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AIR RAID SHELTERS IN BUILDINGS

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AIR RAID SHELTERS IN BUILDINGS

INTRODUCTION

This publication was prepared by the Office of Chief of Engineers, War Department, to provide assistance and information on problems of protective construction. See also the revised edition of *Protective Construction, Glass and Glass Substitutes*, and *Report of Bomb Tests on Materials and Structures*.

There are considerable differences in the types and structural features of buildings suitable for shelter purposes. Therefore, representative examples and general planning policies only are outlined. Alterations and additions to existing structures may be necessary in the majority of cases, in order to provide reasonable protection. Usually, the problems are similar, and certain requirements are basic in achieving maximum protection through use of existing facilities.

An extensive general shelter program would be prohibitively expensive. Common sense and technical knowledge should be combined in applying the protective measures discussed in this pamphlet to any specific situation.

I. AERIAL WEAPONS

The types of weapons used in air attack are as follows:

- a. High-explosive bombs
 - (1) General purpose
 - (2) Semi-armor piercing
 - (3) Armor piercing
 - (4) Fragmentation
- b. Aerial mines
- c. Incendiary bombs
- d. Gas bombs.
- e. Aerial gunfire

The effects of high-explosive bombs on various types of buildings are discussed in sufficient detail for protective planning in the revised edition of *Protective Construction* and in *Report of Bomb Tests on Materials and Structures*, published by the Office of Civilian Defense.

The damage caused by explosive bombs is

variable, and a certain amount of risk should be accepted. There is no measure that results in a total elimination of casualties and damage. Certain precautionary measures do, however, minimize the possibility of injury to personnel and damage to structures.

Fragments from anti-aircraft shells also present a serious hazard to unprotected persons in exposed areas. Most buildings provide sufficient protection from falling fragments provided the persons remain inside. Any structure that meets standard requirements for protection against bomb splinters also gives reasonable protection against aerial gunfire.

Gas bombs are of a different character, and it is essential to have available the necessary equipment for rendering a shelter or refuge room gasproof on short notice. (See the OCD pamphlet, *Protection Against Gas*.)

II. SHELTERS IN BUILDINGS

A. Requirements for Protection in Buildings

It is impractical, generally, to attempt protection against direct hits by high-explosive bombs. For the most part, shelter areas in well constructed buildings will provide reasonable protection against "near misses," the risk of direct hits being accepted. The degree of protection against direct hits depends upon the structural character of the building. A modern reinforced-concrete or steel-framed structure will, to a considerable degree, withstand the effects of impact and the explosive action of a direct hit. In multi-story office, factory, warehouse, department store, and apartment buildings, the bomb is apt to explode either in the top story or penetrate two or three floors, exploding between floors, though six or more have been perforated by bombs with delayed fuses. The shock of impact and explosion are ordinarily sustained by the upper floors, leaving the lower portion of the building and the basement largely unaffected. Thus, a multi-storied building of sufficient height and of sound steel or concrete, framed construction provides greater safety for shelters than do other types of structures.

Buildings with load-bearing walls, either of brick or masonry, suffer considerable damage from blast and from earth shock. If a structure with load-bearing walls must be considered for shelter purposes because no other building is available in the vicinity, the possible amount of debris must be taken into account. It is possible for a structure of this type to be completely demolished from the shock effect of a bomb exploding in the ground near by or the blast effect of a bomb detonating near by the failure of one supporting wall can bring about the collapse of the floors and roof above. In the event of a direct hit, with a bomb exploding on an upper floor, the weight of the debris, as it falls from floor to floor, may bring about the collapse of the remaining structure below, taking supporting walls down with it. Thus,

in any effort to provide stability for shelter strengthening within, the existing walls of the building cannot be used for bearing.

In general, shelter may be provided within existing buildings as follows:

- a. In basements, when adequately reinforced.
- b. In other suitable rooms, corridors, passageways, or ground-level rooms, which would be strengthened where required.
- c. In separate shelters within buildings.
- d. In trench shelters constructed under a ground floor.

1. Classification of buildings.

Types of buildings in which suitable shelter areas or shelters may be provided are listed generally as follows in the relative order of resistance to effects of bombs:

- a. Modern buildings of steel or reinforced-concrete framed construction.
- b. Substantial buildings, not of framed construction but with concrete floors.
- c. Buildings of reasonably sound unframed construction, with wood floors, which would require considerable strengthening to adapt them for use as constituent parts of a shelter.

2. Locations of shelters.

Shelters below ground level provide lateral protection against blast and splinters, but may suffer from earth shock. Basements may present hazards such as flooding, fire, poison gas (which gathers in low places), or the trapping of occupants by falling debris.

Shelters on lower floors are exposed to blast and splinters from the explosion of bombs on the street or road outside, as well as possible contamination by low-hanging clouds of gas.

Shelters two or three floors above street level are preferable in some steel and reinforced concrete buildings, in order to escape the hazards of basements and lower floors. In the average building there should be not less than four reinforced stone-concrete floors and the roof, or their equivalent in protective construc-

tion, above the shelter, which should be located well within the building to provide the maximum of lateral protection. Stairways and doors should be readily accessible for entering or leaving the shelter. Light partitions should be removed or protected, to prevent their falling or blowing down on the occupants.

A careful survey should be made of all buildings in which shelter accommodation is to be provided. Wood construction should be thoroughly examined to insure that all members are sound.

a. *Hazardous features.*—Certain sources of danger should be carefully avoided. Among them are:

- (1) Excessive overhead loads of machinery, stored materials, merchandise, and other heavy objects, such as parapet walls and cornices.
- (2) The close proximity of water and gas mains, sewage systems and drains, pipes carrying steam, hot water, refrigerants, and noxious chemicals.
- (3) The nearby storage of inflammable or corrosive liquids.
- (4) Exposed columns or inadequate supporting walls, the failure of which would cause heavy debris loads.
- (5) Multiple electric conduits and switchboards.

The fracture of gas service pipes may cause fires or asphyxiation of shelter occupants. Similarly, there is danger of flooding in event water pipes are fractured. Utilities should have convenient valves and switches. Removal or rearrangement of pipes and electrical conduits may be necessary in some cases. Outstanding potential sources of danger to indoor shelters or shelter areas in a typical industrial area are illustrated in Figure 1.

AREA "A" would provide a reasonable amount of protection against blast and splinters. Increased lateral protection may be obtained by the erection of additional walls, preferably of brick or concrete. The space, being centrally located, affords convenient access for occupants of the building. Floors directly

above are not so satisfactory, because they offer less overhead protection.

AREA "B" is unsatisfactory because of the exposed columns; their collapse would result in a heavy load of debris.

Nearness of the canal makes AREA "C" unsuitable—damage to the canal wall would quickly flood the shelter. The water tank at the top, which in falling might crush the shelter, presents another serious hazard.

AREAS "D" are unsuitable because of the location beneath heavy machinery and merchandise on the upper floors. However, machinery on the floor directly above the shelter may not prove objectionable, provided its weight has been allowed for in the design of the floor and additional column supports are installed.

AREA "E", though less suitable than could be desired, would serve if no better location could be found. The area is exposed to the danger of the possible collapse of cornice and parapet. The open areaway or pavement lights should be closed to protect the interior.

AREA "F" and the floors directly above are good shelter locations. Inflammable construction or the storage of inflammable material immediately beneath the skylight would present a fire hazard to the whole building, especially in event of perforation by incendiary bombs. However, fire precautions must be taken in such buildings as this, irrespective of whether they have air raid shelters or shelter areas within them.

AREA "G" is in a building of such light construction that no part of it should be used as an air raid shelter. Construction of a separate shelter is recommended in this case, either under the building, as shown, or elsewhere.

AREA "H" is unsuitable because of the heavy debris load that would result from collapse of the tall chimney.

Properly located and well constructed shelters within buildings can furnish as much protection as external shelters providing the same material thicknesses.

3. Planning.

After the proper shelter locations are selected, and the number of persons to be accommodated is determined, a careful survey should be made to ascertain what measures are necessary to meet the requirements. Lateral and overhead protection must be considered, as well as the amount of space necessitated by the needs of sheltered persons. Existing facilities should be utilized, of course, wherever possible.

Entrances should be readily accessible. Emergency exits, which must be visualized from the first, should be as far as possible from the entrances. This precaution is to minimize the possibility of both escapes being blocked by debris, trapping the occupants.

a. *Entrances.*—Access to basement shelters will be, in most instances, by means of existing stairways or ramps. If present ramps or stairways are remote from work areas, or from the basement area used as a shelter, closer means of access should be provided. This is especially important in industrial plants, where large numbers of people must be evacuated quickly from work to shelter areas.

Entrance openings should be not less than 2 feet 6 inches wide for shelters with capacities up to 50 persons. For shelters accommodating 200 or more persons, main entrances should be not less than 3 feet 8 inches in width.

A large group of people, familiarized with routes and entrances by air raid drills, can move in an orderly and fairly rapid fashion to the shelters. The rate of movement is retarded if gas locks are used. The normal assumption is that most occupants will have entered the shelters before an air raid develops and the gasproof doors are closed. Operation of gas locks, therefore, should be necessary for only a small proportion of the occupants.

A baffle or traverse wall is necessary to protect entrances against blast and splinters. Entrances must be so planned that two immediate openings are never directly opposite each other. In basement shelters it is possible that existing walls will offer sufficient protection. However, in a large area that is not completely utilized as shelter space, or where

a shelter is so situated that one wall is an outside wall, with the entrance exposed to blast and splinters, baffle wall protection is requisite.

The baffle wall must be erected opposite the entrance, either outside or inside the shelter. The wall should extend beyond the sides of the entrance openings, to protect against blast and to prevent splinters or debris from being projected directly into the shelter space from any angle, and should extend at least a foot above the opening, as shown in Figures 2 to 6. (The thickness of the baffle wall should at least be equal to that of the shelter walls.) In no case, however, should it provide less equivalent protection than 12 inches of reinforced concrete. Sandbags may be laid up in a wall not less than 2½ feet thick as a temporary expedient, but they should be replaced by more permanent material when such is possible.

Shelters which are also available to the public in an air raid should have protected entrances accessible from the street.

b. *Emergency escapes.*—Means of escape other than the entrance must be provided. Wherever feasible, provision should be made for more than one emergency exit in order to lessen the possibility of shelter occupants being trapped. Preferably, one escape exit should be placed diagonally opposite the entrance. Additional exits may be placed where practicable in the case of each individual shelter.

In a large area, divided into shelter compartments and having a connecting corridor formed by a baffle wall (see Figures 13 and 14), the corridor provides a means of emergency escape. Direct communication between compartments should be provided by means of small openings in the party walls. An adequate opening would be 3 feet high and 2 feet 3 inches wide, with the sill 6 to 12 inches above the floor. To maintain the compartments as separate shelters, yet make the openings available in time of need, they may be filled with brickwork laid in dry sand and lightly pointed on both faces. If the wall is new, this brick filling may be laid up as the wall is built, and a lintel dispensed with. Alternatively, a lintel may be used, and a heavy wooden door and frame used to close the opening. Thus, in a series of inter-

connecting shelters, entrances and exits may be used as alternate means of escape. In cases where adjoining buildings are separated by party walls, escapes may be provided by means of openings through the party walls, if agreeable to the respective owners. Figure 7 shows suitable emergency exits of this type.

Many buildings have suitable shelter locations, where very little additional wall construction will be required. Existing passageways and corridors may be adaptable as entrances and exits.

In all cases, however, there should be at least one outside exit, enabling the shelter occupants to be reached in an emergency, and to escape clear of the building. When first aid stations or medical services are established within the shelter area, emergency escapes should be large enough to permit the passage of stretchers.

The outside exit should have an escape tunnel extending far enough beyond the building that it will not be blocked by debris from the "sheltering" building or adjacent structures (see Figures 8 to 12).

Escape tunnels for basement shelters that are entirely below ground are illustrated in Figures 8(a), 9, and 10(b). The crawl-away tunnel may be constructed of 14-gage corrugated iron pipe, 3 feet in diameter, of the same type as that used in culvert construction. The pipe should be covered by not less than 2½ feet of earth. An escape tunnel may also be built of reinforced concrete, not less than 4½ inches thick, as shown in Figure 10(b). At the point where the escape tunnel joins the existing wall, precautions must be taken, as in normal building practice, to protect against seepage of water into the building.

The opening at the top of any vertical shaft should be not less than 2 feet clear in either dimension, and should be protected by a man-hole cover or heavy wood cover, which can be raised from below. If the end of the tunnel is near enough to any building to be exposed to debris, a hood should be erected over the opening. The hood may be built of reinforced brick or reinforced concrete, having walls 12 inches thick and a reinforced concrete roof slab not less than 5 inches thick, as in Figure

11(a), or a heavy-gage corrugated iron hood may be used, as in Figure 11(b). A curb should be provided to keep water from entering the shaft. For ease of exit there should be a clear opening height of 3 feet above the curb. The open side of the hood should have a door for protection against the weather. Figure 11 shows suitable types.

For basement shelters which are partially below ground level, a tunnel of reinforced concrete or reinforced brick may be built above ground. The minimum inside dimensions are 3 feet high by 2 feet 3 inches wide. The 12-inch tunnel walls should rest on a concrete foundation and be roofed over by a reinforced concrete slab 5 inches or more thick. (The entire structure should be designed as a rigid frame.) See Figures 10(a) and 12(b).

Crawl-away tunnels may also be provided within buildings. Corridors, rooms, and stairways adjacent to the shelter or shelter area do not always lend themselves completely to adaptation as escapes; the storage of machinery and merchandise, or any of several individual circumstances, may make other expedients necessary. Space in closets or under existing stairways can be used with little alteration of the area. Figure 14, escape (c), and Figure 16, emergency exit tunnel, show two possible methods of providing escapes between adjacent buildings.

Escapes from ground-floor shelters may be provided by treatment of existing openings or by means of crawl-away tunnels above ground; for examples see Figures 8(b), 10(a), and 12(b).

For large public shelters the escapes (a) and (b) in Figure 12 can be used for rapid exit by larger groups of people. The passage of stretchers is facilitated by using the larger type of escape sketched in 12(b).

4. Shelter accommodations.

a. *Capacity*.—It is important to avoid as far as possible the gathering of a large group in any one shelter. Considerable numbers of persons should be dispersed, preferably into groups of not more than 50 persons, and there should be, ideally, a minimum clear distance of

25 feet between shelter units. This dispersion tends to reduce the number of casualties that might result from a single direct or near hit. If it is not feasible to provide sufficient space between units, shelters intended to accommodate more than 50 people can be divided into compartments by the erection of reinforced concrete or reinforced brick walls as shown in Figures 13 and 14. The division walls should preferably be more than 12 inches thick, and should extend the full height of the shelter. When it becomes evident that the compartments must take care of more than 50 people, the dividing walls should be increased in thickness to 24 inches, or double walls may be built leaving a space between, such as a corridor.

b. *Space*.—For comfortable occupancy of naturally ventilated shelters for periods not longer than three hours, the minimum space requirements per person should be figured in the three following ways:

- (1) 6 square feet of floor area.
- (2) 30 square feet of internal surface area (walls, floor, and ceiling).
- (3) 50 cubic feet (volume).

The maximum number of persons who may occupy a given shelter must be taken as the least number resulting from any one of the three calculations.

A shelter that is to be completely sealed against gas during periods of occupancy must provide 75 square feet per person of surface area (walls, floor, and ceiling), although the requirements for floor area and cubic capacity may remain the same as for an unsealed shelter. Additional data are contained in Table I following. The permissible capacity for an unsealed shelter, therefore, may be too high should it become necessary to seal the shelter against gas. In this event, unless a mechanical ventilation system is installed, additional space would be needed to care for an equal number of people.

c. *Ventilation* is obviously important to the health and physical comfort of those occupying air raid shelters. Experience has shown that shelters tend to become overcrowded, causing discomfort because of the rise in temperature and humidity. Inadequate ventila-

tion also causes headaches, impaired circulation, and nausea.

Ordinary natural ventilation, such as the opening of entrances and exits, is not completely effective for lengthy periods of occupancy or for shelters housing large numbers of people. When a raid is of long duration, the occasional opening and closing of doors will not compensate for the stale air that is likely to accumulate, and in many cases emergency escapes may not be used for ventilation—as in the case of emergency tunnels to adjoining buildings which would not appreciably improve the ventilation, and that of escape tunnels with manholes and hatchways, which should remain closed while enemy raiders are in the vicinity. Additionally, cold or stormy weather may result in keeping doors closed too constantly for adequate ventilation.

