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MECHANIZED DURABILITY TESTS OF A SIX-FOOT PUNKAH-PUMP

Cresson H. Kearny

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DIRECTOR'S DIVISION
Civil Defense Study Group

MECHANIZED DURABILITY TESTS OF A SIX-FOOT PUNKAH-PUMP

Cresson H. Kearny

JULY 1965

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CONTENTS

		Page
	Abstract	1
I.	Test Objectives	3
II.	Description of the Testing Procedures	3
	1. Model Tested	3
	2. Duration and Location of the Tests	4
	3. Mechanical Drive and Flowrate	4
	4. Plywood "Wings"	6
	5. Maintenance and Repairs	6
III.	Test Results	6
	1. Test 1 (23 hours and 30 minutes)	6
	2. Test 2 (23 hours and 40 minutes)	10
	3. Test 3 (986 hours and 42 minutes)	10
	Flap-Valves Numbers 1 through 10	10
	Flap-Valves Numbers 11 through 20	10
	Pulleys and Pulley-Ropes	12
	Connection of the Pull-Cord to the Pump Frame	13
IV.	Home-Workshop Model Pumps	14
V.	Conclusions and Recommendations	16

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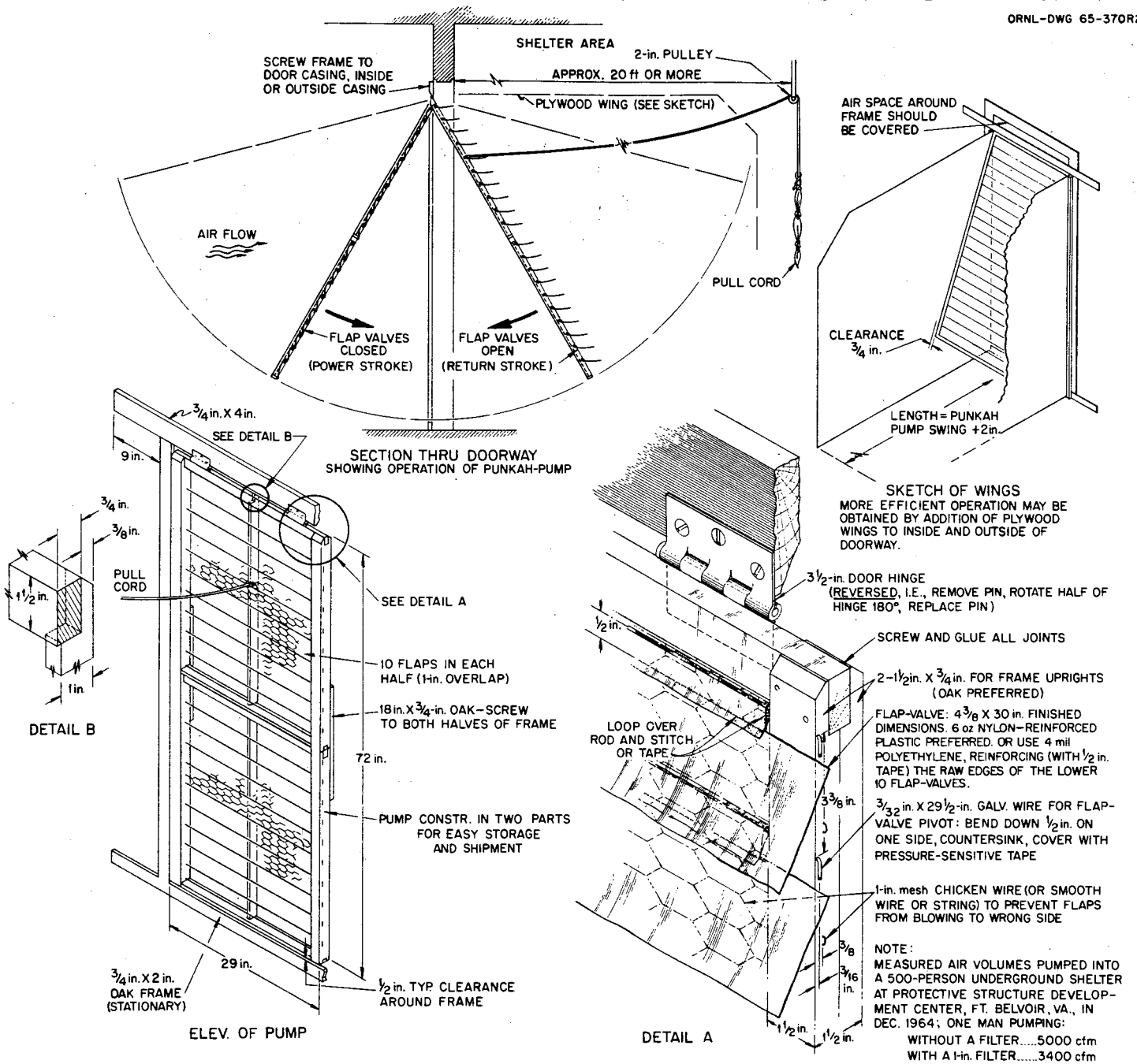
ABSTRACT

