If greater resistance is warranted, a more efficient method generally will be to increase the thickness of concrete.

Reinforced brickwork offers a possible substitute for reinforced concrete. The reinforcing steel and brick joints are likely to cause planes of weakness in the brick. Pending the outcome of tests now scheduled, no definite statement can be made as to a comparison between reinforced concrete and brick shelters.

Unreinforced brickwork or other masonry definitely should not be used for shelter construction.

Mild steel bars are preferable as reinforcement to more brittle steels. Whether due to blast, fragments, earth shock, or debris, the loads imposed on the shelter are impact loads. Tests and observations indicate that the ductility of the reinforcing steel is important in resistance to impact.

Masonry and steel constructions are discussed throughout this pamphlet. Other types of construction can be designed to resist the forces exerted on shelters. For example, rigid wood frames will protect against earth shock and debris. By adding blast and splinter protection, possibly in separate blast walls, together with sufficient overhead cover to defeat antiaircraft shell fragments and aerial gunfire, effective shelters might be provided. Test data are not at present available on the performance of such types and their discussion must be deferred until definite information is available.

2. General structural requirements—

a. *Design.*—A surface shelter is designed to permit the structure to be pivoted by blast pressure or to leave its base under vertical shock. It must be strong enough to hold together under the impact caused by its falling back upon its foundation. Any effort, therefore, to bond the actual shelter floor to the foundation will tend to defeat the purpose of the design and may result in torque loads being applied which will destroy the structure. Accordingly, great care must be taken to make sure that the shelter does rest free of its foundation.

Shelters constructed in accordance with the details shown, and of lengths up to 33 feet, have proved reasonably able to withstand the forces involved without destruction, while behavior of objects in the shelters at the time of the explosion indicates that those sheltered therein will not suffer serious casualties. It is not safe at this time, however, to extrapolate these results by keeping the same section of the shelter and making it indefinitely long, as it is believed that longer shelters might fail by the increased stresses which would result. Pending the completion of scheduled tests which may prove or disprove

this belief, it is thought essential that shelters longer than 33 feet have joints or weak links in roofs and walls at intervals of about 30 feet with cross walls at such intervals. Such cross walls should be of the same thickness as the external walls.

Long narrow forms of shelters have been a development of street sites where shelters of greater width could not be used. A square form will show considerable savings in material. For the present, however, it is not believed safe to increase the roof span to more than 10 feet.

b. Foundation.—The shelter should be erected on firm ground and, whether located on a paved surface or on greensward, should rest on a hard foundation. If the shelter is placed on soil, the sub-base should consist of tamped or hard-rolled crushed stone. The finished floor slab must be above the ground surface. There should be a mastic joint or heavy building paper between the shelter floor slab and the foundation to provide a definite plane of cleavage.

c. Walls.—Outside walls should be equivalent in thickness to not less than 12 inches of reinforced concrete. There should be a solid bond and continuous reinforcement between the walls, floor, and roof slabs so that the entire structure will act as a rigid frame.

Reinforcement at both faces of a wall is preferred. It is permissible, however, to use only a single layer of reinforcement but such a single layer should be placed in the center of the wall and not on one side of the wall only.

Shelter walls constructed of reinforced brickwork should be not less than 12½ inches in thickness. The reinforced concrete floor and roof slabs must be bonded to the walls by means of the reinforcing steel.

In general, there should not be any internal walls in the shelter which do not meet the requirements, such as reinforcing, bonding, and thickness, for cross walls stated above. If light partitions are needed for purposes of privacy, they should be of light curtaining, canvas screening, or wood studding secured to the wall and covered with soft wallboard. They should not be of brick or blocks which may become detached under shock and injure the occupants.

d. Roofs.—The roofs shown in the typical details are thinner than the walls. The roof will not receive a serious pulse from bombs detonating laterally, while the detonation of a bomb directly overhead must be considered as a direct hit.

Roofs should be laid with a slight pitch. A bituminous roofing material may be applied both for protection against weather and also to tone down the whiteness of the concrete as a form of protective concealment.

In general, measures such as are used in normal building practice should be taken to provide weather protection throughout the shelter.

3. Caution.—A fundamental hypothesis of the illustrative designs is that walls, floors, and roofs are so bonded together by reinforcing steel that they act as a rigid frame. Departure from this practice is not recommended and will result in inadequate and undesirable shelters.

C. Planning Considerations.

1. Site selection.—As with any architectural or engineering project, an air raid shelter must be well orientated and suitably planned from the standpoints of accessibility and economy. Persons expected to occupy shelters should not be required to cross large open areas in reaching the shelters.

Shelters such as the communal type can be erected, ordinarily, in streets or on grass strips or verges adjoining them as shown in figure 1. The shelters can be erected either at the edge of the roadway, or they can be erected in the center of the roadway (if the street width warrants) where they will be farthest removed from danger of debris loads from adjacent buildings. In either event, the shelters should be placed so as not to constitute a hazard to normal traffic. Also, if a shelter is to be erected on a sidewalk or verge, there must be sufficient space remaining as to allow continued use of the sidewalk.

When erected in a roadway, the shelter should be separated from the curb to prevent blocking the gutter.