The amount of air needed is dependent upon the following conditions: (1) Floor area, (2) surface area, (3) volume (cubic capacity), (4) method of ventilating, and (5) purpose and kind of shelter.

The following table, assuming that shelter occupants remain more or less quiet, but allowing for some restless movement, gives the minimum space and ventilation requirements per person for a nominal degree of comfort and efficiency:

In buildings having air-conditioning and circulating units, shelter ventilation may be provided by adapting the existing system, using the necessary filters, cut-off valves, etc. It should be determined, however, that the air intake is 20 feet or more above the ground, to preclude absorption of gases into the system. In other buildings a suitable ventilating unit may be installed, if the equipment is available, consisting of a fan, motor (with auxiliary drive in case of power failure), pre-filter, gas filter, connecting headers, by-pass, gas-tight valves, intake and distributing ducts, heater battery, and evacuation valves.

d. *Gasproofing*.—It is reasonably safe to assume that shelters need not be made gas tight during every occupancy. The need for gasproof protection, however, must be recognized.

TABLE I.—*Minimum ventilation and space requirements for shelters and refuge rooms*

a. Natural Ventilation (open to outside air)

Location of shelter	Maximum period of occupancy (hours)	Ventilation rate (cu. ft. per hour per person)	Total surface area (sq. ft. per person)	Floor area (sq. ft. per person)	Volume content (cu. ft. per 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 below ground. {	3	} Gas tight (none).... {	75	6	120
{	12		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 (gas locks, etc.), first aid and decontamination rooms are not included.

Arrangements should be made for the future sealing of all openings; sealing devices must be of sufficient strength and durability so that they will not be dislodged by reasonable shock and strain. If gasproofing measures are to be effective, door frames must be sealed to prevent leakage, and doors must be fitted with gaskets bearing tightly against the frame.

Baffle walls, as shown in Figures 2 to 6 inclusive, may be adapted to form gas locks, which should be sufficiently large to admit several people at one time and to admit casualty cases on stretchers. Doors in gas locks should be so hung that they open inward and must be fitted with handles allowing the door to be operated from both sides: Experience has demonstrated that the outer door may be destroyed by blast, and the inner door blocked by debris from the outside—hence it must swing inward or not at all.

Open cracks in the shelter must be sealed. Minor drains or small outlets should be stopped, or the means for stopping them should be near at hand. Flues and ventilators in or near shelters must be closed. A concrete floor slab is preferable for gasproofing. Wood joist

floors should be covered with linoleum or some other continuous material to seal cracks in the flooring.

See "Protection Against Gas," published by the Office of Civilian Defense, for further details.

e. *Sanitation.*—A minimum of one toilet for each 25 persons should be provided, with separate facilities for men and women in cases where both sexes use the shelter. Sanitary accommodations should be isolated from the shelter room, either in the corridors or alcoves, or by anterooms and partitions extending the full height of the shelter. Makeshift sanitary arrangements, such as subsidiary buckets, and curtains in place of doors, are decidedly unsatisfactory. In large buildings, with several compartment shelters, sanitary facilities should be available from corridors connecting the compartments; it should not be necessary for occupants to cross several compartments to reach the toilets. In cases where space is limited for sanitary arrangements, the preference should be given to facilities for women. The number of women employees in civil capacities in wartime is more apt to

increase than the number of men.

Existing water closets may be used if they are safely accessible to shelter occupants. It would be well to provide them with overhead protection, to guard against falling debris. Water closets rely on a continuous supply of water for operation, and it is possible during an air raid that there may be lack of pressure in the mains, complete stoppage of water supply, or disruption of the sewage system. For this reason a reserve supply of waterproof toilet bags should be provided. These bags are for use during emergencies resulting in water failure. They fit into any toilet, waste basket, pail, or other receptacle. After use the top of the bag is rolled down and securely tied, so that bag and contents can be disposed of in a garbage can or by other dry method. See "Municipal Sanitation Under War Conditions," Medical Division, Sanitary Engineering Bulletin No. 2.

A shelter that is to be sealed against gas should either be self-contained, or have nearby sanitary facilities that can be reached without exposure to gas.

f. *Lighting.*—The ordinary electric service, while in operation, is adequate for shelter illumination. In case of interruption to service, however, there should be an auxiliary lighting system activated by batteries or independent generators. These auxiliary facilities should occupy a separate compartment, so constructed that noxious gases or acids will not endanger occupants of the shelter. Several flashlights should be on hand for use in case lighting facilities are knocked out, and for use in escape tunnels. Candles and fuel-oil lamps or lanterns are not recommended for emergency use, because of the danger from fire, and because of their consumption of oxygen.

g. *Heating.*—The necessity for heating a shelter depends on climatic and other local conditions, type of shelter, and the possibility of its extensive use. Normal heating methods are usually adequate, but the heating plant should be away from the occupied shelter space. For piped systems the amount of pipe should be limited to short runs in the shelter, and a shut-off valve must be provided at the point

where any pipe enters the shelter space. Electric heaters are also very satisfactory.

B. Structural Requirements for Protection in Buildings

1. Overhead protection.

Shelters in buildings may be exposed to excessive debris loads in event of structural damage or collapse of the buildings or adjacent structures. Consequently, the shelter must be capable of supporting heavy superimposed loads. The following general assumptions may be made in estimating the additional loads:

a. For shelters in steel or reinforced-concrete framed structures, potential debris loads may be taken to be 200 pounds per square foot of floor area (over and above the usual design loads), the number of floors over the shelter not to be considered.

b. For shelters in buildings having floors carried on load-bearing brickwork or masonry, the debris load may be assumed at 200 pounds per square foot for two floors above the shelter; at 300 pounds per square foot for three or four floors above the shelter; at 400 pounds per square foot for more than four floors above the shelter.

c. For shelters in buildings having a combination of load-bearing brickwork or masonry with framed or other type construction, intermediate values should be assumed.

These are the minimum static debris loads, and are additional to the normal floor loads. They do not include excessively heavy machinery or stored materials on the floors above, or heavy construction such as chimneys, colonnades, cornices, and other massive features.

Adequate overhead protection must extend over the entire area of the shelter and its necessary facilities.

It is best to avoid using as a shelter any portion of a basement extending out under the sidewalk in close proximity to surrounding structures. Heavy debris or a bomb could fall unchecked, penetrate the pavement, and enter the shelter. Debris falling within a building is checked to some extent at each floor, but heavy masonry falling outside a

building has nothing to retard it and develops considerable force. Basement areas under sidewalks and terraces may, however, be quite useful as one of several emergency exits, if an opening from them is constructed to the sidewalk.

Vault and arch construction for shelters may be suitable, provided it is strengthened by tie rods or steel framing. Arches should never be additionally supported by bearing members placed along the line of the arch crown.

2. Lateral protection.

Materials used for lateral protection of a shelter must be of sufficient thickness to resist blast and splinters, as specified in Table II following.

a. *Walls.*—Shelters that are completely below ground, with earth-backed walls, generally afford the required lateral protection against blast and splinters, but may not be resistant to earth shock. Lateral protection of equal efficiency against blast and splinters may be provided for shelters which are partially or completely above ground level. Table II gives the thicknesses of several materials required to stop fragments and to protect against the blast of a 500-pound bomb exploding 50 feet away:

TABLE II

Material	Required thickness in inches
<i>Preferred:</i>	
Reinforced stone concrete— 3,000 psi minimum.....	12
Reinforced brick—cement or cement-lime mortar.....	13
<i>Acceptable:</i>	
Brick wall—cement or cement- lime mortar.....	13
Plain stone concrete.....	15
Sand or gravel between wood sheathing or corrugated iron....	24
Sandbag wall.....	30

Note.—Recent tests indicate that the above thicknesses will withstand perforation of splinters at 25 feet except in rare cases.

Basement walls, below ground level, should be at least 10 inches thick. Existing outside walls that are part of a shelter, either completely or partly above ground, as in a semi-basement or on a sloping site, should be at least 12 inches thick and consist of solid brickwork, masonry, or reinforced concrete.

Existing walls that are less than the required thickness should be strengthened. Additional thickening may be bonded to the existing wall, if it is sound, or it may be a separate wall. In either case it should extend to the ceiling line of the shelter. If, for any reason the veneer wall is not feasible, a new 8-inch concrete wall may be erected adjacent to the existing wall, and the space between filled with cement and sand [gravel]. A combination of materials may also be used for lateral protection, but their proof thickness should meet the requirements shown in Table II.

Strengthening for walls above ground should be applied on the outside face of the existing wall, and capped with flat tile, slate, brick on edge, or bituminous roofing material, all laid with a slight pitch outward for drainage. The wall should be laid on a solid foundation, and a damp-proof course added for protection against moisture. Downspouts or vent pipes on the wall face should be left in position, accessible for repair.

For shelters in interior rooms or central portions of buildings, some walls of 8-inch thickness are permissible, but only when they are protected by a screen wall not less than the specified thickness for protection. Despite this outer protection, a bomb penetrating the roof and several floors of a building, and exploding near an inner shelter, would cause heavy damage to nearby walls because of the confinement of the explosion. Discounting the likelihood of complete penetration by a direct hit, shelters in the ground floor or other well protected rooms of steel framed structures will provide occupants with a great deal of protection.

In large shed-type industrial buildings, with widespread expanses of working space, an explosion is apt to cause a minimum of material damage to the structure, because the space is

relatively unconfining. Injury of personnel, however, is apt to run high in such a space, because there is nothing to stop the flight of bomb fragments, tools, and pieces of equipment. Protective baffle or screen walls are needed near work benches and other places of concentrated activity. For further confining the damage in large industrial buildings, division walls are advised on the floors of large working areas. The compartments may form areas of from 5,000 to 20,000 square feet, their size depending upon the disposition of machinery, equipment, and storage, and upon circulation and transit facilities. The blast walls should be 12 or more inches thick and not less than 6 feet 6 inches high. There should be no bond between the new blast walls and the existing walls or the structural steelwork. Openings, to allow for movement of traffic, should be provided with baffle protection.

b. *Window and door openings* in a shelter or protected area must be blocked entirely, or protected by a baffle wall or barricade. The thickness of materials for blocking openings should not be less than specified in Table II.

Window openings in walls that require thickening may be bricked up when the new wall or veneer is built. Where the existing wall is already of sufficient thickness, window openings may be blocked or barricaded.

The presence of glass, whether in windows, doors, partitions, or elsewhere, presents a danger to shelter occupants. Experience shows that flying glass is the cause of a great number of casualties. *All glass should be removed.*

The following materials may be used in blocking or barricading window openings: (1) Brickwork, (2) framed barricade, (3) gravel filling between plank forms, (4) solid precast concrete blocks, or hollow blocks filled with concrete, sand, or earth, and (5) sandbags (see Figure 15).

For methods of utilizing these materials, see OCD publication, *Glass and Glass Substitutes*.

3. *Structural strengthening of existing buildings.*

In practice, each problem of structural

strengthening must be dealt with as an individual case. A few general cases may be cited, and a general interpretation given for providing reasonable protection. Clearly, no partial strengthening of an existing building can make it immune from the results of bombing. A great deal can be done, however, to provide reasonable protection.

Strengthening is intended to prevent the collapse of the shelter roof in event of severe damage to the superstructure of the building. Severe lateral movement may be caused by earth shock. Bracing may be dislodged by rebound of the floor system from the impact of falling debris. Therefore, lateral bracing, securely fastened to struts, should be provided in both directions. Care must also be taken in reinforcing concrete members and floor slabs in framed buildings; columns or struts incorrectly placed may weaken the original members instead of strengthening them.

a. *Structural steel strengthening.*—For large buildings the use of structural steel and reinforced concrete is preferred. Steel columns, if available, should be selected from standard rolled sections. They should have top and bottom bearing plates, and their beam and girder connections should be so designed that undue bending moments will not be induced in the columns. There is greater lateral stability when strengthening members are independent of existing walls and ceilings, hence no beam should bear on an existing bearing wall.

The top of each column should be held firmly in position where a beam frames into it, preventing horizontal movement. The top of the column may be stabilized or restrained by means of a cross beam, so placed that its lower flange is at the same height as that of the main strengthening beam, and connected to the column cap or to a point as low as possible on the main I-beam. The base of each column should stand on a concrete footing or on a reinforced concrete base, which will distribute the load to the floor when the existing floor slab rests on solid ground. The column should be wedged into position, and the wedges grouted in, to prevent "kicking out" or swiveling.

The strengthening members must be so designed that the stresses calculated for the combined live and dead loads and assumed debris loads are well within allowable ultimate limits. Steel columns must be completely independent from walls and preferably should not be closer than 12 inches to outside walls.

It is permissible to assume that a fully framed building in which all loads are carried by a steel frame—if it has been designed in accordance with standard practice—will meet the requirements for protection from falling debris even if the floor above the shelter has not been strengthened.

b. *Tubular steel strutting.*—Smaller buildings of reasonably sound construction, with not more than three full floors above the shelter room, may be strengthened by the use of tubular steel struts, light rolled I-beams, and heavy-gage corrugated sheet metal. The struts should be permanently attached to base plates. Cap plates should be used to connect with the I-beams overhead. In computing the length of strut required for a room of specific height, allowance must be made for the depth of I-beams and sheet metal. The I-beams should be calculated to take all loads and should have one coat of red lead or black bituminous solution to prevent corrosion. For a finished treatment to a strengthened ceiling, see Figure 17.

c. *Wood strengthening and strutting.*—Wood, though it consumes more space within a shelter than steel, is capable of carrying considerable debris loads. Plank sheathing, when used to strengthen a ceiling for overhead protection, should be laid against the ceiling or the under side of exposed floor joists. Close spacing of planks tends to increase fire resistance of the structure and to reduce the sifting through of rubble dust. It may be necessary to space the planking to allow for pipe runs or conduits on the ceiling, but the maximum clear distance between planks should not be greater than 3 inches.

The planking, 2 or 3 inches thick, is securely fastened to heavy timber beams and columns, spaced approximately 5 feet on centers. New beams should be placed at right angles to existing joists overhead, and the plank sheath-

ing parallel with the joists. The spacing may be modified slightly for the maximum strengthening effect in a given situation.

Timber columns or struts should be placed on a 2-inch sill plate, continuous for several struts in a row in order to distribute the load over a greater surface. To distribute the pressure farther onto the beams and sill plates, and to avoid excessive crushing of the side grain, base and cap pieces may be inserted at the bottom and top of each strut between the beams and sill plates. Struts should be firmly attached and braced to the beams by bolted members.

It may be assumed that the sill plate will be adequately carried if the floor is directly on the ground and made of concrete, brick, flagstones, or wood blocks. A strip of heavy roofing paper should be placed between the sill plate and any brick or stone flooring. Otherwise it may be necessary to provide brick or concrete piers to give firm bearing for the sill plates.

Bracing against lateral movement is necessary for each line of struts. Bays should be braced in both directions with 2x6-inch members, set diagonally, cut to fit, and bolted or spiked together at the intersections. Structural members, such as beams, struts, and sill plates, should be tied together by some means such as bolted straps or "dogs." Struts should be independent of walls, deriving stability from the strengthening members. Beams should not bear on existing walls, or pin into them. Figure 18 shows one of the methods for strengthening a shelter with wood members.

4. *Separate shelters erected within a building.*

Conditions in one-story industrial buildings may make it necessary to build one or more separate shelters inside individual buildings. There may be insufficient overhead protection to warrant strengthening, as shown in Figure 19. Excessive room heights may make strutting impracticable. The arrangement of machinery and equipment may severely limit the space. Suggestions are given here for the

construction of such intramural shelters, preferably of reinforced concrete or reinforced brick construction; they should provide reasonable protection against blast, bomb fragments, and falling debris.

The shelter should be erected on a solid (but not wooden) floor. To provide a plane of cleavage, a layer of heavy roofing paper should be used between the shelter floor and the existing floor of the building. A separate foundation for the shelter is necessary in some instances; it should be sufficiently strong to avoid subsidence that would produce cracks in the shelter and impair its effectiveness. The shelter floor, not less than 9 inches of reinforced concrete, should be securely bonded to the walls of the shelter.

