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GASPROOF SHELTERS

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CHAPTER 1

VENTILATION

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SECTION I

GENERAL

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1. **Purpose and scope.**—This manual is published for the information and guidance of personnel charged with the construction and maintenance of military gasproof shelters. The subject matter in-

cludes physiological factors, air purification equipment, and architectural requirements for the various types of shelters.

2. Definitions.—*a. Absorption.*—A capillary phenomenon through which a liquid becomes incorporated in a solid.

b. Adsorption.—The condensation of gases, liquids, or dissolved substances on the surface of a solid.

c. Aeration.—The process of exposing to air.

d. Air lock.—An intermediate chamber between the outside and the inside of a shelter.

e. British thermal unit (B. t. u.).—The heat required to raise the temperature of 1 pound of water at its maximum density by 1° F.

f. Collective protector.—A machine used to draw air from the outside atmosphere, purify it by removing chemical agents, and force it into a shelter.

g. Gasproof curtain.—A fabric curtain made of such materials, or so treated with chemicals or water, that gases and vapors from chemical agents will not pass through it. Such a curtain is used to prevent seepage of air through entrances and windows.

h. Gasproof shelter.—A refuge from which toxic gases, smokes, and vapors of the kind and concentrations used in warfare may be excluded, or in which they are so reduced in concentration as to be harmless.

i. Improvisation.—A shelter adapted within an existing structure.

j. Latent heat.—As measured in British thermal units, heat absorbed or given off by a substance without a corresponding change in temperature.

k. Latent heat of vaporization.—As measured in British thermal units, the quantity of heat necessary to change liquid to vapor without change of temperature at its normal boiling point.

l. Protected space.—That part of a shelter from which air contaminated with chemical agents is excluded, or which is supplied with air from which such agents have been removed.

m. Sensible heat.—As measured in British thermal units, heat added to a body when its temperature is increased.

n. Unventilated shelter.—A shelter not provided with a means for changing the air.

o. Ventilated shelter.—A shelter provided with purified air by means of a collective protector.

3. References.—See appendix I.

SECTION II

PHYSIOLOGICAL CONCEPTS

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4. General.—Consideration must be given to the following physiological factors when planning a gasproof shelter:

a. The respiratory process.

b. Oxygen and carbon dioxide as factors affecting life.

c. Air requirements.

d. Effects of temperature and humidity.

5. Respiratory process.—Normal air contains 79.03 percent nitrogen, 20.94 percent oxygen, and 0.03 percent carbon dioxide by volume. Nitrogen is not absorbed by the lungs. Exhaled air contains an average of 4.38 percent of carbon dioxide. Respiration, which is speeded or reduced in direct ratio to the state of body activity, consists of the following processes:

a. Transmission by the lungs into the blood stream of oxygen from inhaled air. Oxygenation of the blood is a continuous process and is vital to the renewal of cells, tissues, and nerve centers of the body.

b. Discharge of carbon dioxide in exhaled air, charged with moisture and at increased temperature.

6. Atmospheric factors (see app. II).—*a. Carbon dioxide.*—An increase of carbon dioxide in breathed air is more serious than loss of oxygen from the air. Shelters should have sufficient ventilation, or a sufficiently large volume of air per person, to prevent the carbon dioxide content from exceeding 2 percent during the anticipated period of occupation. Normal air contains about 0.03 percent carbon dioxide, which may be increased to 1.5 percent without harmful effects. Air containing 3 percent carbon dioxide causes headache and increased blood pressure, while 4 percent content will impair respiration; 5 percent or more is very dangerous.

b. Oxygen.—The normal volumetric oxygen content of air is 21 percent, but this may be reduced in shelters to 14 percent without harmful effect. The minimum for normal breathing is 10 percent. The number of men which a shelter will accommodate is governed more by carbon dioxide content, temperature, and humidity of the air than by oxygen requirements.

7. Air requirements.—In normal outdoor air, a man at rest requires an average of 0.275 cubic feet of air per minute, but the requirement rises sharply with increased physical exertion. Thus, a man walking at 3 miles per hour needs 0.888 cubic feet per minute, while a man walking at 5 miles per hour needs 2.18 cubic feet. In makeshift unventilated shelters, *designed to accommodate men at rest*, 1 cubic foot of air per minute per man should be provided for periods of time up to 3 hours. For a detailed comparison of capacities of shelters when equipped with the various types of collective protectors and subject to varying climatic changes, see appendix III; for unventilated shelters see appendix IV.

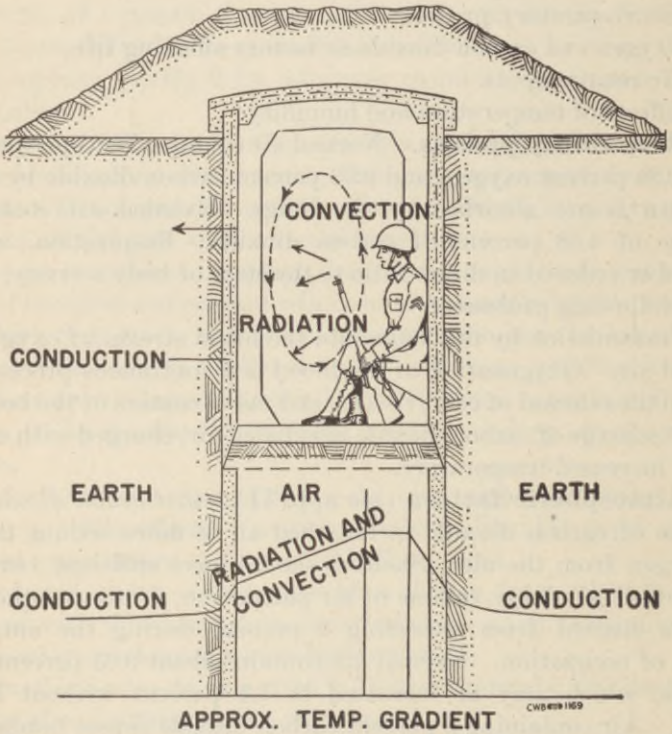

FIGURE 1.—Diagrams showing process of heat dissipation from occupants of underground shelters.

8. Effect of temperature and humidity (see figs. 1, 2, and 3).—*a. General.*—Heat and moisture are generated in the body by the process of respiratory exchange, in which carbon and hydrogen of the animal tissues are combined with oxygen to form carbon dioxide and water. The resultant heat and moisture must be dissipated from the body if the correct body temperature of 98.6° F. is to be maintained. A very slight rise in body temperature is sufficient to produce a condition equivalent to that of fever, while an increase of 1½° maintained for 3 hours is very dangerous.

b. Process of emission.—A man at rest generates each hour about 400 British thermal units of heat, about 0.6 cubic feet of carbon dioxide, and about 1½ ounces of moisture. These quantities will increase with his increasing activity. The heat is lost partly as sensible heat given off directly to the surrounding air by convection and radiation. Part of it is also lost through evaporation of moisture from the skin and lungs, heat furnishing the energy to convert moisture into vapor.

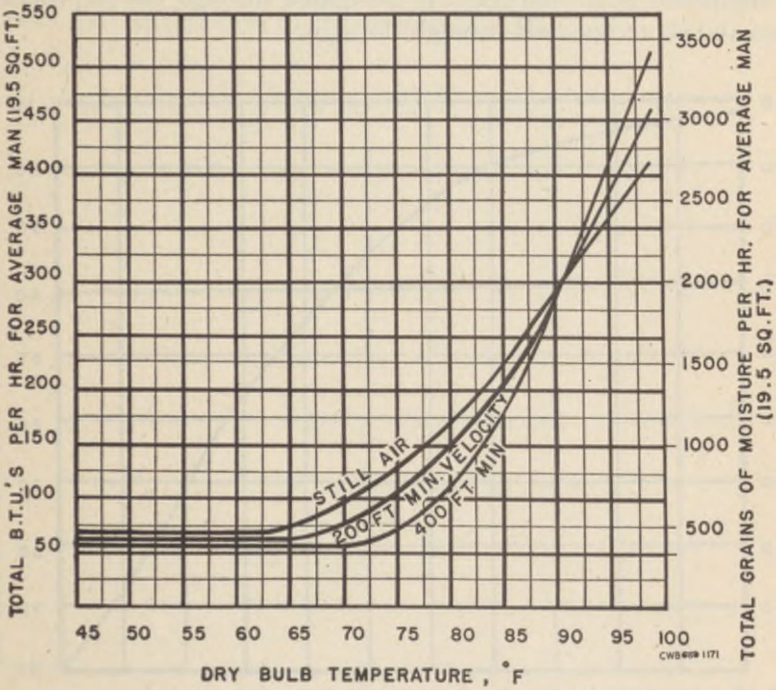

FIGURE 2.—Heat and weight loss from human body by evaporation in still or massing air.

c. Factors governing emission.—While the total emission is relatively constant for a person in a given state of activity, the ratio of sensible heat to latent or moisture heat varies with the temperature of the surrounding air, in that latent heat of evaporation increases with a rise in air temperature. The proportions given in (1), (2), and (3) below for various air temperatures are naturally subject to wide variation with changes in air movement and the rate of ventilation.

(1) At an air temperature of 98° F. practically all body heat is given off by evaporation of moisture, since there is no difference be-

tween the temperature of the air and that of the body to induce radiation.

(2) At an air temperature below 60° F. very little evaporation from the body takes place, moisture coming almost entirely from the lungs. Under such conditions heat dissipated by radiation is at a maximum.

(3) At an air temperature of 70° F. about 77 percent of the total emission takes the form of sensible heat and 23 percent is used to evaporate moisture. About 60 percent of the sensible heat is dissipated by radiation and the balance by convection, while about one-half the latent heat component is dissipated through the respiratory system and about one-half through the skin.

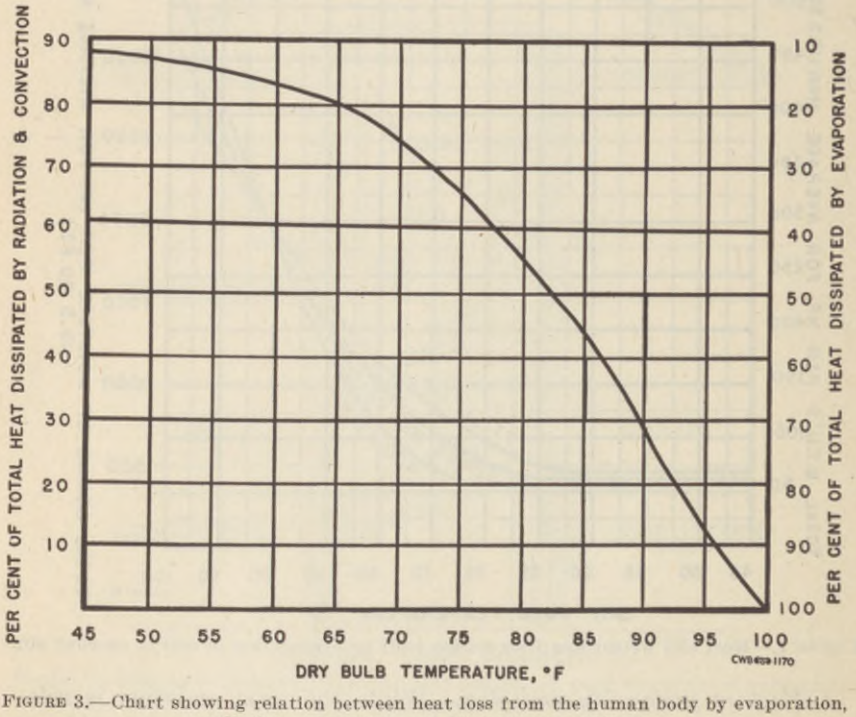

FIGURE 3.—Chart showing relation between heat loss from the human body by evaporation, radiation, convection, and dry heat temperature.

d. Temperature and humidity in shelters.—(1) *Temperature.*—Close packing of men in shelters should be avoided because those in the center would be surrounded by radiating bodies and would not have free access to the bounding surfaces of the room, which ultimately transmit and dissipate all the heat not dealt with by ventilation.

(2) *Humidity.*—Dissipation of body heat can take place only so long as the surrounding air is unsaturated, a condition which cannot be maintained in an occupied unventilated shelter unless the moisture

is extracted. The uncomfortable effect of high humidity is magnified by increased temperature. For example, a temperature of 70° to 75° F. with a relative humidity of 50 to 70 percent is very comfortable, while a temperature of 85° F. and a relative humidity of 90 percent cause acute discomfort, faintness, suffocation, and sense of alarm. A temperature of 98° F. or more, with a relative humidity of 95 to 100 percent, causes a rapid rise in body temperature and is extremely dangerous. The discomfort caused by a combination of high humidity and high temperature can be greatly mitigated by providing a rapid rate of air movement, and for this reason fans in a shelter will greatly improve the comfort even in the absence of ventilation.

CHAPTER 2

SHELTER CONSTRUCTION

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9. Protective structures in general.—No standard procedure can be outlined for the construction of gasproof shelters because such factors as time, location, and availability of materials will necessarily influence the plans for any given structure. However, the following fundamental considerations apply to any shelter project:

a. Accessibility.—Shelters should be as accessible as possible to the normal operating locations of personnel concerned.

b. Accommodations.—Determination should be made in advance of the number of persons normally expected to use the shelter, and accommodations for their comfortable occupancy should be provided accordingly.

c. Ventilation.—Although ventilation with collective protectors (see ch. 3) is desirable for all shelters, it is not essential for those designed to accommodate inactive personnel for short periods. Ventilation must be provided, however, for shelters which are to be occupied by active or inactive personnel who will remain in the shelter for an extended period.

d. Protective features.—If construction time requirements and other factors permit, the shelter should provide protection against both high explosives and chemical agents. This is especially advisable in designing shelters for permanent or semipermanent military establishments, where joint protective measures against explosives and gas can be incorporated in structures designed for full-time occupancy, thus helping to prevent interference with vital functions of administration, supply, communications, etc. All shelters must contain a shelter room proper, at least one air lock entrance, and an emergency exit which may also serve as an alternate entrance. Safety provisions must be made as outlined in the paragraphs below.

e. Location and design.—The influence of terrain, design, and other determining factors are discussed below. Underground shelters are always advisable provided there is no risk of flooding and if an alternate exit can be arranged.

10. Influence of terrain (see figs. 4, 5, and 6.)—*A Natural flow of agents.*—The characteristics of chemical agents used in warfare are pervasiveness and duration. All such agents are heavier than air and may therefore affect an area extending several miles down wind. The concentration decreases rapidly in a vertical direction, however. Unless set in motion by wind or air currents, as described in *b* below, gas tends to flow into gullies and valleys, leaving the tops of hills comparatively free. Normally, therefore, the most logical location for a shelter is at a point higher than the surrounding terrain, preferably in the side of a hill.

b. Air currents.—Terrain features can exert a great effect upon the movement of air currents and of gas clouds carried by them, especially in winds of low velocity. Shelter sites should therefore be selected with reference to terrain features which naturally determine wind paths.

(1) Trenches or ditches extending to the entrance of a shelter may serve to conduct gas toward it in spite of contrary prevailing wind conditions.

