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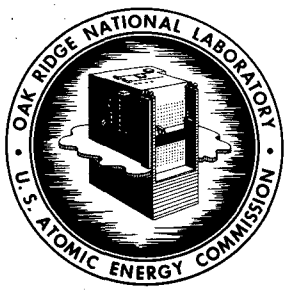

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INSTRUCTIONS FOR BUILDING A HOMEMADE LARGE-VOLUME SHELTER-VENTILATING PUNKAH-PUMP

Cresson H. Kearny

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INSTRUCTIONS FOR BUILDING A HOMEMADE LARGE-VOLUME SHELTER-VENTILATING PUNKAH-PUMP

Cresson H. Kearny

MARCH 1967

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
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TABLE OF CONTENTS

INSTRUCTIONS FOR BUILDING A HOMEMADE LARGE-VOLUME SHELTER-VENTILATING PUNKAH-PUMP

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I. THE NEED FOR INSTRUCTIONS

One solution to shelter ventilation problems would be to place factory-built ventilating fans in all shelters capable of protecting the U. S. population. If one projects the present limited U. S. civil defense budget, the buildup of such a capability would necessarily be slow. Yet it would be possible during a period of an escalating crisis for millions of citizens to provide more usable shelter spaces for themselves if they were given explicit instructions for building an effective ventilating pump. Moreover, one new type of ventilating pump, the punkah-pump, can be built using only materials and tools found in many American homes.

The ability of punkah-pumps to supply large volumes of air to a large shelter has been demonstrated.* Large volumes of outside air (up to 30 cfm per occupant during heat waves in the hottest parts of the country) may be required in many crowded shelters to maintain tolerable temperatures. However, since the average citizen has neither seen nor heard of a punkah-pump, he would need most explicit instructions to build one, regardless of how simple it is to do. Such pump-building instructions might be distributed in a civil defense booklet or printed in newspapers during a worsening crisis as part of general instructions for preparing expedient and hasty shelters, and for providing adequate ventilation for many existing shelters. For this purpose, the following text and illustrations may prove useful (for example, for hurried reproduction by offset printing during a crisis).

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*Engineering tests of punkah-pumps conducted in 1965 at Protective Structures Development Center, Fort Belvoir, Virginia, have shown that a simple six-foot punkah-pump, when operated by a man working at a rate of less than 0.5 hp, can pump 4600 cfm through a shelter, against a pressure difference of 0.02 in. water gauge. To force 5000 cfm through a passageway 100-ft long and only 6-ft high by 2.5-ft wide requires a pressure difference of less than 0.01 in. water gauge; most fallout shelters have available air passageways (doorways, stairwells, elevator shafts, windows) offering lower resistances than 0.01 in. water gauge to the flow of 5000 cfm.

II. PUMP-BUILDING EXPERIMENTS FOR THE DEVELOPMENT OF WORKABLE INSTRUCTIONS

It was found that the average nontechnical individual could not build a satisfactory punkah-pump if given only brief descriptions and engineering drawings for instructions. Therefore, thoroughly explicit step-by-step instruction booklets were prepared, complete with numerous detailed line drawings. Then three successive separate groups of young Boy Scouts served as test groups, building 3-ft models. Boys were selected who had not heard of a punkah-pump. To simulate American adults of less than average ability, boys with an average age of 12 years were chosen. Each of the three successive groups was divided into two three-boy teams. Each team built one pump. The teams were given no pump-building instructions other than the written ones contained in one booklet. A team was provided with only common building materials (uncut boards, nails--including inappropriately large and small ones--tacks, polyethylene film, pressure-sensitive tape, wire coathangers, string, wire, and closet door hinges with screws) and with simple household tools (hammer, saw, pliers, screwdriver, scissors and/or knife, yardstick, and pencil).

After the two pumps had been completed by the two teams of each successive test group, the causes of mistakes and confusion were determined, and, with the help of the boys, the instructions and drawings were clarified and improved.

In the last group test, one team of two 11-year-old and one 12-year-old boys built a well-constructed pump in 3-1/2 hours of working time--including a half hour well spent in carefully studying the instructions. Therefore, it is concluded that most adult male Americans, using only common materials found in many households, could build a serviceable punkah-pump with these same instructions.

III. THE TEXT OF THE FINAL INSTRUCTION BOOKLET FOR BUILDING PUNKAH-PUMPS

The following text contains the same wording and the same distribution of illustrations within the text as was in the final, successfully tested instruction booklets.

HOW TO MAKE A HOMEMADE, LARGE-VOLUME, EFFICIENT FALLOUT SHELTER VENTILATING PUMP: THE PUNKAH-PUMP

Cresson H. Kearny

Oak Ridge National Laboratory
Oak Ridge, Tennessee

Caution

Before you start making this new type of pump--if you want to avoid mistakes or want to divide the work among several people--ALL WORKERS SHOULD READ THESE INSTRUCTIONS AT LEAST THROUGH PAGE 12 before anyone starts work.

If all persons concerned with making this pump first spend half an hour studying these instructions and getting organized, you should be able to build the three-foot model described herein in less than the three hours usually required for three persons. For example, one person can start making the flap-valves (see pages 9 to 11) while others begin work on the pump frame, etc.

These instructions were especially written and tested (by having successive groups of 12-year-olds, who previously had never heard of a punkah-pump, build three-foot models) so as to enable untrained persons to make good pumps.

HOW TO MAKE A HOMEMADE, LARGE-VOLUME, EFFICIENT FALLOUT SHELTER VENTILATING PUMP: THE PUNKAH-PUMP

THE NEED

Especially in warm weather, large quantities of outside air usually must be pumped through a crowded shelter in order that the body heat produced by the occupants will not raise shelter temperatures to dangerously high levels. These instructions will enable you to build a shelter ventilating pump--using only common materials found in most American homes--with which you can pump the large volumes of air required in hot weather to maintain tolerable temperatures in a shelter. If you are located in an area subject to heat-wave conditions and if you are preparing your shelter to be tolerable even during a heat wave, then for long occupancy of a well-insulated shelter you should be able to pump through it up to 30 cubic feet per minute per person. Also, for extreme heat-wave conditions, each person must be provided with four to five quarts of drinking water and one-third (1/3) ounce of salt per 24 hours.