The walls, at least 12 inches of reinforced concrete or reinforced brickwork with solidly filled mortar joints, should be located, at a minimum, several inches away from existing walls of the building. Damp-proofing should be provided where dampness is likely to occur. The inside clear height should be not less than 6 feet 6 inches. Vertical reinforcement, whether in brickwork or concrete, should tie thoroughly into reinforced concrete roof and floor slabs. Reinforcing for brickwork should be quarter-inch bars placed vertically at about 8-inch centers. Recommended reinforcing for concrete is small round bars closely spaced.

A reinforced concrete roof slab 6 inches thick is sufficient for general purposes unless overhead conditions indicate otherwise.

If built as indicated, the resulting rigid structure is independent of existing buildings, permitting relative movement between the two in event of earth shock and blast, the shelter moving independently as a self-contained monolithic unit.

Shelters may be built to accommodate 6, 8, 10, or 12 persons. The individual shelter should be not more than 8 feet wide; its length will depend on the area required for a given number of people. Several 12-person units may be combined under a continuous slab roof, as shown in Figure 20. Chemical toilets are shown at suggested locations for this type of shelter.

Entrances, not less than 2 feet 6 inches wide, should be protected by baffle walls, as shown in Figure 20. In some cases it may be wise to provide combined entrance-exits equipped with baffle protection. Emergency exits must be provided, none of which should be less than 2 feet square. The openings, protected above when necessary with a concrete slab lintel, can be filled with brick laid in dry sand, or with sand and gravel enclosed by two steel plates not less than $\frac{3}{8}$ inch thick. Each plate should overlap the walls $1\frac{1}{2}$ inches on all sides and should be held in place by four $\frac{1}{2}$ -inch bolts, threaded on both ends and fitted with wing nuts. The bolts fit through $\frac{1}{16}$ -inch holes drilled in each corner of the plate.

Where a shelter has been placed near the outside walls of the existing building—and they are sometimes placed in a corner for additional protection—the escape may lead directly outside. The detail for the opening is the same, but, if there is a space between shelter and building wall, it must be suitably protected and another opening, provided with a substantial lintel, be made through the existing wall.

5. *Trench shelters within buildings.*

Trench shelters are not recommended, but it may be necessary to provide them in cases where space limitations preclude other types. They are suitable only where favorable conditions exist for excavation; where they do not interfere with wall foundations, footings, and columns of the building; and where there is no possibility of flooding by surface or ground water, or by the fracture of service pipes and drains.

Given favorable conditions in these categories, trench shelters have definite advantages: They do not interfere materially with the use of existing floor space; they provide good protection against splinters; they offer good overhead protection against debris.

A system of trench shelters may be constructed under existing floors of structures offering little or no overhead or lateral protection, such as one or two-story factory buildings (see Figure 1, space G, and Figure 19). Trenches may be used where space cannot be

sacrificed, yet it is imperative to provide personnel with protection close to working areas. Trenches may be spaced between rows of machinery in heavily encumbered areas. If earth is removed from a foundation within a plane of 45° from the horizontal, underpinning must be provided for the foundation. A foundation wall may be pierced by a trench at right angles, providing the wall is underpinned on each side of the trench and a lintel is constructed over the trench, as in Figure 22, (a) and (b). There should be no bond between the trench and the existing wall. Trenches should be laid out in such a pattern as to allow not less than 25 feet clearance between them. Irregularities and offsets are an advantage, though the location of columns and machinery may limit planning. Figure 21 illustrates the layout of trench systems.

The inside clear dimensions of the trench, depending upon space and the need for accommodations, should be approximately 4 feet 8 inches wide by 6 feet 8 inches high. The reinforced concrete shell should be at least 4½ inches thick all around. For slightly wider trenches the concrete should be 6½ inches thick (see Figure 23). The length of trenches is determined by the number of persons to be accommodated. Not more than 50 persons should occupy any single unit of the system.

Of the several types of linings for trenches, the most satisfactory is reinforced concrete, poured on the site. Linings of other materials, such as sheet metal, wood, brick, or precast concrete slabs require so much additional strengthening that they are not likely to be economical or satisfactory. The trench lining, including the roof and floor, should be built as a rigid frame, having continuous reinforcement. This is necessary to resist earth shock, to prevent lifting of the roof by a near miss and its subsequent collapse, and to provide maximum resistance to debris loads overhead. Lateral loads may vary in force from 200 pounds per square foot at the top of the trench to 400 pounds per square foot at the base.

Baffle walls should be erected as a corporate part of the trench structure at distances not greater than 20 feet apart, and should extend

the full height. Such openings for access passage are shown in detail (a), Figure 21. They are calculated to reduce the effects of a bomb exploding at the entrance or at any point within the system.

Overhead protection should be the same as for other shelters, conforming to the required standards. Earth covering over trench tops should not exceed 2 feet in depth. The floor above may be relaid as it was before. Loose backfill, consisting of ashes, clinkers, brush, or other materials loosely laid, will lessen the possibility of damage to trench shelters from earth shock.

Entrances, not less than 3 feet wide, should lead to the trench system through a hatch-type cover or hood built of brickwork or concrete, with a protective door. A gasproof door or gaslock may be installed at the trench-floor level. Emergency exits may be crawl-away tunnels similar to those discussed on pages 4-5, or by overhead hatchways. Opposite entrances and exits, when left open, are assumed to provide some ventilation. If a trench is made gasproof, mechanical ventilation is obviously necessary.

C. Refuge Rooms

A home shelter or refuge room should provide protection against (1) a near miss (blast and splinters), (2) falling debris, (3) the small incendiary bomb, (4) falling shrapnel from anti-aircraft fire, (5) machine-gun bullets, and (6) military gases.

The room selected should provide maximum lateral protection with existing walls of the building. Moderate protection is afforded by walls of brick, masonry, or concrete. A wood frame building having stud partition outer walls of lath, plaster, sheathing, and an outside finish of shingles or clapboards offers little or no lateral protection against blast and splinters.

A small narrow room is preferable as a refuge room because of the greater strength of short-span members overhead to resist debris loads.

Where no room is available for treatment as a shelter, refuge may be taken under a main stairway or in a central hall or passageway. Openings that give "through circulation" to

the occupied shelter space should be protected by baffle walls or otherwise treated to conform to requirements. All glass should be removed from the shelter, including that in partitions and cabinets.

The resistance of the individual building to fire caused by incendiary bombs is an important consideration in planning an air raid shelter. Fire breaking out in the building may cause abandonment of the shelter or the trapping of occupants. Fire also acts as a guide for attacking aircraft, and the vicinity where fires have started may be subjected to bombing.

Fire precautions and the incendiary bomb problem are discussed in other OCD publications. A few salient points are:

- a. Attic floors or lofts should be cleared of inflammable materials.
- b. Rapid means of access to top floors or lofts must be readily available,

- c. If supports of this floor are adequate to carry the added weight, a 2-inch layer of sand or other fire-resistant material may be spread on the floor, making it possible, if the bomb does not penetrate farther, to deal with it before a serious fire is started.

- d. Fire-fighting implements should be placed conveniently for instant use. They should include buckets for water and sand, long-handled shovels, soda-acid fire extinguishers, and, if possible, an approved type of hand-operated portable pump.

The following types of buildings may be considered for shelter purposes: (1) Office buildings, (2) bank buildings, by agreement only, (3) stores, (4) hotels, (5) apartment houses, (6) warehouses, (7) schools, (8) churches, (9) factories, and (10) residences.

III. ILLUSTRATIVE SHELTER PROBLEMS

Each case must be considered individually when providing shelters in buildings. The following examples are cited for guidance in handling practical situations:

1. *Example Problem*—Warehouse (Figure 13)

A large warehouse similar to that shown in the figure is to shelter 300 persons. The basement is chosen as the shelter area, for its lateral protection from blast and splinters. A reinforced concrete slab provides overhead protection against debris and small incendiary bombs. The compartments A to D are sized according to occupancy and space requirements given in Table I. Reinforced concrete or reinforced brick walls separating the compartments should be 12 inches thick; the same is true of the wall along the corridor. Walls separating the compartments from the corridor should be 8 inches

thick. The storage of merchandise in any warehouse may influence the planning of a shelter. Usually, however, goods can be shifted to make room for a shelter in the most suitable location.

Existing stairs (e) are used as an entrance from the ground floor and from the street. An outside entrance is provided to the basement level at the front of the building; it should be protected overhead by a concrete slab. Emergency exits are provided at points (a) to (d) by blocking the windows with loosely laid brick or sand and gravel held in place by removable steel plates. If the window openings are excessively large, part of the opening may be reduced in size by permanent blocking and the remainder used as an emergency outlet.

Vestibule F is a part of entrance lobby G, and may be used in connection with it to form

a gas lock. Compartment E is intended for sanitary facilities, planned according to the requirements. Compartment H is the first aid and decontamination unit. Access is provided from entrance G to unit H, then into F, and thence to shelter compartments D-A.

Alternative locations are positions J and K, with entrances as shown, and positions L to O. Outside windows in the latter group are at a high level, and should be blocked in a manner suitable for use as emergency exits.

2. *Example Problem*—Large Building (Figure 14)

A large building similar to that shown in the figure is to shelter 400 persons, not more than 50 to a compartment. The building is not new but is substantially built and offers reasonable protection; it has not sufficient stories to permit the use of second or third-floor space for a shelter. There is, however, ample space in the basement. All compartments are away from the streets, which flank the two remaining sides of the building.

Two existing stairways, entering compartments C and J, serve each leg of the compartment layout and provide for rapid occupancy of the shelter. Emergency escapes, all in party walls, are provided at points (a) to (f). Escape (c) is of the tunnel type, protected by reinforced concrete walls and slab; sufficient headroom under the stairway is necessary for this type of outlet. Adjoining buildings should offer additional points of exit. The interconnecting compartments and corridors offer primary means of exit. Emergency outlet (a) gives access to the street; it should be protected by a hood, as shown in Figure 11.

All walls of compartments A to E should be 12 inches thick, except those between the compartments and the corridor, which may be 8 inches thick. The outside walls of the corridor should be of the greater thickness. In compartment C the wall of the staircase is considered adequate in combination with the stairs. Twelve-inch walls are needed to separate compartments F-J from the remainder of the basement, and the front wall of compartment H should be of equal thickness because of

the opposite opening in the corridor wall. Remaining walls require thickening to conform to requirements for walls between large shelters. Area J, not intended for occupancy as a shelter compartment, is strengthened to protect the stairway, which may serve as a means of escape.

3. *Example Problem*—Row Houses (Figure 16)

Shelter is to be provided for 19 persons (room A) having insufficient overhead protection above basement level. The inside entrance to basement room A is accessible from the foot of the stairs. Emergency exits are provided at points (a) and (b) in the party wall. Coal chute (f) may be adapted as an escape exit, providing the walls of the area-way approach from room A are sufficiently strengthened.

Measurement reveals that room A has a floor area of 206 square feet, a surface area (walls, ceiling, and floor) of 906 square feet, and a volume of 1,771 cubic feet. According to the requirements in Table I, the required space for 19 persons would be 114 square feet of floor area, 570 square feet of surface area, and 950 cubic feet of volume. This room, therefore, provides ample space by any of the three requisite measurements. When used as a gasproof shelter, however, it can accommodate only 12 persons.

The entrance opposite the stairs is provided with baffle wall protection. Partition walls, such as those between rooms A and B, require strengthening when they are of light weight construction and not sufficiently screened by other walls of the building. Overhead protection is provided by sheet metal, supported by I-beams and tubular steel struts.

Room B has sufficient space to accommodate 19 persons, as shown by its interior measurements—120 square feet of floor area, 618 square feet of surface area, and 1,032 cubic feet of volume. As a gasproof shelter, however, it can accommodate only 8 persons.

Emergency escapes can be provided at points (c), (d), or (e), the latter as a crawl-away tunnel extending to the party wall, as illustrated in Figure 10 (a). Entrance (g) to

the areaway should be blocked, leaving a small emergency exit. Overhead protection is needed as for room A.

4. *Example Problem*—Home Refuge Room (Figure 24)

A refuge room is to be chosen in a small house such as that shown in the figure. It is assumed that the house is of brick or masonry construction and has no basement. The most suitable refuge space is the dining room, which is protected by walls of the surrounding rooms. Extensive interior alterations are not necessary, but all openings directly in line with the refuge should be blocked or protected from flying fragments by baffle walls. Window blocking (a) and wall-strengthening (e) (e) protect window (f) and one side of the refuge room. Window blocking (b) affords protection from fragments that might penetrate the lightly built kitchen-dining room wall. Barricade (d) and baffle wall (c) further protect openings into the refuge room. Treatment of glass should conform to recommendations in the OCD publication *Glass and Glass Substitutes*. Overhead protection may be provided as shown elsewhere in this publication.

5. *Example Problem*—Separate Shelters for Residences (Figure 24)

As an alternative to the conversion of an inside room as a refuge, a separate shelter may be built similar to that shown in position B. This is a ground-level shelter, connected to the house and garage. The entrance is provided by a small porch, three steps up from ground level at the entrance to the kitchen and garage. Baffle wall protection is provided around the entrance (g) and a closed emergency exit is built into the opposite wall.

6. *Example Problem*—Shelter Rooms in Residences (Figures 25 and 26)

A shelter is to be chosen for a typical two-story house (Figure 25), built of wood frame with shingle or clapboard finish, a combina-

tion of wood frame and brick veneer, solid brick, or masonry. A full basement is available. For this type of construction an outside shelter might be preferable in some ways, but exposure in going to an outside shelter could be more harmful than an actual air raid. It is decided, therefore, to place the shelter within the house.

Position A is chosen as the most suitable, making use of two existing walls. The shelter location is also well removed from the heating unit and from utility outlets, though the cutoffs are readily accessible. New reinforced concrete or brick walls are built to partition the shelter from the rest of the basement. The ceiling overhead is strengthened according to the methods recommended in this bulletin. The entrance and a protecting baffle wall are provided as shown. Window (a) is adapted as an emergency exit.

A separate shelter might be built either at position A or at position B, as shown. This type of shelter, discussed elsewhere in this work, is more expensive, but gives a greater degree of protection. In either case, the basement steps leading to the outside should have additional walls covered by a reinforced concrete slab, so placed over the steps as to provide sufficient headroom. Windows (c) and (d) may be blocked or adequately treated to prevent casualties by flying glass. If outside tunnel exits are planned, they should avoid pipes and drains.

Location A in Figure 26 is also suitable for a shelter room.

7. *Example Problem*—Schools (Figure 27)

If a school building is to be occupied during an air raid, refuge may be taken in interior corridors of the basement and ground floors, provided upper floors, which would be preferable, have insufficient overhead protection. Shaded portions in the figure indicate positions that offer lateral protection against blast and splinters. If required, corridor walls may be thickened for additional protection. Exposed openings should be blocked as shown.

