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WE DEEPLY REGRET HAVING TO ANNOUNCE THE SUDDEN DEATH OF DR. REX MARTIENSSEN WHO WAS FOR TEN YEARS JOINT EDITOR OF THE SOUTH AFRICAN ARCHITECTURAL RECORD

A MEMORIAL NUMBER OF THE 'RECORD' DEALING WITH THE VARIOUS ASPECTS OF HIS LIFE AND WORK WILL BE PUBLISHED IN NOVEMBER.

STRUCTURAL ASPECTS OF AIR RAID PRECAUTIONS

Through the courtesy of the D.F.A.E., Colonel G. H. Cotton, a course of lectures on A.R.P. was given by Captain M. F. Stern, S.A.E.C., from Defence Headquarters. These lectures took place at Kelvin House during May and June, and dealt with the structural requirements for the different degrees of protection against aerial attack on populated areas. Not only were the characteristics of bombs, and suitable protection to meet the varying conditions discussed, but the different forms of shelters, ranging from the simple trench shelter to the elaborate public shelters, as well as methods of strengthening buildings for the purpose of providing basement and other shelters, were surveyed.

The fact that the issues raised were recognised to be of great interest and immediate importance was reflected in the attendance at those lectures of not only members of the Architectural Profession, but also representatives of the Structural Engineers and the South African Institution of Engineers. In view of this fact, permission was obtained to publish a precis of the lectures with the relative diagrams in order that this material should be available to architects and engineers who are concerned with the structural side of C.P.S. work.

The substance of the lectures in precis form has been recorded under the headings which follow:

A Methods for Air Attack.

B Aerial Bombs.

C Effects of High Explosives and Standards of Protection.

D Protection against Unexploded Bombs.

E Sandbagging and Revetment.

F Slit Trenches.

G Underground Shelters.

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I Shelters in Buildings—Domestic.

J Shelters in Buildings—Commercial.

K Obscuration, Ventilation and Protection against Glass.

L Incendiary Bombs and their Effects.

M Protection in Buildings against Incendiaries.

N War Gases and effects.

O Gasproofing of Shelters and Buildings.

At the outset it must be understood that lack of materials and even labour in some instances, will not make possible the erection of many types of shelters. It is thus necessary to adapt and to use available materials and so provide the optimum possible. Reference will be made to such expedients carried out in various towns, in particular Cape Town and Pretoria.

A METHODS OF AIR ATTACKS.

The object of an attack generally is to disrupt industry and communication, create panic and destroy morale. Bombs are fuzed and this fuzing consists of two types, Instantaneous and Delayed. It is the delayed type which, as will be seen later, causes the most damage. The actual bombs are of various types, namely, Anti-personnel, General purpose, Anti-submarine, Semi-armour piercing, Armour-piercing, Incendiary and light case or Gas bombs. The General purpose bomb is the type in use against civilian targets as it is a thin walled type depending less on fragmentation than a high degree of blast to do damage to buildings. The Semi-armour piercing and Armour-piercing types having a high percentage of steel (thick walled) are used against specially protected military targets to gain penetration.

The types of bombing attacks carried out are as follows: (i) High Level (10,000 feet upwards); (ii) Low Level (below 1,500 feet); (iii) High Dive; (iv) Low Dive, and (v) Combined.

B AERIAL BOMBS.

These follow the same lines in almost every army being streamlined and fitted with either tail or nose fuzes, except in the case of German bombs which are armed with fuzes inserted in the side of the bomb and actuated by clockwork. In certain instances some of these fuzes are of the "Anti-handling" type. In the case of the 250 kg. General purpose bomb, the German type measures 6 feet $10\frac{1}{2}$ inches overall length and 1 foot $2\frac{1}{2}$ inches diameter, the Japanese, 5 feet 6 inches long and 12 inches diameter, and the Italian, 6 feet 8 inches long and 18 inches diameter. As stated before the General purpose (thin walled type) bomb is used against civilian objectives owing to their higher percentage of filling. For example, in the 250 kg. class, the German General purpose bomb weighing 236 kg. contains 130 kg. of explosive, while the Armour-piercing (thick walled) type contains 106 kg. of explosive, the respective wall thicknesses being $\frac{9}{36}$ inch and $1\frac{1}{8}$ inch. The instantaneous fuze causes the bomb to burst on impact with the target and thus the chief damage is caused by splinters and blast, whereas the delayed action fuze introduces a time interval between impact and the detonation of the bomb. This allows for penetration before bursting and the damage caused by splinters is nullified but damage may be caused by rocks and other missiles being scattered. The detonating wave in the earth, however, is more dangerous to surrounding structures—being in the nature of a "tamped" charge. The delayed action is also serious where the bomb penetrates into the building and then explodes. The 500 lb. bomb can penetrate three to four concrete floors each of 5 inches to 6 inches in thickness.

C EFFECTS OF HIGH EXPLOSIVES AND STANDARDS OF PROTECTION.

The flight path (Trajectory) of a bomb is theoretically a parabola but in practice is somewhat steeper. Figures given in 1939 are misleading as regards the angle of impact (the angle which the bomb makes with the vertical at the moment of impact). With streamlining and high level bombing the angle is all but vertical and the chances of bombs striking the sides of buildings are less than supposed. The striking velocity of a bomb, that is, velocity at moment of impact, depends on the height of the aircraft at the moment of release. Actually the time of fall varies but little for the various sizes of bombs. This time is given as $0.25\ H^{\frac{1}{2}}$ seconds where H is height in feet of the aircraft at moment of release. Thus striking velocity varies from 390 feet/sec. from 1,000 feet release to 610 feet/sec. from 5,000, 800 feet/sec. from 10,000 and 950 feet/sec. from 15,000. If has now been found that improved design of aircraft has increased their weight carrying capacity, which allows a greater number of bombs of greater average weight to be carried.

When the bomb explodes on the surface, detonation of the filling takes place with a subsequent bursting of the case. The imprisoned gases then pass on, accompanied by fragments. Eventually the fragments are passed by the positive wave as these lose speed and a vacuum is caused so that when the positive wave or blast is spent, air is sucked in and a negative wave or suction is produced. The shock wave, however, does not only pass into the air but also into the earth due to explosion or impact and is intensified especially in the case of delayed action bombs, where the effect is one of a "tamped" charge. The suction is much smaller in magnitude than the positive wave, but lasts for a longer time; the positive wave weakens buildings which are then drawn out by the suction wave. For the 500 lb. bomb the maximum positive pressure is about 6 lb./sq. in at 50 feet and 0.4 lbs./sq. in at 200 feet, while maximum suction varies from 1.4 lb./sq. in at 50 feet and 0.2 lb./sq. in at 200 feet. Velocity of blast wave decreases from 1,250 feet/sec. at 50 feet to 1,180 feet/sec. (velocity of sound) at 200 feet. Buildings are seldom isolated but are usually grouped with others which interfere with the passage of the blast wave, causing reflection and diffraction, and for this reason also the actual transient pressure and suction acting on the structure differ from the measured values by an amount varying in each case, and determined by the lay-out of the street. In streets, when blast is confined in a narrow space, the wave undergoes successive reflections and a periodic disturbance is set up. This may account for many of the so-called freak effects.

"Scabbing" consists of flinging off, from the rear of the target, of a piece of the target opposite the part struck and this may occur whether the target is perforated or not. This is also referred to as "spalling" of concrete. Thus, unless a slab is sufficiently thick, a scab is formed on the rear face and if "d" is the distance which a projectile will penetrate into a thick slab of concrete and the slab is only slightly thicker than "d" inches, the crater formed by the scab meets the crater formed on the front face and the slab is perforated. The scab is objectionable from two aspects:—

(i) It may permit the projectile to pass through a thicker wall than would otherwise be the case, and,

(ii) the scab or the material which is spalled off the rear face may fly from it with considerable velocity and be itself a source of danger whether the projectile passes through or not.

For this reason it is to be considered good practice to introduce a layer of reinforcement near the rear face consisting of expanded metal. In tests with a 6 inch slab, where severe spalls were formed with a square mesh reinforcement, these were prevented by expanded metal (scabs formed in this case but were held in place).

The minimum thickness of unreinforced concrete required to prevent perforation by a $1\frac{1}{4}$ oz. projectile with velocity 4,950 feet/sec. is about 7 inches.

Cratering is another effect of detonation and there are several types namely :

(i) MEDIUM CRATERS. These are the commonest type. The chamber formed when the earth is pushed aside by the explosion is partially filled with debris. Thus for a 250 kg. bomb a crater is formed 30 feet in diameter and 10 feet in depth.

(ii) SUPERFICIAL CRATERS. The dimensions of these are always much smaller than those of medium craters for the same size of bomb and are often found on hard surfaces, where the bomb detonates on impact. The lips are not raised and there is no material on them. Fragmentation has its greatest effect in such a case.

(iii) CLEAN SWEPT CRATERS. These are similar in size to superficial craters. They are free from large lumps of earth and the lips only slightly raised, fragments striking high.

(iv) DEEP CRATERS. The visible crater is smaller than the medium crater for the same size of bomb. Large lumps of material cover the lips and fill the crater concealing the chamber formed by the explosion. Very little blast effect can be expected but damage can be caused by falling or flying debris. Around the cratering will be severe cracking in pavement slabs or other made surfaces and extensive damage may be caused to the basement walls and other underground structures. These effects are caused by earth shock.

(v) CAMOUFLETS. These are found often in soft soil. No blast effect will be observed but considerable ground shock. An underground empty chamber is formed by the explosion and if settlement takes place, this may cause considerable damage.

Houses can be completely demolished (i.e.,, 75—100 per cent. of external brickwork destroyed) and rough radii of such damage is 30 feet for a 250 kg. bomb; 45 feet for a 500 kg.; 60 feet for a 1,000 kg., and 70 feet for a 1,800 kg. bomb.

It is essential that some knowledge should be obtained in regard to safety precautions and safety distances. These are tabulated as follows :

SAFETY PRECAUTIONS AND SAFETY DISTANCES

DETAIL.		50 Kg.	250 Kg.	500 Kg.	Over 500 Kg.
Size of hole of entry		8-12″	14-18″	over 18″	up to 10′
Diameter of crater produced		10-15′	18-25′	25-30′	over 30′
No serious splinter or blast effect if buried		10′	15′	20′	
Dangerous debris confined to circle of radius	Unburied bomb	30′	50′	75′	
	Buried bomb	10′	15′	20′	
Camouflets expected if bomb buried		12′	20′	25′	
Considered "Unburied" up to		2′	4′	6′	
Danger area (Buried) in open Circle of radius		100*	100*	100*	150*
Danger area (Unburied) in open Circle of radius		300*	300*	300*	450*
Protection afforded by 13½″ brick or 2′ 6″ sandbag wall beyond (Bomb unburied)		80′	80′	80′	
Minimum distance of protective sandbag wall from bomb		10′	20′	30′	45′
Safety distance for person in trench	Unburied bomb	15′	30′	50′	
	Buried bomb	25′	45′	60′	
Safety distance for person in *shelter	Unburied bomb	25′	50′	80′	
	Buried bomb	15′	30′	50′	
*(Anderson Shelter covered with earth)					
Distance within which damage is liable to be done to	Cast Iron mains, Concrete or earthenware sewers	50′	90′	120′	
	Brick sewers	25′	45′	60′	
	Cables, Steel pipe	15′	30′	40′	
	Foundations and buildings	50′	100′	150′	
Minimum distance for protective trench for mains, etc.		10′	20′	30′	

*Signifies yards.

So far the effects of High Explosives have been dealt with and before it is possible to consider the various individual types of buildings, it is essential that the types and principles of design be understood.

(i) Less protection is necessary against bombs with instantaneous fuzes than against bombs with delayed action fuzes.

(ii) No shelter is "bombproof" if it stops short of protection against a bomb with a delayed fuze that does not break up when striking a resistant target.

(iii) Protection should consist of burster course, a shock absorbing layer under which the shelter proper is constructed.

(iv) Where deep shelters are provided, 60 to 80 feet of soil on top of the shelter roof is required, assuming no protection at ground level is provided.

(v) The best concrete mix is 1 : 2 : 4. Vibration and continuous depositing are advantageous. Reinforcement in thick slabs should be in strong iron layers at 4 inch to 6 inch centres and laid not less than 6 inch mesh. Shear reinforcement is essential and a close mesh on inside face of walls and underside of roofs is a precaution against spalling. Shear reinforcement is of paramount importance and reinforcement must be adequate against all tensile stresses.

(vi) Ventilation must be provided.

a Unventilated shelters :—Up to 3 hours (normal English summer conditions) 75 square feet surface area (floor, ceiling and walls), 160 cubic feet of air space and 6 square feet of floor space per person should be provided. For periods over 3 hours, 100 square feet surface area should be provided per person. In humid climates such as Durban these figures should be exceeded.

b Ventilated shelters :—The air intake should be well above ground and should draw a supply free from high concentrations of gas. The intake must not be liable to destruction.

Period of occupation.	Shelters above ground. Total surface area per person in square feet.	Shelters above ground. Ventilation per person in cubic feet per hour	Shelters underground. Total surface area per person in square feet	Shelters underground. Ventilation per person in cubic feet per hour
3 hours	30	450	20	450
"	40	150	20	150
Indefinite	50	450	25	450

(vii) Not more than 50 persons should be in a shelter and the absolute maximum provided for should be 200 and then only on a restricted site, 18 inches mean seating must be provided per person, and allowance made for 6 square feet per person for seating and gangway.

(viii) The fundamentals in regard to entry are :

a Easy access to shelter.

b Entry must be boldly marked.

c There should be at least two emergency exits in large shelters.

d Air locks may hinder entrance and necessitate added entrances.

e No entrance is to be less than 40 inches wide. This means 80 persons per minute can pass such an exit or entrance.

(ix) Where shelters or trenches are built, baffle walls providing blast and splinter proof protection must be built.

(x) The protection required is as follows :

a Bombproof, i.e., proof against direct hit—15 feet reinforced concrete in 60 feet of earth. This, however, is not practical and the normal standard in England is 6 feet of reinforced concrete.

b Blast and Splinter proof : Standard adopted is 500 lb. bomb bursting 50 feet away.

Sound brick walls (cement mortar) $13\frac{1}{2}$ inches.
Reinforced concrete, 12 inches.
Unreinforced concrete, 15 inches.
Earth, 30 inches.

c Head cover : This can be provided by 5 inch concrete slab covered with 2 layers of sandbags, or corrugated iron covered with 21 inches of earth over which is a 9 inch burster course.

(xi) Shelters should be gasproofed. This will be dealt with fully later in these notes.

(xii) Protection against splintering obstruction glass must be provided for. This must be designed in conjunction with ventilation and is dealt with later in detail.

(xiii) Fire hazards have to be reduced and require special consideration where not provided for in each individual type of building under consideration.

When considering existing buildings two main factors arise.

(i) The inherent structural resistance and the extent to which it can be increased, and

(ii) the extent to which they can be adapted to provide shelter accommodation.

The extent to which an existing building is inherently resistant to air attack can be judged by comparing its construction with recommendations made for the construction of new buildings. Heavy or high chimney stacks should be replaced by low or light ones where draught requirements do not stand in the way, and unessential prominent features, which may be a source of danger, removed. All heavy objects from attics should be removed. Stanchions and columns supporting heavy loads and in vulnerable positions may be a serious source of weakness and additional support is necessary. Special precautions should be taken in the case of buildings having timber roofs. Provision for easy access to roofspaces for fire fighting is important and partitions in attics should be non-combustible—which could act as fire resisting screens to retard the spread of fire. A 4-inch reinforced concrete slab over roof lights covering staircase wells or over vent shafts for plumbing, extending 2 feet longer in each direction than the opening of shaft, gives protection, does as the extension of party walls to the underside of the roof, of fire resisting material. Windows are to be treated so as to protect against splinters.

The choice of a building for incorporating a shelter brings in many factors, the chief of which are the following :

(i) The question of cover—overhead and lateral.

(ii) Buildings in wide streets or open squares or facing open spaces are preferable.

(iii) Multi-storey steel framed or Reinforced Concrete buildings are first choice.

(iv) Unsuitable features, as affecting the choice of multi-storey buildings to incorporate shelter accommodation include :

a Large proportion of voids to solids in external walls.

b One cell floors, or floors with no partitions between external walls.

c Timber floors or roofs or floors of weak construction.

d Buildings of doubtful lateral stability.

e Roof lights with top glazing.

f Heavy objects, such as storage tanks, safes and machinery on upper floors.

g High chimneys and parapets or heavy architectural features such as heavy cornices and pediments, large gables or towers above roof level.

h Enclosed courts or light wells, owing to the increased risk of damage by blast from bombs bursting in the enclosed space. Where such enclosed courts are unavoidable, it is essential that all enclosing walls should be carried down to the level of the lowest floor and such walls should have the minimum number of openings. Further such openings should be capable of being blocked up or otherwise protected.

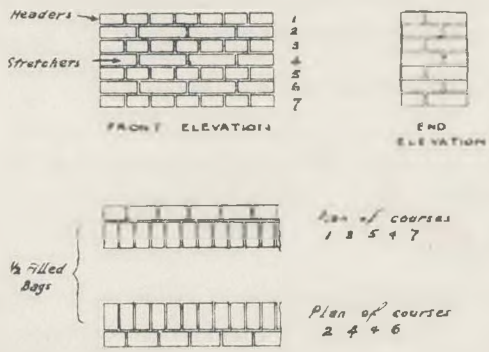
New buildings can be rendered less vulnerable to air raids and no building should be designed without thought to this part of planning or construction. Incendiary air-attack gives fire resistance a new order of importance and timber must be protected against fire either by treatment with an aqueous solution of inorganic salts or treatment with a paint forming a surface coating. A framed structure is less liable to collapse from the effects of bomb explosions than one having solid load bearing walls. Steel or reinforced concrete is the most resistant form of structural framework. In solid loadbearing walls there is the danger of outward movement owing to the lack of bonding of cross and external walls. One of the most difficult structural problems is that of roof design. A conical shape is the best and till recently was not practical in normal building practice. In the notes on shelters will be described a method which has now been proved in practice (Patents have been taken out in England). Where combustible goods are stored, a flat reinforced concrete roof 4 inches to 8 inches thick is advised. Floors must be capable of carrying load of debris and proof against penetration by 1 kilo incendiary bombs.

D PROTECTION AGAINST UNEXPLODED BOMBS.

The protective measures are :

(i) PREVENTIVE TRENCHING TO MINIMISE DAMAGE TO FOUNDATIONS, BURIED PIPES, ETC. The distance within which damage is liable to be done is given in the previous table. A trench should be about 2 feet wide, 2 feet deeper than and as near as possible to the object to be protected, and should be filled in with brushwood. Owing to the size of crater made by explosion of the bomb, no protection can be given by a trench within 10 feet of a 50 kg. bomb ; 20 feet of a 250 kg. bomb, and 30 feet from a 500 kg. bomb.

(ii) SANDBAG ABUTMENTS. The packing of basements, cellars, etc., with sandbags to avoid damage to foundations may be useful in cases where the bomb is so near the building or the foundations are so deep that the depth of the protective trench required would be prohibitive. The method



1. SYSTEM OF BONDING TO BE USED IN SANDBAG WALLS.

consists of packing sandbags into the internal space against the outside wall so as to support it against explosion. The tighter the packing and the deeper the pile the more effective will be the support. In practice a depth of 10 feet is adopted, but sandbags should not extend as far as an internal weight bearing wall, as the latter may be damaged by thrust due to explosion.

(iii) SANDBAG WALLS. The building of sandbag walls to minimize damage from splinters, blast, etc., is applicable in the case of a bomb buried or on the surface close to a building. It may also be used to isolate the effects of a bomb inside a building. The basic principle is that the sandbag wall must be built just outside the crater which would be formed if the buried bomb exploded. The dangerous debris is confined in a circle of radius shown in the table.

(iv) SANDBAG MOUNDS. If bombs bury themselves sufficiently deeply before exploding, they form an underground cavity or camouflet and no crater. In the case of bombs buried less deeply which would otherwise form a crater on exploding, the addition of a mound of sand or earth over the crater area will produce the same camouflet effect. This method aims at driving the explosion underground and has the effect of increasing possible damage to pipes, foundations, etc., but in situations where the added earth shock can be accepted, this method may prove useful. This method is used both to neutralize the effect above ground of buried bombs and to mask splinters from "unburied" bombs. It requires, however, a mound 40 feet in diameter, and 6 feet high to neutralize a 250 kg. bomb and thus may be unpractical.

(v) VENTS TO REDUCE AND DIRECT THE FORCE OF THE EXPLOSION OF A BURIED BOMB. Recent experiments show that a shaft excavated to give access to a bomb, will lessen appreciably the earth shock and movement. Such shafts are only to be made under instructions and supervision by a Bomb Disposal Unit. These shafts are usually 8 feet 0 inches by 4 feet 0 inches or where a bomb is near a wall 12 feet 0 inches by 4 feet. 0 inches.

E SANDBAGGING AND REVETMENT.

Reveting consists of walls or panels to hold up the face of earthworks where the angle is greater than that of the angle of repose.

WALL TYPES.

(i) SANDBAGS. These are 33 inches by 14 inches empty, and when three-quarter filled weigh approximately 40 lbs. A bale of sandbags numbers 250 and weighs 96 lbs. Paper cement bags, may be used but the bags must be perforated by 20 to 30 holes. This can be accomplished by using a slab beater with 6-inch nails. Material for filling must be dry, and a party of three men can fill from 60 to 90 in one hour. Laying entails that the wall is solid and firm, that there are alternate courses of headers and stretchers (or at most three layers of stretchers to one of headers), that joints are broken, the corners tacked in, the tied end (chock) folded under and chock end in headers to the inside, that no seams must show in laying stretchers, the top layer being headers, the bags being beaten and that the top and bottom surface of each course is at right angles to the face of the wall. In design there should be no vertical walls, and a minimum thickness of 2 feet 6 inches on top, if only one slope then a batter of 4/1 and 6/1 if both sides slope, the inner side protected against the building and a footing included, providing drainage and to give the necessary slope. The overlap of a sandbag wall across openings should be not less than the distance from such an opening and protection for the top provided especially when paper bags are used. Drainage is to be provided especially where a sandbag wall is built up against the building.

(ii) SODS. These should be cut 8 inches by 9 inches by $4\frac{1}{2}$ inches, laid in the same way as sandbags with the grass side downwards. Pickets are utilised in some cases, these passing alternately through three thicknesses.

(iii) GABIONS. These are usually made up from expanded metal sheets 6 feet 6 inches by 3 feet 0 inches, which give a prism 1 foot 6 inches square by 3 feet 0 inches long, the additional 6 inches being utilised for fastening. Drums can be used for improvisation.

(iv) CONCRETE HOLLOW BLOCKS. These are economical and form an excellent wall.

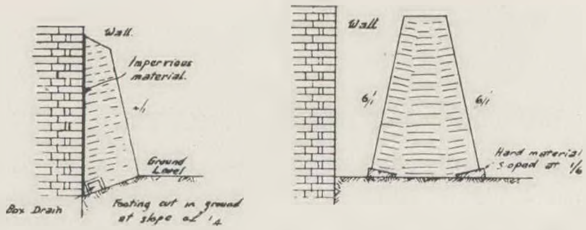
(v) BRICKS. These have been used with success at Cape Town where a half brick wall laid in cement mortar has proved sound and economical.