(2) Under average conditions a shelter built on the windward side of a hill is much more likely to become contaminated than a shelter situated on the leeward side; however, a shelter constructed on what appears to be the normal leeward side of a hill may actually be on the windward side because of the influence exerted by a terrain feature, such as a valley which forms a cross-corridor.

(3) High hills serve as screens against winds. Safe locations can usually be found on their sides, away from the prevailing direction of the wind.

c. Earth texture.—Careful study should be made of soil conditions before selecting the site for a shelter. Wet, swampy ground is particularly objectionable because mustard gas may be covered with water for long periods and again contaminate the area after the water evaporates. In general, the most suitable types of well-drained, firm soil are found on hillsides. Soft, dry ground will absorb liquid agents and thus reduce the danger of direct physical contact. This type of earth will remain contaminated for some time, however, and will therefore continue to give off vapor as the agent evaporates. Hard ground, on the other hand, retards penetration of liquid agents and the gas is thus exposed in a greater degree to the influence of wind, sun, and rain.

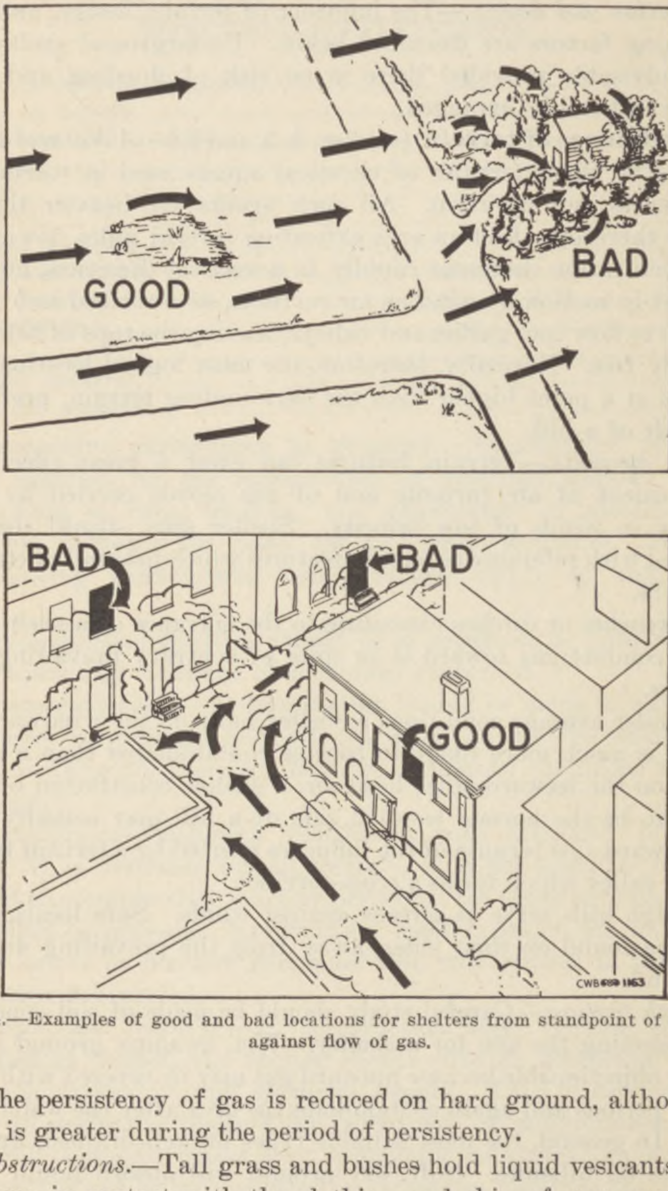

FIGURE 4.—Examples of good and bad locations for shelters from standpoint of protection against flow of gas.

Thus the persistency of gas is reduced on hard ground, although the hazard is greater during the period of persistency.

d. Obstructions.—Tall grass and bushes hold liquid vesicants, which may come in contact with the clothing and skin of men passing by.

Shelters should therefore be located in areas cleared of such vegetation, but where proper overhead cover is provided.

11. Basic designs and materials.—*a. General* (see figs. 7, 8, 9,

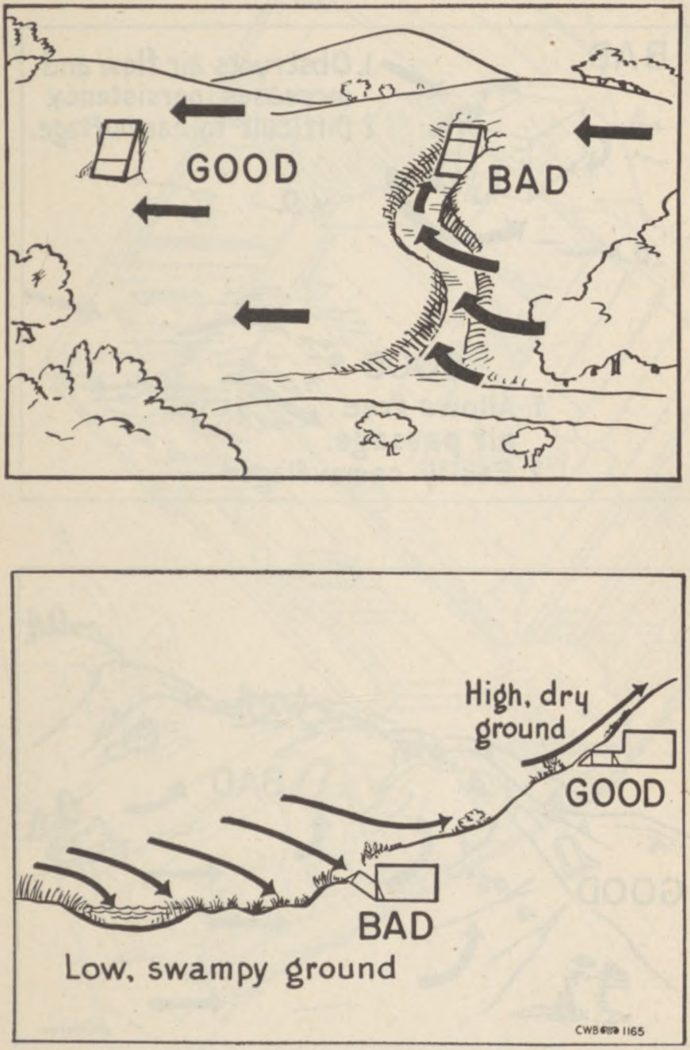

FIGURE 5.—Examples of good and bad terrain conditions affecting location of shelters (camouflage omitted).

and 10).—Construction plans for a gasproof shelter will be determined by considerations discussed in paragraph 8. The final decision on design and materials is made by the unit engineer. Personnel concerned will adapt to their particular problem such information regarding design and materials given in *b* and *c* below as is applicable:

b. Design.—(1) Each situation will present a different problem in providing the required floor space and air volume with the least pos-

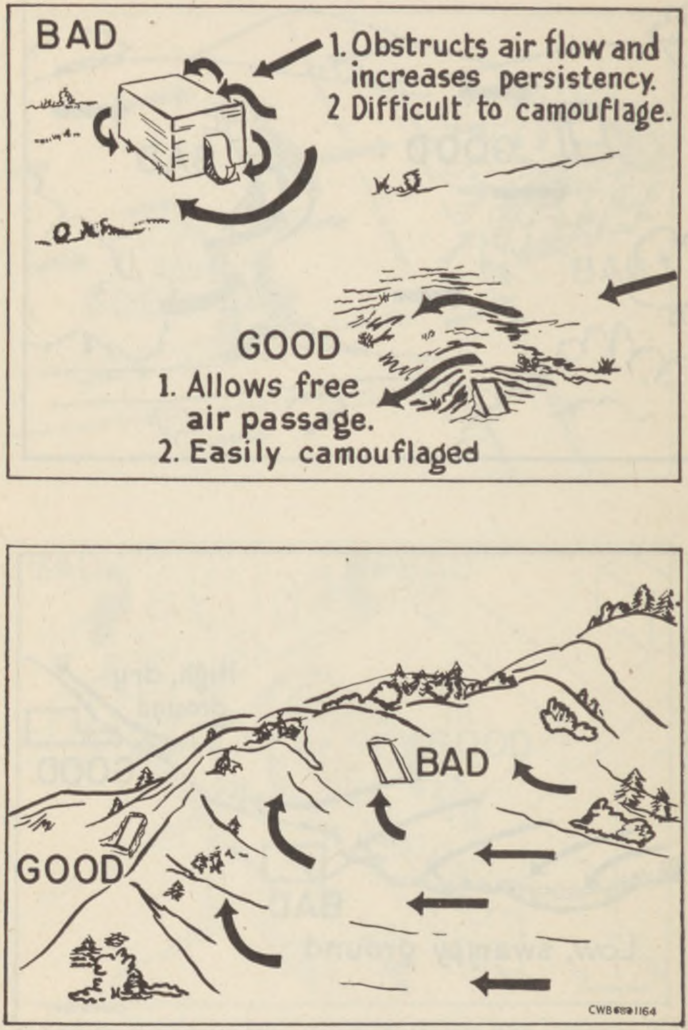

FIGURE 6.—Examples of good and bad terrain influences affecting location of shelters.

sible expenditure of labor and materials. A long rectangle is generally the most satisfactory shape for a shelter. If terrain and other factors permit, the structure should be entirely underground or, at least, the walls and floors should be underground. The amount of

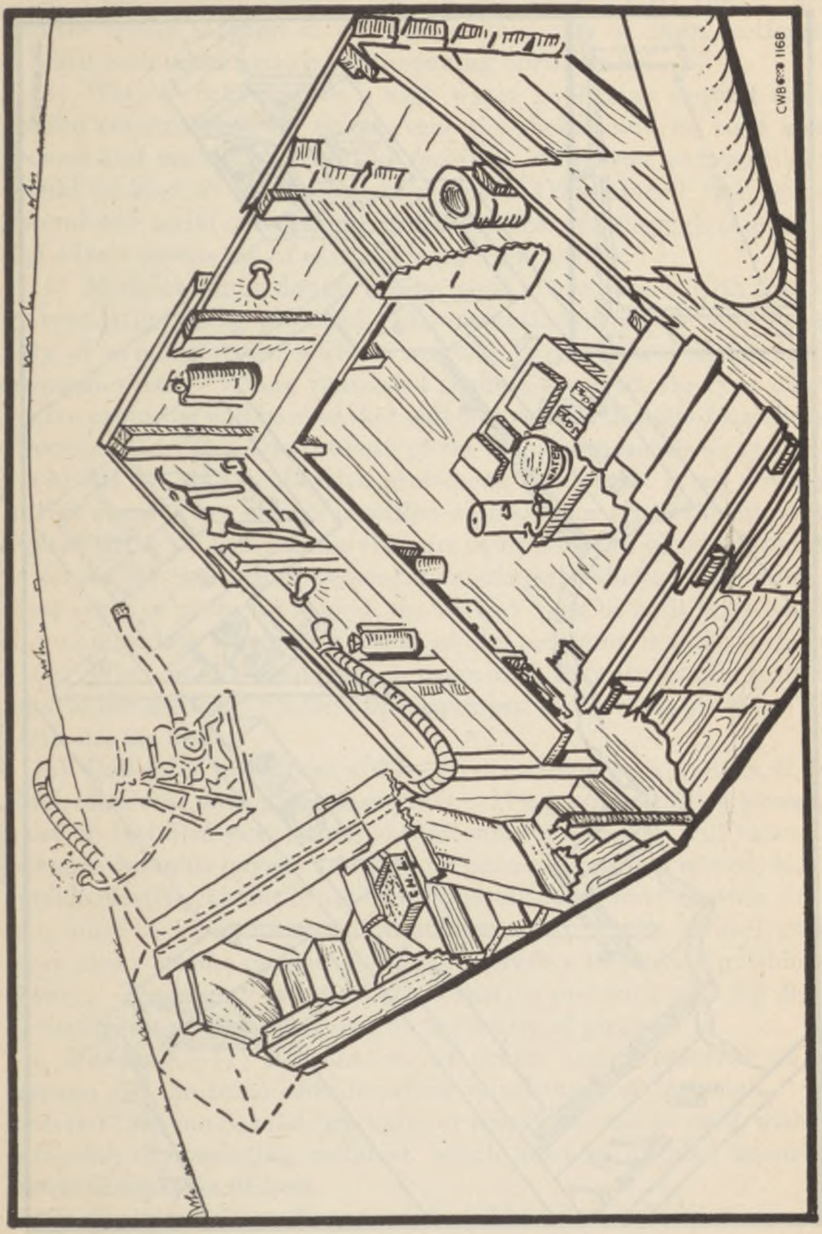

FIGURE 7.—Example of gasproof equipment for underground shelter.

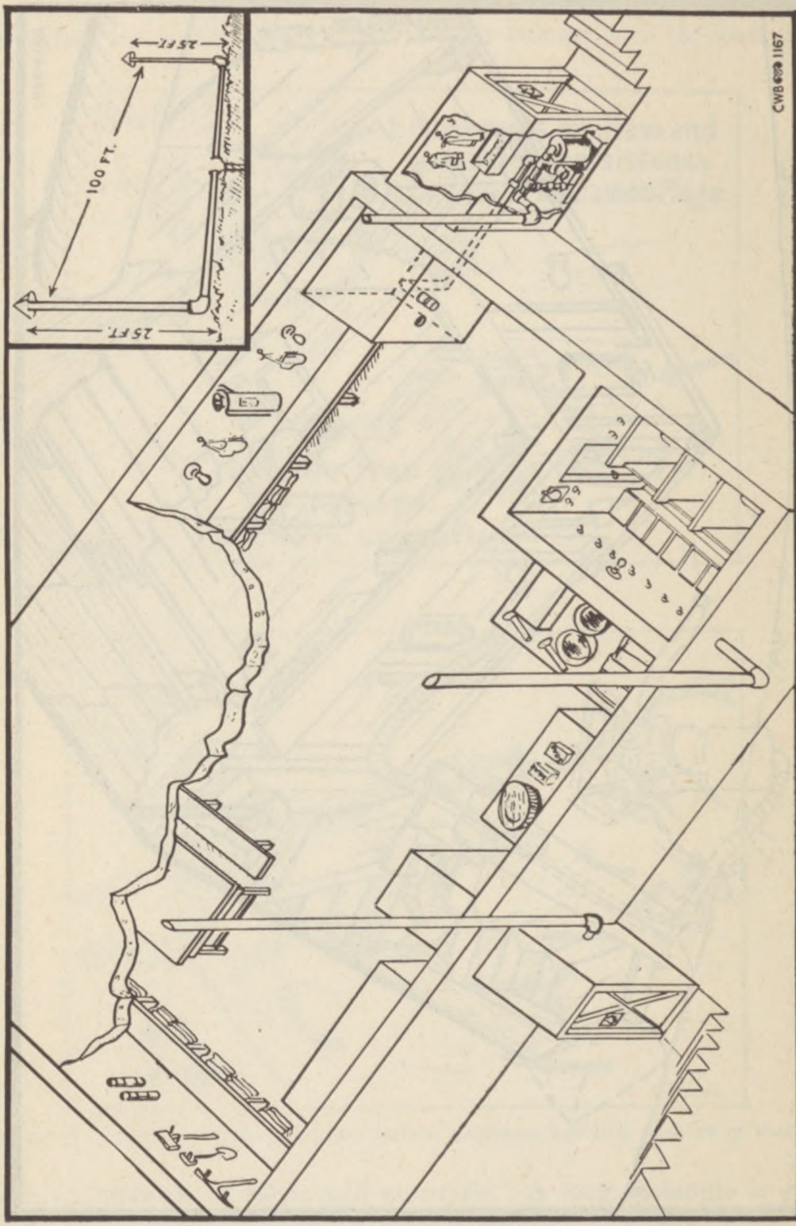

FIGURE 8.—Example of underground ventilated shelter.

protection desired will be an important factor, since deeper shelters will afford more protection against shells and bombs.