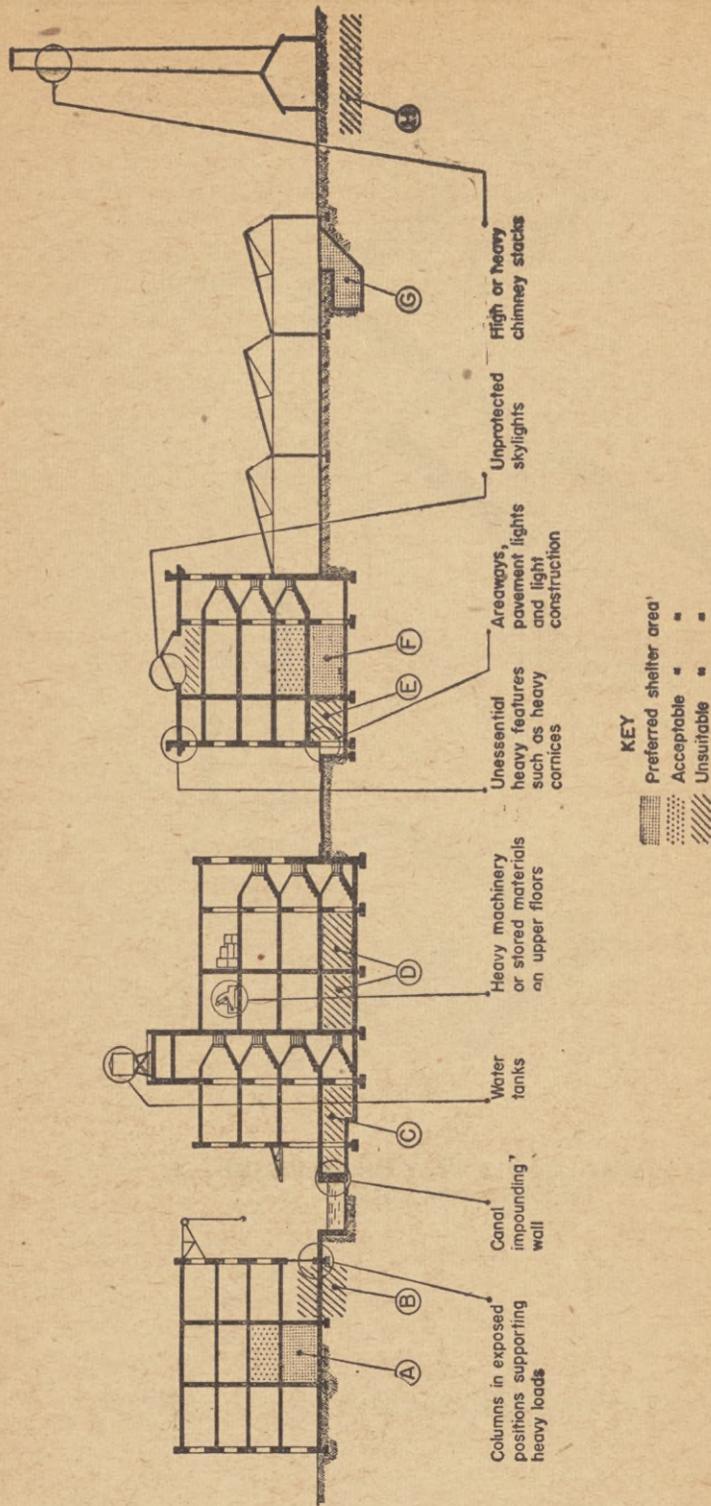


FIGURE 1.—HAZARDOUS FEATURES AFFECTING THE LOCATION OF SHELTERS IN BUILDINGS OF AN INDUSTRIAL AREA

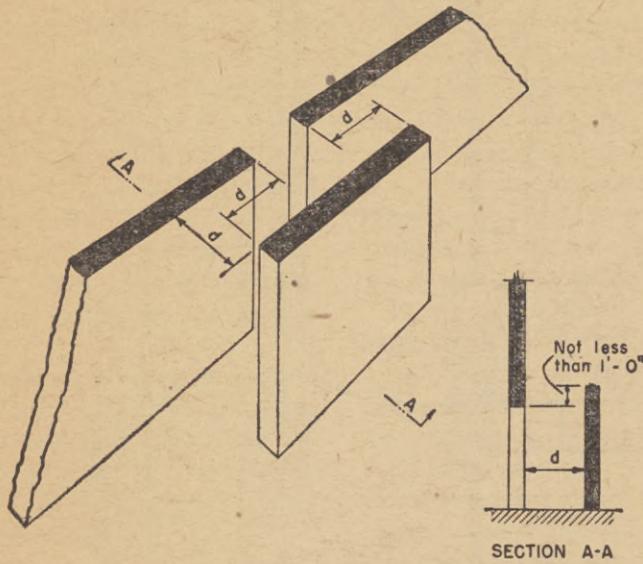
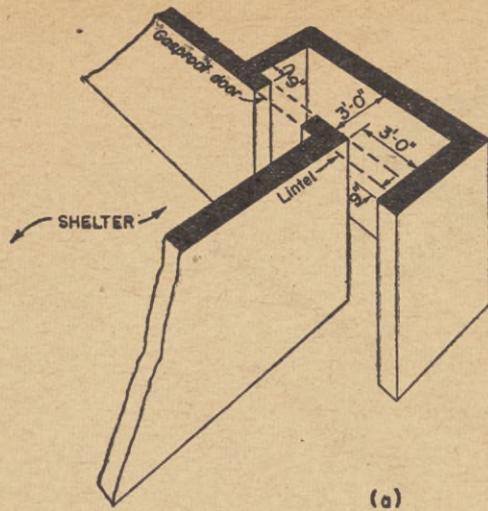
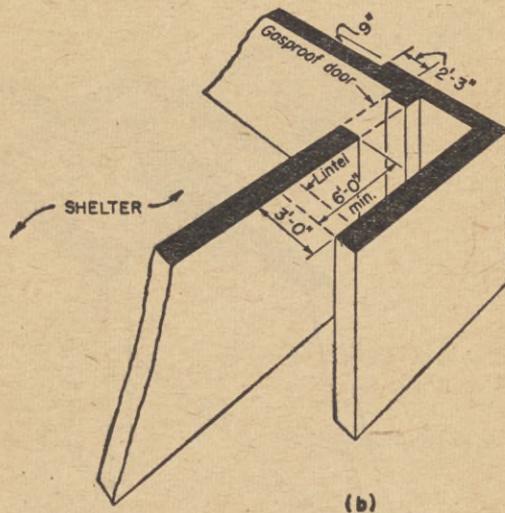


FIGURE 2.—TYPICAL BAFFLE WALL FOR PROTECTION OF ENTRANCES OR EXITS.



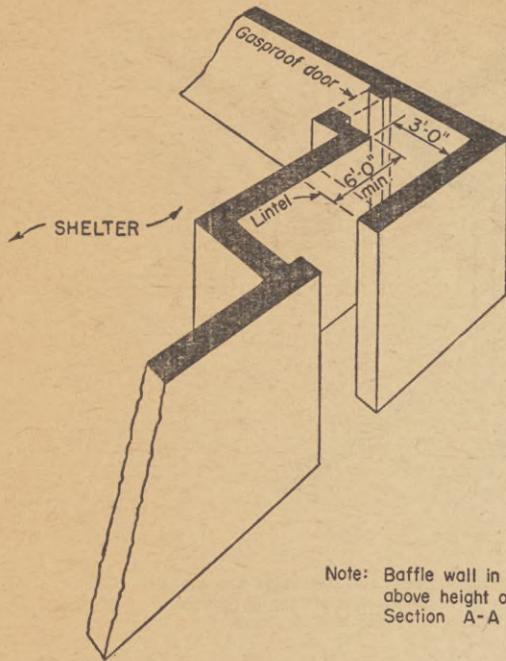
(a)

Note: Baffle wall in all cases must extend above height of opening as shown in Section A-A of Figure 2



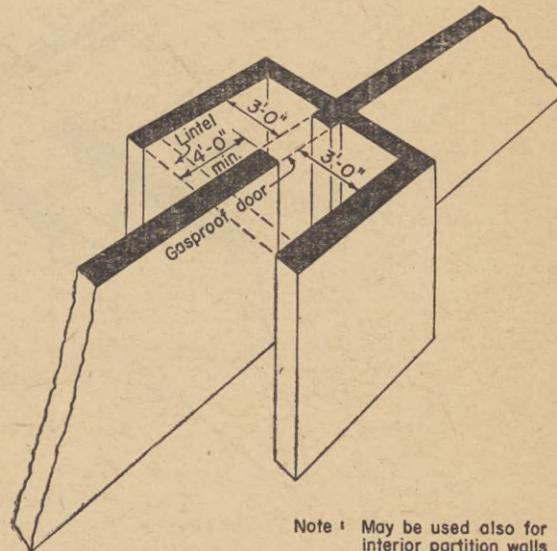
(b)

FIGURE 3.—CORNER ENTRANCES WITH EXTERIOR BAFFLE WALLS.



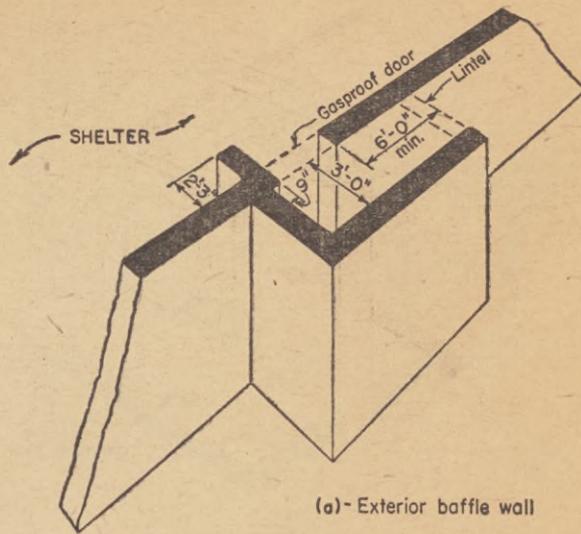
Note: Baffle wall in all cases must extend above height of opening as shown in Section A-A of Figure 2.

FIGURE 4.—CORNER ENTRANCE WITH INTERIOR BAFFLE WALL.



Note: May be used also for interior partition walls

FIGURE 5.—SIDE ENTRANCE.



Note:
 Baffle wall in all cases must extend
 above height of opening as shown in
 Section A-A of Figure 2

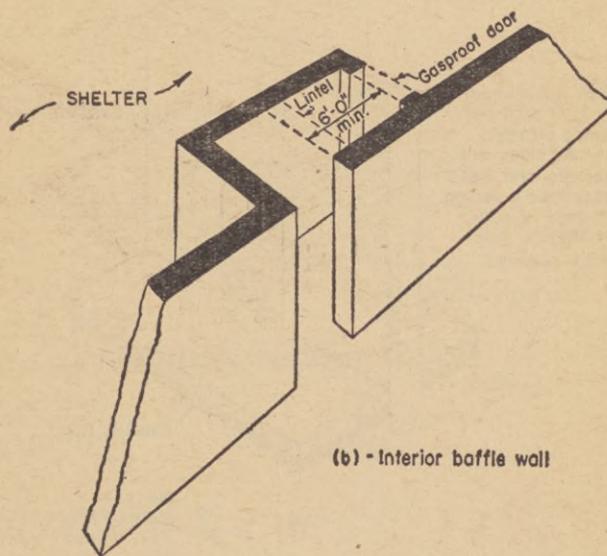
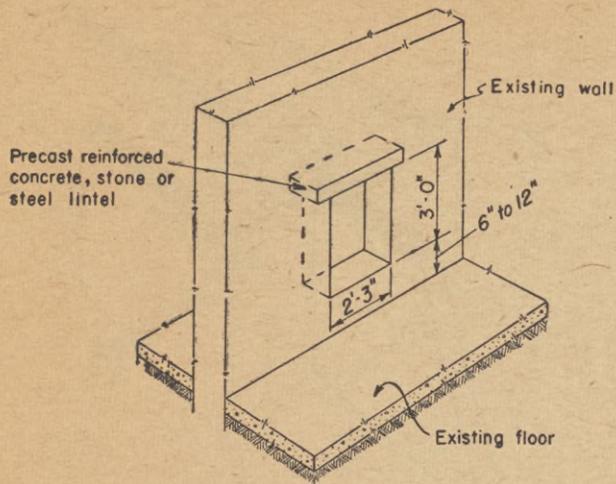
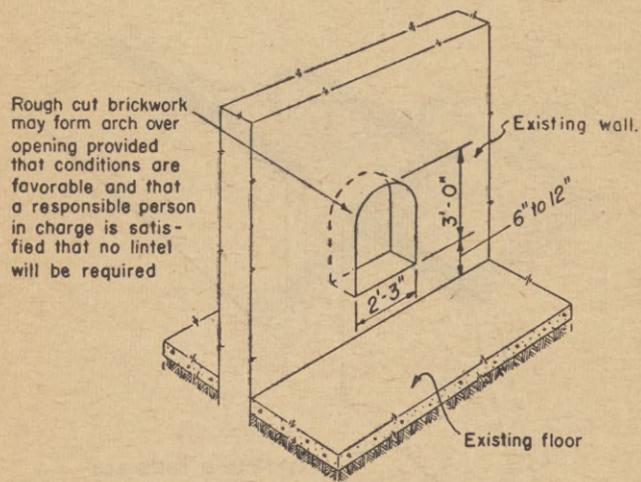


FIGURE 6.—SIDE ENTRANCES.



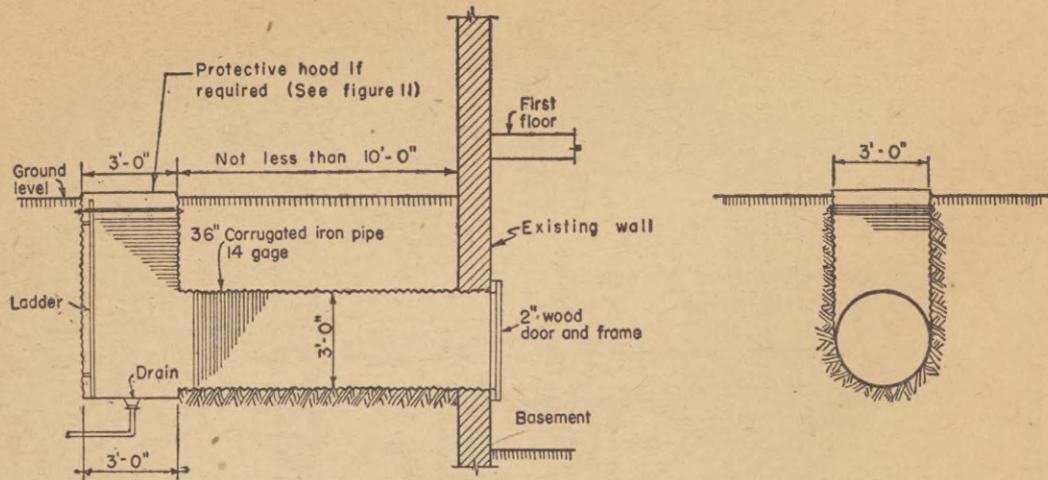
(a)



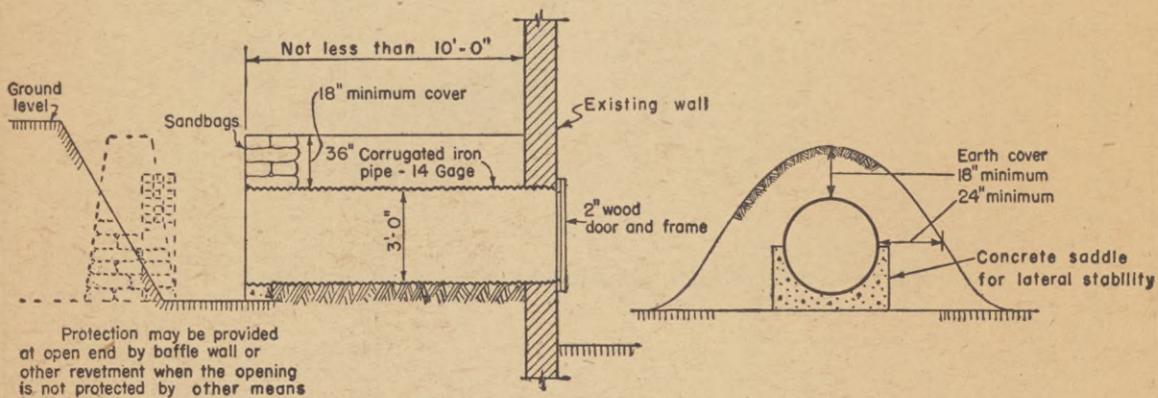
(b)

Note:
Doors should be provided
for these openings

FIGURE 7.—EMERGENCY ESCAPE IN PARTY WALLS.



(a) - Below Ground Level



Note:
Pipe should be placed with slight pitch for draining

(b) - Above Ground Level

FIGURE 8.—EMERGENCY ESCAPE TUNNELS (CORRUGATED IRON PIPE).