SKIN TYPES.

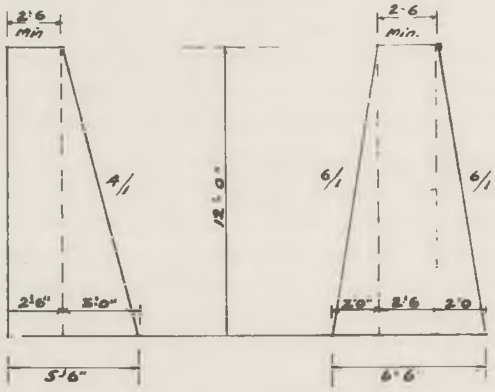
(i) CORRUGATED GALVANISED IRON. In common with all types of skin revetment this is tied back by means of vertical poles at distances centre to centre of not more than 3 feet. The usual sheet used is 7 feet 0 inches by 2 feet 3 inches lap jointed.

(ii) EXPANDED METAL HURDLES. These are 6 feet by 3 feet and are placed on wood frames which are butt jointed.

(iii) BRUSHWOOD HURDLES. 6 feet by 3 feet and butt jointed. These are made like wicker work and wire strengthening is placed at top, bottom and middle.

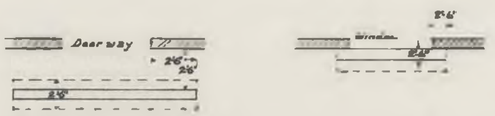


2. Typical examples of the use of sanbag walls for the protection of buildings.

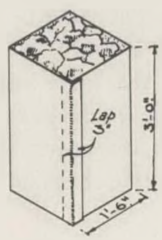


(Figs. 1, 2, 3 and 4 from "Protection Against Gas and Air Raids."—Pamphlet No. 2. Figs. 5, 6, 7, 8, 9 and 10 reproduced through courtesy of D.F.A.E.)

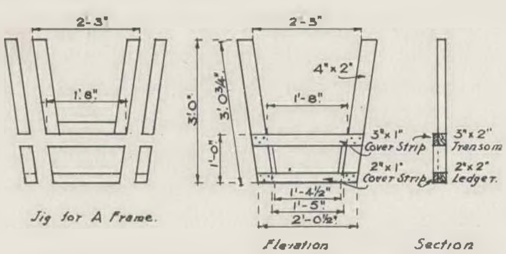
3. Design limits for the building of sandbag walls.



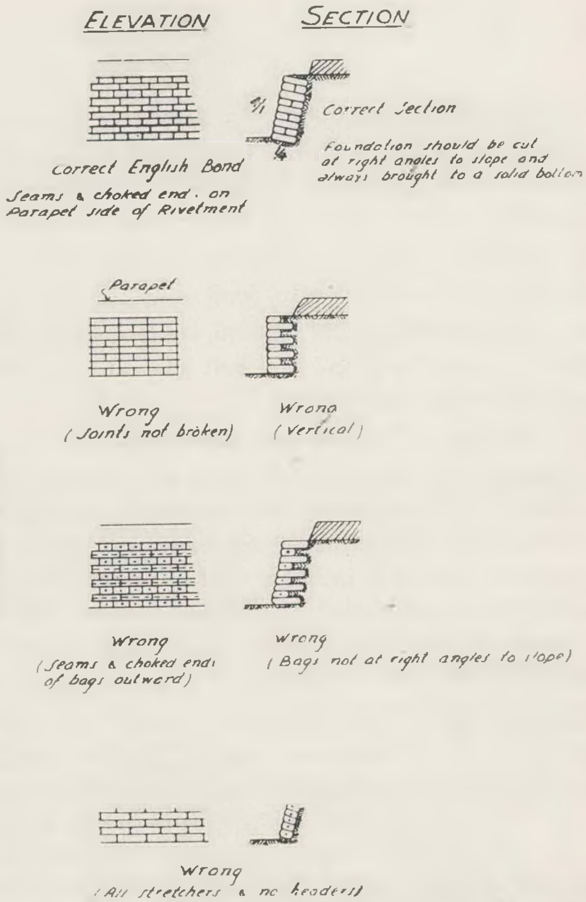
4. Methods of using sandbag barricades to door and window openings.



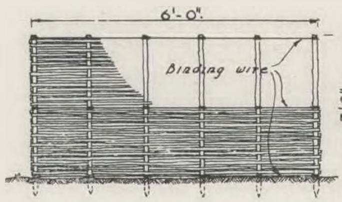
6. Gabion made up from expanded metal sheets, lapped and fastened as shown, and filled with earth.



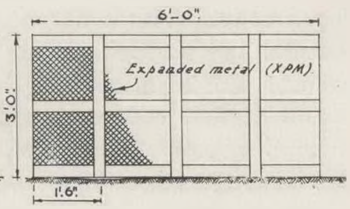
9. Details of a jig for, and a typical "A" frame used as a skin revetment support in a narrow trench. (See also figs. 14, 15, 16.)



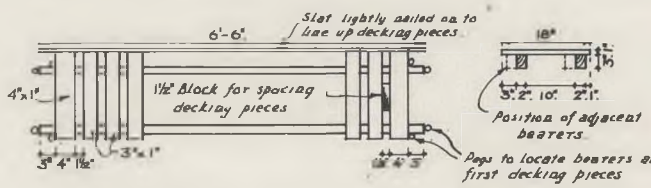
5. SANDBAG REVETMENT.



7. Brushwood hurdle, made by fixing stakes in ground, applying wire binding at bottom, laying in brushwood, fixing centre wire, completing brushwood lacing and fixing top wire. Hurdle then removed and points of stakes cut off.



8. Expanded metal hurdle consisting of a light stiffening framework of timber on an expanded metal sheet.



10. Details of a typical trench board which is supported on the transoms of "A" frames, forming a walkway along a narrow trench. The raising of these trench boards above the level of the bottom of the trench provides a space for drainage.

(iv) BRUSHWOOD LOOSE. 6 feet 6 inches or 7 feet long, breaking joint and stuffed behind pickets, 3 feet apart. By subsequent tightening of pickets a satisfactory revetment is obtained.

(v) PLANKS. This is prohibitive at the moment but if used planks must be laid to break joint.

(vi) WIRE NETTING ON FRAME, HESSIAN OR CANVAS BACKED. 6 feet by 3 feet and butt jointed. This method is very useful in very sandy soils.

(vii) CEMENT. Post and slab construction.

In addition to the above it becomes necessary to make supporting "A" frames for the revetment especially in the case of garden shelters, and over these are placed trench-boards, made up of 3 inches x 1 inch boards, with $1\frac{1}{2}$ inch spaces between on 3 inches by 2 inches runners. The runners are placed off centre in order to allow those of one trench board to side lap those of the next.

PRESERVATION OF SANDBAGS. Damp is the main condition leading to deterioration and can be prevented by: (i) Provision of a waterproof cover, e.g., bituminous felt over the top layer of bags; (ii) The provision of drainage at the base of pile and ensuring it does not stand in water; (iii) The application to the exposed face of the pile of a rot proofing treatment. As a rule sandbag revetments should not exceed 6-8 feet in height and never more than 10 feet. The method of using a cement wash is not now recommended in view of the chemical and physical damage to the fibre of the bags. A treatment can be given with either: (i) a creosote or tar distillate of medium creosote, applied as a water emulsion—65 per cent. creosote 35 per cent. and an emulsifying agent (this can be soft soap), or (ii) an organic copper salt dissolved in creosote or tar distillate as indicated in (i). This treatment should be repeated at intervals not exceeding three months.

REFERENCES.

(i) Specifications, etc., in regard to Permanent Lining of Trenches. Home Office A.R.P., January, 1939.

(ii) A.R.P. Handbook No. 5. Structural Defence.

(iii) A.R.P. Circular 279/1939. Preservation of Sandbags d/d 20/10/39.

(iv) Bulletin B5. Splinter Penetration Tests on Concrete. Ministry of Home Security.

(v) Bulletin 137. Spalling of Concrete. Ministry of Home Security.

(vi) Bulletin C6. Damage to Cast Iron pipes in Works. Ministry of Home Security.

F SLIT TRENCHES AND TRENCH SHELTERS.

The most effective and simple form of protection is the slit trench 3 feet 0 inches wide at top, 2 feet 6 inches at bottom and 4 feet 6 inches deep. The earth excavated is thrown up as parapets leaving a berm (the distance between the excavated earth and edge of excavation) of 18 inches. This can be covered over to give overhead cover. If, however, unrevetted there is the danger of collapse, and the public should be instructed not to bend down in a slit such as these and to keep one hand up while an attack is in progress, thus enabling them to extricate themselves in the event of the trench caving in. Such slit trenches are to be made zig zag in plan, the angle being not greater than 135° or less than 90°. Limbs are to be made from 10 to 15 yards long. The entrances, which can be either steps or ramps must be at right angles to the trench. The big disadvantage, however, is the question of drainage and there should be a minimum of 20 feet 0 inches between the lines of trenches. The Cape Town C.P.S. have developed three types worthy of mention:

(i) Type F.2. SHALLOW SURFACE EARTH SHELTER. (11). Developed for one person.

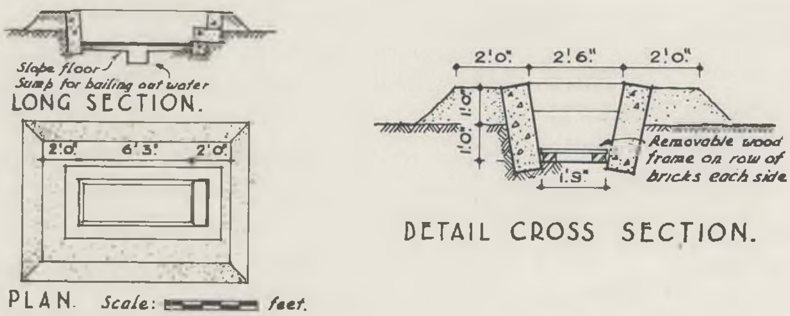
(ii) Type G.2. A SUBSURFACE EARTH SHELTER (12).

(iii) Type E.1. SURFACE EARTH SHELTER (13). This can be sunk and covered over. It will be noted that the big disadvantage of slit trenches, namely lack of amenities is here overcome most skilfully.

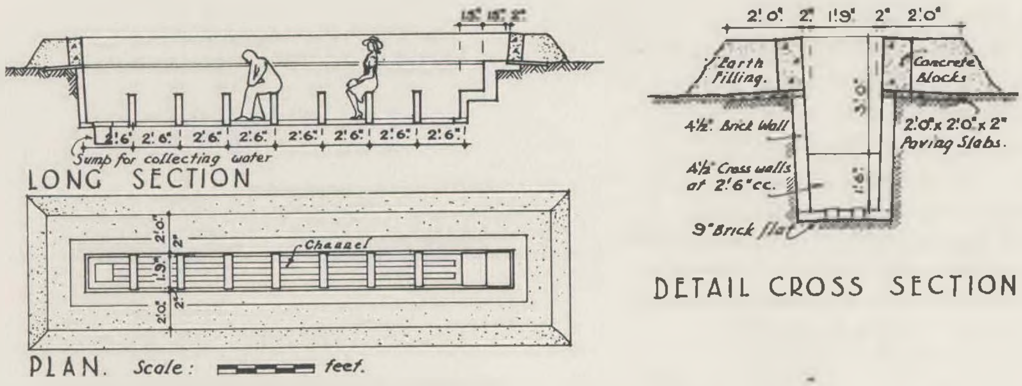
Where ground water is just below surface as in places along the coast special types have been evolved which raise the trenches to ground level, breastworks being formed by planting of poles at 2 feet 0 inches centre with 2 feet 0 inches by 2 feet 0 inches concrete slabs supporting the earth walls. A psychological point has been found in air raids and this is that human beings feel safer the narrower the space and for this reason large lengths are to be avoided and dispersal aimed at.

Trench shelters are an improvement on the slit trench, giving again excellent protection against blast and splinters but suffer as in the case of slit trenches from damp and lack of amenities. In this case not only is a proper entrance required but an emergency exit, in event of blocking of the entrance, must be provided. Arrangements should be made for independent lighting (use of oil lamps should not be advocated), water supply and tools. Where possible sanitary arrangements should be included. There are a number of types: the P.A.D. Slit Trench (14); the approved Garden Trench Shelter (15 and 16); The Anderson Shelter; Garden Shelters constructed from brick, hollow concrete blocks,

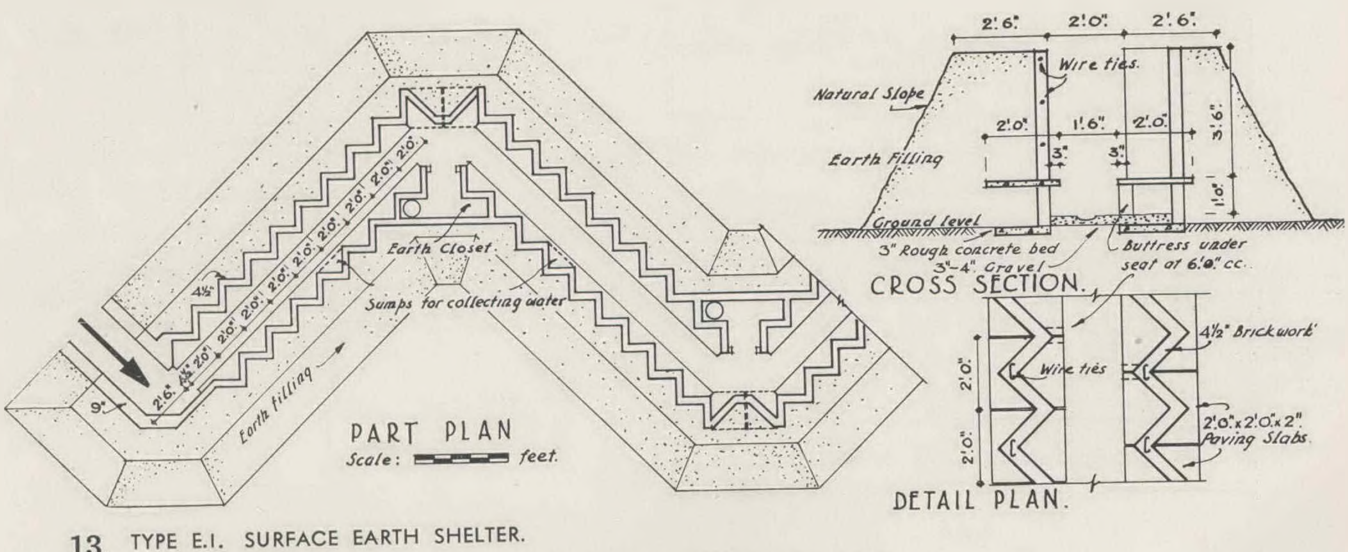
THREE TYPES OF SHELTER DEVELOPED BY CAPE TOWN C.P.S.



11. TYPE F.2. SHALLOW SURFACE EARTH SHELTER.
For private use in areas where water level permits. To accommodate one adult or two children lying down.



12. TYPE G.2. SUBSURFACE EARTH SHELTER.
For private use of eight persons where water level permits.



13. TYPE E.I. SURFACE EARTH SHELTER.
For communal use in waterlogged areas (4½-inch brick walls and paving slabs).

of slabs of concrete; shelters formed from corrugated galvanised iron covered with concrete and earth, and special types for medical services giving typical wards 9 feet wide, 19 feet long and 7 feet height to underside of beams allowing for 8 bunks, and operating theatre 21 feet 6 inches long, 9 feet 6 inches wide, and 7 feet clear height (18, 19). Construction in such cases is of beam and slab construction and connected by trenches 6 feet 6 inches deep, 4 feet wide covered with 6 feet wide slabs.

There should be at least 1 foot 9 inches earth on top of 2 feet 6 inches to side and back. The entrance must have baffle walls more than 15 feet from an existing building and every endeavour should be made to have shelters and exits at least half height of building distant from the building in question. If this cannot be done, the shelter must be made capable of supporting the debris load.

There are a number of common faults in timber construction which are illustrated (17).

In soft soil 1 man excavates 30 cubic feet in 1 hour.
In soft soil 1 man excavates 90 cubic feet in 4 hours.
In medium soil 1 man excavates 20 cubic feet in 1 hour.
In medium soil 1 man excavates 60 cubic feet in 4 hours.
In hard ground 1 man excavates 15 cubic feet in 1 hour.
In hard ground 1 man excavates 45 cubic feet in 4 hours.

Below 4 feet 0 inches an extra man is required to every two men below digging, for shovelling. Earth must be consolidated on the sides and tops of shelters in particular the Anderson, otherwise earth subsides and is washed away.

BOMB RESISTING SHELTERS.

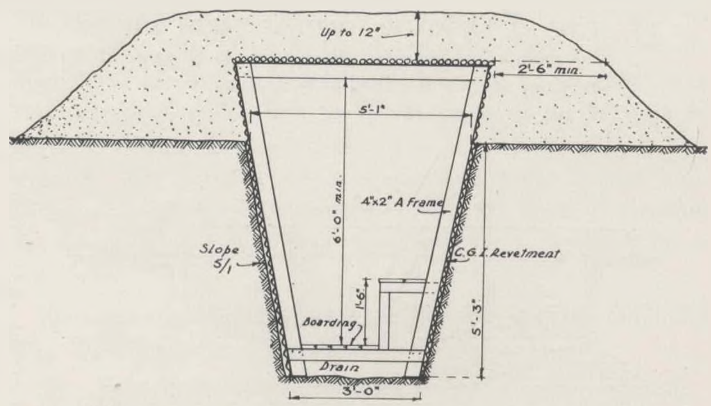
The standards of protection which have been adopted are as follows :

TYPE 1 PROTECTION. Resistance to blast and splinters, debris loads and small incendiary bombs.

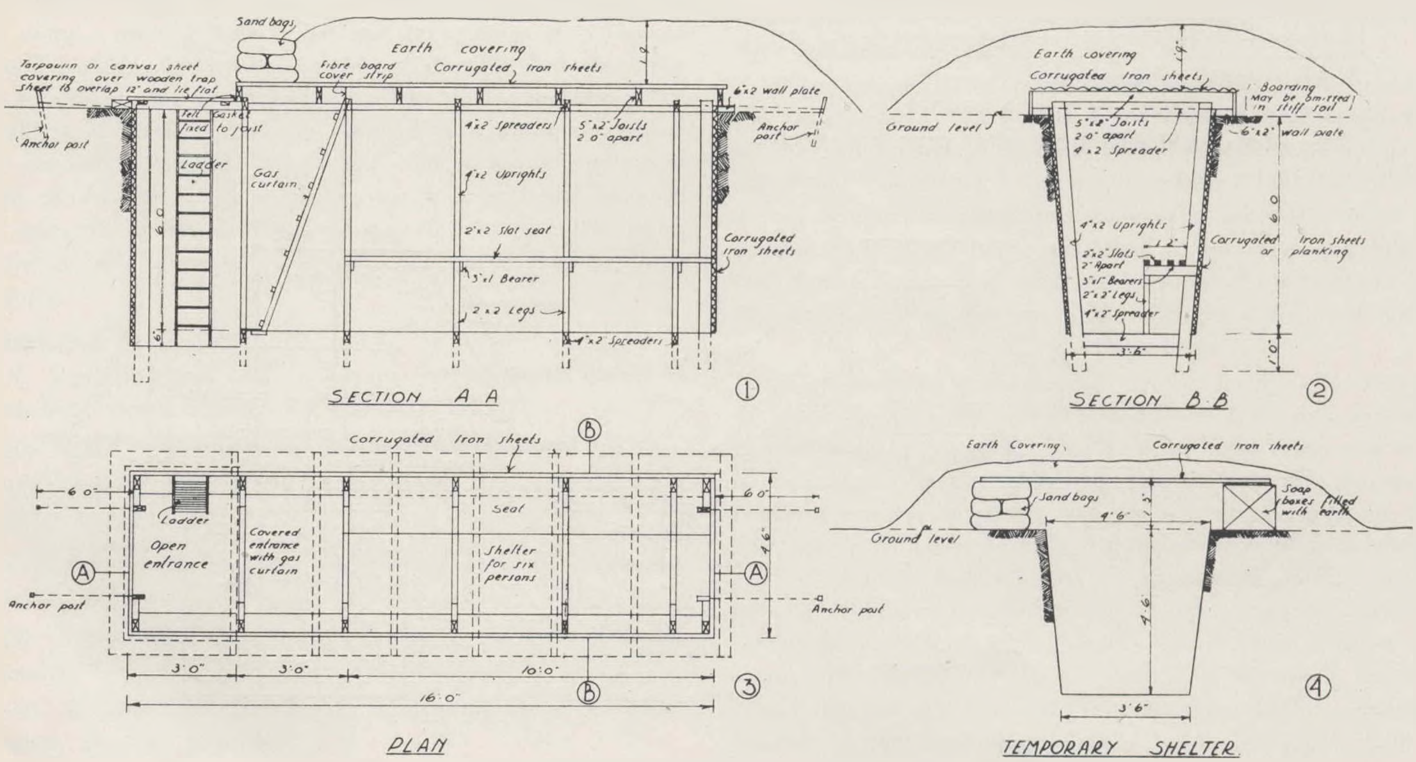
TYPE 2 PROTECTION. Resistance to direct hits of medium weight incendiary bombs and high-explosive bombs up to 50 lbs.

TYPE 3 PROTECTION. Design against effects of heavy high explosive bombs of the medium-case 500 lb. type striking at its maximum velocity.

TYPE 4 PROTECTION. Similar to Type 3, but designed against the effects of a heavy case bomb.