High ground generally will be preferred for better drainage. Locations over gas and water

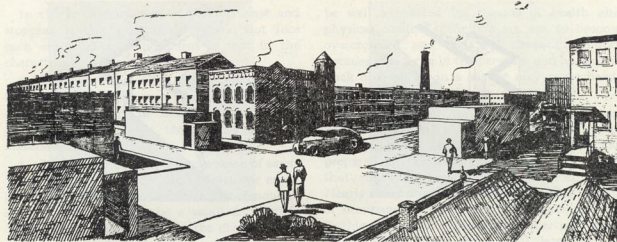


FIGURE 1.—SUGGESTIONS FOR SHELTER SITES

mains, or subterranean construction, are undesirable and care must be taken to avoid them. Equally important is the fact that locations near or under hazardous constructions, such as tall chimneys, water tanks, high buildings (more than two stories) of wall-bearing construction, or buildings with unusually heavy ornaments, must be avoided. The last named could cause especially destructive debris loads.

Other things being equal, it will be preferable to locate shelters in open areas rather than on pavement, since this will permit most bombs to enter the ground about the shelters, thus reducing the danger from splinters.

2. *Accommodation.*—A typical communal shelter will accommodate 18 persons sleeping, or about 25 persons sitting (see figure 5). Communal shelters should not have a designed capacity of more than 50 persons in any one compartment. The psychological effect of a direct hit on a shelter containing many people cannot be ignored.

3. *Entrances.*—Entrances should be not less than 2 feet 6 inches in width nor less than 5 feet 6 inches in clear height. Entrances serving more than 50 persons should be wider. These minimum dimensions will accommodate stretchers for rescue work, but it is probable that for any casualty the actual stretchers need not be taken through entrances to shelters accommodating small numbers of persons.

Any entrance which involves the use of steps or a ramp should be provided with at least one handrail. All such steps should have an easy rise and the slope of the ramp should be not steeper than one in four.

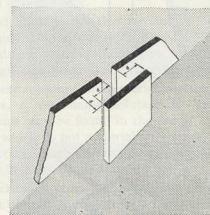
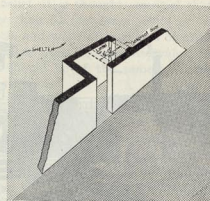
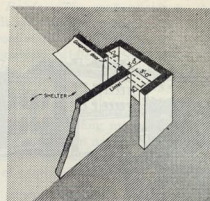


FIGURE 2.—ENTRANCE BAFFLE WALL

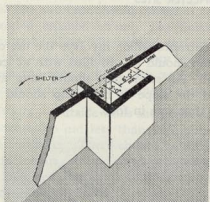
It is essential that entrances be protected (see figure 2). This is accomplished most readily by the provision of entrance baffle walls such as shown in the typical shelter designs (figures 5, 6, 7, 8, and 9). These baffle walls must prevent splinters from entering the entrance of shelters from any angle and appropriately will be of splinter-resistant thickness. They will also serve to baffle blast pressure. Several variations of plans for baffle walls are shown in figure 3.



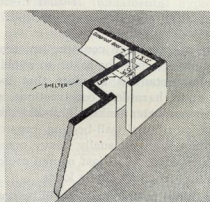
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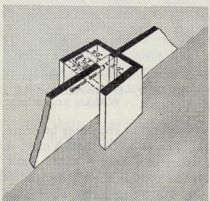
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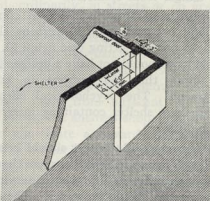
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e



c



f

SIDE ENTRANCES

CORNER ENTRANCES

FIGURE 3.—SUGGESTED LAYOUTS FOR BAFFLE WALLS

In the further interest of baffling blast and stopping splinters, entrances should not face each other. This requirement is met in the characteristic shelter designs.

Splinterproof doors can be substituted for baffled entrances, but such doors are necessarily massive and hard to design properly and, ordinarily, will require the use of strategic materials.

4. *Emergency exits.*—The provision of emergency exits is important and at least one emergency exit must be provided for every communal shelter. This exit can be a small and simple device such as that shown in the characteristic designs.

The emergency exits should be located in the opposite end from the entrance and if several small compartments are combined to form one larger type shelter, exits may connect the adjacent compartments on the assumption that both outside entrances and exits will not be blocked simultaneously.

5. *Sanitation.*—Communal shelters require toilet facilities. Toilets should be of the portable chemical type or of such other type as the health officer may indicate, and there should be a minimum of one for every 25 persons. It is preferable that where men and women are to occupy the same compartments in communal shelters, the sanitary facilities should provide for separate accommodations. In all cases, the sanitary accommodations must be separated from the main shelter room by partitions reaching the full height of the shelter, and they should be provided, preferably, with doors. The doors should be light in weight to reduce risk should they be thrown about by a nearby explosion.

Planning of such facilities will be done in accordance with the best judgment of the planner. Space, at least for the sanitary provisions, should be provided for in the original designs.

The chemical closets should be of suitable material, preferably non-porous, with parts and fittings which permit easy cleaning. The chemicals used should be germicidal and not caustic; they should not create ammonia or other gases which would be undesirable in confined spaces.

6. *Ventilation.*—Communal shelters should

be well ventilated for reasons of health and physical comfort. Shelters are apt to become overcrowded and this will cause discomfort because of the rise in temperature and humidity. Lack of fresh air in a shelter may cause headaches, impaired circulation, and nausea.

