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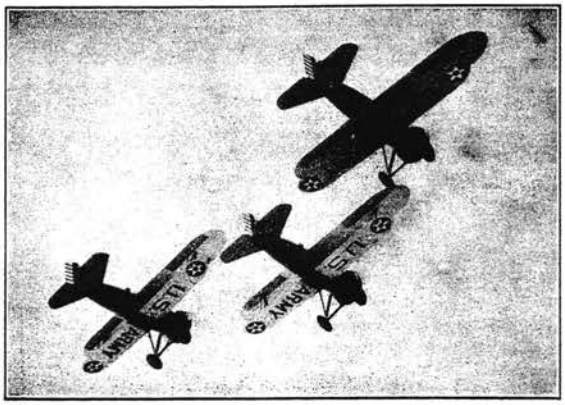

No. Study 14.

SHELTERS FOR CIVILIAN PERSONNEL

MAXWELL FIELD, ALABAMA

10 September 1935

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AC Board
Study #14.

SHELTERS FOR CIVILIAN PERSONNEL.

I.--HISTORY OF THE STUDY. Need for plans and specifications for a gas- and bomb-proof shelter for civilians was encountered in the Office, Chief of Chemical Warfare Service, early in the summer of 1935. These data were desired for incorporation in a handbook being prepared for use of the civil population in obtaining passive protection against aerial bombardment. The Corps of Engineers was requested to prepare the plans and specifications. That arm, in turn, called upon the Chief of the Air Corps for recommendations in connection with the type and sizes of aircraft bombs likely to be used by an enemy attacking centres of population from the air. The matter was referred to The Air Corps Board by 2d Ind., O.C.A.C., dated August 14, 1935, for recommendations covering generally the bomb-proof shelters considered suitable and data as to bombs which a hostile air force would probably employ.

II.--THE PROBLEM PRESENTED. What sort of shelter to protect civilians in American centres of population from aerial bombardment is it most feasible to provide in considerable numbers under emergency conditions?

III.--PERTINENT FACTS AFFECTING THE PROBLEM:

1. The general method of construction to be adopted for a standard type shelter is determined largely by the basic requirements of use. (See Appendix I.)

2. The character and amount of overhead cover is governed chiefly by the type and weight of aerial bomb most likely to be used by the enemy. (See Appendix II.)

3. The technical details of construction are dictated more by the necessity for rapid completion of shelters than by considerations of economy of materials and labor when both of the latter are available as in the normal case; and the type structure to be adopted must lend itself to simultaneous construction of a number of units in the shortest possible time.

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4. The problem of completing sufficient shelter space in time is simplified by adoption of a type shelter of maximum personnel capacity per unit, this maximum being limited by practical difficulties of adequate collective protection against gas, and by the necessity for a number of well-separated entrances

5. The numerous conflicting requirements may demand a compromise, which should then provide for the most immediate, if barely adequate, protection for the maximum number of people with arrangements for extending the degree of protection later.

6. In the final analysis, the plans and specifications for a type bomb- and gas-proof shelter should utilize to the utmost the capabilities for large-scale construction existing in the more important American centres of population, as providing the quickest, cheapest, and generally most satisfactory shelters capable of being provided for considerable numbers in an emergency.

IV. CONCLUSIONS:

1. While the most efficient method of providing shelters for the public against aerial bombardment unquestionably lies in the reinforcement and adaptation of existing buildings to make parts of them reasonably bomb- and gas-proof, this method cannot be relied upon to provide enough shelters; it is feasible only if undertaken systematically a long time before an emergency, when time permits a different solution for each type of structure.

2. Little can be expected in the United States, where the need for such passive defence measures is not apparent, in the way of requiring the incorporation of bomb- and gas-proof chambers into plans for new structures to be built in the immediate future.

3. Once a threat of aerial bombardment becomes imminent, attempts to provide shelters for the civil population should, for the most part, be directed toward the construction of a series of detached structures, as public works. Such a program, while undoubtedly most expensive, offers the advantages of large-scale planning, the establishment of priorities based upon varying needs, the full utilization of all supplies, equipment and labor locally available, and the most rapid completion of shelters where most necessary. Belated voluntary alteration of private property should not, at such a time, be permitted to interfere by competition with the coordinated public program.

4. Best results in time of emergency can be secured by quantity production at well chosen sites of a standard type of shelter designed to meet average conditions to be expected, both as to problems of construction and as to the nature of attack to be resisted.

5. Concurring with the views of the Ordnance Department, the Board believes that the enemy may be expected to employ the minimum size bomb that is of sufficient weight to accomplish the degree of destruction desired against the particular type of target, and to use none larger than is necessary for this purpose, but carry the greatest possible number of the proper minimum weight bomb and thus increase his probability of securing the necessary hits.

6. In conformity with the teachings of The Air Corps Tactical School, the Board feels that the size of bombs selected by the hostile air force will conform closely to the requirements of each type of target, as follows:

a. Light demolition bombs of approximately 45 to 50 kilograms (99 - 110 pounds) in weight are adequate against such targets as railway tracks and rolling stock; against all buildings of steel, brick, stone and concrete construction, including the latest type of factories, warehouses, rail terminals---in fact, all types of construction except sky-scrapers; and against materials and war munitions in process of manufacture and in storage.

b. Medium demolition bombs of approximately 270 kilograms (600 pounds) weight are adequate against concrete docks, light steel railway bridges, and underground railways (subways).

c. Heavy demolition bombs only, weighing upward of 500 kilograms (1100 pounds), are effective against such massive construction as is found in large bridges of either reinforced concrete or heavy steel structure, high masonry dams and spillways, and the like.