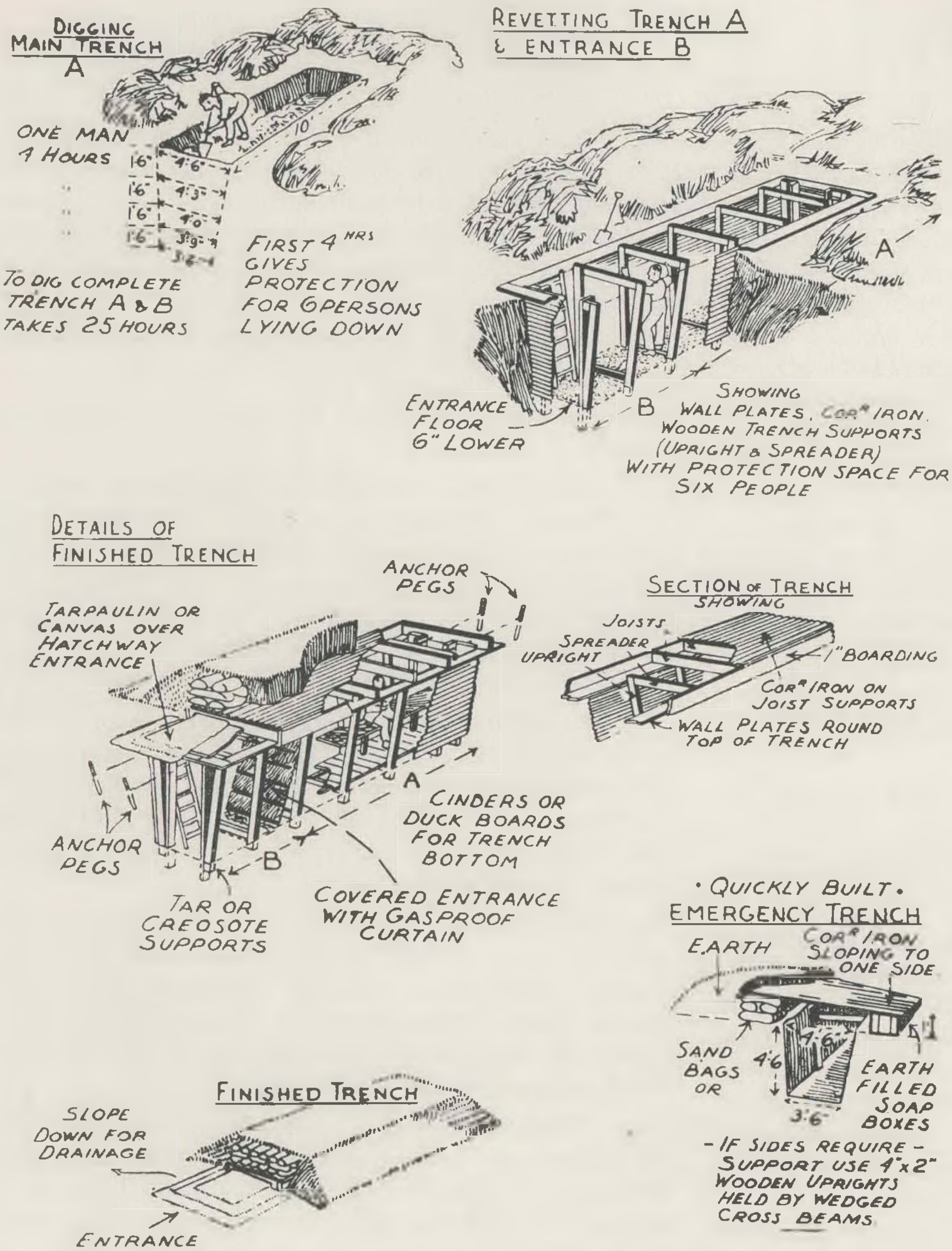


14. P.A.D. SLIT TRENCH.
From Protection Against Gas and Air Raids, Pamphlet No. 2.



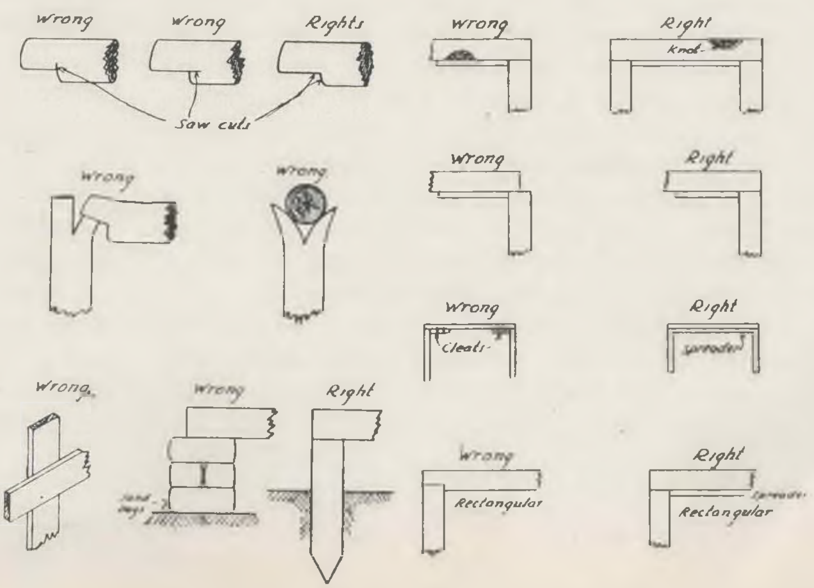
15. APPROVED GARDEN TRENCH SHELTER.

(From the Pamphlet on Garden Trenches.—Home Office, A.R.P. Dept.)



16. DESCRIPTIVE DETAILS OF THE CONSTRUCTION OF THE GARDEN TRENCH SHELTER.

(Reproduced from pamphlet on Garden Shelters.—Home Office A.R.P. Dept.)



17. COMMON FAULTS IN TIMBER CONSTRUCTION.

(From Manual of Field Engineering, Vol. II., R.E., 1936.)

Standards of overhead protection are 5 feet 6 inches Reinforced Concrete Type 3, and 7 feet 6 inches Reinforced Concrete Type 4. The standard of lateral protection above ground Type 3 is 3 feet 3 inches Reinforced Concrete, and below ground 6 feet 6 inches Reinforced Concrete. This further proves the added destructive effect of shock in the earth. The base protection to be provided in Type 3 is 5 feet 0 inches Reinforced Concrete, which can be reduced if more than 25 feet below ground surface in the case of sand or gravel and 40 feet in the case of clay, 6 inches reduction for every additional foot of depth but with a minimum of 2 feet 6 inches. The numbers of persons to be accommodated are limited in any shelter in Type 3 protection to 400 persons and for Type 4 to 1,200 persons. Baffle walls are to be provided and cells should hold not more than 50 persons. There must be 25 feet clear space between shelters whether above or below ground.

REFERENCES :

(i) Home Office A.R.P. Dept.—Pamphlet on Garden Trenches.

(ii) Bulletin C2. Consolidation of earth covering on Anderson Shelters. Ministry of Home Security.

(iii) A.R.P. Handbook No. 5 A. Bomb Resisting Shelters.

SURFACE SHELTERS.

Structurally shelters consist of three types : (i) New Shelters ; (ii) Existing shelters, strengthened or improved, and (iii) adapted buildings, tunnels, mine surface workings, etc. It is chiefly (i) and (ii) which are dealt with in this section. Type (iii) is dealt with under sections I and J. In vulnerable areas it is not always possible to have dispersal but there should be dispersal in the less congested areas. Large shelters are only safe, if they are properly subdivided. Large shelters have certain advantages, viz. : (i) they are easier and quicker to construct per head than small ones ; (ii) material required is reduced per head ; (iii) better amenities can be provided (this does not mean that these must be neglected in small shelters) ; (iv) administration of large shelters is easier, and (v) better arrangements can be made to give proper protection against gas. Nevertheless dispersal of shelters has proved that loss of life is minimised and the psychological element of security in a smaller space is not to be lost sight of. It is possible in the first instance to provide protection against blast and splinters, and later as time and material allows to make such shelters bomb-proof. Surface shelters are more liable to blast and splinters than trench shelters, but are drier than trenches and can give protection against weather and provide comfort. The effects of blast have been undoubtedly over-rated and the effects of ground shock considerably underrated. Small shelters within a radius of 20 to 50 feet of a 250 kg. bomb are lifted bodily and fall back away from the original position—due to earth shock. Thus unless a shelter is monolithic in structure, the floor and roof must be tied in to the walls otherwise separation will take place with the following serious results :

(i) The original stiffening of the walls by the roof and floor is destroyed.

(ii) The walls, floor and roof will not return to their original positions.

(iii) On returning to the ground as separate units, deprived of the stiffening effect of one another, they easily break up. If the explosion is further away, the lateral effect is increased and a serious shearing action is caused by the separate units tending to slide over one another. This is dealt with under strengthening of shelters.

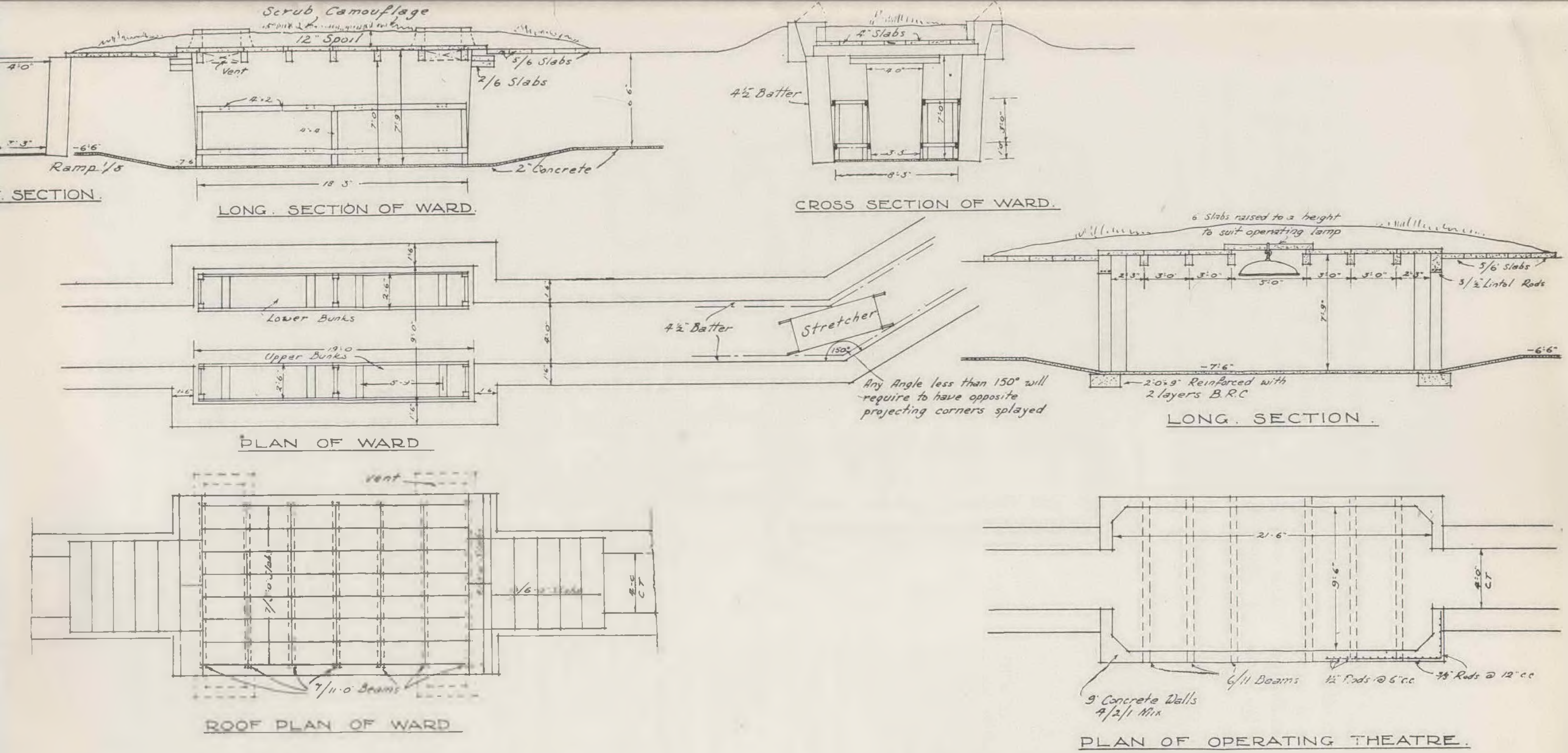
Surface shelters can be divided into various types:

(i) LOOKOUT POSTS. These are built in built-up areas on the tops of suitable buildings and can be of various types—steel or reinforced concrete. A good type was illustrated in "Building," June, 1941—the "Raidsafe," and several steel types have been advertised from time to time for shelter wardens or firewatchers.

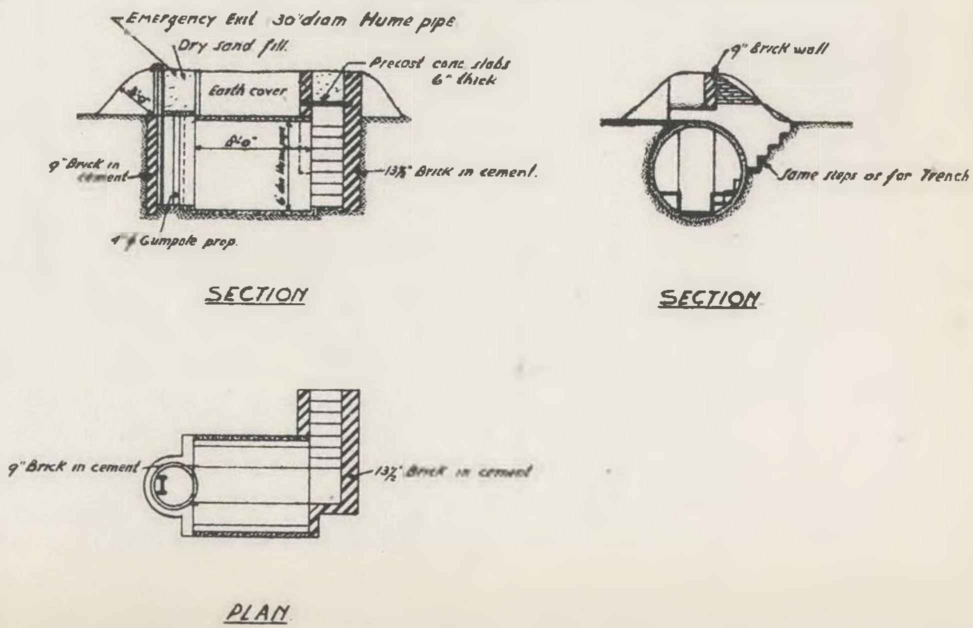
(ii) PROTECTIVE PENS. These are erected to shelter equipment or on central islands to protect the public and usually are built up by means of sandbags, brick, or hollow concrete blocks. When erected the entrance must be made, so that the occupants are protected against blast, that is an overlap must be provided at the entrance.

(iii) SMALL SHELTERS. Typical examples of small brick shelters are given in A.R.P. Memo No. 14—Domestic Surface Shelters, but it will be noted that sufficient strengthening of the walls or tieing in of floor and roof was not allowed for. These can be erected with hollow concrete blocks but in that case are difficult to make monolithic. Mention should be made of a type of shelter utilising 6 feet diameter Hume Pipe evolved by the Pretoria C.P.S. (20).

(iv) LARGE SHELTERS. The AASTA have made a full study of this type and several are illustrated—a sleeping shelter for 588 persons, including all equipment, designed by the AASTA Committee and proof against 500 lb. bombs (21). This can be varied in size but it is not economical to provide for less than 200 persons. Fig. 22 shows the same shelter arranged for 864 persons and for 376 persons. It is planned on a basic sleeping unit for 36 persons (23). It can be built in two stages as set out before. A bomb-proof shelter designed by Mr. C. Helsby for a London Borough



18, 19. SPECIAL TYPES OF TRENCH SHELTERS FOR MEDICAL SERVICES, SHOWING DETAILS OF WARD AND OPERATING THEATRE. By courtesy D.F.A.E



20. A TYPE OF SMALL DOMESTIC SHELTER EVOLVED BY PRETORIA C.P.S., UTILISING "HUME" CONCRETE PIPES.

From "Useful Hints in Case of Air Raids," Pretoria C.P.S.

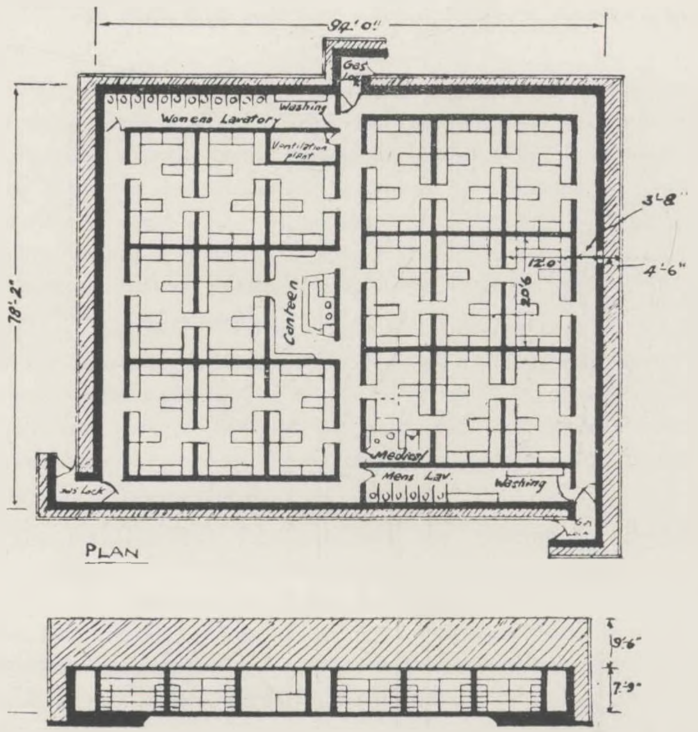
and published in "Building," accommodates 1,200 people, allowing for bunks four tiers high. Brick walls and vaults act as permanent shuttering for the concrete. A school shelter has also been designed by the AASTA Committee. It allows school children to continue education during alerts and raids and can be used for sleeping by the public at night. The shelter (24) has accommodation for six classes of 40 children, or 108 people at night. Access for the children is direct from the school by a protected corridor with a separate entrance for the public. The arrangement of the classroom unit is shown in Fig. 25. The question of shelter for schools is one widely discussed. It is useless sending children home if an air raid warning is given as they are then on the streets, and arrangements for shelter have to be made at the schools either by means of slit trenches, or shelters such as described above or by adapting the school buildings as will be shown under the heading of shelters in buildings. Further the younger children on their way to and from school should be cared for by older ones, trained to know what should be done in event of an air raid taking place between the school and their homes.

(v) TUNNELS OR UNDERGROUND WORKINGS. Where these exist, a large proportion provide very good protection. The Rand is fortunate in having surface workings which can be utilised. Subdivision will have to be made to minimise the dangers to health of large congregations of people, as well as the provision of other amenities. Careful arrangements will have to be practised beforehand to ensure that people are speedily and correctly distributed into these workings. If these tunnels, etc., are situated in clayey soil, they are generally unsuitable unless deep enough. It has been now fully realised that railway arches are unsuitable. The most suitable strata are sedimentary rocks—chalk, sandstone, limestone. In limestone fissures may be formed by percolating water and rockfalls are likely. Igneous rocks—granite, basalt, etc.—may be tunnelled and no lining is needed. Steel, concrete or brick linings are necessary in clay.

(vi) SHELTERS FOR CONVERSION INTO DORMITORIES AFTER THE WAR AND FINALLY TO DWELLING HOUSES. Various authorities, among them the RIBA and AASTA, have tackled this problem. Ove Arup has devised a form of Safe Housing (2 to 5 storeys), and a two storey peace time house and Maisonette were designed by Mr. Cyril Sjostrom (AASTA report "Why wait for the Blitz") from Ove Arup's construction. Mr. S. Bunting also made proposals for the use of Ove Arup's shelter housing on the Clydeside. This type of shelter is one worthy of notice by Municipalities as providing housing after the war.

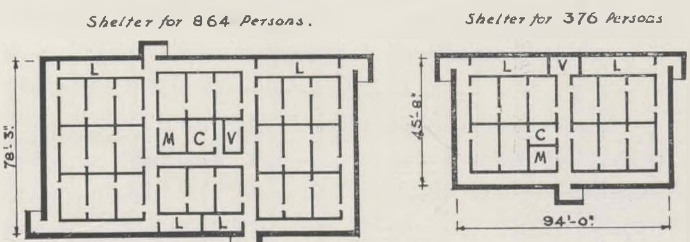
HYGIENE IN PUBLIC AIR RAID SHELTERS.

Where conveniences are accessible or available in closely adjacent houses, no conveniences in or attached to the shelter need be provided. A water-borne system has hygiene advantages but capital cost may be a limiting factor and dry sanitation need only be provided. The scale of provision is two closets (one for each sex) in shelters of 50 persons, and one for every additional 25 persons and urinals provided in addi-

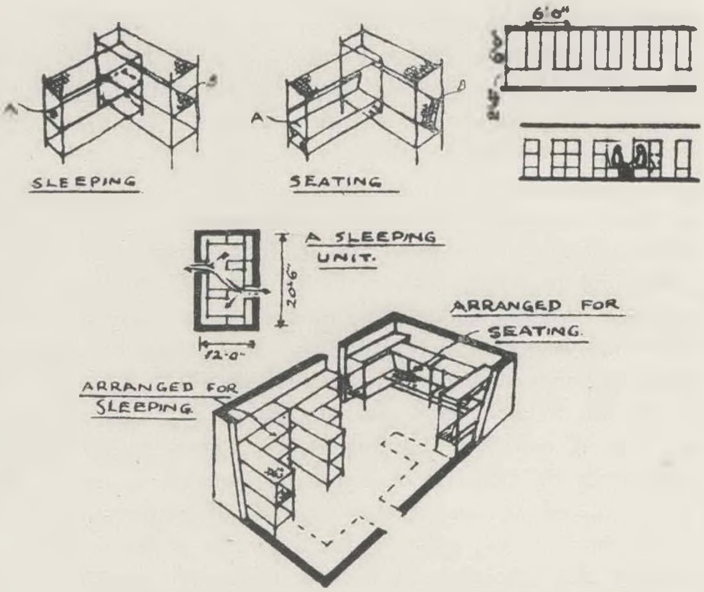


SECTION.

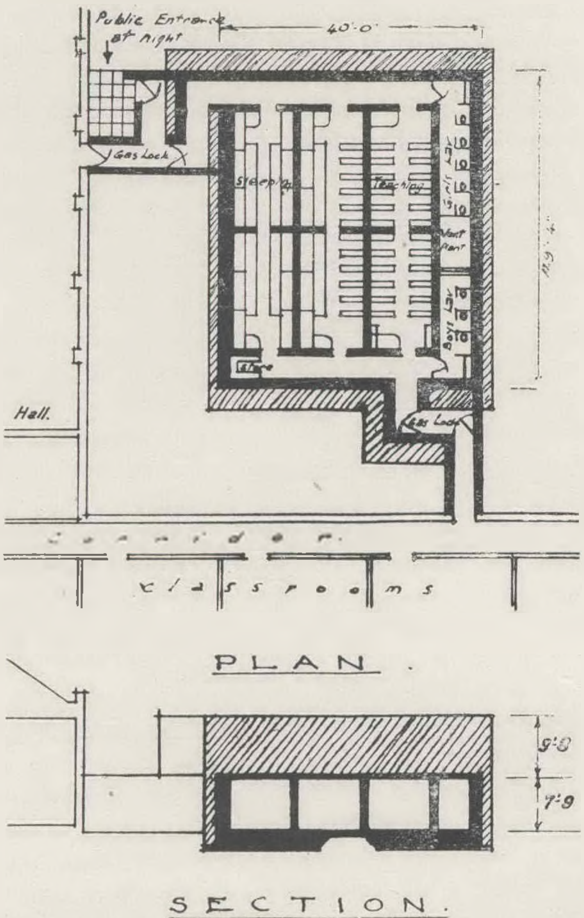
21. DESIGN FOR A SHELTER TO RESIST 500 lb. BOMBS, TO BE BUILT IN TWO STAGES; FIRST, BLAST AND SPLINTER PROOF (shown black); SECOND, PROOF AGAINST DIRECT HITS (shown shaded).



22. ALTERNATIVE LAYOUTS FOR SHELTER SHOWN IN FIG. 21. C-CANTEEN; L-LAVATORIES; M-MEDICAL AID POINTS; V-VENTILATING PLANT ROOM (FIGS. 21, 22, 23, 24, and 25).
(From: "Safe Shelters Now," Fourth Technical Report of the A.A.S.T.A.)



