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INSTRUCTIONS FOR THE ESTABLISHMENT OF CIVIL-DEFENSE AIR-RAID SHELTERS

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INSTRUCTIONS FOR THE ESTABLISHMENT OF CIVIL-DEFENSE AIR-RAID SHELTERS

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AIR RAID WEAPONS

Before we can plan successful defensive measures and make efficient and economical preparation for the equipment necessary to those measures, we must know the method and weapons with which the enemy attacks; we must know the qualitative and quantitative effects of offensive weapons.

A bomb is a weapon or device which, after release from an airplane, strikes the place where its effect, usually destruction, is desired.

The Components Of A Bomb

Within the case of a bomb there is a charge and a fuse. The bomb case is fitted with fins which assure, acting in conjunction with the center of gravity, that the bomb will fall in its trajectory with the tip first, and will strike the target in this position. This permits a more certain functioning of the fuse device, and is also an absolute necessity for correct target impact.

The shape of a bomb is prescribed partially by aerodynamic factors, partially by its placement in or on the airplane, and partially by mass production methods. The bomb shape most often used is cylindrical, with one end pointed.

The charge of a bomb may consist of explosives, or incendiary, illuminating, smoke-or gas-producing agents. These various charges are activated at the proper time by means of a chain of detonation, the bomb fuse device.

The bomb fuse is a device which at the proper point on the trajectory or at the moment of impact, activates or detonates the charge. (See Figure 1.)

Bombs are suspended in the airplane in a horizontal or a perpendicular position. Bombs suspended horizontally are attached to the wing or fuselage of the plane by means of a suspension ring placed at the bomb's center of gravity.

Bombs suspended vertically are hung in the bomb-bay inside the fuselage, suspended by means of a suspension ring at the tip. The suspension device in the airplane is generally electromagnetic, or a manual or automatic device operated by compressed air.

The suspension device is the drop-controlling device of the bombs, as well, by means of which the bomb falls of its own weight upon release at the proper time. By means of the release device it is possible to drop bombs singly, in succession, or all at once.

The nature of the target (bridge, railroads, columns of troops, cities, etc.) and the effect required prescribe the method of release and the number of bombs to be dropped.

Bomb Types

From a tactical standpoint, we can divide aerial bombs according to their effects, into two classes: explosive and special-purpose bombs.

Explosive Bombs

Explosive bombs accomplish their mission by an explosion which causes demolition, fragmentation, or fires.

According to their uses, we can classify them as fragmentation and demolition bombs.

Fragmentation Bombs

Fragmentation bombs are used for the destruction of living and lesser resistant material targets by great fragmentation occuring at their detonation. In order to achieve this great fragmentation, the walls of the bomb casing are thicker, though the explosive charge amounts to only 7 to 20% of the total bomb weight. The charge must shatter the walls of the casing into bits, and impart sufficient energy to the fragments to enable them to accomplish their destructive and wounding missions. The number of fragments at the moment of detonation is generally from 2,000 to 6,000. The energy of the fragments depends, in addition to the quality of the charge, upon the size and shape of the fragments. From the tactical standpoint, destructive fragments are those having an impact force of 8 to 15 m-kg. The weight of the most effective fragments is between 5 and 20 g. By a more precise definition, the scattered bits of the fragmentation bomb are the smaller "splinters," while the bits of casing of the demolition bomb are the heavier "fragments". The average speed of the fragments is [illegible] 800 and 1,200 m/sec; mortal wounds are inflicted within 300 m.

The kinetic energy of the fragments following the detonation is quickly reduced by air friction. The resistance of the air depends upon the shape and velocity of the fragments. At the detonation the walls of the bomb casing are burst into fragments of various weights. From the tactical view the serrated, saw-tooth-edged fragments are the most effective, because these can produce the greatest lacerative effect on the human body. (See figure 2.)

We can differentiate between two types of fragmentation distances:

1. The effective fragmentation distance is the distance measured from the point of detonation, where one effective fragment still falls per square meter, and where the force of this fragment is still possessed of destructive power;

2. The dangerous fragmentation distance is the distance where the fragments reach with still sufficient force to be dangerous.

Fragmentation bombs have instantaneous fuses and, as a result, their explosive or fragmentative effects come approximately at the time of impact on the target. When detonation takes place, the fragments scatter uniformly in all directions. Tactically, only those fragments which are within the height of a man are effective. The energy of the fragments arching upwards is abated when they fall back to earth. Generally, fragmentation bombs are made of weights of from 2 to 50 kg. Demolition bombs also have a fragmentation effect if they are fitted with instantaneous fuses.

Demolition Bombs

Demolition bombs, by virtue of their greater charges which result in significant explosive effects, are suitable for overcoming targets of greater solidity. Modern demolition bombs are made in weights of from 50 to 2,500 kg. Against special targets bombs of 4 to 5 t were used in World War II.

Between 40 and 70% of the bomb casing holding the explosive charge forms large fragments at the time of detonation and is therefore suitable for use against living targets, airplanes on fields, etc. The fuse of a demolition bomb is normally a delayed percussion fuse. The most practical delay time is from 0.05 to 0.15 sec, though it is possible for the time to extend to several seconds, or hours, or even days. This interval is necessary so that the fuse of the bomb will detonate the charge of the bomb or will start the chain of detonation, as a result of its striking the target surface.

The demolition bombs then produces its most effective results by penetrating the target, because of its delay in detonation to a depth where it can produce the greatest destruction by its explosion.

As a consequence, the demolition bomb must possess the proper kinetic energy at the moment of impact to allow it to penetrate the target surface. For this, heavier bombs and a proper drop altitude are necessary. Knowing the weight of the bomb and the drop altitude, the kinetic energy (E) of the bomb at the moment of impact can be computed from the formula:

$$E = \frac{m \cdot v^2}{2}$$

where $m = \frac{\text{bomb weight in kg.}}{9.81}$. its dimension is

$$\frac{\text{kg sec}^2}{\text{m}}, \quad \text{and}$$

v = impact velocity of the bomb in m/sec.

Since for a given bomb the weight is constant, its kinetic energy can only increase with the drop altitude, and it will thereby increase its penetrative depth into the target. However, the increase of the terminal velocity is restricted by the air resistance. The maximum value it can attain is 320 m/sec. The quality of the target (humus, reinforced concrete, steel, etc.) also prescribes the depth of penetration.

At the moment of impact the bomb is subjected to very great stress; therefore the tip sections are correspondingly thicker. The middle section of the bomb receives less shock; thus it has a thickness of only 5 to 8 mm. The small wall thickness makes possible a larger explosive charge.

We should mention, however, that generally demolition bombs weighing up to 500 kg are fitted with delayed-action fuses. Demolition bombs weighing 650, 1,000, or 1,800 kg produce their demolition effects often only by the gigantic power of their very great charges on the surface of the target; therefore such bombs (we also call them heavy high-explosive bombs) are usually equipped with instantaneous (non-delay) fuses. These bombs are usually cylindrical (without a point); the walls of the bomb are 8-12 mm thick. To keep them intact until they strike the target, the terminal velocity can be reduced by a chute or a breaking-vane.

Damping circumstances (yards, streets, open ground) influence to a very great degree the efficacy of the heavier demolition bombs. For instance, the detonation of a 1,800 kg bomb with a charge of about 1,000 kg exerts a pressure of 2.5 t/m^2 in a 50-m radius. This can knock down houses. At a distance of 500 m, the pressure has already been reduced to 0.02 t/m^2, but this pressure will still shatter windows.

Special-Purpose Bombs

Special-purpose bombs, with their various charges and fittings, are used for producing special effects and solving tactical problems.

We classify the special-purpose bombs on the basis of the effects produced in the course of their operations, or on the basis of the nature of their charges.

In this manner we can distinguish the following types:

1. incendiary
2. illumination
3. gas
4. smoke
5. rockets
6. balloon
7. propaganda

These types of bombs are not significant from the standpoint of shelter construction, and we shall therefore not treat them in detail.

Bomb Data

Demolition Bombs	Bomb weight in kg	50	100	220	450	900	1000	1800
	Bomb diameter in cm	18 20	26-27	33-36	41-49	56	50-55	67
	Bomb charge in kg	25	30-50	100-114	200-325	580	460-520	1200

Bomb Data (Concl'd)

Armored Bombs	Bomb diameter in cm	--	25	27-33	29-40	34-37	48	
	Bomb charge in kg	--	20	40	105-140	80-200	205	

THE EFFECT OF DEMOLITION BOMBS

To determine the effect of demolition bombs on various materials and buildings, we shall classify the total effect into parts and examine these separately. The effects of demolition bombs are as follows:

1. The bomb penetrates the target material at the point of impact because of the kinetic energy attained in its fall. We call this effect penetration.

2. The impact delivers a great blow on the target and, as a result, the target vibrates. This effect we call shock.

3. After impact the bomb detonates and produces destruction in the impact area. We call this effect demolition.

4. The explosion causes percussion on materials in the area; this percussion extends as a shock wave in solid materials such as earth or rock, or as air pressure and suction in air.

5. As a result of the explosion, buildings in the vicinity are damaged and some parts of them become debris. This we call the debris effect.

6. When detonated, the bomb casing bursts into little pieces scattered at great speed. These tiny fragments, as well as the debris, are scattered with great speed and are what we call splinters.

7. Demolition bombs, directly or indirectly, can cause fires (incendiary effect).

8. The gases formed at the detonation of demolition bombs can also cause poisoning.

9. The bombs produce indirect effects by collapsing buildings or by damaging public utilities (water, gas, electricity, communications).

1. Penetration

The potential energy of the bomb is converted to kinetic energy by its fall; and it delivers a tremendous blow on the target, buries into it, and passes through the less substantial materials.

The degree of penetration and piercing are prescribed, among other things, by whether the whole area of the target is supported, for instance, stretched on the ground, or whether it is supported only at some points, as in the case of building roofs supported by walls. In the latter case a small part of the kinetic energy exerts a shock upon the structure, thereby reducing the degree of penetration.

The following experimental relationship will serve for computing penetration into various soils or construction materials.

$$h_b = \lambda \, k_b \frac{P}{d^2} v \cos \alpha$$

where h_b is the penetration in m; λ is the undimensioned factor dependent upon the shape of the bomb (the value for an armored bomb is 1.3; in other cases, 1.0); k_b is the factor characterizing the anti-penetration resistance of the substance; P is the weight of the bomb in kg; d, the diameter of the bomb in m; v, the impact velocity of the bomb in m/sec; and α is the angle of the bomb trajectory closing in a vertical direction. (See Figure 3.)

In our computations we shall assume, generally, a vertical impact, a maximum terminal velocity of $v = 320 \frac{m}{sec}$ independent of the bomb weight, and $\lambda = 1$. Figure 3 shows the k_b factor values for various target substances.

In the case of a penetration into substances composed of different materials used in alternating layers, we determine the degree of the penetration into the uppermost layer (see Figure 4); and if the value of this appears larger than the thickness of the layer, we reduce, or increase, the part falling into the next layer penetrated by multiplying by the quotients of the k_b factors of the layers.

If the second layer is more resistent than the first, the degree of penetration into it decreases; if it is less resistant, it increases.

If still more layers of varying materials follow, we multiply the penetration into the third layer by the quotients of the resistance factors of the third and second layers, and we reduce or increase proportionately; we treat additional layers in a similar manner.

Significant deviations are possible between the measured penetrations and the penetrations computed with the constants given in Figure 3, because the resistance capacity of the target material can be analyzed only imperfectly with a single k_b factor. In penetration into soil, the penestratification of the soil and the moisture content influence the penetration decisively; therefore we take 30% higher k_b factor values for soils saturated with seepage.

If the target material is concrete or reinforced concrete supported at its edges, or lying flat on the ground, a bomb falling on it will penetrate it; and if the thickness of the layer is insufficient, then the bomb will pierce it, causing a jagged hole on the inner side. The break-through resistance of layers laid on the ground is greater than the resistance of layers supported only on an edge. The thickness of layers on the ground which will give protection against a piercing, taking the density of the soil into consideration, is at least 1.35 to 1.50 h_b; while for unsupported concrete layers, this value is 3.0 h_b; and for reinforced concrete layers, it is 2.0 h_b. In general, in the case of layers laid on uncompacted soil, 1.50 h_b should be used.

Several thin layers are less resistant to piercing than is a single layer equal to the total thicknesses of the thin layers, though the difference is not significant. Additional layers which are farther apart (for instance, ceilings between floors) are more favorable, because these divert the bomb from the direction of its fall, and, as a result, reduce the degree of further penetration.

Thin layers exert a braking influence upon the bomb as it pierces them. This effect means a reduction of the kinetic energy, and, thereby of the terminal velocity of the bomb.

The formula $E_v = CFd$ shows the degree of energy loss in the function of the roof thickness and of the cross-sectional area of the bomb, F, given in cm^2. In this formula the constant of C for a reinforced concrete layer is 10 to 13 m per kg/cm^3; d is the thickness of the layer in cm; and E_v, the energy loss in m/kg.

The energy loss thus derived is subtracted from the energy corresponding to a terminal velocity of 320 m/sec, giving an energy of:

$$E = \frac{P\,320^2}{2g} - CFd$$

since $E = \frac{P\,v^2}{2g}$ The reduced velocity is $v = \sqrt{320^2 - \frac{2g\,CFd}{P}}$

The value of the energy loss computed in this way is extremely inexact, because the bomb falls, due to its deflection by the individual layers, with a greater cross-section on the layers below. The reduction of terminal velocities computed on the basis of normal ceiling thicknesses and bomb weights is not significant. The 320 m/sec terminal velocity of a 1,000 kg bomb is reduced only to 307 m/sec by its piercing a 15 cm reinforced concrete layer.

2. Shock

It is primarily this effect which must be studied in the designing of bomb-shelter roofs. For bomb shelters, the determination of the wall thicknesses resistant to the various bomb weights, and the use of the known covering systems is made by designing the roof to resist penetration and detonation. These results are independent of the span of the shelter roofs, and the wall and span established in this way are dependent only upon the weight of the bomb and the roofing substance.

Shock cannot be studied in such a general manner, because the degree of shock is a function of the various span roofs, which varies in each shelter roof, and the wall and span established in this way are dependent only upon the weight of the bomb and the roofing substance.

Shock cannot be studied in such a general manner, because the degree of shock is a function of the various span roofs, which varies in each shelter roof, and therefore must be determined for each shelter roof individually. The old air-raid instructions gave a formula by Bazen for the planning of the lamination of shelters covered with doubly-supported layers. This formula gave the bending moment which a bomb of given weight and terminal velocity caused in a shelter roof upon impact. In this formula, one-tenth of the kinetic energy of the bomb was considered equal to the change-of-shape effort in the roof added by the effect of the bomb; and the tension condition resulting from this was considered equal to the first blow of the shock. This phenomenon occurred as follows: At the moment of impact the bomb loses velocity and the kinetic energy is converted to local destruction, heat production, deformation of the bomb, and the introduction of shock upon the roof. The shock starts when the bomb and the roof move with a decreasing velocity; the remaining energy is not absorbed because of the elasticity of the roof shape alteration and is transformed into heat through the dissipating vibrations. The whole roof does not take part in this motion, because its edges are supported by immobile outer walls, and, as a result, it cannot be considered a freely contributing body. This fact asserts itself because we take into consideration not the whole mass of the shelter roof (Q), but only the value of Q' reduced by the so-called Cox Theory:

$$Q' = 4 \int_0^a \int_0^b \frac{w^2}{f^2} \; dx \quad dy$$

wherein 2a and 2b are the length of the sides of the roof, f is the bending of the roof center, w (x y) equals the resilient area of the roof for the force operative on the roof center, and Λ is the weight of a roof of uniform area. The center of the coordinate system is the center of the roof. If we utilize this formula for the interrelationships of the roof elements, in practice we obtain the following result most often for a completely fixed four-sided sheet:

$$Q' = 0{\cdot}158\ Q$$

and for a detached circular sheet:

$$Q' = 0{\cdot}250\ Q$$

Both results refer to an impact on the center of the area.

The combined velocity, u, of the masses of the bomb and the roof is derived from the formula below, presupposing nonresilient impact, giving the equalities of the kinetic forces before and after impact:

$$u = \frac{P\ v}{Q' + P}$$

wherein P is the bomb weight and v the impact velocity. That section of the kinetic energy of the bomb which exerts shock upon the roof produces a double effect, in that it displaces a mass of the shelter roof from its resilient position and it overcomes its elastic resistance. This force (Q' + P) causes the elastic alterations in the roof shape. We note that the kinetic energy of the $\frac{Q' + P}{g}$ mass is equal to the force of the alteration of the shape exerted on the roof as a consequence of the static load of the force of Z, supposed operative at the point of impact. That is:

$$\frac{(Q' + P)\ u^2}{2\ g\ c} = \frac{Z\ w}{2}$$

The $\frac{1}{c}$ section of the total effort becomes the shapealtering force. If Q' is the reduced weight, the roof sheet causes a bending of :

$$Z = \frac{u}{\sigma} Q' \quad \text{or} \quad u = \frac{Z\,\sigma}{Q'}$$

Taking this into account, then

$$Z = \frac{u}{\sqrt{c}} \quad \frac{(Q' + P)\,Q'}{g\,\sigma}$$

If we may neglect the trifling weight of the bomb, P, in comparison to Q', then:

$$Z = \frac{u}{\sqrt{g\,\sigma}} \quad \frac{Q'}{\sqrt{c}} \quad \text{or} \quad Z = V \frac{Q'}{\sqrt{c}}$$

wherein v is the so-called dynamic factor, which expresses how many times greater a static load must be considered so that its effect will be equivalent to the effect of the dynamic load. Therefore we plan the roof on the effect of the concentrated force of Q' multiplied by the dynamic factor drived from the above formula. We presume that the impact or force is directed on the least favorable point, the center of the sheet.

In the case of a doubly-supported frame $Q' = 0{\cdot}4357\,\lambda\,l$, wherein λ is the weight of the longitudinal units of the frame, and l is the span of the frame.

$$\delta = \frac{(Q' + P)\,l^3}{48\,E\,I}$$

by substitution, we get

$$\frac{v}{\sqrt{c}} = \sqrt{\frac{48}{c} \quad \frac{u^2}{g\,(Q' + P)} \quad \frac{E\,I}{l^3}}$$

If c equals 10, the girder must be planned for the following pressures:

$$M = \frac{v}{\sqrt{c}} \quad \frac{(Q' + P)}{4} = \sqrt{\frac{1}{10} \quad \frac{u^2}{2g} \quad (P + Q')} \quad \frac{6\,E\,I}{l}$$

The old air-defense instructions referred to this relationship as the so-called "Bazant Formula." The arbitrary use of c = 10 in the formula is open to criticism, since it cannot be justified either by empirical facts or theoretical considerations. In reality, the value of c is far greater than 10, a fact evident from the following.

Computing on the basis of the idea stated, we generally receive very large forces. It is evident from the formula that M will increase rapidly by reducing the span or by increasing the frame rigidity, and it follows from this, in contrast to the principles of static planning, that a sheet made more rigid as a result of a greater E I, due to the greater requirements, is less favorable than a sheet of lesser rigidity (thickness) due to a smaller E I. This conflicts with the usual principles of static planning, and so it will seem a contradiction. It becomes especially striking if we suppose an infinitely rigid roof sheet, because, according to the formula, infinitely great pressures result. There is no elastic change of roof shape; it simply transmits the shock, the energy of which is absorbed by the resilient ground mass beneath the shelter. It is also possible that at this time the total energy is converted to destruction at the point of impact. Therefore we see that in cases where the roof is unable to absorb the elastic change of shape, our ideas need amplification. This amplification will eliminate the uncertainty caused by the arbitrary c constant. It will show that how much the roof is able to absorb in the form of a resilient change of shape depends on the impact of the bomb, the rigidity of the roof, and the duration of the impact.

In the introduction of the dynamic factor we presume that the shelter at the moment of impact will react as an unsupported free body, because the elasticity of the roof supported at the edges is present only after the motion begins, and thus the u velocity, as the initial velocity of the shock, can absorb it. This idea is valid only if the cyclic interval of the impact is much smaller than the number of autovibrations in the roof, since otherwise the roof will still vibrate beneath the interval of the impact and will not be able to take on the total energy of it, or will degenerate it into a simple static load in the case of a very slow impact. The so-called α, "the degree of rapidity," serves to characterize this phenomenon. This is the relationship of the number of vibrations per minute of the progression of a half sine wave set up by the impact and the number of autovibrations per minute of the shelter roof. If we express the dynamic factor v in the "degree of rapidity" function , we get, in the case of a > 3, a value of $v = 2/\alpha$, which is identical with the $v/\sqrt{g\delta}$ values deduced previously. However, in a case of $\alpha < 3$ the dynamic factor increases rapidly, and when $\alpha = 0$, that is, when the phase of the impact is very long, and in this way the dynamic load plainly degenerates into a static load ($c = 1$), then we receive a large infinite dynamic factor formula needs improvement in the $\alpha = 0$, $\alpha = 3$ section. We have put down the final results of this in Figure 6 without bothering with the mathematical discussion.

The Figure shows that in the case of $\alpha = 0$, $v = 1$, that is, it shows the degeneration of the dynamic load into the static load; besides which, it shows that the dynamic factor at $\alpha = 0.8$ attains the greatest value of $v = 1.7$. This means that the roof, due to the elastic change of shape, in the least favorable case is able to absorb only a small part, prescribed by the $v = 1.7$ value, of the energy of the bomb. The remainder of the energy is used in the impact destruction and the displacement of the roof mass from its state of repose. If we divide the total kinetic energy of the bomb into the parts causing the point destruction and the introduction of shock onto the shelter roof, we see that substantially more energy is turned to the point destruction than when c equals 10. But more arises if we consider the impact of the bomb as the collision of a non-resilient body on the shelter roof, and we compute the remaining energy on the basis of this, since the theory of the impact of non-resilient bodies presupposes free bodies; and this, according to the above, is justifiable only in the case of very fast blow. However, in such a case the combined kinetic duration of the reduced mass of the roof, Q', and the weight of the bomb is short, and α is large; thus, $v \angle 1$, that is, the dynamic effect is less than the static effect, as is the static effect standard.

To demonstrate this, on the basis of the impulse theory, we may put down that

$$\frac{Q' + P}{g} u = (Q + P)t'$$

and, since the impact takes place according to a half sine wave, we may put down from the above formula that

$$t' = \frac{\pi}{2} \quad \frac{u}{g} \quad \text{sec.}$$

The degree of rapidity is:

$$\alpha = \frac{n_1}{n_0} \quad \text{where } n_1 = \frac{60}{2t'} \quad \text{per minute}$$

and n_0 is the number of autovibrations of the roof per minute.

If α is large, it follows that t' duration is short, and thus u and the impact velocity v proportionate to it are smaller; therefore the static effect of the load is larger than the dynamic effect; and as a result, the energy remaining in the impact of nonresilient bodies and turned to the introduction of shock onto the shelter roof will be quite negligible.

Since for a lesser degree of rapidity the shelter roof cannot be regarded as a free body, the theory of the collision of nonresilient bodies upon impact cannot be used, and so, more energy is turned to the point destruction than might be supposed on the basis of the theory.

With regard to the fact that the number of vibrations necessary for computating v can scarcely be prescribed in an absolute manner, we assume that we are always dealing with the least favorable case, that is 1.7. Therefore the assumption of the maximum dynamic factor is also justified, since we are counting on an impact on the roof center, and due to difficulties in computation, we cannot treat an impact on another point.

Since Q' is in proportion to the area of the shelter roof, the bending computed from Z is smaller; the span of the roof is smaller than the static load, as well. If we disregard the weight of the bomb, Z = 1.7Q', for which force the shelter roof must be planned as the static load operative at the center of the roof.

Thus the roofs of bomb-proof shelters must be planned for greater rigidity than this, which means that, since the degree of penetration and the detonation effect prescribe the thickness, the spans of the roofs must be reduced by interior walls so that roof sections of smaller spans can be had. In this case, the usual reinforcing will also be sufficient for the dynamic factor.

3. Explosive Effect

The explosive charge of demolition bombs consists of H E materials, which are converted into a gaseous state under great pressure and with great production of heat within a very short time after the explosion. Immense energy is freed at the time of detonation, and the volume of gases generated by the explosion is 600 to 1,000 times the volume of the original solid. Temperatures generated by the explosion are above 600 C°.

The ground area on which the bomb completely annihilates matter as a result of the explosion, is a sphere described with a radius of r from the center of the explosion; we call r the radius of demolition. The radius of demolition depends upon the solidity of the target substance and the size of the explosive charge. It may be computed from the following tested formula:

$$r_r = k_r \sqrt{C}$$

wherein k_r equals the factor which expresses resistance of the target substance to the explosion, and C is the weight in kg of the explosive charge of the bomb. The center of the explosion is the center of gravity of the charge. The radius of demolition must be measured starting with this center of gravity as the center of the sphere. (See Figure 7.) We obtain the value of r_r in meters from the formula.