7. Considering the preponderance of objectives of light construction in any centre of population, from the point of view of actual numbers, areas involved, or percentage of workers affected; the ease of wide-spread destruction by the large numbers of light demolition bombs, gas- and incendiary-projectiles capable of being dropped in a single mission; and the tremendous military advantage to be gained thereby---it seems conclusive that an overwhelming majority of all aircraft bombs released over a city by a hostile air force will be of the order of about 100 pounds or less.

8. A standard type of protective shelter for the public generally must then be capable of resisting bombs of the effectiveness now obtained by those weighing about 100 pounds; at the same time, it must be capable of being made proof against even heavier bombs, by added reinforcement, whenever the shelter must be located within the danger zone of structures against which heavier bombs would have to be used.

9. In such standard type, a surface shelter is preferable to either a cut-and-cover or cave type, in that it is capable of most rapid completion; is most conspicuous under all conditions; is easiest of entrance and evacuation; is least affected by ground water and flooding; is least subject to settling of heavy concentrations of gas at its entrances; affords most protection to adjacent buildings and underground utilities, and is adapted to the widest range of sites, weather conditions during construction, and availability of special equipment.

10. As indicated by recent bombing tests in the United States and elsewhere, adequate overhead cover can be provided against all weights of demolition bombs; that this may be achieved largely by the use of a suitably reinforced bursting layer of sufficient hardness, although proper shock-absorbing and distributing layers are of course essential; that an adequate bursting layer will cause all weights of bombs up to and including 600 pounds, at least, to behave in practically identical manner, i.e., crushing the delay fuze on impact and with but slight penetration detonating almost instantaneously, practically in the open, so that the explosive effect is mostly dissipated.

11. Such an adequate bursting layer need not be of a high order of thickness that it is impracticable to provide, since even a 7-inch reinforced bridge floor of concrete overlaid by a light road surfacing at the Swift Island Ferry (Pee Dee River) Bridge produced the above results, even in the case of 600-pound bombs dropped "safe" and armed with delay fuzes. This furnishes an index as to the character and thickness of reinforced concrete bursting layer to be provided for a standard type protective shelter; at the same time, the Board does not feel that such a thin bursting layer is necessarily to be considered adequate, and feels that provision of a slightly thicker bursting layer may well be adopted since it can be had without appreciably more difficulty, with slightly more time during construction, and with no enormous increase of materials.

12. Apparently the largest capacity shelter chamber than can be considered practicable with the collective protectors now available and with the necessity for a separate entrance 40 to 50 feet removed from any other for each 25 to 30 occupants, is limited to approximately 125 persons; nevertheless, it is believed possible to design a type of chamber capable of being constructed in a series or chain of any number of separate units of this size, with continuous head-cover over the whole series, thus gaining the maximum protection, facilitating progressive construction operations, and making the fullest use of the few sites that are likely to be available in very congested localities.

13. Where congestion is greatest and available space for shelters is extremely limited, it may be most practicable to set aside one or more whole blocks of side street at its junction with a main thoroughfare for a chain of shelters. This would necessitate suspension of traffic over such blocks only during the period of actual construction, since the burster layer itself would be capable of use as an elevated highway, and form a two-level street intersection as soon as the project were completed.

14. The necessity for rapid completion of shelters, once their general production was found to be necessary, indicated to the Board the vital importance of having the standard type shelter based upon materials that would surely be available commercially in every city in quantities required for such project. The materials to be used must equally be suited to quick-work jobs. In this connection, the desirability of sheet-metal for forms and of alumina cement for all concrete work is readily apparent.

V. RECOMMENDATIONS:

1. That a standard type of protective shelter for use of civilians in large American centres of population in case of air attack be designed, with complete plans and specifications necessary to permit the erection of a number simultaneously by the local resources of a city.

2. That such standard unit be a surface-type shelter.

3. That each unit be capable of accommodating 125 persons for periods up to six hours at a time.

4. That each unit be designed to furnish security against a direct hit of a bomb having the effectiveness of the present type of 100-pound demolition bomb; and that necessary changes in thickness of burster, shock-absorber and distributing layers to furnish protection against 300-pound and 600-pound bombs, respectively, be indicated in foot-notes to the plan and specifications, so as to permit adaptation of the basic structure to special locations.

5. That it be capable of protecting its occupants against gas, surface water, and fire in adjacent buildings, as well as against bombs.

6. That the unit shelter be of such type and constructed of such materials as will allow completion thereof in the minimum time from the start of the project, by local contractors and laborers of ordinary skill and experience.

7. That it also be capable of construction in a continuous series of indefinite number of units, each independent of every other except as to approach ways and overhead cover common to two adjacent units.

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APPENDIX I

FACTORS AFFECTING TYPE OF SEPARATE PROTECTIVE SHELTER.

1. Necessity for separate shelters.--a. At the outbreak of a national emergency involving the threat of an aerial bombardment of cities or industrial centers, the civilian population will take steps to provide itself with protective shelters. First attention will be directed to improvising such shelters within existing buildings; practical considerations demand that the latter be developed to the maximum. Entirely new construction must, at such a time, be limited to the barest essentials so as to interfere least with military and industrial mobilization and the allocation of man-power, materials and transport. In most municipal areas, portions of buildings already standing can ordinarily be adapted, by reinforcement and gas-proofing, as adequate places of refuge for civilians in case of an air attack. This can be done with less work and material, in shorter time, and at lower cost, than would be involved in wholly new structures of equal personnel capacity. Such adapted shelters have two further advantages; first, they are more likely to be readily accessible to those whom they are intended to protect; and, second, by allocation to specific groups, movement of the latter into and from their own particular shelters can usually be most efficiently controlled, without over-crowding and with the minimum of confusion, false-motion and delay.