(2) Underground shelters may be dug with steps leading down into the refuge through an air lock; or they may be dug into the side of a hill with doors and air locks opening horizontally.

(3) Wet or rocky soil, or a high water level, may prevent underground construction, in which event the shelter will be built above ground and made as airtight as possible. Windows and ventilators should be kept at an absolute minimum. Concealment from enemy ground and aerial observation should be arranged through camouflage and advantageous use of existing terrain conditions.

(4) Modification in design will be made in accordance with the type of ventilation being provided. An unventilated shelter need consist only of a refuge room with an air lock entrance and some type of emergency exit. Where ventilated shelters are used, the type of collective protector will be used that will best suit the design of the shelter. Provision must be made for such of the following factors as apply:

(*a*) MI or MIA1 collective protectors, the largest types described in this manual, are always installed with part or all of the apparatus located in the air lock because they are equipped with special apparatus to aerate the clothing of personnel entering the shelter. If either of these types of protector is used, the air lock must be built large enough to accommodate whatever portion of the protector is to be installed.

(*b*) When smaller field protectors are used, they are usually installed outside the shelter. Shelters thus equipped need not be provided with extra size air locks.

(*c*) Collective protectors will be driven with electric motors, if possible, otherwise with gasoline engines. If a gasoline engine is used, it must be installed outside the shelter, since the engine will otherwise consume valuable oxygen and give off poisonous carbon monoxide. If outside electric current is used for an electrically driven motor, provision must be made for an alternate source of power. Diesel generators also consume oxygen and must therefore be located outside the shelter. Thus the location of the collective protector and the design of the shelter may be influenced by the source of power.

c. Materials.—(1) Elimination of drafts and prevention of gas seepage are the basic considerations in selection of materials. Any material that can be made gastight, or nearly so, may be used, with the exception of insulating material, which must be avoided because it resists dissipation of heat.

(2) Shelters built underground should be separated from the outside atmosphere by walls or earth covering at least 6 feet thick to minimize the likelihood of persistent agents filtering into the room. For added

safety and comfort the shelter should be lined with concrete if it is available. Protection against gas infiltration in shelters located above ground may be provided by building the walls of brick at least 9 inches thick, plastered on the inside. They may also be built of concrete, 5 inches thick, or of lumber with all joints and cracks sealed.

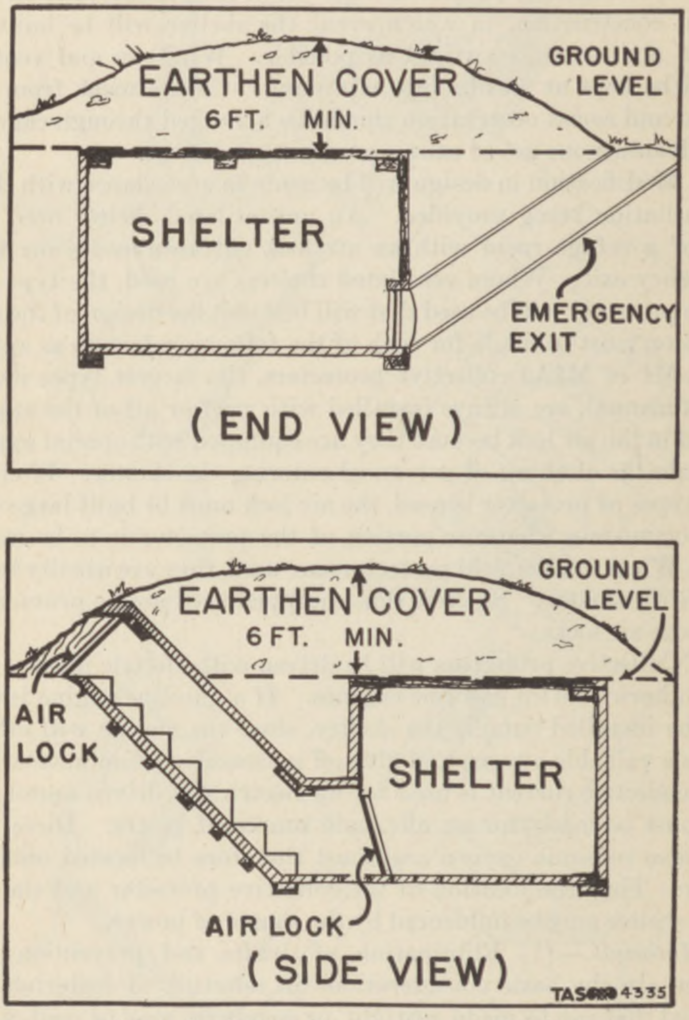

FIGURE 9.—Sections through underground shelter.

(3) If possible, the floors should be of jointless construction. Floors made of wood should have all cracks tightly calked to prevent gas seepage. A thick coating of varnish over the floor will make it even more gastight. Periodic inspections should be made of the floor-

ing to detect cracks, or openings caused by rats or mice. All such holes should be repaired immediately.

(4) Pipes and other conduits leading to the outside should be calked at the point of exit. They can be made permanently airtight with putty cement or bituminous mastic, followed by a heavy coating of varnish.

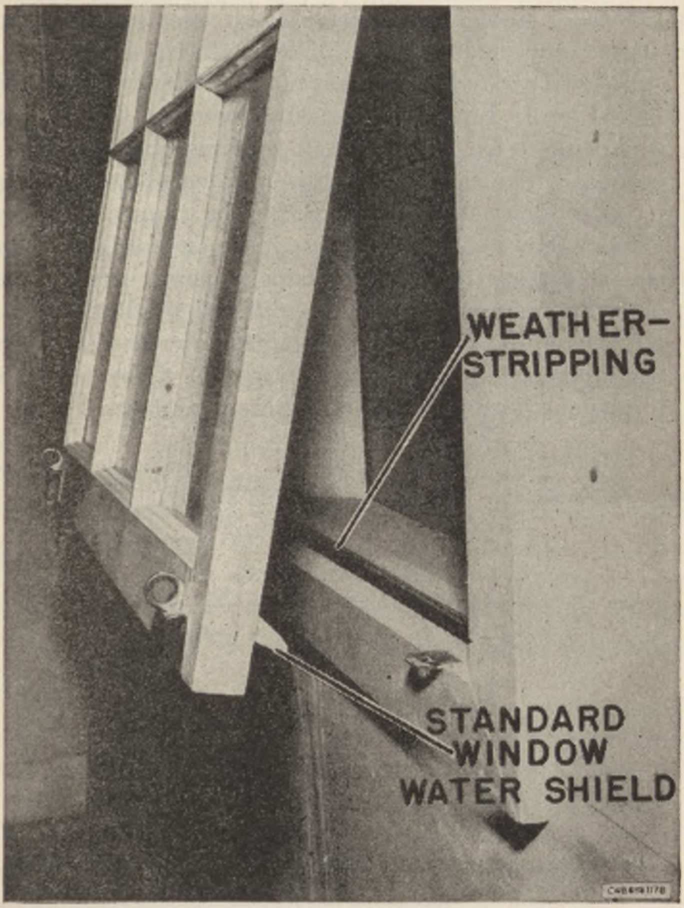

FIGURE 10.—Construction of gastight window.

(5) In addition to the original construction precautions to insure airtightness, walls and ceilings should be further strengthened by plastering or calking. One or two layers of paper should be pasted to the wall and varnished. Concrete walls of an above-ground shelter should be cement washed on the outside.

(6) If windows are necessary for reconnaissance purposes, they should be sealed shut, calked, and provided with steel shutters or sandbags. Curtains should be provided to keep the shelter gastight in case the windows are broken. Any windows which are to be opened periodically for ventilation purposes should be weather-stripped. One method of weather-stripping is shown in figure 10.

12. Capacity.—The number of persons who can safely occupy a shelter depends upon their degree of activity, the provisions made for ventilation, and the limitations of feasibility in size.

a. Unventilated shelters.—Refuges not provided with collective protectors should be used only for personnel who are to remain inactive during occupancy. An inactive man requires about 1 cubic foot of air per minute. The capacity of unventilated shelters is limited in part by the inpracticability of erecting or improvising unusually large shelters. It is also limited by the undesirability of grouping more than 50 persons in a single room during a gas alarm. With 50 persons as the maximum capacity within the limits of both desirability and feasibility, the following table indicates air requirements for various numbers up to and including that figure, and gives suggested dimensions for unventilated shelters in each case:

Number of occupants	3-hour air requirements (rate of 1 cubic foot per occupant per minute)	Suggested dimensions (feet)		
		Length	Width	Height
1	180	7	4	7
5	900	14	9	7
10	1, 800	18	13	8
15	2, 700	22	15	9
20	3, 600	26	16	9
25	4, 500	28	18	9
30	5, 400	30	19	10
35	6, 300	32	20	10
40	7, 200	35	21	10
45	8, 100	35	22	11
50	9, 000	35	24	11

b. Ventilated shelters.—Refuges provided with collective protectors are designed for active personnel. Their capacity is governed chiefly by the size of the protector, since each active occupant requires about 5 cubic feet of air per minute. A secondary but highly important factor is the undesirability of overcrowding in a shelter where personnel are working. As in the case of unventilated shelters, the maximum desirable capacity is 50. The air capacity of each type of collective protector is stated in chapter 3. The type of protectors to be used must be taken into consideration in the planning of a ventilated shelter.

13. Entrances (see figs. 11, 12, 13, 14, and 15).—*a. General.*—Wherever possible the entrance to a gasproof shelter should be a walled-in passageway extending several feet beyond the walls of the shelter proper, both inside and outside, except where steel doors are used; both ends of the passageway should be slanted to receive door frames for the air lock if gasproof curtains are used. The outer door should slant outward, and the inner door inward, to facilitate the use of gasproof curtains. Where the shelter entrance is a simple horizontal passageway the doors are placed from 6 to 9 feet apart. If the entrance is a stairway, one door is placed at the head of the stairs and the other at the foot, provided there is a horizontal passageway for a few feet at the bottom of the stairs. If the stairway leads directly into the shelter room, however, the two doors are placed at each end of the stairway, both slanting outward. In the case of a stairway leading to a first aid station, space between the doors must be sufficient to bring a stretcher inside without opening both doors at once. Modifications in the spacing and arrangement of air lock doors may be made as required, provided the general principles of construction outlined above are preserved. Sufficient space must always be provided to accommodate any portion of a collective protector to be installed in the air lock, as outlined in paragraph 11.

b. Functioning.—The passageway should be designed to prevent a man passing through the air lock from operating both doors at once, thus making it impossible for direct drafts to carry gas-contaminated air into the shelter.

c. Steel doors.—These are best suited for permanent shelters. They should be made gas tight by compression on rubber seatings. Bulkhead doors may be as thick and strong as necessary for the degree of protection desired against bombs, shells, or blasts.

d. Curtain doors.—(1) An air lock with this type of door is usually constructed with MI gasproof curtains, one being used for the outer door and another for the inner door. If the outer door frame of an air lock projects out from the entranceway, the frame must be constructed so that the curtain will be about 4 inches wider and 4 inches longer than the frame. If the air lock is built back into the entranceway, the blanket must obviously be the same width as the frame.

(2) The MI gasproof curtain, which is 7 feet long and 35 inches wide, is made of two thicknesses of fabric. The inside fabric is a cotton blanket, while the outer fabric is impermeable cotton cloth,

type 1. Wooden strips are nailed horizontally to the front and back of the curtain, holding it in place when installed. At the bottom

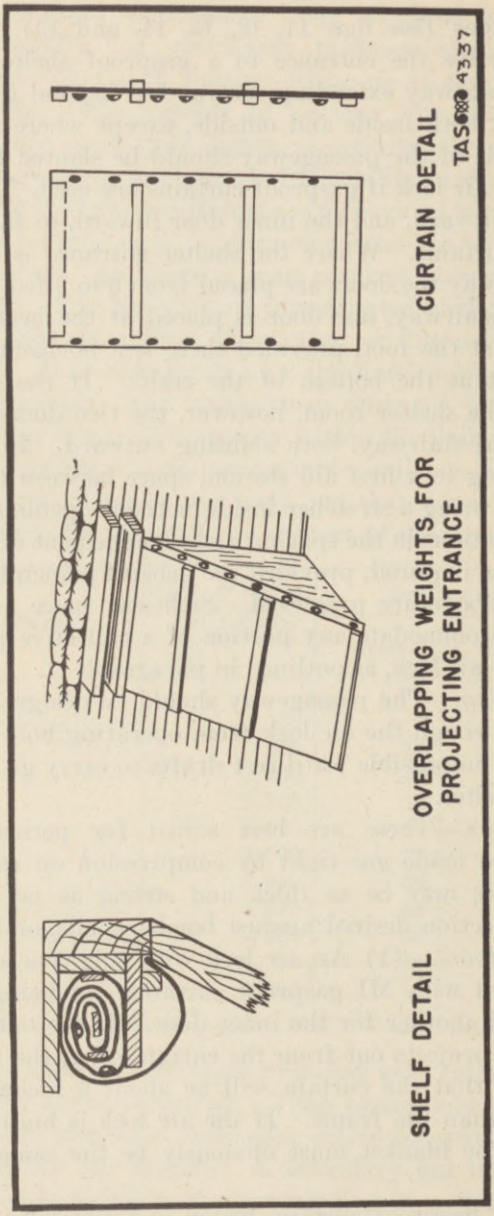

FIGURE 11.—Details of gasproof curtain.

and 11 inches from the top, extra heavy strips are used on the outside surface, the top strip ¾ by 2 by 35 inches in size, and the bottom strip

¾ by 2 by 32 inches. Twenty-six inches below the top strip and 21 inches above the bottom strip are two pairs of smaller wooden strips,