For solid target matter which is covered by a layer of soil at least greater than the diameter of the bomb, instead of the C charge, a smaller active charge C_{ak} must be taken when computing the radius of demolition of the bomb. The reason for this is that, because of the lack of tamping, only one part of the bomb displays an active effect. The weight of the active charge is computed from the following tested formula:

$$C_{ak} = 24{\cdot}264 \sqrt{k^3}\ \text{charge} \quad (d - 0{\cdot}02)^3$$

wherein d is the diameter of the bomb in meters. The formula expresses the active weight in tons.

From the following formula we may compute the measured C_{ak} distance from the tip to the center of gravity of the bomb charge.

$$C_{ak} = (0{\cdot}8 + 0{\cdot}65 \sqrt{k^3}_{\text{charge}})\ d$$

This formula expresses the active distance of C_{ak} in meters.

The factor k_{charge} which appears in the formula is the resistance factor of the mass to the explosion. This factor is not the same as the k_r demolition factor.

If the bomb explodes after penetrating the surface of the ground, the total C charge must be taken. If we wish to determine the radius of demolition into layers consisting of different materials one on top the other, then we proceed as in the similar case of computing the penetration: That is, we compute the radius of demolition for the uppermost layer and multiply the section which falls into the layer beneath by the quotient of the demolition factors of the second and first layers. We reduce or increase this by the product, depending upon whether the substance of the second layer is more, or less, resistant than the first.

We term the total of the effects caused by penetration and explosion the total demolition depth. To derive this we summarize the penetration depth by the radius of demolition, and from this we subtract the distance from the tip of the bomb to the center of gravity of the charge, which distance is 2 d in the case of a detonation taking place in the ground.

We may determine the radius of demolition in the air as in the ground, if the bomb has an instantaneous detonation, understanding that single-story houses, vegetation, etc., are destroyed within this radius, due to the concussion of the air. This value is approximately

$$r = 2 \sqrt[3]{C}$$

Penetration and explosion of the bomb in various soils produces a crater. The depth of the crater is less than the total demolition depth since a part of the dirt will fall back into the crater. Thus the dirt thrown out by a bomb with a delayed action fuse forming a crater upon explosion is about as many cubic meters as there are kilograms in the bomb charges. If the bomb explodes on the surface of the ground with an instantaneous explosion, the amount of the dirt thrown out is only about one-eighth to one-quarter the number of cubic meters as the weight of the bomb in kilograms.

4. Air Pressure, Suction and Concussion

Upon the detonation of the charge, the enormous pressure generated by the formation of gas extends the steel casing of the bomb to about 1.5 times its original diameter, and then bursts it into fragments and splinters. After disintegration of the casing the gases spread out at a speed of 2,000 to 2,200 m/sec, exerting a tremendous blow on the surrounding air. Firstly, the air is compressed by the expansion of gases; secondly, the air starts to vibrate from the effect of the blow, and this blow is further extended along a spherical surface in the form of a rapidly-subsiding shock wave. The speed and intensity of this shock wave are greater than the sound wave; and, in contrast to the sound wave, its compression and rarification phases differ considerably from one another. The intensity and speed of the shock wave reduce as it moves away from its source, and at greater distances it changes to a sound wave.

Thus the shock wave propagated in the air is nothing less than the periodic compression and rarification of the air which results when the air is compressed by the blow from the gases produced in the explosion (air pressure), and then returns or thins out to its original state as a result of its elasticity (suction). The propagation of the shock takes place without a current of air, because the air moves only within a half-wave length between the air pressure and the suction. The duration of the air shock wave is 1/100 of a second.

From the standpoint of structure planning, the air pressure generated by the bomb detonation cannot be compared to the pressure of the wind, since the air pressure from the bomb blast is of a very short duration and this time is usually insufficient to exert a significant motive force. Strains greater than fracture tensions can be exerted on building structures for a short time, and because their duration is short, there is insufficient time to fracture the structure. Therefore damage does not result.

The intensity of the air pressure is much greater than the intensity of the suction effect, though the duration of the suction is 4 to 5 times the duration of the pressure.

Therefore, in practice, most often the suction effect causes the collapse of the building, chiefly in those cases where collapse does not take place as a result of damage to the structure materials, but rather as the result of pulling away part of the structure. The measured dynamic blow on the air mass established at the limit of the radius of demolition has a value of about 12 to 15 t/m^2. At distances greater than this, for an explosive charge greater than 2 t, we can compute air pressure values from the following formula:

$$p = \frac{2\,c}{r^2}$$

Where we must substitute the weight of the explosive charge c in kilograms and the distance r in meters, we get the pressure p in kg/cm^2. For determination of the air pressure the formula below is used:

$$p = \frac{250000\,c^{\frac{2}{3}}}{r^2}$$

where the dimensions are identical to the preceding formula's dimensions, but the value of p is given in kg/m^2.

The explosion of a bomb which has penetrated the ground differs in effect from an explosion which occurs in the open because the force of the explosion is greatest in the direction of least resistance. Therefore it is effective upwards towards the surface of the ground. In addition, the ground also absorbs the pressure of the gases generated in the explosion. The pressure is propagated in the form of damped vibration similar to the air pressure spreading in the air. In dry ground and in loose sand, the vibration is quickly dissipated, while solid rocky soils and seepage areas conduct the shock well.

The force of the shock in the ground, measured in kg/cm^2, is computed from the following formula:

$$p \quad 7{\cdot}75 \left(\frac{x}{r}\right)^3 \quad 0{\cdot}05$$

where we give the point examined by the x coodinate, which we measure starting from point 0 of the 1.5 radius of demolition, and progressing to the center of the explosion. The x and r dimensions in this formula are identical. Values determined with the formula are valid only towards this distance, that is, up to 0·75 r (see Figure 9). From the formula we derive the shock force of 10 t/m² at the limit of the radius of demolition. The built-up condition or the ground configuration of the surrounding area influence significantly the air pressure and suction effect. Thus it often happens that pressure or suction is greater at distant points than near the explosion. The best method of protection against air pressure, if we insure the free circulation of air--and with this end in view, if we supply the corridor rooms with ventilator openings to avoid damping the air--is by turning the corridors and making extensions (air pockets) to receive the compressed air masses.

The air suction phenomenon is also present at fires extending over a larger area because the replacement of air which has become rarified near the center of the fire is accomplished by a high-velocity influx of air from the surrounding area.

5. Debris Effect

As a consequence of the explosive effect of the bomb, those buildings, public works, industrial installations, etc., which are in the vicinity of the impact area are partially or wholly destroyed, and the materials of which they are made become debris. Greater destruction and debris generally occur in a building when the bomb explodes inside the structure. In this way the interior area of the building serves to damp the bomb. Bombs exploding outside buildings cause destruction by air suction or pressure propagated in the air, or a shock wave in the ground. Building damages are much less in steel or reinforced concrete buildings than in brick structures, since the walls of the reinforced structure serve to limit the area and act as heat insulators; also, the destruction of those walls does not cause the collapse of the building. Bombs falling onto buildings of several stories usually explode in the middle stories. Only rarely do they fall as far as the shelter. Therefore the collapse of a building by an explosion does not mean the caving-in of the shelter if its roof can support the weight of the debris. We shall deal more fully with this in the chapters referring to the shelters.

8. Splintering and Fragmentation Effects

Where the bomb is detonated, the shattered casing flies apart in the form of fragments and splinters travelling at great velocity. As a result of the timed detonation, demolition bombs explode after penetrating the target, and in this way the target absorbs a part of the fragmentation. We call the smaller pieces of the bomb casing splinters, and the larger pieces fragments. In general, fragmentation bombs disintegrate into splinters, and demolition bombs into fragments. The fragmentation bomb disintegrates into 2,000 to 6,000 splinters, while the demolition bomb forms 1,000 to 2,000 fragments. The velocity of the splinters and fragments is in proportion to the weight of the bomb. At the edge of a 15-m circle measured from the point of detonation, the velocity of fragments reaches 800 to 1,000 m/sec, and they can cause serious injuries because of their striking force.

Splinter Defense

The degree of penetration of a fragment depends on its shape and weight, as well as its velocity. Walls which afford protection from splinters and fragments are listed below according to thickness and materials:

1. Calked concrete walls, 35 to 45 cm thick, with a cement content of at least 200 kg/m^3;

2. reinforced concrete, 25 to 35 cm thick, with a cement content of at least 270 kg/m^3;

3. prefabricated high quality reinforced concrete units fitted with reticular reinforcing, 10 to 15 cm thick, with a cement content of at least 500 kg/cm^3, compacted with a vibrator;

4. brick walls, 51 cm thick;

5. steel sheet, 4 cm thick.

Several steel sheets laid one on top of the other without air spaces are better than a single sheet.

The armoring of reinforced concrete splinter-protected structures must be set in place on the side which will be struck by fragments, while walls which divide rooms must be fitted on both sides, and the fittings tied together with S-shaped straps imbedded in the concrete.

The armor of splinter protective walls is a squared reticular armor made of Ø 6 or Ø 8 reinforced concrete with a 5-cm mesh.

If necessary, materials of the following thicknesses will serve as splinter protection:

1. dirt, 120 cm
2. sand, gravel, 100 cm
3. soft wood, 80-100 cm
4. hard wood, 70-90 cm
5. brick wall, stacked dry, 50-75 cm
6. adobe walls, 75 cm

Splinter-protective walls must be built in front of the emergency exits of a shelter if the surroundings permit (for instance, if the shelter does not open on the street). The splinter walls should be at least 60 cm, and at most 1 meter from the outer surface of the wall. The splinter wall should cover the opening in such a way that the force of splinters from any possible direction will be arrested. The protective wall should be 50 cm higher than the exit.

An angled air vent must be installed through windows which have been bricked in for splinter protection, and this vent must be secured with a gas-proof (G) device. The dimensions of the vent are 7 by 14 cm.

In constructing splinter-proof shelters provisions must be made so that air pressure and suction will not cause damage. Structures cemented later will give way or collapse at a slight suction effect.

Industrial Splinter Defense

The sensitive machinery of industrial plants, boilers generators, control boards, transformers and all such machinery, the loss of which would paralyze production, all these must be protected against bomb splinters. A good splinter defense reduces significantly the destruction effect of an air raid, because, in the event of a more distant impact it prevents damage to the machines and so, to a large extent, reduces the size of the impact area which will endanger the operating condition of the machines.

Protection of the machines is a much simpler task than the protection of life, since they are insensitive to pressure, smoke, and gas.

The best solution to the problem of providing splinter protection to the sensitive machinery and plant components is when the walls of the plant are so constructed as to give the necessary protection, since there is then no necessity for building walls later which will then obstruct operations because of their positionings.

Since the delicate power-generating machines are normally located in a separate building, splinter defense can be easily assured by the construction of exterior walls which extend to the height of the machines, or by walling up windows to the height of the machines. In such buildings only the most necessary number of doors and low-set windows should be permitted.

Delicate machinery or equipment which is in a large working area must also be protected against an impact on the building, since in this case only one part of the building would be demolished, and the remainder would be subject only to splinters and debris. Interior splinter-proof walls give protection against a blast inside the building. The placement of these in congested workshops is a difficult problem, and is possible only at the price of concessions made in production requirements.

Splinter-proof walls standing in the open, if they are of large dimensions, can be toppled by air pressure, or they can be shattered by nearby explosions and their pieces scattered with a high velocity. Therefore we use well-braced splinter walls, if possible made of reinforced concrete. (See Figures 10, 11, 12.)

From a production standpoint, the best solution for congested workshops is in the form of prefabricated reinforced concrete walls, movable by cranes, which are set into place only when the order for air raid preparations is sounded, and which can be removed quickly in necessary, to allow machine exchanges, for example.

A surrounding splinter protective wall should be at least as high as the object being protected. These walls should not be wall sections independent of each other, but rather should be systems of walls built together and connected to each other at right angles. Such a splinter wall should be as close as possible to the protected object. (See Figures 13 and 14.)

Sensitive equipment standing in the open, such as outdoor transformers, switching areas, and fuel tanks, must have splinter-proof walls built around them. These walls should completely surround sensitive areas, such as sidings. Cylindrically-shaped tanks must be surrounded by arched walls which follow their shapes. Groups of small tanks, transformers, or other delicate equipment should be surrounded by a

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Sensitive equipment standing in the open, such as outdoor transformers, switching areas, and fuel tanks, must have splinter-proof walls built around them. These walls should completely surround sensitive areas, such as sidings. Cylindrically-shaped tanks must be surrounded by arched walls which follow their shapes. Groups of small tanks, transformers, or other delicate equipment should be surrounded by a common arched wall. To assure stability against air and wind pressure, these walls should not be of long, straight sections but should be a broken or curved line. (See Figure 15.)

The pressure of the wind must also be considered in splinter walls of large dimensions. If they will still satisfy this requirement, their thicknesses may be reduced from the prescribed 51 cm to 38 cm, since we shall be satisfied with a lesser degree of security in order to save material.

Industrial pipe lines laid in the open are exposed to great splinter damage, and therefore the sensitive lines must be laid separately underground, or fitted with a casing which will afford splinter protection.

Splinter protection refers to the defense against both the pieces of debris originating in a explosion, and the fragments of defensive shells returning to earth. The scattering of debris is considerable within 50 to 70 m, but sometimes pieces weighing several hundred kilograms will reach as far as 80 to 100 m. Buildings containing sensitive machinery and equipment must be protected from this effect.

In new plants the shops housing these machines must be located outside the limits of possible damage. The roofs of the shops should be of monolithic reinforced concrete, at least 10 cm thick, supplied on the under side with a #8 diameter reticular sheeting of 8-cm mesh. In workshops having a large span, sensitive machinery must be protected with hoods made of sheet iron, or in the case of an already existing light hood, the section which is above the machine to be protected must be made splinter proof by a sheet iron or reinforced concrete floor.

Incendiary Effect

The incendiary effect of a demolition bomb can be direct or indirect. The direct effect takes place when a high-temperature explosion occurs near easily-inflammable solid or liquid materials. The burning fragments strewn about also cause fires. The effect is indirect when combustion takes place from the short circuiting of power lines damaged by the explosion, from the rupture of gas lines, from damages to furnaces, etc.

Toxic Effect

The nitrous gases and carbon monoxide freed in an explosion can cause poisoning in living creatures. The concentration of these in an explosion which occurs in the open is never dangerous, since the explosion itself imperils life within a much greater area than do the gases. However, a bomb exploding in a building can damage the shelter area and the gases from the explosion can seep in through cracks in the roof and walls. As a result, cracks caused by explosions, even without the presence of war gases, should be filled immediately with the available materials (clay, putty, cold glue).

THE EFFECT OF INCENDIARY BOMBS AND POISON GASES

The Effect of Incendiary Bombs

Incendiary bombs and devices generally mean no direct danger to a shelter. The flaming charges of heavy petroleum bombs can come near the shelter. Normally, the walls and roofs of shelters will not withstand a sustained fire. To increase the protection against fire, in constructing the emergency shelters the openings must be carefully chosen and all inflammable materials must be removed from the vicinities of the entrances.

A much greater danger to shelters is an indirect one, the smoke caused by the fire. If the fires caused by incendiary bomb are not put out at once, they cause immense rolling clouds of smoke which can seep into a poorly-sealed shelter. A gas-proof shelter is protected from this.

The Effect of Poison Gases

Shelters which have been built in accordance with existing instructions are completely protected from poison gases. In most cases the exterior of the shelter is exposed to the open air to only a very small degree; and while liquid gases can seep into the shelter through these points, the amount will generally not be sufficiently great to jeopardize the occupants. Mustard gas can be absorbed into the layers of oil paint which cover metal, such as on steel doors. This effect is dangerous and must be neutralized by burning off the paint. Mustard gas tends to remain on rusty metal (it can be neutralized with a boiling sulphurous sodium solution). It will penetrate soft woods to a depth of 15 to 50 mm, and hard wood to a depth of 2 to 4 mm. Soft wood can scarcely be decontaminated; therefore, once it has been impregnated by gas it is worthless. Hard wood can be decontaminated by various solutions, or by planing. Mustard gas will also penetrate painted wood surfaces to a depth of 2 to 5 mm. Decontamination of these is done as in the case of hard wood.

In a 24-hour period poison gases will seep 10 mm into a brick wall, and over a fairly long period, they will penetrate concrete 40 to 50 mm. Immediate steps are not necessary. Over a fairly long period gases will seep 10 to 15 cm into the ground. For shelters, the greatest danger is in the basement walls. Quarry stone or artificial stone basements are generally less sensitive than a bricked one. A white-washed brick wall affords protection against mustard gas. Splinter-proof sand or gravel boxes made of wood and wood-beamed splinter-protection layers are worthless after contamination by mustard gas.

The indirect effects of liquid gases are usually much more dangerous to the shelter than are their direct effects. People who have come into contact with mustard gas outside bring it into the shelter on their clothes; this gas then vaporizes and is very dangerous. With proper planning and equipping of the ante-chambers with dressing and wash rooms this danger can be reduced to a minimum. Not only the danger of mustard gas, but also the danger of aeriform gases in many cases will justify the division of the ante-chambers into two sections. A second room, actually an entrance hall, in the arrangement of the entrance would complete the layout ideally, if there is in front of this hall a gas lock which can be secured from outside.

The aeriform poison gases imperil shelters especially in those shelters whose outer wall surfaces are exposed to the air. Underground shelters (most residence shelters are of this type) are less sensitive to gas seepage than aboveground shelters. To hinder the seepage of poison gases, shelters with varying protective capacities must be built with uniform attention to the requirements of gas-proof securing, the use of gas-proof openings, and the plastering and regular white-washing of the brick walls of the shelters.

THE PLANNING AND CONSTRUCTION OF SHELTERS

The purpose of shelters is the safeguarding of life during an air raid. Shelters which serve to protect personnel may also be used to protect valuables, but only in a very restricted and secondary sense.

According to the degree of protection they afford, we may classify shelters into the following groups:

1. Bomb-proof (BGS /Bomba-, gaz-, es szilank-biztos: bomb-, gas- and splinter-proof/) shelters, which afford protection against the total effects of bombs (gas, splinters, and air pressure), as well as against a direct hit.

2. Debris-, gas-, and splinter-proof (TGS [Tormelek-, gaz-, es szilankbiztos/]) shelters, which, though they will not protect against a direct hit or nearby impacts, will afford protection from the splinters, air pressure, and gas and smoke of the bomb, as well as from the debris of ruined buildings.

3. Emergency shelters satisfy the requirements of a TGS shelter by the utilization of whatever equipment is necessary. The emergency shelters protect against air pressure, gas and splinters, but they will afford protection from the debris only if the shelters are in the interiors of high buildings and so placed that the building can collapse onto the shelter roof. In separated underground shelters, if correctly positioned, there are no special requirements for protection from debris.

TGS shelters can be built only in the cellars of buildings higher than two stories, and then only when the building is being built. Emergency shelters located in the cellars of buildings, the so-called RH (Regihazi -- "old house") shelters, can be installed in a subsequent remodeling of an existing building. They can be built in single-story houses, as well. This type shelter is also called a "trench shelter."

The requirements of the TGS and emergency shelters are identical, and the only decisive difference between them is that the TGS shelter can be built only in the basement of a building several stories high. The increase of stories above a shelter actually increases its degree of protection, because as experiences in the last war proved, the ceilings of the various stories often deflect the course of a bomb which has made a direct hit on a building, or these ceilings will cause the detonation of the bomb; and in this way the protection which is afforded by the shelter against the greater amount of debris arising from the height of the structure is greater.

We may further subdivide the BGS shelters by the weight of demolition bombs scoring a direct hit against which they will offer protection. We differentiate in this way BGS shelters which will protect against 500-, 1,000-, and 2,000-kg bombs.

The estimate of the degree of protection afforded by a shelter is often incorrect because the TGS and emergency shelter values are estimated on the basis of destructions of individual shelters. The TGS and emergency shelters do not offer 100% security, but the security of life in the shelters is much greater than in the open, or in the living or working areas of a building. Experiences of ~~the last~~ war showed the greatest number of those who were killed in air raids were not in shelters.

A. Bomb-Proof Shelters

Bomb-proof shelters are built for important headquarters, institutes, and industrial installations. Both above-ground or underground shelters are possible.

Above-ground shelters are bunkers of several stories surrounded by reinforced concrete walls several meters thick. (See Figure 16.)

Underground shelters are set up in natural or man-made underground galleries. The depth of these below the surface of the ground is 10 to 15 m. Underground shelters may also be built with floor arrangements similar to those of shelters above ground; too, gallery shelters are possible at lesser depths, but in such cases an explosion-absorbent layer of concrete must be used. (See Figure 17.) This solution seems more economical, but because of the destructive effect of ground seepage, this type may be used only in dry ground or with special insulation, and the explosion-absorbent layer of concrete must be of very great dimensions so that it will afford protection from a bomb which strikes at an angle. These things raise construction costs, so that this type shelter, in general, cannot compete with above-ground bunkers.

Bomb-proof bunkers are economical then, when the exterior walls of a minimum cubic content confine the necessary interior area. This requirement is met by a cubiform body delimited by planes at right angles. Therefore bomb-proof shelters could be cubiform. A larger part of the total volume of shelters with small interior areas is taken up by the outer walls, than is the case in the interior area of large shelters. Therefore for reasons of economy, shelters having a large interior area, that is, of large capacity, must be built.

Two shelters housing 500 people each cost almost twice as much as one housing 1,000 people. This factor is often overridden by the requirement of quick accessibility, which, in the case of an industrial installation covering a large area, can be satisfied only by dispersed smaller shelters.

The Planning of BCS Shelters

Corridors and stairs which will assure rapid access, and static considerations as well, determine the ground plan of a BCS shelter. From the chapter dealing with shock effect, we know that the upper shelter roof must be supported as thickly as possible. One or two inner walls parallel to one side of the square must support the square upper sheet in such a way that the spans resulting will not be greater than 5 or 6 m. Similarly, the roof must stiffen the side walls. A practical placement of the stairs is in a central section, set off by interior walls. For a more efficient use of the interior area, two sets of stairs, independent of, and set off from, each other must be constructed. The stairs will permit access to the interior sections at each level. The BGS shelters built in the past often had exterior stairs to each floor, partly supplied with splinter-protective walls and with separate entrances. This arrangement facilitated access, but it was not economical; therefore we now construct only interior stairs which open at each level.

Entrances to BGS shelters must be protected with splinter walls of a thickness close to the thickness of exterior walls, and the gap between the splinter wall and the bunker must be covered with a layer of the same thickness. Due to the double stairs, the interior arrangement of the bunker is divided into two symmetrical sections. The entrances to the two sections are protected by independent splinter walls. Since the entrances are also bomb-proof, and the location of the shelters is such that it is outside the limits of ruins from nearby buildings, the entrances will not be blocked just by the rubble produced by ground impacts near the bunker. Thus separate emergency exits are not necessary.

The number of entrance doors is prescribed by the capacity of the bunker and the requirement that the bunker be able to admit this capacity in 3 to 4 minutes of steady influx.

The entrance doors are double doors, opening in and out, which also form gas locks. From these we enter the ante-chamber in which there are containers for clothes contaminated by gas, as well as lockers containing clean clothes.

Only civil-defense personnel may remain in the ante-chamber during an alarm. On the lowest level of the bunker are an aid station, the local civil-defense headquarters, and rooms for civil-defense personnel. Rooms for the passive personnel will generally have an interior area suitable for 50 people. The two symmetric sections, having independent entrances, must be connected by a corridor on an upper level, and if possible the interior areas must open onto the stairwell. (See Figure 18.)

The Structure and Execution of BGS Shelters

The thicknesses of the roof, side walls, and base plate of a BGS shelter must be determined on the basis of the penetrative and explosive effects of a bomb striking it.

To lessen the penetration of the roof, it is necessary to construct a so-called "explosion layer," a layer of volcanic rock imbedded in concrete 0.70 to 1 m thick. The side walls are in the most advantageous position with regard to the effects of a bomb, since bombs falling from a great altitude will strike almost perpendicularly and will rarely penetrate a side wall. It is more likely that the bomb will slide along the wall and bury itself in the ground at the base of the shelter. Due to the damping caused by the ground such hits place greater stress on the underground sections of the side walls and on that part of the base plate which the bomb can penetrate because of its kinetic energy, than bombs exploding in the open without damping. As a result, the walls are thicker in the underground section. The interior section of the base plate with its lower symmetrical shape can also be made of a smaller thickness.

The uppermost roof and side walls are reinforced concrete sheets covered with special steel reinforcing and concreted without breaks. The steel reinforcing of the sheets differs from the regular static covering, since its purpose is not ~~to~~ take on the ~~in~~terior tensions of static loads, but rather to prevent the shell-like rupture of the sheet on its underside by the impact and explosion of the bomb. Therefore, this steel reinforcing consists of a thick underside or interior network and steel reinforcing running parallel to this, as well as the system of straps running in both directions and tying these together. Besides these, there are inclined straps in the corners reminiscent of the static steel reinforcing of the structure junction points. To reduce the damping of a bomb falling onto the upper layer of the sheet, the steel reinforcing is only in the inner two-thirds of the sheet. The special reinforcing generally will afford protection only against the effects of the interior forces caused by penetration, detonation, and shock. The reinforced concrete structures of the shelter must be planned for their own significant weights; the closed structure must be planned for the static load. Besides the special reinforcing it must also be supplied with a reinforcing proportioned to the load of its own weight. The special reinforcing may be included in the static reinforcing. This refers primarily to the base plate, since in the larger bunkers the base plate receives a considerable bending from surface tensions amounting to 3 to 4 kg/cm^2. To take up this bending a significant static reinforcing is needed. There are no harmful effects from the high surface tension beneath the bunkers, since due to the rigidity of the structures it cannot cause breaks in them. In planning the base plate the reduction of its thickness to that permitted from the standpoint of detonation cannot normally be realized at the center of the plate.