In order to test and to improve the durability of a six-foot manually operated punkah-pump for shelter ventilation (described in a previous report[1]), motor-powered durability tests were conducted at Oak Ridge National Laboratory. This model pump, in a previous volumetric test in December 1964, transferred more than 5000 cfm into the 500-person belowground shelter room at the Protective Structures Development Center, Fort Belvoir, Virginia, when operated by a single man. Its design is shown in Fig. 1.

This model ventilating pump was tested at ORNL for more than 1000 hours. The testing indicated that this pump is dependable for at least six weeks of continuous use, provided the below-mentioned modifications of the flap-valves and pulleys are incorporated. These modified parts were supplied to the Protective Structures Development Center for possible future tests with their six-foot punkah-pump.

The modified punkah-pump, like other manual shelter-ventilating pumps, needs further realistic manual testing operated by average people during a shelter test of more than two weeks duration.

[1] C. H. Kearny, Manual Shelter-Ventilating Devices for Crowded Shelters Cooled by Outside Air--A Preliminary Report, ORNL-TM-1154 (June 8, 1965).



INVENTED BY C.H. KEARNY — OAK RIDGE NATIONAL LABORATORY

Fig. 1. Punkah-Pump.

I. TEST OBJECTIVES

The tests were planned to determine the durability of a punkah-pump which included design features desirable for mass-produced models.

Some features of the pump were more complicated than are necessary in the home workshop models, but which might prove desirable in mass-produced models. These special features include flap-valves which can be mounted and replaced easily and flap-valve hinges and flap-stop wires which are in a recessed plane back of the plane of the face of the punkah-pump frame. This latter feature allows pumps to be shipped without damaging flap-valves, if only the two ends of each flap-valve are turned back before boxing. Other design features (more likely to be incorporated in mass-produced models) which were tested were flap-valves (described as numbers 12, 15, and 19 in the section on test results) of nylon-reinforced plastic (not available in most areas for home workshop construction) and special pulleys.

To illustrate the ease of construction of less complicated models, several simplified punkah-pumps were constructed but not given durability tests. The characteristics of one simplified model will be described later in this report.

II. DESCRIPTION OF THE TESTING PROCEDURES

1. Model Tested

The pump tested was a 72-x-29-in. model with 20 flap-valves. The frame was made of white oak. The materials and hardware were all standard items obtainable in hardware stores, except for the special nylon-reinforced flap-valve material and pulleys previously mentioned and for a special clevis used to connect the pull-cord to the swinging punkah-pump frame. (If a person, in contrast to a motor drive used in a durability test, is pulling the pump, then, if the pull-cord wears through every day or so, it is easy to retie the cord to the pump.)