b. At the same time, the increased number of workers and consequent greater need for floor-space in certain plants will preclude the provision of protective shelters inside the buildings of the establishment for the majority of its employees. In some cases, every inch available for manufacturing will be so valuable as to restrict the interior shelters to corridors and wash-rooms. To maintain morale and keep up efficient production in the face of threatened air attacks, supplementary shelters must be provided outside the existing buildings but in the immediate vicinity. Similar provision must be made for the public generally, especially in downtown areas having large numbers of casuals on the streets, in public parks, and in residential districts characterised by light frame houses, which are highly inflammable and incapable of being adapted as adequate shelters, and which frequently adjoin indistrial districts.

c. These separate protective shelters, constructed to supplement the shelters improvised within existing buildings, must be:

(1) Made available for use almost immediately;
(2) Completed simultaneously, in considerable numbers;
(3) Started at any time of year, regardless of weather;
(4) Erected in any part of the country threatened by air attack;

(5) Built under war conditions; and
(6) Constructed by local contractors or volunteer labor, with no experience with this particular type of structure.

To meet these conditions, it is essential that a standardized type of protective shelter be designed and planned in detail, well in advance, by government agencies having the requisite knowledge, in order that all data may be available to municipal authorities whenever need may arise.

2. Method of construction to be determined.--a. In designing a standard type of protective shelter for use by civilians in case of an aerial attack, the general method of construction to be adopted must first be determined. Choice is limited to one of the following:

(1) Surface shelters, all or the greater part of which are built at or above the surface of the ground.

(2) Cut-and-cover shelters, built within an open excavation that is subsequently back-filled around and over the structure to provide the necessary overhead cover.

(3) Cave shelters, constructed entirely below the surface of the ground by mining methods, and having a cover of virgin or undisturbed earth.

b. In determining which type to adopt, the conditions for use, the time required for completion, the degree of protection afforded, and the facilities available (including personnel, tools, material, transportation, and room for construction activities) are the most important considerations; yet, at the same time, the cost, interference with other activities, and possibilities of use for some other purpose after the emergency should not be overlooked.

3. Conditions for use of protective shelters.--a. The abruptness of an air attack and the rapidity of its execution require practically instantaneous occupation, by civilians in the immediate vicinity, of shelters that will protect them from a number of different perils. Whether the aerial bombardment of a metropolitan or manufacturing center be an isolated raid or one of a series of systematic attacks, the hostile air force will seek to inflict the utmost damage by that operation. To this end, the enemy will use high-explosives, incendiary and chemical agents, and possibly even smoke, in a coordinated attack. By high explosives, he will try to demolish structures and industrial equipment, and cripple such utilities as water-supply, electric, gas, telephone and other signal, fire-fighting, pipe-line, tank-storage, and

surface transportation systems. By incendiary agents, he will attempt to complete the destruction of the objective and endanger adjacent areas by fires that cannot be checked once the utilities are paralyzed. By smoke, he will endeavor not only to screen his own movements, for greater security of the aircraft making the attack, but also to postpone the discovery of fires and to cause traffic congestion by collisions, etc., thus immobilizing vehicles within the area for hours. Finally, by chemicals, the enemy will strive to frustrate all efforts to put out fires or save material threatened by the flames, and to delay the work of restoration and the resumption of normal activities over a maximum period. Although these several types of agents may be used in many different combinations and sequences, it is logical to expect the chemicals in the final phase of the air attack and within a very few minutes of the dropping of the first bombs.

b. As soon as an air attack on a congested center is discovered, streams of people will pour toward the shelters from all directions. The early arrivals may be frightened but still fairly composed. Some moments later, however, panic-stricken individuals, among them the walking wounded and those temporarily blinded by the explosions and chemicals or retching with nausea, will limp and grope and fight their way toward some of the shelter entrances. At these the situation will be like that of a theater audience instantly converted into a frenzied mob by a fire on the stage--only worse.

c. The sudden onslaught, and the demoralization produced (by the blasts of high-explosive, toppling walls, flying debris and splinters, the dust and smoke, unfamiliar fumes thought to be poison gas, the outbreak of fires, and sight of occasional human casualties), considered in connection with the undisciplined state of the civil population, all demand certain arrangements for protective shelters that are either unnecessary or impossible for military personnel at the front.

d. The above conditions demand that the design of a standard type of separate shelter for civilians in case of air attack satisfy each of the following basic requirements so far as possible:

(1) Conspicuous location where crowds can be predicted;
(2) Greatest accessibility as to entrance;
(3) Adequate overhead cover against explosives;
(4) Sustained collective protection against gases;
(5) Exclusion of water, including drainage and water-proofing;
(6) Security of occupants against external fires;
(7) First-aid facilities;
(8) Independent utilities to include water, light, sanitary conveniences, and disposal of chemically contaminated clothing; and
(9) General fitness for occupancy over a period of several hours or even longer.

4. Conspicuous locations.--Rapidity in gaining adequate cover is of paramount importance. This requires that shelters be located near the places where the crowds will be when an air attack is begun and that the refugees know how to reach them without delay. In case of interior shelters this requirement is easily met; not so, however, in the case of separate shelters in such congested places as down-town areas and well built up factory districts. As far as circumstances permit, the latter should always be given prominent sites. They will not, of course, be familiar landmarks when first completed; their locations cannot then be known to all. Vacant lots are to be used whenever available; and in such cases any bill-boards screening the property must be rigorously removed. Whenever conditions compel the erection of separate shelters for the general public on the back lots, behind other buildings, the lack of conspicuous location should be offset by numerous signs indicating the way. General accessibility is favored by providing shelters of relatively small unit capacity, well distributed and in considerable numbers.