For small shelters, which even when overcrowded have no more than 20 occupants, a three-foot punkah-pump will pump enough air to maintain tolerable shelter temperatures even under the worst summer conditions. If you follow these instructions carefully, then, by yourself, in about nine man-hours of working time, you can build a three-foot pump which can force over 1800 cubic feet per minute through a basement shelter with two doorways--more air than can be pumped with a manually operated commercial blower costing over $200. However, if the same pump is used to draw air into a shelter room from a closed house and to force it outside through a three-square-foot window, then against this resistance it will pump only about 500 cubic feet per minute.

For shelters which you anticipate to have more than 20 occupants in hot weather or more than 50 occupants in cool weather, the six-foot punkah-pump described in the last two pages of this booklet is recommended.

HOW A PUNKAH-PUMP WORKS

As can be seen in Figs. 1 and 2 below, a punkah pump operates like a pendulum. That is, it is hinged at the top of its swinging frame. It forces air through its doorway opening when it is pulled as illustrated (or pushed by a pole--see Fig. 14). This is called its power stroke, when its numerous flap-valves are closed against valve-stop wires or strings in the plane of its frame. Then when the pump swings freely back as a pendulum on its return stroke, all the flap-valves are opened by air pressure, and the air stream continues to flow in the pumped direction while the pump swings in the opposite direction.

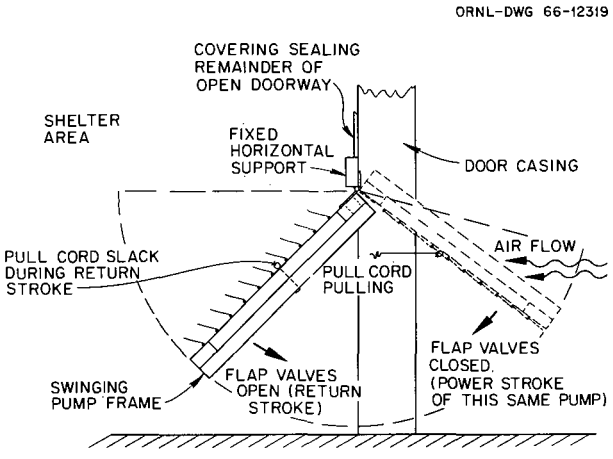

Fig. 1. Section Through Doorway Showing Operation of Punkah-Pump.

For supplying air to a shelter a punkah-pump may either be pulled by a cord as an air-intake pump (see Fig. 1) or pushed by a pole as an exhaust pump.

For distributing air <u>within</u> a shelter and/or fanning the occupants, a punkah-pump may be hung overhead, or in an interior doorway leading to an inner room, and operated as described at the end of these instructions.

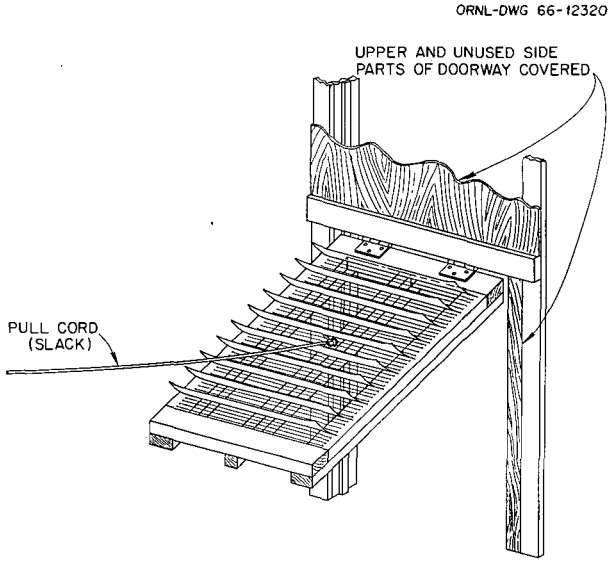

Fig. 2. Punkah-Pump in Doorway (With Flaps Open During Return Stroke).

INSTRUCTIONS FOR BUILDING A PUNKAH-PUMP

A. Materials Needed

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

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

a. A total of 22 feet of 1-x-2-inch lumber, preferably soft wood. (If you have lumber of approximately 1-x-2-inch dimensions, use it; no single piece need be longer than 3 feet.)

b. For the fixed support, 3-1/2 feet of 1-x-4-inch (or 1-x-3-inch or 1-x-2-inch) lumber

c. A pair of ordinary door or cabinet hinges (or strap hinges, or pieces of leather to improvise hinges, or four eyescrews which can be joined to make two hinges)

d. Small nails (at least 18; number 6 box nails are best), plus screws or nails for the hinges

2. For the flap valves (see Figs. 1, 2, 7, and 8)

a. Thirty feet of smooth, straight wire at least as heavy as coat-hanger wire, to make the flap-valve pivot wires (or 10 wire coat-hangers, or 35 feet of thinner smooth wire, or about 35 feet of string)

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

c. Twelve square feet of polyethylene film about three or four mils (3 or 4 one-thousandths of an inch) thick, in pieces at least 30 inches wide (or plastic drop cloth, or raincoat-type light coated fabric, or any combination of pieces capable of being cut into ten strips each 30-x-5-1/2 inches)

d. Pressure-sensitive tape (such as a waterproof tape, or adhesive, Scotch, or masking tape), to be used in strips one inch or less in width to make the hem-tunnel on each flap-valve. Or obtain needle and thread to sew the hem-tunnels

3. For the flap-valve stops

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

b. 90 tacks, or 90 very small nails (desirable, but not essential)

4. For the pull cord

At least 10 feet of cord (or light rope, or wire)

B. Desirable Tools

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

C. Steps to Build a Three-Foot Punkah-Pump

For use in an air-intake or exhaust opening at least 30 inches wide and at least 40 inches high

1. The frame

a. Cut two (2) pieces of 1-x-2-inch lumber each 36 inches long, and two (2) pieces of 1-x-2-inch each 29 inches long; and nail them together (see Fig. 3). Use nails that do not split the wood. Preferably use nails which are long enough to go through the boards and stick out about 1/2 inch 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 on a piece of approximately 1-x-1-inch lumber 36 inches long as a center vertical brace. (If you lack

