ORNL-TM-3916

Contract No. W-7405-eng-26

HEALTH PHYSICS DIVISION
Civil Defense Research Section

HOW TO MAKE AND USE A HOMEMADE, LARGE-VOLUME, EFFICIENT SHELTER-VENTILATING PUMP: THE KEARNY AIR PUMP

C. H. Kearny

AUGUST 1972

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

FOREWORD

These instructions and illustrations were developed by much practical experimentation, involving scores of persons, to enable average Americans, without knowledge of engineering drawings, to build for themselves a simple, large-volume shelter-ventilating pump. This pump, which originally was called the "punkah-pump" by its inventor, was renamed the Kearny Air Pump (KAP) by the Office of Civil Defense. Several research organizations besides Oak Ridge National Laboratory – including the Protective Structures Development Center, Stanford Research Institute, and General American Transportation Corporation – have tested different models extensively and have found KAP's to be effective devices for manually ventilating shelters.

To be sure that average Americans can build, install, and operate homemade KAP's effectively, citizens should be given at least all of the instructions through Sect. VII, Larger Kearny Air Pumps. Although these instructions are unnecessarily detailed for many skilled workers, practical tests have proved that many intelligent Americans need this detail to build KAP's for themselves.

If, during a possible future period of widely recognized need for these instructions, the authorities should decide to make a mass distribution – perhaps within a day or two and in numerous localities – then large numbers of booklets and newspaper supplements could be rapidly produced by offset printing.

PUBLISHED RESEARCH REPORTS DEALING WITH KEARNY AIR PUMPS

1. C. H. Kearny, *Manual Shelter Ventilating Devices for Crowded Shelters Cooled by Outside Air - A Preliminary Report,* ORNL-TM-1154, Oak Ridge National Laboratory, Oak Ridge, Tenn., June 1965.
2. C. H. Kearny, *Mechanized Durability Tests of a Six Foot Punkah Pump,* ORNL-TM-1155, Oak Ridge National Laboratory, Oak Ridge, Tenn., July 1965.
3. O. W. Svaeri and M. M. Dembo, *Simulated Occupancy Tests and Air Distribution in a 480-Person Community Shelter,* PSDC-TR-23, U.S. Army, Protective Structures Development Center, Fort Belvoir, Va., 1965.
4. R. H. Henninger and C. A. Madson, *Natural Ventilation Test of a Basement Fallout Shelter in East Chicago, Indiana,* GARD-1268-61, General American Transportation Corp., Niles, Ill., January 1966.
5. H. A. Meier and C. A. Madson, *Natural Ventilation Test of an Aboveground Fallout Shelter in Evanston, Illinois,* GARD-1268-51, General American Transportation Corp., Niles, Ill., January 1966.
6. C. H. Kearny, *Minimum-Cost Ventilation and Cooling of Shelters,* Second International Civil Defense Symposium on Nuclear Radiation Hazards, International Civil Defense Organization, Geneva, Switzerland, October 1966.
7. C. H. Kearny, *Instructions for Building a Home-made Large-Volume Shelter-Ventilating Punkah Pump,* ORNL-TM-1745, Oak Ridge National Laboratory, Oak Ridge, Tenn., March 1967.
8. O. W. Svaeri and N. I. Stein, *Air Distribution Studies in Multiroom Shelters,* PSDC-TR-21/22, U.S. Army, Protective Structures Development Center, Fort Belvoir, Va., March 1967.
9. T. Hori, *Feasibility of Low Cost Ventilation Techniques,* SRI-4949-251, Stanford Research Institute, Menlo Park, Calif., December 1967.
10. C. E. Rathmann, *Configuration of Effects on Ventilation in Belowgrade Shelters,* GARD-1476, General American Transportation Corp., Niles, Ill., August 1969.
11. A. L. Kapil, H. M. Sitko, and J. M. Buday, *Ventilation Kits,* GARD-1477, General American Transportation Corp., Niles, Ill., November 1969.
12. C. E. Rathmann, *Air Distribution in Shelters due to Kearny Pumps and Pedal Ventilators,* GARD-1476-1-F, General American Transportation Corp., Niles, Ill., August 1970.
13. C. E. Rathmann, *Analytical Studies of Shelter Environments,* GARD-1475-2-F, General American Transportation Corp., Niles, Ill., December 1970.
14. A. L. Kapil and C. E. Rathmann, *Shelter Ventilator Studies,* GARD-1477-1, General American Transportation Corp., Niles, Ill., January 1971.
15. C. H. Kearny, *More Efficient Operation of Kearny Air Pumps for Manual Ventilation of Shelters,* ORNL-TM-3562, Oak Ridge National Laboratory, Oak Ridge, Tenn., September 1971.

CONTENTS

HOW TO MAKE AND USE A HOMEMADE, LARGE-VOLUME, EFFICIENT SHELTER-VENTILATING PUMP: THE KEARNY AIR PUMP

Caution

Before starting to build this unusual type of air pump, ALL WORKERS SHOULD READ THESE INSTRUCTIONS AT LEAST UP TO SECTION V, INSTALLATION, before anyone starts work. Otherwise, you are likely to make mistakes and to distribute the work inefficiently among yourselves.

When getting ready to build this pump, all workers should spend the first half hour studying these instructions and getting organized. Then, after materials are assembled, two average Americans working together should be able to complete the 3-ft model described in the following pages within 4 hours. To speed up completion, divide up the work. For example, one person can start making the flaps while another begins work on the pump frame.

These instructions were especially written and tested by having successive small groups of 12-year-old boys, and also housewives, build Kearny Air Pumps (KAP's). None of these inexpert builders had even previously heard of this type of pump. Their successes prove that almost anyone can build a serviceable, large-volume air pump of this simple type, using only materials and tools found in most American homes.

I. THE NEED FOR SHELTER AIR PUMPS

In warm weather it is essential to pump large quantities of outside air through a crowded shelter to prevent the body heat produced by the occupants from raising the air temperatures in the shelter to dangerously high levels. In hot weather, many times as many persons could survive the heat in typical below-ground shelters through which adequate volumes of outdoor air are pumped than could survive in these same shelters if they lacked forced ventilation. Furthermore, you should realize that even in cold weather some outdoor air [about 3 cubic feet per minute (cfm) for each shelter occupant] must be pumped through many shelters, primarily to keep the carbon dioxide exhaled by shelter occupants from rising to harmful concentrations in the shelter air.

When practical, build a Kearny Air Pump (KAP) large enough to pump at least 40 cubic feet per minute (cfm) of outdoor air through your shelter for each shelter occupant. If 40 cfm of outdoor air is pumped through a shelter and distributed within the shelter as specified below, then – under heat-wave conditions in hot parts of the United States – the effective temperature of the shelter air will be less than 2°F higher than the effective temperature outdoors. The 36-in.-high by 29-in-wide KAP described herein, if used as specified, will pump at least 1000 cfm of outside air through a shelter that has the airflow characteristics outlined.

If your shelter may be occupied by more than 25 persons during hot weather, then it is advisable to build a larger KAP. The 72 in. X 29 in. model described can pump between 4000 and 5000 cfm.

In addition to pumping enough outdoor air through your shelter to maintain tolerable shelter conditions, you also must:

1. Distribute the air quite uniformly within your shelter. If the KAP that pumps air through your shelter does not create air movement that you can feel in all parts of your shelter, then you need to install and operate one or more additional KAP's within the shelter to circulate the air and gently fan all the occupants.
2. Have the shelter occupants wear minimum clothing when they are hot.
3. Supply the occupants with adequate water and salt. (For prolonged shelter occupancy under heat-wave conditions in a hot part of the country, about 4 quarts of drinking water and ⅓ ounce of salt per person are required every 24 hours.)
4. In hot weather, keep pumping outdoor air through your shelter both day and night, so that both the occupants and the shelter itself are cooled off at night.

Almost all of the danger from fallout is caused by radiation from visible fallout particles of heavy, sand-like material. The air itself does not become radioactive due to the radiation continuously given off by fallout particles.

The visible fallout particles rapidly "fall out" of slow moving air. Thus, the low-velocity air that a Kearny Air Pump pumps into a shelter can carry into the shelter only a very small fraction of the fallout particles that cause the radiation hazard outside, and this usually not dangerous fraction can be further reduced if occupants take the simple precautions described in these instructions.

II. HOW A KEARNY AIR PUMP WORKS

As can be seen in Figs. 1 and 2, a Kearny Air Pump (KAP) operates by being swung like a pendulum. It is hinged at the top of its swinging frame. When a KAP is pulled by a cord, as illustrated (or pushed by a pole, see Fig. 24), its flaps are closed, and it pushes and "sucks" air through the opening in which it swings. This is called its power stroke. During its power stroke, a KAP's flaps are closed against its flap-stop wires or strings, which are fixed in the plane of its frame.

When a KAP swings freely back as a pendulum on its return stroke, all its flaps are opened by air pressure, and the pumped air stream, due to its inertia, continues to flow in the pumped direction, while the pump swings in the opposite direction.

To force outdoor air through a shelter, an air-supply KAP can be used either as an air-intake pump (see Fig. 1) by pulling it with a cord, or as an air-exhaust pump by pushing it with a pole (see Fig. 24).

For distributing air within a shelter and/or fanning the occupants, an air-distribution KAP may be hung overhead and operated as described later.

ORNL-DWG 66-12319

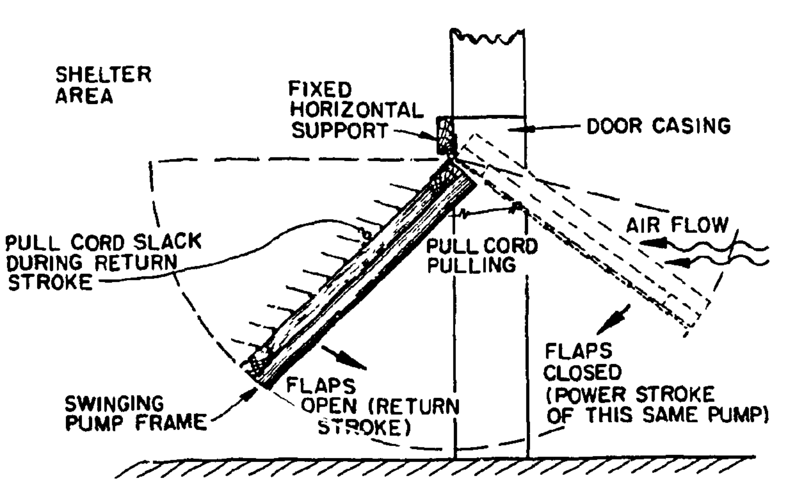


Fig. 1. Section through doorway showing operation of Kearny Air Pump.

ORNL-DWG 66-12320

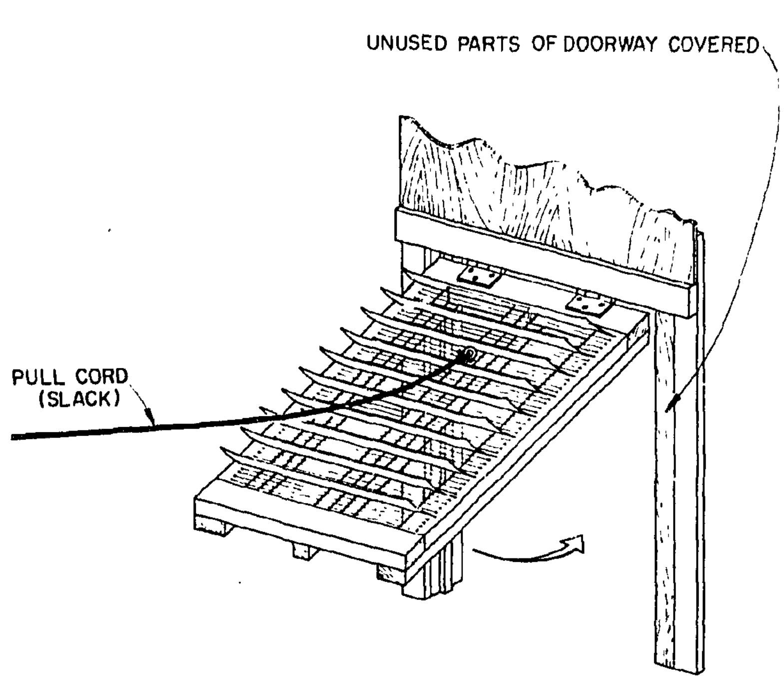


Fig. 2. KAP in doorway (with flaps open during its return stroke).

III. INSTRUCTIONS FOR BUILDING A KEARNY AIR PUMP

A. Materials Needed to Build a KAP 36 in. High by 29 in. Wide

The preferred material is listed first, and second and third choices of materials for each use are listed in order. It is best to spread out and check all your materials before you start building.

1. For the wooden pump frame (Fig. 3) and its fixed support:

a. A total of 22 ft of 1 in. X 2 in. boards. (A 1 in. X 2 in. board actually measures $\frac{3}{4}$ in. X $1\frac{3}{4}$ in., but the usual, nominal dimensions will be listed.) Also, 6 ft of 1 in. X 1 in. boards, all preferably soft wood. (If you have boards with approximately 1 in. X 2 in. dimensions, use them.) No single piece need be longer than 3 ft. (Even straight sticks, metal rods, etc., can be used to make a flat-faced frame.)

b. For the fixed horizontal support, a length of 1 in. X 4 in. (or 1 in. X 3 in., or 1 in. X 2 in.) lumber that is at least 1 ft wider than the opening in which you plan to swing your pump.

c. A pair of ordinary door or cabinet butt hinges (or metal strap hinges, or improvised hinges made out of leather, woven straps, or cords, or four eyescrews which can be joined to make two hinges).

d. Small nails (at least 18; No. 6 box nails are best – about ½ in. longer than the thickness of the two boards, so the nails can be bent over and clinched), plus screws or nails for the hinges.

2. For the flaps (see Figs. 1, 2, 6, 7, and 8):

a. 30 ft of smooth, straight wire at least as heavy and springy as coat hanger wire, to make the flap pivot-wires (or 10 wire coat hangers, or 35 ft of thinner smooth wire, or about 35 ft of string, preferably nylon string about the diameter of coat hanger wire).

b. 30 small staples (or 30 very small nails, or 60 tacks), to attach the flap pivot-wires to the frame.

c. 12 square feet of polyethylene film, best only about 3 or 4 mils (3 or 4 one-thousandths of an inch) thick, in pieces at least 30 in. wide (or plastic drop cloth; or raincoat-type, light, coated fabric; or even tough paper as a last choice, in pieces capable of being cut into ten rectangular strips, each 30 in. X 5½ in.).

d. Pressure-sensitive waterproof tape, such as cloth duct tape or glass tape that does not stretch and then shrink afterwards and wrinkle the flaps (or adhesive, Scotch, or masking tape) – enough to make 30 ft of tape ¾ in. to 1 in. wide – to secure the hem tunnels of the flaps. Or use needle and thread to sew the hem tunnels of the flaps.

3. For the flap-stops:

a. 150 ft of light string (or 150 ft of light smooth wire, or very strong thread)

b. 90 tacks, or 90 very small nails. (Tacks or nails are desirable but not essential, since the flap-stops can be tied to the frame.)

4. For the pull-cord:

At least 10 ft of cord (or strong string or wire).

B. Desirable Tools

Hammer, saw, wirecutter pliers, screwdriver, scissors, knife, yardstick, and pencil.

C. Steps to Build a 36 in. X 29 in. Kearny Air Pump

A 36 in. X 29 in. KAP is most effective if operated in an air-intake or exhaust opening about 40 in. high and 30 in. wide. (If your shelter could have more than 25 occupants in hot weather, read all these instructions, so you will understand how to build a larger pump, as briefly described in a following section.)

NOTE THAT THE WIDTHS AND THICKNESSES OF ALL FRAME PIECES ARE EXAGGERATED IN ALL ILLUSTRATIONS.

1. The frame

a. Cut two pieces of 1 in. X 2 in. boards, each 36 in. long, and two pieces of 1 in. X 2 in. boards, each 29 in. long; then nail them together (see Fig. 3). Use nails that do not split the wood, preferably long enough to go through the boards and stick out about ½ in. on the other side. (To nail thus, first block up the frame so that the nail point will not strike the floor.) Then bend over nail points which go through.