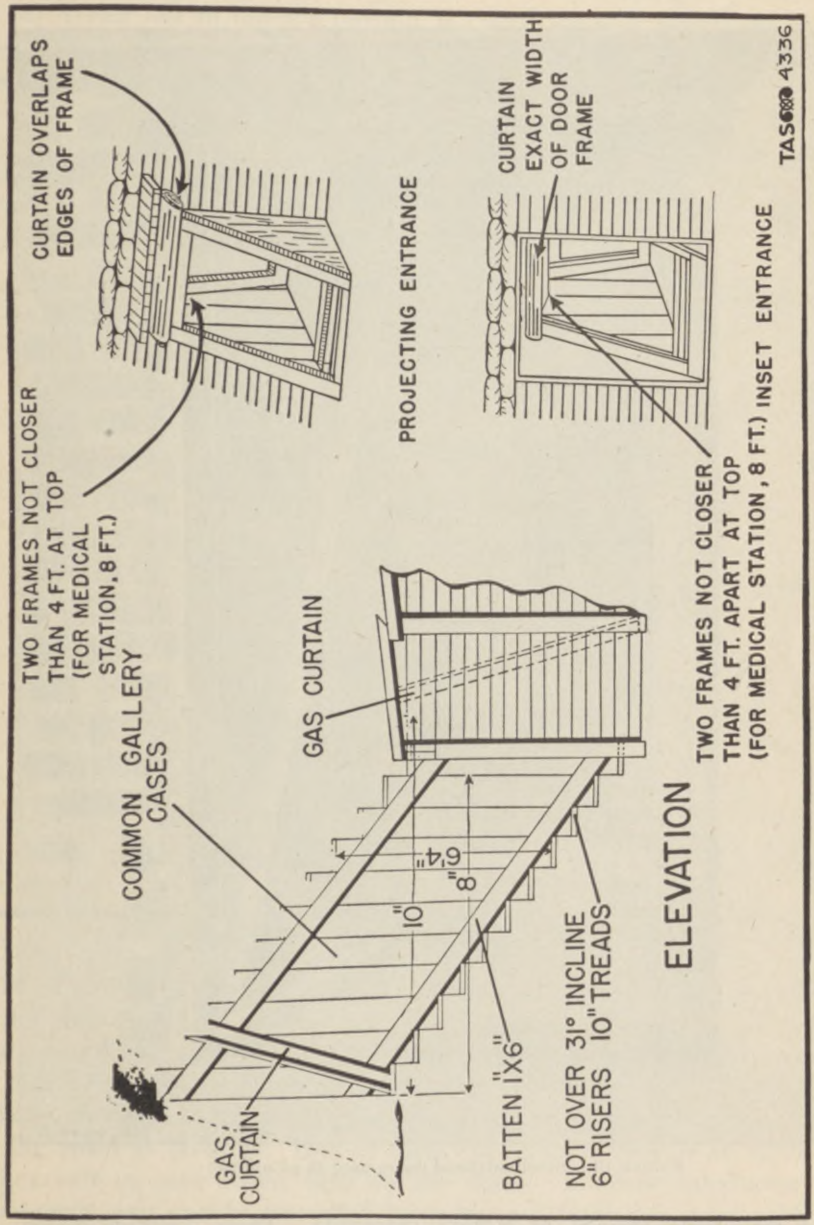

FIGURE 12.—Methods of installing gasproof curtains.

nailed to the curtain in pairs, one to the outer and the other to the back side. The front strip in each case measures ¼ by 1 by 32 inches, and the back strip ¼ by 1 by 26 inches. On the sides of the curtain, ½ inch from the edge and beginning 4 inches from the bottom, are

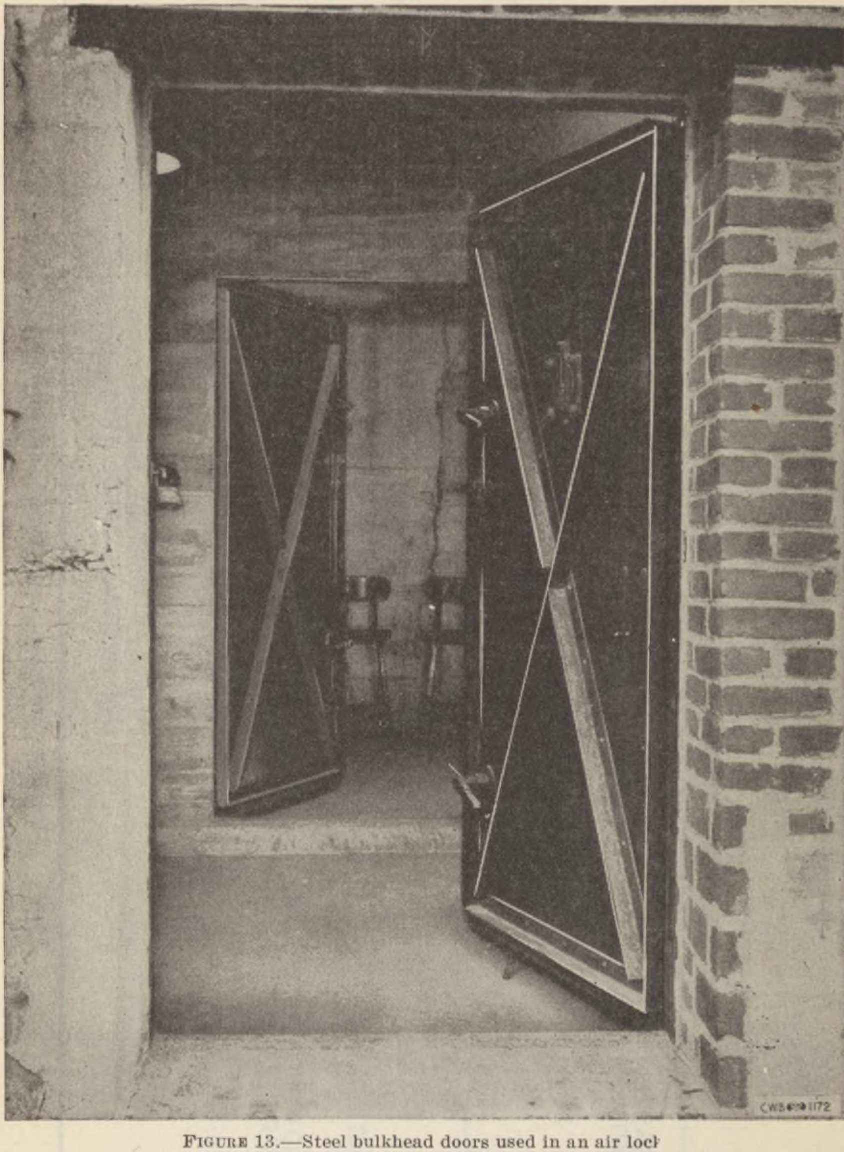

FIGURE 13.—Steel bulkhead doors used in an air lock

brass grommets spaced at 8-inch intervals. These provide holes, ½ inch in diameter, for attaching weights to hold the curtain in place. The curtains are packed two to a wooden box, the packed box having a displacement of 1.35 cubic feet and weighing 29 pounds.

(3) When not in use the curtain is rolled up and placed on the shelf above the top of the door frame. If necessary, a metal cover may be nailed over the shelf to protect the curtain from sun and rain.

(4) To enter a shelter through an air lock equipped with curtains, the curtain on the outer door frame is opened on the leeward side just far enough to permit entrance. The man entering then closes the outer curtain behind him before opening the inner.

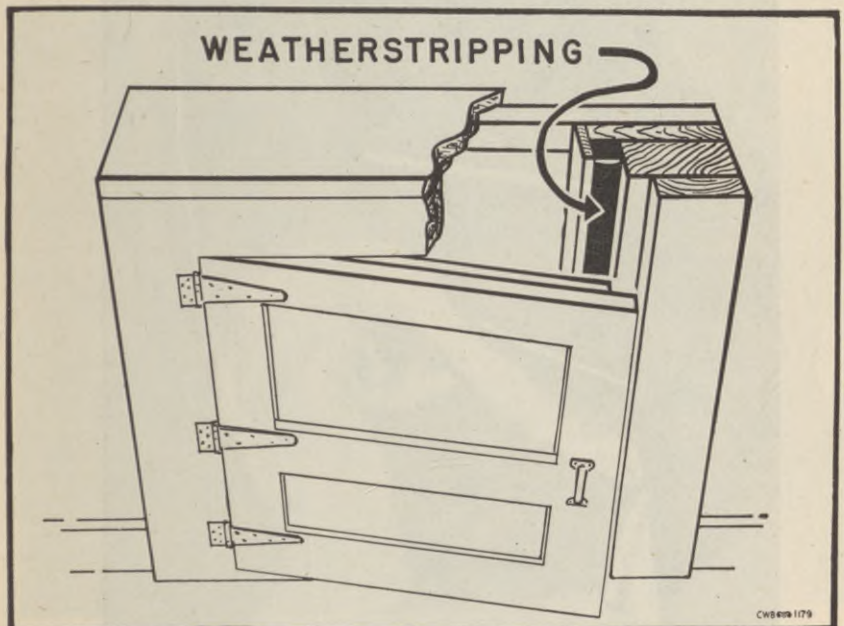

FIGURE 14.—Construction of wooden door used in air lock, showing method of gasproofing.

14. Exits.—All shelters should have one or more emergency exits to be used if the main entrance should become obstructed. These exits should be gastight and capable of easy opening from the inside. It may be desirable to have two entrances, especially when designing a large shelter, in which case the two passageways should be located as far apart as possible. One of them can thus be used as an emergency exit in case debris falls on the other. Another satisfactory emergency exit can be provided by using a 3-foot pipe, preferably of steel, sealed tightly at both the inner and outer ends but capable of being unsealed in an emergency. The pipe may slant upward from the interior to the outside, but the angle must not be so steep as to prevent a man from climbing up through it. The exit should be well camouflaged.

15. Ventilation methods.—*a. General.*—All shelters must be aired after use in order to remove carbon dioxide, unpleasant odors, heated air, moisture, and any gas which may have seeped in or been brought in on the clothes and shoes of men occupying the refuge. Airing should not be attempted until the outside air is free of gas,

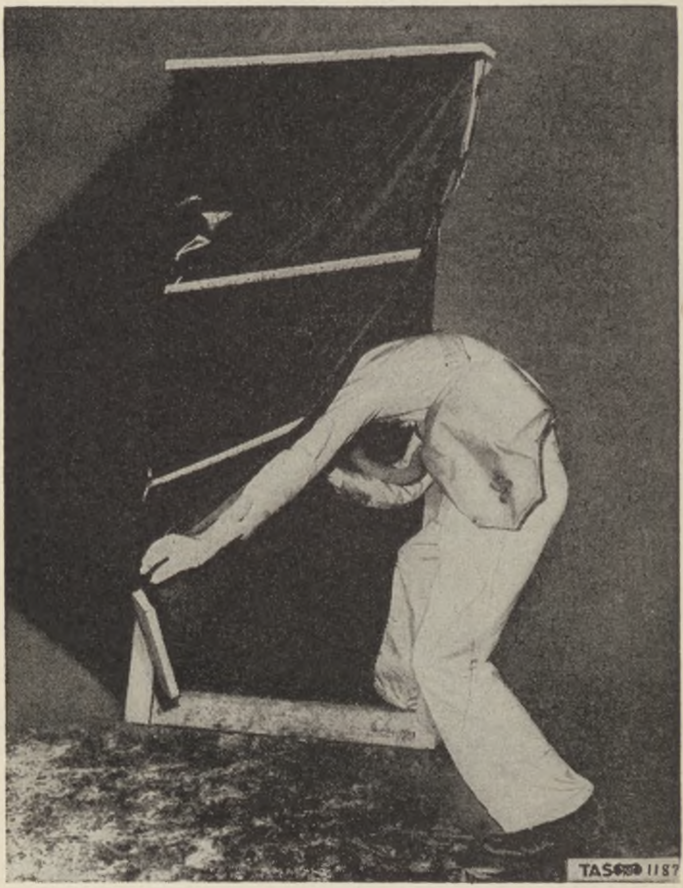

FIGURE 15.—Correct method of entering air lock equipped with gasproof curtains.

however. Daily ventilation, even though only partial, is recommended to keep the shelter ready for immediate occupancy. Buildings sprayed or splashed with liquid vesicants must be decontaminated, and in some cases may have to be abandoned or destroyed, since most building materials will absorb liquid vesicants and give them off as vapor later. In such cases simple ventilation cannot be relied upon to make the shelters safe for future occupancy.

b. Ventilated shelters.—Refuges equipped with collective protectors receive a steady supply of purified air during occupancy. Provision must also be made for recirculation of the air to the outside, however, to avoid the creation of excessive air pressure. This is accomplished by means of two exhaust flaps, one leading from the shelter proper to the air lock, and the other from the air lock to the outside. A standardized exhaust flap now in use (see fig. 16) consists of a flat circular brass plate fitting against a circular brass aperture, the flap swinging outward when air pressure becomes excessive. A manometer should be installed to indicate the air pressure inside the shelter. A manometer consists of a glass U-tube about 12 inches long, half filled with water, with one end open to the air inside the shelter and the other connected to a rubber tube leading through the wall and open to the outside air. (See fig. 17.) After occupancy, a shelter equipped with the MI or MIA1 protector can be aired by opening all doors and running the blower of the collective protector with the air bypassed around the canister. Ventilated shelters using any other type of collective protector must be aired after occupancy as indicated below for unventilated shelters.

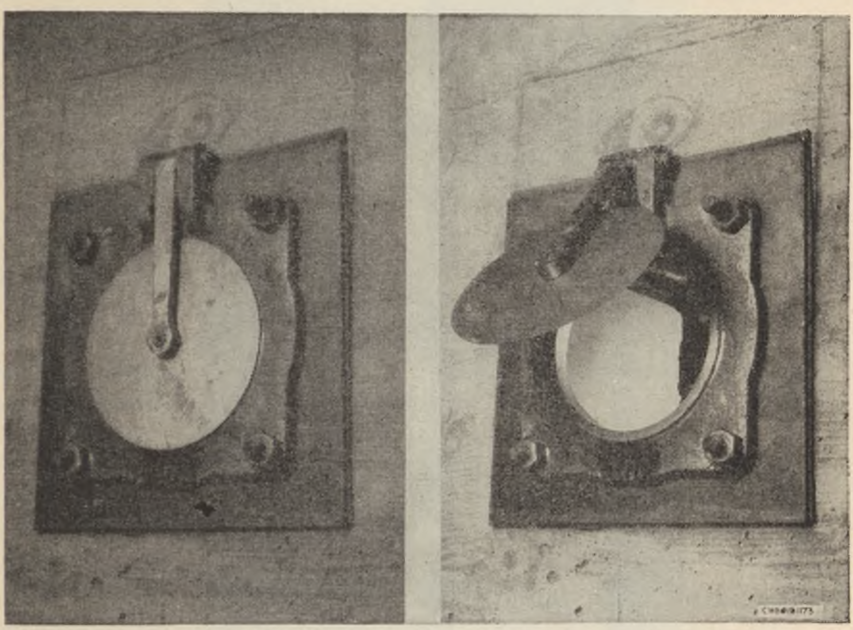

FIGURE 16.—Exhaust flap valve, closed and opened.

c. Unventilated shelters.—(1) Underground unventilated shelters can be aired after use by opening all doors and building a small fire in the center of the room to create a draft. If the shelter has a long passageway leading down to it, the fire should be placed in the passageway, about one-third of the distance from the bottom.