5. Accessibility of entrances.--a. It is vitally important that the entrances to the shelters, as well as the structures themselves, be most accessible from the street under all conditions. The protective chamber must admit personnel to the limit of normal capacity, or even somewhat in excess, without any human jams resulting from delays. There must be reasonable assurance against all the entrances being blocked by debris from a single explosion. At least two entrances should be provided for each separate shelter; these should be at opposite ends, spaced not less than 40 feet apart. For shelters intended for refuge of casuals, as distinguished from organized groups of workers, one entrance is required for every 25 persons to be accommodated. Every entrance should be direct and easy, even at some sacrifice of cover. Since the refugees may be unable to see their way clearly, any such obstacle as a step or stairway is highly objectionable. Approaches to the shelter entrances should be modeled after the ramps of a modern stadium or other place handling large crowds.

6. Overhead cover.--Considerations of the amount and nature of overhead cover are so technical as to require detailed analysis. This is covered in APPENDIX II hereafter, hence will not be discussed in this section, except to point out two salient facts:

a. Sufficient overhead cover for a bomb-proof shelter can be obtained in all three methods of shelter construction described in paragraph 2 by the use of reinforced concrete, if equipment, materials, labor and transportation are available.

b. It is not feasible to construct shelters that are proof against any conceivable weight of airplane bomb; bomb-proof shelters are provided only such overhead cover as to resist the largest bombs likely to be employed in their vicinity.

7. Collective protection against gas.--a. Provision for keeping the air within the shelter free from contamination by gas, smoke and fumes is almost as necessary as furnishing overhead cover. In an aerial attack on an industrial center, whether or not the hostile aviation employs chemical agents, the refugees in the shelters must have a continuous supply of air that is safe for them to breathe. Gas mains, carrying either artificial or natural gas or a mixture of the two, normally lie but a few feet underground and consist of fragile cast-iron pipes easily broken by a hammer blow; if not protected by a hard pavement they are extremely liable to rupture by even the lightest demolition bomb. Carbon monoxide poisoning is a very real danger. Sewer gas is likely to be encountered. Explosions, fires and water in some plants may result in the liberation of considerable quantities of live steam, asphyxiating and poisonous fumes. Large amounts of smoke will be produced by conflagrations if none is released from aircraft. All these must be excluded from the shelter.

b. With a considerable number of persons taking refuge in a small chamber, provision for renewal of the oxygen supply and removal of excess carbon dioxide is indispensable. The only feasible way of maintaining a safe air supply for a large group within a shelter is to force constant stream of air, drawn from the outside through adequate filters, into the chamber at a pressure somewhat greater than that of the atmosphere. This slight super-pressure causes an outward movement of air through all cracks and openings; if these be confined to the entrances only and are not too large, contaminated air is effectively excluded. Apparatus for introducing filtered air under pressure is known as a collective protector.

c. Once security is provided against both the smoke and gases generated by the city itself, as result of an aerial bombardment, and the toxic effects of the exhaled breath of the occupants of the shelter, protection from the enemy's gas adds only slightly to the requirements. To begin with, the enemy is aware that every pound of gas carried necessarily displaces an equal weight of explosives or incendiary agents he might otherwise employ; he will use gas only when it serves his purpose better than any other agent. He recognizes, too, that against a city's population, free to move to the upper stories of buildings, the volatile non-persistent chemicals are not particularly effective. Whenever he does resort to chemicals in his attack on a metropolitan area his main purpose will be the interdiction of salvage, fire-fighting, clearing, repair and restoration work in the industrial district bombarded, rather than infliction of injuries to personnel. For this reason such chemicals as he does use will usually be of the persistent type, such as vesicants, calculated to deny activity in the district attacked for as long a period as possible. The principal danger from persistent chemicals arises when small quantities come in contact with clothing and skin; their vapors are less effective and are filtered from the air taken into the

shelter in the same way as other gases, by the collective protector. What the shelter must furnish is first-aid for individuals contaminated with vesicants before gaining cover, and means for neutralizing the chemicals they introduce on their persons. Thus the additional requirements of a shelter for protection against enemy gas practically are reduced to provision of:

(1) Air-tight waste-cans for disposal of contaminated garments;
(2) Soap and water for washing areas of the body affected by chemicals;
(3) De-gassing materials for neutralization of chemicals tracked in by shoes of the occupants and for clearing the entrances before evacuation; and
(4) Blankets, litters and first-aid kit for treatment of gas casualties.

d. The collective protector is effective only when the chamber is reasonably air-tight. To minimize the leakage of air at the entrances, the latter should consist of a corridor with doors at both ends, thus forming an air-lock. Troops at the front, with superior gas discipline and individual gas masks, can use entrances constructed with slanted door frames covered with gas blankets held down by battens. No such doorway will serve for civilian use; it is too liable to destruction by some frantic refugee seeking admission. Nothing less substantial than a pair of hinged doors seems feasible for a shelter entrance used by the public. The outer or street door should be provided with flexible flaps or metallic weather-strip to keep out winds bearing noxious fumes when doors are closed.

e. The extreme likelihood of lethal concentrations of gases generated by fires in factories and warehouses practically adjoining the shelters makes it imperative to install a special type of canister in the air-intake of the collective protector. Only the all-purpose type of canister will furnish security from the fumes to be expected from a large-scale city fire in which damaged refrigerating plants, burning petroleum products, oils, paints, varnishes, lacquers, celluloid and nitrate products generally, rubber, silk and woolen goods will be ablaze.

f. Due to the possibility that power will be interrupted as the result of an air attack, the collective protector for shelters should invariably be capable of hand operation.