Next, cut and nail onto the frame a piece of approximately 1 in. X 1 in. lumber 36 in. long, for a center vertical brace. (If you lack time to make or find a 1 in. X 1 in. board, use a 1 in. X 2 in. board.) Figure 3 shows the back side of the frame; the flap valves will be attached on the front (the opposite) side.

b. To make the front side smooth and flat so that the flaps will close tightly, fill in the spaces as follows: cut two pieces of 1 in. X 2 in. boards long enough to fill in the spaces on top of the 36-in. sides of the frame between the top and bottom horizontal boards; nail them in place. Do the same thing with a 1 in. X 1 in.

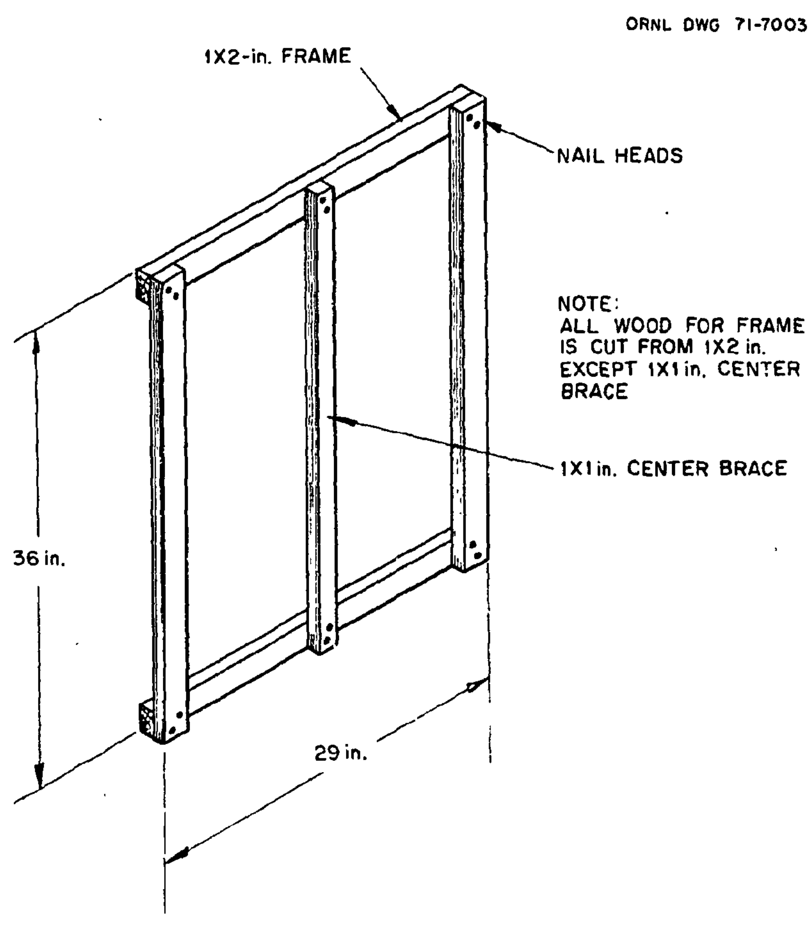


Fig. 3. KAP frame (looking at the back side of the frame).

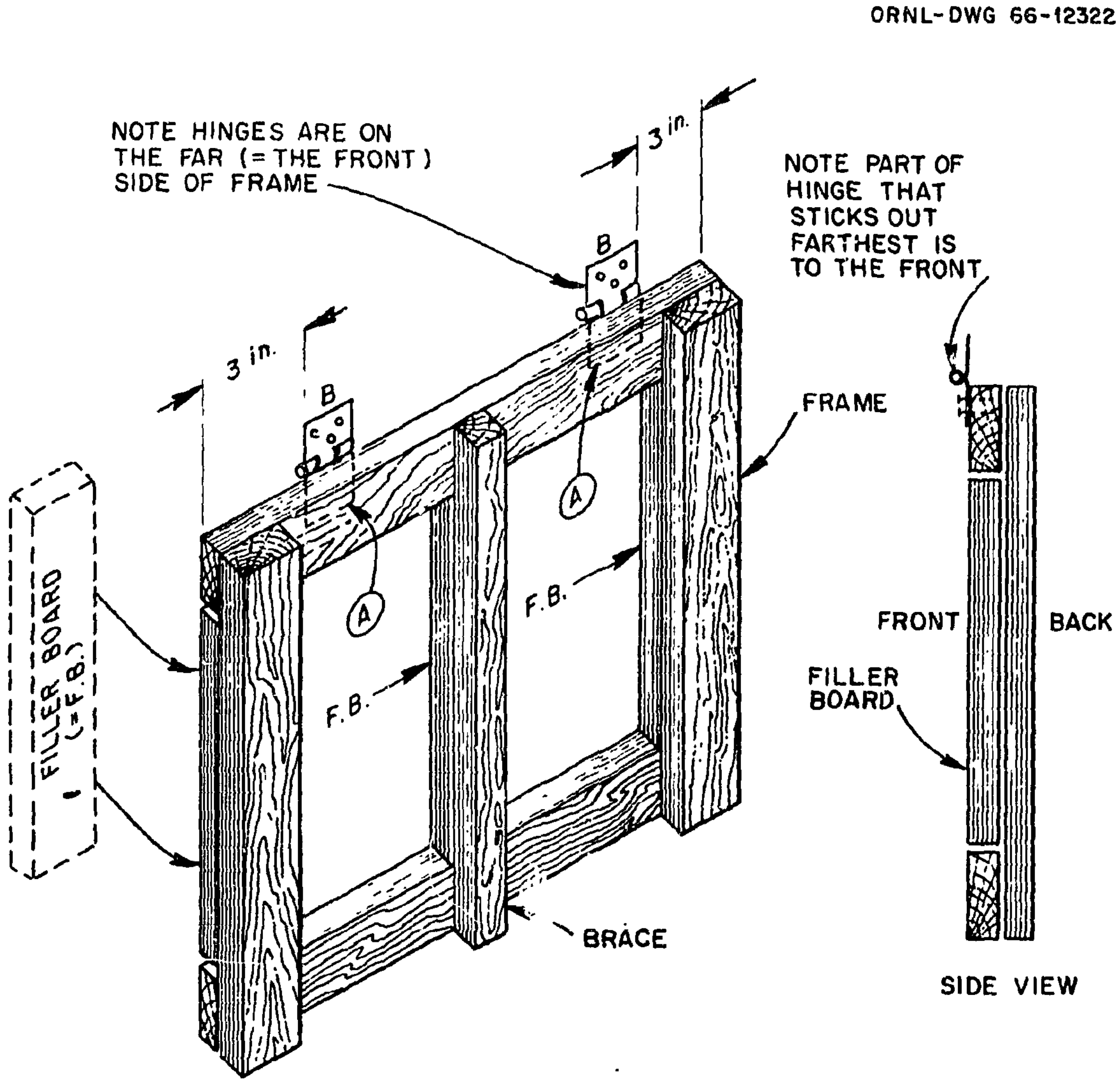


Fig. 4. Completing the frame.

board (or whatever size board you used for the center brace) as a filler board for the center brace (see Fig. 4).

If the frame is made of only one thickness of board $^3/_4$ to 1 in. thick, it will not be heavy enough to swing back far enough on its free-swinging return stroke.

2. The hinges

Ordinary door butt hinges are best, but, in order that the pump can swing even past the horizontal position, the hinges should be screwed onto the top of the frame (pick one of the 29-in. boards and call it the top) in the positions shown in Fig. 4. (If you lack a drill to drill a screw hole, you can make a hole by driving a nail and then pulling it out. Screw the screw into the nail hole.)

3. The flaps

a. Make 10 flap pivot-wires. If you have smooth, straight wire as springy and thick as the wire of coat hangers, make ten $28^1/_2$-in.-long straight lengths of wire. If not, use wire from coat hangers, or strings. First, cut off all of the twisted and hooked vertical "handle" part of each coat hanger. If you have only ordinary pliers, use its cutter to "bite" the wire all around; then it will break at this point if you bend it there. Next, straighten each wire carefully. Straighten all the minor bends so that each wire is straight within $^1/_4$ in. Proper straightening takes 1 to 5 minutes per wire. To straighten, repeatedly grasp the bent part of the wire with pliers in slightly different spots, each time bending the wire a little with the other hand. Finally, cut each wire to $28^1/_2$-in. lengths.

b. Make 10 polyethylene flaps. First cut ten strips, making each strip 30 in. long by $5^1/_2$ in. wide (see Fig. 5). To cut plastic flaps quickly and accurately, cut a long strip of plastic 30 in. wide. Then cut off a flap by: (1) drawing a cutting guideline on a wide board $5^1/_2$ in. from an edge; (2) placing the 30-in.-wide plastic strip clear across this board, with its end edge just reaching the edge of the board; (3) placing a second board over the plastic on the first board, with a straight edge of this second upper board over the guideline on the lower board, and, finally (4) cutting off a flap by running a sharp knife along the straight edge of the upper board.

To form a hem along one of the 30-in. sides of a $5^1/_2$ in. × 30 in. rectangular strip, fold in a 1-in. hem. To

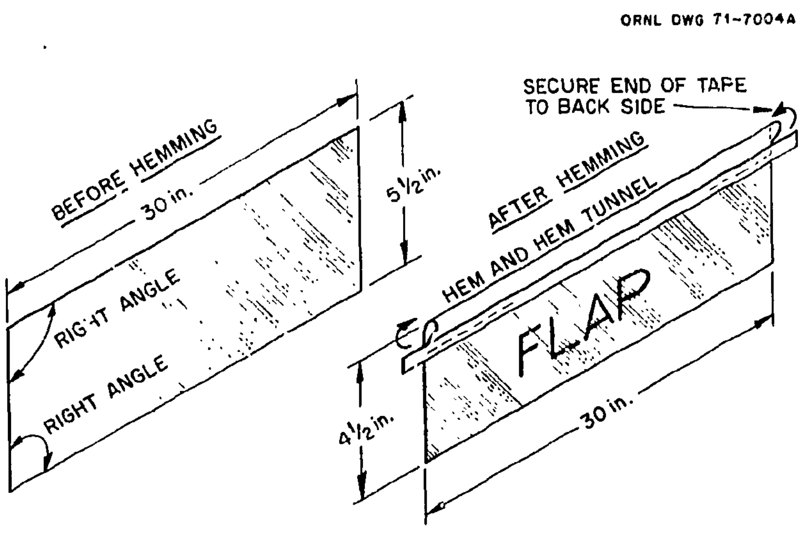


Figure 5.

hold the folded hem while taping it, paper clips or another pair of hands are helpful. Make each hem with two pieces of pressure-sensitive tape, each about 1 in. wide and 16 in. long. Or make the hem by sewing it shut very close to the cut edge, to form a hem-tunnel (see Fig. 5).

After the hem has been made, take a pair of scissors and cut a notch (see Figs. 6 and 8) in each hemmed corner of the flap. Avoid cutting the tape holding the hem. This notch should extend downward about $\frac{1}{2}$ in. and should extend horizontally from the outer edge of the flap to $\frac{1}{4}$ in. inside the inner side of the frame, when the flap is positioned on the frame as shown in Fig. 6.

Also, cut a notch in the center of the flap (along the hem line) so that this notch extends $\frac{1}{2}$ in. downward and extends horizontally $\frac{1}{4}$ in. beyond each of the two sides of the vertical brace (see Fig. 6). [But if you are building a pump using wire netting for the flap-stops (see Fig. 13), then do <u>NOT</u> cut out a notch in the center of a flap.]

c. Take the 10 pieces of straightened wire and insert one of them into and through the hem-tunnel of each flap, like a curtain rod running through the hem of a curtain. Check to see that each flap swings freely on its pivot-wire, as illustrated by Fig. 7 End View. Also see Fig. 8.

d. Put the flaps and their pivot-wires to one side for use after you have attached the flap-stops and the hinges to the frame, as described below.

e. Using the ruler printed on the edge of this page, mark the positions of each pivot-wire (the arrowheads numbered 0, $3\frac{1}{4}$, $6\frac{1}{2}$, $9\frac{3}{4}$ in.) and the position of each flap-stop (the four unnumbered marks between each pair of numbered arrowheads on this ruler). All of these positions should be marked both on the vertical sides of the 36-in.-long boards of the frame and on the vertical brace. Mark the position of the uppermost pivot-wire (the "0" arrowhead on this ruler) $\frac{1}{4}$ in. below the top board to which the hinges have been attached (see Figs. 9 and 10).

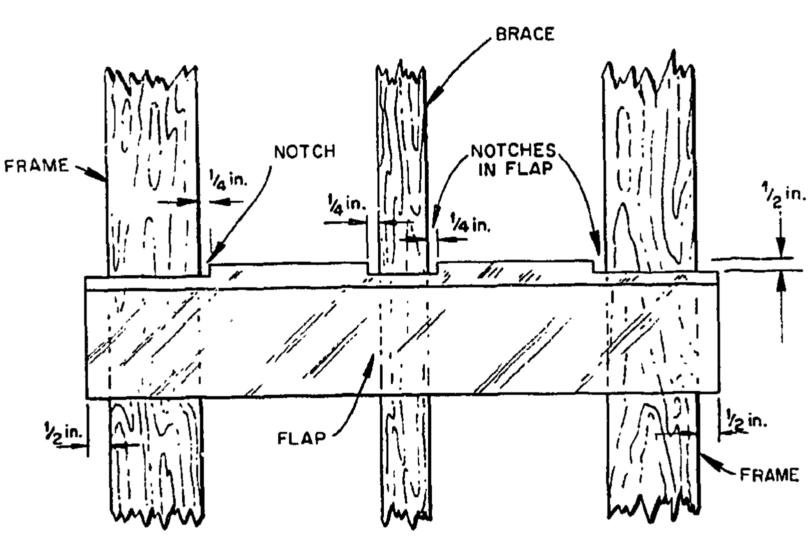


Fig. 6. Size of notches in flaps.

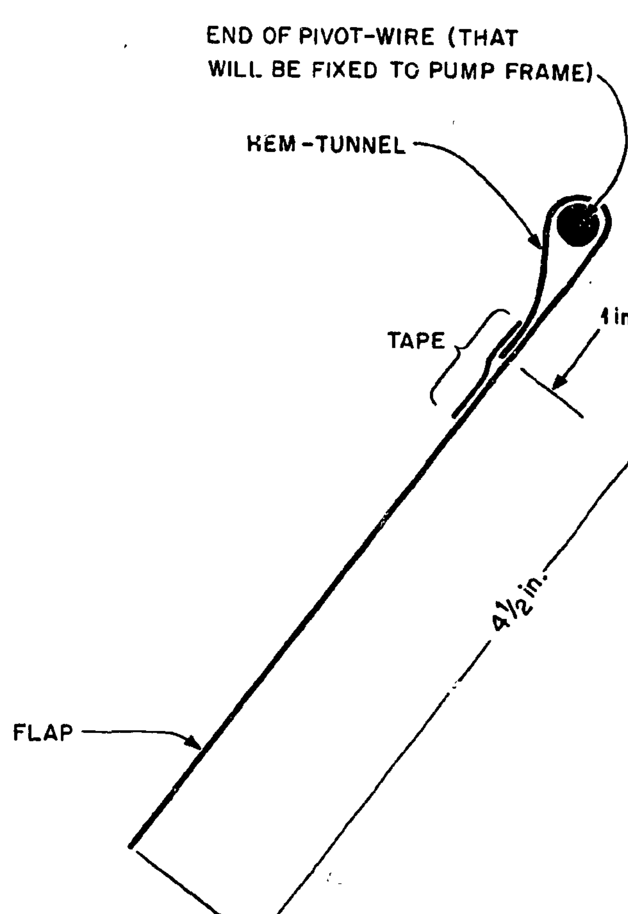
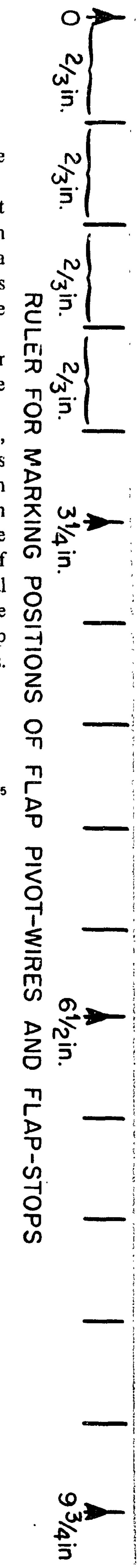


Fig. 7. End view.