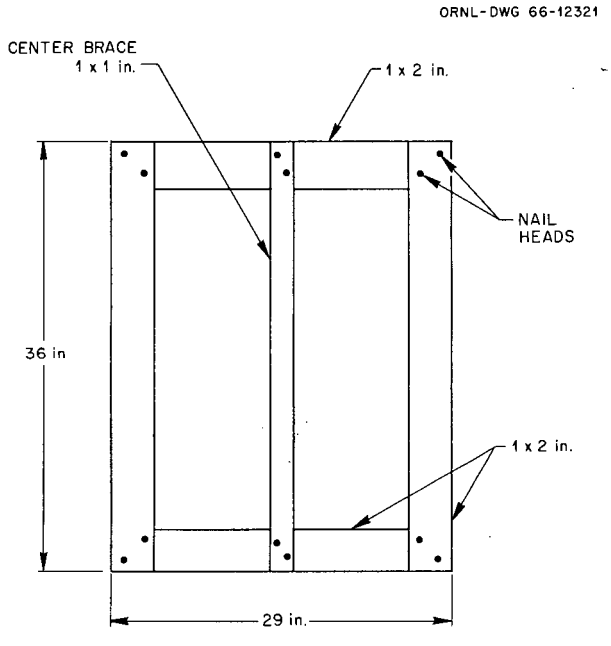

Fig. 3. Punkah-Pump Frame (Looking at the Back of the Frame).

time to make or find a 1-x-1-inch piece, use a 1-x-2-inch.) Figure 3 shows the back side of the frame; the flap-valves will be attached on the front (the opposite) side.

b. In order to make the front side smooth and flat so that the flap-valves will close tightly, fill in the spaces as follows: cut two pieces of 1-x-2-inch board long enough to fill in the spaces on top of the 36-inch sides of the frame between the top and bottom horizontal boards; nail them in place. Do the same thing with a 1-x-1-inch board (or whatever size board you used for the center brace) as a filler board for the center brace (see Fig. 4).

2. The hinges

Ordinary door hinges are best, but, in order that the pump can swing even past the horizontal position, the hinges should be screwed onto

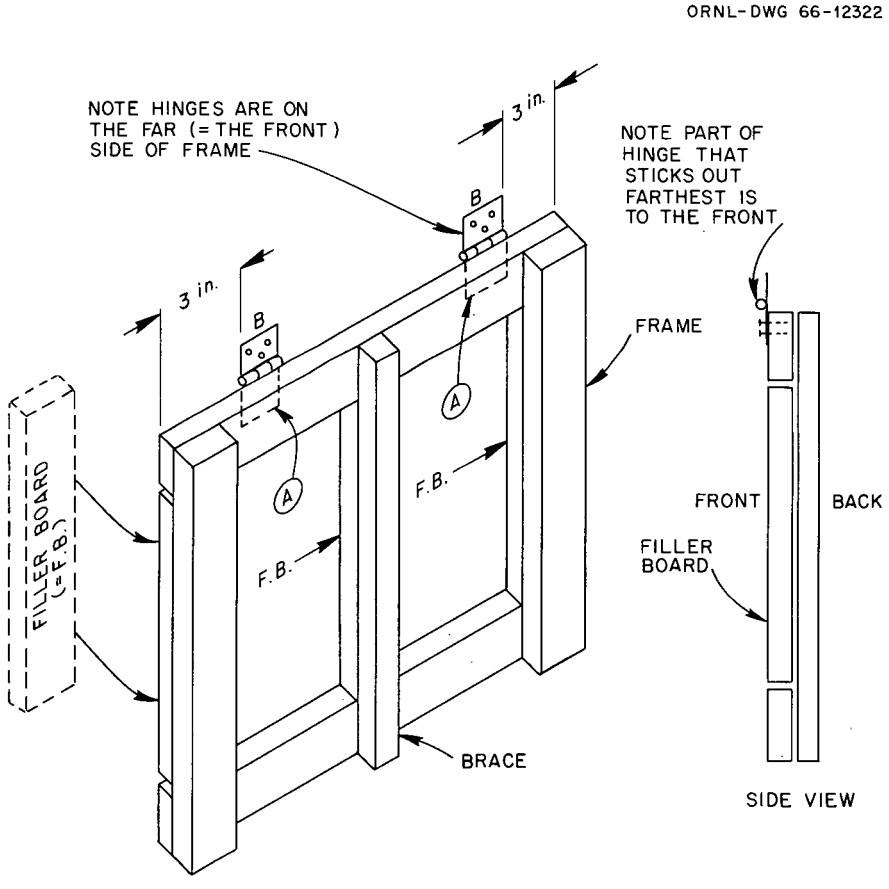

Fig. 4

the top of the frame (pick one of the 29-inch boards and call it the top) in the positions shown in Fig. 4. (If you lack a drill to drill screw holes, drive a nail in each position where you plan to put a screw, then pull out the nail, and screw the screw into the nail hole.)

3. The flap-valves

a. Make ten (10) flap-valve pivot-wires. If you have smooth straight wire as large as or larger than the wire of wire coat hangers, make ten 28-1/2-inch-long straight lengths of wire. If not, use wire from wire coat hangers. 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 as an arrow. Proper straightening takes one to five 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-inch length.

b. Make ten (10) polyethylene flaps. (This is a job best done by two people working together.) First cut ten strips (scissors are best). Make each strip 30 inches long by 5-1/2 inches wide. Then, lengthwise along one of the 30-inch sides, fold in a 1-inch hem while the strip is lying on a table. Make each hem with three pieces of pressure-sensitive tape each about 10 or 11 inches long (or make the hem by sewing it shut very close to the cut edge), so as to form a tunnel-hem. See Fig. 5 below.

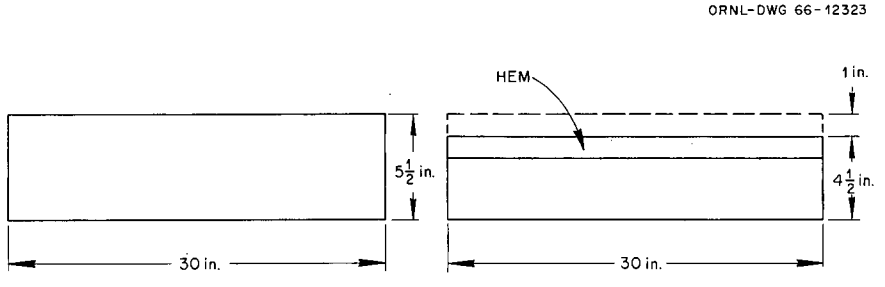

Fig. 5

After the hem has been made, take a pair of scissors and cut a notch in each hemmed corner of the flap (the piece of polyethylene). This notch should extend downward about 1/2 inch and should extend horizontally from the outer edge of the flap to 1/4 inch 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 1/2 inch downward and extends horizontally 1/4 inch beyond the edges of the vertical brace (see Fig. 6).