(2) Shelters above ground can be ventilated after occupancy by opening windows, doors, and other apertures, thus permitting air to

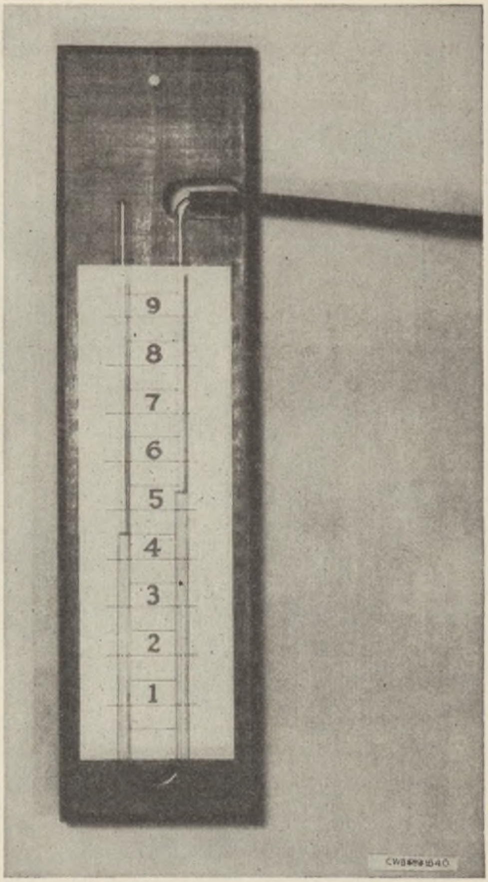

FIGURE 17.—Manometer.

circulate through the building. Fans may be used to hasten the removal of foul air.

16. Humidity and temperature control.—*a. General.*—(1) Both heat and humidity increase when a shelter is used. The temperature increase is caused by heat given off by the occupants' bodies. Increased moisture is caused by emission of moisture by the occupants, moisture in air brought in for ventilation (in ventilated shelters), and moisture introduced by capillary action through the walls.

(2) Only in the most unusual cases will any effort be made to control temperature and humidity. If unventilated shelters are used, the occupants should be inactive, and although the temperature and humidity will both become very high, they will not be intolerable. If the occupants are to be active, or if the shelter is to be used for an extended period, it must be ventilated. Under such circumstances the constant introduction of purified air through the collective protector will prevent intolerable increases in temperature and humidity. For physiological aspects of heat and temperature control, see paragraph 8.

b. Construction factors.—(1) Underground shelters will become humid more quickly than those above ground because of capillary action through the walls and the low temperature caused by the thermal capacity of the walls. This condition may be remedied to some degree by proper construction.

(2) Waterproof concrete will decrease the amount of moisture admitted through underground walls. An unbroken coating of asphaltic material on the outside of the walls is also helpful; but it is difficult to prevent breaks in such a coating.

(3) Double walls and ceilings with a dead-air space between them will likewise decrease the transmission of moisture. The inner wall may be constructed of a thin impervious material and coated with asphaltic material on the outside surface.

(4) Ground around an underground shelter may be drained to a level as low or lower than the floor of the shelter, thus reducing hydrostatic pressure. This can be accomplished by properly placed underground drain tiles or, better yet, by a backfill of loose rock or other porous, loose material.

(5) In shelters designed for special purposes, such as the protection of sensitive equipment, humidity may be controlled and high temperatures avoided through use of commercial air conditioning equipment based upon refrigeration, adsorption, or absorption. If an increased temperature is necessary, it may be obtained by electric heating or any other means which does not consume oxygen or give off noxious fumes. Hot water or steam heating should not be used, however, because of the danger that gas may seep in if pipes are broken by an exploding shell during a gas attack, and because of the risk of damage by steam or hot water.

17. Auxiliary comfort facilities.—*a. Seats.*—A sufficient number of seats should be provided to accommodate all personnel for whom the shelter is intended. Long benches are usually advisable because they require less space, although any other available seating facilities may be used. Seats should be arranged along the walls of the shelter to conserve room and to facilitate more efficient transfer of heat from the occupants' bodies through the walls.

b. Lighting.—Electric lights should be installed if power is available, but in any case the shelter must be equipped with battery-operated lights for emergency use. The lights must be kept dim to prevent excessive heat generation. Candles and oil-burning lamps must not be used because they consume oxygen.

c. Toilets.—Facilities should be provided at the rate of one toilet for each 20 men. If water toilets are used, chemical toilets should be provided in reserve in case the water supply fails. Toilets should not have ventilation pipes. Chemicals used in toilets should be of a germicidal rather than of a destructive nature. The toilets should be placed in a rear corner of the shelter, properly screened. If the refuge is ventilated and of permanent construction, the toilets may be placed in a small room, in which case excess air from the shelter may be forced into this room and out through the wall by means of exhaust valves.

d. Water.—Even if piped water is available, it should be supplemented by drinking water stored in the shelter and changed daily to keep it fresh. At least 1 quart per man should be provided in covered containers.

18. Safety facilities.—The following articles should be provided for purposes of safety:

a. A box containing dry chloride of lime and earth mix (2 to 3 by volume), placed in the air lock for decontamination of shoes.

b. Repair materials, such as extra gasproof curtains, putty, or other material for repairing holes in walls or ceiling, and the necessary tools to use such equipment.

c. Soap, water, and towels for washing.

d. Tools for digging out in case entrances and exits are obstructed by bombs or shell. These would include such tools as a crowbar, shovel, pick, and ax.

e. Fire-fighting equipment, such as sand, water, or foam extinguisher. Carbon tetrachloride and soda acid extinguishers must not be used.

f. Reserve gas masks and protective clothing not in use should be kept in shelters to provide replacements for equipment which may become contaminated.

g. Decontamination material.

h. Printed signs, to be hung outside the shelter giving its capacity and instructions for the use of air locks when entering.

i. Manometer, to show air pressure (needed only in shelters equipped with collective protectors).

j. Reserve canister for the collective protector.

k. If available, the shelter should also be provided with a large first aid kit, a vapor detector kit, folding Army cot, thermometer, humidity indicator, blankets, and miscellaneous suits of coveralls.

19. Testing.—Thorough testing of the shelter to make certain that it is gasproof is especially important in the case of unventilated refuges. Such tests can be made with CN tear pots and smoke pots.

a. With smoke.—The smoke test should be made when wind disturbances are at a minimum. All entrances and exits must be closed and a fire started within the shelter. While the fire is burning, inspecting personnel will remain outside the shelter and watch for smoke to seep out. If any smoke is discovered, the source of escape must be recorded and steps taken to correct it. After the test is completed the shelter will be aired thoroughly.

b. With CN tear pot.—(1) A tear pot test may be made in conjunction with a gas drill, in which personnel will enter the shelter wearing masks after a tear pot has been fired in the immediate vicinity. A gas sentry will be posted outside the shelter to supervise the orderly passage of personnel through the air lock. Special care must be taken to avoid having both doors of the air lock opened at once. The shelter should be occupied for as long a period as possible, preferably longer than the normal period of occupancy during an actual gas alarm, and observations should be made concerning the reaction of personnel. The emergency exit should be tested at the end of drill.

(2) In the test outlined above, clothing of personnel will naturally become slightly contaminated with CN. Since fumes will thus be admitted to the shelter (this will be minimized if the shelter has a collective protector with an aerating blast) the test will not provide an accurate estimate of the shelter's gasproof qualities. Therefore, another test should be made by firing CN tear pots outside the shelter after it has been occupied.

20. Improvised shelters (see fig. 18).—*a. General.*—(1) If a shortage of time, labor, materials, or other facilities prohibits construction of a gasproof shelter as described in this manual, it is usually possible to improvise a refuge by converting a portion of an existing building. This procedure may be highly desirable as a simple but effective provision for the safety of personnel regularly occupying a given structure, although improvisations of this type will usually provide far less protection against explosives than will specially designed underground shelters.

(2) Any building which is well constructed, or any part of such a building, can usually be made gastight. In addition, to provide pro-

tection against explosives, special attention should be given to bombproofing considerations discussed in TM 5–305 (when published).

(3) Dugouts may be converted into effective shelters, provided they can be made gastight and fitted with an air lock. Dugouts, however,

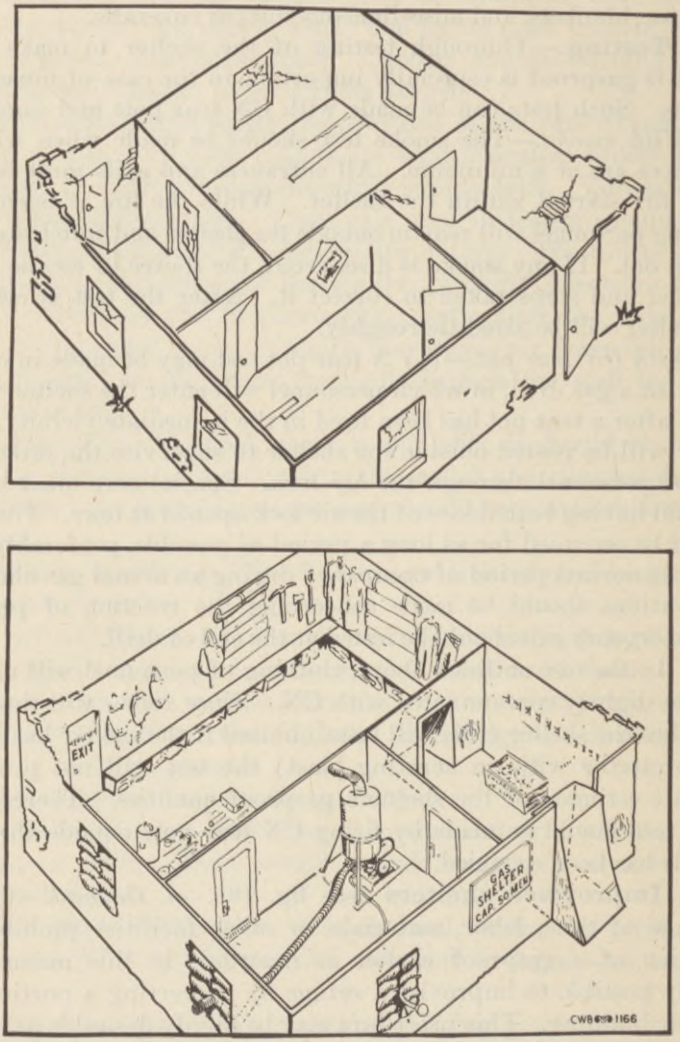

FIGURE 18.—Showing method of improvising shelter within an existing structure.

are usually located in low areas or are dug in lower than the surrounding terrain. They thus attract free-flowing toxic agents.

b. Space requirements.—Enough space should be provided in the improvised shelter to insure sufficient cubic footage of air for personnel concerned, unless a collective protector is provided to purify air brought in from the outside. In the latter case the governing factor is the capacity of the collective protector rather than the cubic footage of the shelter. For air requirements of personnel in ventilated and unventilated shelters, see paragraph 12. Where necessary, two or more rooms in an existing building may be converted into a single gasproof shelter by removing the walls.

c. Preparation of shelter.—(1) All calking and repairs should be undertaken with the object of making them resist air pressure changes which might occur when explosions take place in the immediate vicinity.

(2) Improvised shelters, like those newly constructed, must be provided with air locks. If the building is so designed that a straight air lock passageway is not possible, the lock can be L-shaped, with one door at either end. This method of construction may be necessary in the case of air locks leading from a hallway into a shelter which has been improvised in an adjoining room. If the shelter is to be used as a dressing station, the L-shaped passageway must be wide enough to accommodate a stretcher.

(*a*) If an MI or MIA1 collective protector is to be used, the air blast will be located in the air lock for purposes of aerating the clothing of personnel entering the shelter. Thus the air lock must be made big enough to accommodate the air blast.

(*b*) If gasproof curtains are not available for the two ends of the passageway, woolen blankets may be used provided they are kept wet. Additional protection may be obtained by having the blankets impregnated according to approved methods.

(*c*) Under certain circumstances the erection of a special air lock passageway may be obviated by adaption of existing facilities, such as a smaller room leading from the outside into the shelter room. In such cases the regular doors must be removed and replaced with slanting air lock door frames equipped with gasproof curtains; or slanting air lock door frames and curtains may be erected to supplement the regular doors. Any regular doors incorporated in the shelter plan must be made as airtight as possible by plugging keyholes, calking holes or splits in the wood, and lining the frames with felt or sponge rubber.

(3) Thorough reinforcement should be made throughout the building. The ceiling or the roof over that portion being used for the shelter must be reinforced, if necessary, to make it strong enough to support debris.

(4) All windows in the shelter room should be removed, if possible, and the openings bricked or boarded up. Sandbags may also be used

in connection with the boarding procedure, but do not in themselves provide sufficient protection against gas. If it is impractical to remove windows they should be tightly calked and provided with shutters. Gasproof curtains should be provided to cover any windows that may be broken during the gas attack.

(5) The floor covering, if any, should be taken up. All cracks and holes in the floor will be repaired and tightly calked with paper pulp, putty, or other available material. The floor covering will then be replaced.

(6) If the room contains a fireplace it must be blocked off by stopping up the chimney and calking any cracks which may exist around the hearth.

(7) Special attention should be given to walls. All cracks must be stopped. Cracks too small to be calked with paper pulp or putty may be closed with a mixture of plaster of paris and water. Similar treatment should be given to the ceiling.

(8) Ventilators must be filled with paper pulp and plaster of paris. Any waste pipes or overflow pipes leading to the outside should be plugged or fitted with "S" traps having a liquid seal.

21. Shelters for supplies.—*a. General.*—Chemical agents may damage supplies which are not stored within shelters, both as a result of the original contamination and through acids formed by certain chemical agents upon hydrolysis with water. Moreover, supplies contaminated with liquid vesicants are dangerous to personnel handling them. For these reasons it is highly advisable to protect such supplies as arms, ammunition, food, water, and clothing.

b. Shelter methods.—(1) In some cases supplies may be kept in airtight impervious containers, or they may be placed under impervious coverings.

(2) In other cases it will be safer and more convenient to provide gasproof shelters. Unventilated refuges with air locks will usually provide sufficient protection. Such shelters should be ventilated after a gas attack, as described in paragraph 15.

(3) Certain supplies especially susceptible to damage from moisture cannot be kept in unventilated underground shelters because of the high humidity. Such supplies should be kept in shelters built above ground, or in underground shelters equipped with collective protectors. Where unusually sensitive instruments or materials are involved, additional protection may be provided by installing dehumidification equipment.

(4) Because of the moisture given off by personnel, separate shelters must be provided for men and for supplies affected by moisture.

CHAPTER 3

AIR PURIFICATION EQUIPMENT

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SECTION I

GENERAL

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Advantages and disadvantages	24
Tests	25

22. Description.—All collective protectors consist generally of air intake and air purification equipment. They fall generally into three classifications:

a. Large installed protectors MI and MIA1.—These protectors, generally of the same construction, are the largest types manufactured. They are designed for use in large shelters which require a considerable quantity of air, and are so heavy as to be unsuitable for use as portable protectors. In addition to providing a stream of purified air for the shelter, they are equipped with an air blast apparatus for aerating the clothing of personnel entering the air lock en route to the shelter. These protectors are usually operated with an electric motor, using current from the outside or from a special auxiliary power plant.

b. Large field protectors M2 and M2A1.—These protectors are somewhat smaller than the MI and MIA1 protectors, and are light enough to be semiportable. They have no air blast arrangement, but their capacity is the same as that of the MI and MIA1 protectors. The only difference between the M2 and M2A1 is that the former uses a gasoline engine and the latter an electric motor.

c. Small field protector M3.—This is the smallest type of collective protector, being designed for small installations to be occupied by a limited number of men.

d. Installation.—All collective protectors must be installed and operated under the supervision of an officer trained in this function.