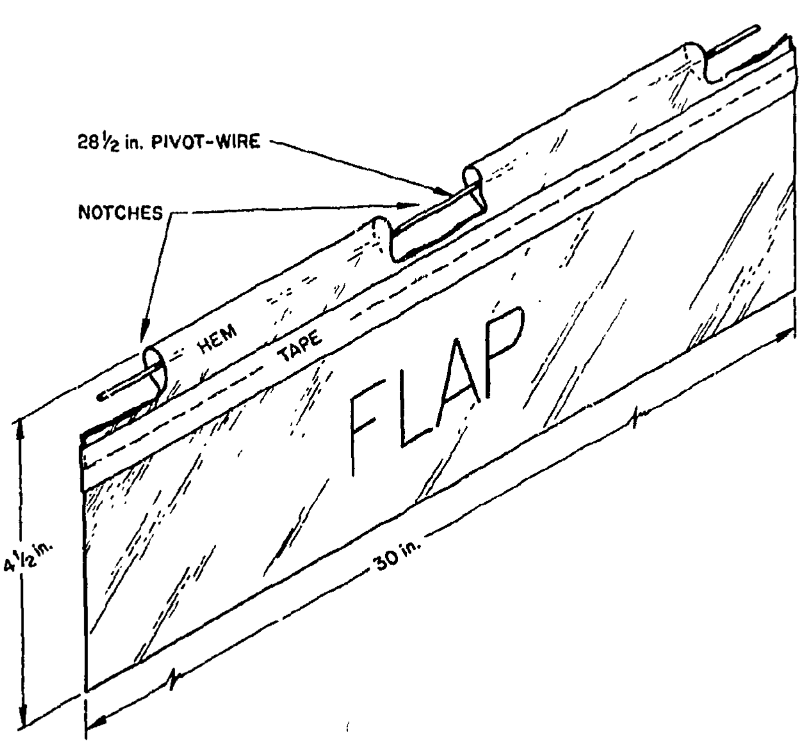


Figure 8.

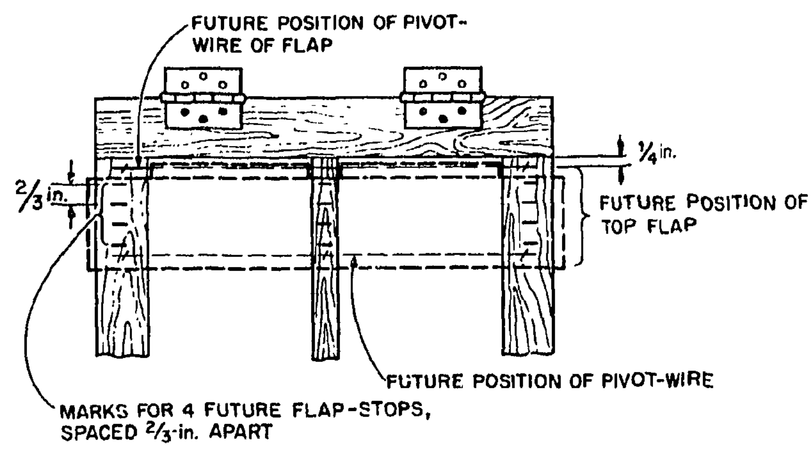


Figure 10.

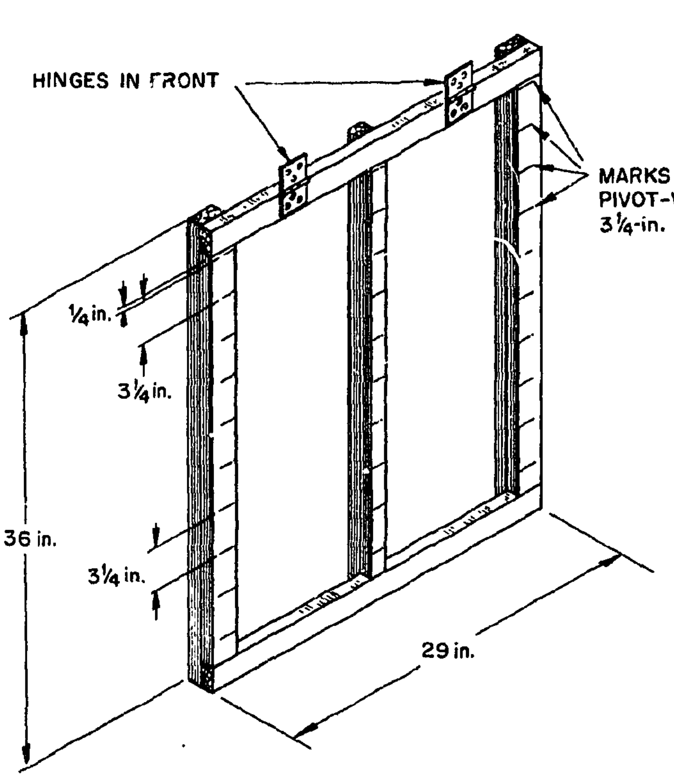


Figure 9.

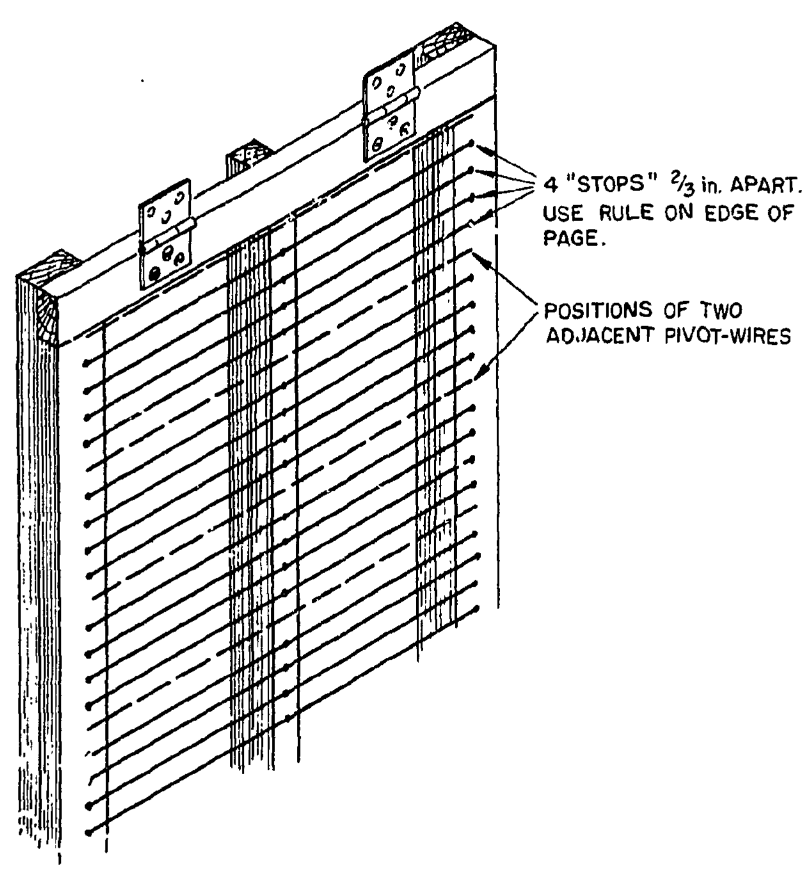


Figure 11.

4. The flap-stops

In order that the flaps may turn (open) on only one side (the front, or face) of the frame, you must attach horizontal flap-stops (strings or wires) across the face of the frame (see Figs. 10 and 11). You should nail or tie four of these flap-stops between each pair of the marked future positions of the horizontal pivot-wires of the flaps, being careful not to connect any flap-stops so that they cross the horizontal open spaces in which you later will attach the flap pivot-wires.

If you have tacks or very small nails, drive three in a horizontal line to attach each flap-stop – two in the vertical 36-in. sides of the frame and one in the vertical center brace (see Fig. 11). First, drive all of these horizontal lines of tacks about three-quarters of the way into the boards. Then, to secure the flap-stop string or thin wire quickly to a tack, wind the string around the tack and immediately drive the tack tight to grip the string (see Fig. 11). (If you lack tacks or nails, merely cut notches where the flap-stops are to be attached; cut these notches in the edges of the vertical sides of the frame and in an edge of the center brace.) Next, secure the flap-stops (strings or wires) in their proper positions by tying each stop in its notched position. This tying should include wrapping each horizontal flap-stop once around the vertical center brace. The stops should be in line with (in the same plane as) the front of the frame. Do not stretch stops too tight, or you may bend the frame.

5. Final assembly

a. Staple, nail, tack, or tie the ten flap pivot-wires, or pivot-strings (each with its flap on it) in their marked positions, at the marked $3\frac{1}{4}$-in. spacings. Start with the lowest flap and work upward (see Fig. 11). Connect each pivot-wire at both of its ends to the 36-in. vertical sides of the frame, and also connect it to the vertical center brace. BE CAREFUL TO NAIL THE PIVOT-WIRES ONLY TO THE FRAME AND THE BRACE AND DO NOT NAIL ANY PLASTIC DIRECTLY TO THE WOOD.

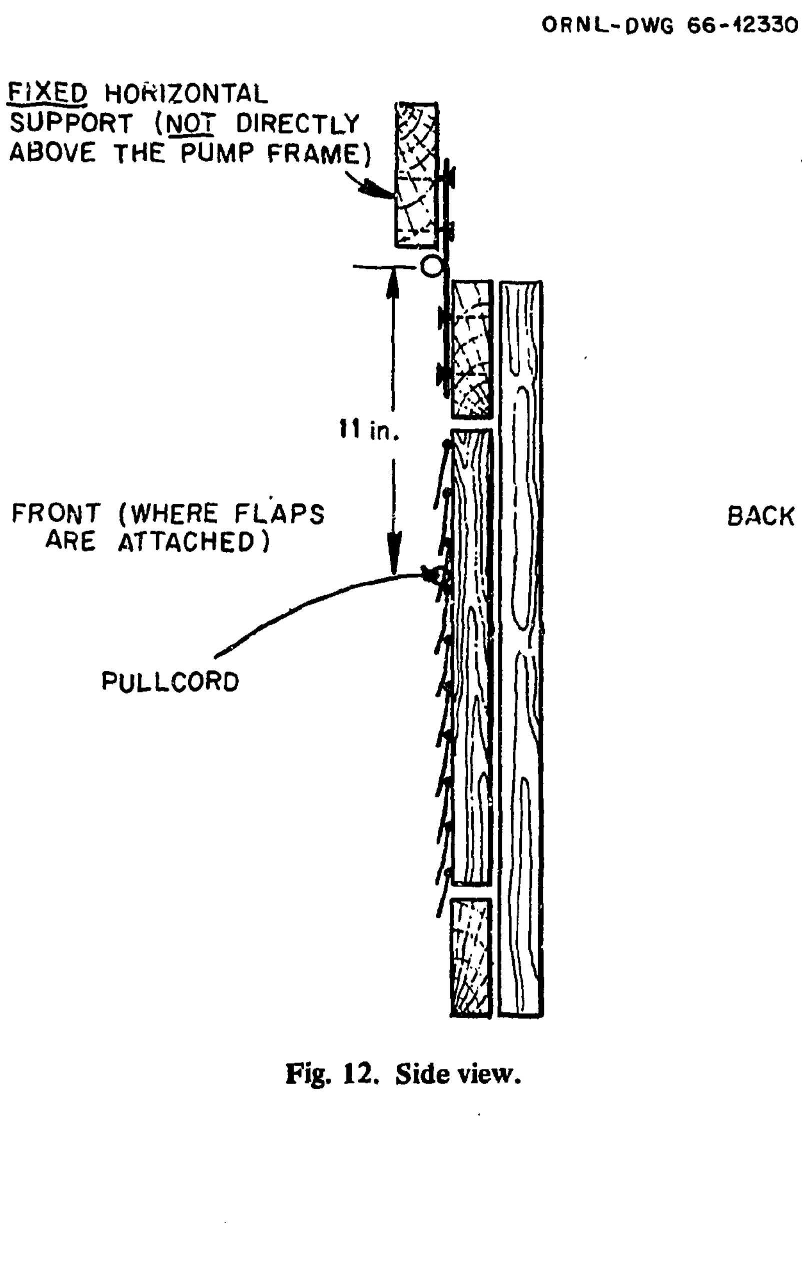


Fig. 12. Side view.

b. Screw or nail the upper halves of the hinges onto the horizontal fixed support board on which the KAP will swing. (A 1 in. X 3 in. board, at least 12 in. wider than the doorway or other opening for this KAP, is best.)

Be careful to attach the hinges in the UNusual, OUT-OF-LINE POSITION shown in Fig. 12.

CAUTIONS: Do NOT attach a KAP's hinges directly to the door frame; if you do, its hinges will be torn loose on its return stroke, or on its power stroke.

If you are making a KAP to fit into an opening, make your KAP 4 in. SHORTER than the height of its opening.

c. For this 3-ft model, tie the pull-cord to the center brace 11 in. below the hinge line. (If you tie it lower, your arm movements will waste energy.) Use small nails or wire to keep the tie from slipping up or down on the center brace. For a more durable connection, see Fig. 22.

IV. A QUICKER CONSTRUCTION

(Skip this section if you cannot easily get chicken wire and $\frac{1}{4}$-in.-thick boards.)

If chicken wire and boards about $\frac{1}{4}$ in. thick are available to use as the flap-stops, the time required to build a given KAP can be reduced by about 40%. One-inch woven mesh is best. (Hardware cloth has sharp points and is unsatisfactory.)

Figure 13 illustrates how the mesh wire should be stapled to the KAP frame. Next, unless the KAP is wider than 3 ft, the front of the whole frame, except for the center brace, should be covered with thin boards approximately $\frac{1}{4}$ in. thick, such as laths. Then the pivot-wires, with their flaps on them, should be stapled onto the $\frac{1}{4}$-in.-thick boards. This construction permits the flaps to turn freely in front of the chicken-wire flap-stops.

With this design, the center of each pivot-wire should NOT be connected to the center brace, nor should the center of the flap be notched. However, the pivot-wires attached this way must be made and held straighter than the pivot-wires used with flap-stops made of straight strings or wires. Or strong pivot-strings should be used. Note in Fig. 13 that each pivot-wire is held firm and straight by two staples securing each of its ends. The wire used should be at least as springy as coat hanger wire. For pivot-strings, nylon about the diameter of coat hanger wire is best.

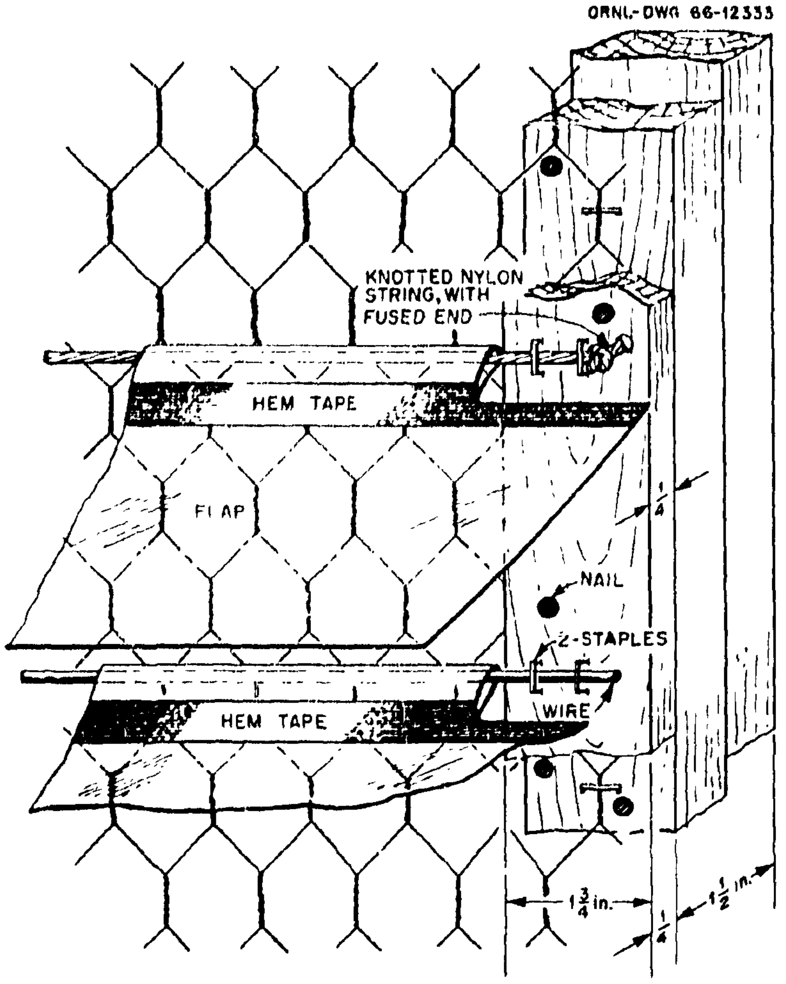


Figure 13.