23. ARRANGEMENT OF 36 BUNKS AND SEATING IN COMPARTMENT OF SHELTERS ILLUSTRATED IN FIGS. 21 AND 22.



24. A SHELTER FOR USE BY 240 SCHOOLCHILDREN BY DAY AND FOR SLEEPING 108 PERSONS AT NIGHT.

tion. Ventilation should be provided at a high level and air from closets must pass to the outside atmosphere and not into the shelters, and divisions between sanitary arrangements (as well as in the case of emergency lighting equipment or mechanical ventilating plant) carried up to the ceiling of the shelter.

VENTILATION IN PUBLIC AIR RAID SHELTERS.

Ventilation is generally least satisfactory in shelters of the basement type. Shelters should have more than one ventilation opening and neither inlet(s) or outlet(s) should have a total effective area of less than 1 square foot per 30 persons in a shelter. If only one opening can be provided, the area must not be less than 3 square feet per 30 persons. In the case of trench shelters, advantage can be taken of the emergency exit, which need not be closed completely—a cowl being fitted to keep out rain and prevent emission of light. A steady current of air should be maintained across the ceiling as this will greatly reduce the risk of moisture condensing on the surface. Ventilating openings must be arranged so that no light shows at night but this must not be achieved at the expense of ventilation. Ventilating appliances must not interfere with the means of exit in case of emergency, and shelter occupants must not block ventilating openings.

BAFFLE WALLS.

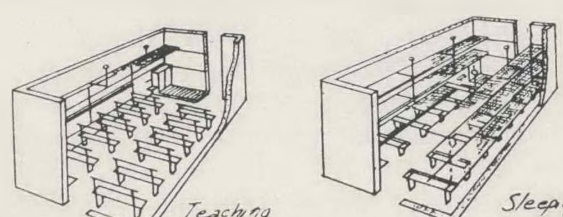
In large shelters, baffle walls must be provided and good practice is to utilise space between two of these to store equipment, to provide sanitary accommodation or space for ventilating plant or emergency lighting equipment.

REPLACEMENTS OF ROOF.

A roof can be replaced by flat hollow tile construction (26), and a system is shown in the "Architects Journal," October 16, 1941, of the use of Flexiform. The light replaceable window panel (27) is illustrated in "Why wait for the Blitz." (AASTA).

VAULT CONSTRUCTION.

An excellent method, devised by Mr. Samuely, is described in "Building," December, 1941. This has since been used in practice and gives an excellent method of utilising Tentest

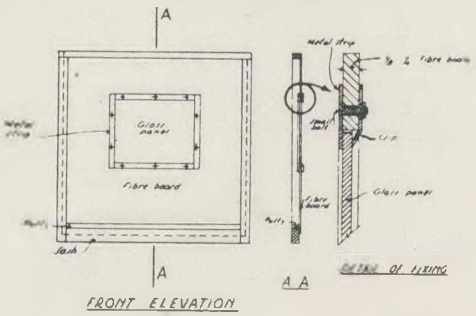


25. THIS SHOWS THE ALTERNATIVE DAY AND NIGHT ARRANGEMENTS FOR EACH COMPARTMENT OF SHELTER ILLUSTRATED IN FIG. 24. A CLASS OF 40 CHILDREN CAN BE ACCOMMODATED BY DAY AND 17 PEOPLE CAN SLEEP AT NIGHT.

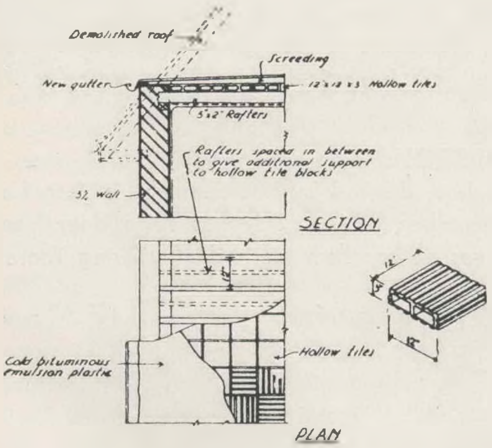
or other suitable board as shuttering—this shuttering remaining in position and giving insulation. Patents have, however, been taken out for this form of construction.

STRENGTHENING OF SHELTERS.

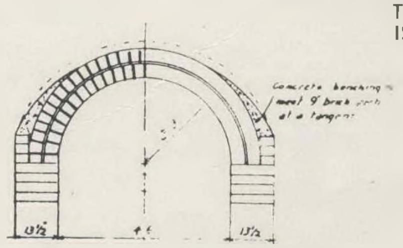
After 1940 it was found that new designs of shelters had to be introduced embodying certain important changes: (i) the use of reinforced brickwork; (ii) the introduction of a bituminous damp-roof course, and (iii) the introduction of the principle of oversailing the roof. As far as existing shelters were concerned, three matters were tackled: (i) Remedial measures for defective mortar—in this connection lime-cement mortar proved non-setting or hardening even after relatively long periods and cement mortar must be used; (ii) Brick arch roofs—these had to be built in cement mortar and the outer ring had to be backed at the springings (of two $4\frac{1}{2}$-inch brick rings) with concrete in fine aggregate (28), and (iii) Damp. In the latter, walls became damp due to inadequate roof drainage, infiltration through roofs and walls, the entry of water over the floor of the shelter and due to rain driving in through unprotected entrances. Trench shelters, in particular those having the approved types of linings (precast reinforced concrete), required strengthening as these types were relatively vulnerable to earth shock from a near-by explosion. Damp was in particular found the greatest trouble from infiltration of subsoil water and caused great discomfort to those using such trench shelter as dormitories. Various water-proofing treatments are recommended for brick and concrete surfaces, viz.: (i) Bituminous paints; (ii) Bituminous emulsions; (iii) Black varnish; (iv) Coal tars for cold application; (v) Coal tar pitch mixes for hot application (these are fully described in Home Security Circular No. 290/1940, Air Raid Shelters 11/12/1940). Subdivision of basements and strutting were other recommendations. These are dealt with under Shelters in Buildings. Diagonal cracking in brickwork, starting at upper corners of entrances or emergency exits, in many instances was the only damage to shelters and these points can be protected by longitudinal reinforcement consisting of two $\frac{1}{4}$ inch diameter rods per course in each of two courses immediately above these openings for a minimum length of 6 feet 6 inches being inserted. Existing shelters poorly built can be improved by either a new $4\frac{1}{2}$ inch outer skin of brickwork, keyed into the old brickwork, or replacing the $4\frac{1}{2}$ inch skin of brickwork and 1 inch layer of cement mortar by $4\frac{1}{2}$ inch skin of reinforced concrete keyed into the old brickwork or a new 4 inch thick skin of reinforced concrete keyed into the old brickwork on the inside of the shelter or a double skin consisting of $4\frac{1}{2}$ inch brick wall bonded to and acting as a shuttering to a $4\frac{1}{2}$ inch thick reinforced concrete core, which in turn is bonded into the old brickwork. (Circular CE/GEN/50 Ministry of Home Security 26/7/41.) These experiments were continued and further deductions on the same lines are given in Circular CE/GEN/51 of the Ministrv of Home Security 26/11/41, the chief points being that bonding is essential and that floors must be provided giving a tie-in between floor, walls and roof.



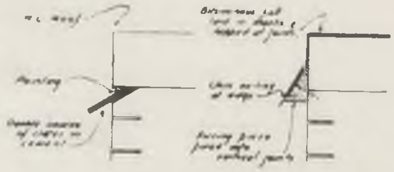
27. LIGHT REPLACEABLE WINDOW PANEL. THIS CONSISTS OF A FIBRE OR PLY WOOD PANEL WITH A GLASS INSET. THE PANEL IS FIXED TO THE INSIDE OF THE WINDOW FRAME WITH LIGHT PANEL PINS, SO THAT IF BLOWN OUT BY BLAST IT IS EASILY REPLACED.



26. REPLACEMENT OF A ROOF WITH FLAT HOLLOW TILE CONSTRUCTION. THIS REDUCES THE NUMBER OF REPAIRS AND INCREASES RESISTANCE TO INCENDIARY BOMBS.



28. DETAIL OF BRICK RING ARCH ROOF FOR A SURFACE SHELTER.



29. DETAIL OF DRIP AND ROOF COVERING TO INCREASE THE WEATHER RESISTANCE OF EXISTING SURFACE SHELTERS.

(Figs. 26 and 27 from "Why Wait For The Blitz," Ninth Technical Report of the A.A.S.T.A. Figs. 28 and 29 from Circular 290/1940, "Air Raid Shelters," Ministry of Home Security.

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(i) An address to Engineers, Architects and Quantity Surveyors—May, 1942—Eng. Dept. for A.R.P., City Hall, Cape Town. R. Stubbs, M.I., Struct.E., A.M. (S.A.), Socy. C.E.

(ii) "Safe Shelters now," AASTA 4th Report.

(iii) "Why wait for the Blitz," AASTA 9th Report.

(iv) "Civil Protection," by Messrs. Samuely and Hamann.

(v) "Safe Housing in War Time," by O. Arup (D. Gestetner, Ltd.).

(vi) Circular P.R.O. 12/1941, Hygiene in Public Air Raid Shelters, 1/3/41, Ministry of Health.

(vii) Circular P.R.O. 26/1941, Ventilation in Public Air Raid Shelters, 14/6/41, Ministry of Health.

(viii) Circular 290/1940, Air Raid Shelters, Ministry of Home Security, 11/12/40.

(ix) Circular CE/GEN/48, Technical notes on Shelter Improvement, Ministry of Home Security, 18/4/41.

(x) Circular CE/GEN/49, Surface shelters in Brick and Concrete, Ministry of Home Security, 2/6/41.

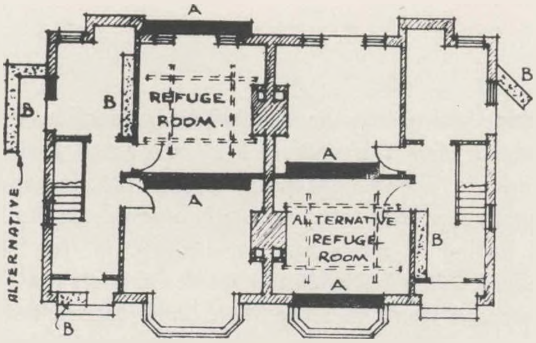
(xi) Circular CE/GEN/50, Strengthening of Brick and Concrete Surface Shelters, Ministry of Home Security, 26/7/41.

(xii) A.R.P. Memorandum No. 14. Domestic Surface Shelters.

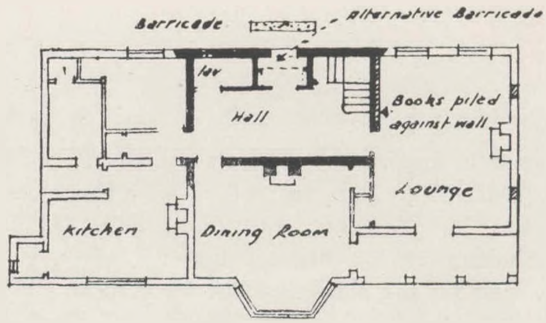
I SHELTERS IN BUILDINGS — DOMESTIC.

Experience of air attack has shown that a house affords a great deal of protection from blast and bomb splinters, from aerial machine gun fire and falling splinters on to Air Raid Shelters. Observation of actual damage has shown that, with normal wooden joists and boarded floors, debris from the upper part of the house rarely came crashing through the ceilings into the ground floor areas of an ordinary dwelling. A direct hit of even a small high explosive bomb usually demolished the greater part of the average small house, but for every direct hit many bombs fall near enough to cause severe structural damage. Very often a bomb explodes below ground and the resulting earth shock brings down one or more main walls of the house. Where the wall is thus shaken down, the ceiling is deprived of its support along at least one side and so tends to fall into the room below. Since the floor boarding is usually well fixed to the joists, apart from the plaster which will flake off, the floor and ceiling remains in one flat piece and either falls hinged on one side, or where all the walls have been shaken down by earth shock, the ceiling will then fall in a more or less horizontal position. For the above reason it has been found that casualties in houses are caused more by the total or partial collapse of buildings than by splinters or blast, and many people have been rescued from demolished houses because they have taken shelter under tables or staircases, where they have received protection from the falling debris. For this reason it is advocated that use should be made of a home for protection. The reasons for this being that if a proper refuge room is erected, all the inconveniences of having to move out, particularly in the winter or rainy season, into slit trenches or garden shelters are overcome. Not everyone wants to leave their home for shelter, in fact, some people cannot. This is sound instinct, provided some protection can be found against the collapse of walls and ceilings. A shelter indoors allows one to sleep at night in reasonable security, and in warmth and comfort, and also provides adequate cover should there be a sudden raid in the day time. A direct hit cannot be guarded against in any form of home shelter, but the risk of such a direct hit is very small compared with that of a bomb bursting near enough to damage the house or demolish it.

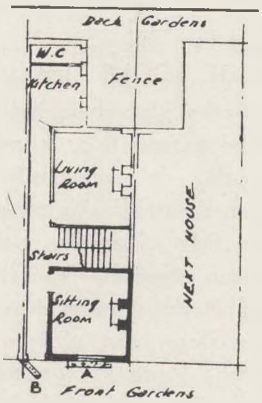
CHOICE OF A REFUGE ROOM. Indoor shelters in the ordinary house should only be placed on the ground floor or basement room, and if the ground floor is used, there should be no basement underneath. It is generally advised that a room on the ground floor be used with no basement underneath as the extra protection given by basement against bomb splinters is more than offset by the greater risk of the occupants being trapped in the basement. A room should be chosen having a solid floor, one with concrete or stone flags or tiles on concrete. These are generally better than the board and joist type. The room should have fairly high window sills and no door which opens on to a garden or street. It should, however, face the garden, if possible, as the soft earth will allow the bomb to penetrate before exploding, and this minimises the danger of bomb splinters. The above is shown in figures 30, 31, 32, 33, 34, 35. The window opening should be protected if the window sill is lower than the top of the shelter. There will be danger to persons in the shelter from bomb splinters which often fly horizontally. Where this is so the window opening should be barricaded with a brick, concrete or earth wall, at least as high as top level of the shelter or better, up to 6 feet above floor level. Any outside doors or french windows should be barricaded in the same way. If protection is fixed to the window opening it must be securely fastened to the walls. It is no use simply piling up bricks or sand bags on the window, as blast may throw them violently into the room. A good method is to fasten thick boards across the window opening both inside and outside, the space being filled with gravel or broken brick or stone. (36, 37.) It will be best to take out the window, or at any rate the glass, before doing this. If window glass is left, then it must be treated to prevent it flying into the



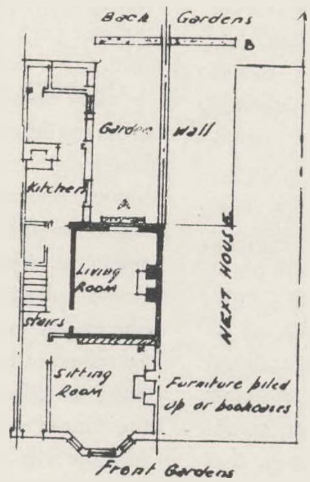
30. PLAN OF SEMI-DETACHED HOUSES.
This shows how a living room or dining room can be protected to form a refuge room. The outside barricades should be at least as high as window sill level, but can be up to 6 feet high, as shown in fig. 36. The inside barricades can be built up with heavy furniture or bookcases.



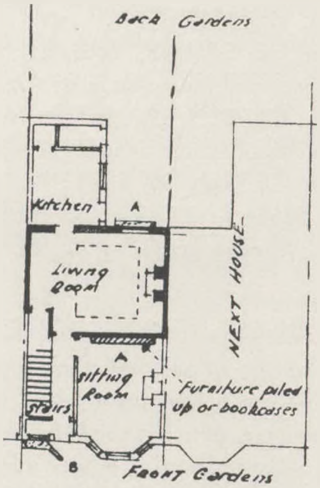
31. THE HALL USED AS A REFUGE ROOM.
The front door requires protection by a barricade either outside or in the lobby. The lavatory window is high and may be blocked, but if left open would not constitute a danger to people sitting down in the hall. The two lounge windows facing the hall door should be blocked if the sills are low.



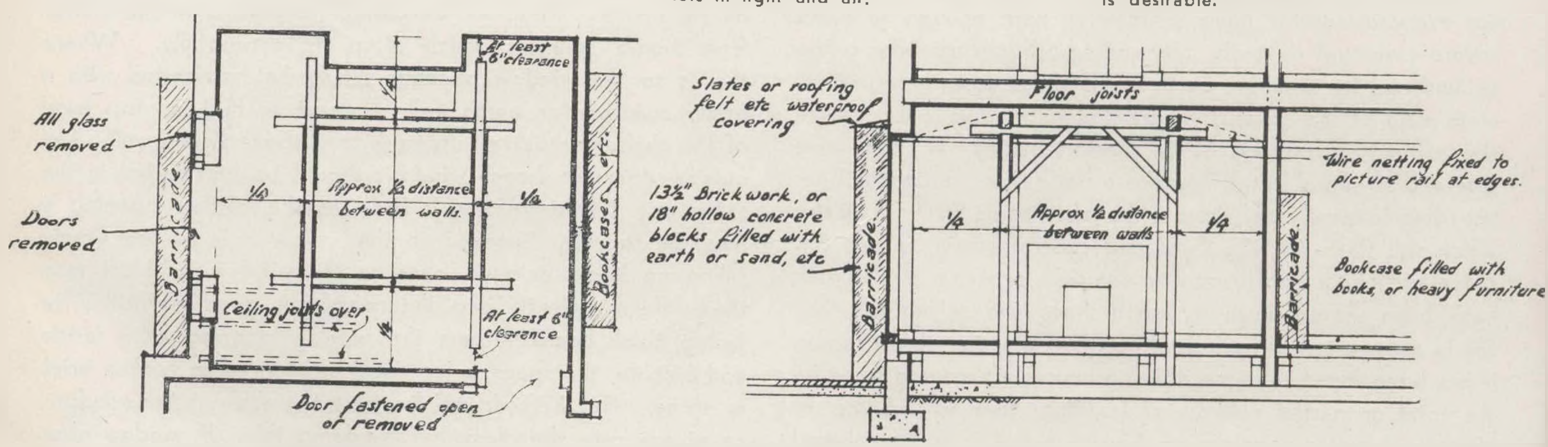
32. THE FRONT SITTING ROOM USED AS A REFUGE.
Barricade "A" is necessary; "B" is desirable.



33. A LIVING ROOM USED AS A REFUGE.
Barricades "A" and "B" are alternatives; "B" costs more but lets in light and air.



34. A LIVING ROOM USED AS A REFUGE.
An indoor shelter is best placed inside the dotted area. Barricades "A" are necessary; "B" is desirable.



35. PLAN AND SECTION OF A TYPICAL REFUGE ROOM, SHOWING THE USE OF A CEILING SUPPORT FRAME WORK. SEE FIGS. 38 and 39.

(Figs. 30 and 35 from Bulletin C.14 (Second Edition), "Refuge Room Dormitories," Ministry of Home Security. Figs. 31, 32, 33, 34 from "Shelter At Home," Home Office.)

room. This will be dealt with at a later stage. It may be added here that a hall or a passage can be very conveniently used for refuge in a home, provided, of course, that all openings such as outside doors, etc., are protected by sand bag walls or other types as previously dealt with. It may also be necessary, where there are thin partition walls, to strengthen these by placing bookcases or any other objects against them which will prevent debris being thrown across the room into the shelter itself. This strengthening is shown in the previous diagrams.

INDOOR SHELTERS. The refuge room having been chosen, consideration must be given to the type of shelter that will be put into it. There are several alternatives, but before considering these alternatives it is necessary to understand the primary function of such shelter, namely, to protect occupants from being crushed by the collapse of the floor above. The secondary functions are:

(i) To protect occupants from falling debris, and for this reason must be designed against a fall of 3 cwt. of brickwork from the height of 6 feet.

(ii) To prevent occupants being exposed above window sill level. If the top of the shelter is not more than 3 feet above floor level then window openings need not be protected.

(iii) To protect occupants from debris moving laterally. It has been found that the human being can withstand without fatal effect a blast of sufficient intensity even to demolish a $13\frac{1}{2}$-inch. brick wall.

The indoor shelter should possess as many of the following features as possible:—

(i) It should be clear of walls, in order to facilitate the occupants leaving the shelter or being rescued.

(ii) Such positions should be selected as will give the best splinter protection, avoiding those positions that would be vulnerable owing to splinters entering through weak places, such as, in a straight line through an outside door or room door. The doors should never be closed during an air raid, as they are liable to be wrenched off and thrown across the room.

(iii) Shelters, other than the massive type, should be movable, as the impact on the shelter will be less in this case.

(iv) For the above reason the shelter should not be fixed to the floor as the floor itself may be disturbed and cause collapse of the shelter.

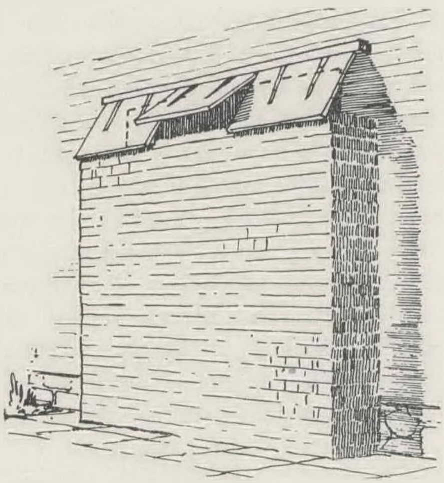
(v) The shelter should have its own floor, as the occupants will then move with the shelter, should it be disturbed.

(vi) The shelter should have a secondary use.

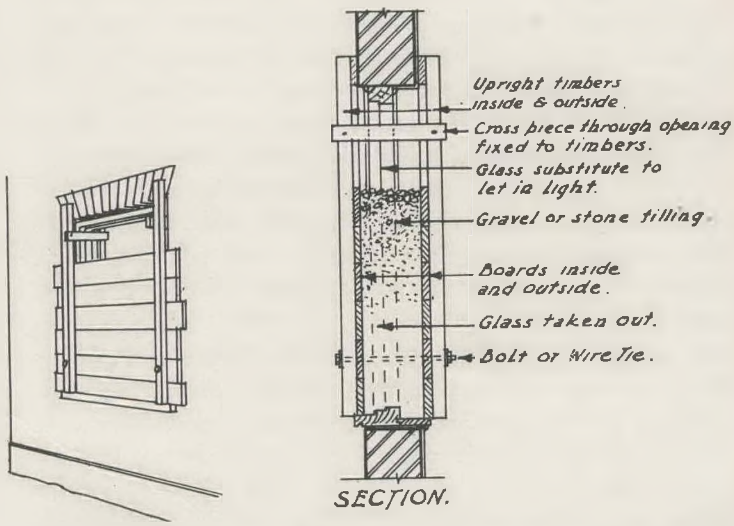
(vii) The shelter should cut out as little light as possible. The open mesh structure at the sides and ends of the Morrison shelter is advantageous for the above reason, and from a point of hygiene, giving the maximum ventilation.

(viii) There should be easy access to the inside of the shelter, which also provides for the most important point, namely, easy exit.