The exterior structures of the BGS shelters will be of concrete, compacted with a vibrator to a solidity of $K_{28} = 40$ kg/m^2. It is very important that the exterior walls and the roof be made by cementing without breaks. The interior walls serving to support the roof are 50 cm thick, and should be built of concrete with a density of $K_{28} = 400$ kg/m^2. The intermediate ceilings are sheets about 20 cm thick, reinforced as necessary to bear the static load along with the stair supports. Reinforced concrete walls, 10 cm thick, reinforced with a medium network, serve to divide the interior areas.

When there is a hit on the uppermost layer, the reinforced concrete protective roof under the main roof serves to damp the falling of debris of a degree. It is desirable to cover this roof with a network similar to the lower network of the upper layer. The construction of this is done in the most practical manner by cementing from the front side.

The thickness of the volcanic stone layer bedded into the concrete covering the uppermost layer should be at least 70 cm. The material for this is volcanic stone, 16-18 cm thick, with a tensile strength of 2,500 kg/cm^2 or greater. The individual stones may be larger. The stones will be set into concrete mortar of a solidity of $K_{28} = 400$ kg/cm^2.

Instead of air holes between the upper layer of a bomb-proof shelter and the protective roof under it, it is possible to use a layer of loose sand. The right angle junctures of the walls and ceilings in the interior of a shelter should be fitted with wedges. In the more important shelters, to prevent the falling of interior debris, it is practical to cover the walls and ceilings with wood. An air space of 2 to 3 cm must be left between the covering and the shelter wall. In the cementing of the bomb-proof shelters, before cementing much care must be given to the careful placement of, or leaving a space for, the intake and exhaust pipes of the filtering equipment, the electric and telephone cables, and the shower drains, since, if this is not done at this time, openings for the pipes cannot be made later in the several-meter-thick concrete walls.

In preparing the concrete for the bomb-proof shelter, sandy gravel with a maximum granular size of 80-100 mm may be used in the uncovered section of the sheet; but in the thickly covered lower layer a granular size of 20-40 mm will be used. Because we must insure the rapid conduction of heat formed in the binding of concrete prepared in large masses, we suggest doing the concreting in cool weather. The cement used should be dry and earth-moist, since otherwise the larger-size gravel used in the upper uncovered layer will sink and settle on the lower network. The compacting of the concrete should be done with a vibrator primarily in the area of the thickly networked reinforcing.

Great care must be taken in the fixed water-cement ratio of the compacted concrete. Therefore, if because of a change in the quality of the material the amount has to be increased, then the quantity of cement must also be raised. The compacted concrete should be earth-moist. The use of cast concrete is not permitted.

With regard to the heavy walls and ceilings, the timbering used will deviate from the usual timbering used in high structures, because it must be planned for the weight of sheets several meters thick and for the lateral pressure of fresh concrete walls several meters thick. The value of this may be taken at 0.3 t/m^2.

After untimbering, the exterior concrete surfaces of the bunker must be painted the same color as the surrounding land. For camouflage purposes, it is unnecessary to paint windows on the walls of the bunker, or to use form-disrupting paint patterns, or to fit it with a peaked roof because in observations from great altitudes it cannot be identified as a bunker and deceptive measures are pointless.

The Interior Equipment of BGS Shelters

The most important equipment of BGS shelters is the artificial ventilation equipment, the electric lighting and the emergency lighting. We shall discuss these items of shelter equipment in detail later. We shall only mention here that the pipes for the equipment and the holes in the wall for these pipes must be included in the plan, because the breaking of such holes later is hardly practical in walls several meters thick. The space between the pipes and the concrete walls is nonrigid; the pipes must be packed with a material to absorb shock. The intake and exhaust air pipes must be of cast iron, so that they will be more likely to shatter in an explosion, than collapse and cause an air failure. The drains leading from the showers of a bomb-proof shelter must be fitted with valves to prevent the infiltration of smoke and poison gases.

Also included in the interior equipment of the bunker are a sufficient number of benches with backs, not supported by the walls, and resting places for off-duty civil-defense personnel. A latrine for 30 people must be installed, if possible in a closed closet.

The equipping of the aid station and the headquarters room is the same as in a TGS shelter. ~~In factory~~ bunkers it is desirable to install switchboards for the machines which continue to operate during an alarm, as well as instruments to signal the operation of the machinery.

Camouflage of the routes leading to the bunker will be done according to familiar camouflage principles.

The bomb-proof shelters must be built outside the limits of where building debris will fall, and also well removed from stores of inflammable or explosive fuels. This requirement cannot be satisfied when shelters must be built in densely built up areas, surrounded by new or existing buildings. In such a case, debris can completely seal a shelter entrance; therefore, in addition to these entrances, a bomb-proof emergency exit must be established in a tunnel leading to the open.

Tunnel and Gallery Shelters

The most economical type of bomb-proof shelter is one which is set up in either existing or new caves or galleries. To know the degree of protection afforded by gallery shelters is much more difficult than for underground shelters made of the prescribed-quality concrete, since relatively little will be known of the soil over the gallery. Because of these uncertainties gallery shelters must be planned for greater stresses. The establishment of the degree of bomb protection, that is, for what weight bombs the strata above the shelter will afford protection, can be made only by a careful study of a section of the ground and by computations based on this. No listing of the strata thicknesses affording protection from various weight bombs, similar to the listing of the wall thicknesses for underground bunkers, can be given here. The following fact should serve only as a guiding principle: In most soils the thickness of ground cover which can be considered bomb-proof begins at 15 m. Since the galleries are dug into the inclined slope of a hill, this necessary thickness is not present near the entrance, and these will be bomb-proof only when the ground above the entrance has been covered with an explosion-proof layer of the proper breadth and thickness. In place of this expensive solution we should rather utilize several entrances, some distance from each other, or a vertical emergency exit leading from the interior of the gallery. (See Figures 19 and 20.)

The system of mine galleries consisting of the usual narrow passageways is less suitable for shelter use, because the long corridors hinder quick access, increasing the time required for the influx of people. The establishment of wider areas, under a layer sufficiently thick to be bomb-proof, is better suited to the purpose. A capacity of 200 to 300 people is possible for a single area. At the bomb-proof section nearest the entrance should be established the shelter headquarters, the aid station, and, if the shelter serves a factory, a store of fire-fighting tools transferred from the factory during air raid preparations.

Entrances to gallery shelters must be formed similarly to the entrances of the underground bunkers, with reinforced concrete splinter walls in front of the entrance, or by entrances to the gallery cut in such a broken line that splinters will not ricochet into the interior. The same type double doors, opening in and out, as are used in BCS shelters must be employed. If a vertical emergency exit shaft is used, the stairs must be run in a broken line and the exit at ground level must be made bomb-proof.

The gallery shelters must be of such a size that they can serve their purpose without man-made ventilation. An exception to this is when factories or sections of factories are installed in the galleries. In such a case the use of large-capacity ventilation equipment is necessary to draw off the dust and manufacturing gases.

The Planning of Gallery Shelters

The galleries must be planned for the static load of the pressure of the mountain and for the dynamic effect brought about by the impact and detonation of the bomb.

The static planning is made on the basis of the Protodjakov process described below. (See Figure 21.)

The pressure of the mountain which is in effect on the vaulted walls of the galleries depends on the depths of the gallery beneath the ground mass over galleries of large spans and shallow depth is in effect on their vaultings above a certain depth and below a certain span. This load, however, does not increase, because one part of the ground over the gallery forms a self-supporting arch. Practical experience has shown that the load-shifting arches develop over galleries of 2.5 m spans only when there is a ground cover of 10 to 12 m. Sections of ground within these arches burden the walled vaulting of the gallery as a vertical load. The lateral pressure of the mountain, directed horizontally, burdens the vaulting from two sides. The two sidewalls operate in a manner similar to abutments serving to support a support wall. We may easily determine the size of the horizontal load on the basis of the Culomb ground-pressure theory from the well-known fact that the ground pressure regarded as vertical, which is in effect on the side walls, consists of the pressure of a prism sliding on a broken plane; and that the assumption of the position of the broken plane is such that the resulting ground pressure should be maximum. This assumption materialises in a vertical direction in the case of a broken plane enclosing an angle of $a = 45^\circ = — \varnothing/2$, where the force, effective in the lower third, equivalent to the effect of the ground pressure,

$$E_1 = \frac{\gamma}{2} h^{12} tg^2 \left(45^\circ — \frac{\varnothing}{2}\right)$$

where γ is the weight of the ground mass, and h is the height of the wall being studied. The increase of ground pressure resulting from the vertical load of the ground mass within the ground pressure arch must be added to the ground pressure derived from the formula. This is identical to the determination of the ground pressure appearing on a burdened surface, except that here the burdened plane is not the outer surface, but the upper horizontal tangential plane of the gallery. The intersection of the broken planes forming two sides of the shelter with the upper horizontal tangential plane determines the breadth of the ground pressure arch. Therefore, since the ground within these points moves, these ground masses are not a part of the ground masses remaining in place as a consequence of the supporting effect of the vaulting. The height of the ground pressure arch can be determined with satisfactory exactness only on the basis of the measured shape changes of the finished gallery. For approximate determinations this hypothesis will meet the purpose: As a result of the horizontal lateral pressure on two sides, the upper ground mass will move upward on the prism broken within the ground pressure arch, and the angle of incline formed in this way is at most the natural angle of incline. According to this theory,

$$h = \frac{d}{tg\,\varnothing}$$

We regard the ground pressure arch as a semi-elliptic, and the load, P^2, falling on the upper plane of the broken prism is in proportion to the area of the ellipse, that is, since $z = h\sqrt{1-\frac{b^2}{4d}}$

then $P_1 \cong b\,\frac{z+h}{4}$ $\quad P_2 = \frac{\gamma}{4}\left[h\,d\pi - b\,(z+h)\right]$

We consider this load a load distributed uniformly on the upper face of the fractured prism, and the lateral pressure on the center of the wall is

$$E_2 = P_2\, tg\left(45^\circ - \frac{\varnothing}{2}\right)$$

The vertical load P_1 on the vaulted gallery is in proportion to the area of the middle part of the ellipse.

The height of the arch over the gallery (h) cannot be determined precisely on the basis of computations based on the natural angle of slope. Therefore it must be corrected on the basis of digging and other facts concerning the quality of the rocks and stratification gained at the site.

We set up the curve of the walled vaulting of the gallery in accordance with the basic principle of vault construction: The upper and lateral pressure of the mountain applies force only on the interior pressure. The determination of this curve is done by assuming the probable curve. Confirmation of the accuracy of this assumption is made by a confirmation of the possibilities of drawing in the curve outlined by the horizontal and vertical loads as the inner band of the assumed vaulting.

This is a complicated procedure and, instead of this process which gives only a limited accuracy, we can determine the center line of the vaulting in a simpler manner. That is, if we consider the vertical load ($P_1 = \frac{2P_1}{b}$) and the horizontal load ($P_2 = \frac{E_1 + E_2}{h'}$) to be evenly distributed on the gallery vaulting, then the center line of the vaulting will be an ellipse, for which a = /Note: value omitted in text/ is the small axis and c = h', the large axis, with the following relationship between the loads (See Figure 22):

$$\frac{a^2}{c^2} = \frac{P2}{P_1}$$

The annular forces at points 1 and 2 are:

$$n_{\varnothing 1} = \text{——}\; cP_2 \qquad \text{and} \qquad n_{\varnothing 2} = \text{——}\; aP_1$$

The elliptic vaulting so constructed must be supplied with corresponding bases under the floor line of the gallery. The force effective on the bases may be taken as approximately $n\varnothing_2$. For greater forces, instead of a floor covering, a lower counter-vaulting must be built.

For computing the effects of an explosion, we differentiate between three qualities of soil:

1. Non-rigid soils: Those soils in which

$$\operatorname{tg} O \leqq 1 \text{ (see Figure 25.)}$$

For non-rigid soils, the thickness necessary for protection is:

$$H_1 = (h_b \quad -c + r_r)k$$

wherein k is the safety factor which may be chosen between 1.2 and 1.5, depending upon the gallery dimensions and the soil quality, and c is the distance between the center of gravity of the charge and the tip of the bomb, about 2 d. The smaller the value of tg and the larger the span, the greater the value of k must be. The increase of the penetration values produced by multiplication by k is not to protect against an actual increase of penetration, but produces the extra degree necessary for safety. When $k = 1.3$, we receive a protective layer approximately as thick as that used in computations for rigid soils.

2. Rigid soils: Those soils in which

$$1 \angle \text{tg}\, \emptyset \angle 4 \quad \text{(see Figure 24.)}$$

For rigid soils the thickness of the protective layer is:

$$H_2 \geqq h_b \_\_ c + r_r + h_1$$

Wherein h_b is the penetration of the bomb into the ground, and h_1 is the height of the semi-ellipse formed in the ground.

3. Soils of solid materials: stones or rocks, in which an inner vaulting does not form (see Figure 25), because faults do not appear due to the solidity of the rocks, and so the depth of demolition extends to the upper level of the gallery. The value for this is:

$$H_3 \geqq h_b \_\_ c + r_1$$

This r_1 is not the same as the radius of demolition (r_r); it may be computed from the formula $r_1 = k_1 \sqrt[3]{C}$, wherein k_1 is the separation factor of solid soil.

The gallery vaulting must also be planned for the percussive effect of the bomb, if it is within the limits of the percussive effect, that is, 0.5 r_r measured from the limits of the demolition depth.

The tunnel sections should be distant from each other, when possible. The following formula will serve to determine the smallest permissible distance in cm:

$$S = 20\sqrt{\frac{b\,H\,r}{2f}}$$

wherein b is the span of the gallery section, in cm; f the solidity factor of the soil or rock (tg $\varnothing$); H the computed protective thickness in cm; and γ the volume weight of the stone in kg/cm^3. The formula not only makes allowances for the effect of the static load by taking H into consideration, but it also considers the fact that the soil shifts and separates, thereby increasing the static load. We receive the value of H in cm from this formula.

Where there are to be several tunnel entrances, they should be a distance apart greater than the squared radius of demolition;

$$L > 4\, r_r \quad \text{(see Figure 20.)}$$

B. TGS Shelters Established in New Buildings

For establishing TGS shelters in new buildings the order from the Minister of Internal Affairs contains the technical principles to be followed. In the following notes, we assume that the reader is familiar with this decree. Thus we shall not state what is included in it, but we simply explain some items in greater detail.

The planning of a TGS shelter begins with the proper locating of it after determining the number of persons to be protected and, on the basis of this, the necessary size of the shelter. The decisive principle in locating the shelter is that the shelter should be at the most suitable part of the basement ground plan. This is the area the greatest part of which must be designated for shelter purposes, and which is under an area of the building having several floors. If this requirement cannot be satisfied, at least a section of the basement under a floor must be used as a shelter. The shelter should not be under a floor heavily loaded with machines or stored materials. Factory shelters should not be near sections of a factory which are liable to burn or explode, or within an area which can be flooded by storage tanks being damaged.

Only 150 people should be housed in one shelter. If the number to be protected is greater than this, we must construct separate independent shelters, each of which will have a capacity of 150 persons at most. The individual shelters are independent of each other, consisting of ante-chambers and interior areas. It may be necessary to construct these at some distance from each other, but means of communications between the shelters must be assured. It is not only necessary that the shelters be built at a distance from each other, but also that the location of the interior areas within the individual shelters be in an extended arrangement. In case of large numbers of personnel and basements of small area, a large distance between shelters cannot be assured. Therefore in such cases there should be only one room, not used as a shelter area, between the shelters. These areas should not be filled with dirt, since this greatly increases damping in a direct hit and, in nearby hits, will conduct the shock wave better than an air space.

The well-located shelter can be reached quickly and easily and, if the building collapses or is destroyed, can be quickly evacuated through emergency exits. To reduce the effects of air pressure and suction, passages leading to a shelter must be built in a zig-zag pattern. However, protection against air pressure is more important than assuring wide access routes, and therefore great stress must be laid on this.

Civil-Defense Personnel

The shelter is prepared for all personnel in the building. This number also includes civil-defense personnel, since they will only remain outside the shelter during an air raid if it is necessary. To establish exactly the number of people to be protected is virtually impossible, since the number of people in a building varies according to its use and time of day, giving rise to a situation in which the shelters of some buildings, for instance office buildings, will be filled in the daytime, but will be empty at night. These will also be relatively empty in the daytime when there are few people in the center of the city and along the traffic routes where passers-by in the street might also make use of them. However, the general principle that shelters must be planned for the maximum personnel must take into account those conditions which might reduce this number in time of war (e.g., restrictions on the personnel capacities of public places, regrouping of factory shifts, etc.). The process for setting up the civil-defense staff mentioned in the order refers only to those residences where the number of residents does not exceed the normal number for which the building was planned. In densely-populated buildings (residences where apartments are shared) when the actual number of residents is a great deal more than the estimated civil-defense personnel, the actual number of inhabitants must be used as a basis. For institutions and industrial plants, serious consideration must be given to what the wartime staff would be. It is also possible to locate shelters for a new building in other buildings near the new structure, if the construction of a shelter in it is impractical because of its arrangement (e.g., a factory in the basement) or because of technical difficulties (e.g., high underground water level), or if the structure itself is especially endangered because of its purpose.

These exterior shelters should not be farther than 200 to 300 m from the building.

During an air raid all shelter openings leading to the open air must be closed. Therefore the air requirements of the shelter may have to be met for some time by the air within the shelter, or by properly filtered air drawn in from outside by the ventilation equipment. The per-person air allotment prescribed in the decree is sufficient only for 1.5 to 2 hours, and sickness and fainting will occur from lack of air if an alarm should be for longer than this. This will not happen where ventilation-filtering equipment is installed, because a continuous supply of air is assured. On the other hand, a malfunction, such as a power-supply failure, can hamper operations. With regard to costs, the cost of constructing a shelter fitted with such equipment is somewhat less than for a shelter without it, since the size of the shelter is smaller. However, because of the difficulties of installing such ventilation and filtering equipment for large areas, this equipment will be used for important shelters, and in those cases where the space available for civil defense personnel is small.

The air space of a shelter can be increased by connecting it with a part of the air space of the section of the basement outside the shelter. This is the so-called "auxiliary air space." It is important that the area of the basement comprising the auxiliary air space be gas-proof, and that openings between this air space and the shelter be fitted with gas-proof locking devices. Where there is an auxiliary air space, the base area corresponding to the personnel in the interior sections must be complied with. Because of the usual low height of basements, when the prescribed base area is complied with exactly, an auxiliary air space will always be necessary. However, if we make the interior area larger than necessary, which in turn also makes the shelter suitable for longer stays, for sleeping, etc., then the air space of the shelter is sufficient without an auxiliary supply.

The Layout and Sections of the Shelter

The ante-chambers of shelter units should not open directly onto the open air, but should be reached via such basement corridors as will prohibit, because of their courses, a straight-line impact of splinters. All interior areas should be able to be reached from the ante-chamber if possible; but if this cannot be done satisfactorily in the layout, then the interior areas may open onto each other. However, only one interior area may open onto another. The purpose of the ante-chamber in a gas attack is the decontamination of those who have been exposed and the locking out of the poisonous agents from the interior areas. For better sealing, the ante-chamber should be double, one part separated from the ante-chamber proper, and formed by a gaslock fitted with a double door. Since the facilities for those exposed to gas are in the ante-chamber, an area of at least 2 m^2 must be assured, possibly segregated as a cubicle from the main area, outside the areas set off by the doors opening into the ante-chamber.

Since, in a direct hit, the interior walls of the basement will, at best, impede the destruction of the separate basement sections, the persons to be protected are not placed in one room within the shelter, but rather are placed in groups of 50 in interior rooms set off by walls of the proper type. Besides increasing the degree of protection, such a division of a shelter aids in maintaining the strict discipline required. An improper arrangement of the leaves of doors between the interior sections and the ante-chambers, as well as those between the interior sections, will impede traffic, causing confusion and panic in a quick evacuation. Therefore the doors must be placed so that door leaves do not touch one another in their swinging. We can do this by placing the doors in corners and by arranging the door leaves so that they will be flat against the wall when opened. (See Figures 26 and 27.)

Wartime experiences proved that the most important part of a shelter is a well-constructed emergency exit. People died in more shelters because of lack of exit possibilities than because of the collapse of the shelter, thereby disproving the idea that a debris-proof roof is the most important requisite of a shelter. In planning emergency exits the planners are often content to assure that the number of exits prescribed in the decree are built, without considering the fact that the exits must be properly positioned. Therefore, often two exits are built so close to one another that with one hit they could both be destroyed, or they could both remain intact, thereby making one superfluous. In determining the locations of emergency exits, it is necessary to weigh the possible extents of destruction, and to employ only as many exits as are absolutely necessary. Therefore where several shelter units are close to each other, the prescribed number of emergency exits can be sensibly reduced; rather, fewer exits, distant from each other, well-executed and prepared by weighing the above points, must be employed. The emergency exits are suitable where they are air pressure- and splinter-proof; this is not satisfactorily by splinter-protective construction. Wartime experience confirmed that reinforced concrete may be considered splinter-proof, that steel doors are not splinter-proof, and that splinter protection may be assured only by walls of the materials and thicknesses given in the chapter referring to splinter protection. (See Figure 28.) Since splinter-protective walls outside a building are not desirable for either traffic or aesthetic reasons, a practical solution is to place them inside the shelter with screens formed by such walls or wall sections as will obstruct any splinters flying in a straight line from outside through the opening. (See Figures 28 and 29.)

An important, though difficult to meet, requirement is the locating of the exits of the emergency routes outside the ranges of debris of the surrounding buildings. In densely built-up sections of a town this can be solved only with very expensive emergency tunnels or with vertical emergency exits. The emergency tunnel is formed by an underground corridor from the shelter to some point in the open outside the debris ranges. It has a splinter-proof exit. The vertical emergency exit is a tower-like tube formed of reinforced concrete which will remain intact by virtue of its solidity and support, thus affording possibilities of escape to the outside during a period of destruction. It is used primarily where there are blocks of row buildings with no chance of escape to an open area. The emergency tunnel and the vertical emergency exits are quite expensive. Therefore the decree states emphatically that it may be used only in special cases for important buildings, as defined by the resolution of the Ministry of Internal Affairs. (See Figure 30.)

The TCS shelter is endangered not only by direct hits on the building, but also by bombs striking nearby. The explosion causes a ground shock wave which can collapse the exterior walls of the cellar, and the explosion can also dump into the cellar a part of the dirt dug up. To guard against this, if the basement structure permits we set up the shelter so that it is to the interior of the building, not touching an outer wall. In such a position, the outermost area absorbs the effect of nearby impacts, leaving the shelter intact. Where there are many shelter units close to each other, to reduce the dangers inherent in congestion, the placement of the shelters in a middle area is obligatory. In such cases, the basement rooms prescribed between shelter units and not being used for shelter purposes, can be utilized as ante-chambers for the shelter units, since they will not be used for sheltering personnel during an alarm. The areas bordering on the exterior walls can be narrow corridors, possibly industrial tube corridors, or ante-chambers set off by doors. (See Figure 31.)

Emergency passages serve for egress from shelters in closed buildings. These are built between adjoining walls, a half-brick thick, 70 x 80 cm, and recessed at least 2 cm from the wall surface. The plane of the walling-in does not coincide with the plane of the existing wall. Therefore the emergency passage may be found even in the dark.

The system of emergency passages, if necessary, assures an easily-accessible connection between the buildings of a single block, which also reduces the burglary security of a building and facilitates entry by unauthorized persons into institutions and factories. Care must be taken to locate the emergency passages where further entry into the building will be blocked. (See Figure 32.)

The expenses of shelter construction are partially reimbursed when the shelters are so set up that they may be used for peacetime purposes. A peacetime usefulness must also be assured even when this requires a ground plan less favorable from the standpoint of a shelter, or when the use to which the shelter is put necessitates some remodeling. This remodeling may be only of such a nature as may be completed within 24 hours, without construction materials or a technical force (the installation of door leaves in existing frames, the erection of prefabricated stored splinter protective barriers, etc). Shelters may be used in peacetime for only those industrial or storage purposes where the industrial equipment or the stored material can be transferred to a safe place within 24 hours after the civil-defense preparations order is given. In residences, the shelter may be used for storage of combustibles or other materials if these can be placed outside the shelter, should it be necessary. An ideal situation would be a peacetime usage which would not obstruct the intended use of the shelter, and which could be continued during wartime (factory dressing rooms, social rooms, medical consultation rooms, session rooms, club rooms, etc.).