If the KAP is wider than 3 ft, then the center vertical brace should also be covered with a $\frac{1}{4}$-in.-thick board, the center of each flap should be notched, and the center of each pivot-wire (or pivot-string) should be attached to the center brace.

V. INSTALLATION

A. Minimum Open Spaces Around a KAP

To pump its maximum volume, an air-supply KAP with good hinges should be installed so that it swings only about $\frac{1}{2}$ in. above the bottom of its opening and only $\frac{1}{2}$ to 1 in. from the sides of its opening.

B. Large Enough Air Passageways

When using a KAP as an air-supply pump to force air through a shelter, it is essential to provide a low-resistance air passageway all the way through the shelter structure from an outdoor air-intake opening to a separate, outdoor air-exhaust opening (see Fig. 14).

For an air-supply KAP, a low-resistance air passageway is one that is no smaller in any of its cross-sectional areas than one-half the size of the KAP pumping the air – for example, not smaller than about $3\frac{1}{2}$ square feet for a 36 in. X 29 in. KAP. Then this size air-supply KAP will force through such a shelter at least 1000 cubic feet per minute (cfm), provided it is installed as illustrated in Fig. 14.

If smaller air passageways or air-exhaust openings are provided, the volume of air pumped will be greatly reduced. For example, if the air-exhaust opening is only $1\frac{3}{4}$ square feet (that is, only $\frac{1}{4}$ the size of this KAP), then this KAP will pump only about 500 cfm. And if the air-exhaust opening is only a 6 in. X 6 in. exhaust duct ($\frac{1}{4}$ square foot), then this same 36 in. X 29 in. KAP will pump only about 50 cubic feet per minute – not enough outdoor air for more than one shelter

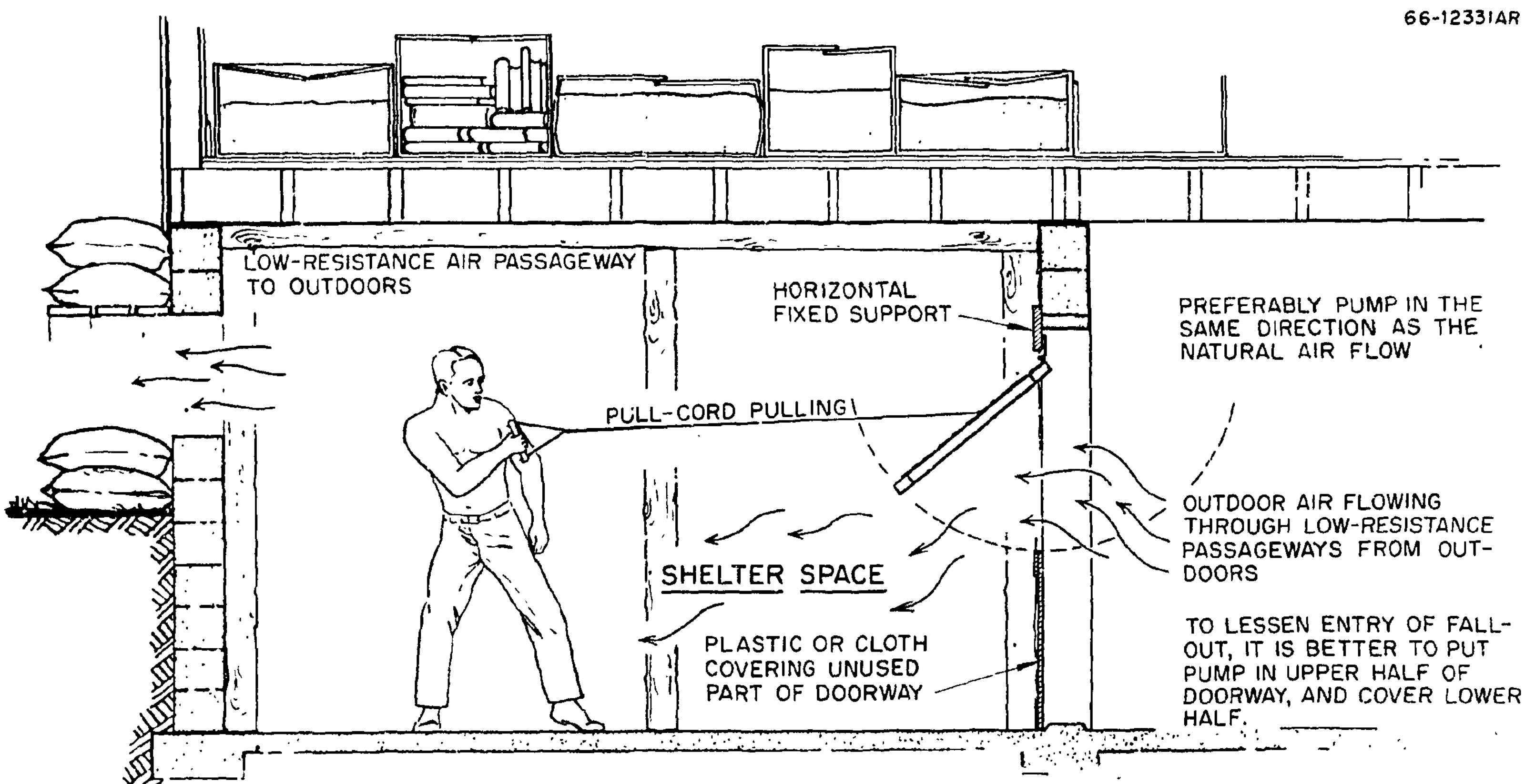


Figure 14.

ORNL DWG 72-6630

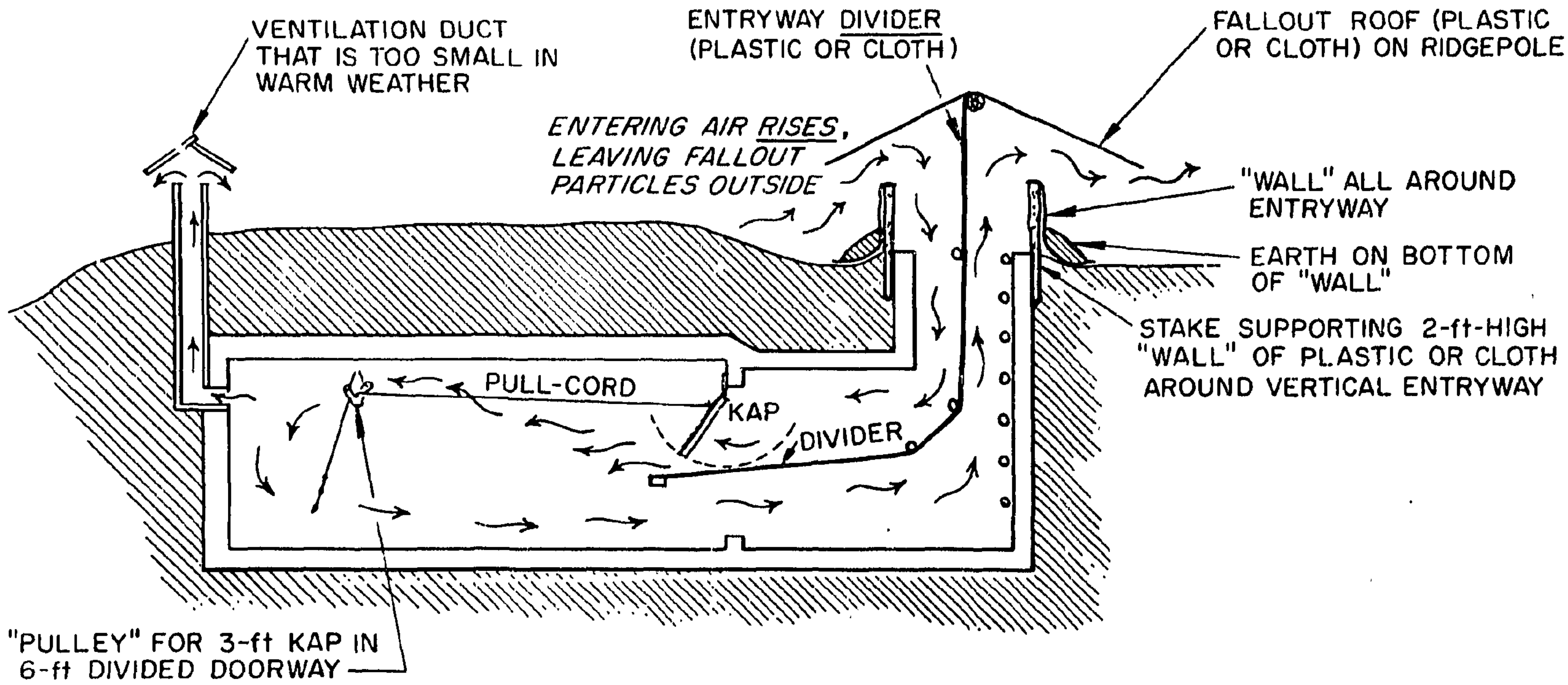


Figure 15.

occupant in a well-insulated shelter under heat-wave conditions in one of the hotter parts of the United States. In contrast, when the weather is cold, and while the shelter itself is cold enough to absorb the heat produced by the shelter occupants, this same 6 in. X 6 in. exhaust duct and the air-intake doorway will cause about 50 cfm of outdoor air to flow by itself through the shelter without using any pump. This is because in cold weather body heat warms the shelter air, and warm air rises. Under these cold conditions – provided the air is distributed evenly throughout the shelter by KAP or otherwise – 50 cfm is enough outdoor air for about 17 people.

To provide adequately large air passageways for air-supply KAP's to ventilate shelters in buildings, in addition to opening and closing doors and windows, you may have to build large ducts (as described below), or even break holes in windows, ceilings, or walls to make large, efficient air passageways.

Figure 15 illustrates how a 3-ft KAP can be used as a combined air-supply and air-distribution KAP to adequately ventilate a small underground shelter with an exhaust opening too small to provide adequate ventilation in warm weather. (A similar installation can be used to ventilate a basement room having only one opening, its doorway.) Note how, by installing a "divider" in the doorway and entryway, the single entryway is converted into a large air-intake duct and a separate, large air-exhaust duct. To attain the maximum increase in volume of fresh outdoor air that can be pumped through the shelter – a total of about 1000 cfm for a 36 in. X 29 in. KAP – the "divider" should extend about 4 ft horizontally into the shelter room, as shown in Fig. 15. The end 6 ft of the "divider" (the approximately horizontal part under the KAP) advantageously can be made of plywood, provided it is so installed that it can be jerked out of the way in a few seconds.

Note also how the entry of fallout into a shelter can be minimized by covering the entryway with a "roof" and by forcing the slow-moving entering air to rise over an obstruction (the "wall") before it flows into the shelter.

C. Adequate Distribution of Air Within Your Shelter

To make sure that each shelter occupant gets his fair share of the outdoor air pumped through the shelter, air-distribution KAP's should be used inside most large shelters. Air-distribution KAP's are used within the shelter, separate from and in addition to air-supply KAP's (see Fig. 16). Air-distribution KAP's can serve in place of both air-distribution ducts and cooling fans. For these purposes, one or more 3-ft KAP's hung overhead from the shelter ceiling are usually most practical. If KAP's cannot be readily hung from the ceiling, they can be supported on light frames made of boards or metal, somewhat like those used for a small child's swing.

You should make and use enough KAP's to cause air movement that you can feel in all parts of your shelter.

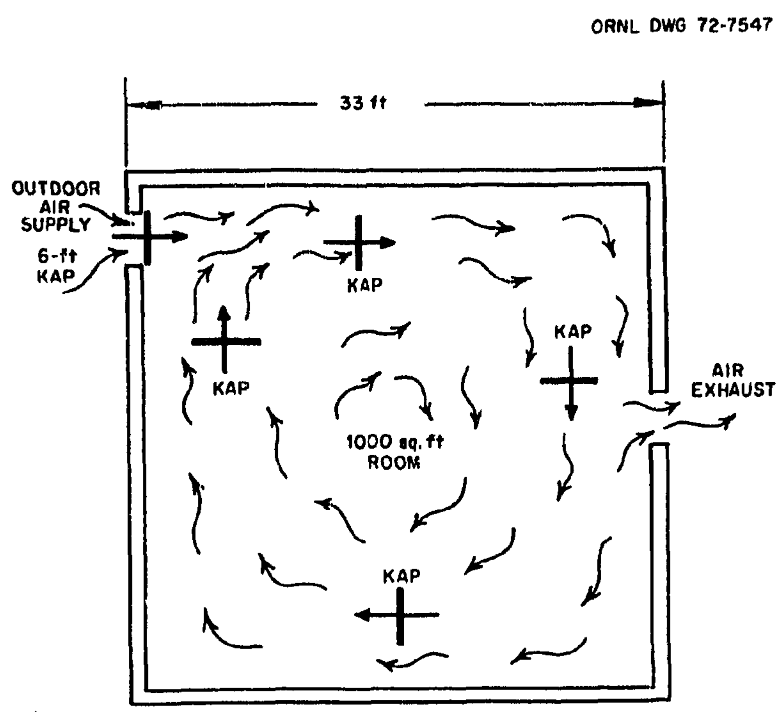


Figure 16.

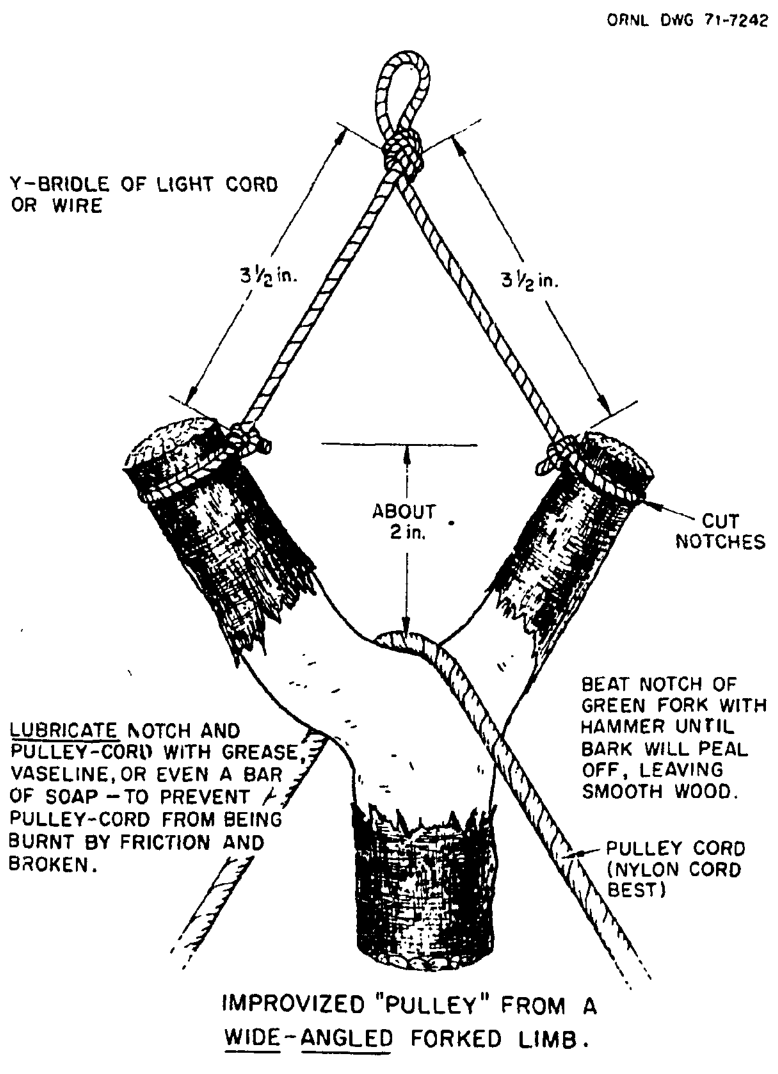


Figure 17.