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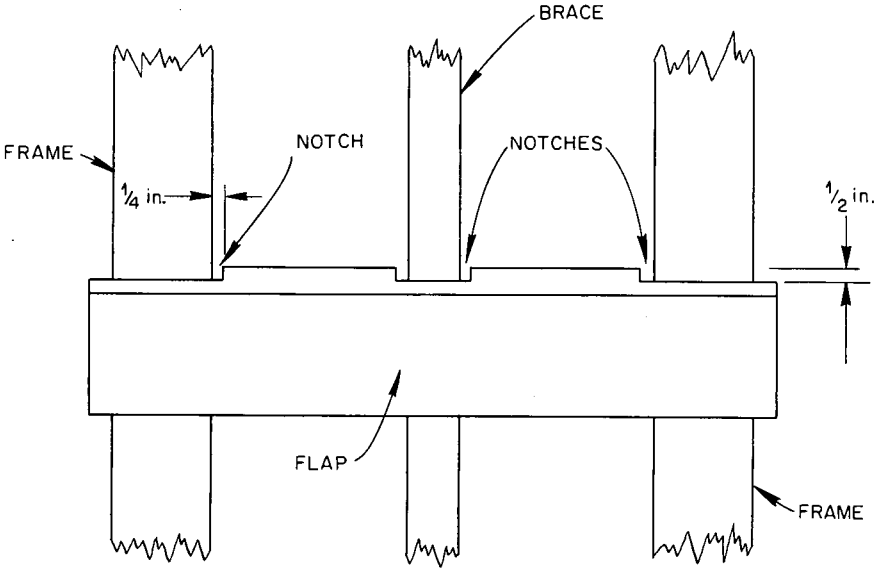

Fig. 6

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

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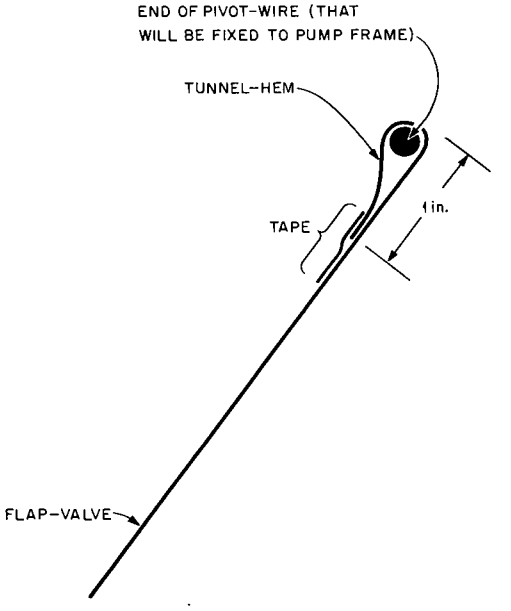

Fig. 7. End View

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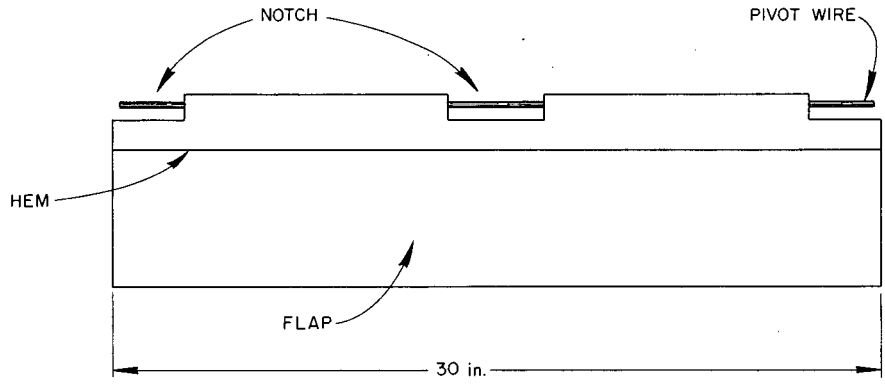

Fig. 8

d. Using a ruler and a pencil, mark the position of each flap-valve pivot-wire on the vertical sides of the 36-in.-long boards of the frame, and on the vertical brace. Measure off 3-1/4-in. segments, starting 1/4 in. below the top board to which the hinges have been attached (see Fig. 9). Start marking from the hinge board downward.

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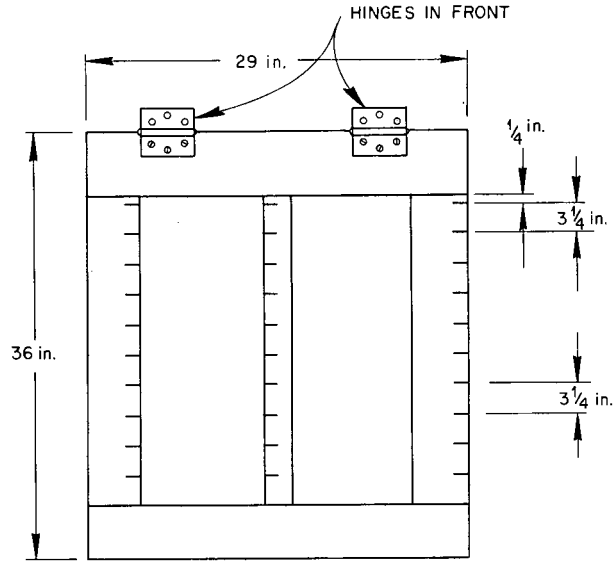

Fig. 9. Front View

e. Put the flap-valves and their pivot-wires to one side for use after you have attached the flap-valve "stops" and the hinges to the frame.

4. The flap-valve stops

In order that the flap-valves may turn (open) on only one side (the front, or face) of the frame, you must attach horizontal "stops" (strings or wires) across the face of the frame. Tie or nail four of these "stops" between each pair of the marked positions of the horizontal pivot-wires of the flap-valves, being careful not to cross the horizontal open spaces into which you later will fix the flap-valve pivot-wires.

a. Between the positions marked for each two adjacent pivot-wires, mark off on both sides and on the center brace four marks equally spaced. Start by measuring down 2/3 in. from the top wire; this will be mark number one. Mark number two will be 2/3 in. below number one; mark number three, 2/3 in. below number two; and number four, 2/3 in. below number three (see Fig. 10).