Shelter Structures

The roof of the TGS shelter must withstand the debris piled on top of it when a building is destroyed. This requirement can be met by properly constructing the shelter roof, or by a structure type which will more or less hamper the formation of debris. The amount of debris formed in a steel-skeleton building is much less than in buildings with brick walls. The steel structure is very resistant to the effects of air pressure and suction and only the poured walls are destroyed. Such a structural arrangement is usually employed in industrial buildings where the danger of an explosion within the building must be considered, as in a boiler house or in an explosives plant, because the easily-poured walls simply collapse in an explosion. The resistive ability of reinforced concrete steel structures can be attained if the reinforced construction is of good-quality concrete without gaps, in accordance with the structural standards. As wartime experiences also proved, patches made in a cross-section of poorer-quality concrete were considerable.

In contrast to the old instructions, the decree to which we refer does not insist upon skeleton construction methods above a certain floor height, if it is unnecessary because of building arrangement, since the value of the steel structure from the civil-defense viewpoint is not commensurate with the basic cost. The poured walls of a steel building are less resistant than the thicker exterior walls of bricked structures. As a result, damages from air shock waves are greater to the walls than to the steel skeleton. Since most of the materials stored in the building are injured in the collapse of the walls, the property protection advantages of the reinforced structure method are dubious. The method simply hampers the formation of debris when there is an interior explosion.

To insure protection from fire in the building above the shelter, the old civil-defense decree prescribed that the uppermost building roof should be of monolithic reinforced concrete. The reason for this was to prevent the spread of a fire to lower floors in case of a fire on top, and to prevent flaming debris falling on the roof from reaching into the building. Since most buildings are made with flat roofs, the protection against fires on top has become superfluous and the protection against penetration to the top floor is doubtful. Therefore the new decree does not prescribe an uppermost roof of reinforced concrete; it simply states that it should not be of combustible material.

When possible, the shelter should be well below the surface of the ground. The lower surface of the roof over an ideal shelter is below the ground level. This is possible only in special cases, since the raising of the basement above ground level is necessary to install windows which serve to ventilate and light it. The maximum permissible height of the first story floor level over the ground is 1.20 m. If, because of a high water level, the basement is raised above the ground higher than this, the 1.20-m height must be gotten by filling in with dirt around the building. If this is impossible because the construction is of a row type, then the basement cannot be used for shelter purposes. In such cases the covered trench shelter, built underground outside the building is better, in spite of the protective effect of the floors above shelters which could be installed in such buildings.

The roofs of TGS shelters must be planned for an evenly-distributed load of debris, the value of which can be determined in the manner set forth in the decree. This load is a good bit larger than the normal load of a basement roof. The debris load comes into being when the house collapses, and its presumed value is the weight of the debris burdening the shelter roof. We consider the debris load to be a static load; it consists of the dynamic impetus of building sections crashing onto the shelter roof, which impetus becomes a static load only as a result of the collapse. Heavy walls, falling from especially great heights, or roof girders crashing down can easily fracture the shelter roof. Nevertheless, wartime experiences proved that planning for a static debris load may be considered sufficient, since after an explosion the building will remain partially intact. The twisted middle floors divert much of the debris from the shelter roof, and a good part of the debris is hemmed in between the walls remaining. As a result, the shelter roof is not burdened to a noteworthy degree. Due to the complexity of the problem, it is impossible to plan the shelter roof for every possible case of destruction. Therefore planning for proven norms, based on actual experience, must suffice.

It is very important that the roof over the shelter be free from cracks and gaps in order to prevent infiltration of smoke and poison gases. This can be achieved only by a monolithic roof structure of good-quality concrete. This so-called "civil-defense roof," at least 15 cm thick, has a strong, reticular reinforcing on the underside, the purpose of which is so that heavy pieces of debris crashing down on the roof will not fracture the lower surface of the roof, allowing dust, gas and smoke to seep in through the roof. Such steels snap suddenly without bending to the vibration produced by the impact.

In special cases, based on the decision of the Ministry of Internal Affairs, a dirt fill, one meter thick, must be placed on the civil-defense roof. The purpose of this is to give protection from radioactive rays of an atom bomb. But this is necessary only if the walls, ceiling, and the surrounding buildings do not provide the necessary shielding. A damp earth fill is much more effective, but this necessitates expensive insulation of the ceiling and walls, as well as continually dampening the layer of dirt.

We can construct the civil-defense roof more cheaply and increase the protection offered by the shelter at the same time, if we brace the shelter roof from within. The bracing is done by girders resting on masonry pillars, so placed that the pillars will fall into the interior areas and not restrict the route of movement.

The civil-defense roof can be a layered roof, ribbed in either one or two directions on the upper or lower side. The outermost shelter walls must be fitted with corniced girders, and the reinforcing steel of the roof must be tied into them. It is necessary to construct a civil-defense roof only over the shelter, the routes leading to it, the emergency passages, and the sections of the basement leading to the emergency tunnel. In practice, such a division of the basement roof and the civil defense roof is difficult to attain. Therefore the civil defense roof must often extend to basement areas outside individual shelters. Similarly, a monolith ceiling will be built over an area bordering the shelter, if it is related structurally to the shelter roof. Prefabricated roofs over basements containing shelters can be prepared only over the shelter and the sections which are structurally independent of the shelter access routes.

An increased security of the stairs leading to the shelter is gained by the fact that, in using prefabricated sections, the stairs or bannisters must be tied to beams by cementing-in the steel rods jutting out.

The outermost shelter walls in contact with the ground must be planned for a ground pressure increased by debris near the building. Since such debris can come only from the collapse of the exterior walls of the building, in computing ground pressure the load discharging effect cannot be considered; we can only consider making the basement roof more rigid. In those reinforced structures where the basement wall is filled in between the skeleton columns, we must provide for tying-in the walls to the reinforced concrete pillars by spikes in the wall gaps. Without this, the filled wall strips can easily be collapsed by a ground shock. The side walls of a TCS shelter cannot be planned for the great force caused by the shock wave of bombs striking nearby. This means that the side walls are not protected against an impact whose distance from the building is less than 1½ times the radius of demolition which a bomb would produce in the roof.

The exterior and interior walls of shelter units, if brick, should be at least 51 cm thick; if stone or of mixed materials, 60 cm thick; or if of calked cement, 40 cm thick. This requirement is usually met in exterior walls, but the thickness of interior walls, if they are not part of the structure, is usually less. We can make the construction of shelters more economical if the 51-cm-thick shelter walls also form the structure walls, thereby increasing the security of the shelter because of the load discharging effect of the basement roof and ascending walls. Walls between the interior areas of the shelter should be at least 25 cm thick, well interconnected to the walls and roof of the structure. Therefore they should be built at the same time as the main walls.

According to the old instructions, the interior surfaces of the shelter must be left unplastered, because impact shocks will cause the plaster to fall. This requirement is retained only for the shelter ceiling. The plaster from walls will not cause injuries, in fact, its sealing effect prevents the infiltration of gas from outside.

Central heating, water, gas, or communications mains should not pass through a shelter. If this cannot be avoided because of the building layout, then the pipes must be run in a closed reinforced concrete conduit, independent of the structure, and if possible buried in the ground. The conduits must be so laid that, if fractured, material spewing from them will fall outside the shelter. This arrangement will afford complete protection should it happen that, during an alarm, other duties would cause those responsible to forget to close the valves of the central heating or water mains.

To make shelters gas-proof, their structures should be such that there are no cracks anywhere to permit the infiltration of gases, and that no such cracks will be formed by slight building tremors. The packing of pipes which lead into the shelter for machinery there will be taken up in the chapter dealing with such machinery.

Shelter Equipment

The outfitting of shelters includes the furniture necessary for its use (benches, tables, chairs, beds) except for machinery; the container for gas-contaminated clothes, and the locker with clean clothes; a first-aid kit; mechanical life-saving equipment; fire-fighting equipment; and the other health facilities (drinking water containers, etc.).

The greater part of the outfittings listed make up the equipment of the civil-defense teams, and only as such do they belong to the shelter. However, for reasons of safety they must be stored there. The quantity and types of such equipment are set down in the instruction referring to the establishment of the civil-defense unit according to the function of the building.

The benches, chairs, and other furniture which are an integral part of the shelter should be comfortable and suitable for a long stay in the shelter. It must be remembered that in time of war, since an air raid may be expected at any hour, with or without an alarm, shelters serving residences may be filled in the middle of the night. Therefore they must be equipped for sleeping. In outfitting shelters built in buildings housing institutes, a number of tables must be placed in the shelter to allow completion of official business if necessary.

The decree authorizes installation of pit-latrines in interior shelter areas. However, if possible, it is desirable to build compartments for these, set off by thin walls. Shelter benches should be fitted with back rests. These permit a more comfortable seating than leaning against a wall, which can also cause injuries if there is a strong shock transmitted by the wall. It is preferable for the benches to be constructed so that the backs may be moved to a horizontal position, converting to a bed.

The shelters require continuing maintenance; this is done best by using them in peacetime. Maintenance should include whitewashing the walls, sweeping, cleaning, and regular ventilation of rooms, primarily to prevent mustiness. Therefore steel windows are preferably removed in peacetime and replaced by ventilation grills. The maintenance of machinery necessitates the periodic checking and repairing of defects.

C. Shelters Installed in Existing Buildings

The requirements governing TGS shelters built in new buildings also govern shelters installed in existing buildings. However, for these shelters the requirements can be satisfied only imperfectly, due to existing conditions. In order to differentiate between them, these shelters are not called TGS shelters, but RH (Regihazi: "old house") shelters; although with proper execution they are quite equal to the TGS shelters in new buildings. Therefore it is desirable, in setting up RH shelters, to meet fully the requirements prescribed for TGS shelters even if it means sacrificing material. It is obligatory to meet them in the old houses if at all possible.

The essential qualitative difference between the RH and TGS shelters is that the roofs of the latter are built for a debris load determined originally, while roofs of RH shelters must be made suitable for shelter purposes by a subsequent strengthening. A roof subsequently strengthened is not equal to a civil defense roof constructed originally for the load, and the installation of supporting braces and pillars restricts the use of the interior areas of the shelter. In old houses the shelters must be built between existing structural walls, possibly with slight alterations and by constructing a few new walls. This is possible, when considered against an ideal ground plan, only at a sacrifice of material. While in new structures we build basements which are suitable for shelter purposes, in old buildings we can only mark the most suitable basement section for use as a shelter. This must be done on the same basis as is used in planning new shelters; i.e., the individual shelter units must be removed from each other and they must be inter-connected with emergency entrances and exits. (See Figure 33)

The RH shelter should be at the point affording the greatest protection, under the section containing the greatest number of stories; and its placement within the ground plan should be such that quick access to, and egress from, the shelter are assured.

The interior areas of the shelter should not be placed close to each other in a square, but should instead by somewhat more distant from each other, situated lengthwise in smaller rectangular shapes. With such an arrangement, there is a greater likelihood that only part of the shelter will be destroyed by a direct hit.

Within buildings the individual shelters units should be apart from each other; however, where houses are joined by fire-walls, the shelters should be situated beside each other on both sides of the firewall. The reason for this is that normally when a building collapses, the center collapses and the exterior walls supported by adjoining houses remain standing. The damaged floors become inclined planes bending towards the exterior walls; these divert the debris falling towards the outer walls into the center of the building because of their inclined conditions. Another advantage to such an arrangement is that the adjoining shelters open onto each other at the emergency exit; thus it is not necessary to strengthen the roof over the route leading to the emergency exit.

The shelter should probably be near the stair housing, and the descent should lead to the interior areas in a short but crooked route. The access route should be short and without stairs; in a fast-moving procession of people, the slightest obstacle in the dark can cause accidents and injuries, and ensuing panic. A short access route also reduces the expenses of roof strengthening.

We do not use basement areas containing water or gas conduits for an RH shelter. Neither do we use an area with pipes imbedded in the wall, because if the pipes are broken the water or gas will flood the shelter; too, all ascending pipes permit smoke and poison gases to enter the shelter from outside. In no case are gas-consumption meters allowed in a shelter. If there is no possibility of placing the shelter in a site which does not contain pipes, then the pipes crossing the shelter must be treated according to the statements in the chapter dealing with machinery. Communications and central-heating conduits afford less danger than the gas and water pipes.

The ministerial decree, in the interest of reducing new interior partitions to be built in interior areas of RH shelters, permits a capacity of 70 people instead of the 50 allowed in a TGS shelter. It does not prescribe a separate ante-chamber, but only requires the installation of a gas lock where necessary. With this easing of requirements, RH shelters can be established in existing basements normally with few interior alterations. An important relaxation of requirements is also the fact that for an RH shelter, in addition to the shelter roof, a roof of not three non-combustible materials, as is the case for TGS shelters, but of only one material is required. This also aids in installing RH shelters with few interior alterations, providing the basement of the structure is of the permissible depth beneath the ground.

The reason for this relaxation is that the more expensive TGS shelters are not practical if they are not prepared with the increased security assured by a position under the several stories, while the smaller installation costs of the RH shelters are in accord with the protection assured by the given elements of the site. Shelters of single-story houses, where the basement is sufficiently deep, are nearly equal to underground trench shelters, but the latter are generally much more economical.

The level of the roof above an RH shelter may be 1.5 cm above ground level, as against the 1.2 cm prescribed for TGS shelters. If this level is 1.2 cm or less, the thickness of the sidewalls should be at least 51 cm; if it is between 1.2 and 1.5 cm, they should be at least 65 cm thick.

If the existing sidewalls are thinner, they must be strengthened by exterior or interior wall additions tied into the original walls. The strengthening wall, regardless of the thickness prescribed, should be laid into cement mortar at least 38 cm thick. Strengthening may also take place by packing with dirt. RH shelters may not be installed in basements where the floor level is higher than 1.5 cm above the ground level.

Assuring splinter protection for the RH shelter is more difficult than for the TGS shelter, where the shelter is planned without windows or with few windows from the beginning, since the whole row of existing basement windows in old houses must be walled up after the construction of the building.

Those basement windows and other openings to the outside which do not serve as emergency exits or which are not needed in the peacetime use of the shelter may be covered by walls built in front of them, in the wall plane, or behind them. A wall built before an opening may be used only when there is sufficient space available for it in front of the house, and when it may be so constructed that the opening protected is covered by an overlap on the sides and the top of at least 50 cm. Walls in the interior of the shelter will overlap in the same way as the exterior walls, and should be tied into the existing walls with steel rounds, or fitted with walled-in braces, to offset the effects of air pressure.

To ventilate the shelter, Z-shaped ventilation ducts may be used in the walled-up section, or the exterior or interior wall may be placed 5 cm at most in front of, or behind, the opening. The rectangular cross-section of the ventilation opening should be at least 7 by 14 cm. It should be fitted with bolts on the inside which will be gas proof when locked. (See Figures 34 and 35.) The opening should be fitted with a strong lock and with hinges deeply imbedded in the wall. Plugging the opening with a stopper is not good, since the air pressure will blow the stopper into the shelter.

The steel or reinforced concrete shelter windows used in the last war cannot be considered splinter proof; experience has shown that they resist only air pressure. Emergency exit windows and access doors will normally be suitable only when splinters moving in a straight line ~~cannot~~ penetrate into the interior areas or the ante-chamber of a shelter. If the layout of the shelter does not assure such protection, then splinter-proof walls must be built inside or outside the opening. If this is not possible because of the lack of space, then the wall recesses closed by the steel or reinforced concrete emergency exit doors must be filled out by boxes of sand or connected wooden stakes. This arrangement must be joined to the wall with the proper bracing rods.

Since an improperly formed emergency exit imperils a shelter more than it increases its security, we construct only the most necessary number of exits; and, instead of exits opening directly onto the outside, we use emergency passages or exits which open onto the outer air from an area outside the shelter.

Splinter security for HI shelter openings to the outside may also be assured by such methods as are necessary (wooden stakes, earthworks, piles of stones, etc.). However, these methods are not durable, and require constant maintenance. As a result, in contrast to their apparent economy, they serve their purpose rather badly. (See Figures 36 and 37.)

We do not make an HI shelter gas-proof by walling up all openings, since this rules out the possibility of ventilating the shelter. However, we install gas-proof locks at the openings. ~~Thus~~ in the interests of ventilation, chimney connections within the shelter area are not to be walled up, but the smaller openings, such as cracks in the walls and door casings must be sealed with the proper material.

The choice of the devices to be used in strengthening the roof of an RH shelter will depend upon the structure of the existing roof. The basements of old houses in most cases are covered with barrel vaults. In the past the debris capacity of these has been overestimated when considered against the flat roof. The fact is that the load on a barrel vault, if distributed evenly, may be increased to a greater degree than in a flat roof without danger of breaking. On the other hand, the unsupported middle walls of a building are in a much more disadvantageous position, due to the great vault pressure. The load on the vault may be increased only if evenly distributed. When the load is unevenly distributed the vault is more sensitive than the flat roof. In the following section we shall deal with the strengthening of shelter roofs, taking these points into consideration.

The Examination of Barrel Vaults for Debris Load

The examination of barrel vaults, according to the old civil-defense instructions, was made by the so-called "line of support" process. In this process it was necessary to draw the curve of a presumed uniformly distributed load of debris, of a size fixed by regulations, by experiments in accordance with the requirements of the line of support process. This curve would remain within the vault. Thus the maximum tension originating in the vault would not be greater than the permissible tension.

The strengthening of barrel vaults consisted of supporting the vault with beams along its members, presupposing that any reactions would be transmitted at the support points. In determining the reactions, the curve found by the line of support process was used in such a way that reactions at the points of support were absorbed as exterior forces operative from below upwards. At the point of these concentrated forces the curve broke. The break could only be small, since the curve could not leave the interior section of the vault. In this way the forces operative on the supports were trifling. In view of the unavoidable inaccuracy in drawing the line of support, the value of the forces thus derived was quite uncertain; and the fact that the braces were supported by such a force influenced decisively their sizes. When set in loosely the brace did nothing, and when set in tightly it raised the vault, causing it to crack. In time many of the wedges worked loose, or the brace settled into the ground; as a result, in most of the braced vaults, the sub-bracings were completely ineffective. The bracing of beamed roofs gives much better results since the roof beams are much more elastic than vaults, and, in practice, the wedging-in of them can be done much more easily.

Thus bracing of vaults along their members is difficult. It requires much bracing material; its value is dubious and, therefore, it will not be used. We shall keep, in principle, the line of support process serving for the static examination of vaults, but we shall not employ the inexact and tedious graphic method. We shall use computation.

We may state the balance condition of the line of support process -- the polygon of the load will remain within an interior band of the vault-- in the following form, logically equivalent to the proceeding. The arch of the vault may be regarded as a doubly-supported brace, supported on one side by a fixed joint, and on the other, by a swivel joint. If we consider the debris load a load on the joints distributed in a straight line, the stress figure of the brace for the effect of the load will be that of an imiginary doubly-supported brace at a point directly between the joints. We consider the rigidity of the joints in such a way that we presume horizontal forces (H) of an equal, but opposing, magnitude across them. The stress figure of these forces will be a figure related to a figure delineated by the straight line of the joints and the arch of the vault. We receive a stress figure for the whole structure by a synopsis of the two figures. We presume horizontal forces, corresponding to the theory of the line of support, not from the conditions of elasticity, but by meeting the requirement, so that in a cross section of the maximum stresses the interior tensions of the arch will be less than the maximum permissible. While the normal line of support permits a shift of the centric force of the arch only within an interior band, our process fixes this requirement by conceding the maximum stresses which the shift produces. The ordinate of these stresses will not be proportionate to the ordinate of the line of support as measured from the center line of the vault, since the centric pressure of the vault is shifted along the arch. Thus the distance of the pressure forces from the center line is not proportionate to the above-determined stresses.

In the following we shall examine the relation of a cross-section of a one-meter wide vault band, and of the interior force burdening it eccentrically. The old instructions insisted that the centric force should remain within the inner third of the cross-section, because only in this way could it be assured that the total area of the cross section not employed in pulling should be employed in pressure.

According to the new instructions, the force may go beyond the inner third to a point where the edge pressure building up on the edge of the only partially employed cross section does not exceed the permissible tensions. Both instructions assumed the magnitude of the centric pressure to be given, and on this basis, looked for the permissible exterior position. In examining this problem, we shall assume the centric pressure to be unknown. We shall solve for the point at which the tension of the exterior line is the just permissible tension, and the stress of centric force on the center line is the greatest of the points. Where there is a force of such a position, we may presume maximum stresses of the cross section by adhering to the permitted edge pressure. (See Figure 38.)

Using the labelings of the figure, the edge pressure and the stresses on the center line may be written from the following formula:

$$\sigma = \frac{2Q}{3zb} \qquad M = Q\left(\frac{v}{2} - z\right)$$

Eliminating Q from the formula and solving for M, we get:

$$M = \frac{3b\sigma}{2}\left(\frac{vz}{2} - z^2\right)$$

By this we produce M as the function of Z, which, according to Z, becomes a differential and equal to 0; for the above requirement we got $Z = v/4$. By adhering to the permitted edge tension, the flexing stress of the cross section is maximum when the eccentric pressure force is operative in the inner quarter. This supposition cannot be maintained at the shoulders and at the center point of the arch at the same time, because we prescribe the same stresses in the shoulders and center point, the danger sites, though the interior pressure is greater in the shoulder than at the center. This fact will cause an insignificant excess of the permitted tension in the shoulder cross-section.

Since the thickness of barrel arches is almost always 15 cm, and since the permissible edge pressure may be taken to be 24 kg/cm^2 for the debris load in only one instance, on the basis of the above condition assuring maximum flexing stress, the maximum value of the N centric pressure, and the stress of this on the center line may easily be determined. ($\sigma = 8$ kg/cm^2.) (Twice this the permitted edge pressure, and the value increased by 50% is the stress permitted in effect in only one instance.)

In the following we shall examine a circular arch section with a radius of r above a span of l. We have chosen a circular arch section because most vaults are circular arched. Taking the center of the circular arch as the line of support, the q load of the circular arched section is derived as follows, from the formula $Hy'' + q = 0$:

$$q = \frac{Hr^2}{(r^2 - x^2)^{\frac{3}{2}}}$$

This q load uses the vault for pure centric pressure, but if the debris load deviates from the load forming a part of this line of support, then stresses arise in the vault, the maximum value of which may not be greater than the M_0 stresses as determined above.

We render the load deviating from the load forming the line of support in such a way that we add a second load to the load produced on the line of support. The first member of the total formed in this way causes centric pressure in the vault, and the second member causes flexing; or, corresponding to the line of support theory, we permit a deviation of the centric force in the individual points of the arch only to such a degree that its stress on the center line would be the flexing stress originating in the second load member. According to the preceding, these stresses are the stress figures of the second load member produced on a doubly-supported brace formed by a horizontal projection of the arch. For reasons of practicality, we choose the following single-member Fourier line for the second load member:

$$P_1 = P_0 \cos \frac{2\pi x}{l}$$

We can come very close to the directly distributed load by adding this load, after choosing an adequate P_0, to the load of the line of support. From the well-known formula for

$$\text{flex-} \quad \frac{d2M}{dx^2} + P_1 = 0$$

the stresses forming the P_1 load are:

$$M = M_0 \cos \frac{2\pi}{l} x \quad \text{where } M_0 = \frac{l^2}{4\pi^2} P_0$$

Thus according to trigonometry, the stress figure distributed in similar manner is a part of the distributed load, where the load figure can be produced from the stress figure by multiplying by the factor of proportion, $\frac{4n^2}{l^2}$. Similarly, by taking into account the indirectly distributed load, we produce the following load, with the stress figure accompanying it in the previous case:

$$P_2 = P_o \sin \frac{2\pi}{l} x \qquad M_o = \frac{l^2}{4\pi^2} P_o \sin \frac{2\pi}{l} x$$

In the two cases discussed, the stress and the load attain in places the maximum values of

$$\cos \frac{2\pi}{l} x = 1 \quad \text{and} \quad \sin \frac{2\pi}{l} x = 1$$

respectively. The connection between the g and p load is shown in Figure 39.

Due to the structural formation of vaults, only the middle section, comprising about four-sixths of the span, is 15 cm thick; the sections at the shoulders each comprising about one-sixth of the span are 30 cm thick. This fact facilitates the study of the arch, because the stress may not exceed the permissible limits only on the middle section. If we assume a vault thickness of 15 cm throughout, and if we produce a load appropriate for the line of support on the thus determined center line (the line of support) of the vault, then we may reduce between the limits of the member the part of the load which falls on the section of the thickened vault components. If we draw the tangent in the staggered progression of the thickening of the line of support and this remains at least 15/4 or 3.75 cm from the edge of the thickened vault, then the thickened vault sections may be without a load, or they may be encumbered by any condition between the line of support load and non-load. Therefore it is sufficient to study only the middle vault section.