These conditions are not too serious and can be borne for short periods of occupation up to, say, two hours. Nearly every nation which has prepared for raids has gone on the assumption that the raids would be of short duration. Nearly every one has finally come to long periods of occupancy. Whatever the probabilities are in this country, the prudent planner will make provision of space which will later permit installations found necessary.

Natural ventilation by the occasional opening and closing of doors will not allow an adequate change of air in the shelter. Nor will it be practical to open and close the emergency exits to provide cross ventilation. Variations in weather must be considered with the possibility that openings may have to be kept closed during the entire period of occupancy.

Mechanical ventilation for smaller type shelters may be too costly in terms of the total expenditure for shelter, and on account of the strategic materials required, may not be available.

Where economy and material become primary factors, a reasonable solution to ventilation problems may be found in the use of a few roof vents which do not materially diminish the total protection. Such vents, of course, may have to be sealed in event of gas attack.

Mechanical ventilation in normal shelters may be put out of commission by a "near miss" which does not necessarily damage the shelter itself. Therefore, if and when a mechanical ventilating system is used, protective construction should be provided for housing the equipment. Where practicable the ventilating unit should be placed in a separate compartment.

In considering the several aspects of ventilation with due regard for factors, such as size of shelter, degree of anticipated use, location (vicinity), and length of time of expected occupancy, the decision is not one which can be stated generally, but with the various points before him, the planner can reach his own

solution. It will be prudent to provide space at least in which mechanical ventilation can later be installed.

The factors which will determine the amount of air necessary for a shelter are the floor area, the surface area (walls, floor, and ceiling), the volume of the shelter, and the number of persons sheltered. The following table gives minimum ventilation and space requirements for providing reasonable comfort in shelters.

When a shelter is not in use, all doors and hatches should be opened for as long periods as possible, to freshen the shelter.

7. *Gasproofing.*—Gas has not yet been used as a major weapon in the present war, but the possibility of its use cannot be ignored. Gasproofing can be obtained best in a shelter in connection with a mechanical ventilation system which maintains a slight pressure in the shelter so that cracks in the walls or doors do not per-

mit the infiltration of gas-laden air. The necessary filters and other equipment can be added to large mechanical systems without excessive increase in cost, but they are somewhat impractical for small shelters. Where gasproofing is contemplated either in the initial construction or later, it will be necessary to provide a gaslock or leave space available which may be converted to a gaslock. Gasproofing requires considerable work and material, and some idea of the extent of detail required may be obtained from a study of the gasproof door shown in figure 4.

The installation of gaslocks without the accompanying mechanical ventilation in communal shelters of the type shown in this publication is useless as the shelter may be breached during a bombardment and still be safe for its occupants, but then will no longer stop the passage of gas into the shelter.

Table I.—Minimum ventilation and space requirements for shelters

a. Natural Ventilation (open to outside air)					
Location of shelter	Maximum Period of Occupancy, Hours	Ventilation Rate, cu. ft./hr./Person	Total Surface Area, sq. ft./Person	Floor Area, sq. ft./Person	Volume Content, cu. ft./Person
Above ground.....	3	.....	30	6	50
Above ground.....	12	.....	60	6	75
Below ground.....	3	.....	30	6	50
Below ground.....	12	.....	50	6	75
Above or.....	3	(G a s t i g h t (none).	75	6	120
Below ground.....	12	(G a s t i g h t (none).	100	6	350
b. Mechanical Ventilation*					
Above ground.....	.....	300	40	8	60
Below ground.....	.....	300	30	8	60

*Information furnished by the Chief of Chemical Warfare Service.
Note.—The above figures are based on occupied space only; passageways, sanitary arrangements, entranceways (gaslocks, etc.), first aid and gas cleansing rooms are not included.

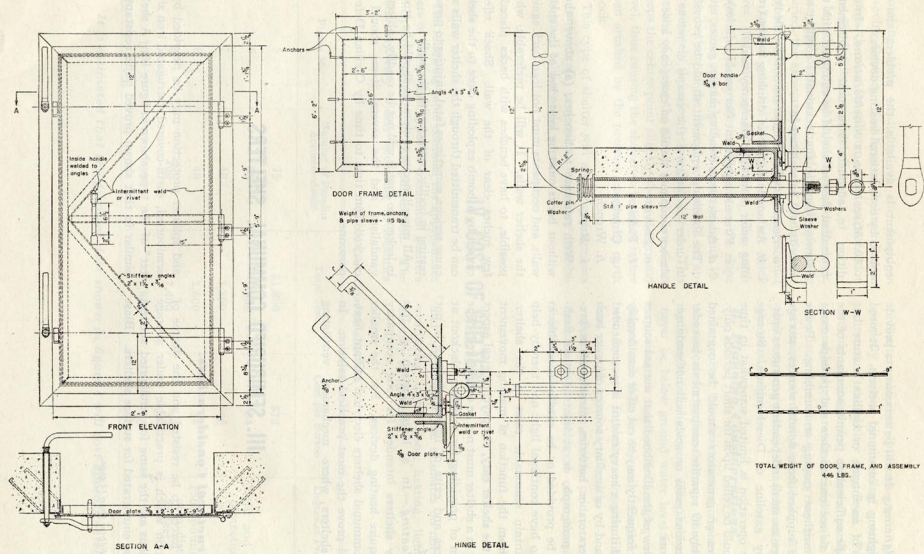


FIGURE 4.—A GASPROOF TYPE DOOR AND DETAILS

8. *Lighting.*—It will be necessary to provide some lighting in communal shelters. It need not be of an intense or brilliant nature but should be sufficient to permit occupants of the shelter to see one another and perhaps move around without groping or stumbling. Power may be supplied from normal sources, storage batteries, or small independent generators operated by gasoline or Diesel engines. Storage battery operation is limited somewhat in time and should be relied upon for short periods only. Batteries or generators should be contained preferably in separate compartments in order that noxious gases or acids will not endanger occupants.