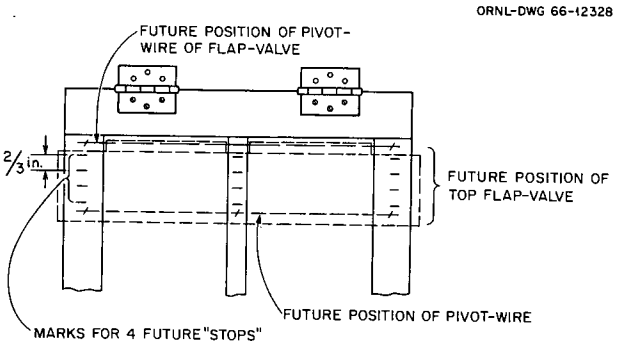

Fig. 10

b. If you have tacks or very small nails, drive three in a horizontal line to secure each "stop"--two into the vertical 36-in. sides of the frame and one into the vertical center brace. First, drive all of these horizontal lines of tacks about 3/4 of the way into the boards. Then to secure the string 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 stops are to be places, cutting these notches in the edges of the vertical sides of the frame and in an edge of the center brace. Next, secure the stops--string or wires--in their proper positions by tying each stop in its notched position, wrapping each horizontal stop once around the 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.

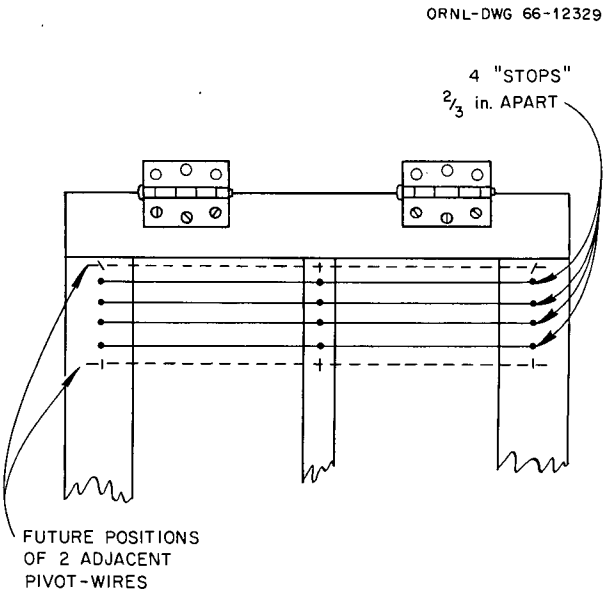

Fig. 11

5. Final assembly and operation

a. Screw or nail the upper halves of the hinges onto the horizontal fixed support (a 1-x-3-in. board 3-1/2 feet long is best) on which the punkah-pump will swing. Be careful to attach the hinges in the UNusual OUT-OF-LINE POSITION shown in Fig. 12.

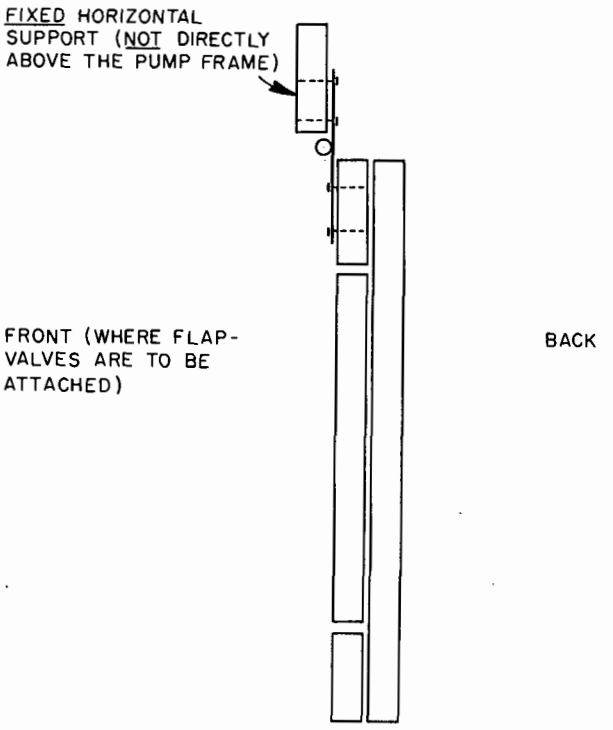

Fig. 12

b. Staple, nail, tack, or tie the ten flap-valve pivot-wires (each with its flap-valve on it) in their marked positions, at the marked 3-1/4-in. spacings, starting with the lowest and working 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--being CAREFUL TO NAIL THE PIVOT-WIRES ONLY TO THE FRAME AND THE BRACE AND NOT TO NAIL ANY PLASTIC DIRECTLY TO THE WOOD.

c. Nail or screw the horizontal support (with the complete punkah-pump attached to it) across an open doorway or window opening which you have decided to use for an air supply (intake) opening (see Figs. 2 and 13). If you lack a pulley (for efficient pulling by pulling downward like tolling a bell), place the pump in part of the doorway with its bottom about 1/2 in. above the floor, and pull it with a cord or string. Place the pump so that its flap-valves face the inside of the shelter; thus, the pump will force outside air into the shelter. Hang the pump so that one side swings only about 1/2 in. from one side of the doorway casing.