Remember that if KAP's are installed near the floor and the shelter is fully occupied, then the occupants' bodies will partially block the pumped airflows more than if the same KAP's were suspended overhead.

As a general rule, for shelters having more than about 20 occupants, you should provide one 3-ft air-distribution KAP for every 25 occupants. In relatively wide shelters, these interior KAP's should be positioned so that they produce an airflow that circulates around the shelter and prevents the air that is being pumped into the shelter from flowing directly to the exhaust opening. Figure 16 illustrates how four KAP's can be used in this manner to distribute the air within the shelter and to fan the 100 occupants of a 1000 square foot shelter room. You should avoid positioning an air-distribution KAP so that it pumps air in a direction at more than a right angle to what will be the final direction of airflow in its location.

D. Operation with a Pulley

A small KAP, if installed at head height or higher, can be pulled most easily by running its pull-cord over a pulley, or over a greased homemade "pulley," such as one of those described in Figs. 17 and 18. The pulley, or "pulley," should be hung at approximately the same

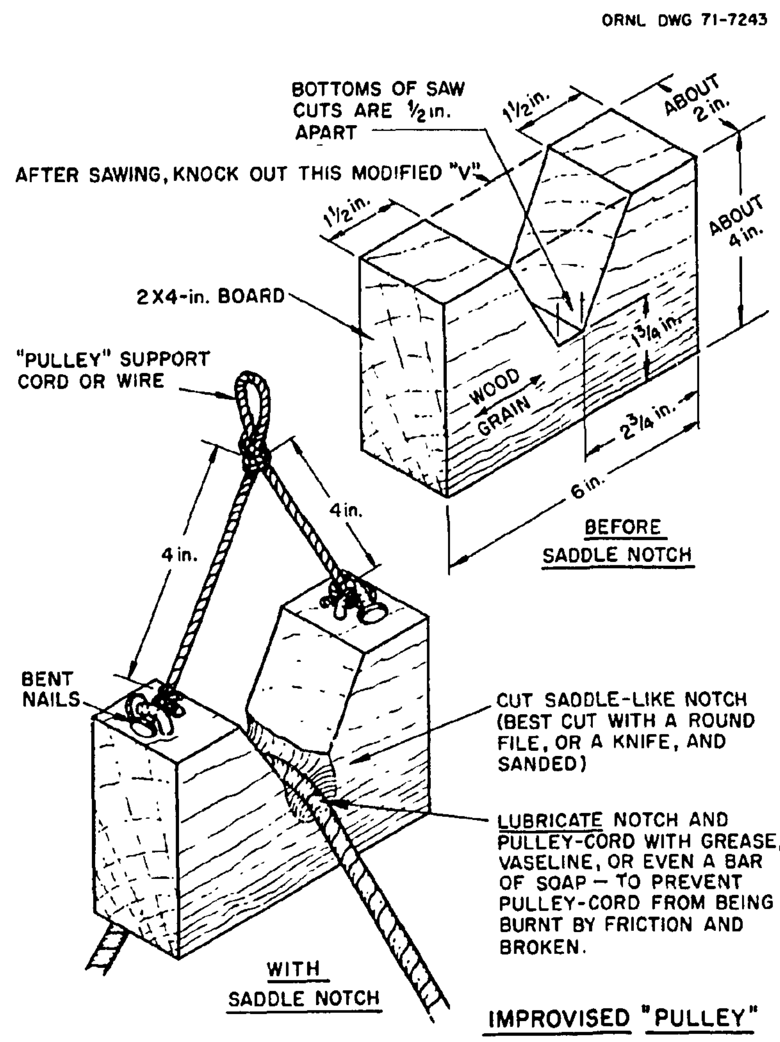


Figure 18.

height as the hinges of the KAP, as illustrated in Fig. 15. To make a comfortable hand hold on which to pull downward on the end of the pull-cord, tie two or three overhand knots in a strip of cloth.

Such a "pulley" can also be used to operate a bail bucket remotely to remove water or wastes from a shelter.

E. Quick-Removal Brackets

The air-supply KAP that pumps air through your shelter is best held in its pumping position by mounting it in quick-removal brackets, for the following reasons:

1. A KAP provided with quick-removal brackets can easily be taken down and kept out of the way of persons passing through its doorway when it is not in use. It can be kept in a place where people are unlikely to damage it (see Fig. 19).
2. By installing two or more sets of quick-removal brackets, you can quickly reverse the direction in which your KAP pumps air, and thereby take advantage of changes in the direction of natural airflows through your shelter.
3. If you install your KAP on quick-removal brackets, then, if an emergency arises, in 3 or 4 seconds a man standing beside your KAP could grasp its frame with both hands, lift it upward a few inches to detach it, and carry your KAP out of the way. This ability could enable you to prevent hurricane-like blast winds

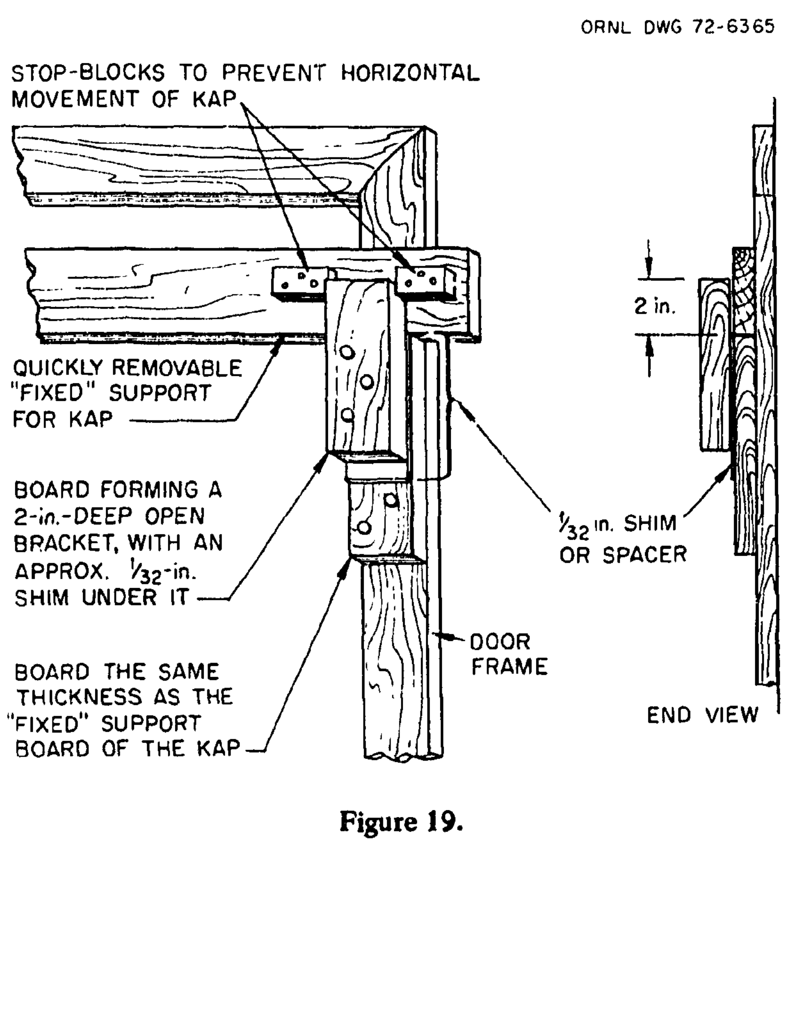


Figure 19.

(that in extensive areas around a nuclear explosion would cause damage without destroying shelters) from wrecking your KAP and possibly injuring shelter occupants -- as described in more detail in VI. C., below.

Note that the KAP's "fixed" support board (to which its hinges are attached) is supported in a bracket only 2 in. deep.

To prevent too tight a fit in the bracket, be sure to place a $^1/_{32}$-in. shim or spacer (the cardboard back of a writing tablet will serve) between two boards of the bracket, as illustrated. Also, make about $^1/_{16}$-in. spaces between the lower inner corners of the stop-blocks and the sides of the outer board. And, to prevent possibly cutting your hands, you should tape over the exposed ends of wires near the outer edges of the frame of a KAP that you intend to remove rapidly.

VI. OPERATION AND MAINTENANCE

A. Pumping

You can operate your 3-ft KAP by pulling it with an easy, swinging motion of your arm. To pump the maximum volume of air, you should pull it toward you until its frame swings out almost horizontal. Then you should quickly move your hand so that the pull-cord is kept slack during the entire, free-swinging return stroke. Figure 22, in the following section on LARGER PUMPS, illustrates this necessary motion.

Be sure to provide a comfortable hand hold on your pull-cord. Blisters can be serious under unsanitary conditions (see Fig. 21).

To pull a KAP via an overhead pulley with minimum effort, sit down and pull as if you were tolling a bell – except you should raise your hand and keep it raised – so that the pull-cord remains slack, during the entire return stroke. Or move back away from the pulley and operate the KAP by swinging your extended arm back and forth from the shoulder.

B. Taking Advantage of the Natural Direction of Air Flow

A KAP can pump more air through a shelter if it is installed so that it pumps air through the shelter in the direction in which the air naturally flows. Since this direction can be reversed by a wind change outdoors, it is desirable to provide means for quickly removing your pump and repositioning it so that it pumps air in the opposite direction. This can be done by making one set of quick-removal brackets in one air opening and a second set in the other.

C. Using Quick-Removal Brackets to Reduce Blast Hazards

Beyond the area in which shelters are actually wrecked by a nuclear explosion is a much larger area in which injuries can be caused by this same explosion. As an extreme example, a 25-megaton weapon, if surface bursted at a distance of 9.2 miles away, can produce blast overpressures of 4 pounds per square inch (psi), with accompanying blast winds blowing 130 miles per hour. Nineteen miles away, the blast overpressure is reduced to about 1.4 psi, and the velocity of the blast wind is only some 50 mph.

However, over these extensive areas in which most fallout shelters would survive, hurricane-like blast winds would rush into the surviving fallout shelters. The relatively low-level shock waves and blast winds experienced in these areas could pick up a KAP or other object that remained in a doorway and could hurl it into the shelter room. Shelter occupants could be injured if they were hit by such flying objects, whereas they probably would not be hurt by the hurricane-velocity winds themselves if they had taken protective action.

Shelter occupants expecting an attack should be ready, if they see a very bright flash, to get out of the path of the blast winds that might soon enter, and to lie down on the floor.

Between the moment a typical foreign nuclear weapon would explode and give off a very bright light, and the moment the shock wave and blast winds would reach a fallout shelter located far enough away so as not to be destroyed, enough time would elapse to permit prepared shelter occupants to get KAP's and themselves out of entryways and other pathways of entering shock waves and blast winds. For example, at a point 3 miles away from a one-megaton surface burst, the maximum unreflected overpressure is 4.2 psi, and the accompanying blast wind blows about 130 mph and takes 9 seconds to arrive. At the same overpressure and wind velocity from a 10-megaton surface burst, the distance is 6.5 miles, and the time interval is about 20 seconds.

If a 6-ft KAP is supported in a quick-removal bracket (see Figs. 19 and 27), then a man standing beside it can – within 3 or 4 seconds of seeing a bright flash – grasp the pump frame with both hands, lift it upward a few inches, and carry the KAP out of the way.

D. Maintenance

To operate your KAP efficiently, you must keep its flaps in good repair and make sure that there is the minimum practical area of open spaces (both in and around the KAP) through which air can flow back, in the opposite to the pumped direction. Therefore, keep in your shelter at least some extra flap material, some extra tape, and the few tools you may need to make repairs.

VII. LARGER KEARNY AIR PUMPS

A. Construction

A 6-ft-high by 29-in.-wide model can be constructed in the same way as a 3-ft model – except that it should have a horizontal center brace (a board about $^3/_4$ in. thick and $1^3/_4$ in. wide is best), as well as a vertical center brace of this size board. To increase the strength of a 6-ft KAP, all parts of its double-thickness frame and its vertical center brace should be made of two thicknesses of approximately $^3/_4$ in. × $1^3/_4$ in. softwood boards, securely held together with clinched nails. Also, to increase the distance that the pump will swing back by itself during its return stroke, it is worthwhile to attach a 6-ft piece of $^3/_4$ in. × $1^3/_4$ in. board (not illustrated) to the back of each side of the frame. Do <u>not</u> attach weights to the bottom of the frame; this would slow down the pumping rate.

The flaps on the lower part of a large KAP must withstand hard use. But if $^1/_2$-in.-wide strips of tape are attached along the bottom and side edges of these lower flaps, then even flaps made of ordinary 4-mil polyethylene will remain serviceable for over 1000 hours of pumping. However, the lower flaps of large KAP's can advantageously be made of 6-mil polyethylene.

The pull-cord should be attached to the vertical center brace of a 6-ft KAP about $14^1/_2$ in. below the hinge line. A $^3/_{16}$-in. nylon cord is ideal.

To adequately ventilate and cool very large and crowded shelters in buildings, mines, or caves, KAP's larger than 72 in. × 29 in. should be used. You can take better advantage of large doorways, elevator shaft openings, etc., by "tailor-making" each air-supply KAP to the size of its opening – that is, by making it as large as is practical. The frame and brace members should be appropriately strengthened, and one or more "Y" bridles should be provided, as described in the section below. A 7 ft × $5^1/_2$ ft KAP, with a $^1/_4$-in. pull-cord attached 18 in. below its hinge line, and with two "Y" bridles, pumped over 11,000 cubic feet per minute through a large basement shelter.

To make a durable connection of the pull-cord to the center vertical brace you can: (1) Attach a wire loop (see Fig. 20) $14^1/_2$ in. below the hinge line; this loop

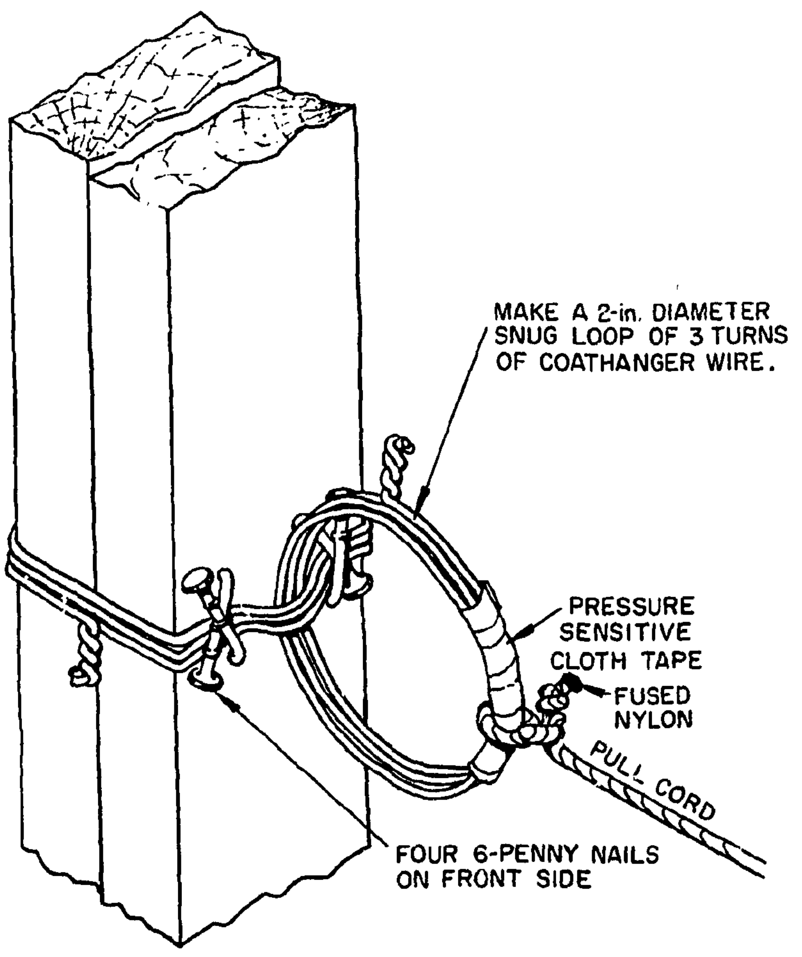


Figure 20.