In view of the likelihood that normal sources of light frequently may be cut off or considerably reduced during a heavy raid, it is recommended that stand-by or auxiliary sources of power such as generators or batteries, mentioned in preceding paragraph, or at least adequate flashlights, be provided or be readily accessible in order to have continual light and thereby help to maintain reasonable calm in the shelter. Aside from the function of making movement within the shelter easy, the psychological aspect of light in a shelter must not be overlooked. The problem of providing for complete blackout at entrances and exits of lighted shelters is not difficult.

9. *Heating.*—In a large portion of this country shelters intended for long occupancy will require heating devices. For the smaller type communal shelters electrical radiant heating will prove the most practical solution. In large shelters where mechanical ventilating

equipment is available, the problem can be solved by conventional heating devices.

10. *Miscellaneous considerations.*—In addition to adequate structural requirements, communal shelters should be equipped with the following items so that reasonable comfort and security will be maintained:

- a. Benches (where bunks are not installed).
 - b. An ample supply of drinking water (running water or airtight emergency tank).
 - c. First aid equipment (for minor injuries).
 - d. Amusements (reading matter, games, etc.).
- The following equipment should be provided in order to facilitate the escape or rescue of shelter occupants should an emergency arise:
- e. Shovel.
 - f. Pickax.
 - g. Crowbar.
 - h. Wrench.
 - i. Rope.

With reference to benches, (a) above, those without backs must be kept clear of the shelter walls, and occupants must not lean back against the shelter walls. It will be preferable, where possible, to have benches with backs placed a few inches clear of the wall. Shock effects caused by a bomb exploding close to the shelter can be transmitted through the shelter walls and cause serious, sometimes fatal, injuries to persons resting in bodily contact with the wall.

All miscellaneous equipment should be stored in lockers so that it will not be readily subject to vandalism, and the several items should be checked from time to time by Civilian Defense personnel.

III. SEMIBURIED COMMUNAL SHELTERS

A. Structural Considerations.

The forces to be resisted and the degree of protection which is practicable under average conditions are the same for semiburied shelters as those enumerated for surface shelters. Blast

and splinter protection may be provided by a semiburied, earth-covered corrugated iron shelter* of the type shown in figure 10. A shelter similar to that shown proved quite resistant in

*Not lighter than 12 gage.

bombing tests conducted at the Aberdeen Proving Ground. This type of shelter relies on the earth cover for splinter and blast protection and for distribution of debris loads.

In order to diminish the effects of earth shock, this type of shelter should be only partially buried, the excavated earth being used to cover the top of the shelter. The earth cover should be tamped and not less than one foot thick over the center of the cylinder. The earth cover should increase in thickness as the slope approaches ground level, as shown in figure 10. The bottom of the 90-inch pipe should be approximately three feet below ground level. This method of placing the shelter at a shallow depth keeps the center point slightly above the ground level, thus causing the shelter to be lifted rather than crushed by the pressure exerted by earth shock.

This type of shelter will also stop fragments of antiaircraft projectiles, incendiary bombs, and small caliber aerial gunfire.

Shelters not entirely above ground should be properly drained by providing a sump at the entrance of the shelter floor level. Failure to provide drainage for shelters partly below ground level may result in considerable expense at a later date when a pump may be necessary to remove water that has collected. The whole shelter structure should be made waterproof by the usual methods.

B. Planning Considerations.

In general, the considerations of planning are the same as for surface shelters. One point may be brought out, however. The shelters should never be below ground water level as tamped explosions are much more damaging in water-logged soil than in dry soil. Furthermore, a wet floor will introduce excessive discomfort and may be injurious to health.

Special attention must be paid to ventilation because of the likelihood of condensation in subsurface shelters.