It is therefore seen from the above that the shelter should be placed centrally in a room to allow for easy exit and never against outside walls. All light removable partitions or objects, as well as internal glass, should be removed. The various alternatives, or rather types of shelter, are as follows:—

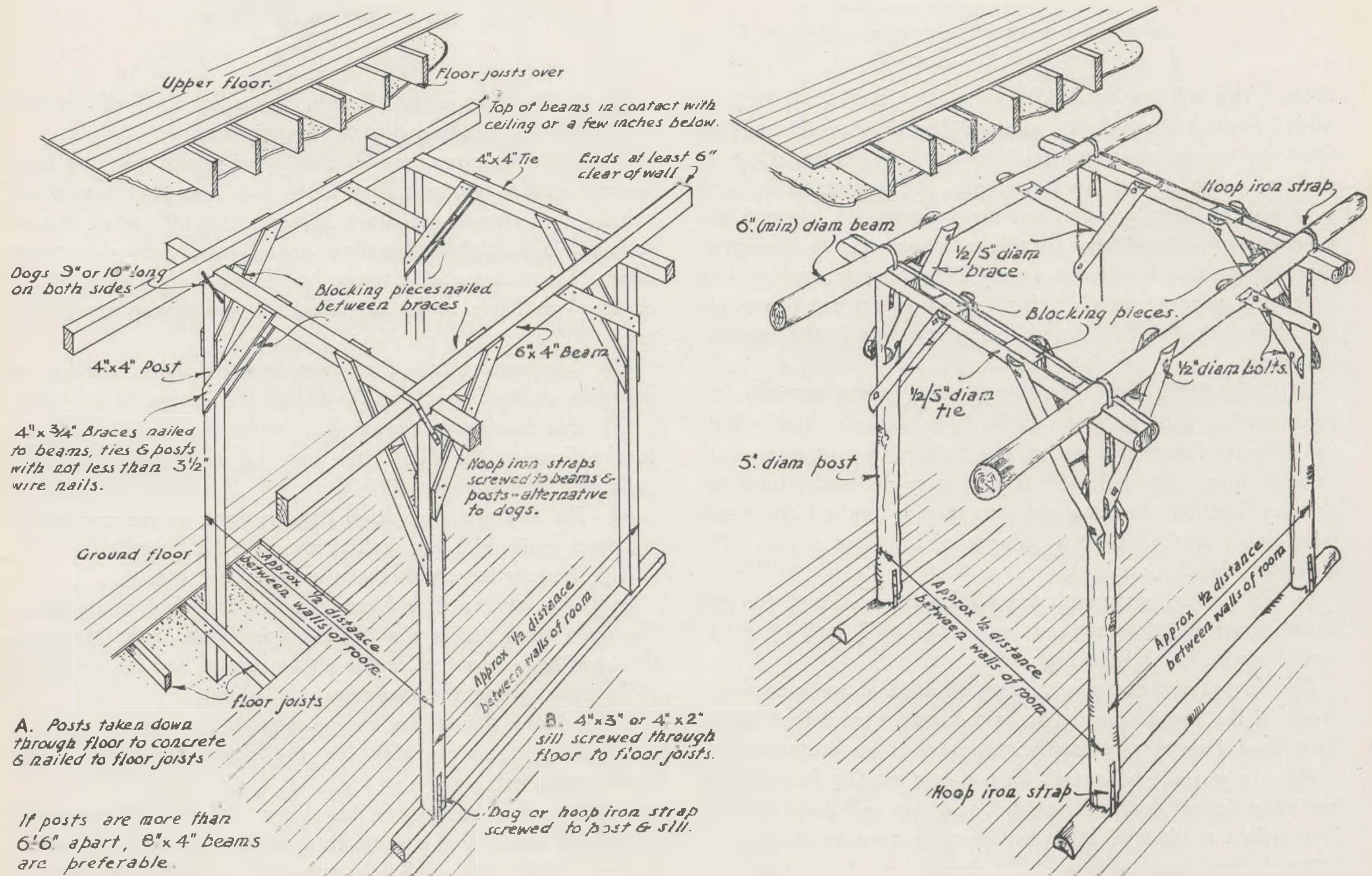


36. A 6-feet high barricade built of brick, covering the french window of a refuge room. A ventilation opening between the top of the barricade and the window opening has been fitted with 2-inch thick sloping wooden shutters, fixed to outside, so that they cannot be blown into the room by blast.



37. The window is protected by planking and timbers fixed inside and outside, the space between being filled with gravel or broken stone. The two sets of planks and timber must each overlap the window and be strongly fixed to each other with cross timbers, bolts and nuts, or wire ties.

(From "Shelter at Home," Home Office.)



38, 39. INDEPENDENT CEILING SUPPORT FOR REFUGE ROOM. Alternative methods of constructing the framework using squared or round timber.

(i) The ceiling support framework. This has been fully described in Bulletin No. C.14 and is illustrated here in diagrams 38, 39. The framework itself is independent of the structure of the house and the supports of the frame should be at a distance of one quarter of the distance between walls, from the wall on either side, with the top of the frame having at least a 6-inch clearance from the walls. In order to prevent falling debris such as flags or dust falling into the shelter it is as well to have netting fixed to the top of the frame of the shelter.

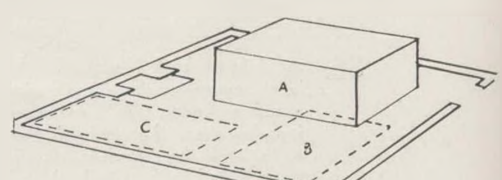
(ii) Where protection is to be provided in large buildings of load bearing wall construction, the shelter structure is more solid than the refuge room type as described above, and consists of a braced self-supporting timber framework. This arrangement is shown in Bulletin No. C.25. It is as well to remove any partition walls weighing less than about 60 lbs. per square foot, as these must be regarded as vulnerable.

(iii) The steel table (Morrison Shelter). This was decided on in December, 1940, as a Government issue and is a steel framework 6 feet 6 inches long and 4 feet 0¾ inches wide, consisting of steel framework with mesh on the sides and ends and a metal lathe mattress. The framework itself it built up of mild steel rolled angles to which is bolted a ⅛-inch thick steel top. This has proved successful, and was based upon the observation that a number of people were saved by taking refuge under an ordinary kitchen table.

(iv) The Wooden Table Shelter. An alternative shelter can be constructed of ordinary green timber, the design of which is shown in Bulletin C.26 and also C.27. This type of shelter affords a standard of protection against the fall of debris, little, if at all, short of that given by the Morrison Steel Shelter.

The position for such a shelter is shown in diagram 40.

40. A diagram showing the best position for an indoor shelter. Position "B," with one end against a wall, is not as good, and position "C," in a corner, should never be used.



REFERENCES:

The protection of your home against air raids.
—Home Office.

Shelter at home.
—Home Office.

Bulletin C.14.—Refuge Room Dormitories.
—Ministry of Home Security.

Bulletin C.15.—Notes on Indoor (Anti-Debris) Shelters.
—Ministry of Home Security.

Bulletin C.21.—Wooden Table Shelter.
—Ministry of Home Security.

Bulletin C.25.—Protected accommodation in large buildings of load-bearing wall construction.
—Ministry of Home Security.

Bulletin C.26.—Timber shelters for countries where timber is plentiful and steel difficult to obtain.
—Ministry of Home Security.

Bulletin C.27.—Shelter Design 14/4/42.
—Ministry of Home Security.

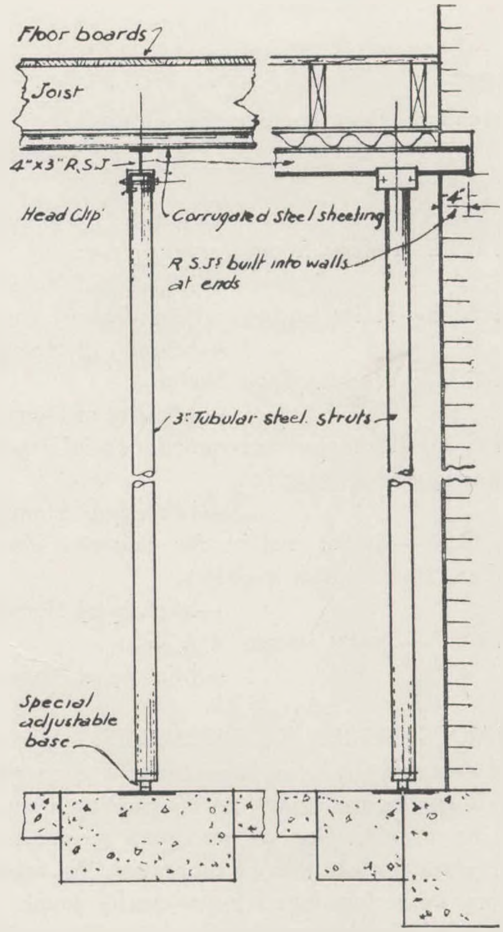
AIR RAID SHELTERS IN BASEMENTS. A considerable portion of available shelter in large towns is provided in basements. This applies particularly to the built-up areas. Instructions for the strengthening of basements to ensure that the floor over would be capable of supporting the debris load if the building were demolished by a nearby bomb explosion, are given in A.R.P. Memorandum No. 10. The position, however, has since been reviewed by Professor J. F. Baker in Bulletin No. 27, "Shelter Design," who has made the following recommendations enabling certain economies in material to be effected. There is no necessity to introduce the factors to cover such a misfortune as accidental overloading, as the debris load is in fact in the nature of an accidental overload and all that is required of the design, in short, is that the structure does not collapse under it. Overstraining of the material and deflections which would be considered objectionable in a structure under normal circumstances can be allowed, since the shelter will be called upon to sustain its "accidental overload" only once. Certain buildings will need strengthening, but others, due to their inherent strength, can, as constructed, sustain this load quite safely. Briefly, in a fully framed building the floor above the basement shelter need not be strengthened to afford protection from falling loads if it forms part of a fully framed structure; if it was designed under the usual design rules, assuming a permissable stress of not more than 8 tons per square inch in the beams for a superimposed load of at least 80 lbs. per square foot; and if the actual load carried is not more than a quarter of the superimposed load assumed in the original design of the building. Professor Baker again refers to the fact that failure in diagonal tension is the most probable cause of collapse in reinforced concrete members, which are rarely of uniform strength. But, however, where the area of bottom reinforcement is constant throughout the beam and the concrete is of a strength equal to the lowest value allowed by the "Code of Practice" for "reinforced concrete" (2,250 lbs. per square inch), test results so far available indicate that the inclusion of a central prop increases the load carrying capacity of the member between three and fourfold, though the energy which can be absorbed may not be so increased. It has been found that where basement shelters had been strengthened in accordance with the revised code requirements, no injury has been sustained in them, when the buildings over such shelters have received direct hits. The Bulletin C.27, "Shelter Design," by Professor J. F. Baker, is one worthy of thorough study, as it brings up to date all factors involved, and was issued 14/4/42 and supersedes to a very great extent Bulletins C.1 and C.3.

Shelter accommodation below ground affords good lateral protection, and there are two types of accommodation to be considered, that is, basements in private houses and basements which can be adapted to provide shelters in factories and industrial buildings, and all public shelters for persons caught in the street. However, in the case of the basements, very careful calculations must be made and the various points carefully studied before passing the basement fit for use as an air raid shelter. Danger of collapse and the possibility of flooding is so serious that competent engineers must be consulted in the surveying of shelters, particularly owing to the difficulty of extricating persons trapped in basements. Actually a room on the ground floor with the necessary lateral protection may actually be better than a basement shelter. The question of overhead protection and lateral protection will be given attention in the next section when dealing with large framed commercial buildings. However, if it is decided to utilise a basement as an air raid shelter it is necessary to provide certain standards of accommodation. There should be not less than 6 square feet of floor area per person in the shelter, nor should there be less than 50 cubic feet capacity per person in the shelter, nor less than 25 square feet of surface area of wall, floor and roof per person. The above figures are given if entrances and exits are kept open. There should not be more than 50 persons in one shelter and the entrance should have a minimum width of 2 feet 6 inches. All basement shelters should have two exits, one, if possible, leading into an adjoining building. Where the shelter only accommodates 12 or less people it may only be necessary to provide one exit. Sanitary accommodation must not be forgotten, and where possible existing facilities utilised. It is necessary to provide for emergency lighting. The question of overhead protection has been revised, but the conditions laid down for design have not altered, and for unframed buildings are as follows:—

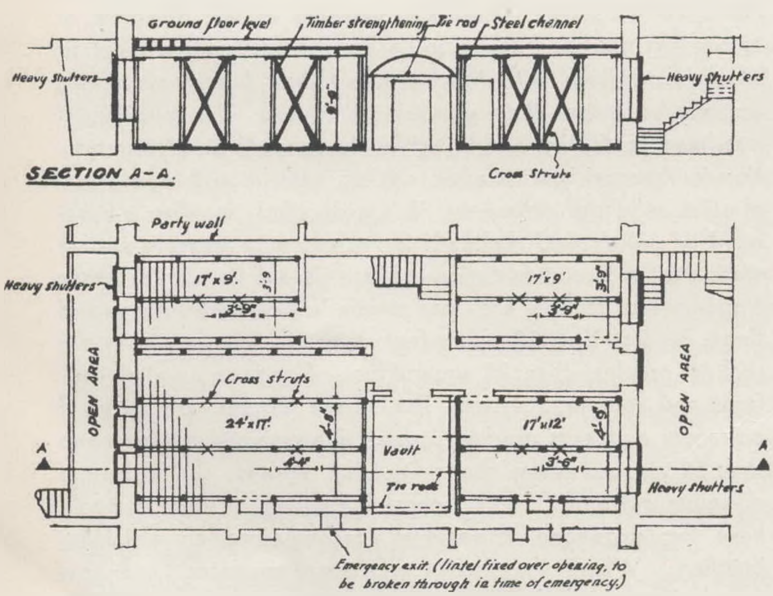
In framed buildings it is necessary to design for a debris load of 200 lbs. per square foot, irrespective of the number of storeys over. The question of protection against fire is a very important one in basement shelters and the standard protection will be dealt with in a later section under incendiary bombs. Lateral protection is provided by having shelters entirely below ground level, but it has been found that when there are pavement lights or any similar openings where there is a possibility of a tamped charge, a protecting wall of 22½-inch brickwork or 13½-inch brickwork reinforced will have to be provided. Overhead protection is provided by not less than 6-inch thickness of concrete, brickwork or masonry arches where the arching is not less than 8½ inches (good first class brick in cement mortar), or earth or sand in bags, ballast or broken stone not less than 1 foot 6 inches thick. Concrete encasement of steel members introduced for the support of debris is not necessary in the provision of the shelter.

In the selection of basements certain matters must receive attention. First amongst these is cleanliness. Rooms in which offensive materials have been stored or offensive processes carried out will often not be suitable as a shelter. They should be free of vermin and any connection to drains should be put into good repair.

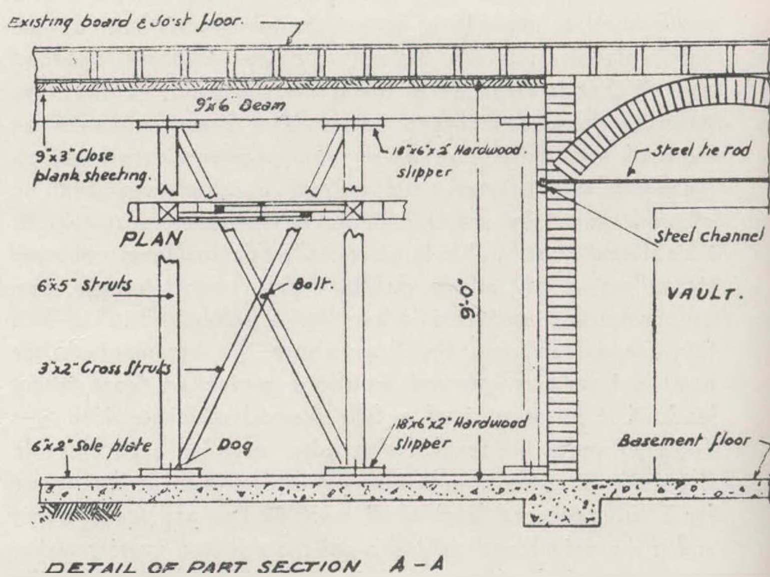
The existing building structure should be surveyed by competent persons to ensure that the brickwork and masonry is sound. It is absolutely essential that certain hazardous features



41. DETAILS OF STEEL STRENGTHENING FOR BASEMENT AGAINST DEBRIS LOAD.



42. EXAMPLE OF A TYPICAL BASEMENT STRENGTHENED WITH TIMBER FOR DEBRIS LOAD.



43. DETAILS OF TIMBER STRENGTHENING SHOWN IN 42.

(From A.R.P. Memo. No. 10, "Provision of Air Raid Shelters in Basements," Home Office.)

should be avoided. This applies particularly in industrial areas and such hazards may consist of:

(i) Tanks with inflammable or corrosive liquids or gases.

(ii) High chimney stacks, water towers, coal bunks, etc.

(iii) Possibility of flooding from large water mains and sewers as well as canals.

(iv) Water tanks or heavy machinery on upper floors and heavy cornices and other features on the building.

It may be necessary to strengthen the floors over basements, and this is shown diagrammatically in diagrams 41, 42, 43. The question of exits is extremely important and various types are shown in diagrams 44, 45, 46, 47, 48, 49, 50. A.R.P. Memorandum No. 10 will give the placing of air raid shelters in various types of basements, and the examples given are well worthy of study as they give a general indication of the dangers to be avoided. Basements, having steam or gas pipes passing through, should be avoided as shelters unless such pipes are bye-passed.

REFERENCES:

A.R.P. Memo. No. 10.—Provision of Air Raid Shelters in Basements.

—Home Office.

Bulletin C.1.—New Design Methods for Strutting of Basements.

—Ministry of Home Security.

Bulletin C.3.—The Propping of Reinforced Concrete Beams.

—Ministry of Home Security.

IN CONNECTION WITH THE PROVISION OF SHELTERS IN BUILDINGS CERTAIN FUNDAMENTAL PRINCIPLES WILL APPLY TO ALL BUILDINGS.

(i) EFFECT OF BOMBS ON STRUCTURES. Taking the 250 kg. bomb as a standard, a house with 9-inch brick walls will be completely demolished if the bomb falls within a distance of 22 feet of it. Up to a distance of 44 feet such a building is so damaged as to be beyond repair, and up to 70 feet the damage incurred will make the building uninhabitable but capable of repair. This applies to a buried bomb, the corresponding figures for an unburied bomb being 30 feet, 60 feet and 120 feet respectively.

As regards steel framing it can be taken that destruction of steelwork will only occur in the actual crater area or just beyond it. Thus for a 250 kg. bomb the average crater radius being 18 feet, the maximum recorded offset was found to be 20 feet and maximum distance within which steel framework might be destroyed being 38 feet from the edge of the crater. The minimum distance at which not more than slight damage will be done to an unshielded wall panel in steel framed structures (in the case of the 250 kg. bomb) is 155 feet to a $4\frac{1}{2}$-inch, 78 feet to a 9-inch, 52 feet to $13\frac{1}{2}$-inch, and 39 feet for an 18-inch cement mortar brick wall; and 26 feet for a 6-inch, 13 feet for a 12-inch, 9 feet for an 18-inch, and 6 feet for a 24-inch. reinforced concrete wall.

In the case of average panes of glass (not shop windows) all glass may be broken within a distance of 200 feet when a 250 kg. bomb explodes, and these panes may be expected to be safe beyond 800 feet.

In clay soil the horizontal distances in feet beyond which damage to pipes, etc., should not occur in the case of a 250 kg. bomb are 30 feet for cast iron or concrete pipes, 24 feet for steel pipes or cables, and 50 feet for earthenware, stone or brick drains and sewers.

(ii) DAMAGE TO ROOF COVERINGS. A near miss by a heavy bomb will shatter asbestos cement sheeting over a large area and break many of the purlins, if of timber construction. Steel purlins, however, are only damaged slightly and then only locally. It has been found that 15,000 square feet of sheeting has been destroyed where a 50 kg. bomb has burst under such a roof, the purlins and trusses being only damaged in the immediate neighbourhood of the explosion. Lining of asbestos sheeting increases the extent of the damage considerably. Where corrugated steel sheeting or Ruberoid Steel Decking is used, this type of roof is not likely to suffer extensive damage from a near miss of a 50 kg. bomb, but bending of sheeting and buckling of the supporting steelwork over a comparatively small area may occur. The area of sheeting likely to be destroyed by a 50 kg. bomb is about 1,000 square feet.

The ordinary end fixings of the truss in the normal long span shed roof ("umbrella" or "apex lattice" girder) to the wall will usually be inadequate for the uplift (1.25 tons per 50 feet truss spacing 12 feet 6 inches centre to centre) and a simple method of rendering these safe is to hold down the ends of the trusses by means of wire ropes fixed to concrete blocks cast in situ—about 3 feet by 3 feet by 3 feet in the above case. Where a main girder or stanchion may be cut, deflection may be limited by hydraulic jacks or brick piers (see Bulletin C.5).

(iii) DESIGN OF NEW BUILDINGS. Damage to buildings shows the importance of the three following points if the maximum resistance to collapse is to be obtained.

a Buildings should be fully framed. That is to say ALL load should be carried by the steel framework, and not part by the framework and part by external walls.

b The steel framework should be as continuous as possible. That is to say beams and girders should be joined together over supporting stanchions and beam to stanchion and other connections should be as rigid as possible.

c A "safety valve" type of construction should be adopted wherever possible, but particularly in small buildings. That is to say if brick panel walls are required for the protection of plant and personnel they should be of the minimum height necessary to give the required protection. Above this height the walls should be of light sheeting designed to blow out under internal blast without damaging the structural framework.

(iv) STRENGTHENING STEELFRAMED SHED BUILDINGS. This can be effected by welding to strengthen valley beam splices, increasing the cover-plates by site welding to enable them to span across two bays if a stanchion is destroyed. The ends of each pair of trusses framing into a valley should be independently connected to it. In the hangar type, wind bracing in the plane of the rafter (or top chord) should be provided at intervals, not exceeding twice the span of the trusses along the hangar.

(v) WELDING FOR THE REPAIR OF STEELFRAMED SHED BUILDINGS AND FOR STRENGTHENING THEIR RESISTANCE TO AIR ATTACK. Repairs are often delayed and made difficult owing to the very limited stocks of steel sections available for this purpose. When welding is adopted alternative sections may be used in many cases, without difficulty. The following repairs can be carried out by average welders for the strengthening of existing structures and repair of damaged members.

a Strengthening of eaves or valley beams—welding of ends together by developing the top and bottom flanges and webs of the R.S.J.s.

b The provision of additional rafter bracing.

c Repairs to damaged Roof Trusses.

d Repairs to damaged Lattice Girders.

e Repairs to damaged R.S.J.s.

REFERENCES:

Bulletin No. C.5.—Steps that should be taken to increase the resistance of "Umbrella" Type shed roofs to collapse due to air attack.

—Ministry of Home Security.

Bulletin No. C.8.—Structural Damage caused by recent air raids to some single storey buildings.