One-half (lengthwise) of the 1-in.-mesh chicken wire used for the stop-flaps was enameled to see if smoothing the wires would result in less wear to the flaps. No difference in wear of the flap-valves was noted.

2. Duration and Location of the Tests

The pump was tested for a total of over 1033 hours and 52 minutes between February 2, 1965, and May 6, 1965. Numerous interruptions in the testing occurred during the first two months of the test period, due to breakdowns of the mechanical test drive mechanism and by delays while improved pump parts were being obtained. The tests were monitored daily, except on weekends. On those occasions when a broken pull-cord or pulley stopped the pump at an unknown hour, no test time was recorded for this unobserved interval.

3. Mechanical Drive (Fig. 2) and Flowrate

A 3/4-hp heavy duty electric motor was coupled to a Radicon worm gear speed reducer (Foote Brothers, Chicago), turning a 13-in. crank at 25 rpm (Fig. 2). A rotating stud near the end of the crank was connected to a 1/4-in. nylon-dacron braided rope which passed over a 2-in. pulley suspended in line with the swinging pump frame. The resultant 26-in. pull (via a 3/16-in. braided nylon pull-cord tied at one end to the 1/4-in. pulley rope and at the other end connected to the pump frame 16 in. below its horizontal hinge-line) resulted in the swinging pump frame being jerked to a stop before it reached what normally would have been the end of its pendulum-like return stroke. This restriction of the swing put more stress on the flap-valves than would occur if the pump were operated manually. It also reduced the flowrate.

Because of the limited backswing, the inward height of swing (the maximum height above the floor of the bottom of the swinging pump frame) averaged 4 ft 1 in., but the maximum height of the restricted return stroke was only about 2 ft. The volume of air pumped (measured through the open exhaust doorway of the test room) was 3950 cfm. Small openings in the test room accounted for additional minor air flows. The arc of swing during these mechanical tests was about 115 degrees versus about 135 degrees when manually operated and pumping 5000 cfm.