8. Exclusion of water, drainage and water-proofing.--a. Provision against flooding the protective chamber of a separate shelter is mandatory. It is futile to save a group of people from the somewhat remote danger of being blown to pieces only to subject it to wholesale chemical injury or drowning below ground. An aerial bombardment will nearly always cause the breaking of water pipes in the buildings hit and the clogging of surface

drains in the immediate vicinity with debris. Any efforts to fight fires will surely add to the local flood. There is considerable risk that a bomb may rupture a water main and at the same time block the main sewer. At water-power sites, often found along the Atlantic seaboard, and where the water supply of the city is impounded in a reservoir at higher level, the possibility that the dam may be blown out, releasing a wide-spread torrent, is not at all remote. No system of drains, even if supplemented by pumps, could make an underground chamber safe once the sewer failed and the locality of the shelter were flooded.

b. Aside from such major disaster, there is the ever present risk of comparatively small amounts of surface water washing persistent chemicals, such as the vesicant type, into the chamber of a subterranean shelter by way of the ramp or stairway entrances. This danger is twofold. In their fancied security within the chamber, refugees might be unaware of chemical contamination until extensive injuries had developed; it must be remembered that degree of disability depends upon the concentration multiplied by the time of exposure. Then, too, the chamber would remain a menace to all subsequent occupants unless it were thoroughly disinfected--an operation by no means simple or certain in results if surface water runs in or seeps through.

c. To avoid the dangers of flooding during occupancy and of the washing in of persistent chemicals following an air attack, the floors of separate shelters should be at least as high as the ground level and the whole structure itself should be reasonably water-proof. Only if these two precautions be observed will such shelters be continuously safe for public use.

9. Security of occupants against external fires.--a. With separate shelters necessarily located near the potential objectives of hostile air attack, they must furnish their occupants security against serious fires. This involves three-fold protection: against smoke, fumes and steam (considered in collective protection against gas generally); against introduction of water (considered under drainage and water-proofing); and finally, but by no means least, against flames and radiated heat. A general conflagration and obstruction of traffic in the area subjected to air attack will prevent the escape of refugees and compel them to keep to their shelters for a considerable period.

b. The provision of adequate collective protection against gas and of sufficient overhead cover against explosives at the same time secures the separate shelter against external fires, except as to its entrances. The latter, therefore, must be not only located as far as possible from the buildings, but actually heat-resistant. Steel outer doors are indicated; wooden doors, should never be used save as a last resort, and even then should be protected with armor of sheet metal, asbestos, or whatever other means may be available.

c. It will be seen that the conventional gas-blanket used by troops for entrances to their trench shelters is hopelessly inadequate as the outer door of a shelter for city use--not only because it obstructs rapid use of the entrance, may be torn off by frantic refugees, and is not proof against splinters, but mainly because it affords no security against fire.

d. In conflict with the requirement that shelter entrances be direct and easy of access, considerations of fire point to the desirability of a concrete baffle or traverse at the entrance, to give maximum protection against flames and radiated heat.

10. Other requirements.--a. A considerable number of protective shelters may have to accommodate their occupants for periods of several hours, or even longer. Only in those parts of a city not directly subject to attack will it be safe to leave the shelters as soon as the last of the hostile airplanes have disappeared. In the districts bearing the brunt of the attack the refugees will ordinarily be forced to remain in their shelters until the fires have practically burned themselves out, the smoke has lifted, and special transportation has arrived or the police, firemen and other public guardians have established lanes of exit safe for pedestrians. Even then there will be casualties awaiting removal to hospitals and the bodies of the dead.

b. The standard shelter must therefore be designed for such continued occupancy whenever the emergency requires. Seats are needed if for no other reason than that standing individuals consume more oxygen. Space for litters, which may be suspended one over the other in racks to conserve floor-space, is essential; and an elevated platform for first-aid treatment is likewise required. City water connections are desirable, but a small storage tank holding the minimum water necessary for drinking and for washing of vesicant-gas casualties is indispensable, since the water supply may fail or be contaminated. Toilet facilities should be provided. An independent source of light should be furnished; the electric power is likely to be interrupted, yet the need for light for examination of occupants for wounds and collapse, and for emergency treatment will be continuous.

11. Unit capacity.--a. The completion of sufficient shelter room in minimum time is greatly facilitated by building protective chambers of considerable capacity, thus accommodating a larger number of people with fewer separate structures. There is, of course, a limit to the size of structure which can be built with a saving of total construction time for the whole project, but this limit is not even approached in practice because of other reasons indicated below. In general, saving of construction time, materials and labor is effected by adoption of a type chamber that will adequately accommodate the most people, especially if these

chambers can be made practically contiguous to one another. If the latter plan be followed, the least movement of forms and equipment is required, dumps of materials may serve several chambers equally, and some overhead and side cover may be made common to two adjacent units, with work progressive through the series.

b. The limitations of efficient gas protection, more than any other factor, determine the maximum number of people to be accommodated in a single chamber. Each collective protector of the type now available is capable of maintaining a safe air supply for about 66 individuals. The use of more than two collective protectors does not promise satisfactory results, in the opinion of the Office, Chief of the Chemical Warfare Service. The largest single chamber would thus seem to be restricted to 20,000 cubic feet---a capacity of 125 persons.

c. Large shelters are provided with at least three entrances, and preferably four, to meet all emergencies. Each entrance should lead in from a different place and at a different angle so far as possible, permitting entrance and escape in any event. Entrances should be spaced to avoid danger of a single bomb burst blocking two of them, a minimum of not less than 40-45 feet apart and separated by a baffle or similar obstacle to debris. In view of the lack of discipline to be expected among the civilian refugees in case of aerial bombardment, at least one entrance should be provided for each 25-30 persons to be accommodated within the chamber. This limitation also affects the size of chamber which will be found practicable, but does not operate to reduce the capacity below 125 persons, since four entrances may be provided.