The sum of the line of support load determined for the middle section added to the load on the middle section, written

$$P_1 = P_o \cos \frac{4\pi^2}{l^2} x$$

gives the nearly evenly distributed load on the center section, possibly by a reduction corresponding to P_o. The P_o reduction means that we do not utilize the load capacity of the vault to the extreme limit, and we assume smaller stresses corresponding to eccentricity.

To judge the unequally distributed load which may be permitted, the load forming a part of the line of support is added to the load along the span, $P_2 = P_o \sin \frac{4\pi^2}{2} x$.

Problem: What is the load capacity of the vault shown in Figure 40?

The open height of the vault is $f = 1.20$ m.

$$r = \frac{6{\cdot}0^2 + 4 \times \overline{1{\cdot}20}^2}{8 \times 1.20} = 4{\cdot}35$$

The maximum lateral pressure and stresses which may be permitted with the dimensions of the cross-section:

$$H = 24 \times 11{\cdot}2 \, \frac{100}{2} = 13{,}500 \text{ kg}$$

$$M = 13{,}500 \, \frac{0{\cdot}15}{4} = 506 \text{ mkg}$$

The values of the line of support load are:

$$x = \text{at point o} \qquad q = \frac{13500}{4.35} = 3100 \, \frac{\text{kg}}{\text{m}}$$

$$x = \text{at point } 2{\cdot}0 \qquad q = 13{,}500 \, \frac{4{\cdot}35^2}{(4{\cdot}35^2 - 2.0^2)^{\frac{3}{2}}} = 4750 \, \frac{\text{kg}}{\text{m}}$$

The maximum value of the load causing flexing is:

$$P_c = 506 \, \frac{4\pi^2}{4{\cdot}0^2} = 1250 \, \frac{\text{kg}}{\text{m}}$$

The study of the cross-section between the thin and thick vault section is:

$$\sin\varphi = \frac{2{\cdot}00}{4{\cdot}35} = 0{\cdot}46 \qquad \cos\varphi = 0{\cdot}888 \qquad Q = \frac{H}{\cos\varphi} = 15{,}200 \text{ kg}$$

Eccentricity:

$$e = \frac{506}{15200} = 0{\cdot}033 \text{ m}$$

$$\sigma = \frac{2 \times 15200}{3(7{\cdot}5 - 3{\cdot}3)100} = 24{\cdot}3 \, \frac{\text{kg}}{\text{cm}^2}$$

Figure 42 depicts the load diagram on the middle section of the vault.

We shall consider two more loads which cause flexing, in addition to the line of support load. The first is the symmetric cosine wave, with separate positive and negative values; the second is the antimetric sine wave, also with positive and negative values. The load wave length of the sine wave is the whole span, since in a smaller wave length the line of support would break at the progression into the thickened section, or it would suffer a great change in curvature in a small section.

Any load curve may be assumed within the shaded areas shown in the figure; y-directed loads of the curves, produced by a diminishing to an arbitrary point are also permissible. It is evident from the figure that the evenly distributed load can be easily produced with the figure bordered by the symmetric load; too, an alteration of the load is possible within a fairly large gap, while the vault will support only a small unilateral load according to the asymmetric load diagram.

The average value of the loads is fairly large, about 3,700 kg/m^2, while the decree states the maximum debris load for a six-story brick structure as 2,250 kg/m^2. This means that the vaults, provided they are not formed by basket curves or some other unfavorable shape, will generally be satisfactory, without reinforcing, for evenly distributed loads or for loads distributed on the center line according to a symmetric wave. The vault is more sensitive to a unilateral load and only slight load differences between the two sides are possible. In a concentrated load, the fill over a vault distributes the load along a broader line; thus the fill increases the load capacity. The study of the exterior and central walls serving to support the vault is connected with the checking of the debris load capacity of the vault, and serves to supplement the checking. Vaults of usual dimensions will support the debris load prescribed by regulation if it is evenly distributed, while many main central walls are not adequate for a dangerous debris load in effect on only one side. These walls, therefore, must be strengthened. For the reasons mentioned earlier, the lateral pressure of the vault may not be reduced by underpinning and the strengthening of the central walls may be done only supports. The ground will support the outer walls sufficiently if the vault shoulder is below ground level, as it usually is. So it is not necessary to check these buttressing walls separately for a passive ground pressure, since we desire rigidity for only a short period against a debris load effective under extraordinary circumstances. Therefore, fairly great changes of shape and, possibly, even the destruction of the outer walls may be permissible.

If the vault is supported by a central wall standing in the open, the wall can resist the effect of lateral pressure only when a load on the wall is stable and when the resultant of the horizontally-directed lateral pressure remains within the wall in the degree prescribed by the permissible edge pressure. This condition is satisfied, according to the old civil-defense instructions, by the fact that we do not presume the load-discharge force on the middle of the wall.

This justifies the assumption that the basement wall operates as a doubly-supported prop, supported at its base against lateral pressure and fixed in the plane of the first-story floor; and also that the centric pressure operative on the middle of the wall originally is shunted into the pressured sections as a result of the fixing at the point of greatest pressure and the break which occurs in the plane of the shoulder on the section depicted. (See Figure 43.)

Let us examine the stability of the central wall in the least advantageous case: When, in a double-tract vaulted basement divided by a central wall, the ceilings over one tract collapse, and the ceilings over the other are left standing. In this case the tract remaining intact discharges the load on the central wall, and, in most cases, this corresponds to the normal debris load.

Should both tracts collapse, the equal or nearly equal lateral pressures from the vault shoulders of equal or nearly equal height balance each other.

The structure bracing a central wall should be of brick or concrete, since wooden braces come loose because of drying-out or the compressing of the wedges, and will, therefore, serve their purpose only with constant maintenance and restoring.

We may now establish that the vaults, not including their side walls, will support the debris load generally with a good bit of safety. If, due to dimensions deviating from normal, they will not support this load, then they must be strengthened, not by braces, but by dividing walls, at least one and a half bricks thick, perpendicular to the axis of the vault, and wedged in carefully between the wall and the vault. The ground plan determines the spacing of the dividing walls; but if they are needed for strengthening, then the spacing of the walls should not be greater than twice the span of the vault.

The most practical method of bracing central walls is by buttresses tied into the wall with saw-tooth links. This is an expensive solution and may be used only in exceptional cases. Dividing walls perpendicular to the axis of the barrel vaulting may also be employed for bracing central walls. Dimensioning of the buttresses is done in the usual manner.

The Strengthening of Flat Ceilings for Debris Loads

The covering of the basements of the fairly old structures was done, for the most part, by barrel vaulting, though sometimes Prussian miter vaultings set in place between steel braces are found. Basement ceilings built more recently are layers, ribbed layers, or thickly ribbed reinforced concrete laid between the steel supports.

Steel-Supported Ceilings. The strengthening of steel-supported ceilings is done by placing braces at one or more points. Normally, a single brace, placed at the middle of the span, is sufficient. The Prussian miter vaults, if made of solid bricks, need not be examined for debris loads separately; vaults made of hollow bricks, or the so-called "straight vaults" (Reti-type ceiling) must be checked for debris loads. In our discussion of reinforced concrete ceilings, we shall touch upon the examination and possible strengthening of reinforced concrete layers between steel supports. In the early days of reinforced concrete construction, many layer-ceilings made of slag concrete were built supported between steel braces or directly on walls. These (compact-ceilings, Matra-ceilings) are now generally in bad shape and require careful study before strengthening.

Since prefabricated concrete ceilings were seldom used in the past, and since their use over shelters in new buildings is not permitted, the problem of strengthening this type will seldom occur. The entire lower surface of such ceilings must be covered with planks, and the planks must then be properly braced.

As a rule, the steel ceiling braces will not stand the usual debris load and must be strengthened. By using a prop in the middle, the originally doubly-supported steel beam becomes a triply-supported brace. By presuming the shape alterations remaining, the dimensioning of this is made for stresses of

$$M = \frac{pl^3}{11.65}$$

in the span as well as at the brace. We shall increase the permissible tensions by about 50%, since the load of debris will be in effect only once and the ceiling thus burdened must support the load for only the length of time required to evacuate the shelter. By the use of the central support and by increasing the permissible tension, the load capacity of the steel beam increases to approximately the ninth part [sic] of the original capacity. (See Figure 44.)

The strengthening device is a steel or wooden beam which supports the steel girders in the ceiling, and which is in turn braced by a pillar or timber. This bracing is effective only when the supporting beam underprops the ceiling girders in such a way that it assumes one part of their load. This can be done by driving wedges above or below the brace, if a wooden timber is used, or by inserting wedge-shaped steel sheets at the point of repose of the beams, if steel-beamed pillars are used. In inserting the wedges, care must be taken that they are of the right sizes, since too-thick wedges will raise the beams, while too-thin wedges will result in a serious flexing of the beam. Either case will produce a fracture of the element between the steel beams. Wooden bracing will lose its effect in time because of the drying of the wood and the working loose of the wedges. Therefore constant checking and maintenance is required. Another disadvantage to this type bracing is that, due to its makeshift nature, it can easily be pulled down for some other use, as post-war experiences have proven. As a result, when possible, strengthening of a more permanent nature is used: steel-beamed walled pillars or, if the ground plan permits, solid central walls. In such cases, the beams resting on all walls must be fitted with wedges, and suitable bases must be put under the supporting devices.

Reinforced Concrete Ceilings. The load capacity of a reinforced concrete beam supported at two points can be increased by a brace at the middle, in spite of the fact that the concrete beam does not have an interior reinforcing sufficient to absorb the negative pressures arising above the middle brace. The lack of the upper steel causes a severe upper fracture in the beam when subjected to a load of debris. When this happens, the supported concrete beam acts as two doubly-supported braces, independent of each other. The fracture has no effect on the load capacity or rigidity. The fact that the original ceiling plans are usually not available, and, as a result, the reinforcing of the ceiling is unknown, makes the strengthening of reinforced concrete ceilings more difficult. In these cases, we compute the reinforcing on the basis of the useful load, prescribed by regulation, of the arrangement of the room above, and consider this as the reinforcing in dimensioning the doubly-supported braces formed after supporting. If one central support is insufficient, then two should be employed in such a way that of the three spans thus formed, the middle span is the largest.

Reinforced concrete layers and reinforced brick ceilings are supplied with a continuous bracing, and the static estimate is made as for an independent steel beam. The buttressing devices are the same as for steel-beamed ceilings.

To hinder the inevitable falling of debris, the whole ceiling must be covered with thickly ribbed elements made of stiffened, prefabricated, or other thin elements. We may judge the necessity for the sub-ceiling when we find the condition of the existing ceiling to be cracked in several places and we ascertain that there are loose elements which will fall easily if there is a concussion.

The lower plaster coat of the ceilings in RH shelters must be knocked off, but the plaster on the walls may be left intact.

The Equipping and Arranging of RH Shelters

In principle, the fitting and equipping of RH shelters is the same as for TGS shelters, though a few relaxations of rules are permitted.

D. TRENCH SHELTERS

If an RH shelter cannot be installed properly within a building, then trench shelters are set up outside it. Trench shelters are used to protect substantially smaller numbers of people than TGS or RH shelters, because they do not have the advantage of the ceilings over these types of shelters. However, they do have an advantage in their dispersed arrangement rendering them less sensitive to nearby hits than the large, connected basements which stand above the surface of the ground. Therefore their value should not be underestimated. Trench shelters can serve their purpose only if they are splinter- and air pressure-proof, qualities attained only in covered shelters. Consequently, open-trench shelters, the so-called "communication trenches," will not be employed. These shelters afford only a limited amount of debris protection, but there is really no necessity for such protection, since the trenches are outside the debris limits of nearby buildings. There will be no debris beyond that caused by bombs exploding in the ground. The trenches will generally afford no protection from gas, though they can be made gas-proof by installing such equipment as is necessary.

If trench shelters are built to serve residences or groups of houses which are not suitable for the installation of RH shelters, they should be constructed near the homes of those to be protected, or in the case of blocks of houses, in the center of the area formed by the plots of the buildings which the shelter is to serve, at a point which can be reached in 4 to 5 minutes.

Trench shelters prepared for the workers of industrial installations or other areas which will be in danger must be built as far away from the endangered area as possible while still maintaining the time required to reach them.

The disadvantage of trench shelters is that they are usually of a temporary nature, and if they are unused for a long time, without proper maintenance they will become run-down or deteriorated. They are primarily sensitive to moist earth, because over a certain period the moist earth will attack the wood, brick, or reinforced concrete structure which supports the bracing wall on two sides and will cause it to fall apart completely.

The planning of Trench Shelters.

Trench shelters must be built with an interior section of about 1.95 x 1.40 m, in a zig-zag or meandering line. Long, straight tunnel sections must be avoided and, when possible, the angle between adjacent tunnel sections should be 120°. Sections formed by right angles should be employed only when there is insufficient room to extend the shelter with 120° angles. A single straight section should be no longer than 8 to 10 m. Three persons may be accomodated per running meter in a shelter with the cross-section mentioned above. Each person will have about 1 m^3 of air. Thus in one straight section, 25 to 30 people may be accomodated. One trench shelter system may consist of five straight sections at most, giving a maximum capacity of 150 people. For more people than this several trenches must be planned alongside each other. The distance between the axes of zig-zag trench shelters having parallel symmetric axes should be: t = 10-40 m minimum. (See Figures 45, 46, 47.)

To keep the shelters dry, the shelters must be constructed with an approximate slope of 5% in front of the entrances, and they must be so placed on sloped ground that the natural slope assures the slope at the entrance. Because of the slope then, the passageways are always at the deepest section of the shelter. If the level of the water table in the vicinity of the shelter is closer than 1.80 m to the surface, then the crown line of a vaulted shelter may be raised by one-half its interior height. If the water table is between 1.40 m and 1.80 m below ground should be constructed near the homes of those to be protected, or in the case of blocks of houses, in the center of the area formed by the plots of the buildings which the shelter is to serve, at a point which can be reached in 4 to 5 minutes.

Trench shelters prepared for the workers of industrial installations or other areas which will be in danger must be built as far away from the endangered area as possible while still maintaining the time required to reach them.

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In shelters serving more than 50 people, an ante-chamber closed off with a gas-proof door and two entrances is desirable. Where more than 75 people will use the facility, construction of a second entrance is required. In the wall of the entrance section a chimney with an interior dimension of 15 x 15 cm must be built, with a column-like extension protruding above the ground on the outer wall. A ventilation pipe from the latrine, with a flue connection from the interior area must be installed in the shaft. A chimney corner seat for the stove must be constructed on the upper side of the interior area. It may be necessary to build a wall fireplace. The chimney must be extended above the ground and must be fitted with a concrete cover plate.

The flooring of the entrance section should be of smooth concrete or brick. The walls and the chimney base should extend at least 30 cm below the floor. A water drain must be built at the lowest section of the passage. The drain must be covered with bars and it must be fitted with air pockets or blow-through openings to equalize the air pressure. To prevent the intrusion of splinters into the shelter, the ante-chamber and the shelter will be at right angles to one another. The entrance doors should be gas-proof packed doors, if possible, of concrete. For trench shelters with a capacity of fewer than 50 people, an emergency exit may be set up instead of a second entrance. Shelters housing more than 100 people must be equipped with an emergency exit situated at the middle in addition to the double entrances. The emergency exit is a window opening out of the shelter area, covered with an easily-removed cover and fitted with an iron ladder. The opening connecting the shelter with this window is walled in a manner similar to the emergency corridors, and is marked by an "Emergency Exit" sign. The shelter must be closed off into sections with a capacity of 30 people by gas-proof doors on both sides. (See Figures 48 and 49.)

In addition to its own weight and the weight of its earth cover, the covered trench shelter must be planned for an evenly-distributed load of only 200 kg/m^2. The shelter should be so situated that it is removed from main streets. Trench shelters must be situated at a distance from the exterior walls of buildings equal to at least one-half the height of the cornice /sic/.

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The Execution of Trench Shelters.

To avoid excessive loosening of dirt, the trench may be dug only as wide as necessary for insulation work to be completed. In firm soils the side walls of the trench may be vertical, but in loose soils bracing must be used. The excavated dirt must not be piled up at the edge of the trench, because the wall of the trench can be collapsed easily from this load. The ground cover of the shelter roof should be about 0.50 m, at most 0.70 m, with a crown at least 1.30 m wide, double sloped at a minimum pitch of 1:2. If stone or brick is available at the construction site, it must be used to give an extra cover over the shelter, at least 20 to 30 cm thick. This serves to prevent the penetration of firebrands.

Tunnel shelters are fitted with a drain under the surface to get rid of interior moisture; to get rid of exterior moisture, run-offs are used. Since insulation is necessary against both interior and exterior moisture, the insulation is put in place on the outward side of the material which forms the interior cross-section of the shelter. For brick or concrete construction this insulation is a coat of insulating mortar; and for wooden structure, more sensitive to moisture, it is a cemented insulated sheet. The insulation of shelters assembled from prefabricated units of water-tight concrete is simpler and cheaper. In these shelters the only insulation necessary is water-tight packing at the joining points. (See Figures 50, 51, and 52.)

Trench Shelter Equipment

There should be at least one pit latrine in every interior area. For ventilation, each interior area should have at least three 0.15 x 0.15 m ventilation pipes which can be locked with a gas-proof device from inside the shelter.

It may be necessary to string electric lights in the shelter. The possibilities of emergency lighting must also be considered by installing shelves for candles.

Since the trench shelters are outside the residences or working places of those to be protected, and since they must be reached in the dark in the event of a night raid, signs or directional lights to assure proper orientation in the dark must be set up for quick and uninterrupted access.

Because of the sensitivity of trench shelters to moisture, they require an extra amount of maintenance, most important of which is a frequent airing, especially in the period immediately following construction. Cracked insulation must be replaced immediately and water which breaks through the surface must be drained off; these things can cause the complete collapse of a shelter.

The most economical and quickly-built trench shelters are formed of ready-made reinforced concrete units, though they have the disadvantages of having to be prefabricated at a plant and of being difficult to transport to the site, because of their large size and great weight. The vaulted brick shelter is more difficult to construct and insulate, but it has the advantage of requiring no special construction materials. The wooden shelter is especially resistant to ground hits and, therefore, is best of the three, but the difficulties of procuring wood and its sensitivity to moisture require that this type be sparsely used.

E. Special-Purpose Shelters

Safe, properly equipped shelters must be built to assure that civil defense commands and certain groups in important institutions can carry on operations during an alarm. The shelters built for the institutions have arrangements varying according to their purpose. As a result, general principles for their establishment cannot be set down. However, the shelters serving the civil defense commands are prepared with nearly identical arrangements, fixed by civil-defense procedures, and general guiding principles can be laid down for their establishment. This is also true of municipal aid stations, public shelters, and the command shelters of industrial plants.

Municipal Civil Defense Centers

In towns and larger cities the highest municipal civil defense control originates in the district (Kerulet) civil defense centers. Therefore it is especially important that these be safe, if possible bomb-proof, in the interest of the continuity of defense. Because of the relatively small staff of the individual commands, the construction of separate bomb-proof bunkers is not economical. These command groups then should be situated in existing bomb-proof galleries if possible, or, lacking these, in TGS shelters having sufficient safety and removed from endangered areas.

In choosing the site of the civil defense center, it is necessary to take into account the possibilities of the most economical construction of communications lines and the possibilities of the access from, and the surveying of, the area comprising the command. The civil-defense center shelter differs from other shelters in that it operates not only during an alarm, but also day and night during civil-defense activity. Consequently it must be arranged in a way suitable for continuing stays. Proper temperatures for the living quarters must be assured for year-round day and night operation. The operational areas must be insulated against moisture and interior vapor, in the interest of protecting the sensitive electrical equipment placed there, as well as for comfort. The number of people staying in the shelter must form the basis for setting the air and space requirements. The interior air space should be at least equal to a TGS shelter built without a filter. In addition, an exhaust-filter machine must be used in each case. The exhaust-filter equipment should be so located that the noise of its motor will not disturb work.

As in a TGS shelter, the civil-defense shelter consists of an ante-chamber and interior areas. The largest interior area, located in the central section of the shelter, is the analysis room, with which the Signal Center /Hirado Kozpont -- apparently a specific superior unit/ is closely connected. Complementing these two rooms are the office, off-duty rooms, and the room for the exterior civil-defense personnel (aid teams, rubble cleaners, sanitation personnel, etc.). The ante-chamber should open directly onto the analysis room, but this room should not serve as a corridor into the rooms further on, though it should connect to the receiver room (communications center), also reached from the ante-chamber. In addition, there should be access from the analysis room into the office and from the commander's quarters into the room containing the radio and alarm equipment. The showers, personnel quarters, stockroom, machine room, etc., should all open onto the ante-chamber and should not be connected to other rooms. (See Figure 63.)

The most expensive technical equipment of the civil-defense center is in the analysis room and in the telephone room. Therefore these rooms should be in separated protected places whence emergency exits do not open on the outside. The communications equipment and the switchboard which operates the alarm system should be protected with splinter-proof walls. The telephone operators should work in sound-proof booths; their reports should be handed through a small window into the analysis room. Good sound-proofing is very important, because the noise of talking will disturb others and make the service more difficult.

The ante-chamber and the analysis room should be large, if possible, since couriers and other personnel will arrive in the ante-chamber and wait there. The minimum area of the analysis room should be 12 to 14 m^2. It must be borne in mind that the commands of neighboring districts may be interrupted, making it necessary for the existing commands to take over their jobs; this will be possible only if the center is planned for a larger area at the beginning.

Because of the constant work of the center, more comforts for those working there must be assured than in TGS shelters by the proper lay-out and equipping of the center. Therefore the shelter must be equipped with running-water showers and flushing toilets; and all the rooms must be heated by hot-water supplied from an independent boiler. Emergency lighting powered by a storage battery must also be considered, in addition to the electric lighting powered by outside sources.

This principle must be borne out in the interior equipment, by installing comfortable beds, chairs, and tables. It is not absolutely necessary that the personnel quarters be in the shelter near the civil defense center, but they should at least be located near the shelter in the building above the center.

If other shelters are also located in the basement area where the civil-defense center is set up, their access routes should not coincide with the center's access routes. The line conduits should not enter the shelter all at one place, but, rather, at several points on opposite walls, so that it would require several nearly direct hits to cut off all the conduits. Special care must be given to setting up emergency exits, and if local conditions hamper the installation of these, then emergency tunnels or vertical emergency exits must be established.

The command shelters of the larger industrial plants are similar to the civil-defense centers. In these plant shelters the alarm and communications equipment is simpler. In these shelters the sensitive plant equipment (electric and caloric power machines, etc.) is placed, as are the remote-control instruments and such aid equipment as is proper for the nature of the plant. Since the industrial command shelter must be within the endangered area of the plant, it should be made bomb-proof if possible.

Civil Defense Aid Stations

The civil defense aid station is the bridge between the temporary aid stations which administer first aid, and the hospitals which give treatments extending for fairly long periods. Civil-defense aid stations must be established, since there will be a need for many emergency operations following an air raid, and there will be insufficient time for many of the wounded to be transported to the distant hospitals.

To this end the aid stations should be so set up that there are facilities for decontamination, medical examinations, and surgical operations, as well as facilities where the sick may rest for a few days before their transfer to a hospital.

Since the aid station will serve both wounded and gas-contaminated casualties, the layout must be such as to prevent the entry of gas contamination from outside. This is done by having the sick people come in the "contaminated" entrance, where, after admission, they will place their clothes into a decontamination unit equipped with its own ventilator. They will then pass through a shower-bath into the examination room. If the examination shows that further treatment is unnecessary, the patient dons his now-decontaminated clothes and departs through a sterile exit. It is of vital importance, then, that the "contaminated" entrance and the sterile exit within a building not be directly connected, and that anyone having come through the entrance be able to reach the exit only via the decontamination room.

If further treatment is necessary after an examination, the patient steps into the dressing station next to the examination room, or into the preparation room next to the dressing station, and thence on into the operating room. After the operation the patient is moved into the men's or women's ward if he or she is to remain at the aid station.

In its basic layout the aid station consists of three major parts: 1) the integral grouping of the receiving, decontamination, examination, preparation and operating rooms; 2) the men's and women's wards and the nursing room, attached to these; and, finally, 3) the business and administrative section, composed of the kitchen, pantry, office and doctor's room. In larger shelters it is preferable to set up an isolation room for nerve cases or others requiring quiet surroundings. The three groups each form closed units, most especially the first, where the arrangement of the rooms one after the other must be maintained without fail. If conditions demand, the three groups may be somewhat removed from each other.

The aid station must be constructed for the degree of safety required of TGS shelters, and special care must be taken to guard against the health-detrimental effects of placement in the basement.

Public Shelters

In periods of peak traffic, shelters of buildings along the main city routes would be insufficient to accomodate the passers-by in the area. Therefore public shelters must be set up along the busy streets for the use of large groups of people. Besides preparing public shelters, shelters must also be set up where there are groups of single-story or basementless residences, for which it is impossible to establish TGS shelters.

In choosing sites for public shelters those local conditions which will afford more protection than a TGS shelter must be exploited. Such conditions (caves, galleries, etc.) are usually removed from the busy sections of town, but experience has shown that the populace would prefer these, even though a longer time is required to reach them, since they know that such shelters offer greater protection than shelters in residences.