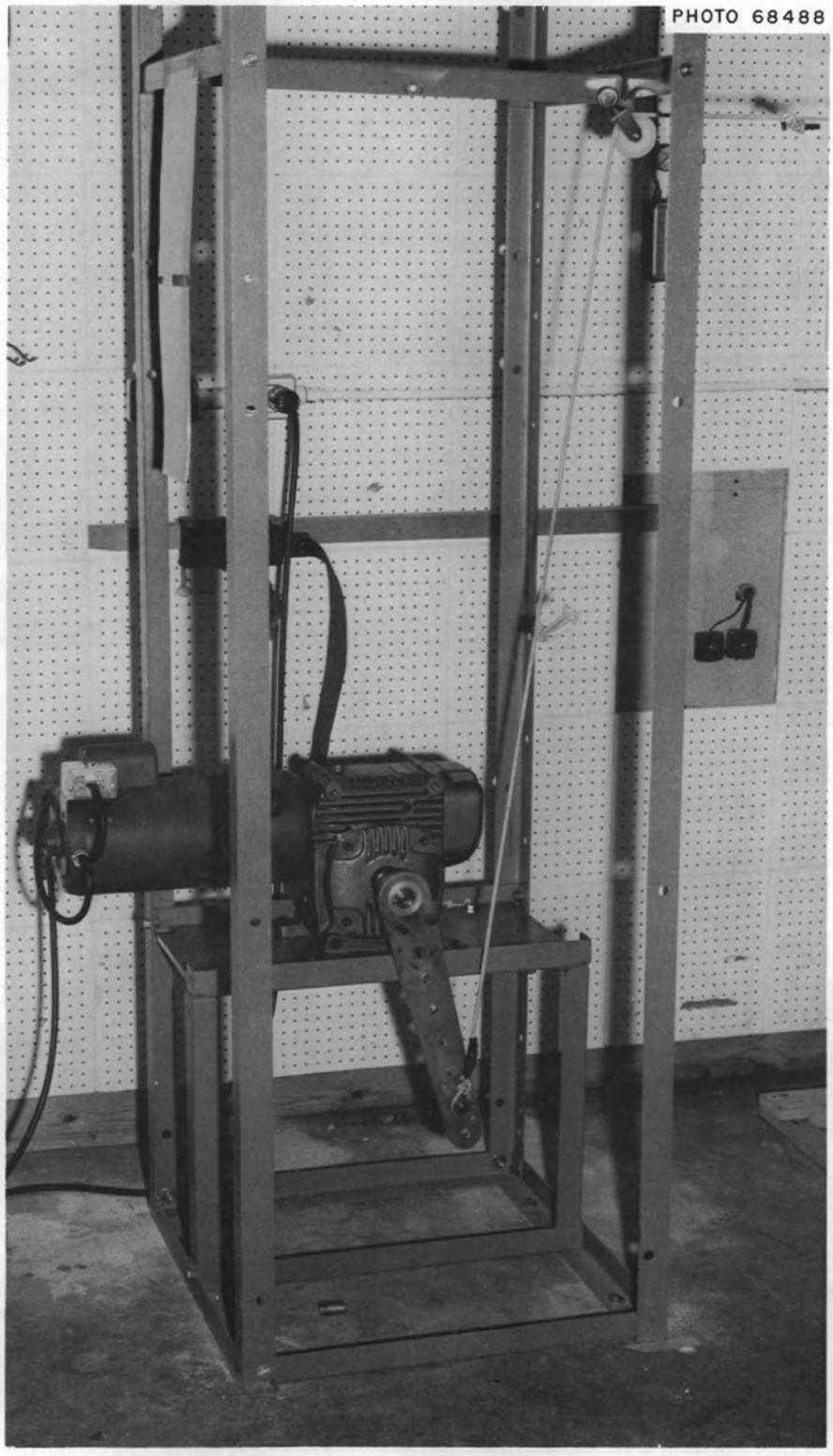


Fig. 2. Electric power unit producing a 25-rpm, 13-in.-radius crank drive, thus giving a 26-in. reciprocating movement to the 1/4-in. pull-cord running over the 2-in. pulley toward the punkah-pump.

4. Plywood "Wings"

Two "wings" of braced 3/8-in. plywood were built inside the doorway to increase the volume of air pumped. However, for this pump no measurements were made of flow rates with and without wings. Such wings also probably increased the stresses on the flap-valves, compared with operating without wings. Clearances between the sides of the swinging pump and the wings were 3/4 in. to 1 in. The wings are drawn in Fig. 1 and may be seen in Figs. 3 and 4.

5. Maintenance and Repairs

No parts of the pump were oiled or greased until after 879 hours of testing, at which time the door hinges and the pull-cord clevis-pin were oiled to reduce squeaking.

Pulleys and pulley ropes were replaced as noted below, and at each daily inspection any tears in flap-valves were repaired with ordinary paper masking tape. These flap-valve repairs only involved the flap-valves made of common plastic, rather than the special reinforced material.

III. TEST RESULTS

1. Test 1 (23 hours and 30 minutes)

A variety of flaps (all types described in Test 3 below, except for nylon-reinforced vinyl fabric) were tested. A 1/8-in. braided nylon pull-cord was tied directly to the oak pump frame. At some time during the second day of testing, friction between the oak frame and the cord caused the latter to break, ending the test.

Since on the lower half of the pump some of the pure polyethylene flap-valves which did not have diagonal end reinforcements of pressure-sensitive cloth tape were beginning to have their ends torn, before the start of Test 2 all flap-valves had their ends thus reinforced with tape (Fig. 5).