IV. COST OF SHELTERS

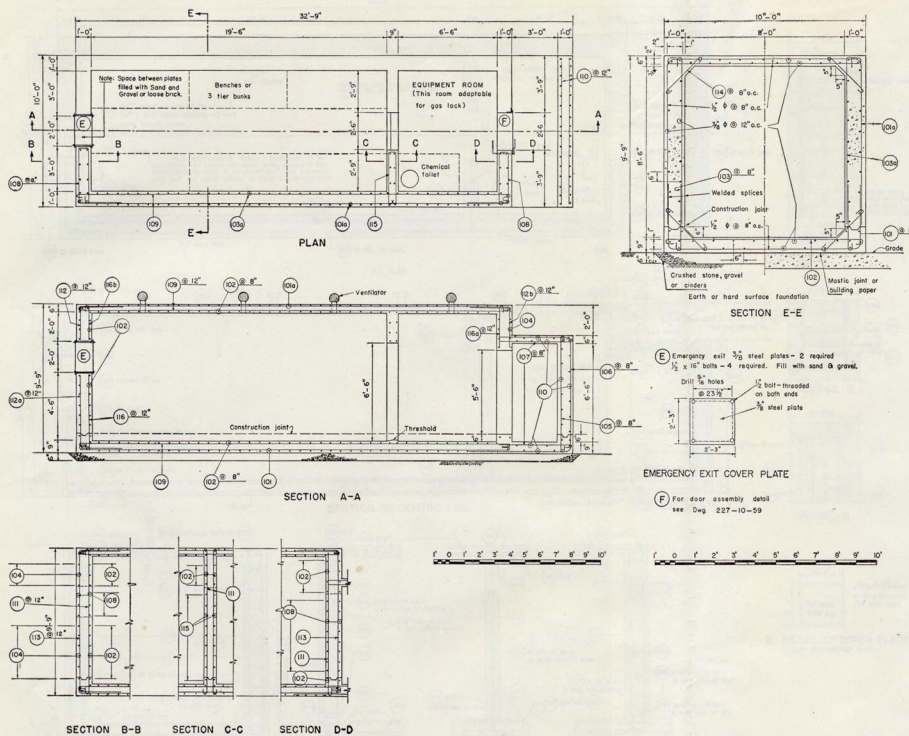
The following table contains the approximate costs of the several types of communal shelters which are discussed in this publication. The costs may vary widely according to localities

and conditions. The estimates do not include ventilating installations, heating, lighting, or sanitary equipment.

Table II.—Cost of shelters

Figure No.	Number of Persons Accommodated	Total Cost	Cost per Person	Degree of Protection
5	25	\$1,800	\$72	Blast and splinter protection. (500-pound bomb at a distance of 25 feet.)
6	25	1,600	64	
7	48	2,200	46	
8	48	2,600	54	
9	200	7,400	37	
10	50	1,800	36	

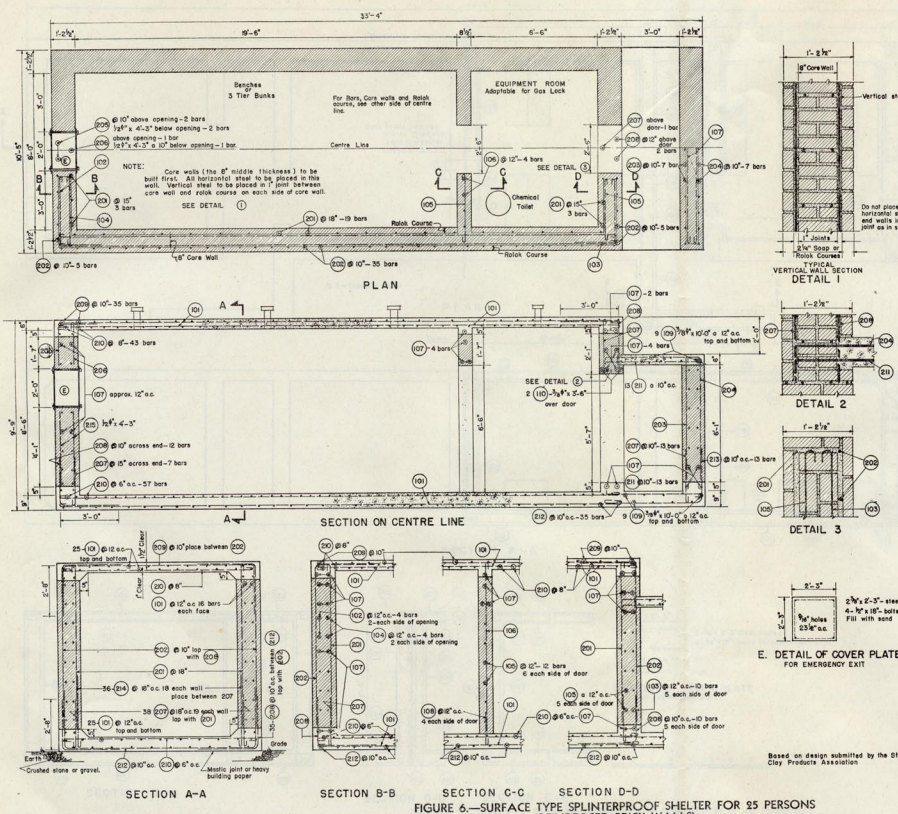
It is estimated that the gasproof door shown in figure 4 will cost approximately \$80.