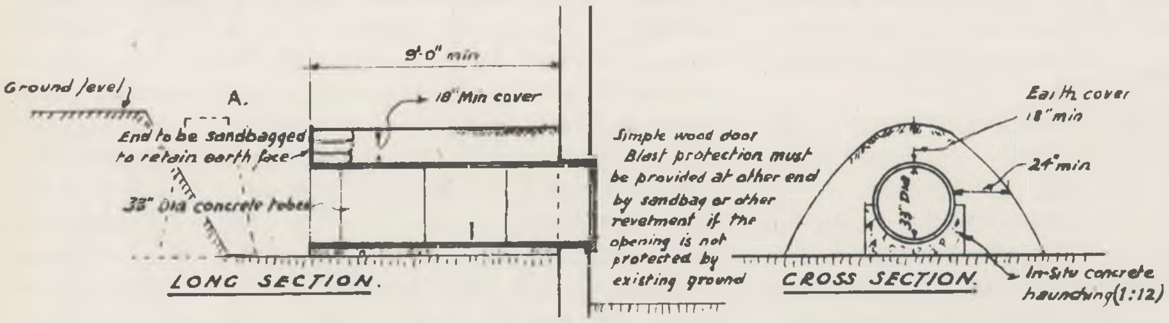
—Ministry of Home Security.

Bulletin No. C.15.—Strengthening steel framed shed buildings against collapse due to air attack.

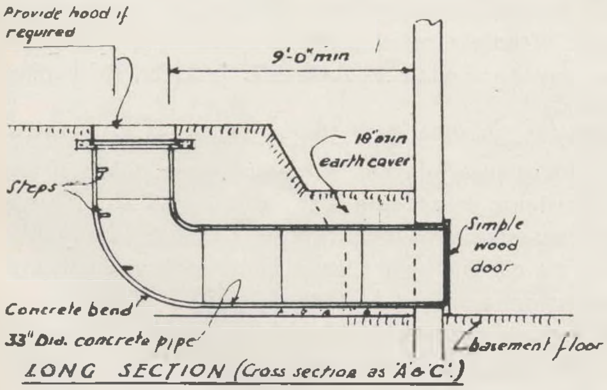
—Ministry of Home Security.

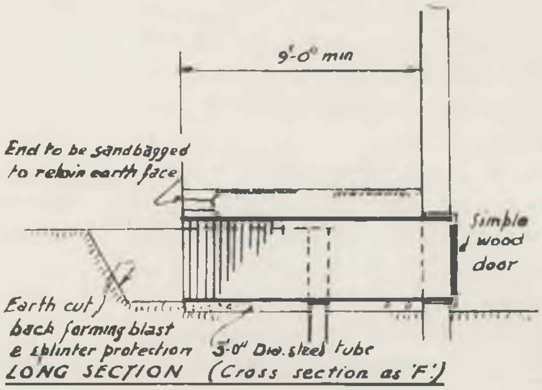
Bulletin No. C.19.—Welding for the repair of steel framed shed buildings and for strengthening their resistance to air attack.

—Ministry of Home Security.



44. STRAIGHT CONCRETE TUBE EXIT USED WHERE GROUND LEVEL IS NOT MORE THAN 4 FEET ABOVE INVERT OF TUBE.

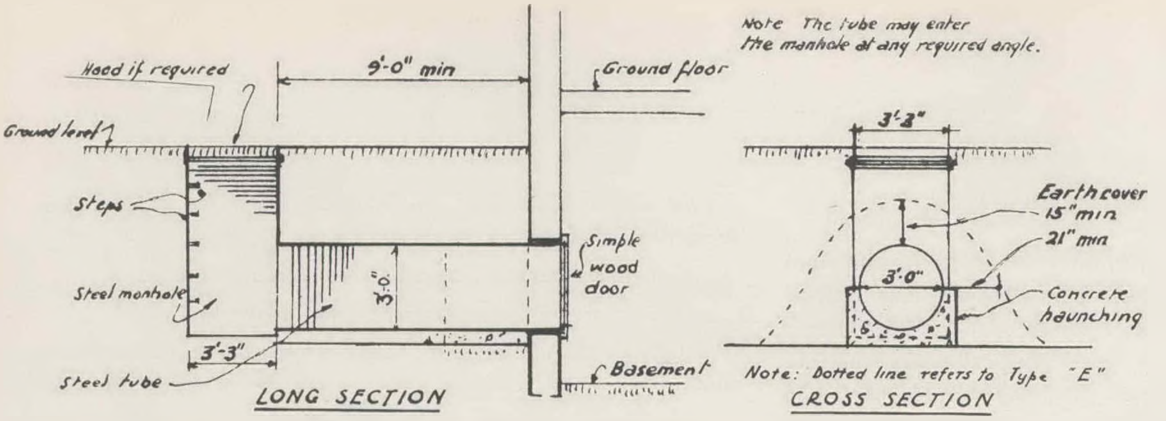




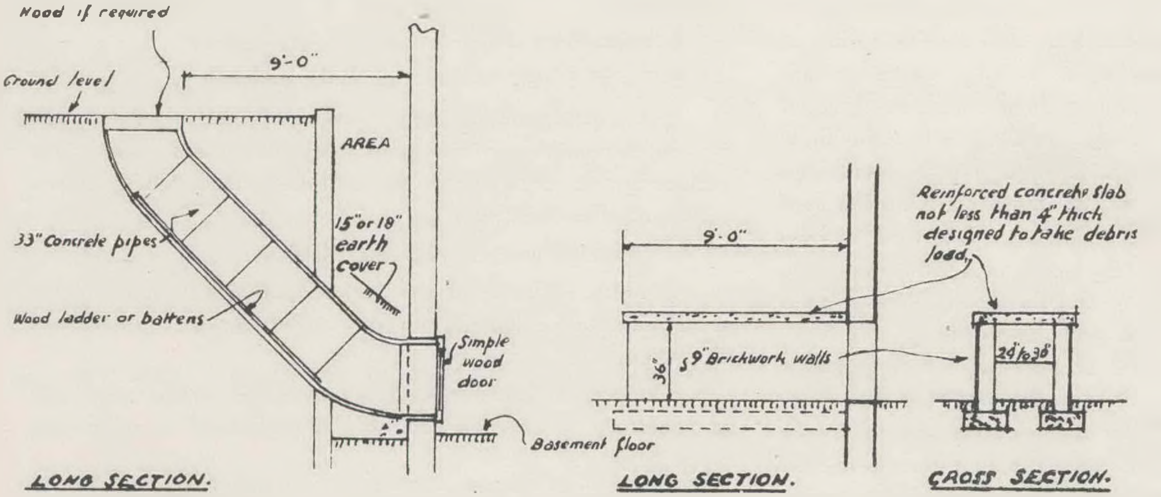
45. CURVED CONCRETE TUBE EXIT.

49. ☛ ISOMETRIC SKETCH OF STEEL HOOD FOR EMERGENCY EXIT.

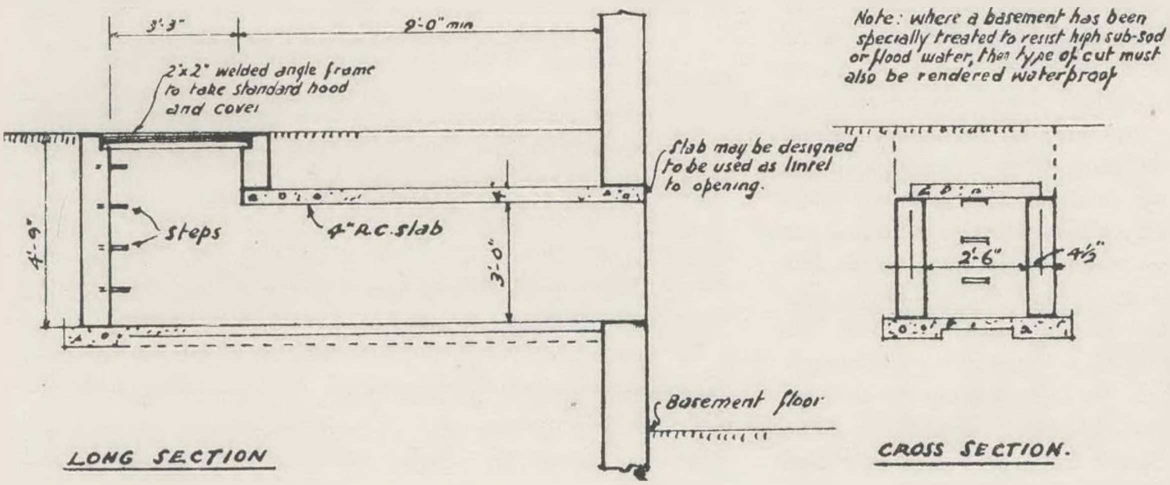
(Figs. 44 to 50 from A.R.P. Memo. No. 10, "Provision of Air Raid Shelters in Basements," Home Office.)



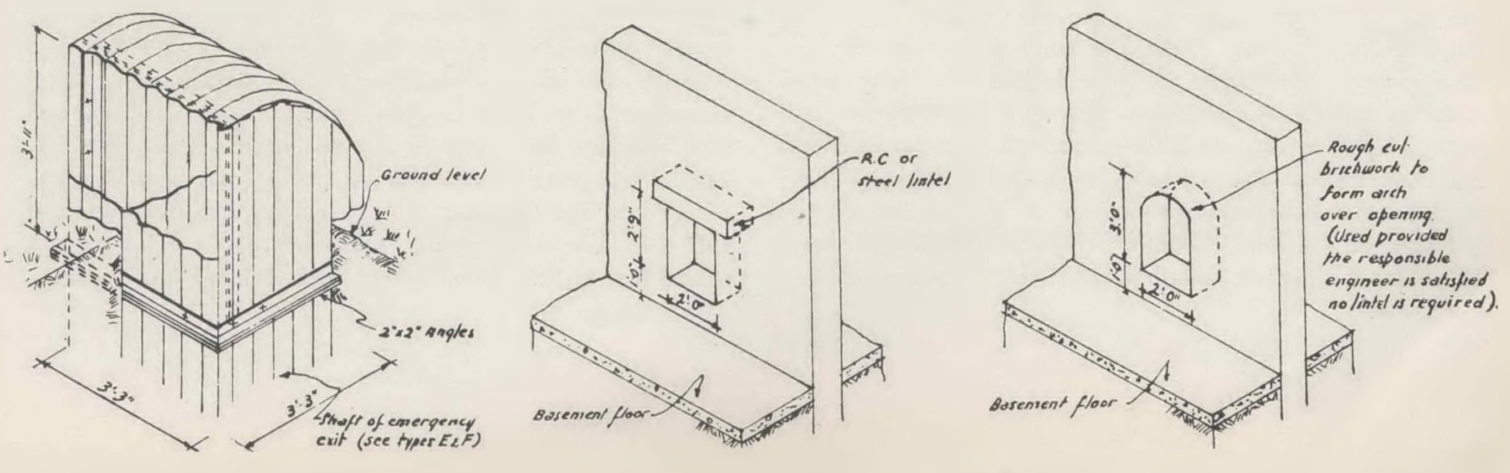
46. CORRUGATED STEEL TUBE AND MANHOLE EXIT.



47. CONCRETE TUBE EXIT AT 45° OR OTHER SUITABLE ANGLE AND A BRICKWORK AND CONCRETE EXIT.



48. BRICKWORK AND CONCRETE EXIT WITH BRICK MANHOLE.



50. TYPES OF EXITS IN PARTY WALLS, THE FIRST WITH A LINTEL, THE SECOND WITH A ROUGH CUT ARCH.

J SHELTERS IN BUILDINGS — COMMERCIAL.

SHELTER IN FRAMED BUILDINGS. Due to the inherent resistance to collapse of modern multi-storeyed fully framed buildings (of which commercial buildings such as large stores are typical examples) and to the high probability that no bomb, unless of the delayed fuse type, will penetrate more than the roof and three floors, portions of higher buildings (more than four storeys high) can be chosen, affording even greater protection than other existing shelters, with the exception of deep tunnels. It is thus possible in a fully framed multi-storeyed building to provide at a very small cost a bomb proof shelter. No multi-storeyed framed building will completely collapse due to a near miss, but panel walls may be demolished with the structural framework still capable of carrying the load from the upper floors of the building. Brickwork can be increased and reinforced from 13½ inches to 22½ inches, up to a height of at least 6 feet above floor level where the ground floor is used, but where possible avoid using the ground floor. If using floors above for a shelter, at least 13½ inches brickwork to a height of 6 feet above floor level should be provided. Glazing should be removed from the windows and the space above any new brickwork should be filled in with non-splinter glass substitutes and/or a ventilator light trap. There is also the possibility of a glancing blow, but penetration under these conditions has not been as great as was expected. The lateral protection against near misses as described above will usually provide adequate protection against a glancing blow from a high level bombing attack. The greatest secondary danger is that from flying splinters of glass. Any internal partitions, doors, etc,, in the shelter space must be removed and, where possible, if alterations involved are not excessive, all doors and light weight internal partitions weighing less than 60 lbs. per square foot should be removed. Heavy false ceilings may collapse and should therefore be removed from over the shelter space in framed buildings. It is possible to accommodate 200 persons in a shelter of this kind, and any sub-divisions of the compartments should have walls of at least 13½ inches of brickwork or equivalent. Spaces between cells can be used to provide lavatory accommodation and means of access to the shelter compartments. Corresponding compartments on the floors immediately above and below should not be used as a shelter. The danger of being trapped by heavy debris is not as serious as in basements, but it is still important that emergency exits are provided. The load due to occupants and bunks may be assumed safely to be 30 lbs. per square foot of floor area. An excellent example of how shelters can be provided on the lower floors of a typical steel framed block of offices is shown in Bulletin C.27, "Shelter Design."

AID RAID SHELTERS IN FACTORIES. The lateral protection to be provided should not be less than:—

a 1½-inch thickness of mild steel plate or plates.

b 12-inch thickness of reinforced concrete.

c 13½-inch thickness of sound brickwork or sound stonework.

d 15-inch thickness of ordinary or structural concrete unreinforced.

e 2-feet thickness of ballast or broken stone.

f 2-feet 6-inch thickness of earth or sand, or

g A corresponding aggregate thickness of a proportionate combination of such materials and overhead protection, subject to the requirements for protection from falling debris, by means of not less than;

a ¼inch thickness of mild steel plate.

b 4-inch thickness of structural concrete reinforced if and as necessary or otherwise suitably strengthened or effectively supported.

c 6-inch thickness of ordinary concrete reinforced if and as necessary or otherwise suitably strengthened or effectively supported.

d Concrete in hollow type construction conforming with the requirements set out in the appendix to part I of the code.

e 8½-inch thickness of arching in sound brickwork or sound stonework.

f 1-foot 6-inch thickness of ballast, broken stone or earth.

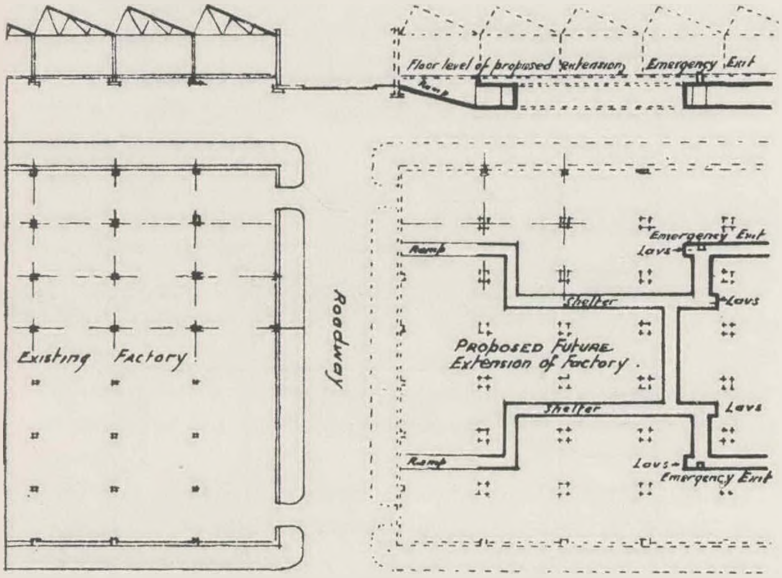
g A corresponding aggregate thickness of a proportionate combination of such materials, or

h A substantial building overhead consisting of a roof and not less than three floors (including that covering the shelter) where such structure is enclosed with walls of brick, stone or concrete.

The space required in shelters, subject, of course, to limits of accommodation, is determined in accordance with the following rules:—

(a) In the case of a shelter accommodating not more than 12 persons, or in the case of a trench shelter having openings at both ends into the open air, it must have for every person accommodated a floor area of not less than 3¾ square feet.

In the case of a shelter other than as described in rule (a) above, not intended to be permanently sealed against gas and ventilated by the entrance and exit or otherwise efficiently ventilated by natural means or by mechanical means at a rate of not less than 50 cubic feet of air per hour per person, it must have for every person accommodated not less than 6 square feet of floor area, not less than 50 cubic feet capacity,



51. SUGGESTED LAYOUT OF TRENCH SHELTERS TO ACCORD WITH FUTURE FACTORY EXTENSION.

not less than 25 square feet of surface area of all walls packed by earth. Other walls not less than $8\frac{1}{2}$ inches thick, floor and ceiling or roof.

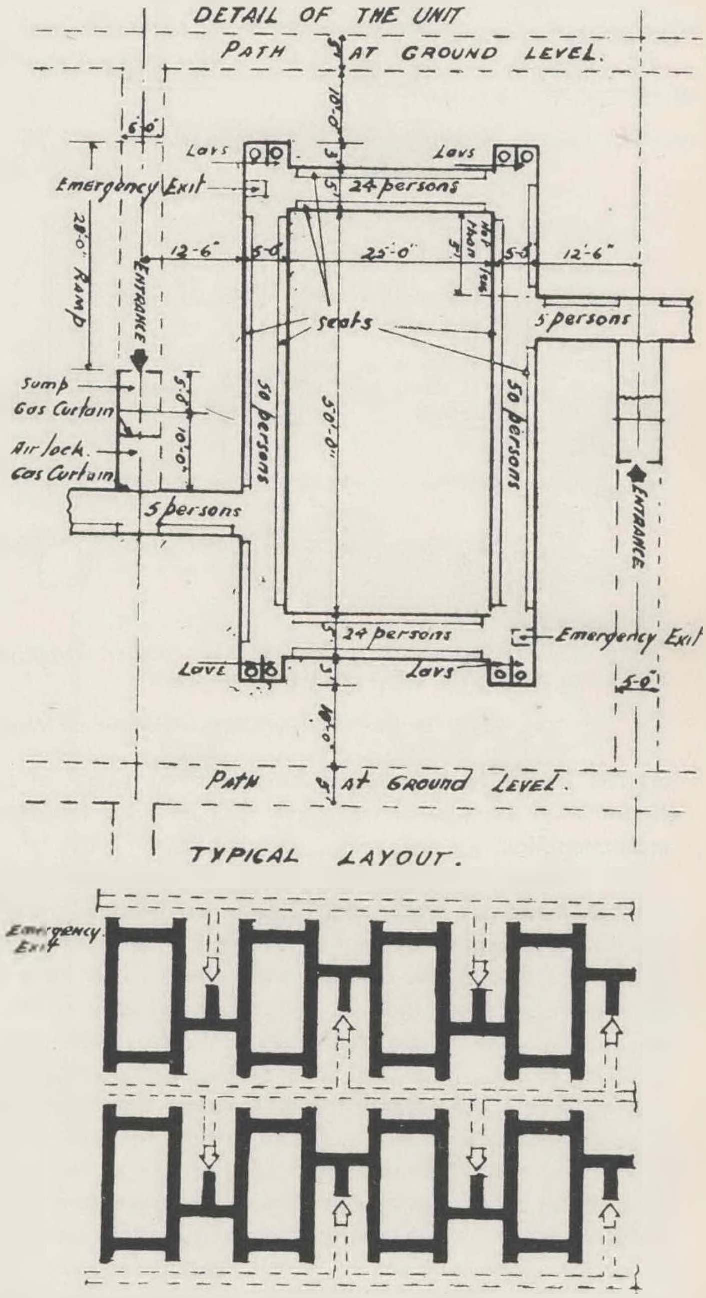
Provided that the floor area capacity or internal surface area of any such shelter may be of less extent subject to the following conditions:—

(i) that the shelter is ventilated mechanically at a substantially higher rate than the normal (exceeding 450 cubic feet of air per hour for every person in the shelter) and provided that satisfactory arrangements are made for emergency operation of the ventilating plant when it will be sufficient if there is a floor area of $3\frac{3}{4}$ square feet for every person in the shelter, or

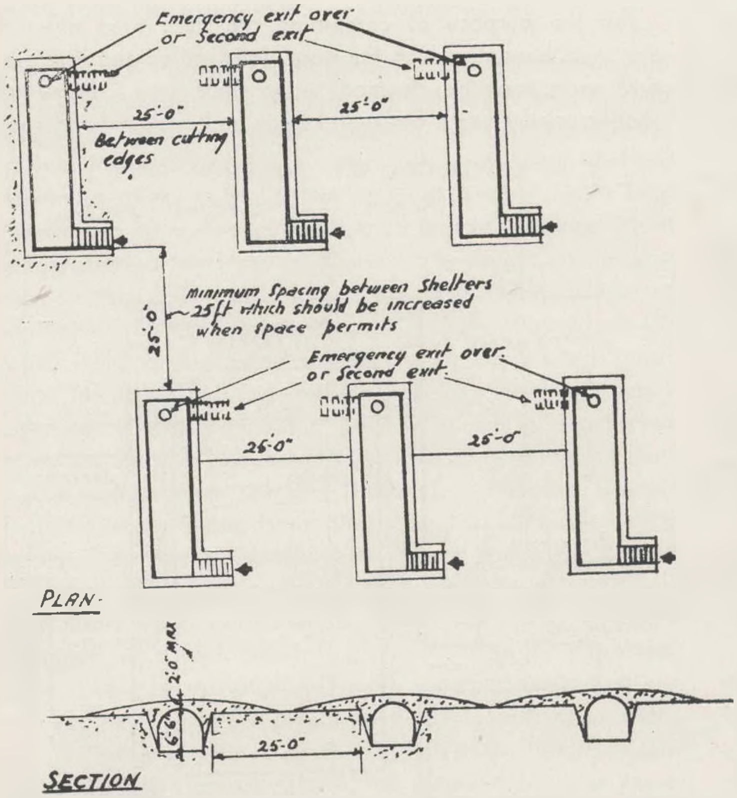
(ii) that the shelter being entirely below ground level has abnormal massive construction with dividing walls not less than 3 feet in thickness at any part inclusive of any solid filling subject to authorisation of the Minister.

In the case of an unventilated shelter accommodating more than twelve persons intended to be permanently sealed against gas during the whole period of occupation. It must have for every person accommodated not less than 6 square feet of floor area. Not less than 50 cubic feet capacity, not less than 75 square feet of surface area of all walls packed by earth. Other walls not less than $8\frac{1}{2}$ inches thick, floor and ceiling or roof.