12. Compromise type essential.--a. It is clearly feasible to design an adequate shelter embodying all the above requirements, if only the structure may be built in time of peace when the earliest possible completion is not made a mandatory condition. Such a structure would be admirably suited for use as a public toilet, first-aid station, police sub-station, etc., and should cost but a trifle more than any other permanent building for one of these purposes. It would then be ready for use as a refuge in case of such a disaster as a wide-spread city fire, even though the air attack were never likely.

b. The fact remains, however, that the construction of shelters of the sort deemed necessary will be deferred until the emergency actually exists. The possibility of aerial bombardment of American cities is not apparent; and with no necessity for such measures of passive defence clearly foreseen, little can be expected for this sort of construction in time of peace.

c. The main problem in designing protective shelters is, then, the matter of speed in construction. Any requirement conflicting with the most rapid completion of the exterior, at least, will be ignored when the emergency exists. The great majority of shelters will then be thrown up in a belated effort to secure some protection quickly. Since this must be the case, the design of a standard type shelter should start with minimum time of completion as the initial requirement and incorporate every advantage which is possible under this limitation. The result will necessarily be a compromise--but a compromise type that is practicable.

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APPENDIX II.

FACTORS GOVERNING SIZE OF BOMB TO BE RESISTED BY SHELTERS.

1. Problem presented.--In any future war waged against the continential United States, aerial bombardment of cities and industrial districts of great strategic importance is to be feared immediately after, or possibly before, the declaration of hostilities. In such attacks, the enemy will operate either against specific objectives or against certain selected areas within each city rather than against the municipality indiscriminately. The effects of his bombs, however, cannot be confined to targets of military importance; it is inevitable that the civil population be endangered. To minimize this danger to persons, protective shelters will be provided in and adjacent to the objectives likely to be attacked by the hostile air force. The question then arises: Against what weight of bombs must these protective shelters afford security?

2. Main object of the enemy.--a. Analysis of this problem demands, first, consideration of the main object of the enemy. The latter will seek to destroy the usefulness of each strategic center attacked rather than the whole center itself. The certain destruction of a large area not only involves too many bombs and a far greater number of airplanes than he can devote to that single task, but it is, moreover, entirely unnecessary. The enemy's purpose will be accomplished once he succeeds in paralyzing the normal activities of the place, thus making it of almost negligible value to the nation in the conduct of the war. To accomplish this, the hostile air force will tend to concentrate its bombs upon those vital installations which give the city its special importance in the scheme of national defense. It will normally single out for attack those particular manufacturing districts or commercial facilities upon which the industrial life of the city is most dependent. Its effort will be brought to bear on towns where a moral result may be anticipated, but more especially on strategical points where it will at the same time curtail the duration of the war by elimination of vital resources: depots, workshops, public utilities such as gas, water and electric plants, transportation systems, and so forth. It will try to cripple these in the shortest time and with the fewest possible aircraft. In such effort, the form of attack as well as the specific objectives will vary according to local circumstances, but in every case the enemy will employ bombs of a size or of sizes calculated to produce the maximum havoc per pound of bombs dropped.

b. All cities of consequence within the industrial regions of the United States have these points in common:

(1) The storage, switching, repair and transfer yards, the freight terminals, together with the numerous factories, warehouses, material yards, and utilities along the railways that penetrate the city, collectively constitute most profitable area targets for hostile aviation in that they are---

(a) Large in extent;
(b) Conspicuous from the air;
(c) Readily identified landmarks;
(d) Extremely sensitive points as affecting industry generally;
(e) Bottlenecks through which the great mass of raw and finished products of the city must necessarily pass;
(f) Reservoirs containing at all times a large bulk of the mobile reserves of materials within the industrial district;
(g) Generally speaking, structures and equipment of light construction subject to destruction or serious damage by even the lightest weight demolition bombs;
(h) Highly inflammable "fingers" reaching into the very heart of a city otherwise quite immune to widespread fires; and
(i) Breaks in the municipal highway system, dividing the latter into several distinct road-nets with relatively few connecting thoroughfares and these liable to interruption by a general conflagration.

(2) Flanking the industrial belts along the railways are zones of cheap, congested housing of the laborers who live within walking distance of their jobs. Such zones are given over to flimsy frame structures or to buildings having wooden floors, stairways, interior partitions and roofs; blocks are solidly built up as a rule, and present a great fire hazard. They are of no military importance in themselves, but serve to extend the effect of bombardment of the railways and industrial plants along the tracks.

(3) Employees who do not live within walking distance of their jobs are largely dependent upon suburban trains, street railways, or motor transportation to and from work. These suburban trains operate over the railways running through the industrial belts, while the street railways and motor busses also are linked to the railways in most precarious manner; they often run parallel and alongside the latter for considerable distances with their trolley lines and roadbeds within the danger zone of bombing; in other cases they approach the industrial belts fringing the railways over a few streets traversing the zones of cheap, inflammable housing mentioned.

(4) The areas between the several industrial belts are characterised by successive blocks of light structures mostly of brick, stone, concrete, and other permanent materials. These zones consist of apartments, long rows of houses, stores and office buildings, and the like, with detached frame houses becoming more common toward the city limits. All buildings of this sort are liable to destruction by the smallest demolition bombs, but are comparatively immune to a general fire under ordinary circumstances. Because they have no military importance, they do not constitute profitable targets for aerial bombardment at any time.