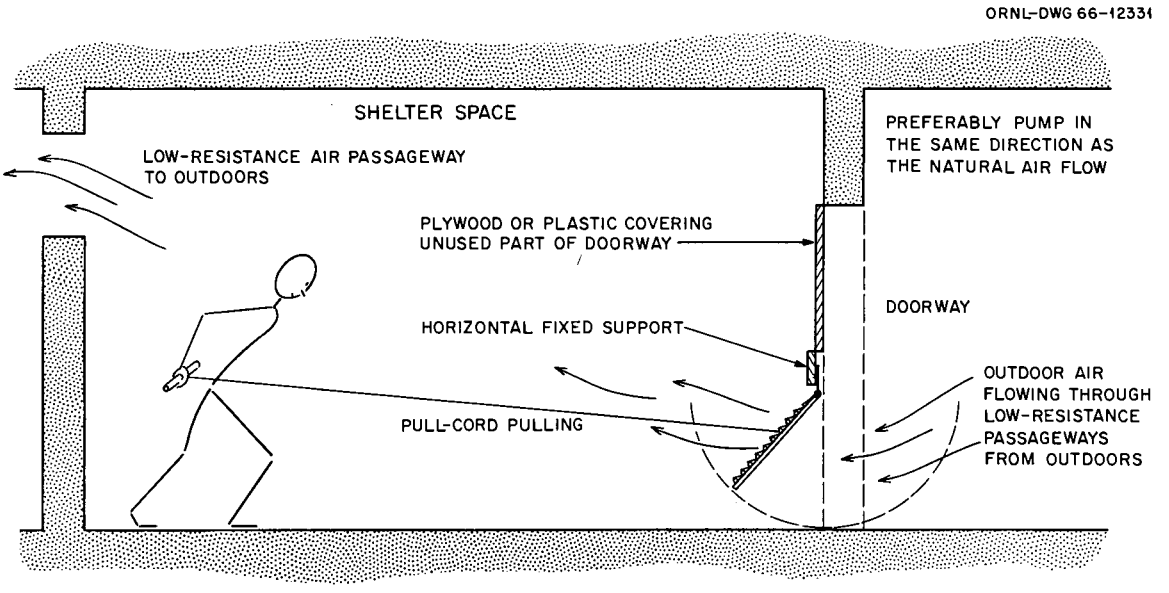

Fig. 13

d. Alternative location. If the punkah-pump is hung in the upper part of the doorway, it will pump less air. However, for use in exposed doorways or in dry, windy regions (situations which may change the hazard due to fallout entering the shelter along with the ventilating air from an unimportant to a consequential problem), it may be advantageous to hang the pump as high as possible above the floor and to cover the lower part of the doorway. The operator should stand on a table or use a long pull-cord.

CAUTION: When using a punkah-pump to ventilate a shelter in a building, it is essential to open and/or close windows and doors so as to provide a low-resistance passageway all the way through the building and the shelter from an outdoor air inlet opening to a separate, outdoor air exhaust opening. For a punkah-pump, a low-resistance air passageway is one no smaller at any point than one-half the size of the pump employed--for example, not smaller than about four square feet for a three-foot punkah-pump. If an exhaust window is not large enough, break out the glass.

If, for use with a three-foot model, you provide an air passageway having no cross-sectional area less than four square feet, then the resultant low resistance to air flow will enable you to pump over 600 cubic feet per minute of outdoor air through the shelter. This is enough air to adequately cool up to 20 people under extreme heat-wave conditions. If you have provided a separate air-exhaust opening in the shelter, cover that part of the doorway not occupied by the pump with any airtight material (plywood, plastic, canvas, or boards). Leave at least 1/2-in. clearance on both sides of the pump. This doorway covering is to make sure that all the air you pump must flow <u>through</u> the shelter, and not for the most part flow back out of the same doorway.

e. If there is only <u>one</u> opening (a doorway) to the shelter room, hang the punkah-pump in the upper half (or in the lower half) of the doorway. Leave the other half of this doorway open to serve as an air exhaust opening. The pump can thus supply about 300 cubic feet per minute to the shelter room (enough for 10 adults under heat-wave conditions). This arrangement can also be used to distribute air into dead-end side rooms within a larger shelter or basement to which sufficient outdoor air is being supplied, by using an additional punkah-pump for each such room.

f. Tie a pull-cord (or pull string, wire, or light rope) to the vertical center brace 15 in. below the top of the frame and at the top of the fifth flap-valve--if you intend to pull the pump directly with a cord and without a pulley. (When you have time to make a longer-lasting connection, tie the pull-cord to the central brace via a small loop of wire--like a chain link--which can pivot on the bent-over head of a long finishing nail. This nail should be driven through the central brace and should have its protruding sharp end bent over on the far side of the brace.)

If space is available, use a pull-cord at least ten feet long. A simple cross-stick handle or a knotted piece of cloth for a handle on the end of the pull-cord will save sore hands. If you have a pulley and a pull-rope to fit this pulley, attach the pull-cord to the vertical center brace of the pump only about nine inches from the top of the pump frame, and rig up so as to pull the punkah-pump with an easy downward pull, like a bell toller.

g. When operating the pump with a simple pull-cord, stand directly in front of it, do not jerk, and be sure to let the pull-cord go slack immediately after the end of the power stroke so that, like a free pendulum, the punkah-pump can swing back as far as possible on its return stroke.

You now have sufficient information to build a three-foot punkah-pump. The remaining sections describe additional uses, other constructions, and larger models.