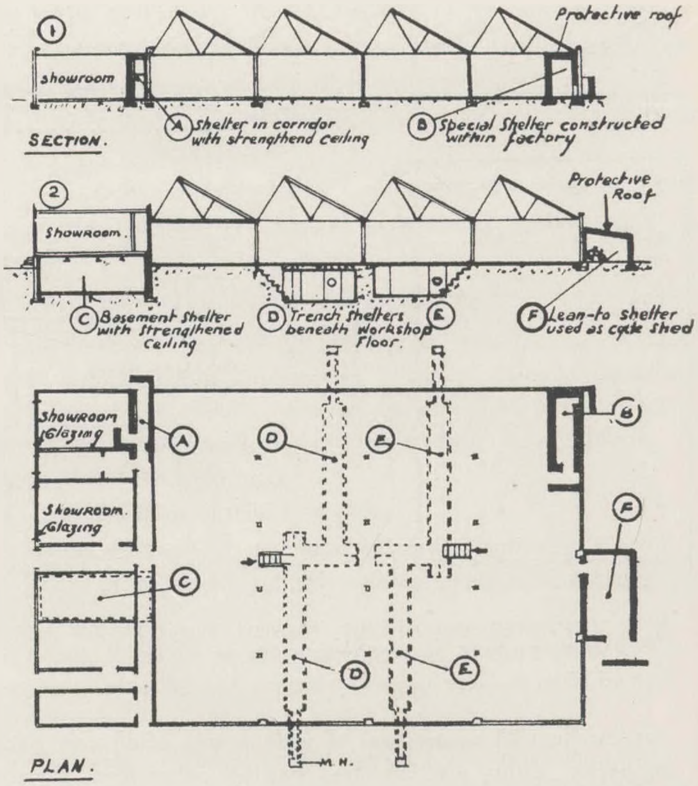
For the purpose of computing the floor area when there are seats beneath which the floor does not extend, the area of such seats may be deemed to be floor area. Every trench shelter usually has a horizontal floor and a clear head room of



52. BLOCK SYSTEM OF TRENCH SHELTERS.
(Figs. 51 and 52 from "Air Raid Shelters for Persons Working in Factories, Mines and Commercial Buildings."—Revised Code, Home Office.)



53. LAYOUT OF INDEPENDENT SHELTERS, EACH ACCOMMODATING NOT MORE THAN 50 PERSONS.



54. SUGGESTIONS FOR THE PROVISION OF SHELTERS IN SINGLE STOREY BUILDINGS WITH LIGHT ROOFS.

(Figs. 53, 54 55 from "Air Raid Shelters for Persons Working in Factories, Mines and Buildings," Revised Code, Home Office.)

not less than 6 feet extending throughout the length of such shelter or of as much of its length as is intended to provide accommodation.

All shelters for more than twelve persons should be, if possible, made gas proof, and shelters must be boldly marked and access provided by day or by night. Entrances should not be less than 2 feet 6 inches wide and exits (at least two per shelter for more than 12 persons) should give access to the open air and be so situated as to be free from danger of falling debris. If the exit is to another air raid shelter the opening should not exceed 3 feet 6 inches high and 2 feet 9 inches wide. Drainage must be carried out and sanitary facilities supplied. The lighting should be such as to have an independent source and if generators of large storage batteries are used, these must be isolated and have separate ventilation. Dangerous pipes must not be permitted in shelters and water and gas pipes provided with valves to permit of their being isolated where they pass through the shelter.

METHODS OF PROVIDING SHELTERS.

a Air raid shelters above or below ground or trench shelters outside the buildings;

b (i) Trenches or tunnels constructed beneath the first floor of the building.

(ii) Using existing basements.

(iii) Adapting any existing rooms on ground or other floors to provide shelters.

(iv) Shelters specially built within the buildings or lean-to's erected against the wall of the building or boundary wall. The above are illustrated in figures 55, 56, 57 and 58. It is important in the case of trench or tunnel shelters that there should be a clear space of not less than 25 feet in any one direction, but clear space from 40 to 50 feet may be provided if the site permits.

PROTECTIVE WALLS IN FACTORIES. These walls were set out originally in Bulletin C.18 (13/6/41). It was found, however, that blast alone was seldom the cause of casualties or of damage to plant, hence the term " blast wall " is a misnomer. The different types of protective walls which have now been recommended are:—

a A buttressed wall of reinforced brick or concrete built on the floor surface:

Suitable for construction in existing factories where space permits and there are objections to opening up of ground.

b A reinforced concrete slab partly embedded in the ground:

Partly suitable for projected factories and where extra high walls are required.

c A wall comprising reinforced brick or concrete panels held at intervals by steel supports partly embedded in the ground:

Suitable for construction in existing factories where space is restricted but conditions permit post supports being driven or sunk.

d A similar wall except that the steel supports take the form of inverted Tees standing in or on the floor instead of being cantilevers:

Suitable for construction in existing factories where space is restricted.

e A movable wall, intended to permit the passage of large objects, such as aircraft, down the lines of production consisting of a series of inverted V-shaped steel frames on wheels with reinforced concrete panels, designed to nest.

The details of the above types of design are set out in full in Bulletin B.10 and certain precautions have to be taken when these protective walls are in single storey factories along the line of existing stanchions. Protective walls, if built into these stanchions increase the risk of damage to the framework by blast, since such walls can then transmit horizontal force to the framework and prevent blast pressure equalising itself around the stanchion. Thus protective walls are best kept separate from the stanchions, or gaps may be left to allow for blast equalisation. Where the fire risk is high and where the type of roof allows for it, the protective wall can be built into existing stanchions, but it is usually virtually impossible to make adequate provision for the resistance of the stanchions to blast, which will shear cap connections and leave the roof unsupported. It may become necessary to heighten and strengthen protective walls and the method of design is set out very fully in Bulletin C.24.

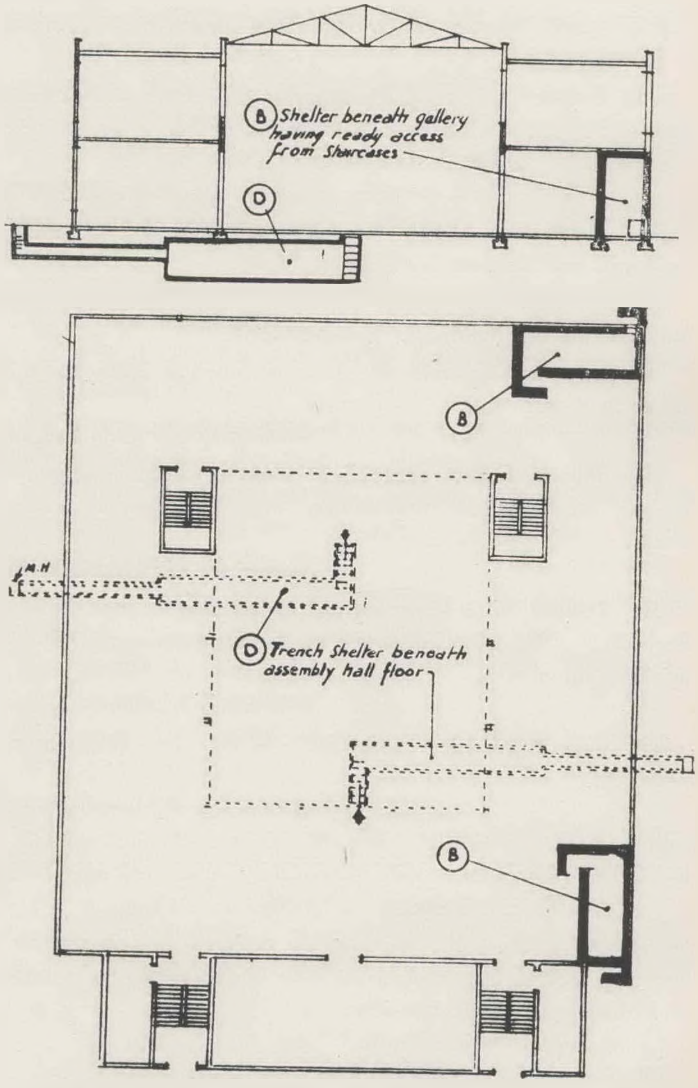
FIXING OF CORRUGATED STEEL SHEETS IN FACTORY ROOFS. It has been found satisfactory to use 3/16ths-inch bolts of the usual standard shape. The area of sheet per hook bolt being 8 square feet. It was found that by using more rigid fixings that damage was caused to the roof structure where blast occurred within the building. By using a less rigid fixing, the roof covering was able to be blown away without damage to purlins, etc. It was also found that the lining of roofs increased the damage to the roof, particularly where such linings were fixed solidly.

REFERENCES:

(i) Bulletin C.18.—Recent Developments in Protective Design for Factories.

—Ministry of Home Security.

(ii) Protection of Plant and Personnel in Factories, Power Stations, etc.



55. SUGGESTIONS FOR THE PROVISION OF SHELTERS IN FACTORIES WITH LARGE ASSEMBLY HALL.
The types of shelters suggested for Single Storey Buildings with light roofs are applicable also in this type of building.

(iii) Memorandum on the Revised Code, "Air Raid Shelters for persons working in Factories, Mines and Commercial Buildings."

—A.R.P. Dept. (Home Office).

(iv) Bulletin C.12.—Single Storey Wartime Factory Design.

—Ministry of Home Security.

(v) The Present Position of the Design of Fixings for Corrugated Steel Sheets for War Factory Roofs. (October 15th, 1941.)

—Ministry of Home Security.

(vi) P.A.D. Measures in Store Sheds and Workshops.

—War Office.

(vii) A.R.P. Memorandum No. 16.—Emergency Protection in Factories.

(viii) Circular issued by the Minister of Labour and National Service for the Guidance of Occupiers of Factories, to which the Factories (Glass Protection Act) 1940, applies.

—Ministry of Labour and National Service.

(ix) A.R.P. Handbook No. 6.—Air Raid Precautions in Factories and Business Premises.

(x) Air Raid Shelters for Persons working in Factories, Mines and Commercial Buildings. Revised Code.

(xi) Circular CE/GEN/52.—Use of Salvage Bricks for Civil Defence Works.

—Ministry of Home Security.

(xii) Bulletin C.24.—Protective Walls in Single-Storey Factories. Methods of Heightening and Strengthening existing Walls.

—Ministry of Home Security.

(xiii) Bulletin B.12.—Precautions to be taken when building Protective Walls in Single-Storey Factories along a line of existing Stanchions.

—Ministry of Home Security.

(xiv) Bulletin B.10.—Protective Walls in Single-Storey Factories.

—Ministry of Home Security.

K OBSCURATION, VENTILATION AND PROTECTION AGAINST GLASS

Generally speaking the work to be covered in this section is not only that of obscuration but also the treatment of windows and other openings to provide:

(i) Adequate natural light.
(ii) Reasonable ventilation in the blackout.
(iii) Protection from flying and falling glass.
(iv) Protection from weather if the glass is broken.
(v) Maintenance of the blackout if glass is broken.

The effect of high explosive bombs is to shatter glass completely within 200 feet of the bursting of the bomb, but this can take place even up to distances of 800 feet and glass has been cracked at distances of 1,200 feet. It can therefore be seen that if an opening is to be maintained, glass must be replaced in such a case by a flexible substitute. In large buildings, rising out of the previous remarks three most important points have to be borne in mind and provided for:—

(i) Protection of plant and products, etc., from the weather after glass is broken, i.e., maintenance of use of the building.

(ii) Maintaining obscuration when the glass is broken.

(iii) Protection from flying and falling glass.

It is all important that a good working light be maintained, and when natural light has been shut out artificial light should then be of a higher standard than the officially recommended minimum. The factors governing design are as follows:—

(i) The proportion of existing glazing to be permanently obscured should be determined so as to give reasonable uniform day-light on the working plane over the greater part of the day-light hours.

(ii) Where the permanently obscured proportion is high, the cost of extra artificial illumination must be considered.

(iii) Methods of obscuration should allow for adequate artificial light without risk of light leakage.

(iv) Methods of obscuration should give access for cleaning the glass.

(v) Labour and maintenance costs in working controllable obscuration must be considered in relation to first cost.

(vi) The appropriate glazing to be fitted for controllable obscuration (which is relatively expensive) against that which is permanently obscured will be less if the interiors are painted a light colour.

(vii) In deciding on the proportion of permanent and controllable obscuration the fact should be noted that certain types of controllable obscuration cut off a certain amount of light even when open.

(viii) The most valuable light sources should be retained.

(ix) The availability of materials is a matter of extreme importance to the designer.

(x) Considering various factors above a decision must be made as to

a Degree of weather resistance desired if the glass is broken.

b Degree of protection against flying and falling glass to be aimed at.

(xi) Controllable obscuration must be so constructed as to be effective very quickly.

(xii) It must be remembered that with controllable obscuration when the glass has been broken the interiors will be darkened until such time as new materials are obtained and fixed.

With all types of obscuration and treatments of glass, care must be taken to use materials with the utmost economy. There must be no waste in thickness of structural members and any gearing and operating parts should be simple. All types should prevent light leakage and thought given to questions of speed of operations and maintenance and risk of faults in operation.

CONTROLLABLE OBSCURATION.

(i) EXTERNAL MOVABLE SHUTTERS. Generally economical for use on roof glazing only and last at least three years.

ADVANTAGES:

a Easily rendered weather proof.

b Eliminates "shine" and permits camouflage treatment continuous over roof.

c Not interfered with by internal obstructions such as roof trusses, pipes, runways, etc.

DISADVANTAGES:

a No protection (by themselves) to interior protection against flying glass.

b Do not lessen risk of glass breakage.

c Cannot be relied upon for camouflage unless capable of being rapidly closed on receipt of air-raid warning.

Avoid use of cement-asbestos sheeting or other brittle materials.

(ii) INTERNAL MOVABLE SHUTTERS. Also only economical for roof glazing. May be of less durable materials than external.

ADVANTAGES:

a Complete protection against flying glass when closed.

DISADVANTAGES:

a Harder to waterproof than external shutters.

b Protection against flying glass necessary, which cuts down daylight.

d Pipes and runways may complicate design and render method uneconomical.

(iii) INTERNAL LIGHT WEIGHT SCREENS. Used for vertical glazing.

ADVANTAGES:

a Simple and cheap.

b Light and easily put into place.

c Protect against flying glass if of suitable material and in place.

DISADVANTAGES:

a Only temporary weather resistance unless special precautions taken.

b Protect against flying glass only if in position.

MATERIALS:

a STOUT KRAFT LINER BOARD: Min. .016 in.

b CORRUGATED FIBREBOARD.

c SOLID FIBREBOARD.

d WALL OR BUILDING BOARD.

e PLYWOOD.

f WIRE NETTING AND FABRIC.

g BOX SHOOKS: Frame and cross battens necessary.

h THIN METAL SHEETS: If weight not excessive.

i BITUMINOUS SHEETING OR LINOLEUM: Framed.

j PLASTERBOARDS.

k FIRE RESISTING SHEET MATERIAL.

l INSULATING BOARDS.

m MATTING Dense, bound at edges. Wire netting advantages.

(iv) BLINDS OR CURTAINS. Blinds for vertical or sloping glazing, but curtains only for vertical.

ADVANTAGES:

a Often cheapest form.

b Affords slight weather protection with vertical glazing.

DISADVANTAGES:

a Unless specially designed cannot be relied on to give weather protection, especially in sloping glazing.

b Unless of heavy material, cannot give complete protection against flying glass.

PERMANENT OBSCURATION.

(i) GLASS REPLACED BY WEATHER RESISTING SHEET MATERIAL. The only way to eliminate flying glass.

(ii) EXTERNAL FIXED SHUTTERS.

(iii) INTERNAL FIXED SHUTTERS.

(iv) OPAQUE MATERIAL FIXED TO GLASS.

(v) PAINT.

PROTECTION FROM FLYING GLASS.

(i) GLASS REPLACED BY FLEXIBLE SUBSTITUTE. Ideal but costly.

(ii) GLASS REPLACED BY WIRED GLASS.

(iii) WIRE NETTING PLACED BEHIND THE GLASS.

(iv) ANTI-SCATTER ADHESIVE TREATMENTS FOR GLASS.

a Textile materials.

b Transparent films.

c Strip treatments.

d Liquid coatings.

VENTILATION:

GENERAL: Natural ventilation can be obtained by the use of ventilation light traps and often by suitable modifications of arrangements for obscuration. Ventilation light traps allow passage of air without leakage of light, either directly or indirectly from sources inside the buildings.

VENTILATOR LIGHT TRAPS:

(i) PRINCIPLE:

a To offer minimum interference with passage of air.

b No direct light or light undergoing specular reflection from polished surfaces should be visible at its exterior entrance.

(ii) EFFECT ON VENTILATION. Reduction of supply of air. Additional ventilations may be necessary.

(iii) DESIGN. Upkeep and replacement and weather resistance must be borne in mind. Devices should be well made.

Light must be EFFECTIVELY trapped. Use of matt black paint. A source of light may be any large, brightly lit, light coloured surface.

Ventilating devices must not unduly obstruct sources of natural light, e.g., at windows.

Question of cleaning windows is to be remembered.

Ventilators should themselves also be kept clear so that passage of air is not obstructed.

CAMOUFLAGE REQUIREMENTS AND OBSCURATION:

Glazing may need camouflage. This, especially for large factories in suburban or rural areas.

a Paint on glass or external shutters.

b "Anti-shine" treatment.

c Nets (reduction 30% to 40%).

Vertical glass appears dark from air and need only be painted to continue camouflage pattern. (Loss of daylight 5% to 50%).

Reliance cannot be placed on receipt of warning, even if quick closing external shutters are used—"Anti-shine" treatment to be used for roof glass.

PROTECTION OF PLATE GLASS WINDOWS:

There is no method of preventing fracture of glass under blast except by complete closing of window openings.

Minimise results of fracture by:

(i) BOARDING UP EXTERNAL DISPLAY WINDOWS: Boarding with stout framing, securely fixed, and provided with hinged shutters over openings exhibited display space. May be displaced. Rolling shutters of steel or wood give less protection than boarding.

(ii) BRICKING UP DISPLAY SPACE: Wall $13\frac{1}{2}$ inches.

(iii) IMPROVING PANELLING BEHIND DISPLAY SPACES:

(iv) WIRE NETTING: $\frac{1}{2}$-inch netting securely fixed and as close to the glass as possible.

(v) BLINDS AND CURTAINS: Moderate degree of protection.

(vi) ADHESIVE TREATMENTS: Only against scatter of glass.

a Varnish and fabric or strong textile netting.

b Textile strips (interspaces 6 inches each way) where considerable transparency is required.

c Transparent film of "cellophane" type.

The above adhesive treatments cannot be used for obscured glass. Liquid coatings and paper strip are not recommended for plate glass.

REMOVAL OF GLASS AND REPAIRS:

Safest plan to remove plate glass and replace if necessary by translucent or opaque materials. Much glass in interior partitions, show cases, fanlights over doors, etc., can be dispensed with. If opening bricked up, leave a glazed aperture 4 feet by 2 feet which will allow inspection from street and indicate shop is open.

PROTECTION OF WINDOWS IN COMMERCIAL AND INDUSTRIAL BUILDINGS:

(1) PROTECTION AGAINST NEAR EFFECTS:

The standards of lateral protection are as described in the code as previously stated. The protection, therefore, against near effects can be divided into two classes:—

(i) Blocking the window opening either wholly or partially.

(ii) Providing some form of moveable shelter either internally of externally.

Under (i) blocking is the easiest and cheapest form of affording protection in ground floor windows and the methods of blocking are as follows:—

(i) Brickwork.

(ii) Frame barricades.

(iii) Filled block barricades.

(iv) Ballast filled shutters.

(v) Concrete block shutters.

(vi) Sandbag barricades (only a temporary measure).

(vii) Barricades made of dry bricks or blocks of stone or concrete.

Such barricades should be at least 6 feet above the level of the floor of the room to be protected. Shutters should be regarded primarily as a method of protecting windows on upper floors where blocking is impracticable.

(2) PROTECTION AGAINST DISTANT EFFECTS:

As stated before, all glass up to 200 feet will be broken by intense blast effects. It is hardly possible to give the extent of the area around the bomb in which glass will be broken except to state that it may be 150 times larger than the area of intense blast effects. The protection therefore of windows against the distant effects of blast is important to prevent dislocation of activities. If windows are left wide open there is less likelihood of the panes being broken and a semi rigid fixing is better than a rigid one, but it must be remembered that where glass is strong in relation to the frame the frame may buckle or be forced out. Wired glass is not just as easily broken by blast as unwired glass in equivalent sheets, but does not even fly out in small dangerous splinters. Glass bricks are excellent, particularly where held in a light framework of reinforced concrete and, where protected against bomb fragments, they can withstand blast up to 50 feet away from the bomb unless they are in exceptionally large areas. It is a peculiarity in the survey of damage done that it has been found that glass partitions and door fanlights have been broken whereas external windows have remained undamaged through being left open. Various adhesive treatments have been applied to glass and these are fully treated in the various A.R.P. Bulletins. It must be remembered that the aim of these treatments is purely and simply to prevent glass from flying into small dangerous splinters—they cannot prevent breakage.

ROOF LIGHTS are a very serious problem. If possible the best is to remove the glass and cover over with galvanised corrugated sheets or other means. Another excellent method which also, however, means a total obscuration is to cover the glass and frames with hessian soaked in bitumen. It is then advisable to put another coat of bitumen over the impregnated hessian. Underneath the glass a lining of half-inch mesh wire netting should be provided. It will be found that this method will allow for a few days of weather resistance even when the glass has been cracked. It will enable replacements to be made when there is an opportunity and permits the various operations to proceed, such as in factories, etc.

REFERENCES:

1. A.R.P. Memorandum No. 12.—Protection of Windows in Commercial and Industrial buildings.

2. Bulletin C.13.—Obscuration, Ventilation and protection from glass in large buildings.
—Ministry of Home Security.

3. Pencil points data Sheets, January and April, 1942.

4. Bulletin C.10 (Revised).—Translucent substitutes for glass.
—Ministry of Home Security.

5. Bulletin B.3.—Effect of broken glass on tyres.
—Ministry of Home Security.

6. Bulletin C.9.—The protection of plate glass windows.
—Ministry of Home Security.

7. Circular issued by the Minister of Labour and National Services for the guidance of Employers of factories to which the Factories (Glass Protection) Order, 1940, applies.

8. Bulletin B.8.—Mildew on Window netting.
—Ministry of Home Security.

9. List of materials approved for the Building Research Station as Anti Scatter treatment for window glass.

L INCENDIARY BOMBS AND THEIR EFFECTS.

Several types and sizes of incendiary bombs have been tried at one time or another by different countries, but the pattern which has been most effectively used is that known as the Electron Bomb weighing not more than 1 kilo.

The German 1 kilo bomb consists of a thick wall tube 9 inches long by 2 inches in diameter made of an alloy of magnesium with a small proportion of aluminium. On one end of this tube there is a tail 5 inches long to steady the bomb in flying, and in some cases fitted with a small explosive charge. The tube itself is filled with a priming composition of a thermite type set off by an igniter. The actual weight of the German type is 2 lbs. 4 ozs. and with exception of a few ozs. is almost entirely made up of incendiary material. This is important when one compares it with the oil types which can range from 50 to 500 lbs. The larger types are filled with oil and in the case of the 250 kg. bomb approximately 16 gallons of inflammable material is used.

The Japanese types are either 50 or 60 kilogrammes being filled with thermite or thermite in conjunction with paraffin wax and kerosene; approximately only half or less of the entire weight of such a bomb consists of inflammable material. The Japanese type causes a major fire of a character considered to be a Fire Brigade responsibility.