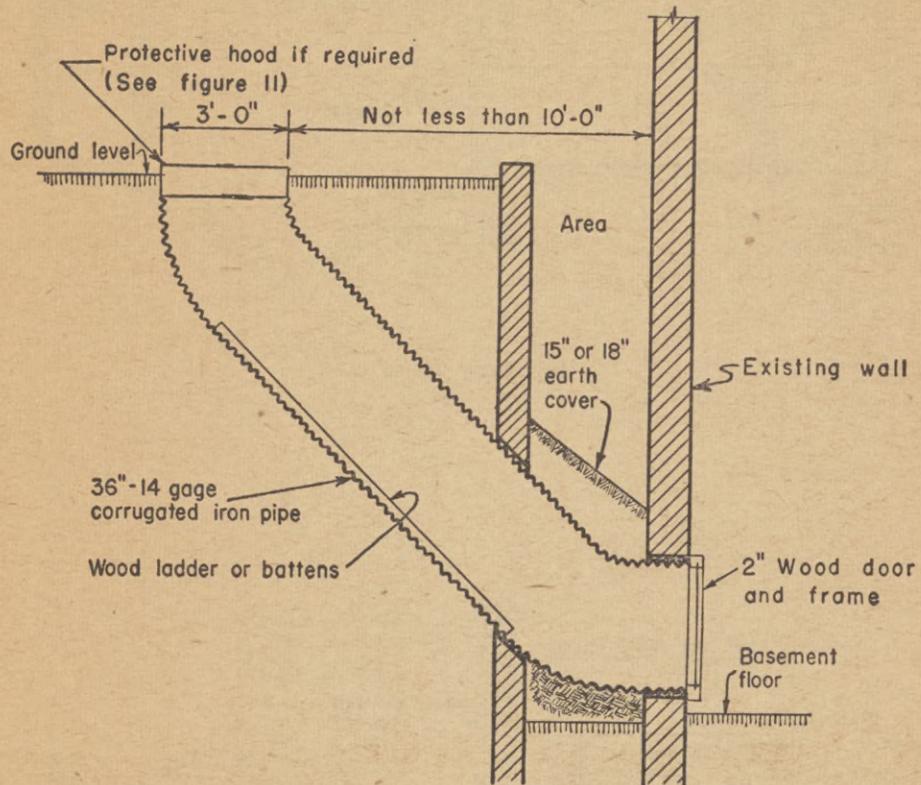
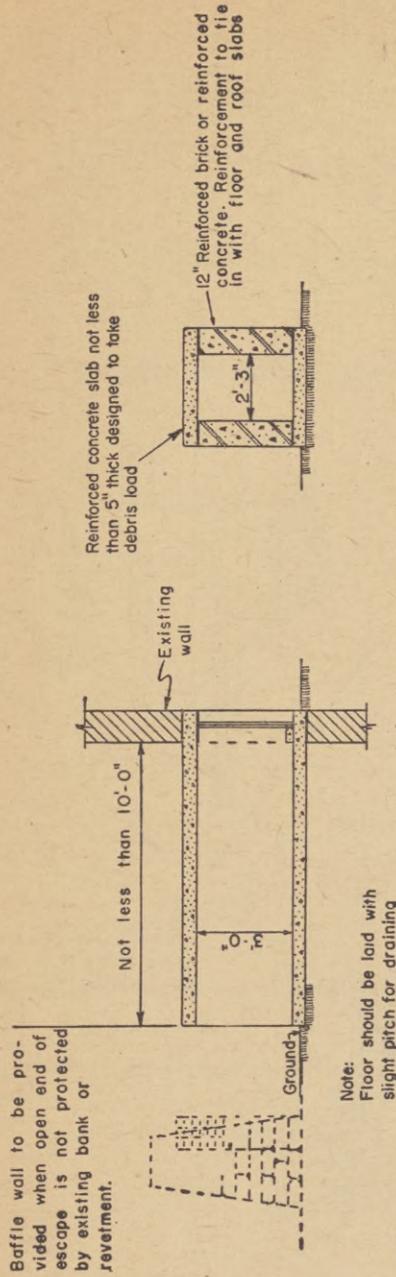
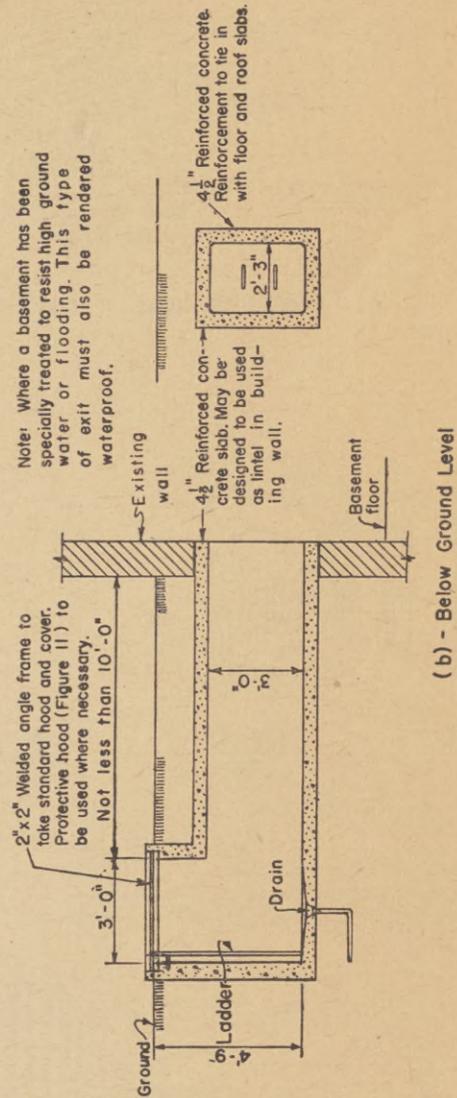


FIGURE 9.—SUGGESTION FOR ADAPTATION OF ESCAPE TUNNEL.

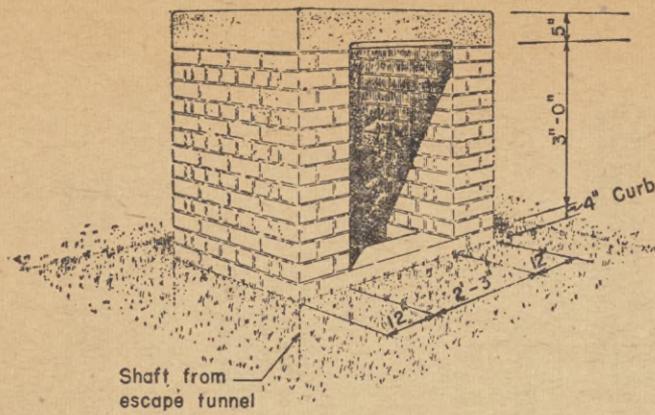


(a) - Above Ground Level

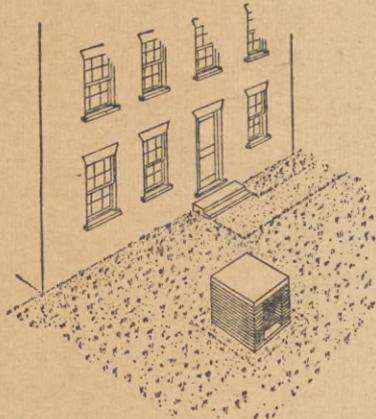


(b) - Below Ground Level

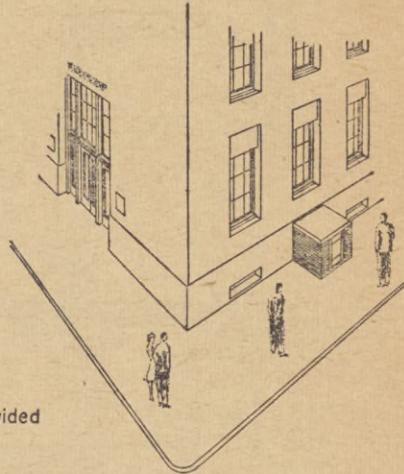
FIGURE 10.—EMERGENCY ESCAPE TUNNELS OF REINFORCED CONCRETE AND BRICK.



(a) - Protective hood of reinforced brickwork (or reinforced concrete)

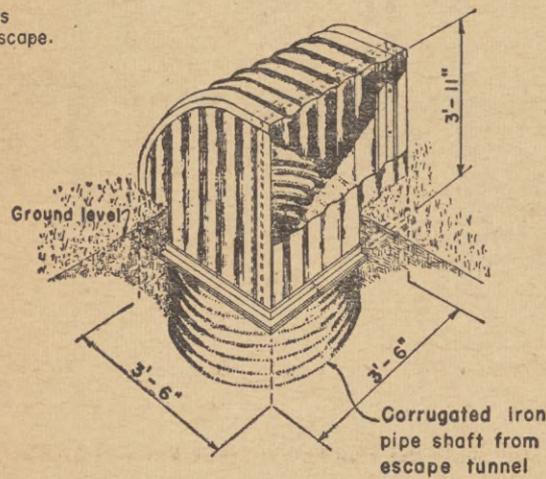


Type (a) or (b) - Use of hood where overhead protection is required for an emergency escape.



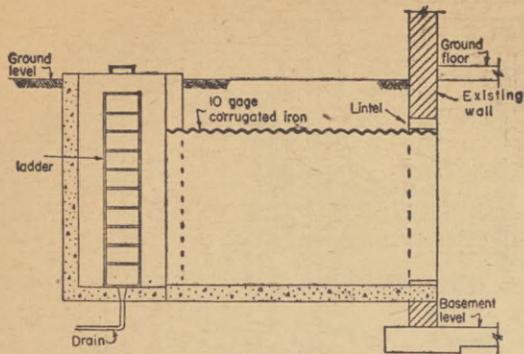
Note:
Doors should be provided for hood escapes.

Type (a) - Use of hood where space is limited for emergency escape

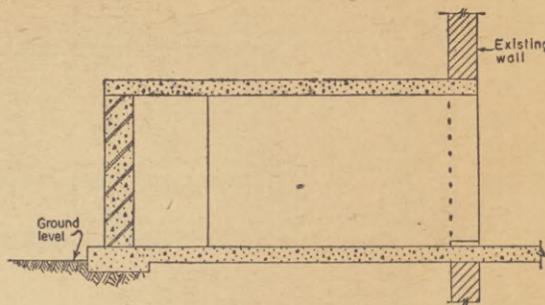


(b) - Corrugated iron hood

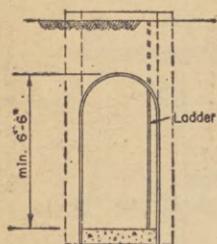
FIGURE 11.—PROTECTIVE HOODS FOR EMERGENCY ESCAPE TUNNELS.



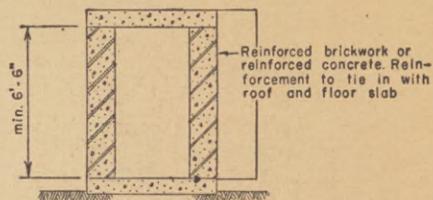
SECTION B - B



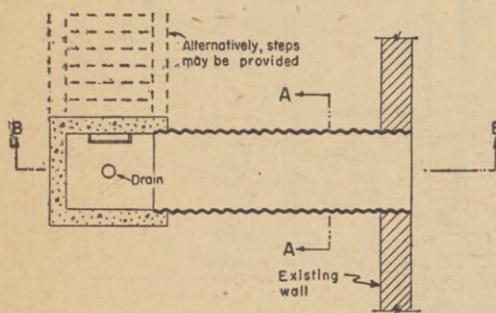
SECTION D - D



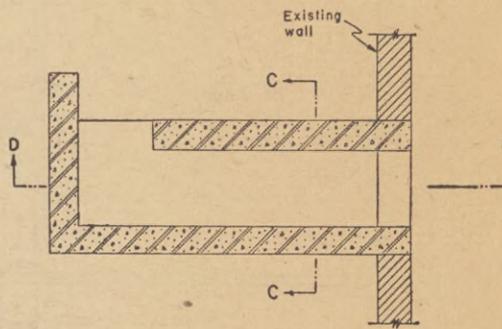
SECTION A - A



SECTION C - C



PLAN



PLAN

(a) ESCAPE BELOW GROUND LEVEL

(b) ESCAPE AT GROUND LEVEL

FIGURE 12.—SUGGESTIONS FOR EMERGENCY EXITS IN LARGE PUBLIC SHELTERS.

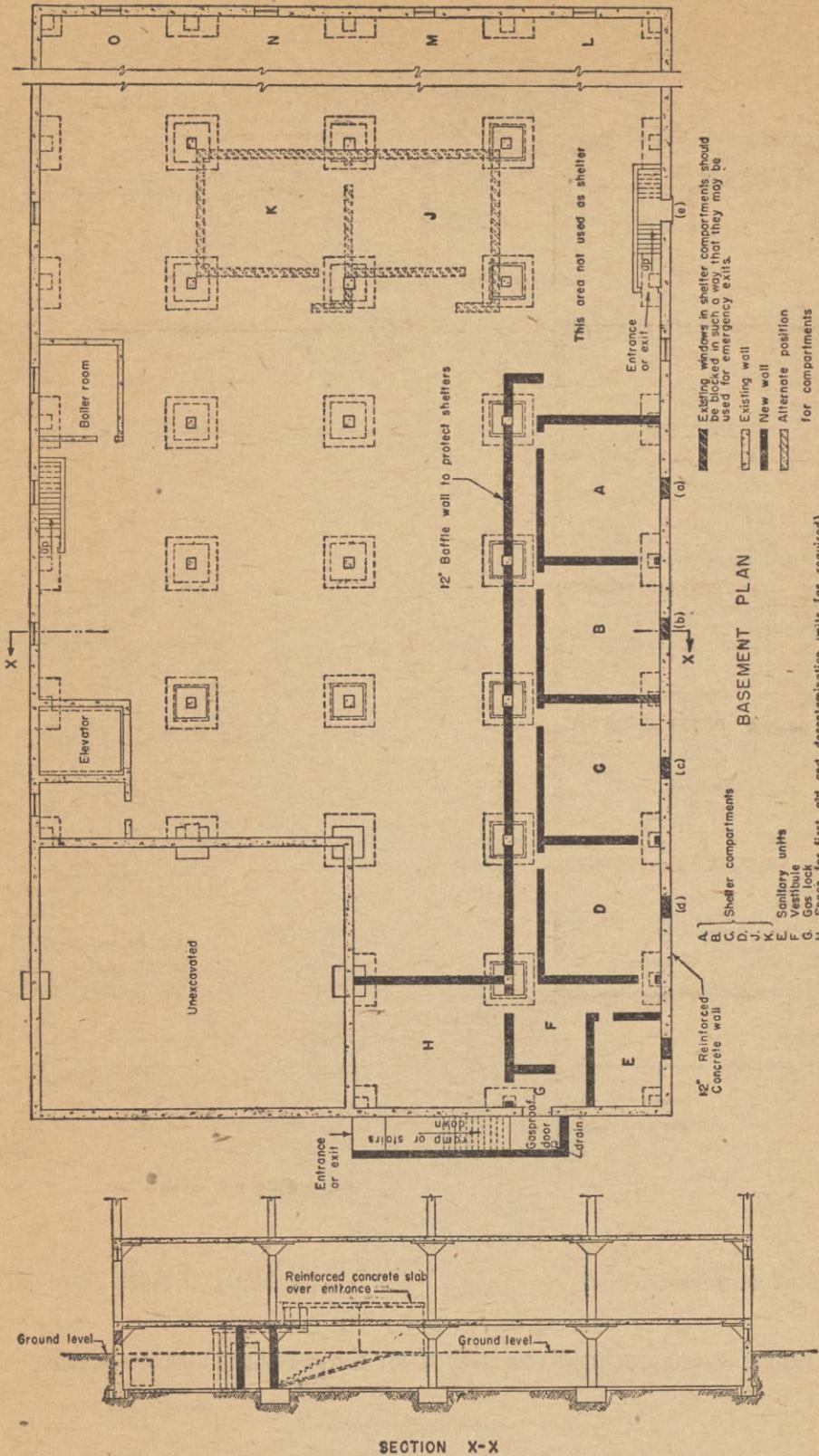
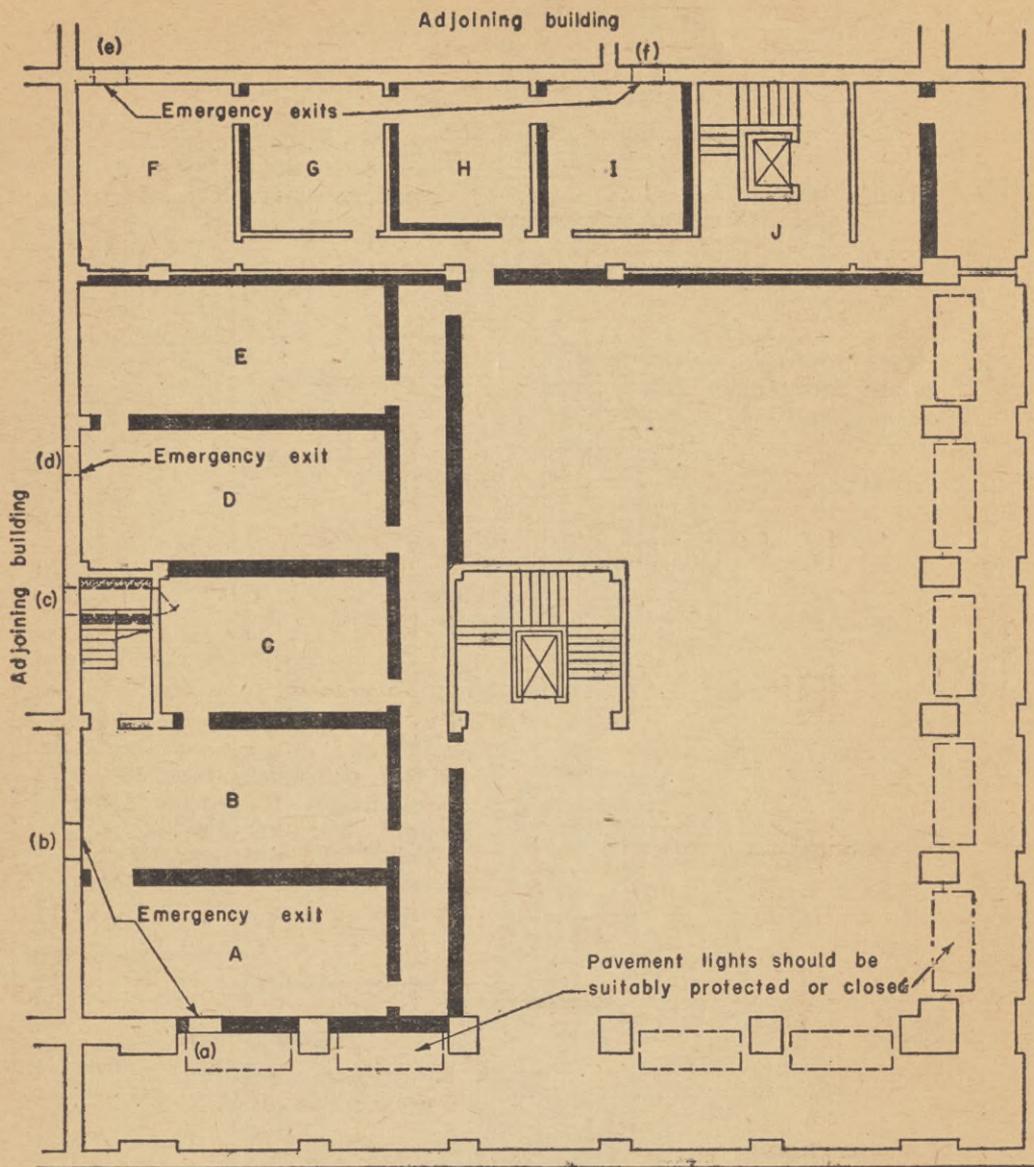