Above-ground, bomb-proof bunkers are very good for use as public shelters. These can be built at the most suitable sites in the city, although to protect the populace adequately bunkers would be required in such numbers as are impractical from an economic standpoint. There is a danger in having too few bomb-proof public shelters because during an alarm masses of people greater than the acceptable capacity would flock in. This would result in crowding and panic which can endanger lives.

Therefore most municipal public shelters will be set up in existing buildings. Either buildings having a large basement, or basements of residences built for workshops or storage are suitable for setting up public shelters. The protection afforded by shelters under timbered surfaces is much less than that of TGS shelters set up in the basements of houses several stories high. The depth of the ground cover and the insufficient thickness of the roof will not protect against a direct hit. A single direct hit is enough to completely wipe out the shelter, because large masses of people are crowded together in a small area. Trench shelters constructed with the arrangements given above are both much cheaper and much safer than these.

The basic arrangement of shelters built in existing buildings with the degree of protection offered by TGS shelters are not much different from the normal arrangement of TGS shelters, except that a separate room must be assured next to the ante-chamber for the use of the commander, charged with the control of the shelter and the maintaining of order. If the capacity of the public shelter is more than 150 people, several shelter units must be set up independent of each other.

During an alarm, people who are not familiar with the access routes will use the public shelters. Thus an important requisite is the planning and arrangements of those routes, as well as a clear marking of them, to assure quick access. Public trench shelters built in open areas must be so situated and formed that they can be reached quickly from any direction, and that they will meet completely the requirements of good trench shelters.

Civil Defense Shelter Chambers

Shelter chambers are prepared in industrial plants and other endangered areas to operate as damage observation stations during an alarm. The role of a damage observer is to observe the outer area or the interior machine areas, and to report by telephone to the authority concerned any fires, explosions, or other damages noted. When shelter chambers are located outside, they are on building roofs or at other elevated points from where fairly large areas can be seen. When they are inside, they are placed near the machines which will remain in operation during an alarm. In locating shelter chambers care must be taken that only as many as necessary are used, and that these are placed at the best observation points. The shelter chamber must be safe from air pressure, splinters, and debris. To achieve protection from air pressure, the shelter chamber is built so that it can be sealed airtight. The structure is connected to the building structure above or below in such a way that it cannot be upset by air pressure. The problem of safety from debris in shelter chambers located within or next to buildings or in the open is solved by the small size of the chamber. Due to its splinter-proof construction, this type is usually sufficient in itself. Because of its small interior dimensions, the shelter chamber will accomodate two, or, at most, three people. Splinter protection is assured by the side walls of the chamber and the roof forming an integral unit with these, and also by screening walls in front of, and overlapping, the entrance. A shelter chamber constructed with splinter-proof walls of the materials and thicknesses given in the discussion of splinter protection will meet the need. However, in practice, instead of brick or concrete walls, chambers are built almost exclusively of reinforced concrete. With cement of 270 kg/m^3, the reinforced concrete should be at least 25 cm, and, at most, 35 cm thick. If the cubic solidity of the concrete reaches 500 kg/cm^3, a wall thickness of 15 cm is possible.

Usually the shelter chamber is of a cylindrical shape with a semi-spherical terminal reinforced by the side walls. Air pressure slips around the surfaces of the sphere thus formed, and its real effect on the chamber is less than if it were formed of plane surfaces. There are observation ports in the cylindrically shaped walls at seated or standing eye levels. The observation ports must be cut out of steel sheet at least 20 mm thick, with the extensions of the sheet cemented into the concrete of the shelters. The width of the opening should be no more than 8 to 12 cm. The observation ports must be fitted with small, thick glass, steel-framed windows, opening inward and air pressure-proof. In this way the exterior glass surface can be cleaned easily by opening the window from inside. (See Figure 55.)

The reinforcing of the shelter chamber is of #6 to #8 steel rounds, in a 5 x 5 mesh network which must be placed near the surface of the wall lying next to the person or object to be protected. It is preferable to tie the reinforcing network into the side walls by means of straps, extending to the outer edge of the wall and holding to the 5 x 5 network, situated every 50 cm in checkerboard fashion.

To build the shelter chamber of steel sheet would require steel sheet 35 to 40 mm thick to be splinter proof; this is not economical.

If the shelter chambers are joined to a wall of a building, or are adjacent to reinforced concrete pillars, the chambers must be tied into the walls or pillars with the proper reinforcing. Shelter chambers standing in the open must be built with a base frame wide enough that the common center of gravity of the shelter and its base frame will be well below the surface of the ground. Shelter chambers located on building roofs are connected to the walls or the uppermost roof beam.

The door should be a reinforced concrete or a steel shelter door, set in an angle-iron casing which has been tied into the shelter concrete. The surface of the door opening out of the shelter is flat and therefore does not follow the curvature of the cylindrically shaped chamber. Splinter-protective walls must be built in front of the entrances by the same method used in constructing the walls of the chamber. Access to the chamber may also be gained via a lower shaft by breaking through the ceiling over it. In this case the chamber is closed on all sides and the entrance door is in the shaft wall on the lower surface of the chamber. This wall is built of the same material as the chamber. In such an instance the splinter-protective wall in front of the door may be dispensed with. (See Figure 57.)

Shelter chambers placed in interior working areas should be situated, whenever possible, at wall junctions or other points where the existing exterior walls of the building will afford protection from splinters from outside. Since such a shelter is connected to the walls and would offer observation in only one direction, it is more practical to build these in a square rather than a circle.

Telephone lines coming into a shelter chamber standing in the open should be laid in underground concrete pipe, brought into the shelter through an underground entry.

Shelter chambers are not gas-proof. Personnel in the chambers should be equipped with gas masks as protection against poison gases.

MECHANICAL EQUIPMENT OF SHELTERS

Securing Devices for Openings

The devices which are used to secure openings do not really belong under mechanical equipment, but we have included them here for a uniform discussion of the built-in steel fittings.

The devices used in a shelter to secure openings are:

1. The entrance or "ante-chamber" door, leading into the shelter from the outside or from within the building;

2. The so-called "interior area" door, the door or doors connecting the ante-chamber and interior area(s) or between interior areas.

3. The "emergency exit windows," the doors or windows closing off the emergency exits.

In contradiction to the old decree, the various securing devices for shelter openings may not, on the basis of wartime experience, be considered splinter-proof. These afford protection only against air-pressure and gas. These openings are made splinter-proof only by building splinter walls in front of or beside them.

We may consider the devices used to secure shelter-openings splinter- and air-pressure-proof when, in an interior location the outer doors are of 1 t/m² density, protected by splinter walls and, in shelters standing in the open without splinter walls, the doors are of 2 t/m².

and when in both cases the locking devices will withstand a static pressure or suction of 5 t/m^2. The exterior doors of bomb-proof shelters must be planned for a static pressure of 10 t/m^2.

To afford protection from air pressure the securing devices must be built in with great care. The extensions which serve to anchor the angle iron casings may not be cut off or shortened to facilitate installation. The frames must be set in place by imbedding the claws into the concrete, and by carefully filling the strips between the frame and the wall with cement mortar.

In general, the door frames are in the outer plane of the wall, so the locking devices do not terminate in the interior wall grooves when closed, but rather fit tight against the wall. Locking devices lying in the plane of the wall grooves may be used only when this plane is at least 20 /sic/ because of an ability to be raised above the edge of the angle iron lintel. Normally, the doors should open outward from the shelter interior. While this is an advantage against air pressure, it is a disadvantage against air suction and against the blocking of the door by debris falling in front of it. The debris-diverting canopy presently in use or a chamber opening outward around an emergency exit hinder such blocking. If a debris-diverting device cannot be devised, the entrance doors and emergency exit windows will have to open inwards.

The opening locks are made gas-proof by rubber packing sunk into grooves made at the border. The rubber packing is gas-proof only when it stretches well along the door frame and the ends of the packing in the opened groove join perfectly to each other. Rubber packing may be used over a long period only if properly maintained. (See Figure 58.)

Two steel bolts, equipped with interior and exterior levers, serve to secure the opening locks; these hold to the claws which are welded to the angle iron frame. (See Figure 59.)

The interior measurements (free frame dimensions) for the ante-chamber and the interior area are 85 x 185 cm; for the small emergency exit windows, 70 x 50 cm; and for the large emergency exit windows, 70 x 85 cm.

The devices to secure the openings may be of steel sheet, reinforced concrete, wood, or various compounds. Emergency-exit devices of steel sheet will be used only in bomb-proof or other important shelters.

The emergency exit windows and the doors of TOS shelters which open onto the outside should be reinforced concrete to secure the openings. The ante-chamber and interior area doors which open into these areas from within the building may be gas-proof wood. Any cracks in the wooden doors must be made air-tight. Felt strips will be used to get an air-tight seal between the frame and the door. If necessary, when treated thusly, any sort of regular plank or dressed wood door may be considered gas-proof (G-door).

The regulation MOSZ 800 /Magyar Orszagos Szabvany: Hungarian National Regulation/ prescribes the shelter door structures, their safety requirements, and the means of testing those requirements.

Shelter Ventilation

An indispensible condition to the usefulness of a shelter is that the air necessary for sustaining those inside must be assured. This air must be pure to be suitable for breathing. In addition, the air should not be in such a condition that it brings about a sensation of oppressiveness.

The vitiation of the shelter air can be traced to both exterior and interior reasons.

Contamination of the shelter air from outside sources can be caused by poison gas vapor, dust, radioactive particles, and bacteria. We may also include the case when the exterior air is heated by flames or by indirect heat radiation to a point where it is unsuitable to be fed into the shelter.

Exhaustion of the interior air supply is caused by the consumption of oxygen and the production of carbon dioxide by those inside the shelter. An increase in the temperature and vapor content of the interior air makes the shelter uncomfortable. These things are caused by heat production and giving off of moisture by the persons inside, or even by other sources of heat (lights, motors, etc.).

In case of danger, vitiation of the air by an outside source is caused by either blocking off the outer air, or by using air filter-ventilation equipment.

The shelter is completely isolated by its devices for securing openings, the ante-chamber, and, possibly, by a sliding lock on a built-in ventilator.

The complete isolation of the shelter guards against all exterior vitiation. However, special care must be taken as regards the rubber packing around the devices which secure the openings, in crack-free plastering of the walls, in perfect packing of pipes which may run through the shelter via holes in the shelter walls, and in any other condition (e.g., door frames improperly set in the walls) which would permit unsuitable air to enter the shelter from outside.

The use of air-filter ventilation equipment partially prevents a vitiation from without. With this equipment, poison gases, smoke and dust can be removed by the smoke filter from the air brought in from outside, though it will not take out carbon monoxide. Dust filtering will absorb dust and radioactive particles at the same time; however, extremely fine dust particles will pass through the filter and enter the air space of the shelter. The filter will not protect against bacterial contamination, nor will it prevent heated air from entering the shelter.

While poison gas, smoke, and dust contamination may last for a long time, the presence of heated air or radioactive particles will last only for a few minutes. Bacterial contamination probably will not see strategic use.

Thus the shelters are protected from vitiated outside air in such a way that before an attack, unfiltered air will be used for ventilation; during and after an attack, the shelter can be completely isolated for 10 minutes; after which the filters will be used to block off the gas, smoke, and dust contamination; or, if there is no such contamination, ventilation with unfiltered air can be begun again.

The decree states that if there is no filtration-ventilation equipment, an air space of at least 2.5 m^3 per person must be assured for those in the shelter. If there is filtration-ventilation equipment, then the smallest premissible air space per person is 1.6 m^3.

Consumption of oxygen and production of carbon dioxide cause the air to be exhausted in a closed room.

The human body will not suspect a reduction of oxygen even when the carbon dioxide present is causing serious discomposure. No more than a 2% carbon dioxide quantity may be permitted within a shelter. If those inside the shelter must perform manual labor, only 1.5% carbon dioxide may be permitted; and if fatiguing mental work is being done, the carbon dioxide content must not rise above 1.0%.

The average carbon dioxide production per person is 0.3 to 0.6 1/min, if the person is at rest.

From the above data it may be seen that for passive personnel in a shelter with 2.5 m^3 of area per person, a 3-hour stay in the shelter, even when the shelter is completely closed, would not be injurious to health. Since, for complete safety a 5-hour closing-off of ventilation must be counted on, an air space of 12 m^3 per person must be assured for active personnel, 18 m^3 for doctors, and 6 m^3 for passive personnel.

If the provisions of safety permit, to reduce the accumulation of carbon dioxide the ventilation of the shelter can be begun by opening the securing devices or bringing in air through the filter device.

The degree of the carbon monoxide accumulation depends not only on the air space, but also on the size of the ventilation system.

Thus in an air-filter ventilation system, a 30 l change of air per minute per person in a shelter set up in a residential building must be considered. This change of air should be 30 to 50 l in an area housing the civil-defense aid detachment, 50 to 80 l in a shelter first-aid station, and 80 to 100 l in a command area and telephone center. In a surgical operating room, the change of air per minute and per person should be about 200 l. (See Figure 60.)

The shelter walls, the securing devices for the openings, etc., must all be packed so well that, in bringing in air through the filter, an excess pressure corresponding to 2 mm on the column of water will arise.

In planning special shelters where a relatively large air space is available for a small number of persons, and where the walls have excellent packing, as for instance in surgical operating rooms or in the command areas, we must take as our basis for computation the principle that "the filter ventilation equipment should move at least as much air per hour as one-half the cubic area of the room in question."

The filter ventilation equipment and its parts, can be built to move 600, 1,200, 2,400, and 5,000 1/min. Equipment of capacities greater than those can be used, based on the principles given for the 5,000 l size.

The data of the types listed is given in the following table.

Filter-ventilation capacity in liters per minute	Greatest number of persons which can be served			
	Passive personnel	Civil-defense personnel	Aid station	Command Area and telephone center
600	20-30	20-12	12-8	8-6
1200	40-60	40-24	24-16	16-12
2400	80-120	66-48	48-32	32-24
5000	170-250	170-100	100-66	66-50

The filter-ventilation equipment must be used whenever there is electric power; it must have a motor and a hand drive, as well. The hand drive may be omitted only where emergency power generating equipment is available, installed in an area of the identical same security as the shelter. If no emergency power source can be set up, only such filter ventilation equipment as can be driven manually by two persons will be used.

The filter ventilation equipment consists of the following components:

aspirator, air filter, pipes and other fittings such as an excess-pressure-reducing valve, dust collector, air-quantity meter, damping regulator, intake-pipe lock valve, air-distribution valve (clack-valve) and dehumidifier, flexible connection pipes (rubber hose), by-pass pipes, and instructions for use. (See Figure 61.)

The aspirator produces a movement of air. Machinery based on the principles of differences in air weights may not be used. At present two types of aspirators are permitted: the centrifugal type and the diaphragm-piston type. Both types meet the proscribed requirements and both are fitted with an electric drive. The centrifugal type aspirator must always be fitted with an air-quantity meter (in the case of a manual drive, as well). The diaphragm-piston unit requires this meter when it is to be operated by the electric drive. In both machines the damping regulator valve must be opened completely in manual operation, but in electrical operation the valve must be throttled when the air quantity meter does not show the desired amounts.

By-pass pipes must always be used in filter-ventilation equipment. By means of these not only do we rest the filter equipment during pauses in an attack, but also make possible the ventilation of the shelters in those cases where the temperatures inside and outside are nearly the same and the natural ventilation will not start after opening the secured doors.

All ventilators and motors must be of a size sufficient to bring in at least $2\frac{1}{2}$ times as much through the by-pass valves as through the filters.

The air filter consists of gas, dust, and smoke filters. The dust collector must be installed in the intake pipes to ease the load of the smoke filter. The air filter may be changed while the shelter is in use; an intake branch lock valve is necessary. The air filter can be screwed into the aspirator by a standard threading, while flexible connections usually link the air filter with the intake pipes.

One part of the ventilation pipe must be situated outside the shelter. This pipe should be made of cast iron or asbestos cement, so that, if it is damaged, it will not collapse but will break instead, thereby not closing off the route of the air. Mild steel pipes will be used in shelter walls and, within the shelter area, pipes of mild steel or welded steel sheet will be used.

The total resistance of the pipes (intake pipes, distribution pipes, and return-air pipes) cannot be more than 20 mm on the column of water. The flow resistance of the pipes is

$$H = \frac{L.v^2}{400D^5} \quad \text{where in}$$

L = length of the pipe or equivalent length of the fittings (in meters)
v = quantity of air coming through (in cubic meters per second)
D = interior diameter of the pipe (in meters).

Equivalent lengths of fittings are: curved pipe, 4 m; elbow, 15 m; perpendicular branches, 10 m. The wall thickness of the steel sheet pipe should be at least 1.5 mm for an interior diameter of up to 100 mm, and 2 mm for an interior diameter of 100 to 120 mm. The sleeves of the coection which are outside the shelter should be installed facing downwards, so that rain will not enter. The interior pipes should be airtight. The pipes should be protected inside and out against rust.

The filter equipment must be set up in the shelter, so that, except for the intake pipes, all of it will be within the shelter itself, thus in a place protected from the effects of an explosion. Air should be drawn from 2 to 5 m above ground level. In closed courts the end of the pipe is taken up to the crest of the roof.

If a vertical emergency exit is built, the tube may have its own air intake pipe.

The head of the intake pipe is protected by a locking cap against the entry of rain and other material. The dust collector might be installed here too. In equipment of 1,200 l/min capacity, one intake pipe is sufficient; however, for units larger than this, at least two intakes are installed. Any branch-offs should be inside the shelter. The intake pipe branchings, if possible, are led out of the shelter at opposite points, and intake heads should be as far apart from each other as possible. The dehumidifier is installed in the pipes inside the shelter. The pipes should slant as far as the dehumidifier. Beyond the dehumidifier, all intake pipe branchings should be equipped with valves. If we wish to use the dust collector in the shelter, it is installed between the dehumidifier and the lock valve. Following this, the intake pipe is connected to the air filter in such a way that the air brought in passes first through the smoke filter, and then through the gas filter, in the direction of the arrows painted on the canister.

With the filter ventilation equipment we produce an excess air pressure equivalent to 2 mm on the water column. The diverting of the superfluous air takes place in the valve reducing the excess pressure. The valve reducing the excess pressure between the interior area and the ante-chamber of a shelter should open and close automatically between water column pressures of 5 to 5 mm. The excess-pressure-reducing valve must work by gravity, since in a shelter the maintenance of spring-operating equipment is difficult. Valve devices are to be protected against rust. The diameter of the pressure reducing valve and of the pipe which may lead from it should be at least eight-tenths the diameter of the intake pipe. The lead-out pipe is of cast iron or asbestos cement. For easy manipulation, the valves should be placed at normal head level. The valve should be able to be locked.

To measure pressure a pressure gauge is placed in the shelter.

The flow of air within the shelter is directed so that the air taken in and filtered is routed first to the interior area, then into the ante-chamber, and then, possibly by diverting it through unused rooms, into the open. It is also practical to route the air through the latrine, thereby cross-ventilating it. Pressure-reducing valves should be placed in the wall according to this principle, and if it is deemed necessary, pipes may also be inserted. Repeated openings of the door do not disturb the course of the air flow; therefore we may locate the valves near the door.

The purified air may also be brought into the interior area through several openings in the delivery pipe, if this method affords better distribution of air, as, for instance, in long and relatively narrow shelters. We can also effect the supply of air by the use of several aspirators. It is permissible for one aspirator to supply purified air through delivery pipes to several interior areas located next to each other. However, there should be valves which can be locked by hand between the individual interior areas. (See Figures 62, 63, and 64.)

It is very important that the air-distribution valve be able to be fixed in a position adjusted to the proportion of the delivery-pipe air supply. This is necessary lest someone quartered in the shelter change the setting of the valve either through curiosity or ignorance. Such setting changes can influence the air distribution to the individual interior areas greatly and, by causing greater choking, make the operation of the aspirator more difficult.

The correctly-planned wall cuts for the filter ventilation equipment should be marked on the execution plans of the shelter. Wall cuts below ground level must be made at the same time as the insulation work on the wall, and the pipes must be put into position, since the insulation cannot be replaced satisfactorily after a cut is made in the finished wall insulation.

If there is opportunity, we must wait for the newly constructed or remodeled basement to dry out. Only then will the filter ventilation equipment be installed, except of course, for the components set in the wall. After installation, the surfaces which will receive wear must be painted with a good rust-protecting paint. However, the factory marking and the seal showing inspection by the authorities must not be covered.

Storage of the air filters with their locking caps is best in a hermetically-sealed condition. In peacetime it is practical to connect the filter equipment to the aspirator with a flexible hose. In this way we may run tests, in addition to storing the filters in the best manner. The reserve filters, with their protective covers screwed on well, are stored in the shelter on a layer of wood, or in a box, so that they will not hit against the wall or the floor.

Fitting should be done by a competent enterprise, experienced in this field.

Personnel must be instructed in the use of the aspirator. This is done on the basis of operating instructions always required of the producer and concurred in by the authorities.

One spare filter for each of the filters must be procured and stored at the site. Filters kept in operation through repeated attacks must be replaced.

Natural cross-ventilation during periods when there are no attacks must be assured for all shelters, even those with filter ventilation equipment. Doors and emergency exits can be used for natural cross-ventilation.

Other phenomena, such as the interior temperature and an increase in relative humidity, which cause vitiation of interior air, will be discussed in the section dealing with the heating of shelters.

Shelter Heating

The heating of shelters is not prescribed by the decree, but the experiences of the last war, as well the economical peacetime use of shelters, show it to be necessary. The shelters must have heat just as any room serving for continuing habitation requires heat. Therefore the gas-proof sealing of the chimney opening must be taken care of by the small-opening lock developed for this purpose. Heat can be supplied from tile stoves built outside, but it is more practical to use hot water, steam, or electric heaters.

Personnel within the shelter generate heat. This heat generation amounts to about 100 calories per person per hour.

In general, an air space of 2.5 m^3 per person is assured in shelters. One cubic meter of air space amounts to an average of 1.6 m^2 of area. Since shelter walls are very thick, or a good bit of the shelter is below ground, the heat transmitted remains below 30 calories per hour. As a result we must take into account a warming-up in an inhabited shelter which in mild weather may amount to excessive heat.

This heat can extend so far in summer weather that remaining in the shelter becomes uncomfortable and, for some, unbearable.

The rise of the moisture content of the interior air occurs along with the warming up of the shelter. One person, with his transmittal of heat, gives off 30 to 70 g of water or water vapor per hour. This quickly saturates the air and the relative humidity of the air approaches 100%. (See Figure 65.)

The cooler walls of the shelter promote the reduction of heat and the partial precipitation of the water vapor. (See Figure 66.)

In an experiment conducted on 27 December, 25 people were placed in an area of about 78 m^3 interior air space with a 50 m^3 change of air per hour. Within one hour the temperature rose from 17° to 22° C. In summertime, the rise of the interior temperature was even more marked.

In those shelters where the interior temperature does not fall below 10° to 12° C in wintertime, heat is superfluous; in fact, it is disadvantageous from the standpoint of the condition of the air.

In those shelters where there is 6 to 12 m^3 of air space per person (aid stations, command posts, communications centers) and where the interior temperatures drop below 8° to 10° C during the winter, the installation of heating equipment is necessary.

Stoves are not used for heating shelters. In central hot water and steam heating the equipment should be of a type which will allow the shelter section to be disconnected.

Generally, electric heating can be employed well.

Hot air heat and air conditioning can be employed very well in the larger and special purpose shelters.

Heating and Ventilation of Special-Purpose Shelters

In shelters where normal work must be conducted during an attack (hospital shelters, civil-defense centers, higher offices, etc.,) proper ventilation and heating equipment must be installed where:

1. the air must not exceed the given relative humidity,
2. the desired temperature is to be maintained in winter and summer,

3. the condition of the air prescribed for habitation must be maintained for hours or, possibly, several days after a complete shutdown,

4. the air brought in through the filter-ventilation equipment is greater than the quantity prescribed.

These conditions are met by air-conditioning, by circulating the interior air, by oxygen feeding, and by drawing off the carbon monoxide.

Air-conditioning includes air cooling.

Shelter Lighting

Lighting of the same type and intensity as is used in working areas and residences quarters must also be used in shelter whenever possible. In addition to the general illumination, lighting of the proper intensity must be made available for work places (on desks).

Bad lighting gives rise to dejection and to anxiety in many people; it makes the completion of work difficult and leads to fatigue quickly.

The general lighting of the shelters should be uniform. For this reason several sources of light must be employed. Lamps are suspended up high when possible, and bulbs or tubes which impart good illumination are employed. Lamps are not hung on the walls or pillars, but instead, from the ceiling; lamps hung on pillars throw especially strong and sharp shadows. Light from bare bulbs causes glare; therefore these should be fitted with diffusing or opalescent covers.

Illumination must be planned for a point one meter above the floor. Light from the emergency units should be at least three luxes. The following are the light requirements for various activities:

Activity of a nonprecise nature: simply staying in the shelter, handling the shelter equipment, removing splinter fragments, cleaning: 8 luxes.