The 1 kilo type, on the other hand, is one which can be tackled by the individual—and has to be—as a large bomber can carry anything between 1,000 to 2,000 of these light bombs, depending, of course, upon the weight of petrol carried. It requires 5,000 feet for a 1 kilo bomb to reach its maximum velocity, which is about 350 feet per second. Generally speaking, owing to the fact that these bombs are not streamlined, they cannot be aimed accurately and are thus spread out as they fall. A group of 1 kilo bombs dropped simultaneously from 5,000 feet will cover an area of about 100 yards square. For special targets heavier bombs are utilised, as these are streamlined and can be dropped with greater accuracy on the target chosen. The 1 kilo bomb functions as follows:—

The priming composition (thermite) is ignited and this in turn ignites the magnesium tube which is the main incendiary agent. The priming composition burns from 40 to 50 seconds at a temperature of about 2,500°C. This heat serves to melt and ignite the magnesium and the molten magnesium then burns for 10 to 15 minutes at a temperature of about 13,00°C. This will set fire to anything inflammable within a few feet. During the first 15 seconds while the priming composition is still burning, the bomb looks very violent, but with proper training, which is not covered in these notes, these bombs can be tackled, extinguished or removed. The 1 kilo bomb itself has poor powers of penetration but will penetrate an ordinary roof and is likely to remain in the upper storey, thus either starting a roof fire, or, if it falls on a boarded floor immediately below the roof, the bomb will probably fail to penetrate, but will burn through in a few minutes and set up a conflagration. If there is only a lath and plaster ceiling below the roof, the bomb will penetrate this at once.

M PROTECTION OF BUILDINGS AGAINST INCENDIARIES:

Amongst the materials which have been found to be proof against fractures by impact are the following:—

Mild steel plate—$\frac{1}{4}$-inch thick.

One layer of sandbags laid as closely as possible.

$3\frac{1}{2}$ to 4 inches of good quality reinforced concrete.

With regard to burning, the action of the bomb on floor boards has been found to vary greatly but, generally speaking, it will burn through boards $\frac{7}{8}$-inch thick in four to five minutes. Lead is melted almost at once but corrugated iron (20 gauge) is proof against burning, but during the burning of the composition if a vent hole of the bomb is against the sheet, the blow pipe effect may cause a hole. Also the sheet will get very hot and if in contact with the floor boards may set them on fire. The following materials, amongst others, also provide protection against burning:—

Dry sand 2 inches thick.

Foam slag 2 inches thick.

Household Ash $2\frac{1}{2}$ inches thick.

Earth 2 inches thick (free from vegetable matter).

Preparations, for instance, of the plaster type, made up mainly of ground rock and anhydrite, about $\frac{3}{4}$-inch thick.

Asphalt (certain types) about $\frac{3}{4}$-inch thick.

It must be remembered, however, that sand is heavy and floors must be strong enough to support this weight. The above, of course, deals with protection against 1 kilo bombs. In the case of the larger types, the fire precautions laid down by various Municipalities would have to be adhered to to give full protection.

Generally speaking, however, immediate action is the first essential, but certain measures can be taken for protection against incendiary bombs which are as follows:—

(i) Inflammable material—this should be removed from top floors and roof spaces in buildings with roofs which might be penetrated by incendiary bombs.

(ii) Dispersion—Important inflammable stores should be dispersed and not concentrated. They should be kept where risk of fire is least, provided that they are located well clear of shelters for personnel.

(iii) Material protection—Attic Floors should be covered with non-inflammable material as set out above, but it must be remembered that all plaster boarding used should be free from cement, as sheets containing cement are apt to split under intense heat. To reduce risk of fire, woodwork in attic and roof spaces should be coated with fire-resisting paint or lime wash. For the latter the mixture to be used is:—

2 lbs. of slake lime,

1 oz. of common salt, with

1 pint of COLD water.

Two coats should be applied, the second coat after the first has dried. An excellent method of reducing the possibility of bombs rolling in under the eaves was illustrated in the Pencil Points Data Sheets, March, 1942. Where certain buildings contain important stores of inflammable materials, these should be given overhead protection against the lighter incendiary bombs.

(iv) Observation—early information regarding bombs is essential.

(v) Means of access—Arrangements should be made for all parts of each building, particularly attic spaces, to be reached without delay. Telescopic ladders or suitable step-ladders should be immediately available. Keys should be in their doors or held by the lookout responsible for the building.

(vi) Small fire-fighting equipment—this should be available in all buildings whether large or small.

(vii) Training—every able-bodied man or woman should understand the immediate action necessary for dealing with incendiary bombs and fires.

(viii) Water—water is generally the best means for fire-fighting, but water mains may be damaged in an air raid, or the flow restricted by fire-fighting operations. Consideration should, therefore, be given to alternative sources of supply, while a reserve in buckets or baths should be maintained in each house in times of emergency.

(ix) Chemical fire extinguishers—Chemical fire extinguishers such as those using carbon tetrachloride or methyl bromide should be avoided in closed spaces, as, if the liquid falls on the bomb, toxic gases may be formed. The soda acid extinguisher which ejects ordinary water can be used under any conditions.

STANDARD OF FIRE RESISTANCE IN BASEMENTS—No precaution need be taken by way of fire protecting encasement of any member introduced to strengthen floors against debris loads. Where the floors over the shelters are of temporary construction, not pugged, precautions should be taken in the installation of any strengthening work to ensure a reasonable degree of fire resistance of the building floor system equivalent to construction offering half-an-hour's fire resistance when it is in accordance with British Standard Definition No. 476.

This can be achieved by inserting a continuous layer of suitable protective material between the existing floor and the strengthening.

The required degree of fire resistance is provided by the following:—

(i) Slabs of reinforced concrete together with reinforced concrete or steel beams and columns.

(ii) Slabs of reinforced concrete and hollow tile construction together with reinforced concrete or steel beams and columns.

(iii) Brickwork or masonry arches above or in combination with steel or reinforced concrete beams.

(iv) Concrete slabs and steel joists (Pillar joist Construction).

(v) Pugged timber floors.

(vi) Existing timber floor beneath which is laid a continuous layer of reinforced concrete or a continuous layer of steel sheeting not less in thickness than 16 gauge.

(viii) Existing timber floor beneath which is placed closely spaced timber sheeting not less than 2 inches in thickness.

(The above notes on basement supplied by Professor J. F. Baker, Bulletin C.27, Shelter Design.)

The following table gives fire protection for protection of plant in factories, power stations, etc., and can be applied to larger commercial buildings.

	CAUSE OF FIRE.			
LOCAL PROTECTION AGAINST 1. Fire starting in roof.	High Explosive. High Explosive will penetrate ordinary roof.	Large Incendiary Bomb (Oil bomb. etc.) will penetrate ordinary roof.	In both cases no combustible material should be tolerated in the roof, and good access should exist in whole roof.	Kilo Incendiary Bomb. (i) Make roof covering weak enough to give probability that Incendiary Bomb will penetrate roof, can be extinguished on the floor. (ii) Make roof resistent to small Incendiary Bomb.
2. Fire starting on floor or floors.	All kinds of bomb	i. Elimination of treatment or all combustible parts of building. ii. Permanent access to all parts of floor, balconies, rack roofs, etc.		
3. Fire starting among stores or processes.	All kinds of bomb	Surrounding protection of all inflammable and combustible stores and processes.		
PROTECTION AGAINST SPEED OF FIRE.	i. Segregation and dispersal outside main shed of all inflammable stores and processes. ii. Dispersal inside factory of all combustible stores and processes. iii. Sub-division of floor and roof space by fire-resisting barriers in order to restrict spread of fire, thereby (a) localising damage; (b) restraining temperature; (c) concentrating firefighting area. iv. Surrounding of hoist and lift wells, protection of holes for pipes, traps, etc. v. Provision of full equipment, and ample mains and static water. vi. Efficient firewatching and firefighting organisation.			
DESIGN AGAINST COLLAPSE DUE TO FIRE.	i. Incombustible roofs, floor and wall materials. ii. Such materials to be also resistant to breaking up under effects of fire and water. iii. Strengthening of structure to eliminate spreading collapse. iv. Encasement of stanchions, etc.			

REFERENCES:

1. Protection of Plant and Personnel in Factories, Power Stations, etc.

—Ministry of Home Security.

2. Automatic Devices for the detection of Incendiary bombs. Bulletin C.22.

—Ministry of Home Security.

3. A.R.P. Handbook No. 9.—Incendiary Bombs and Fire Precautions.

4. Chemical Fire Extinguishers. Bulletin C.11.

—Ministry of Home Security.

5. Bulletin C.23.—Technical Notes on the Structural Protection of Building against Incendiary Bombs.

—Ministry of Home Security.

N WAR GASES AND EFFECTS:

A War gas is any substance whether solid, liquid, or vapour used in war for its poisonous, irritant or blistering effect.

The number of poisonous substances which could be employed offensively in war is limited and, although experiments have been carried out with numerous gases, only a few proved to be of any practical use in the Great War.

Since then the development of respirators and of anti-gas appliances has advanced considerably; and in the opinion of scientists the probability of a new gas being discovered is remote.

War gases are classified as being persistent, i.e., liquid which evaporates slowly, or non-persistent gases, i.e., gases which when released may be carried away by the wind and are quickly dispersed. They are further divided into four groups according to the action which they have on the human body. The groups are:—

1. CHOKING GASES:

These are usually non-persistent and the respirator gives complete protection.

2. NOSE GASES:

These are harassing agents only and do no permanent damage. They are non-persistent and the respirator gives complete protection.

3. TEAR GASES:

These are harassing agents only and do no permanent damage; respirator gives complete protection.

4. BLISTER GASES.

These are persistent and can do extensive damage to the skin or any part of the body it comes in contact with. Respirator gives protection against vapour inhaled into the lungs, but extensive damage can be done to the skin which is not protected by anti-gas capes or other means.

It is not the intention here to go into the methods of decontamination. The gases that must be considered from the structural point of view are chiefly those which can enter a building, i.e., vapour.

O GAS-PROOFING OF SHELTERS AND BUILDINGS:

In the United Kingdom all members of the public as well as the armed forces are supplied with respirators, and in addition gas-proofing has been carried out in shelters, dugouts, etc. In buildings unless they are strong enough to withstand severe cracking, it is difficult to gas-proof effectively.

The two methods, of course, of gas attacks from the air which have to be considered are:—

(i) GAS BOMBS—These are usually made with light cases and contain as much gas as possible. Blister gas is the most probable filling on account of its persistency and casualty possibilities. The use of choking gas is possible, though to be effective high concentrations are required, which are difficult to produce in the open.

(ii) GAS SPRAY—This form of attack is unlikely except against concentration of troops or other persons in the open for the following reasons:—

a Gas spray falling on roof is ineffective.

b People in buildings are completely protected.

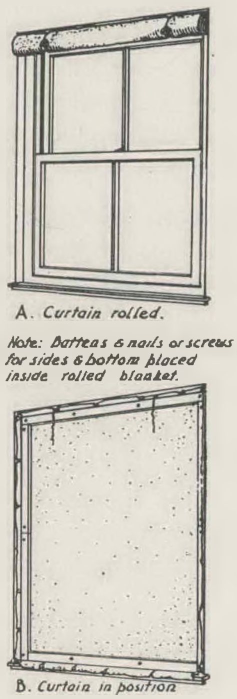
c Spray dropped from a fair height evaporates in a few hours. Where this form of attack is adopted only blister gas is likely to be used.

METHODS OF GAS PROOFING:

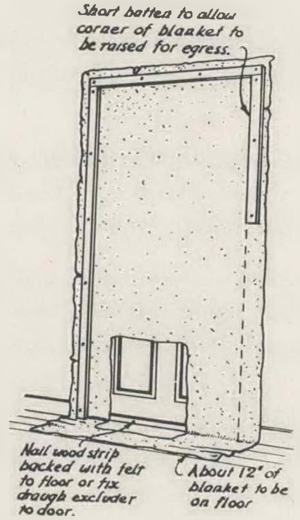
1. GENERAL. When an air attack is imminent, shutters, where provided, will be fixed in window frames. Complete protection against the entry of any type of gas can be obtained by the gas proofing methods described below. Should a gas proof room be holed by blast or splinters, it may be possible to preserve the gas proofing by the use of extra material held in readiness inside the building. Should this be impossible respirators should be used to give protection.

2. WINDOWS. As windows should be opened the provision of inside gas proofing is necessary.

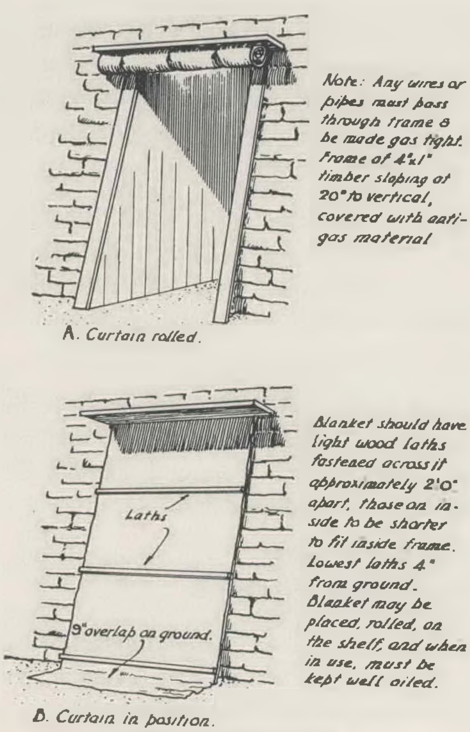
Fig. 56 shows one method. Gas proofing material (cloth, union, anti-gas; blankets, closely woven carpets; cotton or linen sheets backed with strong brown paper, etc.) of a size to overlap the whole window should be held in place at the top by a wooden batten. When not in use the curtain may



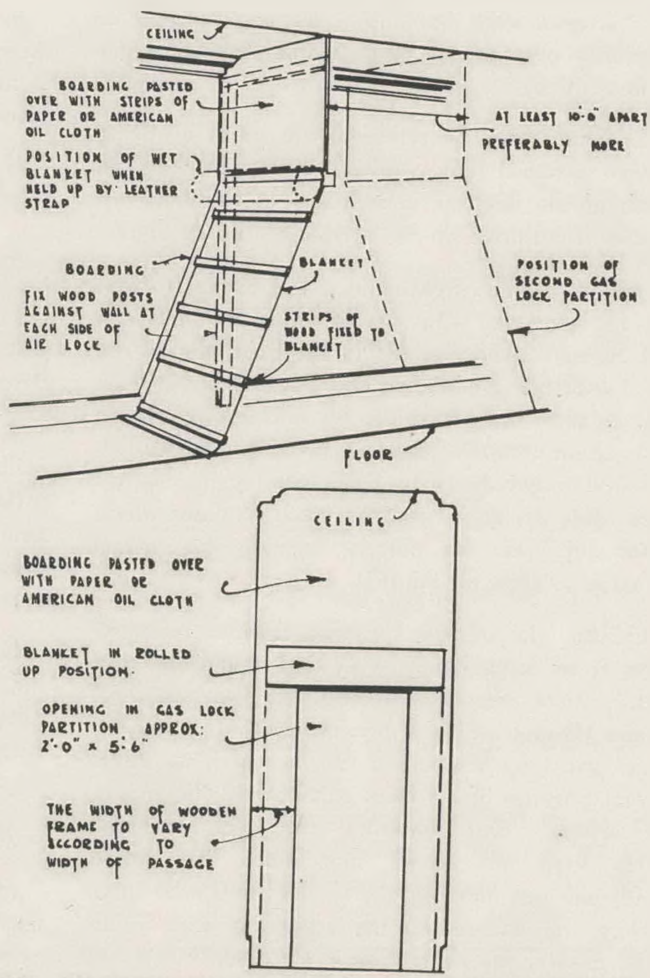
56. GAS PROOF WINDOW.



57. GAS PROTECTED DOOR.



58. TYPE OF AIR LOCK.



59. AIR LOCK CONSTRUCTED WITH BLANKET SCREENS.

be rolled up to this batten and held in place by strings. Spare battens cut to size with the necessary screws or nails should be available for holding the bottom and sides of this curtain against the window frame.

In the case of steel framed windows, the bottom and sides of the curtain when in use should be fixed to the wall with adhesive tape 2 inches to 4 inches wide.

Treatment of the gas proofing material with heavy oil will increase the protection; water should not be used for this purpose as it is only temporarily effective and increases the humidity in the shelter.

Improved protection against both gas and glass splinters is given by a frame of iron or wood which will fit accurately on the inside of the window. Over this frame may be placed galvanised iron sheeting, ply wood, or blanket material supported on both sides by small mesh wire netting. The frame should be provided with strips of felt or other material to ensure close contact with the window frame. Wedges or bolts with butterfly nuts should be available for fixing this frame quickly in position.

3. DOORS. Doors may be rendered gas proof by fixing strips of suitable material (felt, rubber, baize, blanket) all round the edge of the door or door frame; a wooden strip may be necessary in addition at the bottom of the door.

Alternately, doors may be treated in a way similar to that recommended for windows, with the following modification: The gas proof curtain should be outside the door; the batten on the handle side of the door should end about five feet from the floor level to allow the blanket to be raised by a person using the door; about 1 foot of blanket should be left trailing on the floor and a weight should be fixed to bring the blanket back into place after the door has been used. In cases where the door opens outwards, the material forming the curtain should be increased to allow for this (57).

4. AIR LOCKS. In all gas proofed shelters entrances which may have to be used during an air raid should be fitted with "air locks." These are compartments with two gas proof doors or curtains through which a person entering or leaving the shelter must pass. By having one or other of these doors closed the direct passage of air from outside into the shelter can be prevented. Gas entering the air lock will be diluted to such an extent that when the inside door is opened, any gas entering the shelter will be so weak as to be harmless. For this reason, the larger the space inside the air lock the greater the protection it will give.

Fig. 58 shows one method of construction, by setting up two blanket curtains across the entrance passage. The curtains should be at least 4 feet apart; 10 feet should be aimed at to give greater protection and to allow for a stretcher case with bearers to enter. The best arrangement is for the blankets to rest on inclined frames to ensure a close fit.

The blanket should have light wood slats fastened across it approximately 2 feet apart to keep it hanging flat. A shelf should be fixed above the curtain, on which it can be placed, rolled up, when not in use. When in use the curtains should be kept oiled.

Fig. 59 shows a modification of this method for use where the ceiling is high. Similar methods may be employed for air locks in shelter trenches. Air locks can be elaborated according to circumstances. For example, a whole room or passage may form an air lock provided they have two gas proof doors and the remainder of the room or passage is gas proof.

5. FIREPLACES. Fires will be put out and the fireplaces themselves made gas proof. If the opening to the chimney is small, this can be proofed by filling it with old rags or pieces of cloth or a mush of newspaper soaked in water.

If the opening is large it must be dealt with in the same way as the inside of a window.

6. VENTILATORS, CRACKS OR HOLES IN WALLS, CEILINGS, FLOORS, DOORS, KEYHOLES, ETC. These should be covered with tough gummed paper or filled with pieces of cloth, old rags, mush of newspaper and water, putty, strips of stout paper or any other convenient method.

7. VENTILATORS BELOW THE FLOOR OF THE BUILDING IN WHICH THE GAS PROOF ROOM IS SITUATED. In a normal building there are ventilators just below the floor at ground-level all round the building and these produce a current of air circulating under the floor of the whole building.

If the floor is not sufficiently well made to be gas proof it will be necessary to gas proof all these ventilators to prevent gas being drawn through them and entering the gas proofed rooms themselves through the floor.

8. OVERFLOW PIPES. Any pipes of this type leading to the outside should be plugged.

FIRST AID AND GAS CLEANSING STATIONS. These must be provided for, an example being an excellent design produced by the Cement Association.

REFERENCES:

1. P.A.D. Protection on Hospitals. War Office.

2. Ministry of Home Security. Report on Decontamination and Cleansing, June, 1941.

3. Preliminary Report on Trial Arrangements for Decontamination of Clothing at Knowle Mental Hospital, July, 1941.

4. A.R.P. Sheets—Don Graf data sheets "Pencil Points," January to June, 1942.

5. Blast and Splinter "Screens—Building," June, 1942.—Hollow Concrete Blocks.

6. A.R.P. Handbook No. 5. Structural Precautions against bombs and Gas.

7. A.R.P. Memorandum No. 5. Anti-gas training.

8. A.R.P. Handbook No. 1. Personal Protection against Gas.

9. A.R.P. Handbook No. 2. First Aid Nursing for Gas casualties.

10. A.R.P. Handbook No. 3. Medical Treatment of Gas casualties.

11. A.R.P. Handbook No. 4. Decontamination of Materials.

12. The Protection of Foodstuffs against Poison Gas. Ministry of Home Security.

A complete set of the publications referred to in this article are held in the offices of the Institute of South African Architects, and are available for reference.

Although not having specific reference to the subject matter discussed in this article, the following references have been included as being of general interest and of use to C.P.S. personnel.

REFERENCES:

1. A.R.P. Memorandum No. 2. Rescue Parties and Clearance of Debris.

2. A.R.P. Memorandum No. 11. Camouflage of Large Installations.

3. A.R.P. Memorandum No. 4. Organisation of the Air-raid Wardens Services.

4. A.R.P. Memorandum No. 7. Personnel Requirements for Air-raid and Fire Precautions Services.

5. A.R.P. Department Circular No. 248/1939. Road Traffic during an Air-raid Warning.

6. Home Security Circular No. 8/1940. Exemptions from the Lighting (Restrictions) Order Saw-milling.

7. A.R.P. War-time Lighting Restrictions for Shops.

8. Home Security Circular No. 53/1940. Aids to Movement of Traffic.

9. Home Security Circular No. 89/1940. Railway Lighting during Air-raids.

10. Home Security Circular No. 11/1940 Lighting (Restrictions) Order, 1940.

11. A.R.P. Department Circular No. 121/1939. Aids to the Movement of Traffic to be installed in Roads and Streets in the absence of Street Lighting.

12. A.R.P. Department Circular No. 345/1939. Street Lighting.

13. Home Security Circular No. 105/1940 Lighting (Restrictions) Order, 1940.

14. A.R.P. Department Circular No. 319/1939. Shop Window Lighting.

15. Home Security Circular No. 60/1940. Lighting Restrictions and use of Orchard Heaters.

16. A.R.P. Department Circular No. 346/1939. Supply and Use of Petrol for Civil Defence Purposes.

17. Ministry of Home Security. Bulletin No. B.11. The Vulnerability of Dams to Enemy Action.

18. A.R.P. Memorandum No. C.7. Air-raid Precautions for Canals, navigable rivers, Land Drainage Channels and tidal Embankments.

19. Air-raid Shelters Report of the Lord Privy Seal's Conference.

20. A.R.P. Department Circular No. 310/1939. The Testing of Air-raid warning Sirens.

21. Home Security No. 6/1940. Faults in Air-raid Warning Sirens.

22. A.R.P. Department Circular No. 339/1941. Distribution of the Preliminary Caution Air-raid Warning Message to Civil Defence Personnel. Ministry of Home Security.

NOTE ON THE PUBLICATION OF THIS ISSUE

At the time that it was decided to publish these lectures given by Captain M. F. Stern, it was agreed that copies should be available to persons other than members of the Institute of South African Architects at a cost of 2s. per copy. A considerable number of applications have been received, for which only a sufficient number of additional copies will be printed owing to the restrictions on the use of paper. Should further copies be required, applications must reach the Secretary, Transvaal Provincial Institute of South African Architects, 611, Kelvin House, 75, Marshall Street, Johannesburg, on or before November 2nd, 1942, after which no application can be accepted.