REINFORCING			STEEL SCHEDULE				
MARK	SIZE	DESCRIPTION	LENGTH	NO. REQUIRED		WEIGHT	
				1st POSUM	2nd POSUM	TOTAL	EACH TOTAL
101	1/2"		8'-0"	44	4.4	102	449
101a	1/2"		29'-9"	44	4.4	172	757
102	1/2"		10'-9"	48	6.3	109	71
103	1/2"		3'-6"	88	8.8	3.3	29
103a	1/2"		8'-0"	88	8.8	5.8	510
104	1/2"		15'-0"	2	12	14	143
105	1/2"		8'-6"	16	16	5.7	91
106	1/2"		7'-6"	16	16	10.9	174
107	1/2"		5'-3"	16	16	3.2	112
108	1/2"		11'-0"	22	22	7.4	163
109	3/8"		29'-3"	25	51	76	11.0
110	1/2"	STRAIGHT	9'-6"	10	20	3.6	108
111	1/2"		10'-3"	24	24	3.9	94
112	1/2"		5'-0"	2	2	1.9	4
112a	1/2"		7'-9"	2	2	2.9	6
112b	1/2"		5'-6"	2	2	2.1	4
113	1/2"		15'-0"	12	12	5.6	67
114	1/2"		3'-3"	88	88	176	1.2
115	1/2"		8'-3"	2	16	18	3.1
116	1/2"		5'-3"	2	2	2.0	4
116a	1/2"		3'-0"	2	2	1.1	2
116b	1/2"		2'-6"	2	2	0.9	2
TOTAL			WEIGHT - LBS.	4,769			

Note: Shelter capacity = 10 persons with 3 tier bunks
= 25 persons with benches
Shelter may be located in suitable open space, or in street.
Do not dowel or bond shelter floor to type foundation used.

FIGURE 5.—SURFACE TYPE SPLINTERPROOF SHELTER FOR 25 PERSONS
(REINFORCED CONCRETE)

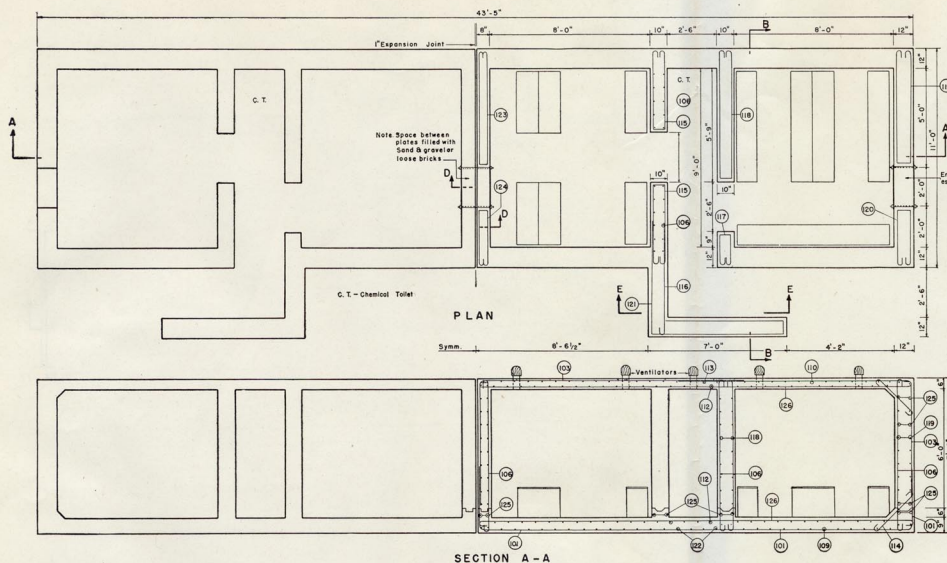


REINFORCING STEEL SCHEDULE					
NOTE: All dimensions are "out to out".					
MARK	SIZE	DESCRIPTION	NO. REQUIRED	WEIGHT	
			BASE	MAILLTOP	TOTAL EACH TOTAL
			SLAB	SLAB	
201	1/2"	8'-0" x 11'-0" above opening - 2 bars	30	8.01	300
202	1/2"	11'-0" x 8'-0" above opening - 1 bar	10	8.01	80
203	1/2"	8'-0" x 11'-0" above opening - 1 bar	13	8.01	104
204	1/2"	11'-0" x 8'-0" above opening - 1 bar	13	8.01	104
205	1/2"	8'-0" x 11'-0" above opening - 1 bar	2	2.34	2
206	1/2"	11'-0" x 8'-0" above opening - 1 bar	1	1.84	1
207	1/2"	8'-0" x 11'-0" above opening - 1 bar	1	1.84	1
208	1/2"	11'-0" x 8'-0" above opening - 1 bar	2	2.34	2
209	1/2"	8'-0" x 11'-0" above opening - 1 bar	35	35.00	350
210	1/2"	11'-0" x 8'-0" above opening - 1 bar	43	43.00	430
211	1/2"	8'-0" x 11'-0" above opening - 1 bar	13	13.00	130
212	1/2"	11'-0" x 8'-0" above opening - 1 bar	35	35.00	350
213	1/2"	8'-0" x 11'-0" above opening - 1 bar	13	13.00	130
214	1/2"	11'-0" x 8'-0" above opening - 1 bar	36	36.00	360
215	1/2"	8'-0" x 11'-0" above opening - 1 bar	3	3.00	30
101	1/2"	8'-0" x 11'-0" above opening - 1 bar	25	25.00	250
102	1/2"	11'-0" x 8'-0" above opening - 1 bar	4	4.00	40
103	1/2"	8'-0" x 11'-0" above opening - 1 bar	10	10.00	100
104	1/2"	11'-0" x 8'-0" above opening - 1 bar	4	4.00	40
105	1/2"	8'-0" x 11'-0" above opening - 1 bar	22	22.00	220
106	1/2"	11'-0" x 8'-0" above opening - 1 bar	5	5.00	50
107	1/2"	8'-0" x 11'-0" above opening - 1 bar	5	5.00	50
108	1/2"	11'-0" x 8'-0" above opening - 1 bar	9	9.00	90
109	1/2"	8'-0" x 11'-0" above opening - 1 bar	9	9.00	90
110	1/2"	11'-0" x 8'-0" above opening - 1 bar	2	2.00	20
Total Weight				466.7	

Note: Shelter capacity - 18 persons with 3 tier bunks
25 persons with benches
Shelter may be located in suitable open space
or in street.
Do not dwell or bond shelter floor to type of
foundation used.