D. Additional Uses

1. As an exhaust pump operated with a push-pole (see Fig. 14)

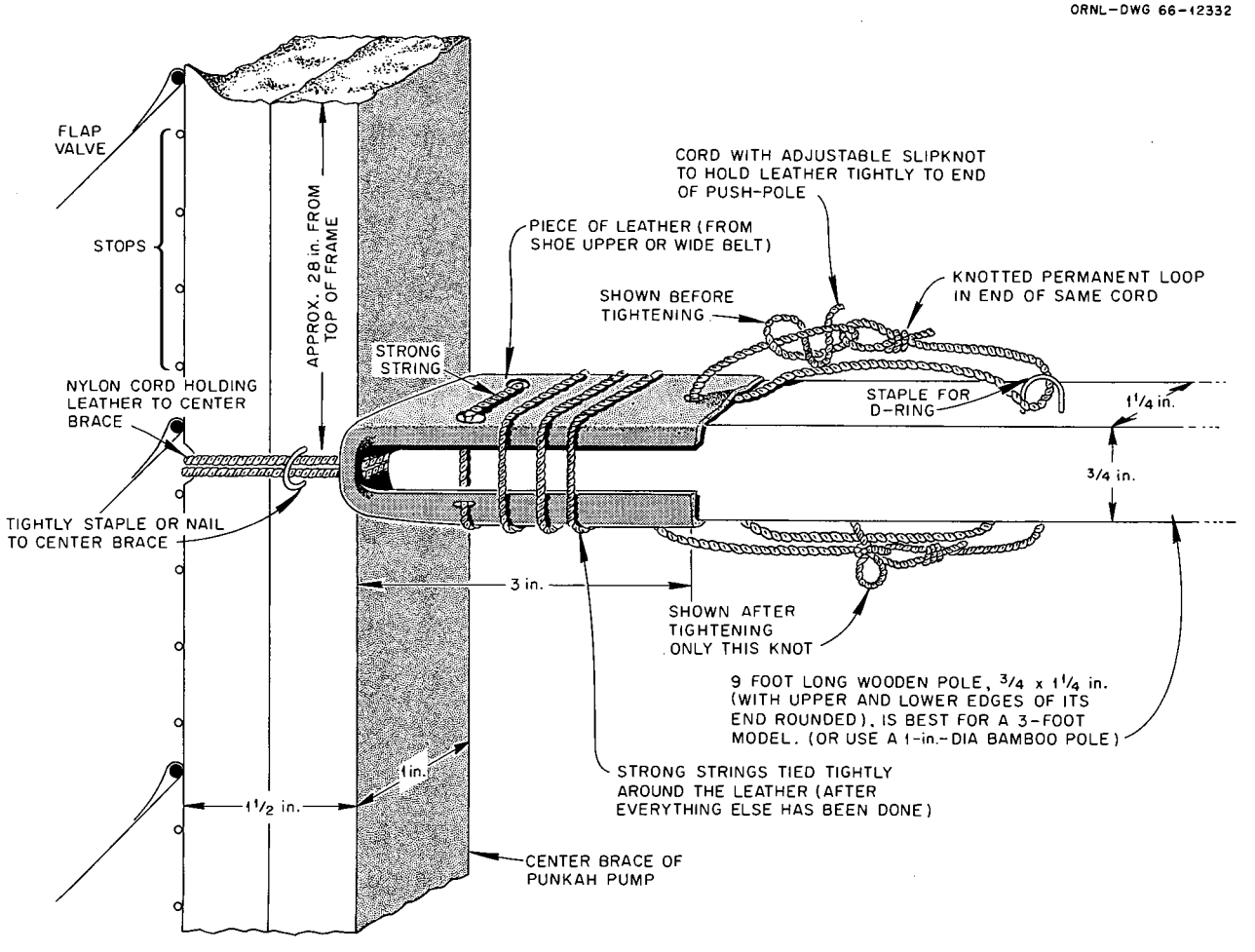

Fig. 14. Push-Pole Flexible Connection

In some shelter situations, it is desirable to exhaust air up an elevator shaft or up a stairwell or out of a doorway. Or, one may need to increase the natural, but inadequate, flow of air through the shelter or to draw air into a basement shelter through such air-inlet openings as holes broken in the ceiling. Then it is often better to push a punkah-pump by means of a push-pole rather than pull it by means of a cord.

Figure 14 shows a simple, improvised, flexible connection of a push-pole to the center brace of a pump. The push-pole should be connected to the center brace about 28 in. from the top of the frame. With such a flexible push-pole connection, one can pump (exhaust) air out of a shelter by merely holding the free end of the pole in one hand and swinging the pole back and forth with a pendulum-like, wide-swinging arm movement.

2. Punkah-pumps used in place of ducts

Even if sufficient air is pumped through a typical large basement shelter, most of this air is likely to flow directly to the exhaust opening. Thus during warm weather the occupants who are in those parts of the shelter where the air supply is inadequate to remove their body heat (for example, in dead-end side rooms) will be subject to excessive effective temperatures.

Three-foot punkah-pumps can be hung from the shelter ceiling, positioned to pump air so as to distribute it fairly to all occupants. For example, 13 three-foot punkah-pumps were hung from the ceiling and near the sides of a 4600-square-foot basement shelter. With them, an internal circular air flow of about 10,000 cfm within the shelter was easily maintained. Less than 0.01 horsepower is required to operate a three-foot punkah-pump hung from the ceiling and pulled via a good pulley.

3. Punkah-pumps used as fans

A punkah-pump hung overhead is a more efficient fan than is an ordinary punkah--the hinged frame covered with canvas, used as an overhead fan in India. Especially if shelter occupants are in tiered bunks, three-foot punkah-pumps are efficient means of mixing the cooler air near the floor with the hotter air near the ceiling. In this way the occupants of upper bunks can be provided with air only about a degree, rather than many degrees, warmer than the air near the floor.

E. Other Constructions

1. Side baffles

To increase the volume of air that a punkah-pump can force through a shelter, side baffles can be rigidly fixed to form two stationary vertical baffles ("walls") on each side of the swinging pump frame (see Fig. 15). Side baffles can be made of plywood, boards, doors, table tops, or even plastic. (A space, i.e., a clearance, of 1/2 in. to one in. should be maintained between the inner side of each baffle and the outer side of the swinging frame.) Baffles can be effective even if placed only on one side of the opening (usually a doorway) in which a pump is hung. When used with side baffles, a punkah-pump functions more like a piston in a cylinder.

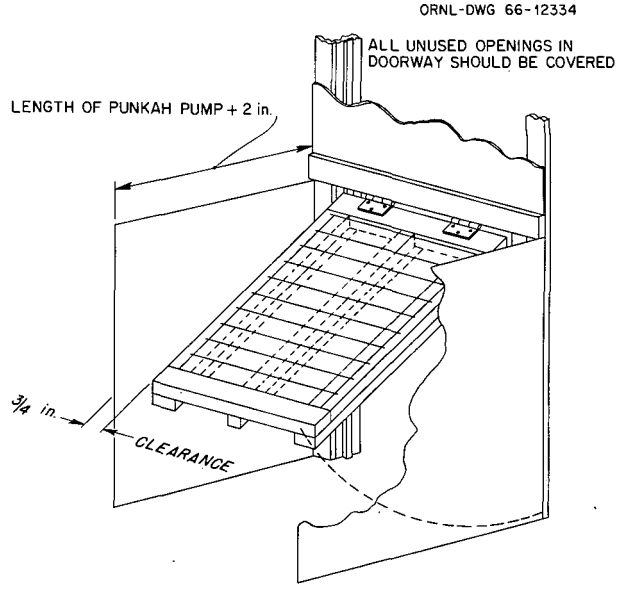

Fig. 15. Side Baffles

For example, a six-foot-high by 29-in.-wide punkah-pump was tested in a shelter while swinging 45° from vertical both backwards and forward. Against pressure differentials up to 0.015 in. water gauge--which is more than the resistance offered to an air flow of 5000 cubic feet per minute by most shelters having two doorways--this punkah-pump without baffles pumped through the shelter 3700 cubic feet per minute. With baffles placed on both sides and against pressure differentials up to 0.019 in. water gauge, it pumped 4450 cubic feet per minute.

2. Filters

If a doorway is available as the shelter exhaust opening, then a six-foot model has been found capable of pumping 3400 cfm through a one-in.-thick, 26-square foot fiberglass dust filter and through a typical large basement shelter. However, even if a stairwell or other enclosed space outside the shelter is not available as a "settling basin" to

remove almost all fallout from the air before it enters the shelter, supplying filtered air to a shelter is usually of very secondary importance as compared to supplying adequate ventilating and cooling air. (Even in the unlikely event that high rates of forced ventilation are maintained while fallout is descending, the radiation dose to the occupants of a typical basement shelter from the fallout pumped into the shelter with the ventilating air will usually be less than one percent of the dose they would receive outside.)