23. Use.—Collective protectors are provided for the purpose of supplying gasproof shelters with fresh air. Air is drawn in from the outside atmosphere, purified in a canister, and then delivered to the shelter room. The three general types described above provide a sufficiently wide range of capacities to accommodate shelter projects of any given size. Where necessary, more than one protector may be installed. If collective protector facilities fail to function, the shelter should be used in the same manner as an unventilated refuge and its occupancy restricted accordingly.

24. Advantages and disadvantages.—*a. Advantages.*—(1) Mechanical ventilation makes it possible to increase the number of people accommodated within a shelter, and enables them to remain for a longer period of time. This reduces the size of the target afforded by the shelter and lessens the amount of material needed to build it.

(2) Ventilation keeps the air in a desirable condition during the entire period of occupancy, new air being rendered free of gas, and foul air being removed through exhaust ducts.

(3) The shelter is always ready for use and does not require periodic evacuation for cooling and drying.

(4) A positive pressure is maintained within the shelter, and as a result all minor leaks will be outward, provided the total volume of leaks is not so great as to offset the intake of air.

(5) Exhaust air can be vented continuously through lavatories, air locks, or decontaminating compartments.

(6) The effects of overcrowding are much less serious than in an unventilated shelter.

(7) Humidity is kept at a lower level, making conditions healthier. This is especially helpful in minimizing the danger of catching cold upon leaving the shelter.

b. Disadvantages.—(1) Extra labor and additional matériel are required to install a collective protector in a shelter. When gasoline engines are used, extra space must be provided for the protector outside the protected space.

(2) Gasoline or electrical energy must be provided, thus adding to the problem of supply.

25. Tests.—The protector and the shelter should be tested at regular intervals to make certain that all equipment is in proper working order. These examinations should be made monthly and semiannually.

a. Monthly inspection.—The entire collective protector installation should be tested monthly, inspection being made of both the shelter proper and the collective protector.

(1) An examination should be made of such of the following items as are included in the installation: air pressure relief valves, air pressure manometer, flap valves, air blast valve, air lock valve, electric switch, starting rheostat, electric motor, gasoline engine, blower, treadle, and air blast nozzle.

(2) The canister should be tested by means of a wet-and-dry bulb psychrometer. This is done by starting the blower and forcing air through the canister in the same manner as if the shelter were in use. The psychrometer is held in the stream of air entering the protected space, relative humidity of the air being calculated from the readings. If the relative humidity exceeds 75 percent, the canister should be replaced.

b. Semiannual inspection.—Effectiveness of the canister should be tested each 6 months by maintaining a concentration from a CN tear pot around an outside air intake. The tear pot should be placed about 10 to 15 feet from the intake. A man standing with his face in the stream of air entering the protected space from the collective protector canister should test for gas by odor and lacrimation. If penetration is noticed the canister should be replaced.

SECTION II

MIA1 COLLECTIVE PROTECTOR

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Advantages and disadvantages	27
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Installation	29
Operation	30
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26. General description and use.—*a. Description.*—The MIA1 collective protector consists chiefly of a blower driven by an electric motor or gasoline engine, a canister for removing chemical agents from the air, and an air blast mechanism for aerating clothing of personnel. It occupies an area approximately 95 inches long, 22¾ inches wide, and 69½ inches high, under one standard arrangement, while in another position it requires a space 67½ inches long, 50¼ inches wide, and 69½ inches high. The difference in space requirements is caused by changing the position of the air blast treadle. The apparatus weighs approximately 1,210 pounds, and delivers 200 cubic feet of air per minute. It is almost identical with an earlier model, the MI, described in section III of this chapter. (See figs. 19, 20, and 21.)

b. Use.—The MIA1 protector is used to provide purified air for large permanent shelter installations, such as forts, headquarters, and hospitals. If necessary, more than one protector may be used in an installation. For a detailed comparison of capacities of shelters equipped with the MIA1 collective protector and subject to varying climatic conditions, see appendix III.

27. Advantages and disadvantages.—*a.* Advantages of collective protectors are outlined in paragraph 24. The MIA1 collective protector offers a specific additional advantage in the air blast arrangement set up in the air lock to aerate clothing of personnel entering the shelter. This decreases the amount of gas carried into the protected space.

b. Disadvantages of collective protectors are also discussed in paragraph 24. A specific disadvantage of the MIA1 protector is its heavy weight and the consequent difficulty of installation. It cannot be moved and installed without considerable expenditure of time and effort.

28. Nomenclature.—Component parts of the MIA1 protector are the air inlets, pipes from the inlets to the blower, the blower, an electric motor or gasoline engine for driving the blower, a canister, a bypass for diverting air around the canister, valves for controlling the bypass, pipes, and openings into the protected space from the canister, and an air blast mechanism for aeration of clothing.

a. Air inlets.—These pipes should be placed at least 100 feet apart and should extend at least 25 feet above the ground. The wide separation will prevent both inlets from being blown off by a single explosion outside the shelter. The 25-foot height is advocated to minimize the entry of gas-laden air, which clings close to the ground. The top of each inlet is covered with a cone-shaped protector to prevent rain water from entering. The bottom of each inlet pipe is connected to a 4-inch standard black steel pipe. These latter pipes run horizontally to a T-joint, where they are connected to a vertical 4-inch pipe which leads to the blower. The air inlet system may be adjusted as required for each individual shelter project.

b. Blower.—This is a commercial-type rotary blower with a capacity of 200 cubic feet of air per minute.

c. Motor.—A ½-horsepower electric motor is ordinarily used to drive the blower, but a commercial-type, air-cooled, ½-horsepower gasoline engine may be used, provided it is not installed in the protected space and every effort is made to vent fumes to the outside.

d. Canister.—The M1 canister is used, which is cylindrical in shape, 39½ inches long by 21 inches in diameter, and weighs 314 pounds. The canister is connected at the bottom by means of an elbow and a gasket to a 4-inch pipe leading to the blower, and at the top by means of a fitting to a 4-inch pipe leading into the protected space.

e. Bypass.—At one side of the canister, and operated by flap valves at the top and bottom, is a 4-inch pipe through which air may be by-passed around the canister when the protector is used for ventilation purposes.

f. Air blast.—This mechanism is approximately 70 inches high and is made with sections of 4-inch black steel pipe. It consists of three flat nozzle sections, each with five air blast holes, and four pipe sections which serve to connect the nozzle sections; or it may be made of a single piece of 4-inch pipe with holes equally spaced along the entire length. It is operated by a treadle, connected by a chain to a valve at the top of the air blast mechanism. When the operator stands on the treadle, purified air is blown into the air lock through the series jets in the air blast pipe. The blast is powerful enough to remove loose vapors from contaminated clothing of personnel entering the shelter. The resultant contaminated air is pulled from the air lock back into the collective protector through a valve, and is again passed through the canister.

g. Outlets.—These are 4-inch pipes through which air passes from the canister to one or more openings in the protected space.

29. Installation.—*a. General.*—(1) Permanent installations of collective protectors should be made under supervision of the unit engineer in accordance with approved drawings.

(2) Power requirements must be considered in advance, since the protector must obviously be equipped to handle alternating current of a given voltage and frequency (cycles per second), or direct current of a given voltage. Competent personnel can usually adapt available current to a protector already on hand by means of a transformer or with motor generator sets, although this requires extra equipment and labor. If direct current is used, a rheostat must be attached to start the motor. If an auxiliary source of power is made available for use in case the main source fails, it must be of the same voltage, or else equipment must be installed to convert it.

(3) The MIA1 protector may be installed in the air lock. If it is more convenient, installation may be arranged so that only the air blast is in the air lock, the other parts of the protector being placed in another convenient location. It is not advisable to place protectors in the protected space, however, because noise from the motor and blower may interfere with important activities. If a shelter is

equipped with two or more protectors, it is usually of such size that two or more air locks are also needed. Each air lock should be equipped with an air blast apparatus. Remaining protectors and parts of protectors may be placed in any convenient location except in the protected space itself.

(4) Two or more protectors may be connected to the same discharge line leading into the protected space. One-way valves should be placed between each canister and the common discharge line, however, to prevent air from being forced backward through the canisters.

b. Assembly.—(1) A firm foundation, preferably of concrete, must be provided.

(2) Blank flanges are removed from the canister. The canister, motor, and air blast apparatus are placed on a flanged steel base which is fastened to the foundation. The lower, flanged end of the elbow at the bottom of the canister is bolted to the flanged outlet of the flap valve at the bottom of the bypass.

(3) The elbow at the top of the flap valve above the canister is connected by a short piece of 4-inch pipe to the fitting at the top of the bypass.

(4) The fitting at the top of the bypass is then connected by a piece of 4-inch pipe, of proper length, to the valve at the top of the air blast, the other end of this valve being connected to a discharge pipe leading to the protected space.

(5) All the bases are then bolted securely to the foundation.

(6) The intake line is connected to the blower and the motor is connected to the electric line.

(7) All screwed joints in the pipe lines should be luted with white lead paste-in-oil.

(8) The air blast may be installed with outlets facing away from, or to either side of, the blower. The treadle is installed facing the air blast outlets, one end being fastened to the floor while the other end is connected to the air blast valve by means of a chain. The chain should be adjusted so that the end of the treadle to which it is attached may move downward 3¾ inches to the floor.

30. Operation.—*a. Flow of air.*—Air is brought in from the air intakes through pipes to the blower, which forces it through the canister or the bypass. It then goes into pipes which lead to the outlets into the protected space. When the air blast mechanism is used for aerating clothing, the air blast valves are operated by each man in turn standing on the air blast treadle. Air then leaves the canister and goes out the air blast. A special intake line within the air lock is opened, and a cut-off valve in the air line leading to the protected space is closed. By this means gas-laden air from the air lock is recirculated through the canister and blower, and flows out again into the air lock without entering the protected space.

b. Operational procedure.—(1) Valve adjustments are explained in figure 19.

(2) When the MIA1 protector is used for protection against chemical agents, all windows, ventilators, doors, conduits, etc., within the protected space and the air lock must first be closed. Valves regulating the flow of air through the canister are placed in the position

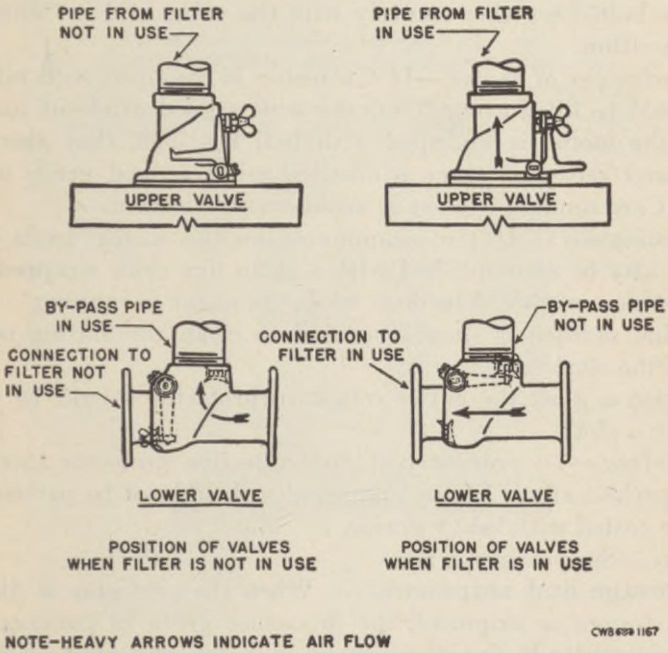

FIGURE 19.—Valve operating diagram for collective protector MIA1.

marked, "When filter is in use." The motor and blower are started with the switch or rheostat, depending upon whether the motor is driven by alternating or direct current. The air pressure relief valves of the protected space are inspected to make certain they will open when pressure within the shelter rises to equal the pressure of ½ inch of water in a manometer.

(3) When the protector is used as a ventilating system, windows, ventilators, and air lock doors are opened as necessary to provide comfort. Valves in the collective protector are placed in the position marked, "When filter is not in use." The blower is started as described in (2) above.

31. Care and maintenance.—*a. Replacement of exhausted canister.*—A method of testing effectiveness of the canister is outlined in paragraph 25. Special attention should be given to this matter during prolonged periods of damp weather. To replace the canister the upper flap valve should first be opened and unbolted from the canister. The valve is held to prevent it from rotating, and is raised (turned right) by the nipple. The canister is unbolted from the base elbow and removed. A new gasket is inserted at the bottom and the new canister is then put in place with the "air out" end up. No gasket is required between the upper flap valve and the canister, which are bolted together securely with the valve held in "filter-not-in-use" position.

b. Lubrication of motor.—If the motor is equipped with oil cups they should be filled every 3 months with a good grade of machine oil. If the motor is equipped with ball bearings, they should be cleaned and repacked every 6 months, using a good grade of cup grease. Care should be taken to avoid overlubrication.

c. Cleaning.—(1) If the commutator on the motor needs cleaning, this may be accomplished with a clean dry cloth wrapped on a wooden stick, and should be done while the motor is running.

(2) Fine sandpaper should be used to clean the sliding contact points of the starting rheostat.

(3) Once a week the entire collective protector should be wiped clean with a cloth.

d. Painting.—To prevent rust, the collective protector should be painted periodically. Valves and nipples should not be painted, but should be coated with heavy grease.

e. Tests.—See paragraph 25.

32. Storage and shipment.—*a.* When the protector is dismantled for storage or shipment, the procedure given in paragraph 29 will be reversed. It should be stored in a dry, sheltered place, and must not rest directly on the ground. It should be kept away from the fumes of chemical agents, acids, or other corrosive materials, as they may corrode the equipment.

b. The protector is packed in four boxes containing—

(1) Canister, weighing 433 pounds, boxed, and displacing 14.2 cubic feet.

(2) Blower and bypass, weighing 1,080 pounds, boxed, and displacing 66.8 cubic feet.

(3) Air blast, weighing 250 pounds, boxed, and displacing 11.5 cubic feet.

(4) Miscellaneous parts, weighing 175 pounds, boxed, and displacing 5.02 cubic feet.