FIGURE 13.—SUGGESTIONS FOR PLANNING SHELTERS IN LARGE BUILDINGS.



BASEMENT PLAN

— New wall

FIGURE 14.—SUGGESTED DIVISION OF SPACE FOR SHELTER COMPARTMENTS IN LARGE BUILDINGS.

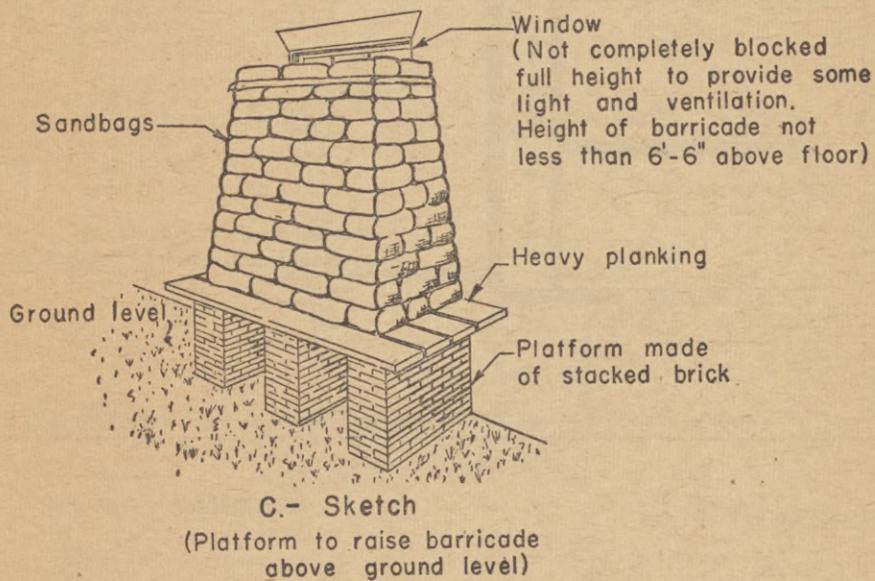
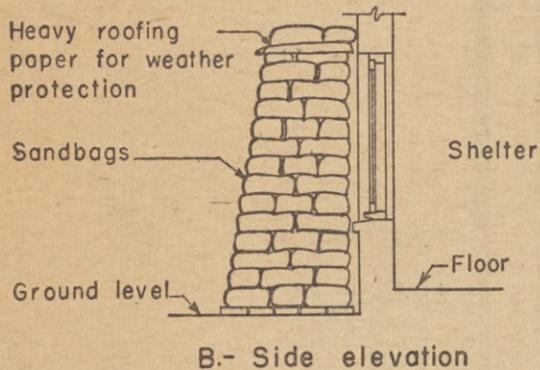
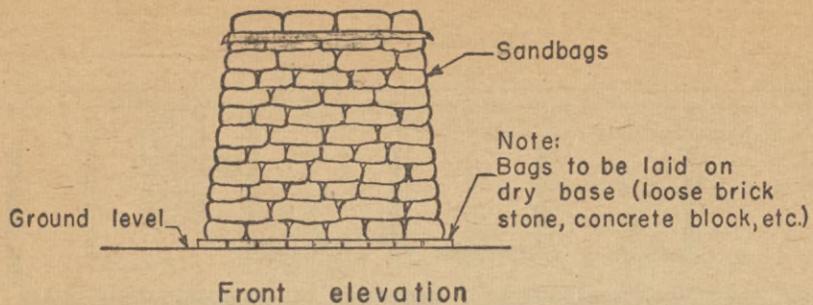
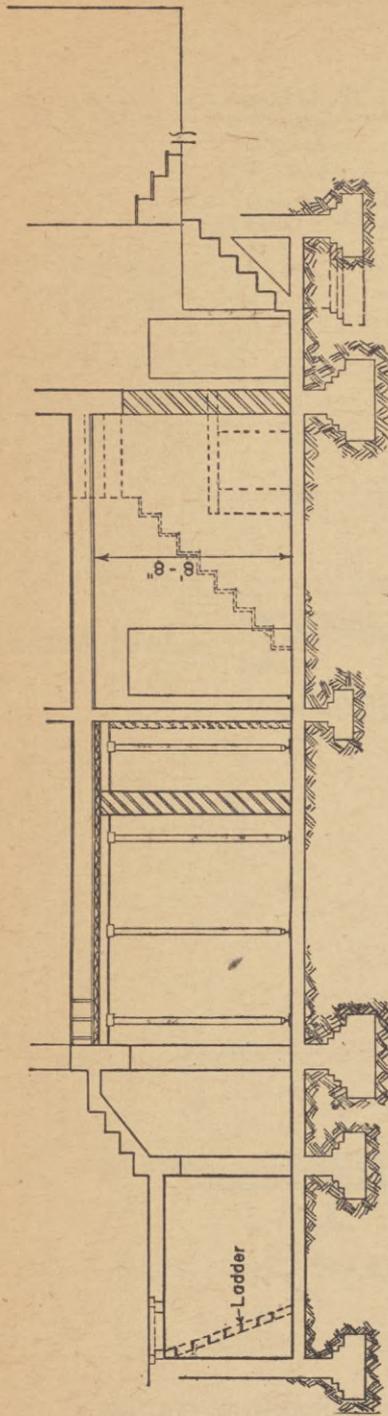


FIGURE 15.—SANDBAGS FOR BARRICADES AND WINDOW BLOCKING.



SECTION X - X

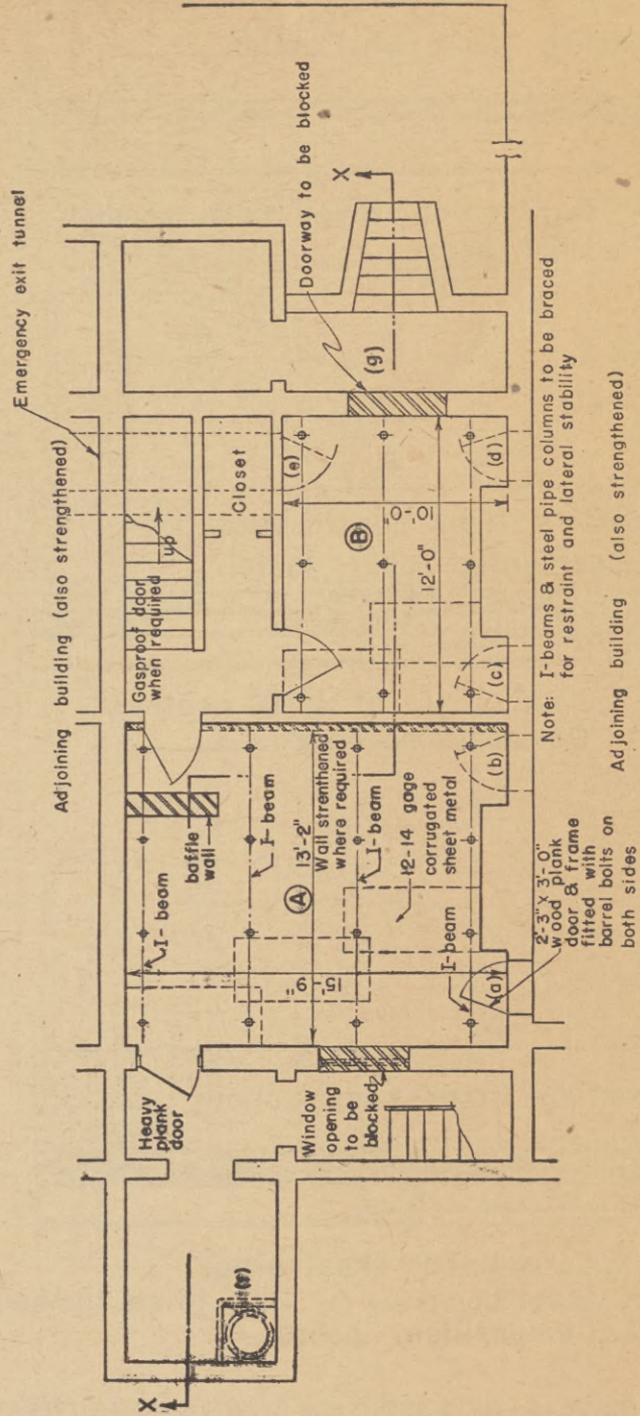


FIGURE 16.—SUGGESTIONS FOR STRENGTHENING ROOMS.

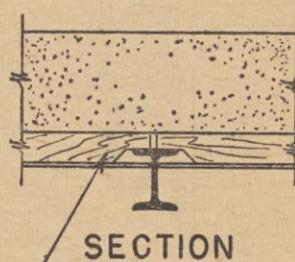
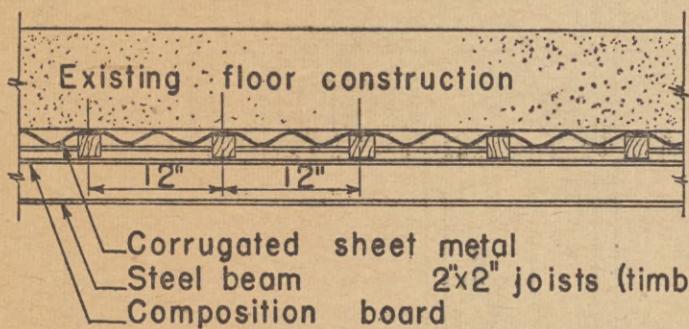
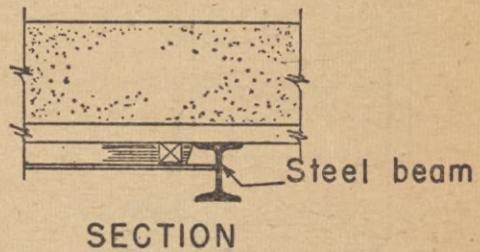
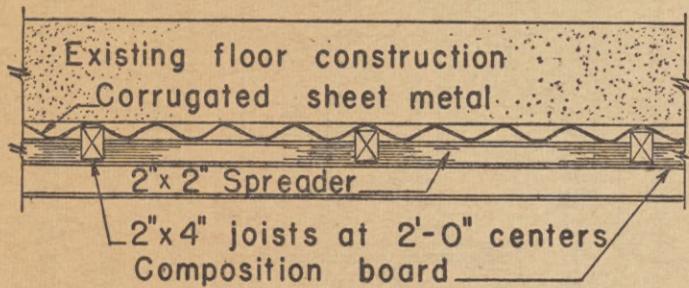
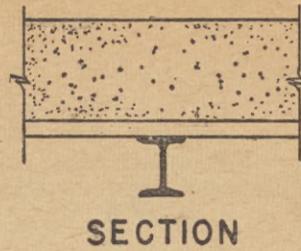
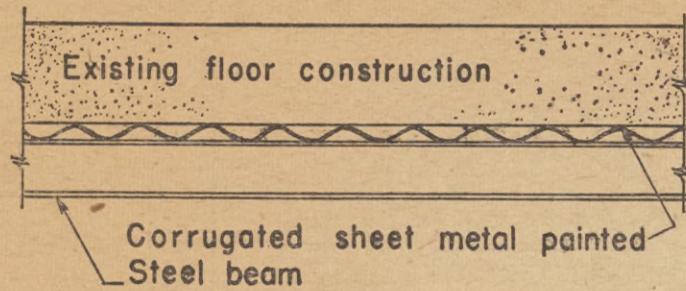
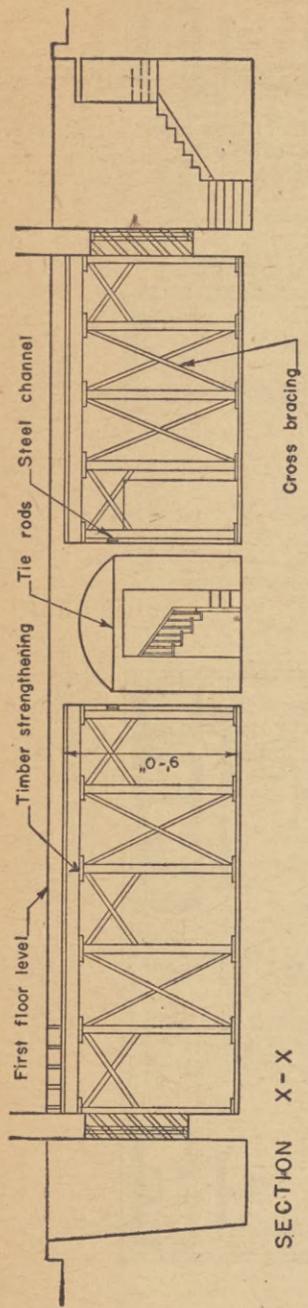
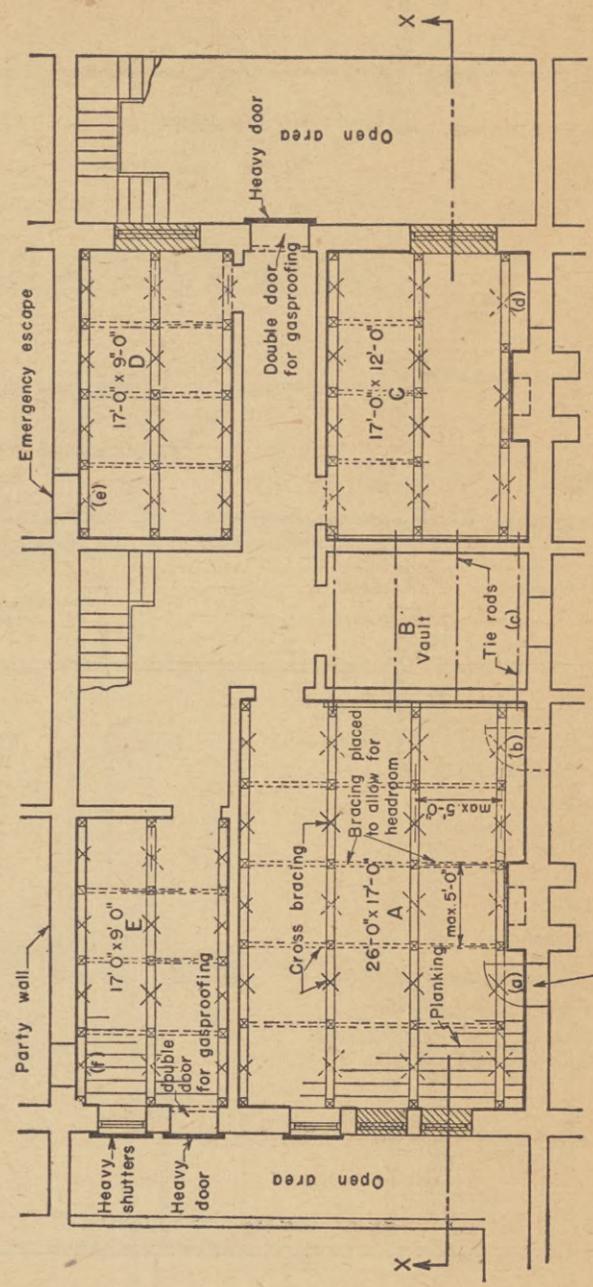


FIGURE 17.—SUGGESTIONS FOR GIVING A FINISHED TREATMENT TO STRENGTHENED CEILINGS.