Moderately precise work: telephone, alarm and signal apparatus operation, medical stores, storeroom operations, etc., 20 luxes.

Precision work: typing, writing in general, reading, etc., 60 luxes.

Very precise work: stenography, drawing with colored pencils, medical activities (ambulance, surgical operations, bandaging, etc.): 100 luxes.

Under no circumstances may open-flame lighting be used in a shelter; it not only consumes the shelter's oxygen but also produces gases in its combustion and these gases taint the shelter air. For these reasons electric lighting is used almost exclusively in shelters. In special cases a very weak light, effective only when the current is off, can be produced on a large surface by fluorescent paints.

Emergency Lighting

Emergency lighting, supplementing the lighting powered from the outside network, must be considered for those periods, long or short, when the power is interrupted because of damages. The power source of the emergency lighting may be, in the larger shelters, a generator connected to some power machine or a storage battery of the necessary capacity, equipped with a charger. It may happen that both sources are used. In the smaller shelters, hand lamps powered by storage batteries or dry cells may be used.

As a rule, a current of a lower voltage than that of the power net is used in emergency lighting. Either automatic battery illumination or a buffer plant is installed; these consist of fairly small cells, and are in themselves fairly small. In this way we may use cheaper storage batteries. Due to its lower voltage a separate line net must usually be built for the emergency lighting. The emergency power equipment must be planned so that an automatic switch will turn on the emergency lights when the net current fails.

Normally the electric net of a shelter must be installed according to the requirements for damp rooms. Acid-proof pipes, and water-proof connections and fittings must be used; otherwise, the equipment will be deteriorated by the weather, and this can cause a disruption of the lighting system. In a shelter arrangement with several interior areas, the lighting net must be broken into several circuits, so that, when something goes wrong in one room, the whole shelter will not be plunged into darkness. Since it is very difficult to notch or drill through the reinforced concrete sections of the shelter, and since this reduces the load-bearing capacity of the structure, the locations of the recessed pipes and the wall-holes should be made when the structure is cemented.

Current Generators, Storage Battery

Current-generating batteries of varying capacities and voltages can be readily obtained. In the civil-defence centers of larger cities the generator unit which operates the main siren may be used for the emergency lighting of the shelter. If the generator cannot be placed within the shelter interior area, it must be located near the shelter at a point which affords the same degree of protection as the shelter. The exhaust gases must be conveyed directly to the outside through pipes; in addition, to supply the engine with fresh air, the intake pipe of the engine must be connected to the outside. The operation of the current generator should also be controllable from the interior shelter area by telephone.

In the emergency lighting equipment of a shelter basic batteries are used to good advantages; the operation of them is simple, they are long-lived, insensitive to slight shocks, and can be stored well in a discharged condition. In contrast, acid batteries are cheaper, but they require very careful handling. They must be kept filled constantly, because otherwise they will deteriorate. In addition, the acid fumes from them contaminate the shelter air and attack metal surfaces within the shelter.

The batteries should be of a size large enough to supply emergency lighting for a period of 8 to 10 hours continuously. Shelter shut-downs must be used for charging. The storage batteries must not be almost completely discharged, because the recharging of a completely dead battery takes a long time and requires greater skill. The best method of charging shelter batteries is the so-called "drop charging" done while the unit is in operation. In this method the charging of the battery is constant and continuing and stops automatically when the battery is overcharged. In an alternating current net the most practical means of charging the battery is with a selenuim cell rectifier.

Lighting Units

The network bulbs and the emergency lighting bulbs can be separate units, but it is more practical to use lamps fitted with double sockets in which filaments for both the net voltage and emergency power supply (low voltage) are contained.

Water Supply and Disposal

Water for each person's drinking and other needs must be stored in shelters set up in residence buildings. Even more water is needed in larger or special purpose shelters, for example, for showers, baths, the washing of contaminated clothing, in aid stations, in surgical operating rooms, for decontamination, and perhaps for flushing toilets.

At least one-half liter per person must be taken as the drinking water requirement. This quantity, when used frugally and according to the decree, is sufficient for 12 hours. More water is needed for washing facilities, but at least this much must be stored. Keeping an ample supply of water in readiness is especially important in large cities, since, in large-scale destruction, whole sections of a city may be left without a water supply when a quick replacement of the water level is impossible. At such a time, the needs of the shelter can best be complemented by the water stored in the residence units above.

Methods of Water Storage

Drinking water may be stored separately in fairly large water storing equipment. The drinking water must be stored separately in a case where water suitable for drinking is not available in abundant quantities. Good water in abundant quantities occurs in areas with a high water table level or in cities where the drinking water comes from good artesian or natural wells. Drinking water is stored in covered jugs, bottles, or special drinking water containers. Mineral water may also be kept in jugs. The containers for drinking water should have wide openings, so that they may be cleaned easily. For residence building shelters 25- to 50-l containers are suitable.

Water for washing may be stored in large jugs and buckets in the smaller shelters; iron or "Eternit" containers placed under the ceiling may be used in the larger shelters. Both the drinking and washing water must be kept free from pollution; therefore the vessels in which the water is kept must have tight-fitting covers.

In shelters housing fairly large numbers of personnel, or where the peacetime usage requires, several wash basins may be placed alongside each other.

Large water conduits will normally supply both water for drinking and for other needs. These will be installed in those shelters where they will service social rooms for peacetime use, and where baths are installed.

Because of the usual dimensions of shelters, the shelter water containers have to be placed at a low height, thereby producing such a low pressure that it is insufficient for conveying the water in an extended network properly. To increase the water pressure, the water containers may be of a closed type, equipped with a small compressor.

Hot water containers may be used in the shelters, too. Open-flame types may not be employed within the shelter; therefore the water may be heated by electricity or by heaters located outside the shelter. Such containers are needed primarily in operating rooms and aid stations.

Water Disposal

The problem of the storing or disposing of water which has been used in the shelter is as great as the water supply, and it must be studied carefully. For small quantities of water (as in HH shelters) sewage buckets or containers may be used. In TOS shelters where the quantities of used water are still not significant, a sewage drain is usually recessed into the shelter (ante-chamber) floor. Through this the water travels by a natural fall or by a rise (hand pump) to a cesspool or into the municipal sewer network.

Only piston pumps of the best quality will be used in the shelters, since only these will give a fairly long period of service.

The sewage drains of larger shelters types must be of single- or double-drain types. In the double drain type, the pump is below the water level; The sewage flows to the pump by its own weight; as a result, defects in the pump pipe will not prevent the transport of the water.

In the water drainage system locks fitted with backlash valves must be employed. These are needed, since, without them, sewer gases, poison gases, and illuminating gas as well, can enter the shelter through the drains. Simple gas traps filled with water or small siphons are not sufficient in themselves, since the explosion of a bomb can empty the water from the traps or siphons, giving the toxic gases a clear path into the shelter. Unused siphons must be filled with a steam-proof liquid. Traps fitted with backlash valves will be used in the main shelter drain. In other places simple water traps can be built. Instead of trap locks, gas-proof pipes may be installed. The drain pipe will be cut off outside the shelter. If the running-water pipes discharge into the drain at a point below the overflow outlet, the drain lock will not be free to react either to suction or to air pressure. Exterior drains must be protected from freezing. Construction and equipment details for shelter water supply and drainage are covered by official regulations; these must be complied with in full. The points at which pipes pass through the outer shelter structure must be sealed with a packing material which will remain pliable.

Gas-Proof Sealing of Shelters

The practical requirement of the gas-proof sealing of an air-raid shelter is satisfied when the shelter can be made air tight to a point where a pressure of at least 2 mm on the water column can be maintained (in mechanically supplied air). Gas-proof sealing of shelters which are not equipped with filter-ventilation equipment is of course also required. In this case, a pressure in the shelter of 5 mm may drop to 3 mm at most within 5 minutes. It is not necessary to meet the gas-proofing requirement only as a protection against poison gases, but also as a protection against the indirect effects of detonations and incendiary agents in the shelter vicinity. No less dangerous are dust clouds from collapsing buildings, smoke from nearby fires, illuminating gas from broken gas mains, and sewer gas which creeps into the basement from sewer pipes and then on into the shelter.

Thus, gas-proofing of the shelter must be attained in all structural details. The following points must be checked:

a. imperfectly-sealed surfaces of the various devices used to secure the openings (doors, emergency exits, ventilation opening locks, chimney covers, etc.);

b. other defects of the securing devices, or defective structural elements (locks, peepholes, grooves for rubber packing, breaks in the sheet metal);

c. between the frames of the securing devices and the wall which touches them;

d. those points where any sort of pipe, conduit, beam or cable passes through the outer structure (wall, ceiling, floor);

e. through hidden or visible wall cracks;

f. through the pores of the wall.

In addition to careful structural solutions and masonry, a sealing material is also needed to insure an air-tight seal between the individual structural elements in case of shocks or motion caused by temperature reactions.

In general, the guiding principle is: what we can attain by masonry, we should not attempt to attain by the use of sealers.

The pipes passing through the outer shelter walls are both hot and cold. Thus it must be borne in mind that the same material is not always suitable to produce a gas-proof seal in both cases. The sealing material must be pliable, and it must adhere well to various materials (walls, concrete, steel, oil paints). Its adhesion should not break as the result of mechanical motion or motion caused by temperature reactions. Other requirements must be considered (water-proof, electric insulation, corrosion-resistant, etc.), so that such material should not be employed until a thorough testing is made and, if possible, official permission granted. (See Figures 67, 68, 69, and 70.)

One of the best insurances for the gas-proof sealing of a shelter is careful plastering. Without question, plaster falling from the ceiling on those inside can cause few injuries, apart from the unpleasantness of it, but it has a bad psychological effect. However, leaving the ceiling unplastered does not influence the gas-proof sealing of the shelter because the shelter ceiling is always made of reinforced concrete, which at the normal thickness, will always satisfy the need of a gas-proof seal. Thus in no case will the ceiling be plastered, but all side walls next to exterior areas must be plastered.

Signs and Markers

Signs and markers are needed to mark the route to the shelter, the shelter entrances or exits, the ante-chamber and interior area, and also the emergency exits and passages. A subsequent decree will prescribe uniformity of these in usage, materials, and placement methods.

This refers not only to residence shelters, but to all other shelters as well.

Acceptance of Shelters

The finished shelter may be put into use only after a careful acceptance procedure. It is not always necessary to separate the shelter acceptance, in the case of a new structure, from the acceptance procedures of the whole building; but certainly, due to its special points, it requires extra care.

The main points of acceptance are:

1. Checking the shelter dimensions and general structural execution for technical competence in construction materials, masonry, and other work.

2. Inspecting the devices which secure the openings and the mechanical ventilation equipment.

3. Inspecting the obligatory equipment.

4. Inspecting the gas-proof sealing of the shelter.

Special equipment is not needed to check the sealing of the shelter. Pressure is produced by a 250-g Berger candle for an interior area of about 120 to 140 m^3. In a gas-proof shelter the pressure will jump to a pressure of 50 to 100 mm in 30 sec. Where there are fairly small imperfections in the sealing, this pressure lasts 10 to 15 sec, after which the pressure gradually falls to 0. As a result of the cooling of the Berger candle gases and the loss of air through small imperfections, a rarification of 5 to 10 mm water column pressure is present. We use the equalization of this rarification for the examination. Naturally, this test may have to be repeated if the pressure values noted above are not attained. This shows that there are relatively large seal imperfections in the shelter and these must be found. The points at which the smoke from the Berger candle seeps out can be observed, and after repairing these, the above test must be repeated.

The test itself is done as follows:

The regulation peephole of the opening securing device is removed with its case, and in its place a glass or metal tube set into a cork or rubber stopper is inserted. At one end of the tube we connect a manometer, at the other a rubber seal. The rubber seal serves to enable us to leak off the great pressure arising in the interior area. When the manometer registers 0, the blow-out branch must be locked. At this point the rarification in the interior area begins. We can begin measuring when the rarification has a negative pressure of 3 mm. We must measure whether the rarification value becomes greater or smaller than 3 mm within three sec.

Gas masks must always be used in the testing. After the test the shelter must be thoroughly ventilated. In thickly-populated sections of the city the smoke used in the test can disturb those living nearby. Therefore the test must be conducted with the proper caution and according to the laws governing such matters.

APPENDICES

APPENDIX I

The Decree of the Minister of Internal Affairs No 01/67-1951 VI, concerning the construction of TGS (Tormelek-, Gaz-, Es Szilankbiztos /Debris-, gas-, and splinter-proof/) shelters in residences and public buildings.

1. The Establishing of Shelters

(1) TGS shelters must be established in all newly-constructed residence and public buildings, or in those to be reconstructed or remodeled, for which the civil defense-group exceeds 50 persons, based on Sec. 2 (4) below, and which are suitable technically for the installation of shelters as set forth in Sec. 6 (1) below.

(2) The Minister of Internal Affairs Decree No 01/20-1951 VI, governing the civil defense of industrial plants, deals with industrial plant shelters separately. However, the technical requirements of TGS shelters as set forth here will also refer to TGS shelters in industrial plants.

2. The Parts of the Shelter and the Civil-Defense Group

(1) The shelter consists of an ante-chamber and an interior area. One ante-chamber and three interior areas with a capacity each of 50 persons at most comprise a shelter unit. In one shelter unit, therefore, a maximum of 150 persons can be accomodated.

If the ante-chamber opens directly onto the stair well, an open corridor, or the outside, a gas lock should be installed behind the entrance door of the ante-chamber. The area of the gas lock should be at least 2 m^2, and it should be set off from the ante-chamber by a gas-proof door placed in a wall 25 cm thick.

(2) At least 30, and at most 50, people may be placed in one interior area. If the ground plan of the shelter cannot be formulated with openings from the ante-chamber into all the interior areas to assure peacetime use and economical utilization of space, then the interior areas may open onto each other. However, only one interior area may be reached from another. If several shelter units are built within the basement of one building, they should be as far apart as possible. To assure this distance, there should be a layer of dirt or a room, at least 2.5 m wide, not being used for shelter purposes, between the shelter units. The walls of the rooms dividing the shelter units should be reinforced concrete, 25 cm thick, reinforced with # 8 10 cm-mesh reinforcing on both sides, ties into the main walls of the building by inserting the rounds into the gaps of the brick wall. This room may also serve as the shelter ante-chamber if sufficient space is not available. If, in this way, more than two shelter units are set up next to each other, a central area in the basement, not touching the exterior walls, must be formed if possible, and the basement pipes must be run ~~in~~ the outer area. This latter arrangement is preferable in establishing one or two shelter units, if peacetime use and economy will permit it.

(3) Centrally-located public shelters must be available for blocks of houses, for groups of smaller residences, or other grouped buildings (settlements) if separate shelters in each building are either impossible because of technical reasons, or impractical for reasons of economy. These must be built only for the staff ordered by the separate decree of the Ministry of Internal Affairs.

(4) The civil defense group of a building is determined by the following method:

a) In residence buildings it is necessary to count on one person per 8 m^2 of area in residences of two rooms or smaller, and on one person per 10 m^2 of area in residences of three or more rooms. It is not necessary to include the areas of secondary rooms (toilets, kitchen, bath) in the area of the rooms. Base areas are computed by measuring between the plastered wall surfaces.

b) In residence buildings where there are rooms serving as businesses, workshops, or similar purposes, one person per 20 m^2 of used area must be counted.

c) Shelters for industrial plants and for other buildings in which the establishment of TGS shelters is obligatory must be planned for the maximum force present in the building or in the plant area during an alert. In establishing the civil defense staff for industrial plants, a possible regrouping of the shifts must be considered to reduce the staff. The civil-defense staff for offices located in residence building must be determined in the same manner.

(5) The shelters must be constructed and completely outfitted concurrently with the construction of the building, but they may also be used for peacetime purposes. Only such peacetime usages are permitted as can be halted immediately if necessary, and which will allow the return of the shelter to its original purpose within 24 hours. Those peacetime uses of the shelter which do not impede its original purpose, and which can be continued during an alert, are especially desirable.

3. Shelter Size

(1) The base area of the ante-chamber should be 0.1 m^2 times the number of persons which can be accomodated by the interior areas of a shelter unit where there are two interior areas, and 0.15 m^2 where there are three. In any case, it should be at least 4 m^2. The narrowest part of the ante-chamber should be 1.5 m. The height of the ante-chamber and the interior area should be at least 2.2 m. Where there is a ceiling ribbed on the underside, the lower plane of the ribs should be at least 1.90 m from the basement floor. The route leading to the shelter and the ante-chamber should be so laid out that a stretcher, 0.51 x 2.26 m, can be carried into any interior area.

(2) The interior base area per person should be 0.75 m^2 and the air space per person, 2.5 m^3. If the responsible officials permit the use of air-filter equipment and it is installed when the shelter is built, the base area per person may be reduced to 0.6 m^2, and the air space to 1.6 m^3.

(3) If the air space of the interior areas is smaller than that computed to be necessary, an auxiliary air space of the size necessary to make up the deficit must be connected to the air space of the interior areas from the basement sections outside the shelter. Openings in the auxiliary air space which open onto the outside must be closed with gas-proof securing devices or walled up. The connecting of the interior areas with the auxiliary air space is done with 25 x 25 or 30 x 30 cm openings placed one above the other. These should be able to be secured with gas-proof locks from within the interior area. These openings should be at the point farthest from the entrance.

(4) The area of an interior area should be at least 24 m^2; the height, 2.20 m; and its narrowest width, 2.20 m.

(5) One square meter per 30 persons must be set off in the interior areas for pit latrines, closed off by a single curtain. In setting up the interior area air space it is not necessary to subtract the cubic area of the latrine.

(6) An open area of at least 2 m^2 must be left in the ante-chamber for the placement of materiel.

4. Entrances and Emergency Exits

(1) Basements containing shelters must open onto a stairwell or other closed area. These, along with the door openings, can serve as entrances to the shelter.

(2) The entrance door of the ante-chamber should be one door, opening outward, per 150 persons. The door should be placed in a corner in such a way that it will be flat against the wall when open; it should be able to be unhinged from inside. The interior area doors should also be placed in corners if possible, and they should open from interior areas into the ante-chamber.

(3) Each independent shelter unit should have at least two emergency exits. One of these may be the emergency passage treated in point (7) below. Where shelter units are built next to each other, fewer emergency exits may be made, if they still afford possibilities for escape from all interior areas in the event that some parts of the building are destroyed. To insure this, neighboring shelter units must be connected by emergency passages. Emergency exits should be relatively far apart and on opposit sides of the building.

(4) The shelters of row buildings must be equipped with vertical emergency exits, if emergency exits cannot open onto the outside from the shelters. For reasons of material economy, vertical emergency exits may be built only in important buildings.

The vertical emergency exit is a reinforced concrete cylinder with walls 25 cm thick and with an interior diameter of 0.90 m. It extends to the ceiling of the second floor, and it has openings at the ground level and at the top. The exits should be two-thirds the height of the interior areas. The reinforced concrete cylinder must be built with exterior and interior reticular reinforcing with a mesh of 20 x 20 cm. It must have an angle brace connection at the basement ceiling level and a hinged connection at the level of the second floor ceiling. The exterior lengthwise reinforcing are #10 steel rounds, the interior, #8;

the exterior and interior circular reinforcing are #6 rounds. The reinforced concrete cylinder must be equipped with built-in steel ladders, inside and out.

(5) The openings of the emergency exits should be beyond the ranges of destruction which can be expected in the building or neighboring structures. For important buildings, circular emergency tunnels, 0.8 m wide, or with an interior diameter of 0.9 m, must be built to lead to open areas.

(6) If splinters, coming in a straight line, can reach the interior area through the emergency exit openings, regardless of the fact that the openings are covered, then exterior or interior splinter-proof walls must be built to cover the openings. The splinter wall should afford protection against the impact of splinters flying in a horizontal direction. The distance between the splinter wall and the emergency exit should be 018 to 1 m. Brick walls, laid with improved mortar, 51 cm thick, or caulked reinforced concrete walls, 35 cm thick, containing at least 200 kg of cement per cubic meter, can be considered splinter-proof.

(7) Adjacent basement areas of neighboring buildings must be connected by emergency passages. These passages are vaulted openings, measuring 0.7 to 0.8 m, walled with bricks. To assure easy removal of the walling, they must not be tied to the existing walls. The plane of the walling on one side should not coincide with the plane of main wall.

5. Devices to Secure Openings

(1) The following are the devices which secure the shelter openings:

a) the entrance door leading into the ante-chamber (ante-chamber-door). Its interior dimensions are 0.85 x 1.85 m.

b) the door leading from the ante-chamber into the interior area (interior area door), with interior dimensions of 0.85 x 1.85 m.

c) the windows which close the openings serving as emergency exits (emergency exit windows). The dimensions of the small emergency exit windows are 70 x 50 cm, of the large, 70 x 85 cm. The emergency exit windows fit against the outer surface of the wall and open outwards.

(2) From the standpoint of protection, the devices which secure the openings protect against gas and air-pressure (GL) [Gaz es legnyomas], or only against gas (G) [Gaz]. Openings in the outer walls of a shelter

unit must always be closed off with GL devices which open outwards; within the shelter units G doors must be used. Doors between interior areas and the ante-chamber should open outwards into the ante-chamber.

(3) If, in addition to the emergency exit windows and the ante-chamber door, more openings in the outer walls of the shelter are necessary for its peacetime usage, either they must be equipped with GL devices or they must be so formed that, if necessary, they can be walled up by bonding into the grooves cut previously in the wall. Basement sections which serve as shelters may be prepared without windows. Shelters should be equipped with only the absolutely necessary openings.

(4) To ventilate the shelter, at least one Z-shaped ventilation opening may be cut in the interior area wall which borders on the outer air space. This opening should have a cross-section of 7 x 14 cm and should be fitted with a grill on the outside and a small gas-proof door on the inside.

(5) The devices which secure the shelter openings are of steel or prefabricated reinforced concrete. Both types are equipped with angle-iron frames placed in the wall. Regulation No. MOSZ 800 /Magyar Orszagos Szabvany: Hungarian National Regulation/ prescribes the dimensions and structure of the frame. Reinforced concrete shelter doors and emergency exit windows can not be considered splinter-proof.

6. The Shelter Roof and The Building Above The Shelter

(1) TGS shelters may be built only in the basements of buildings where there is a roof made of at least three noncombustible materials above the shelter roof.

(2) In buildings with brick walls, a cornice beam must be used with the shelter roof, as well as with the uppermost roof.

(3) The floor level of the roof over the shelter may not be more than 1.20 m above the lowest ground level. If this requirement cannot be met because of the subterranean water level, a fill with a height corresponding to a crown width of at least 5 m must be made at the outer wall of the shelter. The upper plane of the fill must be regarded as the exterior ground level.

(4) If the stairs in a building housing a structure are built of prefabricated units, either the extended rounds must be cemented into the supporting structure, or the individual units must be connected to each other and to the supporting structure by screws and other connecting devices.

(5) A so-called "civil-defense roof" with an increased load-bearing ability must be built over the shelter and the access route leading to it. The civil-defense roof is made of reinforced concrete at least 15 cm thick, with a 20 x 20 cm reticular mesh reinforcing of 8 mm steel rounds cemented in at the place of use (not prefabricated). It may be either a reinforced concrete sheet or it may be under-ribbed reinforced concrete, in either case made to support a doubly-directed load of the amount prescribed by civil defense regulations. The lower reticular reinforcing may be counted in with the structural reinforcing, but it may not be substituted by a wider-meshed reinforcing of the same size rounds.

(6) In addition to its own weight, the roof over the shelter and its access route must be planned for the following evenly-distributed loads:

a) In non-steel structures, a load totaling 1,000 kg/m^2 for the ground and second stories and 250 kg/m^2 for each additional floor.

b) In steel structures, a load totaling 1,000 kg/m^2 for the ground, second, third, and fourth floors, and 100 kg/m^2 for each additional floor.

(7) Beyond the loads given above, the useful load of the roof must be considered only if there is a large concentrated load (heavy machines) operative on it.

(8) The economicalness of the civil-defense roof must be insured by the use of heavy braces or small spans.

(9) The concrete in a civil-defense roof should be at least of B 200 quality; the steel rounds used should be of at least 36.22B or 36.24B quality.

(10) In planning the civil-defense roof, the load must be calculated with a safety factor of 1.1, and it must allow for the extreme tensions stated in the regulation covering reinforced concrete.

(11) In special cases, for which the Ministry of Internal Affairs will make separate arrangements, a dirt fill 1 meter thick must cover the shelter roof. In this case the height of the first story floor level should not be more than 1.2 m above ground level. If the basement cannot be built at the necessary depth because of a high water level, refer to Section 3, point (8). In planning the roof, the weight of the dirt on the roof must be considered independently of the civil defense load.

7. Shelter Walls

(1) If the height of the ground mass placing ground pressure on the shelter and access route walls is more than 3 m, the shelter walls--without the load-discharging effect of the walls and ceiling--must be planned for a ground pressure computed by assuming a ground level burdened with the same load as the civil-defense load of the shelter roof.