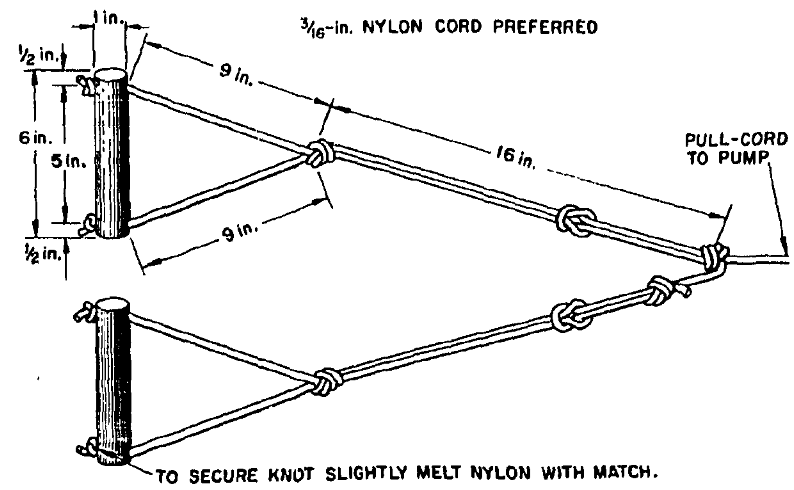


Fig. 21. Y-bridle for pull-cord on Kearny Air Pump.

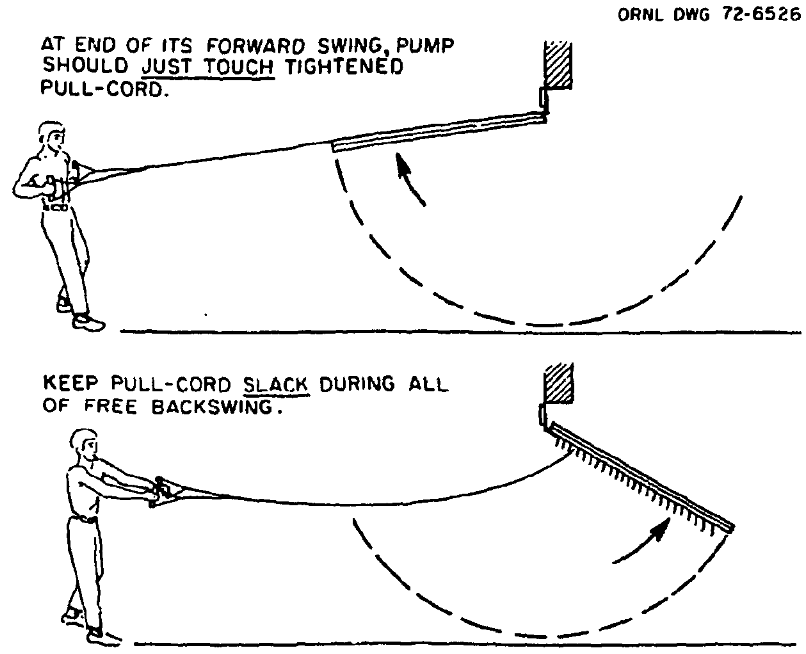


Figure 22.

should be made of coat hanger wire, or a softer single-strand wire, and should be kept from slipping on the center brace by bending four 6-penny nails over it in front, and two smaller nails in back. (2) Make a free-turning, triple-wire loop connected to the fixed loop. (3) Tape one end of the free-turning loop, and tie the pull-cord to this loop, tightly over the tape.

B. Operation of Larger KAP's

A larger KAP can be pulled most easily by providing it with a "Y" bridle (see Fig. 21) attached to the end of its pull-cord.

An average man can operate a 6 ft X 29 in. KAP by himself, pumping over 4000 cubic feet per minute through a typical large shelter, without working hard; tests have shown that he must deliver only about $\frac{1}{20}$th of a horsepower. However, most people prefer to work in pairs when pulling a 6-ft KAP equipped with a "Y" bridle.

To pump the maximum volume of air with minimum effort, study Fig. 22 and follow the instructions given below for operating a big KAP:

1. Gradually start the pump swinging back and forth, moving your arms and body as illustrated, and pulling mostly with your legs and body.

2. Stand at such a distance from the pump that you can pull the pump toward you until the forward-swinging pump just touches the tightly stretched pull-cord – and at such a distance that you can keep the pull-cord slack during the whole of the pump's free backswing.

3. To be sure you do not reduce the amount of air you pump, rapidly move your arms forward as soon as the forward-swinging pump touches the tightened pull-cord – and hold your arms forward until the pump again starts to swing toward you.

VIII. SOLUTIONS TO SPECIAL PROBLEMS

A. Increasing the Effectiveness of a KAP

If you want to increase the volume of air that a KAP can force through a shelter, you should install side baffles (see Fig. 23). Side baffles should be rigidly fixed to form two stationary "walls," one on each side of the swinging pump frame. They can be made of plywood, boards, doors, table tops, or even well-braced plastic. A space, or clearance, of ½ in. to 1 in. should be maintained between the inner side of each baffle and the outer side of the swinging frame.

Provided your KAP is in good repair and the openings around it are small, by installing side baffles you may be able to increase the volume of air it will pump by up to 20%.

ORNL-DWG 66-12334R

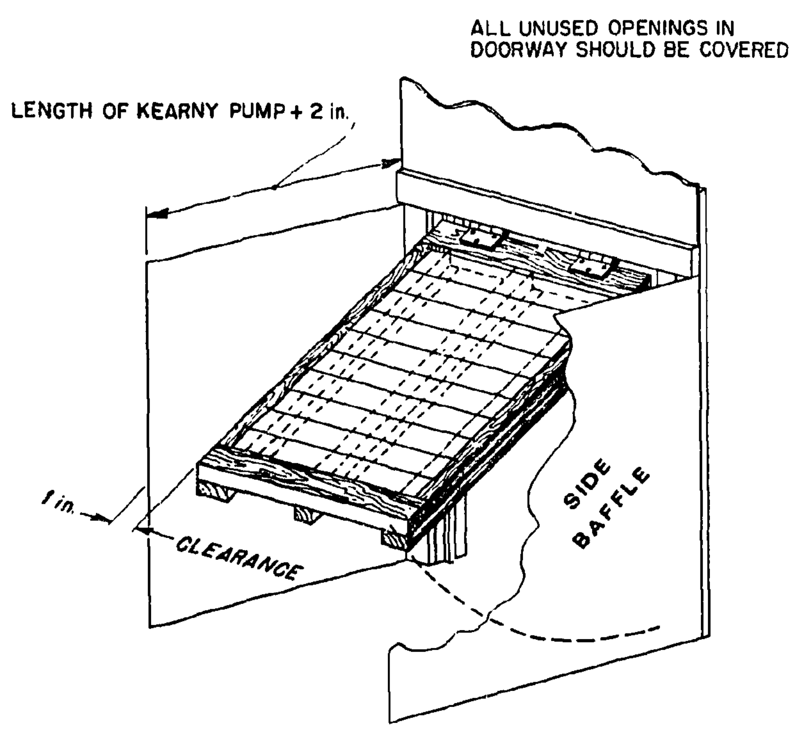


Fig. 23. Side baffles.

B. Operating a KAP as an Exhaust Pump

In some shelters, a KAP can be operated most effectively by using it as an exhaust pump – by pushing it with a push-pole attached to its center vertical brace. Push-pole operation is sometimes the best way to "suck" outdoor air into a shelter by pumping air out of the shelter in the natural direction of air flow, for example, up an elevator shaft or up a stairwell. This method is especially useful in those shelters in basements in which the air-intake openings – such as exposed small windows, or holes broken in the shelter ceiling – are impractical for installing KAP's.

Figure 24 shows an improvised flexible connection of a push-pole to the vertical center brace of a 6-ft KAP. This connection is best made 28 in. from the top of the frame.

To pump a large KAP most effectively with a push-pole, stand with your back to the KAP, grasp the push-pole with both hands, and – using mostly your leg muscles – push the KAP by pulling the free end of its push-pole toward you.

ORNL-DWG 66-12332R

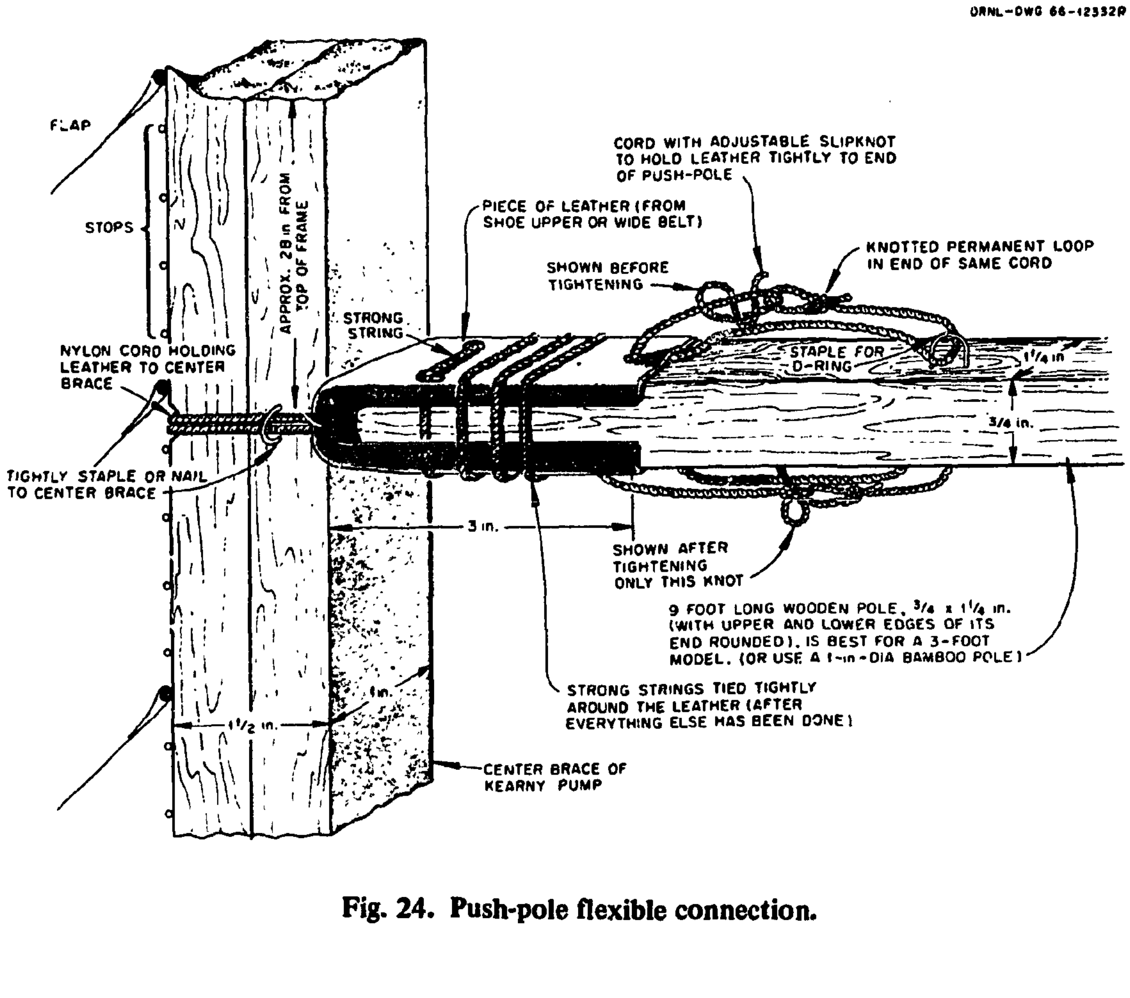


Fig. 24. Push-pole flexible connection.

C. Ventilating a Shelter with Only One Opening

Some basement rooms that may be used as shelters have only one opening, the doorway. A KAP can be used to ventilate such a shelter room – provided enough well-mixed and distributed air is moving, or can be pumped in from outdoors by another KAP, so as to flow past this doorway, just outside it. Figure 25 indicates how to ventilate such a one-opening room by operating a 3-ft KAP as an air-intake pump in the upper part of the doorway.

Below such a doorway KAP, a "divider" 6 to 8 ft long can be installed. The "divider" permits the exhaust air to flow out of the room, without much of it being "sucked" back into the room by the KAP swinging above it. Plywood, reinforced heavy cardboard, or even well-braced plastic can be used to make a "divider." But, in any case, a "divider" should be installed so that, in a possible emergency, it can be jerked out of the way in a few seconds.

When used thus with a "divider," a 36 in. X 29 in. KAP can pump almost 1000 cubic feet of air per minute into and out of such a shelter room. Whereas 1000 cubic feet of well-distributed air is sufficient for several times 25 shelter occupants under most temperate climate conditions, it is enough for only about 25 people in the one-entry room under exceptionally severe heat-wave conditions. Further, to make it habitable for even 25 people under such conditions, the air in this room must be kept from rising more than 2°F above the temperature outdoors. This can be done by pumping through enough outdoor air with a second air-supply KAP, plus in some cases also using air-distribution KAP's in spaces outside the one-entry room. The KAP in the doorway of the one-entry room should supply 40 cfm per occupant of this room.

In order to prevent any of the used, warmed exhaust air from the room from being "sucked" by the doorway KAP back into the room, a stiffened rectangular duct can be built so as to extend the lower part of the doorway-opening several feet outside the one-entry room. Such a duct can be built of plastic supported by a frame of small boards. It can be used to discharge the exhaust air far enough away from the KAP and "downstream" in the airflow outside the one-entryway room, so that no exhausted air can be "sucked" directly back into the room.

D. Building More Durable KAP's

If you are building KAP's in normal times, you may want to use materials that will make your pumps last longer, even though these materials are more difficult to obtain and are somewhat more expensive.

Durability tests have shown that the parts used with a KAP that wear out first are the flaps and the pulleys. In 6-ft KAP's, the lower flaps are subject to hard use; lower flaps made of 6-ounce (per square yard), clear, nylon-reinforced, plied vinyl have lasted undamaged for over 1000 hours of full-stroke pumping, without having their edges reinforced. Lower flaps made of 6-mil nylon-reinforced polyethylene, without edge reinforcements, have lasted for 1000 hours with only minor damage.

The best pulley tested was a marine pulley (such as is used on small sailboats), with a Delrin (DuPont) 2-in.-diameter wheel and $^3/_{16}$-in. stainless steel shaft.

ORNL DWG 72-8203

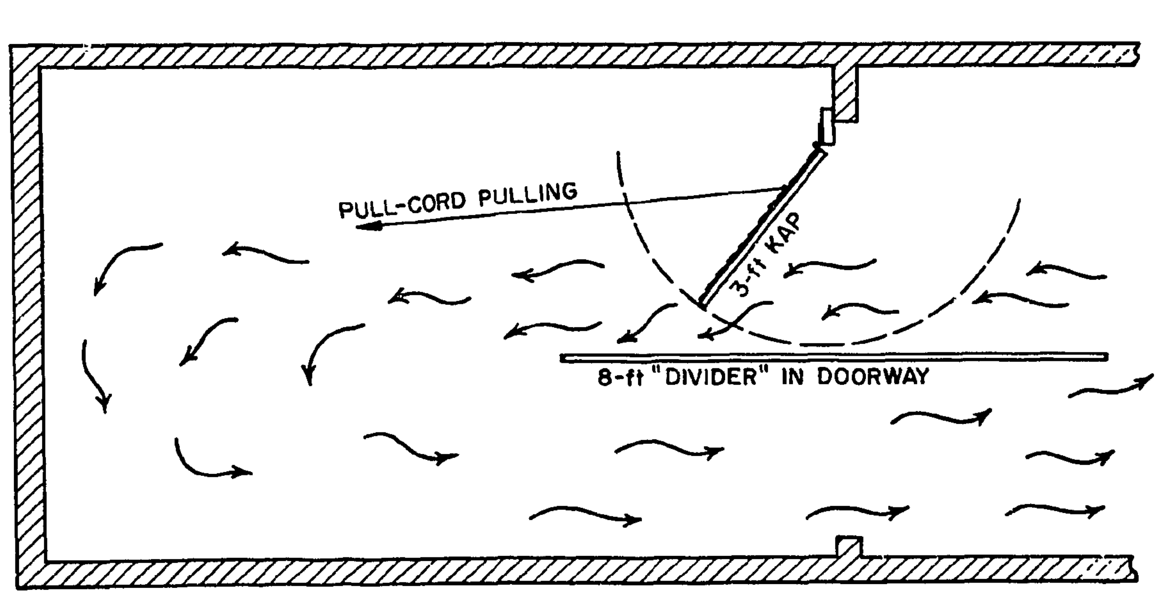


Fig. 25. Use of "divider" to ventilate a shelter with only one opening.