(5) There are also in every large city a considerable number of structures of medium-heavy construction grouped, for the most part, closely together in the down-town business district. These include such works as the modern sky-scraper, certain public buildings of the heaviest masonry, subways and elevated railways. All of these are practically fire-proof and so surrounded by similar structures that damage from aerial bombardment would be extremely localized. Because of the extensive use of structural steel and reinforced concrete they are comparatively proof against the lightest demolition bombs of approximately 45 to 50 kilograms (99-110 pounds) weight. To secure effective results against them the enemy would have to employ medium-weight bombs, of about 300 to 600 pounds each. Although a building struck by such a bomb might itself be practically demolished the other buildings in the same block could be expected to remain intact. Few structures of medium construction are vital to the commercial life of the city, inasmuch as the great majority contain offices and stores effectively duplicated many times over. Should any of these offices be wiped out by bombs, their reestablishment elsewhere within a few days is altogether probable. Even the loss of several important stores would affect the city but little. Speaking generally, the works of medium construction cannot be considered especially profitable targets for enemy aviation, and from this standpoint they fall far short of the railway-industrial belts first mentioned.

(6) Finally, each large city has a relatively few structures of heavy construction, which include such works as the largest railway and highway bridges, reinforced concrete and masonry docks, the dams of water-power sites and of important water reservoirs, railway underpasses, and tunnels. With few exceptions, these structures are situated outside the congested areas; most of them are found over rivers, on large bodies of water, or at the outskirts of the city. As a rule, each of these works is unique and of vital economic importance to the locality, hence for this very reason is likely to be attacked by the enemy. None, however, is an area target in any sense. The destruction of any one can be accomplished from the air only by a precision bombing operation involving, for example, from six to twenty airplanes each carrying several heavy demolition bombs weighing upward of 400 kilograms (880 pounds) apiece. The enemy will try to place every bomb within 50 feet, at least, of some

critical part of the structure attacked. On account of the precision attempted, the relatively small number of bombs dropped, and the general isolation of the target, protection against such heavy bombs becomes a very special case and does not properly fall within the main problem of bomb-proofs for the public generally. The provision close to such structures of shelters having headcover enough to withstand the heaviest bombs is utterly impracticable where only a few workers might possibly be caught at the site at the outset of a bombing attack. Common sense will preclude the erection of shelters for the public closer than several hundred yards to such an objective; even that distance will ordinarily be exceeded unless the most urgent considerations, as in the case of a transport dock or an extremely long and crowded passenger bridge, compel a closer location.

c. Complete destruction of the objective is not always sought by the enemy, hence the number of bombs to be expected in any locality is certain to be quite limited. In this sense, aerial bombardment is not comparable to the indirect fire of artillery on important objectives behind a military front. The enemy's air force can see the effect produced during the progress of the operation. It will therefore content itself with the systematic destruction of vital small areas that may readily paralyze the entire production of an industrial district. Once the desired degree of destruction has been accomplished the objective in question will have been reduced to negligible military importance, not worthy of further attack. This attitude on the part of the enemy has a most significent bearing on the amount of sustained bombardment which any protective shelter may be expected to have to resist.

3. BOMBS TO BE RESISTED.--a. It follows from the above that the size of bomb to be resisted by a protective shelter depends almost entirely upon the location of the shelter with reference to structures the enemy might seek to destroy.

b. The Ordnance Department has enunciated the general rule for choice of size of bomb, which may be expressed as follows:

(1) Always use a bomb of sufficient size to accomplish the destruction desired. If an 1100-lb. bomb is required, two 600-lb. bombs will not suffice.

(2) Having determined the proper size of bomb, never use a heavier bomb, but carry more of the proper size lower weight bombs and thus increase the probability of securing the necessary hits.

The hostile air force may be expected to observe this rule, using the minimum weight bomb that will accomplish the end in view, for each particular type of target.

c. Reference Data published by the Air Corps Tactical School indicates that the 100-pound demolition bomb is adequate against all types of structures, equipment and materiel of military importance in a city except:

(1)	Sky-scrapers;	
(2)	Light steel railway bridges	)- requiring 600-lb.
(3)	Underground railways	)
(4)	Concrete docks	)
(5)	Heavy steel RR bridges	)
(6)	Reinforced concrete pier bridges	)--- requiring 1100-lb.
(7)	Massive reinforced concrete suspension-and-pier bridges	)- requiring 2000-lb.
(8)	High masonry dams and spillways	)

Analysis of all the targets presented to the hostile air force within an important industrial district or large centre of population will show that there is a great preponderance of targets against which the 100-lb. bombs would unquestionably be the most likely unless even lighter bombs of the desired destructiveness were employed.

d. Since the workers in each essential war-time industry, in public utility plants generally, and even the general public in crowded areas, all would require headcover sufficient to protect them against the bombs likely to be dropped by the enemy in the particular area in which they each ordinarily are, it is seen then that the overwhelming majority of protective shelters provided require, basically, overhead cover sufficient to resist bombs of the effectiveness of the present-day 100-pound demolition bomb.

e. At the same time, objectives of importance which probably would be attacked by the hostile air force with bombs heavier than the 100-pounder may also require bomb-proof shelters near by. If the standard type of protective shelter can be adapted by thicker burster layers and deeper shock-absorber and distributing layers without other modification, it would serve for these special cases also. Such adaptation seems feasible, in view of data immediately following.