Section III

COLLECTIVE PROTECTOR MI

Paragraph
General description and use -- 33

33. General description and use.—*a. General.*—Except for the value arrangement, the MI collective protector is identical with the MIA1, the currently approved model. Except as indicated in *a* and *b*

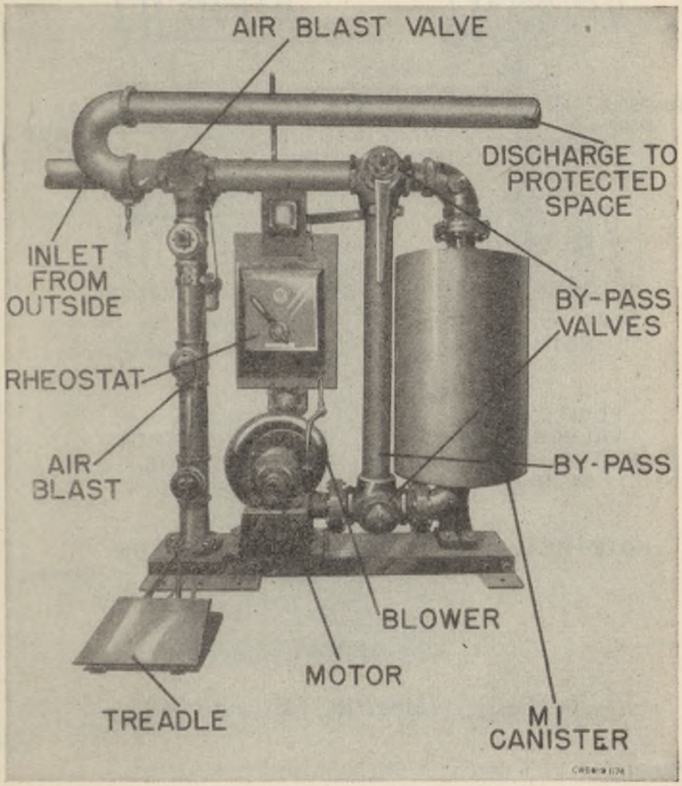

FIGURE 20.—Collective protector MI.

below, instructions regarding installation, operation, care and maintenance, storage, and shipping are the same as those given in section II of this chapter for the MIA1 protector.

b. Valves (see fig. 21).—The MI protector has three-way valves located at the top and bottom of the bypass, directing air through the canister or bypass as desired.

c. Replacement of canister.—The adjustable flange at the top of the canister should be removed from the canister and the pipe line. The canister is then unbolted from the base elbow and replaced with a new canister, the latter being installed with the "air out" end up. Gaskets must be replaced at all joints. The adjustable flange is replaced and bolted securely.

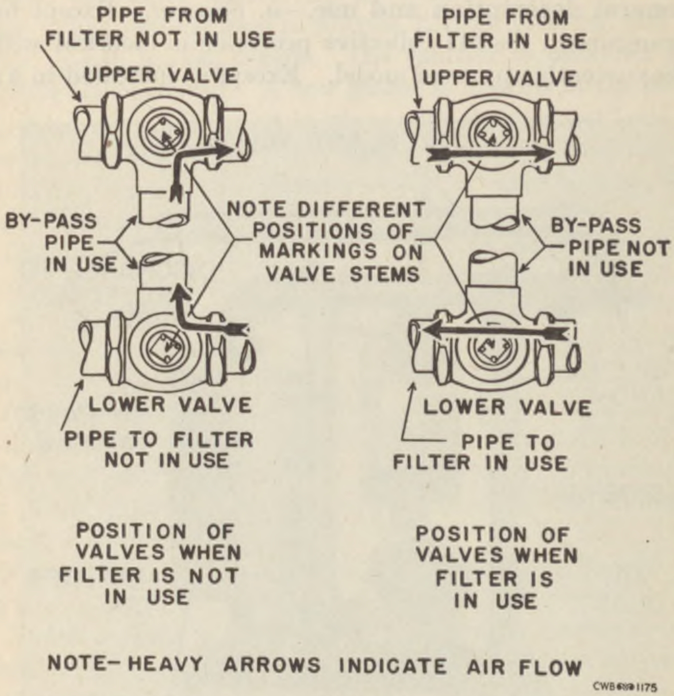

FIGURE 21.—Valve operating diagram for collective protector M1.

SECTION IV

COLLECTIVE PROTECTOR M2

	Paragraph
General description and use	34
Advantages and disadvantages	35
Nomenclature	36
Installation	37
Operation	38
Care and maintenance	39
Storage and shipment	40

34. General description and use (see figs. 22, 23, and 24).—*a. Description.*—The M2 collective protector consists of a blower, driven by a gasoline engine, and a canister for removing chemical agents from the air. It requires a space approximately 31 inches long, 31 inches wide, and 66 inches high, and weighs approximately 650 pounds.

b. Use.—The M2 protector is used to provide air for semipermanent and temporary shelters. For a detailed comparison of capacities of shelters equipped with the M2 collective protector and subject to varying climatic conditions, see appendix III.

35. Advantages and disadvantages.—*a. Advantages.*—In addition to the general advantages of collective protectors outlined in

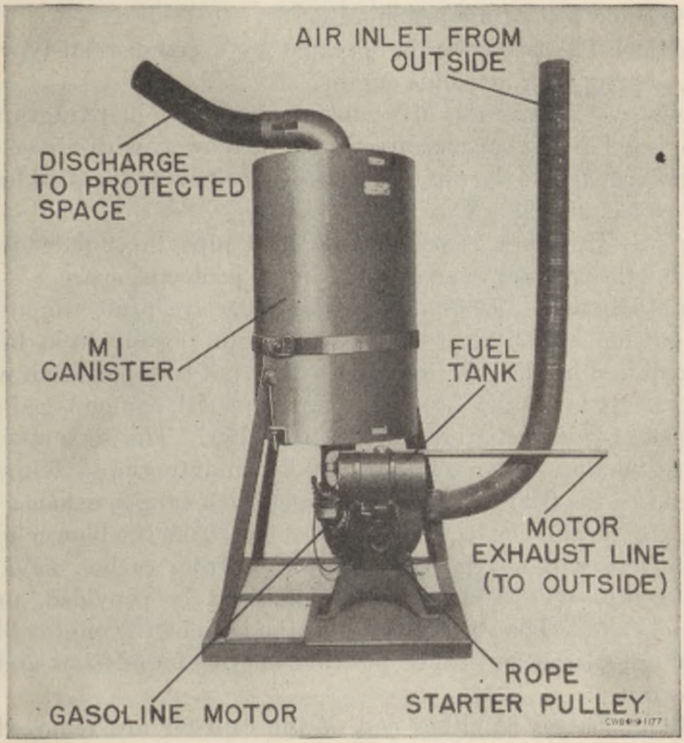

FIGURE 22.—Collective protector M2.

paragraph 24, the M2 protector has the additional advantage of lighter weight and fewer parts, making installation and transportation easier. It also requires less space while providing the same amount of purified air.

b. Disadvantages.—Disadvantages of collective protectors in general are discussed in paragraph 24. The M2 protector has two additional specific disadvantages: First, it has no air blast to aerate the clothing of men entering the air lock, as in the case of the MI and

MIA1 protectors; second, it is driven by a gasoline engine, and therefore must not be installed in the air lock or the protected space.

36. Nomenclature.—The M2 protector is composed of a canister, blower, gasoline engine, air inlets, pipes from the inlets to the blower, and conduit leading into the protected space.

a. Air inlets.—These are the same as those described in paragraph 28 for the MI and MIA1 protectors, except that a 4-inch flexible steel pipe is used to connect the inlets to the blower.

b. Blower.—This is a commercial-type rotary blower with a capacity of 200 cubic feet of air per minute.

c. Engine.—The protector is operated by a commercial-type, air-cooled, ½-horsepower, gasoline engine.

d. Canister.—This is the M1 canister, described in paragraph 28. It is connected at the bottom directly to the blower, with a gasket inserted between, and at the top by means of an elbow to the pipe leading into the protected space.

e. Outlet.—This is a 4-inch flexible steel pipe through which air passes from the canister to an opening in the protected space.

37. Installation.—*a. General.*—The collective protector must be located outside both the protected space and the air lock, because oxygen required by the gasoline engine must not be taken from within the shelter. It is usually feasible to erect a small, camouflaged shack for the protector immediately outside the shelter. The air intake must be located so that water will not be drawn into the system. The muffler end of the flexible exhaust tubing which carries exhaust away from the engine must be located some distance from the blower intake, since canisters will not provide protection from carbon monoxide.

b. Assembly.—(1) A firm foundation must be provided, preferably of concrete. The steel frame and the base of the engine-blower assembly are placed in proper position on the foundation and fastened down.

(2) Blank flanges at either end of the canister are removed and the "air in" end of the canister connected to the discharge outlet of the blower. The necessary gasket and cap screws for this connection are removed from the blank flanges. The eyebolt hanger clips are connected to the canister so that the weight rests on the steel frame and not on the blower.

(3) The upper or "air out" end of the canister is connected by means of an elbow to flexible steel piping which leads through the wall into the protected space.

(4) Another 4-inch flexible steel pipe is connected to the blower. The outer end of this pipe can be used as an air intake in an emer-

gency. Where possible, however, a double air intake, such as that described in paragraph 28, should be used, the flexible piping being connected to it. Screen ends should be attached to the outer ends of both intake and outlet to prevent the entrance of insects and small rodents.

38. Operation.—*a. Flow of air.*—Air from the intake passes through the blower, is forced up through the canister, and thence into the pipe leading to the protected space.

b. Operational procedure.—(1) All windows, doors, ventilators, conduits, drain openings, and other apertures in the protected space must be closed preparatory to operating the collective protector.

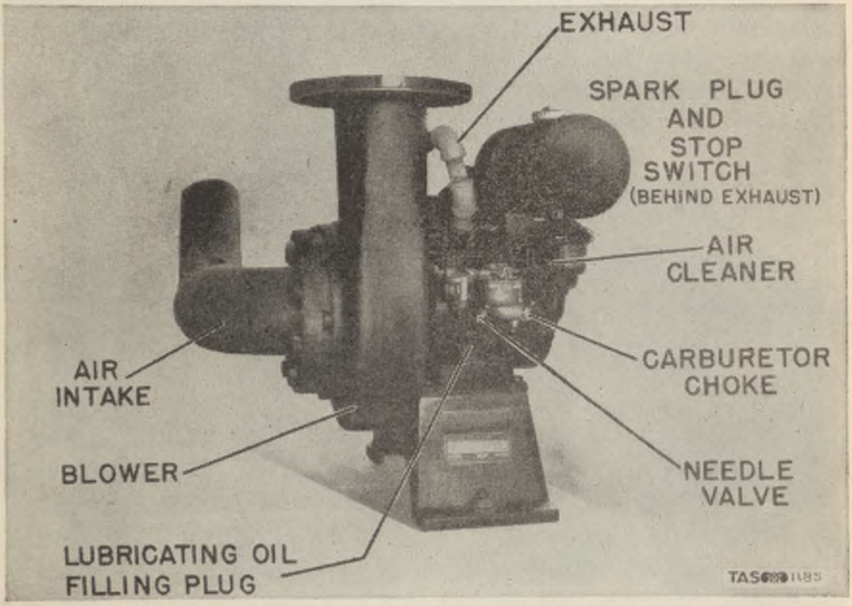

FIGURE 23.—Detail of engine and blower, collective protector M2.

(2) Nomenclature of the gasoline engine is shown in figure 23. To start the engine the gas shut-off valve is opened by turning the valve to the left. The carburetor choke is closed by turning the lever in a clockwise direction. The operator then winds the starting rope clockwise around the starter pulley, placing the knot in the pulley notch. Using a quick, steady pull, the flywheel is spun and the engine is primed. Next, the choke is opened about halfway and the engine started by using the starting rope again. As the engine warms, the choke is opened gradually until it is wide open; the engine should never be operated for an extended period with the choke partially closed.

(3) The engine is stopped by pressing the stop switch (mounted upon the cylinder head) against the end of the spark plug. The gasoline supply is then shut off by turning the valve to the right.

(4) Adjustment of the carburetor is achieved by first closing the needle valve clockwise as far as possible without using force. From the closed position the valve is opened one-half to three-quarters of a turn. Final adjustment to the point of smoothest operation should

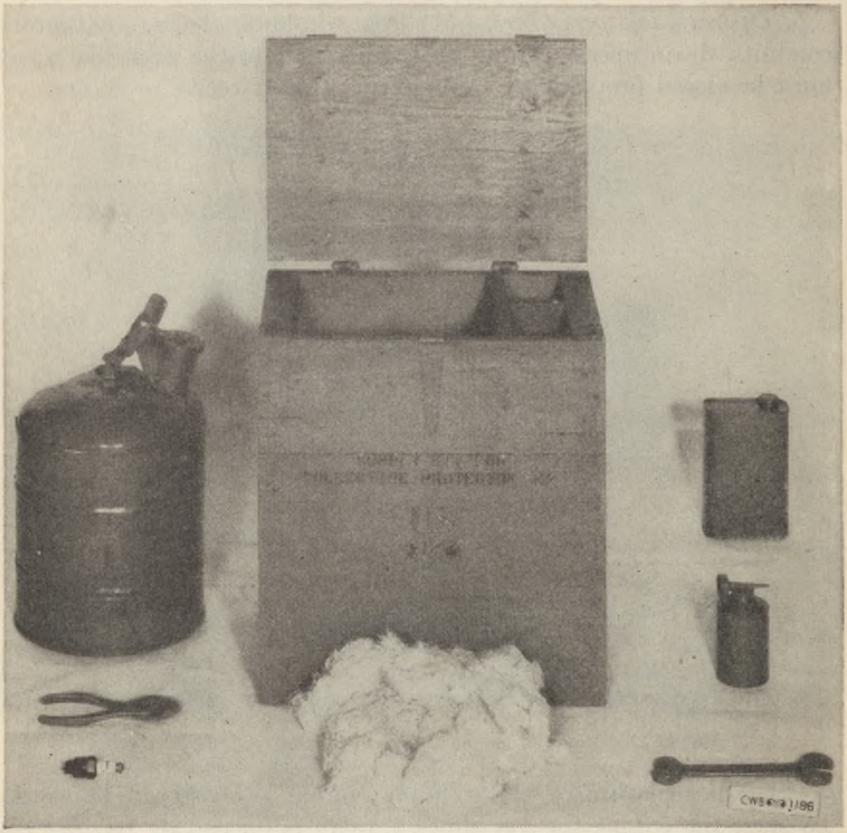

FIGURE 24.—Supply kit for collective protector M2.

be made after the engine has been started and warmed, the adjustment being made with the choke wide open.

(5) A good grade of clean and fresh gasoline should always be used. Oil must not be mixed with the gasoline.

(6) The collective protector should never be used as a ventilating system, since it is not equipped with the bypass mechanism and therefore cannot be operated without deterioration of the canister.

39. Care and maintenance.—*a. Replacement of exhausted canister.*—The elbow is removed from the "air out" end of the canister, after which the canister is unbolted from the blower discharge outlet and removed. The new canister must be installed with the "air out" end up, its weight supported by the three supporting clips on the frame. Gaskets must be replaced at all joints. The elbow is then placed back in position and the canister bolted securely in place.

b. Lubrication of engine.—The crank case must be filled with lubricating oil to the top of the filler fitting. SAE 20 oil should be used in both summer and winter. The oil supply should be replenished after each 8 hours of operation, and the crankcase drained and refilled after 25 hours' use. The crankcase must never be flushed with kerosene.

c. Tests.—Standard test procedure for collective protectors is outlined in paragraph 25. The M2 protector should be tested by operation 1 or 2 minutes each month, or after each change of location, thereby determining the efficacy of the gasproofing. Operation of the gasoline engine should also be checked periodically.

d. Miscellaneous.—(1) Spark plugs should be cleaned regularly. The points should be reset to .025 of an inch clearance after each 100 hours of operation.