This pulley was undamaged after 324 hours of use operating a 6-ft KAP and appeared good for hundreds of hours more.

The best pulley-cords tested were of braided dacron or nylon.

E. Using Air Filters

Supplying shelter occupants with filtered air usually would be of much less importance to their survival and health than providing them with adequate volumes of outdoor air to maintain tolerable temperatures. However, filtering the entering air could prove worthwhile, provided:

1. You work on filters after you have completed more essential work.
2. You have enough low-resistance filters (such as fiberglass dust filters used in furnaces and air-conditioners) and other materials with which to build the necessary large, supported filter in front of your KAP.
3. Your KAP can pump through your filter and your shelter an adequate volume of air.
4. You install the filter so that you can easily remove it if shelter temperatures rise too high.

To prevent a filter used with a KAP from causing too great a reduction in the volume of air that the KAP can pump through your shelter, you must use large areas of low-resistance filter material. For example, in one ventilation test of a large basement shelter (which had two ordinary doorways at its opposite ends serving as its air-intake and its air-exhaust openings), a 72 in. X 29 in. KAP, operated in one doorway, pumped almost 5000 cubic feet per minute through the shelter. But when a filter frame holding 26 square feet of 1-in.-thick fiberglass dust filter was placed across the air-intake stairwell, then the KAP could pump only about 3400 cfm through this filter and the shelter.

F. Pre-Cooling Shelters

If the shelter itself is cool, then more of the body heat of occupants can flow into its cool walls, ceiling, and floor. Therefore, especially during hot weather, it would often be advantageous to pre-cool a shelter that might soon be occupied. KAP's (or other air pumps or fans) can be used to pre-cool a shelter by forcing the maximum volume of outdoor air through the shelter and by distributing it within the shelter. A shelter should be pre-cooled at all times when the air temperature outdoors is lower than the air temperature in the shelter when the shelter is not being ventilated. Then, if the pre-cooled shelter is used, the occupants would be kept cooler at a given rate of ventilation (because the air will not have to carry all of their body heat out of the shelter), than if the shelter had not been pre-cooled.

G. Increasing the Usefulness of Shelters by Supplying 40 cfm per Planned Occupant

If a shelter is fully occupied for days during hot weather and is cooled by pumping through it and distributing at least 40 cubic feet per minute of outdoor air for each planned occupant – more than is required to maintain tolerable temperatures at night – then:

1. The shelter occupants will be exposed to effective temperatures less than 2°F higher than the current ET's outdoors, and at night will get relief from extreme heat.
2. The floors, walls, etc., of a shelter so ventilated will be cooled at night well below daytime temperatures. Therefore, during the day a consequential fraction of the occupants' body heat will flow into the shelter itself, and thus during the hottest hours of the day less body heat will have to be carried out by the exhaust air. Therefore, daytime temperatures will be reduced.
3. Since the shelter occupants will be cooler and will sweat less, especially at night, they will require less water than they would have required if the shelter had been ventilated at a rate of less than 40 cfm per occupant.
4. If the shelter were to be endangered by the entry of outside smoke, carbon monoxide, or other poisonous gases, or heavy descending fallout under windy conditions, the ventilation of the shelter could be temporarily restricted or stopped for a longer period than would be practical if the shelter itself were warmer at the beginning of such a crisis period.
5. The shelter could be occupied beyond its rated capacity without overcrowding causing as serious problems as would be the case if smaller-capacity air pumps had been installed.

H. Installing a KAP in a Steel-Framed Doorway

If you need to install a KAP in a steel-framed doorway and it is not feasible to screw or otherwise permanently connect it to the doorway, you can attach your KAP by using a few boards and some cord, as illustrated by Figs. 26 and 27. The two horizontal boards shown extending across the doorway are squeezed tightly against the two sides of the wall in which the doorway is located by tightening two loops of cord, one near each side of the doorway. One loop is illustrated. A cord is first tightened around the two horizontal boards so that the upper and lower sides of the cord are horizontal. Then the cord is further tightened by binding and squeezing it in its center.

ORNL DWG 72-6364

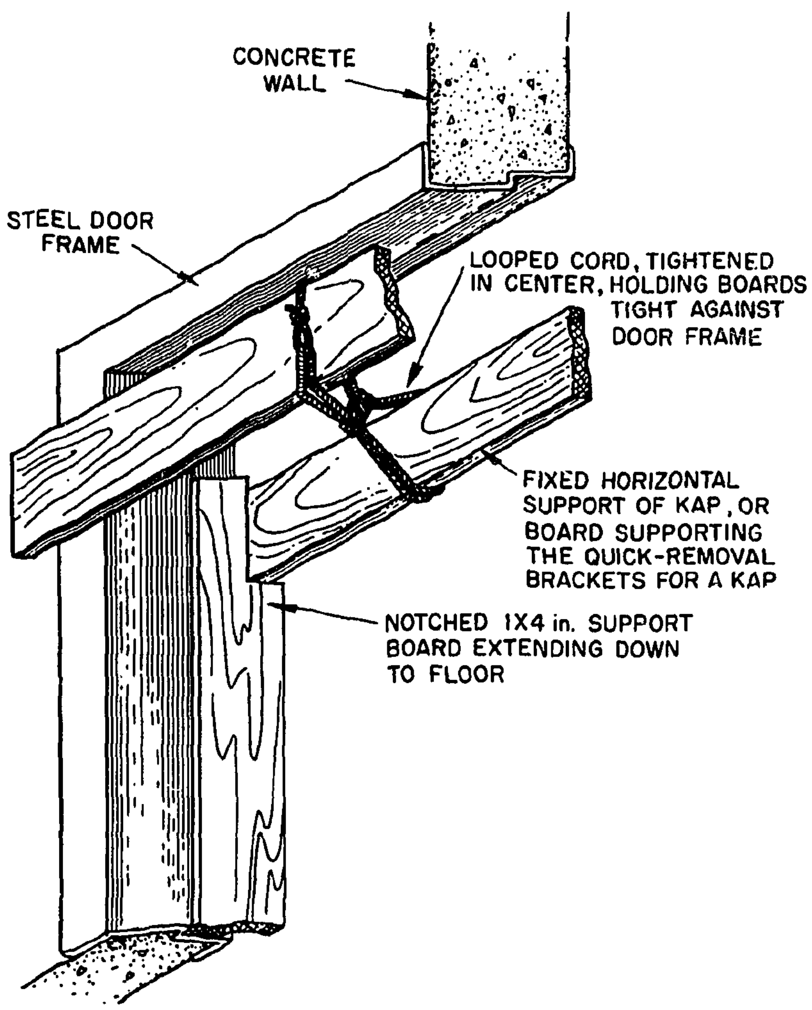


Figure 26.

ORNL DWG 72-6617

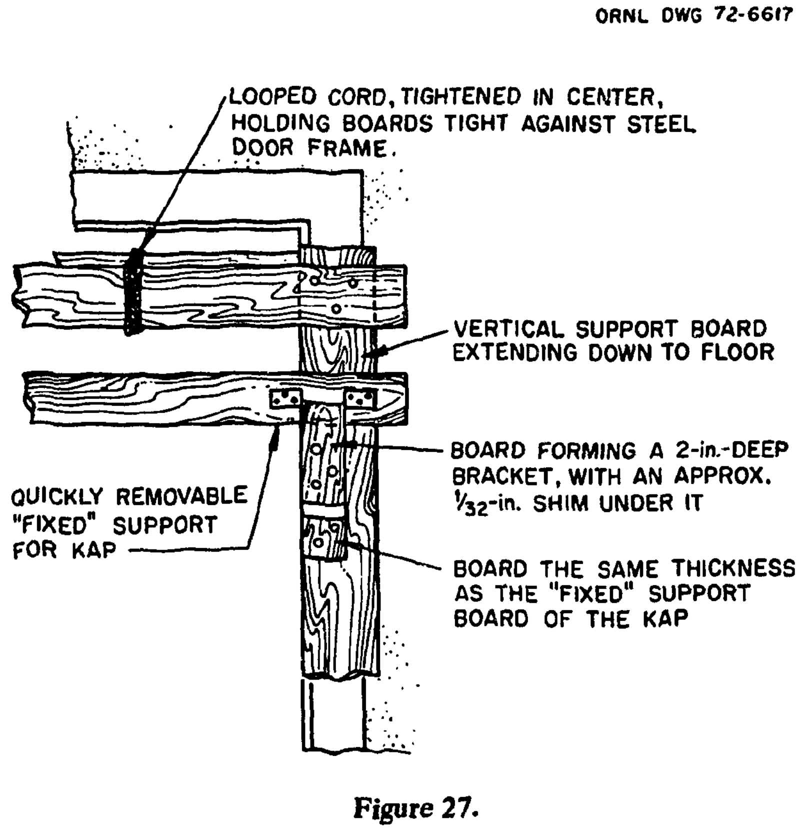


Figure 27.

Two large "C" clamps serve even better than two looped cords. However, secure support for a swinging KAP still requires the use of a vertical support board on each side of the doorway, as illustrated.

Figure 27 shows a quick-removal bracket supported by two horizontal boards tightened across the upper part of a doorway by looped cords, as described above. Also, study Fig. 19.

I. Making Dependable Lights for Shelters

For the successful operation of a shelter, at least very low levels of illumination are essential. Since public power is likely to fail and other light sources may prove inadequate or unreliable during a possible prolonged shelter occupancy, citizens lacking large supplies of candles should make for themselves self-adjusting lamps that burn oils and fats of the kinds used in the kitchen. Because such lamps also could prove useful to many citizens in the event of a major power failure in peacetime, the instructions for quickly making two types of homemade lamps are given on a separate page, following this page.

J. Managing the Consumption of Water and Salt

If shelter occupants are to sweat enough to enable their skins to act as fully effective evaporative coolers when exposed to large volumes of moving air in the manner described in these instructions, they must drink enough water. A good rule of thumb for a person to apply when trying to conserve water over a period of days and keep healthy is to drink enough so as to urinate only about one pint every 24 hours.

When an adult is living at normal temperatures and is not sweating much, he requires a daily total salt intake of about 1/6th of an ounce. Since the average American diet contains approximately 1/4th of an ounce of salt, a person eating normally requires no additional salt – even if he is living in a quite warm shelter. But if an adult is living in a well-ventilated shelter during very hot weather and must sweat some four quarts a day to survive, he should consume a total of about 1/3 ounce of salt a day. Hence, if he is living for days under these very hot conditions and is eating very little, he will benefit by taking 1/3 of an ounce of salt daily, and will find that water with some salt dissolved in it tastes better.

DEPENDABLE LIGHTS FOR SHELTERS

If a nuclear attack occurs, normal electric power is likely to fail, even in communities completely outside the areas of blast damage. Furthermore, people building hasty or expedient shelters where they cannot get public power should save their portable electric lights for postattack use. Therefore, to be sure your shelter will have dependable, safe lights:

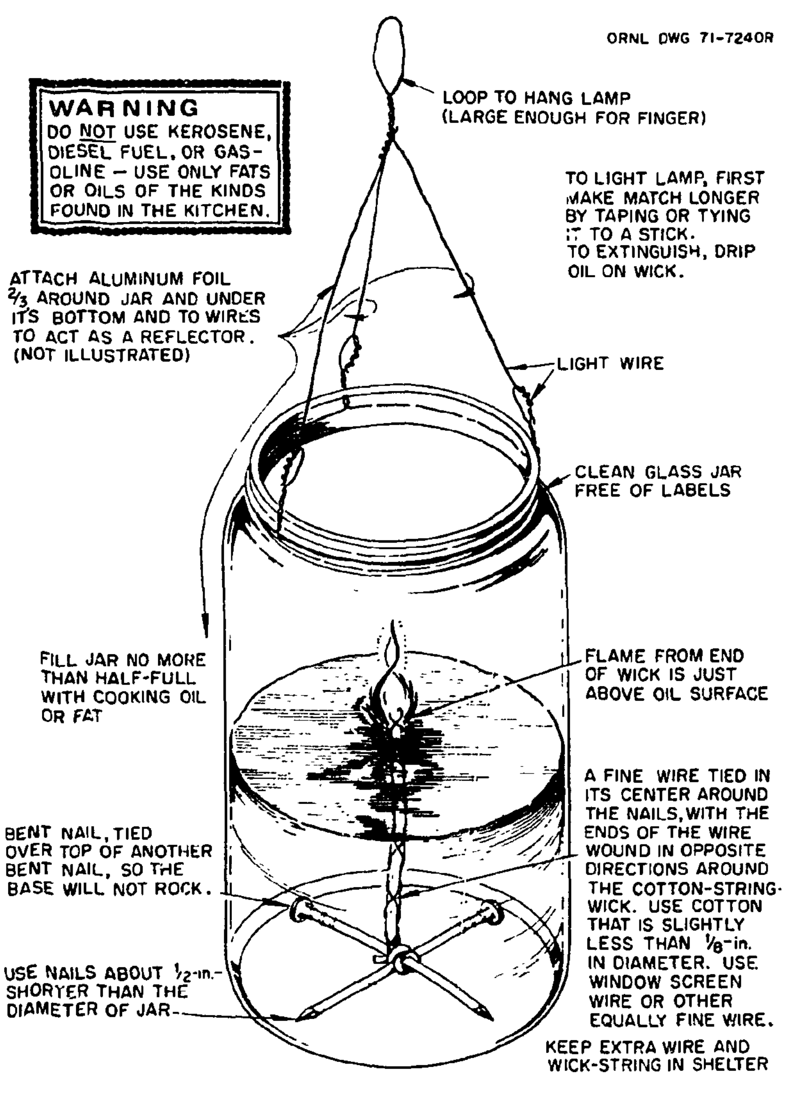
1. You should instruct persons coming to your shelter to bring with them all available flashlights, electric lanterns, extra batteries and bulbs, and candles.

2. In most communities, not enough such emergency lights are available to provide shelters with even very low-level, continuous illumination for several weeks. Therefore, you should at least prepare to make homemade lamps by taking to your shelter edible fats and oils and the other common household materials needed to make and operate several self-adjusting homemade lamps, as described on this page. An even better preparation is to make, test, and store in your shelter these homemade lamps before they are needed. (With the smallest practical wick, a lamp burns only about 3 ounces of edible oil, fat, or grease in 24 hr.)

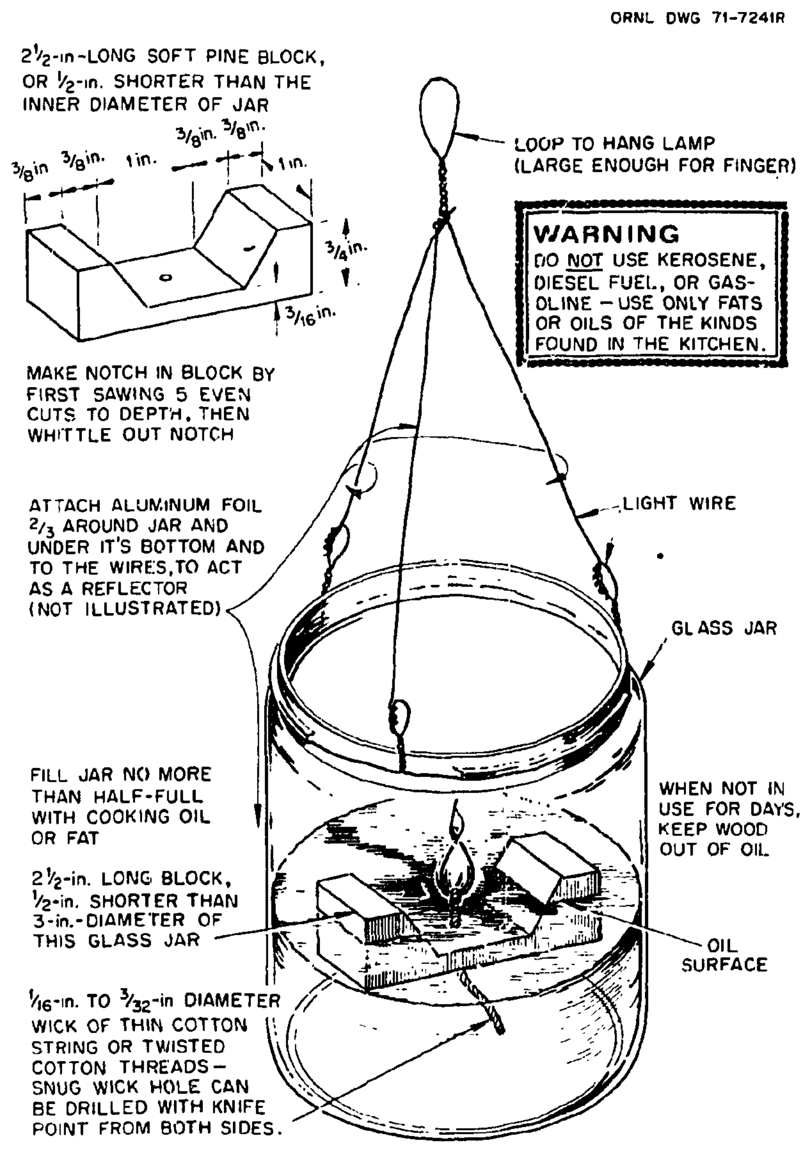
3. Because the air of an occupied shelter frequently becomes so damp that it makes exposed matches difficult or impossible to strike, you should provide moisture-proof match containers.