3. Chicken wire used as "stops"

Considerable labor can be saved if chicken wire is used as the "stops" for the flap-valves; one-in. mesh is best. Figure 16 illustrates how the mesh wire should be stapled to the frame. Next, the front of the whole frame (except for the center brace) should be covered with thin boards approximately 1/4-in. thick, such as laths. Then the pivot-wires and their flap-valves should be stapled onto the 1/4-in.-thick boards. This construction permits the flap-valves to turn freely in front of the chicken-wire valve-stops.

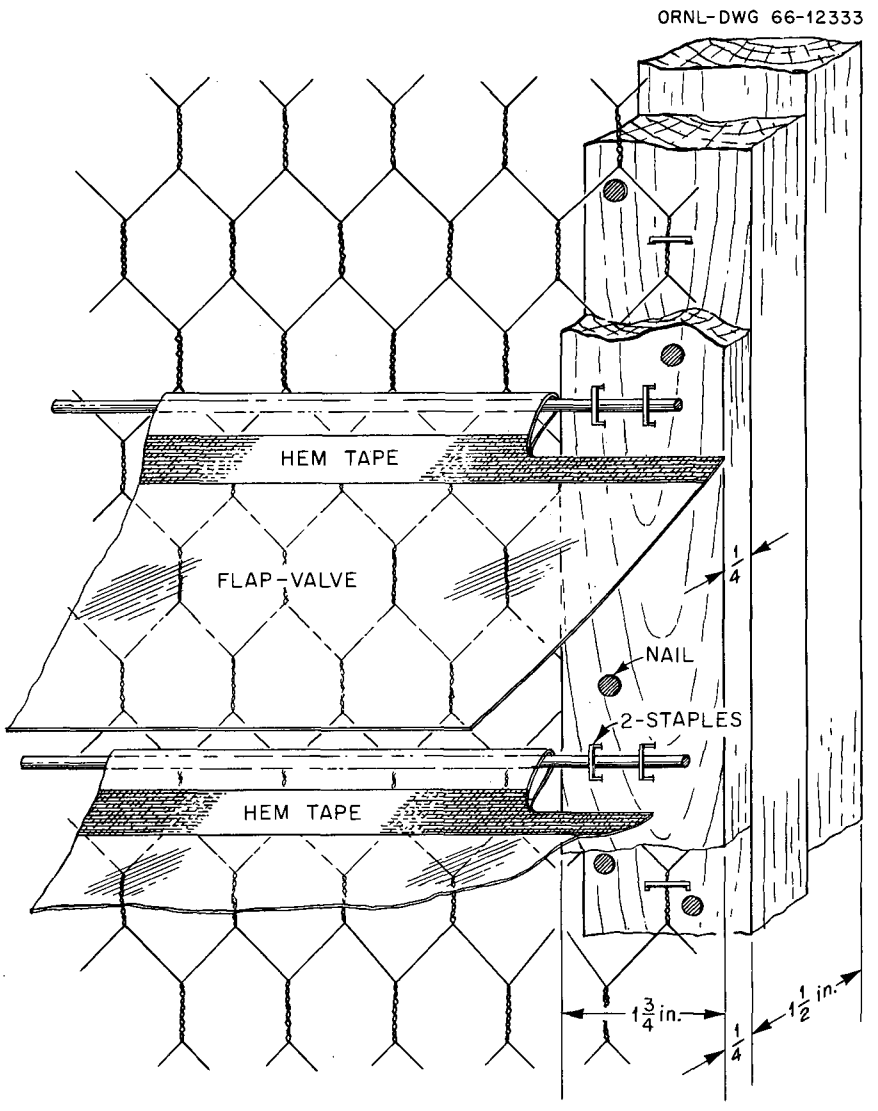

Fig. 16. Chicken Wire Used as "Stops" for Flap-Valves

With the aforementioned arrangement, the center of each pivot-wire should NOT be connected to the center brace. However, the pivot-wires attached this way must be made and held straighter than the pivot-wires used with "stops" made of straight strings or wires. Note in Fig. 16 that each pivot-wire is held firm and straight by two staples securing each of its ends. If the wire used has as small a diameter as ordinary coathanger wire, then it should be at least as springy as coathanger wire.

F. Larger Punkah-Pumps

1. The frame

A six-foot-by-29-in. model can be made with the same construction as a three-foot model, except that it should have a horizontal center brace (a 1-x-2-in. board), as well as a vertical center brace. Also, to increase the strength of the frame, each of its members (each is made of two boards) should be held together with numerous nails, and these nails should be clinched.

2. Flap-valves

If a six-foot model is used for hundreds of hours and if its flap-valves are made of ordinary polyethylene, then its lower-most flap-valves may develop tears which spread inward from the edges. Such tearing may be prevented by taping the edges with 1/2-in.-wide pressure-sensitive tape. If thus reinforced, even the lower-most four-mil polyethylene flap-valves will be serviceable for over 1000 working hours.

3. Power requirements

Less than 0.05 horsepower is required to operate such a six-foot punkah-pump when it is pumping about 5000 cfm of air through a typical basement shelter which has both an air-intake and an air-exhaust doorway. This is an easy work rate for one man, especially if he powers the pump by pulling downward like a bell toller on a pull-cord run over a pulley. Make a comfortable hand hold, at least one in. in diameter by tying a row of knots in a piece of cloth.

4. Pulley operation

In this case, the pull-cord should be connected to the center vertical brace about 16 in. from the top of the frame. A high-grade, two-in.-diameter, swivel-eye pulley is best; a "Delrin" model was in good condition after two weeks of continuous use.

To operate a six-foot punkah-pump with maximum efficiency, the pulley should be hung about 6-1/2 feet above the floor, directly in front of the pump and 15 to 20 feet distant from it. Often the easiest way thus to position a pulley in a shelter is to suspend it from the top connection of a tripod made of three boards each about 8 feet 3 inches long. The tripod can be tied at its top with a rope which is run through holes near the tops of the three boards. The three tripod feet can be kept from spreading too far apart simply by connecting them with rope or wire. For stability during operation on a concrete floor, the tripod should be held down with heavy objects.

5. Push-pole operation

If it is desirable to operate a six-foot model as an exhaust pump by means of a push-pole, use a pole 8 to 10 feet long and about 1-1/2 in. in diameter. (See Fig. 14)

6. Operation against higher resistances

A six-foot model with side baffles on both sides has been found capable of pumping 3000 cfm through a basement shelter against a pressure difference of 0.03 in. water gauge. This was the resistance to air flow when the exhaust opening was reduced to only about five square feet.

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