(2) The air cleaner should be removed and washed in kerosene after every 100 hours of operation. It should be kept filled with SAE 20 oil up to the mark indicated on the cleaner case.

(3) The protector should be painted whenever necessary to prevent rusting.

40. Storage and shipment.—Storage instructions, as given in paragraph 32 for the MIA1 collective protector, should be observed. The M2 collective protector is packed in two boxes containing—

a. Canister, weighing 433 pounds, boxed, and displacing 14.2 cubic feet.

b. Engine, blower, tool box, and miscellaneous parts, weighing 483 pounds, packed, and displacing 24.2 cubic feet.

SECTION V

COLLECTIVE PROTECTOR, M2A1

Paragraph
Description 41

41. Description.—The collective protector M2A1 is identical with the M2 protector, except that it is operated by a ½-horsepower electric motor while the M2 uses a gasoline engine. Instructions as to care and maintenance of the electric motor are given in paragraph 31.

SECTION VI

SMALL FIELD COLLECTIVE PROTECTOR, M3

	Paragraph
General description and use	42
Advantages and disadvantages	43
Nomenclature	44
Installation	45
Operation	46
Care and maintenance	47
Storage and shipment	48

42. General description and use (see fig. 25).—*a. Description.*—The M3 collective protector consists of a blower, driven by a 1/8-horsepower electric motor, and a canister for removing chemical agents from the air. It requires a space approximately 16 inches wide, 16 inches deep, and 54 inches high, and weighs 225 pounds. It provides 50 cubic feet of air per minute.

b. Use.—This protector is used to provide purified air for small groups of men performing their functions in trailers or other small spaces. For a detailed comparison of capacities of shelters equipped with the M3 collective protector and subject to varying climatic conditions, see appendix III.

43. Advantages and disadvantages.—*a. Advantages.*—In addition to the advantages of collective protectors generally outlined in paragraph 24, the M3 protector has the additional specific advantage of being light in weight and therefore easily moved.

b. Disadvantages.—The protector has a specific disadvantage of extremely small capacity, making it useful only for small groups of men.

44. Nomenclature.—The apparatus consists of a blower, an electric motor for driving the blower, a canister, elbow outlet for the canister, and flexible pipe to conduct air to and from the protector.

a. Pipe.—Flexible pipe, used for the air intake and to carry purified air into the protected space, is 3 inches in diameter.

b. Blower.—This is a commercial-type rotary blower with a capacity of 50 cubic feet of air per minute.

c. Motor.—This is a standard commercial-type, 1/8-horsepower, electric motor.

d. Canister.—The M2 canister, a cylindrical, 75-pound apparatus, 36 inches long and 10½ inches in diameter, is used with the M3 protector.

45. Installation.—*a. General.*—(1) The motor must be suited to the available electrical current, as outlined in paragraph 29.

(2) The protector will preferably be located outside the protected space. but if this is not onvenient it may be placed inside.

b. Assembly.—(1) The base section, which includes the motor, blower, and a common foundation, should be bolted to the floor in the desired location.

(2) Blank flanges are next removed from the ends of the canister. The "air in" or lower end of the canister is connected to the blower

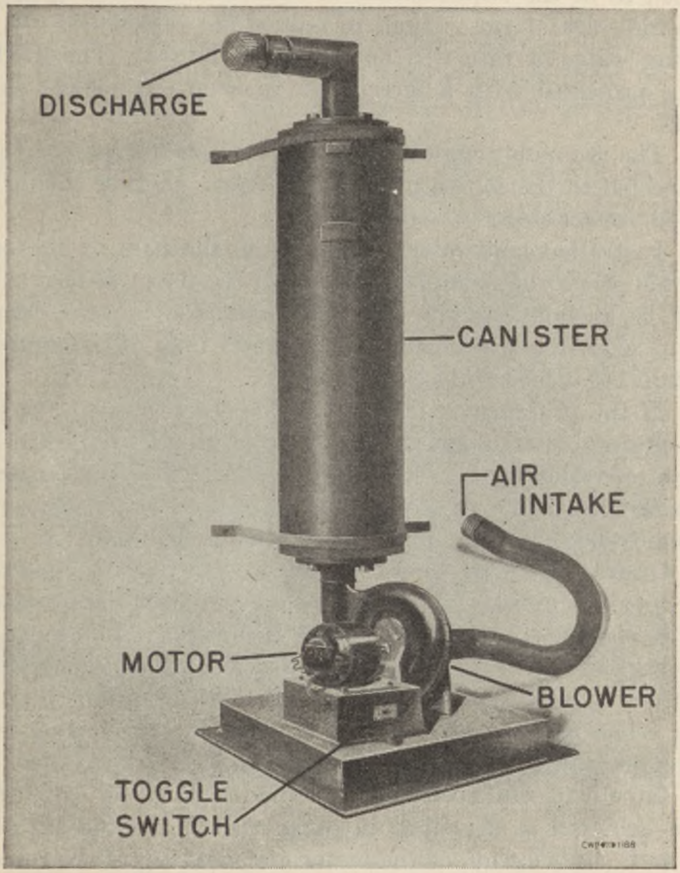

FIGURE 25.—Collective protector M3.

discharge outlet, using the gasket and bolts removed from the blank flanges. This joint must be made gastight.

(3) The elbow on the upper "air out" end of the canister is next mounted, its purpose being to discharge purified air in the desired direction. One of the screen ends furnished with the protector is attached to the outer end of the elbow to prevent rodents and insects from entering.

(4) The 3-inch flexible tubing is connected to the air inlet side of the blower and extended through the wall or roof to the outside atmosphere. Rigid pipe may be used for permanent installations. The outside air intake must be protected with a hood or shield so that water will not be drawn into the intake, a special shield being designed to fit the requirements of each installation. It must have an opening area large enough to reduce the velocity of air, so that dripping water or rain will not enter the intake. The intake must also be protected with a screen end to keep out insects and small rodents.

(5) The two-pole toggle switch mounted on the base of the motor is connected to the source of electric power. A fuse should be provided to protect electrical equipment.

(6) In trailers and other mobile units the base of the collective protector should be securely fastened to the floor, while the canister should be anchored to the wall of the vehicle by two straps, each made of semicircular segments. The center lines of the straps should be within 1½ inches of the canister ends.

(7) If the protector is located outside the protected space, which is the preferable arrangement, the flexible pipe is connected between a screen end and the elbow on the canister. The pipe extends into the protected space. A screen end is attached to the blower intake, which must be shielded to prevent the entrance of water.

46. Operation.—All doors, windows, ventilators, conduits, and other openings must be closed before operation of the protective collector is started. The button on the electric switch is moved to the "on" position to start the motor blower and place the system in operation. The button is moved to the "off" position to stop operations. The protector should not be used for ventilation purposes. Testing procedure is outlined in paragraph 25.

47. Care and maintenance.—Replacement of an exhausted canister is achieved as described in paragraph 39 for the M2 collective protector. Lubrication of the motor and cleaning of the motor parts is handled as described in paragraph 31. The entire protector should be painted whenever necessary to prevent rusting.

48. Storage and shipment.—Storage instructions given in paragraph 32 for the MIA1 collective protector should be observed. The M2 collective protector is packed in two boxes containing—

a. Canister, weighing 118 pounds, and displacing 4.05 cubic feet.

b. Motor, blower, flexible pipe, screen ends, and elbow, weighing 280 pounds, boxed, and displacing 13.05 cubic feet.

SECTION VII

NONSTANDARD SYSTEMS

	Paragraph
General	49
Adaptation of air conditioning systems	50
Improvisations	51

49. General.—If a standard collective protector is not obtainable, it is sometimes possible to improvise one, although great care must be taken in construction, testing, and use of the improvisation to avoid placing dependence on a defective system.

50. Adaptation of air conditioning systems.—As ordinarily constructed and installed in existing buildings, air conditioning sys-

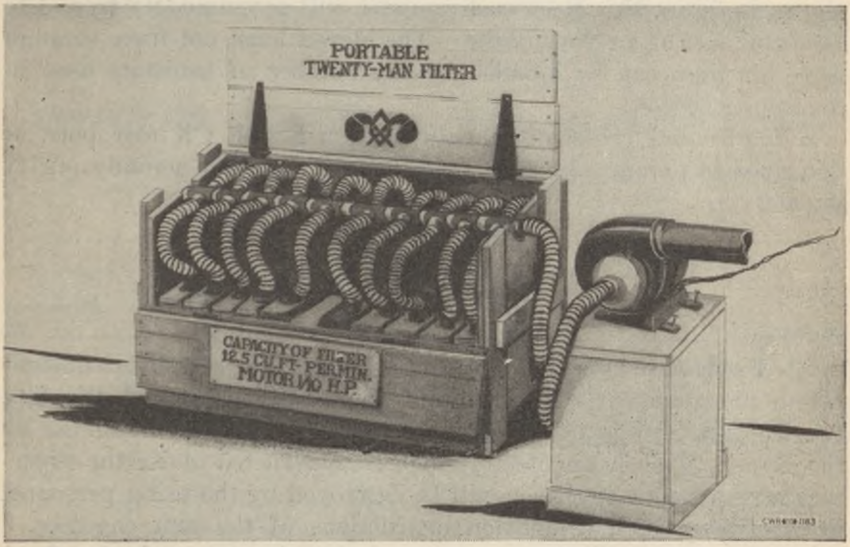

FIGURE 26.—Method of improving collective protector using canisters from human gas masks.

tems should not be adopted for use either as collective protectors or in conjunction with them; nor should any part of air conditioning systems, such as air lines, be connected to the collective protector. However, air conditioning may be used in a building equipped with a collective protector provided the system is stopped and all vents and openings are closed immediately at the time the gas attack starts. This is necessary because air conditioning equipment may bring in sufficient contaminated air within a few seconds to contaminate a shelter, and recirculation of air by air conditioning equipment will spread any gas that might enter the shelter through cracks or holes in the wall caused by enemy fire or bombing that could, otherwise, have been confined to one room or area. The air conditioning system should not be used again until the outside air is free of gas. Air conditioning equipment, designed and installed by the unit engineer in shelters to be used in conjunction with collective protectors, may be used according to his instructions.

51. Improvisations.—*a.* If an M1 or M2 canister is available it may be connected to a blower which does not force more than 200 cubic feet per minute through the M1 canister or 50 cubic feet per minute through the M2. If proper intake and exhaust pipes are then added, a fairly satisfactory substitute protector may be improvised.

b. A protector of smaller capacity may sometimes be improvised by using a blower with gas mask canisters connected in parallel, as shown in figure 26. Each such canister will accommodate from 1 to 1½ cubic feet of air per minute. The blower must not force through more air than can be handled by the number of canisters used in the improvisation.

c. Improvised protectors should be tested with CN tear pots, as described in paragraph 25, to make certain that they actually purify the air.

SECTION VIII

DEMOLITION

Paragraph
Procedure 52

52. Procedure.—In the event of a retrograde movement necessitating abandonment of a gasproof shelter, all Chemical Warfare Service protective equipment must be destroyed to prevent its use by the enemy. The shelter itself, which is constructed under the supervision of the unit engineer, will be destroyed by the using personnel in accordance with demolition instructions of the unit engineer.

a. Gasproof curtains, gas masks, protective clothing, and other flammable Chemical Warfare Service matériel used in the shelter will be placed in a pile and ignited.

b. Motors, switchboxes, flexible piping, exhaust valves, and other fragile equipment will be smashed with a heavy hammer.

c. To destroy the canister, the top air connection is removed and an incendiary grenade, M14, placed in the opening. This will burn its way into the canister and destroy it.

d. To demolish other parts of the collective protector, especially in the case of an MI or MIA1 installation, it may be necessary to place TNT blocks under the protector and detonate them. This can be done in cooperation with the unit engineer at the time the shelter itself is demolished.

Appendix I

LIST OF REFERENCES

FM 5–15, Field Fortifications.
FM 5–25, Explosives and Demolitions.
FM 21–40, Defense Against Chemical Attack.
FM 23–30, Grenades.
TM 3–215, Military Chemistry and Chemical Agents.
TM 3–240, Meteorology.
Air Raid Precautions Handbook, No. 5. (British)
Chemical Warfare Service Supply Catalog.
"Chemicals in War," Prentiss, Col. A. M.
"Civil Defense," Glover, C. W.
Standard Nomenclature and Price List of Chemical Warfare Matériel.

Appendix II

EFFECT OF VARYING AIR CONDITIONS UPON THE HUMAN BODY

Condition of air				Effect
Temperature (deg. F.)	Relative humidity (percent)	Oxygen (percent)	CO_2 (percent)	
70–75	50–70	21	0.05	Comfortable conditions in normal shelter.
85	90			Acute discomfort, faintness, and a feeling of suffocation and alarm.
92	90			A dangerous rise in body temperature, pulse, and rate of breathing, accompanying panic.
98 or higher	95–100			Rapid rise in body temperature inevitable. Conditions extremely dangerous.
		Reduced to 14.		Not harmful.
		10		Minimum necessary for normal breathing.
			Up to 1.5	Quite innocuous.
			3	Increased blood pressure and headache.
			4	Gradual impairment of respiration due to poisoning effect.
			5 and over	Dangerous.

Appendix III

CAPACITIES OF VENTILATED SHELTERS

(With each type of collective protector, considering the factors of temperature, shelter construction, and degree of activity)

Temperature of outside air	Men performing normal duties						Men completely at rest		
	Underground shelters or above ground shelters with walls of low heat conductivity [1]			Above ground shelters with walls of high heat conductivity [2]			Rest shelters		
	M1	M2	M3	M1	M2	M3	M1	M2	M3
Above 90° F	40 to 72	40 to 72	10 to 18	50 to 100	50 to 100	12 to 25	100 to 133	100 to 133	25 to 30
Below 90° F	50 to 100	50 to 100	12 to 25	66 to 133	66 to 133	16 to 36	133 to 200	133 to 200	30 to 50

High relative humidity decreases the number of men that a shelter will accommodate.

[1] Walls of wood or dry earth have low heat conductivity.
[2] Walls of metal, concrete, masonry, and damp earth have high heat conductivity.

Appendix IV

CAPACITIES OF UNVENTILATED SHELTERS

	Capacity (number of men)	Outside air below 90° F		Outside air above 90° F	
		Space (cu. ft.) per person [1]		Space (cu. ft.) per person [1]	
		Totally at rest	Normal desk work	Totally at rest	Normal desk work
Underground or aboveground walls of low heat conductivity.[2]	10	200	360	240	500
	25	300	540	360	725
	50	400	750	500	1, 000
Aboveground walls of high heat conductivity.[3]	10	150	270	180	360
	25	235	425	270	540
	50	300	540	380	720

[1] Based on occupancy period of 3 hours.
[2] Walls of wood or dry earth have low heat conductivity.
[3] Walls of metal, concrete, masonry, and damp earth have high heat conductivity.

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BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

J. A. ULIO,
Major General.
The Adjutant General.

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