4. To minimize the danger of an open flame setting fire to your shelter or contaminating the air, whenever practical all open flames and tobacco smokers should be restricted to locations near the air-exhaust opening of your shelter.

5. You should not allow any gasoline to be taken into your shelter, and should not light a kerosene lamp unless you are sure no blast wind will enter your shelter and knock it over.



WIRE-STIFFENED-WICK LAMP



FLOATING WICK LAMP

K. Preparing to Shelter the Maximum Number of People in a Large Basement – an Example

1. The problem

In a shelter-deficient small town located in the Deep South, the best available shelter – as regards both its size and radiation protection factor – is in the basement of a multi-story industrial building. This town is so distant from likely targets that dangers from blast and fire would be minimal. Fallout, however, could be heavy.

Figure 28 shows this basement. Its four one-entry rooms are below ground level. The eight windows of its two largest rooms are small and high, just above ground level. This basement has been surveyed and marked as a shelter, but is not stocked. It has no forced ventilation system. Fortunately, only a small fraction of its floor area is covered with stored boxes.

2. Some solutions

To enable the maximum number of people to be sheltered in this big, hard-to-cool basement <u>in hot summertime</u> – and within 48 hours of beginning work during a possible future escalating crisis – the town's civil defense director:

a. Makes preparations to have the local newspaper print a supplement during a possible future crisis. This supplement would include the assignment of all the townspeople either to existing shelters – including this big basement – or to expedient shelters that they would build for themselves during a crisis. The civil defense director has concluded that if most of the residents were to work hard for two days improving and building shelters, they could provide all residents with shelters having at least a protection factor of 100. (PF 100 means that the radiation dose inside a shelter is $^1/_{100}$th the dose outside the shelter, in the open.)

Thus, during a rapidly worsening crisis most of the townspeople would build or improve the shelters that they and their families would use, and bring to their designated shelters needed items – especially enough water containers to store 14 gallons per occupant, enough for a 14-day shelter stay under heat-wave conditions. Some spot surveys have indicated that many homes have enough portable water containers to store 14 gallons for each person in the family, if householders are informed how to make their garbage cans usable by first cleaning and disinfecting them. Strong polyethylene film or bags can be used to line water containers, including boxes, both to make them water-tight and to improve the taste of water stored in them. To improve the healthfulness of stored water, to each 5 gallons add one teaspoonful of $5\frac{1}{4}\%$ chlorine solution, such as "Clorox."

Except under very severe conditions, 14 gallons per occupant should provide enough water a day to enable each occupant to use a pint every day to rub off with his fingers most of the salt and filth on his skin – the results of heavy sweating and evaporative cooling. By so

ORNL-DWG 72-8222

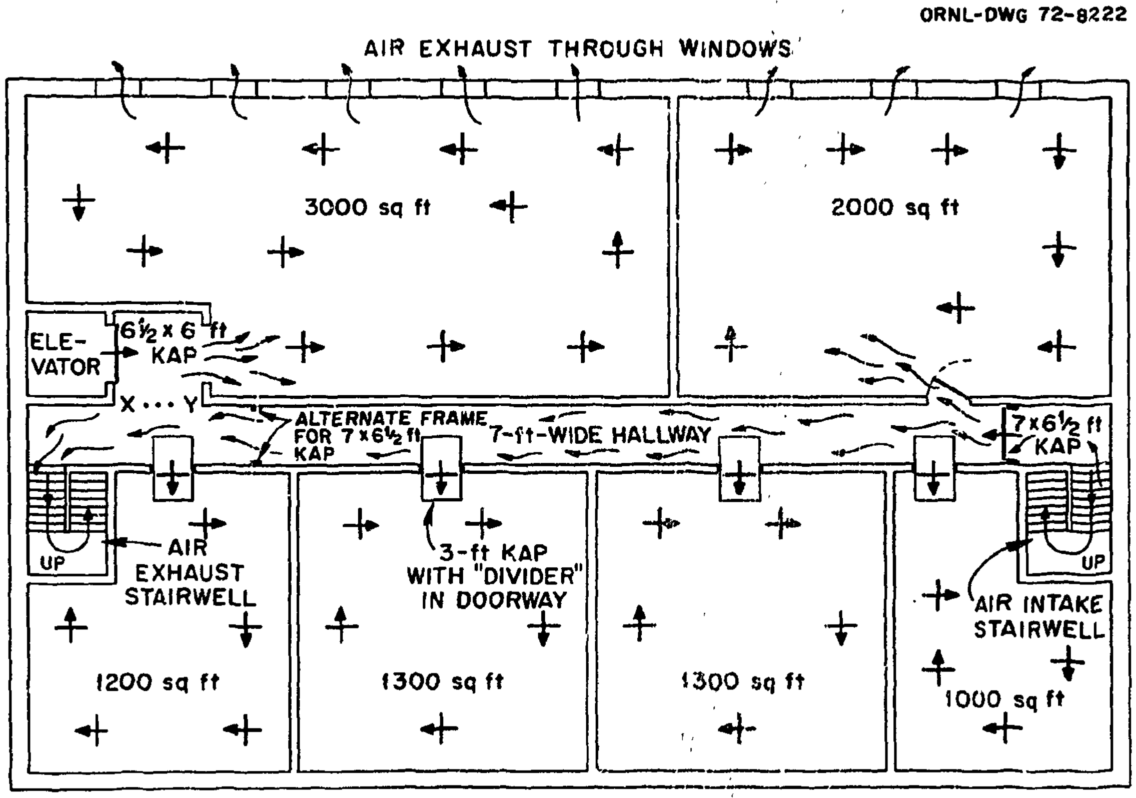


Figure 28.

doing, an occupant of a hot shelter would reduce the chances of his getting skin rashes and infections.

b. Plans in detail what sizes and numbers of KAP's to have built, and where to install them in this big basement. These air-supply and air-distribution KAP's are:

(1) Air-supply KAP's (all "tailor-made" to fit the largest openings available – since this shelter is difficult to provide with adequate outdoor air – and with quick-removal brackets):

One $6\frac{1}{2}$ ft X 6 ft wide KAP, to be installed in the doorway to the freight elevator shaft – for operation when the elevator is two or more stories up, and upper-floor doors and windows are opened to provide large air passageways to the outdoors. The opening (X ... Y, in Fig. 28) to the hallway is to be closed with a canvas or plastic framed partition, so that this KAP can be used to ventilate the 3000 square foot room as a separate unit, with a maximum ventilation rate of some 12,000 cfm.

This KAP will also be equipped for push-pole operation, so it could be used to exhaust air up the elevator shaft when the wind is blowing too hard in through the five windows.

To minimize the entry of both fallout particles and radiation through basement windows, the townspeople should use sacks and doubled pillowcases to make earth-filled sandbags. Sandbags should be placed over rectangular board frames built so as to extend the window openings outward. The total number of square feet in all of the exhaust openings should be at least 20, that is, at least half the area of this KAP. Earth should be mounded against the wall between these board frames. When less than the maximum ventilation rate is required, additional sandbags should be used to further reduce the entry of radiation through these air-exhaust openings.

Two 7 ft X $6\frac{1}{2}$ ft wide KAP's, to be installed and operated in the 7-ft-wide hallway with its $7\frac{1}{2}$-ft ceiling. In the easiest and least effective planned ventilation system, only one of these big KAP's will be used, positioned in one of the two 2 in. X 4 in. frames to be built in the hallway. This KAP – that is bigger than any available doorway – can be positioned to pump air from left to right, or from right to left, depending on the wind direction and the direction of the resultant natural flow of air through the basement when first-story outer doors and windows are opened. This size KAP can be operated to force about 4000 cfm of outdoor air through the 2000 square foot room and out of its three small windows, and at the same time also to pump some 10,000 cfm down the hallway and out through the stairwell on the left. This 10,000-cfm airflow down the hallway is to supply the four one-entry rooms.

Four KAP's sized and installed to operate with a "divider" (see Fig. 25), in the upper halves of the four doorways to the four one-entry rooms. Each of these four KAP's will pump air out of the airstream flowing down the hallway, and exhaust warmed air back into the hallway. Thus the one-entry rooms farthest down the hall from the pump will be supplied with air at effective temperatures so much higher than the ETs of the air outdoors that the air temperatures in them could become intolerable during very hot, humid weather.

With this installation of KAP's and if each occupant has 10 square feet of floor, only about 20 cfm per occupant can be supplied to the occupants of the five shelter rooms ventilated by one 7 ft X $6\frac{1}{2}$ ft KAP.

If it becomes feasible to knock holes the size of large doorways in the partition walls between the four one-entry rooms, then a more effective system for cooling the four one-entry rooms can be provided by:

1. Removing all four of the small doorway KAP's and their "dividers,"
2. Shutting the doors of the two central rooms, and
3. Increasing the volume of air pumped through all four one-entry rooms by making a large KAP to operate in the doorway of the 1000 square foot room, to increase the airflow produced by the 7 ft X $6\frac{1}{2}$ ft KAP in the hallway.

If it becomes feasible to knock large air-exhaust holes in the ceilings of the four one-entry rooms (using sledgehammers, etc.) and to open or break windows in ground-floor rooms so as to provide efficiently large air-exhaust openings to the outdoors, then a ventilation system capable of supplying about 40 cfm of fresh outdoor air per occupant can be provided by:

1. Dividing the hallway with a partition placed between the doorways to the 1000 sq ft and the adjacent 1300 sq ft room,
2. Adjusting the door openings of the 2000 sq ft and the 1000 sq ft rooms so that about two-thirds of the 14,000 cfm of air pumped down the adjacent stairwell by the 7 ft X $6\frac{1}{2}$ ft KAP (almost 10,000 cfm at its maximum rate) flows through the 2000 sq ft room, and one-third (about 4000 cfm) flows through the 1000 sq ft room, and
3. Installing the second 7 ft X $6\frac{1}{2}$ ft KAP in the alternate frame, near the left end of the hallway, so that, when the doors to the 1200 sq ft and the two

1300 sq ft rooms are properly adjusted and the partitions between these three rooms are intact, then almost 40 cfm of fresh outdoor air for each occupant can be pumped through the open doorways of these rooms, and exhausted upward, out through the large holes in the ceilings. An airflow can be divided fairly accurately into desired fractions by using paper streamers as air velocity indicators. Paper streamers can be made of half a width of rolled toilet paper, with these strips cut in lengths a little shorter than the heights of the openings to the tops of which the streamers are to be attached.

Following an attack, there may be a population explosion of flies and mosquitoes. Therefore, the shelter supplies should include insecticides and enough insect screen or netting to cover both the air-intake and air-exhaust openings. However, since putting anything in the air openings reduces the volume of air that can be pumped, screens should be installed only at those times when the insect problem becomes more serious than the requirement for adequate shelter cooling.

(2) Forty air-distribution KAP's – used as indicated in Fig. 28 by the small crosses, each with a directional arrow. These are standard 36 in. X 29 in. KAP's, provided on the basis of one for about each 250 sq ft of floor. They are suspended from the ceiling and operated via pulleys or improvised "pulleys" (see Figs. 17 and 18) also suspended from the ceiling (see Fig. 15).

When two or three air-distribution KAP's are hung in the same straight line, they may be connected with wires attached to their central braces, in a manner similar to that illustrated by Fig. 20 for a pull-cord connection; then one person can operate two or three KAP's. In one shelter test involving 13 air-distribution KAP's hung from the ceiling near the walls of a 4000 sq ft basement room that was almost square, these 13 KAP's produced a measured airflow of over 10,000 cfm. Adequate air velocities were attained except near the center of the room. If two or three more air-distribution KAP's had been available, these could have been operated near the center of the room, and then air velocities in all parts of this large shelter would have been high enough to have fanned all occupants effectively.

The total of 40 air-distribution KAP's required for this whole basement can be built in a day by a small fraction of the 1000 persons assigned to this basement shelter. If before any crisis arises, plans are made to utilize mechanized home workshops and some skilled workers who are assigned to this basement shelter, then no more than 100 man-hours of work may be required to build these 40 KAP's – to judge from the fact that two Seabees, after spending 25 minutes reading the instructions and learning about KAP's for the first time, took only 64 minutes to build a 36 in. X 29 in. KAP. They had the materials needed, and used only hand tools.

L. Regulating the Ventilation Rate During Hours When the Air Outdoors Is Very Dry and Hot

Under these conditions, it may prove advantageous to pump less than 40 cfm of outdoor air per occupant through a shelter, but decisions regarding ventilation rates should be based largely on the reactions of the shelter occupants.

The advantage of supplying 40 cfm per occupant, rather than a smaller number of cubic feet per minute, is that this high a ventilation rate reduces the rise of the effective temperature of the air inside the shelter, as compared to the rise of the ET that would result at lower ventilation rates than 40 cfm. However, much smaller increases in effective temperatures result when a given volume of very dry hot outdoor air enters a shelter, than when an equal volume of average or humid hot air enters the shelter. For example, in one test only 13 cfm of dry air (at 100°F, relative humidity 18%) was supplied under conditions that necessitated all body heat being removed by evaporative cooling of sweat. Yet the resultant increase in effective temperature was only about 1.2°F, accompanying a decrease in dry bulb air temperature of 6.8°F. If an increase of this magnitude in ET is tolerable, then, rather than limit the increase in effective temperature to about one-half a degree by supplying 40 cfm of dry hot air per occupant, it may be advantageous to supply only 13 cfm during some or all of the hottest hours of the day.

The disadvantages of supplying as much as 40 cfm per occupant of very dry hot air are:

1. The shelter itself will be heated in less time to temperatures approaching or exceeding skin temperatures, and the time will be lessened during which significant fractions of the occupants' body heat can flow into the shelter floor, walls, and ceiling. This consideration can be important in a below-ground, poured-concrete shelter covered with damp clay, since heat can readily flow into and out of these materials. This consideration is unimportant in a wooden shelter in dry sand.

2. The shelter occupants may have to sweat more, and drink more water due to the greater quantity of heat brought into the shelter by 40 cfm per occupant of dry air at temperatures higher than the surface temperature of dry skin – than if less than 40 cfm were supplied.
3. The KAP operators will have to work harder, thereby producing more body heat, to their own and the other occupants' disadvantage.

M. Designing Shelters for Efficient Manual Ventilation

If a shelter is designed to be adequately and efficiently ventilated by KAP's in hot weather, then the shelter should:

1. Have no more than 1000 sq ft of floor space, if 10 sq ft of bare floor space is to be provided for each occupant; or have no more than 500 sq ft, if the shelter is to be efficiently furnished with benches and overhead board bunks, so that each occupant will require only 5 sq ft of floor space,
2. Be much longer than it is wide, and
3. Have a doorway, or other sizeable entryway, at each end.

Restricting the number of occupants of a low-cost, single-use shelter to about 100 persons not only lessens the problems of disease control, shelter management, and fire hazards, but also makes adequate ventilation with KAP's quite easy – even in hot weather when 40 cfm of outdoor air per occupant is to be pumped through the shelter.