4. Character of burster layer.--a. Protective works to resist high explosives intended to penetrate on impact and then detonate are based upon the principle of causing detonation as close to the outer surface as possible. If penetration of the projectile can be restricted to a negligible amount, the mining action of the explosive is minimized, the explosion occurring in practically free space without tamping effect. To limit penetration a dense outer or burster layer is employed.

b. Recent bombing tests at the Swift Island Ferry (Pee Dee

River) Bridge demonstrated that any explosive bomb dropped from an altitude not less than 6000 feet, or having an impact velocity exceeding 600 ft/sec, is detonated almost instantaneously upon striking such a resistant surface as reinforced concrete, with only slight penetration. In these tests bombs up to and including the 600-lb. bomb were employed. Here both the 300-lb. and the 600-lb. demolition bombs with delay fuzes striking the bridge floor of but 7 inches of reinforced concrete overlaid with light road surfacing gave practically instantaneous detonation. Only small holes were torn in the bridge floor by both types of bombs, the 600-lb. bomb cut some of the reinforcing rods while the 300-lb. bomb did not; and the 600-lb. bomb made about twice as large a hole in the floor as the 300-lb. bomb. In this connection, it may be noted that the possibilities of longer-delay fuzes, to permit further penetration before detonation appear to be extremely limited, since 600-lb. bombs dropped "safe" and not armed at all detonated on impact due to crushing of the fuze by force of impact. While the test is limited, it is felt that the 7-inch reinforced concrete surface may serve as an index to the thickness and character of burster layer that should be provided for protective shelters, even though a burster layer so thin is not necessarily to be considered as wholly safe for bombs of medium weight.

c. In case of protective shelters constructed behind the lines, a monolithic layer of appropriate reinforcement and thickness should be not especially difficult to provide, inasmuch as continuous power mixes of wet concrete should be available.

d. The use of quick-hardening, or alumina, cement concrete in place of standard Portland cement is indicated because the former attains about 75% of its full strength in 24-hour periods, against 24 days for Portland cement concrete. Use of the quick-hardening cement is indicated. Data as to the relative strength and availability of the alumina cement is not locally available. In case of doubt as to the availability of this type of cement everywhere in sufficient quantities, plan and specifications for a standard type of concrete shelter might well indicate data for each type of cement, to permit alternative construction.

1 Extra Copy of Report No. 14
in bottom file drawer

WAR DEPARTMENT
Office of the Chief of the Corps
Washington

Memorandum for

Gen Westover:

The Plans Section recommends the Chief Air Corps approve the attached study ~~and~~.

V. B. D. H CLD

VINCENT B. DIXON
Major, Air Corps,
Assistant Executive.

WAR DEPARTMENT
Office of the Chief of the Air Corps
Washington

Memorandum for 1/13

Plans -

Why shouldn't a study like this be sent to the General Staff for their info - with a view of getting formal acceptance as Policy?

H. H. ARNOLD,
Brigadier General, Air Corps,
Assistant Chief of the Air Corps.

(9)
RB-sr

May 27, 1937

Study No. 14 - Shelters for Civilian Personnel.

President,
The Air Corps Board,
Maxwell Field, Alabama.

The following letter from this office to The Adjutant General, together with 1st Indorsement thereto, is quoted for your information:

"January 14, 1937

Subject: Study No. 14 - Shelters for Civilian Personnel

To: The Adjutant General

1. The attached Study No. 14 - "Shelters for Civilian Personnel", which has been approved by the Chief of the Air Corps", is forwarded for your information.

2. It is requested that the recommendations of the Air Corps Board be approved as a policy of the War Department.

For the Chief of the Air Corps:

(s) V. B. Dixon,
Lieut. Colonel, Air Corps,
Executive.

1st Ind.

War Department, A. G. O., May 10, 1937 - To the Chief of the Air Corps.

It is not desired to publish plans and specifications for gas and bomb-proof shelters at the present time. Consideration and recommendations of the Air Corps Board, contained in Study 14, "Shelter for Civilian Personnel", has therefore been deferred.

Copy of the report has been withdrawn for file in this office.

By order of the Secretary of War:

(s) E. R. Householder,
Adjutant General."

AG 381 National Defense (1-14-37)(Misc.) D

1st Ind.

CCW-ahc

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RB/sr

(9)

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For the Chief of the Air Corps:

Lieut. Colonel, Air Corps,
Executive.

1 att.
Copy No. 14

C.A.C. Board Study Shelter - Misc. Reports

RB-sr

(9)

January 8, 1937

MEMORANDUM FOR - Chief of the Air Corps:

SUBJECT -- Air Corps Board Studies Nos. 14, 23 and 28.

1. According to the records of the Plans Section, Air Corps Board Studies Nos. 14, 23 and 28 have been forwarded to the Chief of the Air Corps; however, this Section has no record of these studies having been returned.

2. These studies have been reviewed by the Plans Section and the following action is recommended, in order that the studies may be of authoritative value to the personnel of the Office, Chief of the Air Corps:

STUDY NO. 14 - BOMB-PROOF SHELTER FOR CIVILIANS

a. Approval by the Chief of the Air Corps.
b. That a copy be furnished to the War Department for their information.

STUDY NO. 23 - SHELTER FOR AIR FORCE PERSONNEL ON FIELD SERVICE

a. Approval by the Chief of the Air Corps.
b. That a copy be furnished The Quartermaster General, thru The Adjutant General, requesting it be given due consideration in the development and procurement of tentage.

STUDY NO. 28 - PROPOSED AIR CORPS EXPANSION

a. Approval as a guide for coordinated planning.

Note: Three copies have been furnished the War Department.

RUSH B. LINCOLN,
Colonel, Air Corps,
Chief, Plans Section.

RB

A.C. Board Studies - Miss Rand

May 12, 1936

Subject: Request for completed
Air Corps Board Studies.

TO: President
The Air Corps Board
Maxwell Field
Montgomery, Alabama.

Study No. 1 - Test of Fluorosulfonic Acid - Sulfur Trioxide Smoke Mixture

Study No. 14 - Bomb Proof Shelter for Civilians. ✓

Study No. 24 - Photographic Equipment for GHQ AF Observation Units (Confidential)

R.M.J.

(See study No. 24 for copy of letter submitted.)

3 copies of Study No. 14 received in OCAC by 1st Ind. dated May 15,1936