SECTION X-X



PLAN

Note: Where windows are bricked up, provide air brick or section of hollow tile for air.

FIGURE 18.—SUGGESTIONS FOR WOOD STRENGTHENING.

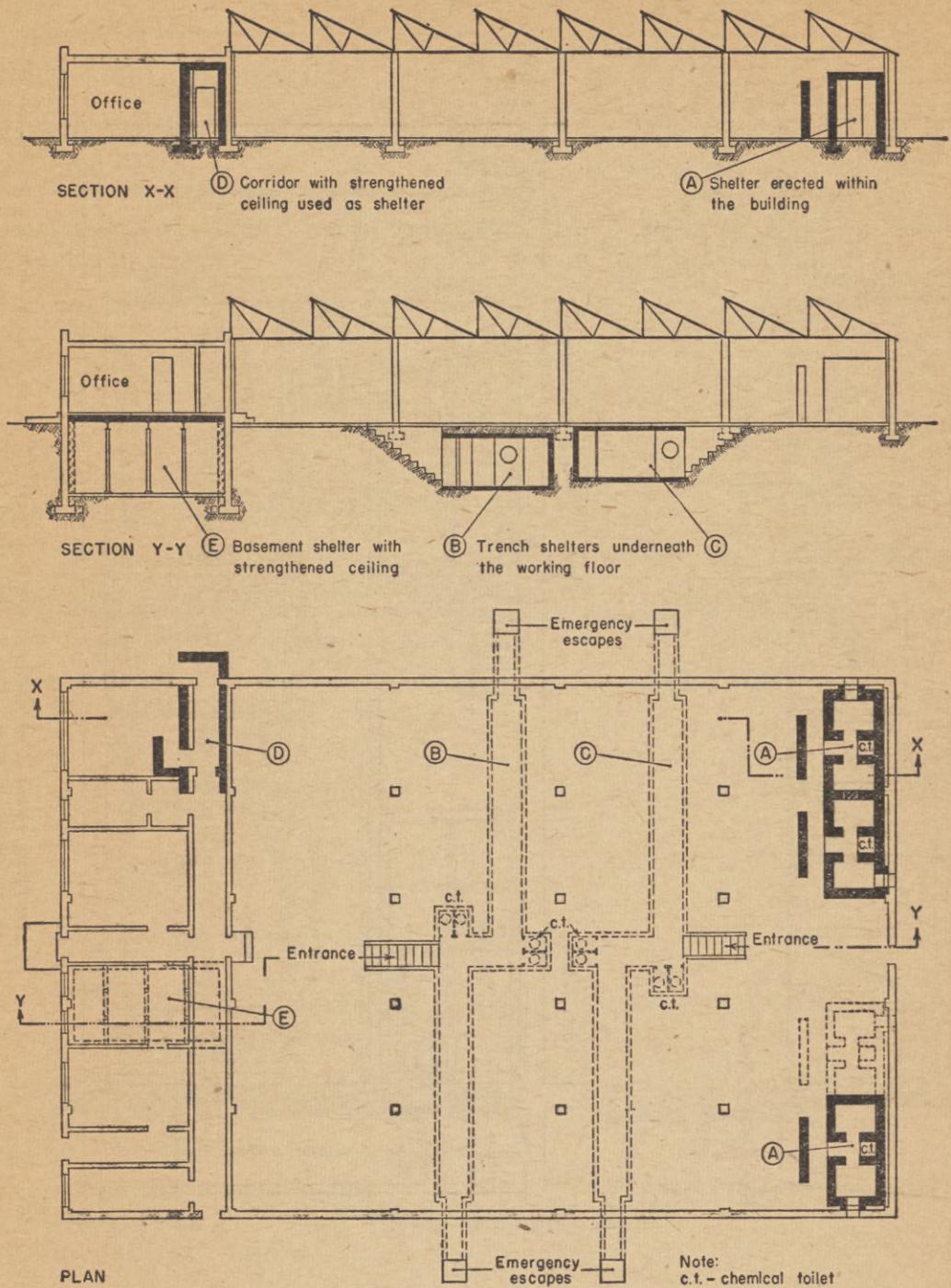
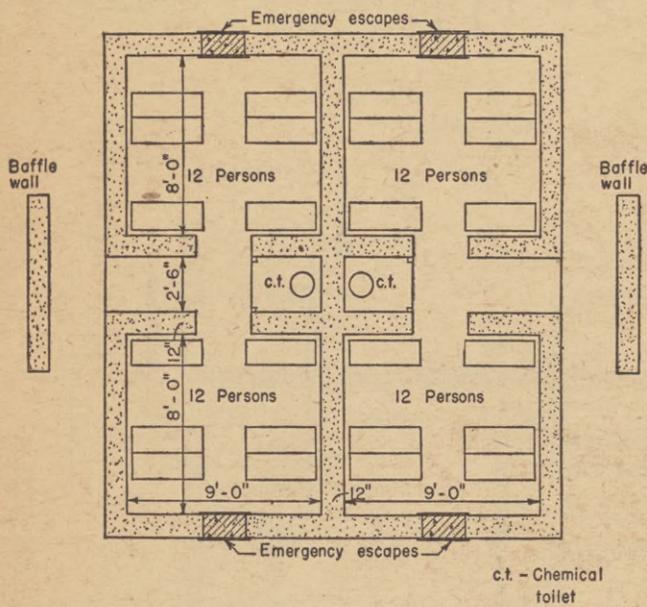
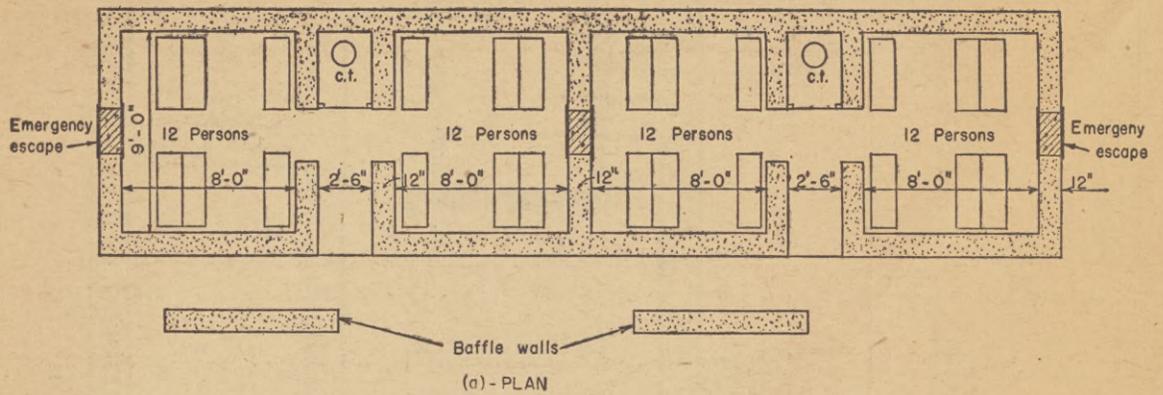


FIGURE 19.—TRENCH SHELTERS AND SHELTERS ERECTED WITHIN A BUILDING.



(b) - PLAN

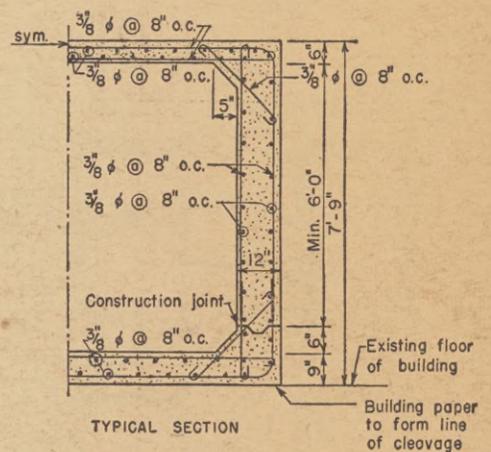
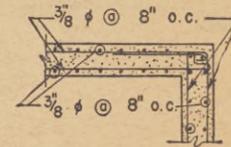
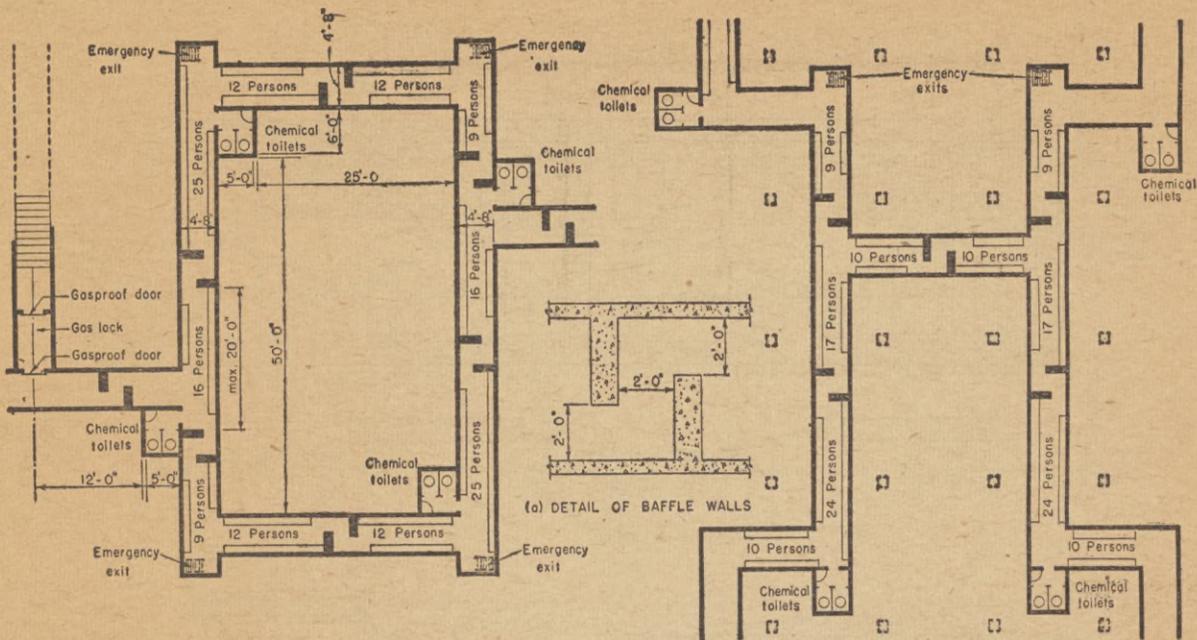
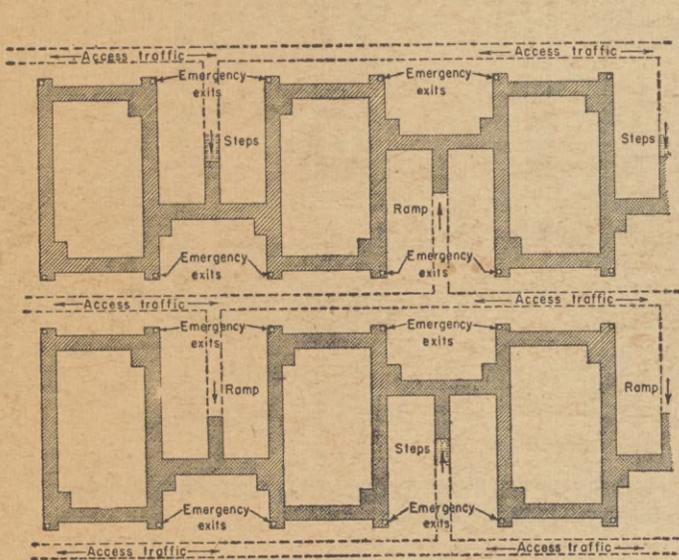


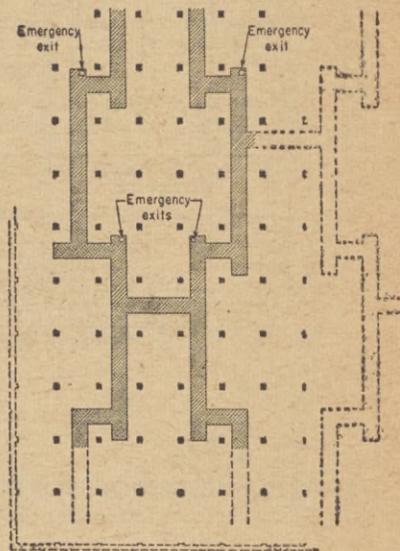
FIGURE 20.—SUGGESTIONS FOR SEPARATE SHELTERS OF REINFORCED CONCRETE ERECTED WITHIN A BUILDING (12-PERSON UNITS).



TYPICAL DETAILS OF SINGLE UNITS

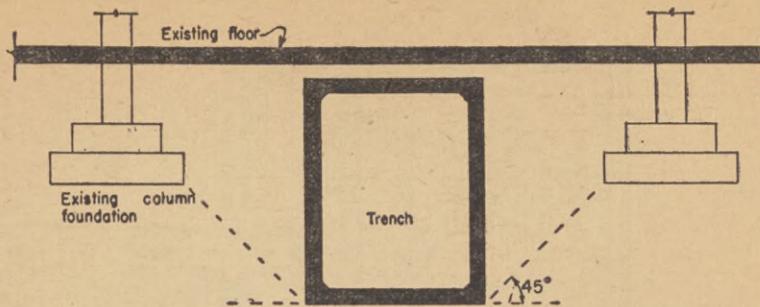


BLOCK SYSTEM OF TRENCH LAYOUT

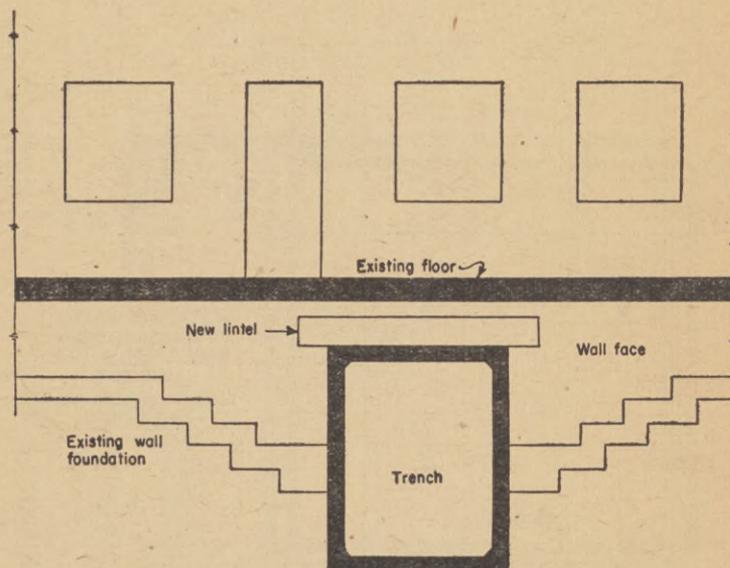


SUGGESTION FOR ADAPTATION OF BLOCK SYSTEM,
WITH RELATION TO EXISTING FOUNDATION

FIGURE 21.—TRENCH SYSTEMS.