Based on design submitted by the Structural
Clay Products Association

FIGURE 6.—SURFACE TYPE SPLINTERPROOF SHELTER FOR 25 PERSONS
(REINFORCED BRICK WALLS)

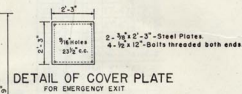
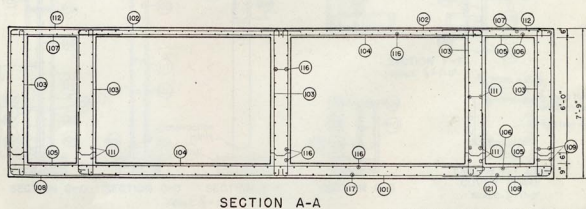
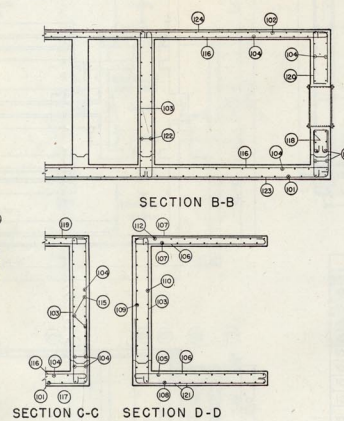
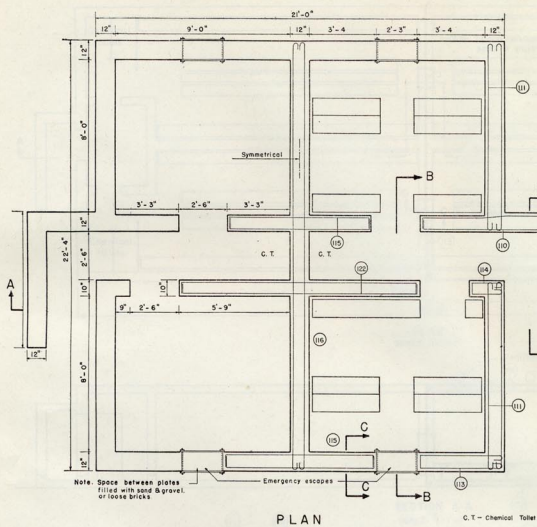


MARK	SIZE	DESCRIPTION	NO. REQUIRED	LENGTH	WEIGHT
					LBS.
101	3/8"	2'-0" x 2'-0"	28	2.8	28.6
102	3/8"	2'-0" x 2'-0"	16	1.54	15.4
103	3/8"	2'-0" x 2'-0"	28	1.84	1.84
104	3/8"	2'-0" x 2'-0"	16	1.7	1.7
105	3/8"	2'-0" x 2'-0"	16	8.8	8.8
106	3/8"	2'-0" x 2'-0"	320	10.11	10.11
107	3/8"	2'-0" x 2'-0"	8	7	7
108	3/8"	2'-0" x 2'-0"	16	22	22
109	3/8"	2'-0" x 2'-0"	60	381	381
110	3/8"	2'-0" x 2'-0"	60	521	521
111	3/8"	2'-0" x 2'-0"	60	266	266
112	3/8"	2'-0" x 2'-0"	22	50	50
113	3/8"	2'-0" x 2'-0"	22	93	93
114	3/8"	2'-0" x 2'-0"	22	28	28
115	3/8"	2'-0" x 2'-0"	36	22	22
116	3/8"	2'-0" x 2'-0"	18	41	41
117	3/8"	2'-0" x 2'-0"	18	28	28
118	3/8"	2'-0" x 2'-0"	18	10	10
119	3/8"	2'-0" x 2'-0"	8	39	39
120	3/8"	2'-0" x 2'-0"	8	22	22
121	3/8"	2'-0" x 2'-0"	22	155	155
122	3/8"	2'-0" x 2'-0"	22	73	73
123	3/8"	2'-0" x 2'-0"	8	39	39
124	3/8"	2'-0" x 2'-0"	8	19	19
125	3/8"	2'-0" x 2'-0"	80	345	345
126	3/8"	2'-0" x 2'-0"	68	577	577
127	3/8"	2'-0" x 2'-0"	20	58	58
128	3/8"	2'-0" x 2'-0"	10	35	35
129	3/8"	2'-0" x 2'-0"	10	48	48
Total					4616

NOTE: All bars spaced 8" c/c unless otherwise noted.

NOTE: Shelter may be located in suitable open space or in street.
Do not dwell or bond shelter floor to type foundation used.