(2) If the height of the ground mass placing ground pressure on the exterior walls of the shelter and its access route is less than 3 m, it is not necessary to plan for the ground pressure, but the following requirements must be met:

The thickness of stone or mixed materials walls should be at least 60 cm, with mortar containing 250 kg of cement per cubic meter.

The thickness of fired clay brick walls should be 51 cm, with a mortar containing 250 kg per cubic meter.

Where caulked concrete containing 180 kg of cement per cubic meter is used, the walls should be at least 40 cm thick.

The thickness of reinforced concrete walls without bracing pillars should be 30 cm; those with pillars should be 20 cm thick.

(3) The shelter roof must be cemented in with a cornice beam, reinforced according to regulations, extending the full width of the basement. If the building is of reinforced construction, the shelter walls should be caulked concrete walls tied into the reinforcing with cemented-in straps, or 51-cm-thick brick walls.

(4) The walls between interior areas of a shelter should be at least 25 cm thick, if they are fired clay brick walls laid with portland cement mortar. They should be at least 20 cm thick if they are caulked concrete walls containing 200 kg of cement per cubic meter.

(5) The interior walls of shelter units should be either fired clay brick walls laid with a mortar containing 100 kg of cement per cubic meter, or reinforced concrete walls as described in Sec. 7 (2) above.

(6) The shelter ceiling must not be plastered. The shelter walls must be plastered. The ceilings and walls should receive three coats of whitewash.

8. The Shelter Floor

(1) The flooring of the ante-chamber and interior areas of the shelter should be a smoothed concrete floor or paving placed into cushion concrete. The cushion concrete must be poured at least 10 cm thick and, for support, must be tied into the walls.

9. Pipes Running Through the Shelter

(1) If possible, pipes of various types (central steam-and hot water-heat, water and sewer) should not run through the shelter. However, sometimes this requirement cannot be met, so only thick-walled mild steel pipes will cross in the shortest route. Brittle pipes must be fitted with a reinforced concrete protective covering, with both ends terminating outside. To close pressure branches, main locks, easily manipulable from the shelter, must be built. Valves to prevent infiltration of gas must be built in sewer pipes.

(2) The passing of gas pipes through a shelter is forbidden. If gas pipes pass through an already built shelter, or if there are gas meters there, these must be completely isolated from the shelter by walls around them.

(3) At least one chimney terminus outside the shelter area should be in a basement housing a shelter. A chimney soot-door and other openings extending into the shelter must be gas-proof.

10. Shelter Lighting

If there is electric lighting in the building housing a shelter, this must be run into the shelter.

11. Closing Instructions

(1) The instructions herein shall be used for all residences and public buildings built in municipal or industrial areas, except where there is an aggressive water level above 1.5 m, when Sec. 6 (3) above will not satisfactorily meet the problem, shelters must be built only under certain buildings, after prior permission of the Ministry of Internal Affairs is obtained. This must be done in such a way that the buildings without shelters will also serve in supplying the civil-defense group.

(2) The Ministry of Internal Affairs may permit deviations from the statements of this decree, where justified.

(3) This decree comes into effect on 31 December 1951. The following decrees are herewith void:

BMA - 4374-5/9, 1950 /See Note 1 below/

Biz. 4374-84/1950, VI/4 /See Note 2 below/

Biz. 4374-136/1950, VI

/Note 1: B. M. of this abbreviation probably equates to Belugyiminiszterium; the A could be a number of words, the most likely of which are AKTU (document), ATIRAT (official communication), or even ALLAMVEDELMI (pertaining to national security)./

/Note 2: The "Biz." here probably equates to BIZALMAS (confidential) and may refer to a classification./

APPENDIX II

Decree No 0158-952, VI of the Minster of Internal Affairs concerning the establishment of emergency shelters.

1. General Instructions

(1) Emergency shelters are HI shelters established in the basements of existing buildings, and trench shelters built underground in open areas.

(2) HI shelters are differentiated from TOS shelters so that certain relaxations of principles of decree No 01/67-1951. VI of the Minister of Internal Affairs may be permitted.

2. Determining the Site of an HI Shelter

(1) If possible, the HI shelter should be located in an interior section of the basement not bordered by outside walls. It should be in that part of the basement over which there are the most floors.

(2) If, because of the structural layout of the building, it is impossible to establish the shelter as prescribed in Sec. 2 (1) above, then it must be located along the firewall bordering the next building or at a point where it may be easily reached from the stairs, doorway, or courtyard.

(3) If possible, the shelter should be in a part of the basement where there are no gas and water pipes.

(4) The shelter must be located in an extended arrangement with its components divided by the existing structural walls. Connections, via the basement sections outside the shelter, between shelter units and between the shelter and emergency exits (emergency passages) must be assured. If there are several shelter units located within the basement of a single building, they should be as far apart as possible, with at least a 2.5 m-wide space which is not being used for shelter purposes, between them.

(5) Where possible, the shelter, -- if the requirements of this decree allow -- must be built in basement areas used as RH shelters during the last war.

3. The Shelter Components and the Civil-Defense Group

(1) The shelter consists of an ante-chamber and interior areas. One ante-chamber and a group of interior areas, each accomodating a maximum of 70 people, comprise a shelter unit. One shelter unit may accomodate a maximum of 210 people.

(2) The interior areas should, if possible, open onto the ante-chamber, but if this is not feasible because of the structural layout, then they may open onto each other.

(3) If the shelter has only one interior area and the entrance opens into the shelter from the building interior, the entrance may open directly onto the shelter interior area, omitting the ante-chamber. However, in such cases, gas locks must be installed, as necessary, to replace the ante-chamber.

(4) The shelter must be set up for a civil-defense group, determined in the following way:

a) In residences of two or less rooms, one person must be estimated per 8 m² of living area. Where there are three or more rooms, one person per 10 m² of living area must be estimated. It is not necessary to include the area of auxiliary rooms (receiving hall, toilet, kitchen, bath). If there is a hall in the residence, it is to be counted as a room. The base areas are computed by measurements between the plastered wall surfaces.

b) Shelters of industrial plants, public buildings, and other institute buildings requiring the installation of TCS shelters must be planned for the maximum staff working in the building or in the plant area during the period of a civil-defense alert. In determining the civil-defense staff, the possible regrouping of shifts must be considered, in order to reduce the civil-defense group. The civil-defense group of offices located in residences must be determined in the same way.

(5) Shelters should be formed in such a way as to permit peacetime usages; however, only those peacetime usages which can cease immediately, returning the shelter to its intended purpose within 24 hours, may be allowed.

An ideal peacetime use is one which does not hamper the intended shelter use and which can continue during civil-defense preparations.

4. Shelter Size

(1) The smallest width of the ante-chamber should be 1.20 m, and the smallest area, 4 m^2. The lowest permissible height of the ante-chamber and the interior area is 1.80 m. There may be an ante-chamber passage section which can be closed off by doors.

(2) The interior area base area per person is 0.75 m^2, the air space 2.50 m^3. If the authorities permit the use of air-filter equipment, and it is installed at the same time the shelter is constructed, the base area per person may be reduced to 0.6 m^2, and the air space to 1.6 m^3.

(3) If, after computations are made, the air space needed is more than the air space of the interior areas, then an auxiliary space of the proper size must be connected to the air space of the interior areas from a basement area outside the shelter. Openings onto the outside in the auxiliary air space must either be walled up, or fitted with gas-proof securing devices in the same way as the shelter openings. The connecting of the auxiliary air space to the interior areas is done by means of gas-proof openings which can be secured from inside the shelter. These should be at least 25 x 25 cm openings, placed one above the other.

(4) One square meter for each 35 persons housed in an interior area must be set off for pit latrines, closed off by a curtain and possibly located in a wooden compartment. In computing the air space of the interior areas, it is not necessary to subtract the cubic area of the section closed off by the curtain.

(5) An open space of at least 2 m^2 must be left in the ante-chamber for the placement of materiel. If this cannot be done because of the structural layout, then it may be set aside in the interior area.

5. Entrances and Emergency Exits

(1) If there are openings in a basement to the outside, the shelter must be situated so that it is accessible from the stairs or other closed area. If the basement is reached from a closed area, its entrance may open directly onto the ante-chamber of the shelter.

(2) Preferably, there should be at least one outward-opening door in the ante-chamber for each 150 persons. The doors should be placed in corners and hung in such a way that they will lie flat against the wall when open, and that they can be unhinged from inside. Interior area doors should also be placed in corners if possible, and should open outwards from the interior area into the ante-chamber.

(3) Each separate shelter unit should have at least two emergency exits. These may be the emergency passages discussed in Sec 5 (7) below. Where shelter units are located next to each other, there may be less than two exits per shelter, if they are placed so that there will be opportunities for egress from any interior area if some sections of the building are destroyed. To assure this, shelters next to each other must be interconnected. Emergency exits should be located fairly far apart and on opposite sides of the building. If possible, they should be beyond the limits of possible debris from nearby buildings.

Emergency exits should be in basement areas removed from the shelter entrance. The emergency exit should be a basement window, 70 x 50 cm, which can be secured with a GL (gas- and air-pressure-proof) door, and so placed that splinters coming from any direction will strike a brick wall at least one and a half bricks thick. If this is impossible, due to the layout of the building, then a splinter wall must be built in front of or behind the emergency exit.

(4) All shelter openings, as well as those of the auxiliary air space connected to the shelter, which open onto the outside must be

secured with gas- and splinter-proof devices. Any cracks through which there is direct contact with outer air must be sealed with gas-proof sealing. Securing of openings is done by walling them up, or fitting them with covers.

(5) Basement windows used for peacetime purposes and not used for emergency exits may be walled-in with walls built in front of or behind them, or in the wall. Walls in front of and behind openings should be made with at least a 50-cm overlap at the top and sides. They should be anchored into the main wall with straps made from steel rounds. The walling-up of the openings must be done with indented tie-ins on both sides of the existing wall. For ventilation a Z-shaped shaft must be cut in a walled-in opening.

(6) If necessary, the following will serve for splinter- and gas-proofing:

a) a layer of dirt 70 cm thick, or a layer of sand at least 50 cm thick supported by round timbers, 10 cm in diameter, between planks.

b) a stack of logs 40 cm thick made up of timbers at least 10 cm in diameter, supported between piles driven outside the opening to be protected.

These solutions will be used only in exceptional cases since they are easily damaged and require constant maintenance.

(7) The shelter should connect to all parts of the basement. Emergency passages must be made between basements of buildings containing shelters and basements of neighboring buildings. These emergency passages are brick-wall openings, 70 x 80 cm, laid with lime-mortar. To assure easy removal, the walls may not be tied into the existing structure walls. The plane of the walling-in on one side should not coincide with the structure walls.

6. Devices To Secure Openings

(1) The following comprise the devices which secure the shelter openings:

a) the entrance leading into the ante-chamber (ante-chamber door),

b) the door leading from the ante-chamber into the interior area(s).

The inner dimensions of these doors are 0.85 x 1.85 m.

c) the windows used to secure the emergency exit openings. The dimensions of the small window are 70 x 50 cm, of the large, 70 x 85 cm. These windows fit against the outer surface of the wall and open outward.

(2) So far as protection is concerned, the securing devices offer protection against gas and air pressure (GL devices) or only against gas (G device). All openings on the outer walls of shelter units must be fitted with GL devices opening outward: within the shelter units, G doors must be used. Doors between the interior areas and the antechamber should open outwards.

(3) The securing devices are of steel or prefabricated reinforced concrete. Both types are hung in angle iron frames placed in the wall. The dimensions and execution of the securing devices are prescribed by Regulation No. MOSZ 800. The claws used in walling-in the angle iron frames must be carefully cemented into grooved holes.

7. The Shelter Roof and its Dimensions

(1) The level of the roof over the shelter may be 1.5 m above the level of the ground at most. If its elevation is 1.20 m or less, the shelter wall should be at least 51 cm thick; and if it is between 1.20 and 1.50 m, the wall should be at least 63 cm thick. If the walls are thinner than these requirements, they must be strengthened with interior or exterior buttressing. The strengthening wall, regardless of the thickness of the wall it braces, should be at least 38 cm thick and laid in cement mortar.

(2) If the elevation of the shelter roof is between 0.50 and 1.50 m above ground level, the roof over the shelter should be made of at least two noncombustible materials. If the elevation is 0.50 m or less, the roof should be of at least one such material.

(3) The roof over the shelter, its access route, and the routes to the emergency exits and passages must be planned for the following evenly-distributed loads of debris, in addition to its own weight:

a) in non-steel structures, a total of 1,000 kg/m^2 for the ground and second floor, and 250 kg/m^2 for each floor above these.

b) In steel structures, a total load of 1,000 kg/m^2 for the ground, second, third, and fourth floors, and 100 kg/m^2 for each additional floor.

(4) It is necessary to consider a useful load capacity of the basement roof, in addition to the loads above, only when there are heavy machines or concentrated loads on it.

(5) Flat roofs are strengthened by bracing the roof ribs or roof girders. When possible, the bracing must be done by brick pillars or interior dividing walls. In special cases, the roof girders can be braced by wooden beams held in place by wooden supports.

In determining the size of the bracing devices, except for towed-out bracing, the permissible tensions must be increased by 50 percent. Basement ceilings having several gaps must be planned for the most dangerous load produced by alternating debris and self-weight loads.

(6) Reinforced concrete girders and sheets may be braced at the center of the open space or at some other point, if there is no reinforcing over the bracing sufficient to absorb negative pressures. It is only necessary to consider whether the lower reinforcing of the doubly-supported beam thus formed is suitable to absorb the positive flexing pressures which arise.

(7) Most barrel vaults of the usual dimensions will satisfy the civil-defense load without strengthening. It is only necessary to support the side walls against the lateral pressure of the vault. The load capacity of a vault cannot be increased by bracing it, nor can the lateral pressures be significantly reduced in this way. Therefore, vaults are not to be braced.

(8) All existing walls within the area into which the shelter is to be placed that are at least one brick thick can be used as dividing walls within the shelter. The outer walls of the shelter should be at least 51 cm thick.

(9) The old plaster on the ceiling over the shelter must be removed, and the lower surface of the ceiling must be whitewashed. Plaster on the walls must be left intact.

8. Pipes Running Through the Shelter

(1) If at all possible, central steam- and hot water-heating or

water or gas pipes should not run through the shelter. However, this requirement cannot always be met; when it cannot, then thick-walled mild steel pipes will cross in the shortest route. Brittle pipes must be covered with a reinforced concrete protective covering with both ends of this covering terminating outside. Main locks for closing the pressure branches, easily manipulable from the shelter, must be built in. Valves to prevent infiltration of gas must be built into the sewer pipes.

(2) The running of gas pipes through the shelter is forbidden. However, if gas pipes cross an already-existing shelter, then the pipes, and the meters, too, if they are within the shelter, must be completely set off from the shelter by walls.

(3) In basements containing shelters, there should be at least one chimney terminus in the shelter area. Chimney soot doors or other openings must be made gas-proof with securing devices.

9. The Construction of Trench Shelters

(1) The whole of a trench shelter is at least 2 m deep below the ground surface. A trench shelter may be an open or covered trench, flaring out at the top to a width of 1.20 m.

(2) When possible, the trench shelter should be splinter- and gas-proof. For this reason the roof must be covered with a layer of dirt at least 50 cm thick, and gas-proof ante-chambers must be set up at the entrances. Open-trench shelters should not be used if it can be avoided.

(3) The trench shelter consists of a number of sections, each at most 8 m long, arranged symmetrically in a zig-zag pattern along a straight axis. The individual sections must be separated by gas-proof doors if possible. The distance between the axes of several parallel trench shelters must be at least 10 m, preferably 40 m.

(4) One trench shelter may consist of five straight sections at most, with a maximum capacity of 150 people.

(5) If the capacity of the shelter is more than 50 people, entrances at both ends must be set up; if it is less than 50 people, an emergency exit may be substituted for one entrance.

(6) The structure of a trench shelter may be reinforced concrete poured at the site, prefabricated concrete units, brick circular vaulting, or wooden bracing similar to mine shafts.

(7) Trench shelters benches must be arranged so that their backs are independent of the shelter structure.

(8) The execution of trench shelters as described above should be undertaken only if the Ministry of Internal Affairs hands down a separate ruling for it.

10. Closing Instructions

(1) The Ministry of Internal Affairs, in special cases, may permit deviations from the standards contained in this order.

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FIGURES

Figure 1. /See page 6, original/

1. suspension hook
2. wooden insert
3. bomb case
4. safety screw
5. packing ring
6. bottom
7. fins
8. drop safeties
9. explosive charge
10. case of pressed material
11. detonator
12. detonator charge
13. fuse
14. percussion cap
15. striker spring
16. striker body
17. safety ball
18. fuse body
19. air screw shaft
20. transport safeties
21. air screw

Figure 2. /See page 8, original/

1. suspension hook
2. fuse
3. detonator
4. explosive charge
5. bomb case
6. fins

Figure 3. /See page 13, original/

Surface	$10^{-6}k_1$	k charge	$\sqrt{k^5}$ charge	kr	kl
1. freshly turned earth	13.0	0.60	—	1.40	—
2. loose sandy soil	9.0	0.56	—	1.12	—
3. ordinary dirt	6.5	0.53	—	1.07	—
4. settled sand	4.5	0.50	—	1.04	—
5. packed clayey sand	5.5	0.50	—	1.00	—
6. clay, blue clay, rocky soil	7.0	0.50	—	0.99	1.93
7. sand mixtures	5.0	0.50	—	1.00	—
8. clay mixtures	6.0	0.50	—	1.00	—
9. ~~sand-gravel mixtures~~	4.5	0.33	—	0.98	—
10. loess, rocky soil with clayey sand	4.5	0.24	—	0.93	0.9
11. marl, compact blue clay	4.0	0.24	—	0.94	1.70
12. limestone, sandstone, clayey shale	3.0	0.23	—	0.92	1.17
13. limey or sandy rock	2.0	0.25	0.125	0.92	—
14. granite or gneiss	1.6	0.50	0.355	0.86	1.00
15. pine	5.0	0.30	0.165	0.60	—
16. oak ash, beech	4.0	0.30	0.165	0.60	—
17. dry brick walls	8.0	0.25	0.125	0.96	—
18. dry stone walls	3.0	0.25	0.125	0.98	—
19. brick wall set with cement mortar	2.5	0.25	0.125	0.88	—
20. stone wall set with cement mortar	2.0	0.20	0.090	0.84	—
21. quarry stone concrete	1.6	0.18	0.076	0.70	—
22. 200 kg/cm^2 concrete	1.3	0.18	0.076	0.70	0.52
23. 400 kg/cm^2 concrete	1.0	0.16	0.064	0.60	0.50
24. 200 kg/cm^2 reinforced concrete	1.2	0.14	0.052	0.60	0.47
25. 300 kg/cm^2 reinforced concrete	1.1	0.135	0.050	0.56	0.47
26. 400 kg/cm^2 reinforced concrete	0.8	0.13	0.047	0.42 0.52	0.47
27. volcanic slabs bedded into 400 kg/cm^2 concrete in at least 1.5 k_b strata thickness	0.7-1.2	0.15	0.047	0.60	—

Figure 4. /See page 14, original/

Figure 5. [See page 14, original]

first layer

second layer

Figure 6. [See page 20, original]

Figure 7. [See page 22, original]

Figure 8. [See page 23, original]

Figure 9. [See page 26, original]

Figure 10. [See page 29, original]

interior is not splinter-proof

angle iron

Figure 11. [See page 30, original]

concrete

angle iron

Figure 12. [See page 31, original]

Figure 13. [See page 32, original]

Figure 14. [See page 32, original]

Figure 15. [See page 33, original]

Figure 16. [See page 37, original]

volcanic stone

sand or turf

vents or sand

Figure 17. [See page 38, original]

Figure 18. [See page 39, original]

Figure 19. [See page 44, original]

locks interior area emergency exit

ante-chamber

protective wall

Figure 20. [See page 45, original]

A-B section

emergency exit

store of fire-fighting tools

Figure 21. [See page 47, original]

Figure 22. [See page 49, original]

Figure 23. [See page 50, original]

safety layer

Figure 24. [See page 51, original]

Figure 25. /See page 52, original/

Figure 26; /See page 56, original/

interior area

interior area

ante-chamber

Figure 27. /See page 56, original/

100 people per door

to emergency exit

lock

ante-chamber

interior area

interior area

interior area

maximum capacity: 150

to emergency exit

Figure 28. /See page 57, original/

debris-proof roof

A-B section

roof edge

Layout

Figure 29. /See page 57, original/

A-B section

Figure 30. /See page 58, original/

jointed connection

angle firm connection

shelter

Figure 31. [See page 60, original]

Corridor

inner area

inner area

ante-chamber

inner area

inner area

ante chamber

inner area

inner area

Corridor

Figure 32. [See page 61, original]

dry-walled

A-B section

15 cm walling,
bound to the
and laid with
white lime-mortar

plaster

floor line

limit walls

Figure 33. [See page 69, original]

street

street

street

shelter

street

emergency exit

Figure 34. [See page 71, original]

section

Plan view

Figure 35. [See page 71, original]

section

Plan view

Figure 36. [See page 72, original]

Figure 37. [See page 75, original]

Figure 38. [See page 76, original]

σ edge

Figure 39. [See page 79, original]

Figure 40. [See page 80, original]

Figure 41. [See page 80, original]

Figure 42. [See page 81, original]

Figure 43. [See page 83, original]

Figure 44. [See page 85, original]

Figure 45. [See page 88, original]

Figure 46. [See page 89, original]

Figure 47. [See page 89, original]

Figure 48. [See page 90, original]

interior area

ramp

LC [abbreviation not known]

ante-chamber

Figure 49. [See page 90, original]

interior area

ante-chamber

LC [abbreviation
not known]

Figure 50. [See page 92, original]

two steel spikes, ∅10

thin concrete flooring

A-B section

Figure 51. [See page 93, original]

insulating layer

reeds, straw, etc.

sand

dirt

roof joists

board covering

insulation

ground plate, 12-18,
space filled with gravel

drain pipe

Figure 52. [See page 94, original]

replaced earth

25 cm thick circular strengthening
rib, placed every 4 meters

insulating mortar

rammed during construction

preferably 0.25 m thick
maximum above water table plane

drain or brick gutter

Figure 53. /See page 98, original/

emergency exit   microphone   corridor   ante-chamber   gas lock   shower   ventilation machine   emergency exit

emergency window   alarm radio   telephone booths   telephone center   toilets

emergency window

aku (storage batteries ?)

emergency window   commander's quarters   personnel office

analysis room   quarters   quarters

emergency exit   commander's office

Figure 54. /See page 100, original/

entrance   gas lock   classification room, disrobing area   ventilation

examination room

baths, showers

toilet, shower   dressing room

office   corridor, waiting hall   dressing (bandaging) station

medical room   decontamination room

preparation room

isolation room   operating room

toilet, shower   men's ward

women's ward

exit   ventilating equipment   emergency exit

Figure 55. /See page 103, original/

A-B section

observation ports, steel
sheet, 20 mm minimum

Figure 56. /See page 104, original/

A-B section

Figure 57. /See page 105, original/

A-B section

C-D section

Figure 58. /See page 108, original/

Properly joined

Improperly joined

Figure 59. /See page 109, original/

threading

Figure 60. /See page 112, original/

cubic area of the shelter interior area, in m^3

number of
people
within
the
shelter

liter per
minute
quantity
per person

interior base area of the shelter,
in m^2

liter/minute
capacity of
filter
ventilation
equipment

Figure 61. /See page 114, original/

dehumidifier

flexible connections

by-pass pipes

air filters

ventilator

throttle clack-valve

air quantity meter

Figure 62. /See page 117, original/

toilet

ante-chamber

interior area

toilet

interior area

emergency exit

Figure 63. /See page 117, original/

emergency exit

toilet

emergency exit

ante-chamber

toilet

toilet

toilet

toilet

emergency exit

ante-chamber

toilet

Figure 64. [See page 118, original]

Intake pipe

Head of intake pipe

Head of intake pipe, with dust collector

Dust collector in the intake pipe

Dehumidifier in the intake pipe

Lock valve of intake pipe

Aspirator with air filter (the number shown is the cu. m/minute capacity)

Aspirator with air filter, 5 m^3/min

Distribution (delivery) pipe

Adjustable air distribution valve

Wall opening

Automatic pressure reducing valve

Manually adjustable circular slide valve (star-valve)

Pipe for used air

Pressure gauge

Figure 65. [See page 120, original]

Humidity (gr/m^3), temperature (C^0)

CO_2 content

Temperature

Humidity

hours

Figure 66. [See page 121, original]

temperature of the air

temperature of wall surface

hours

Figure 67. [See page 127, original]

gypsum

flexible packing material

(stranded ?) packing

plaster

wall

Figure 68. [See page 128, original]

base coat

pliable sealing material

wall

Figure 69. [See page 129, original]

jute wrapping

base coat

lead pipe

pliable sealing material

wall

Figure 70. /See page 129, original/

gypsum

flexible packing material

tape sealing

heat insulation

plaster

wall

[redacted]