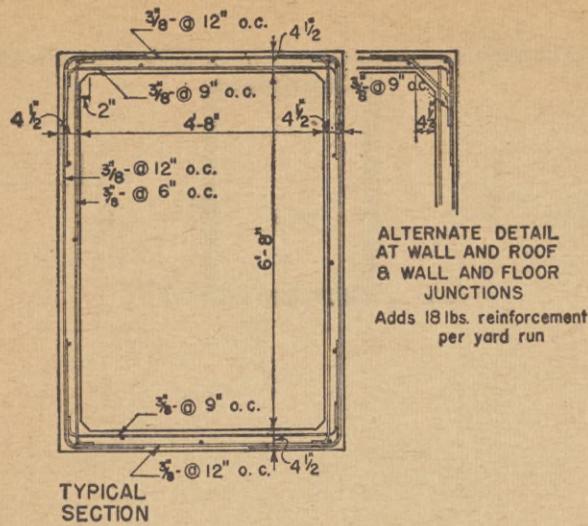


(a)

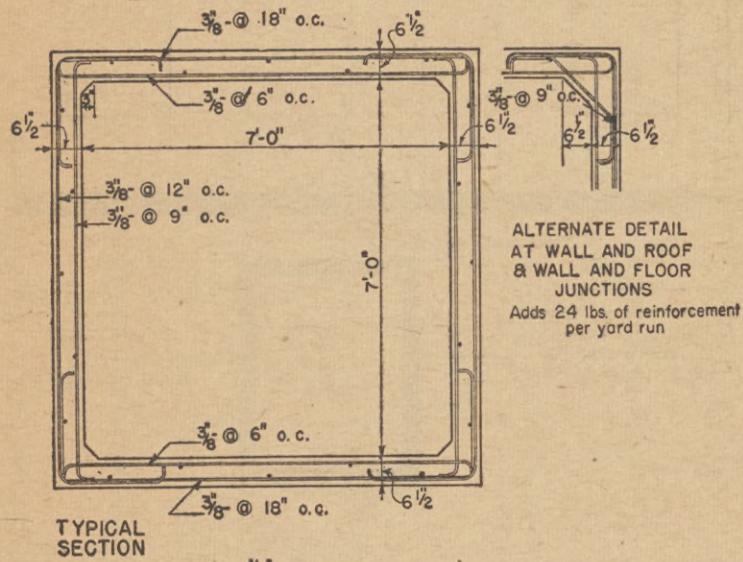


(b)

FIGURE 22.—TRENCHES WITH RELATION TO EXISTING FOUNDATIONS.

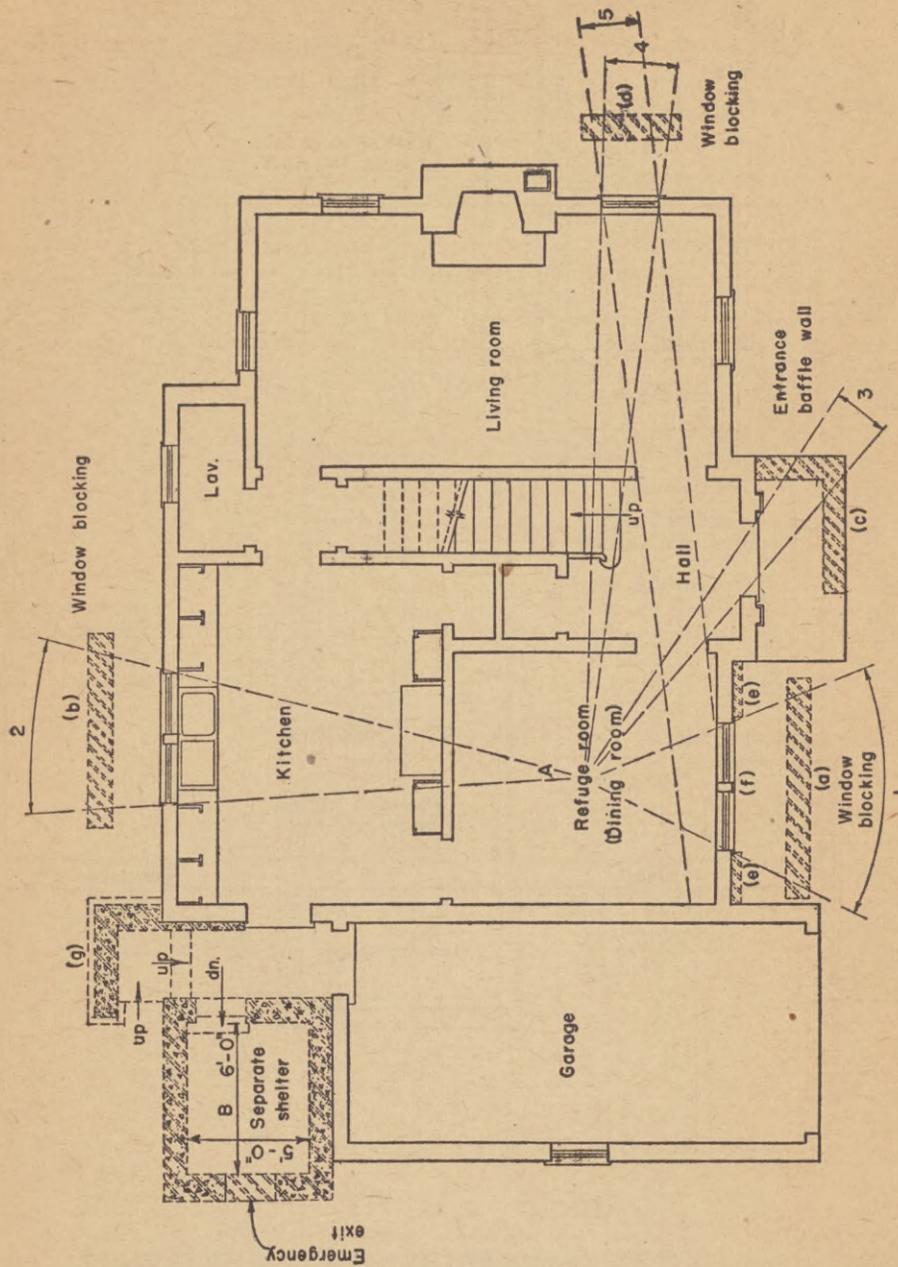


(a)



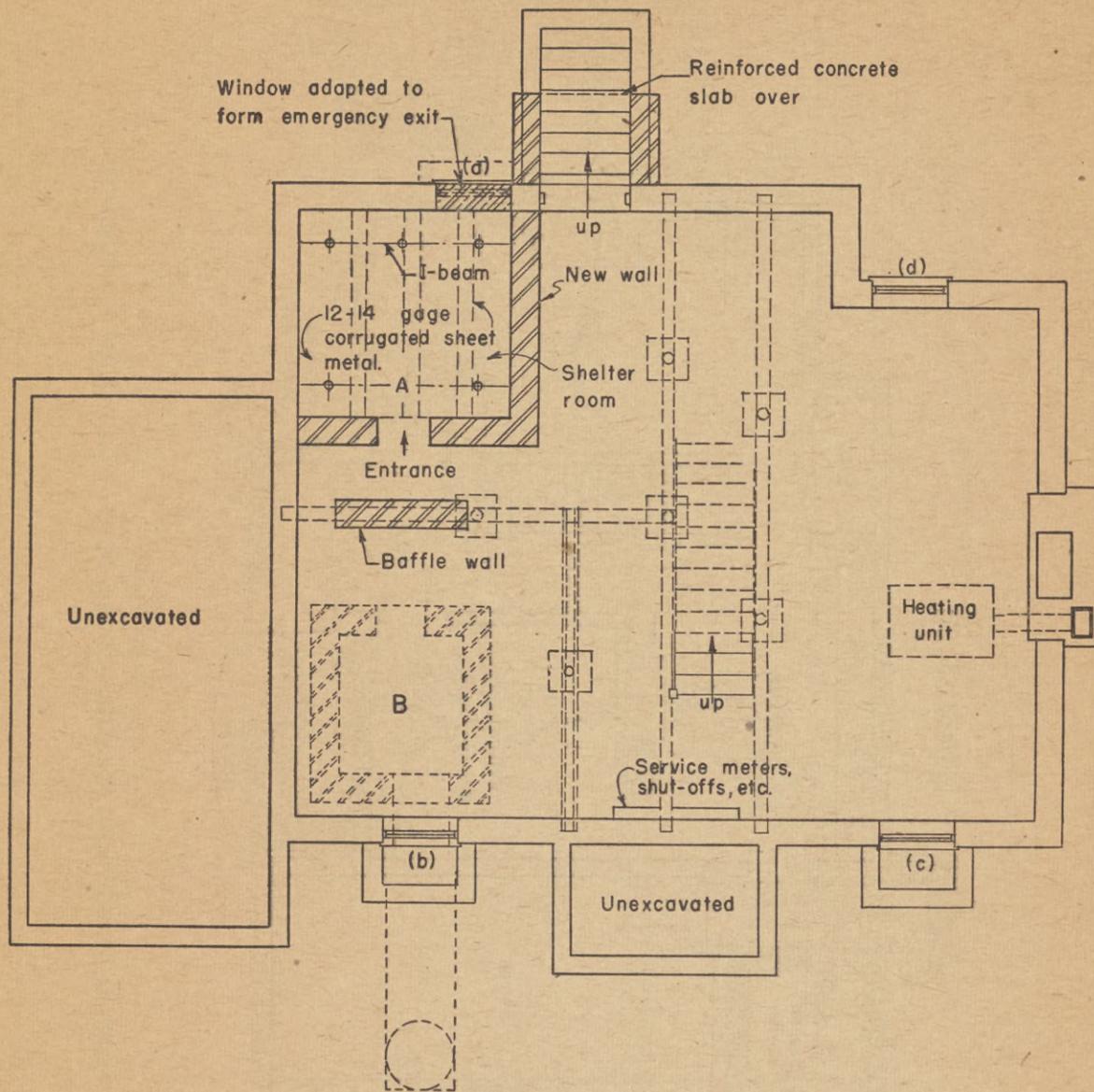
(b)

FIGURE 23.—TRENCH LINING.



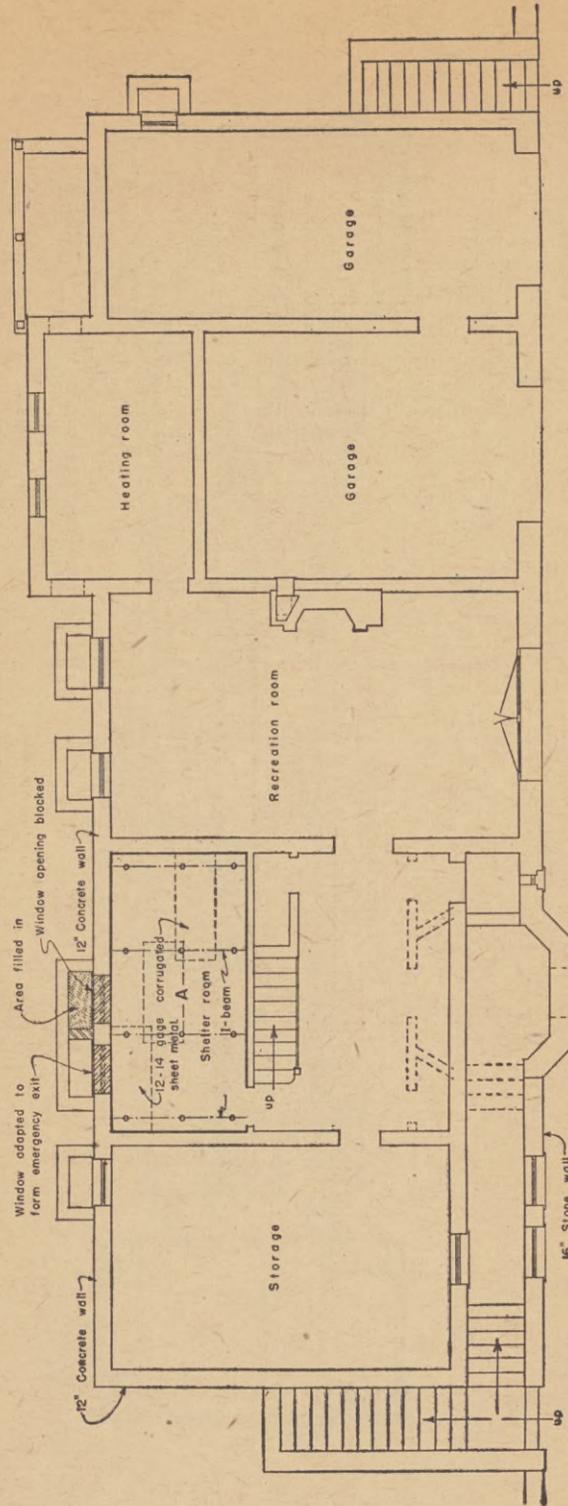
FIRST FLOOR PLAN

FIGURE 24.—SUGGESTIONS FOR REFUGE ROOMS OR SEPARATE SHELTERS FOR RESIDENCES.



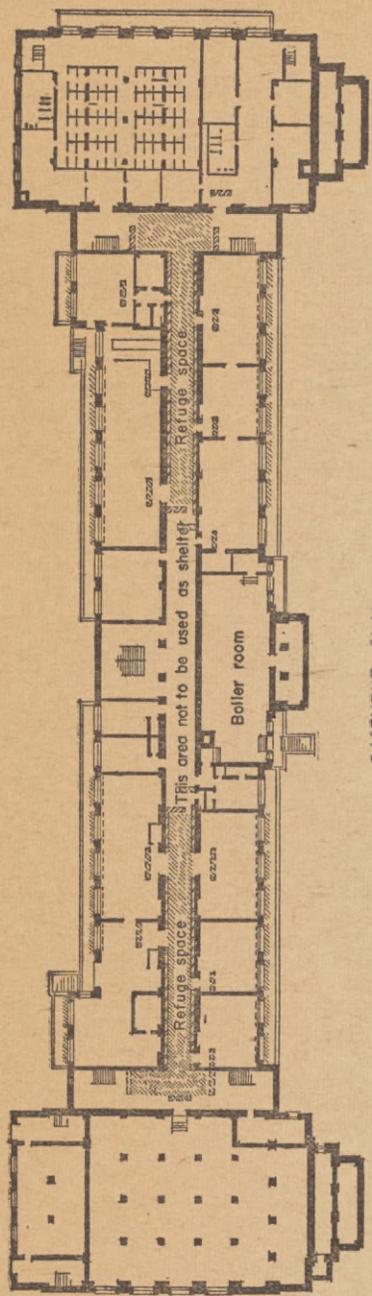
BASEMENT PLAN

FIGURE 25.—SMALL RESIDENCE WITH SHELTER PROVIDED IN THE BASEMENT.

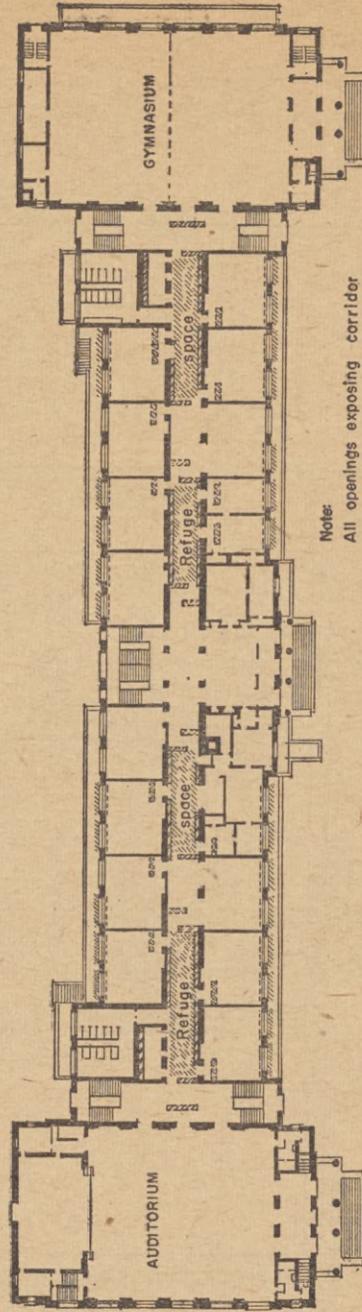


BASEMENT PLAN

FIGURE 26.—RESIDENCE WITH SHELTER PROVIDED IN THE BASEMENT.



BASEMENT PLAN



Note:
All openings exposing corridor
refuge space must be protected

- FIRST FLOOR PLAN
-  Existing wall
 -  Additional wall to meet lateral protection requirements

FIGURE 27.—SUGGESTED LOCATIONS FOR REFUGE IN SCHOOL BUILDINGS OF STEEL FRAME OR REINFORCED CONCRETE CONSTRUCTION.