FIGURE 7.—SURFACE TYPE SPLINTERPROOF SHELTER FOR 48 PERSONS
(REINFORCED CONCRETE, SCHEME I)



REINFORCING STEEL SCHEDULE

Note: All dimensions are "out to out"

MARK	SIZE	DESCRIPTION	NO REQUIRED	WEIGHT
				LBS.
101	#6	27'-0" x 32'-0"	30	310
102	#6	17'-0" x 32'-0"	60	397
103	#6	27'-0" x 32'-0"	260	821
104	#6	27'-0" x 32'-0"	100	810
105	#6	27'-0" x 32'-0"	44	105
106	#6	27'-0" x 32'-0"	20	57
107	#6	27'-0" x 32'-0"	20	42
108	#6	27'-0" x 32'-0"	18	49
109	#6	27'-0" x 32'-0"	18	144
110	#6	27'-0" x 32'-0"	18	55
111	#6	27'-0" x 32'-0"	72	285
112	#6	27'-0" x 32'-0"	18	79
113	#6	27'-0" x 32'-0"	36	162
114	#6	27'-0" x 32'-0"	18	27
115	#6	27'-0" x 32'-0"	36	122
116	#6	27'-0" x 32'-0"	84	735
117	#6	27'-0" x 32'-0"	28	252
118	#6	27'-0" x 32'-0"	16	23
119	#6	27'-0" x 32'-0"	28	285
120	#6	27'-0" x 32'-0"	8	19
121	#6	27'-0" x 32'-0"	10	39
122	#6	27'-0" x 32'-0"	20	99
123	#6	27'-0" x 32'-0"	4	37
124	#6	27'-0" x 32'-0"	4	38
TOTAL				4587

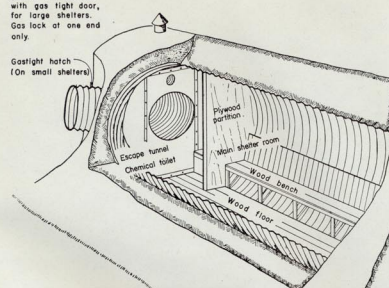
Note: All bars are spaced 8" c/c. unless otherwise noted.

Note: Shelter may be located in suitable open space or in street. Do not cover or bond shelter floor to type foundation used.

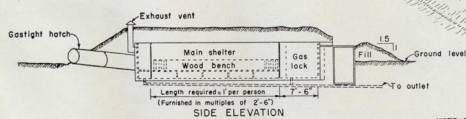
FIGURE 8.—SURFACE TYPE SPLINTERPROOF SHELTER FOR 48 PERSONS (REINFORCED CONCRETE, SCHEME II)

NOTE:
Provide entrance-way
similar to other and
with gas tight door,
for large shelters.
Gas lock at one end
only

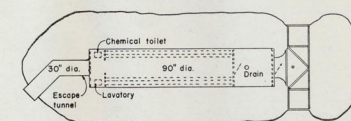
Gaslight hatch
(On small shelters)



Toe of slope

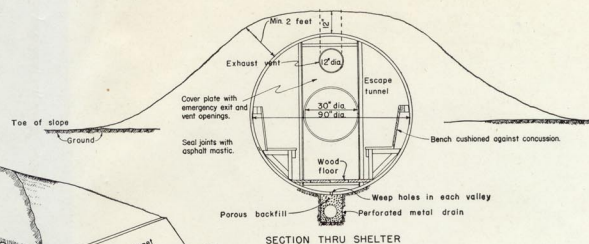
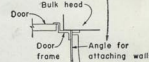


SIDE ELEVATION

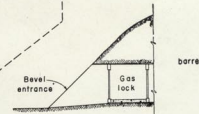
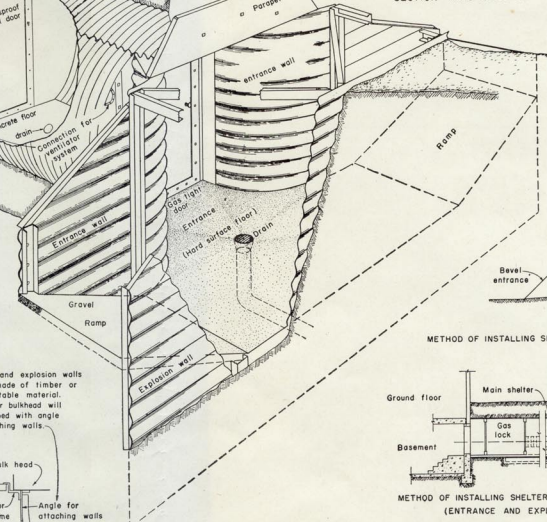


PLAN

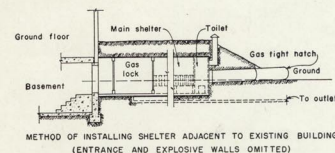
NOTE: Entrance and explosion walls
may be made of timber or
other suitable material.
Front door bulkhead will
be equipped with angle
for attaching walls.



SECTION THRU SHELTER



METHOD OF INSTALLING SHELTER IN HILLSIDE LOCATION



METHOD OF INSTALLING SHELTER ADJACENT TO EXISTING BUILDING
(ENTRANCE AND EXPLOSIVE WALLS OMITTED)

FIGURE 10.—SEMIBURIED TYPE SPLINTERPROOF SHELTER FOR 50 PERSONS
(CORRUGATED IRON)

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