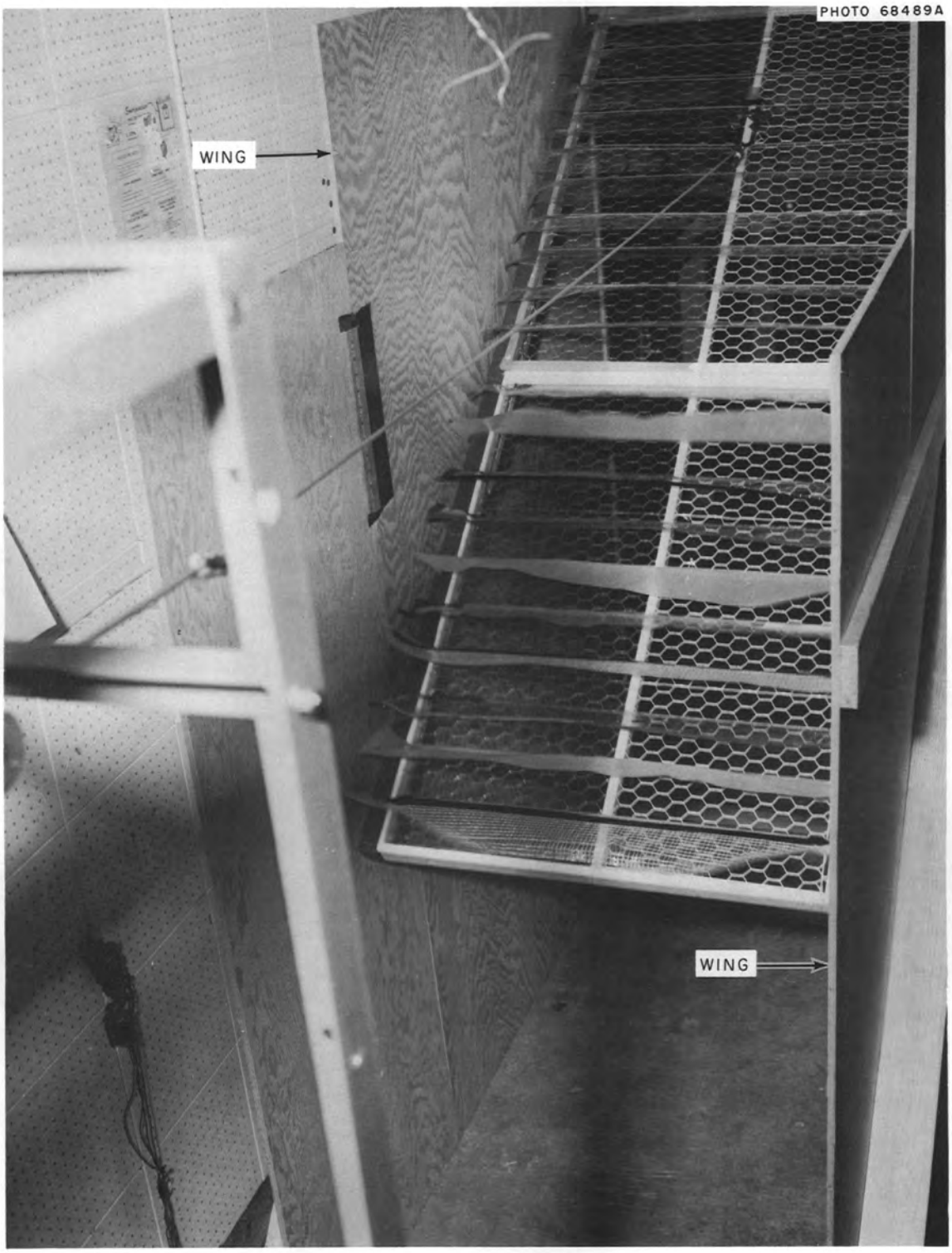


Fig. 3. The Six-Foot Punkah-Pump After 54 Hours of Test 3, Showing Flaps Open During Outward Return Swing. Note different kinds of flap-valves tested.

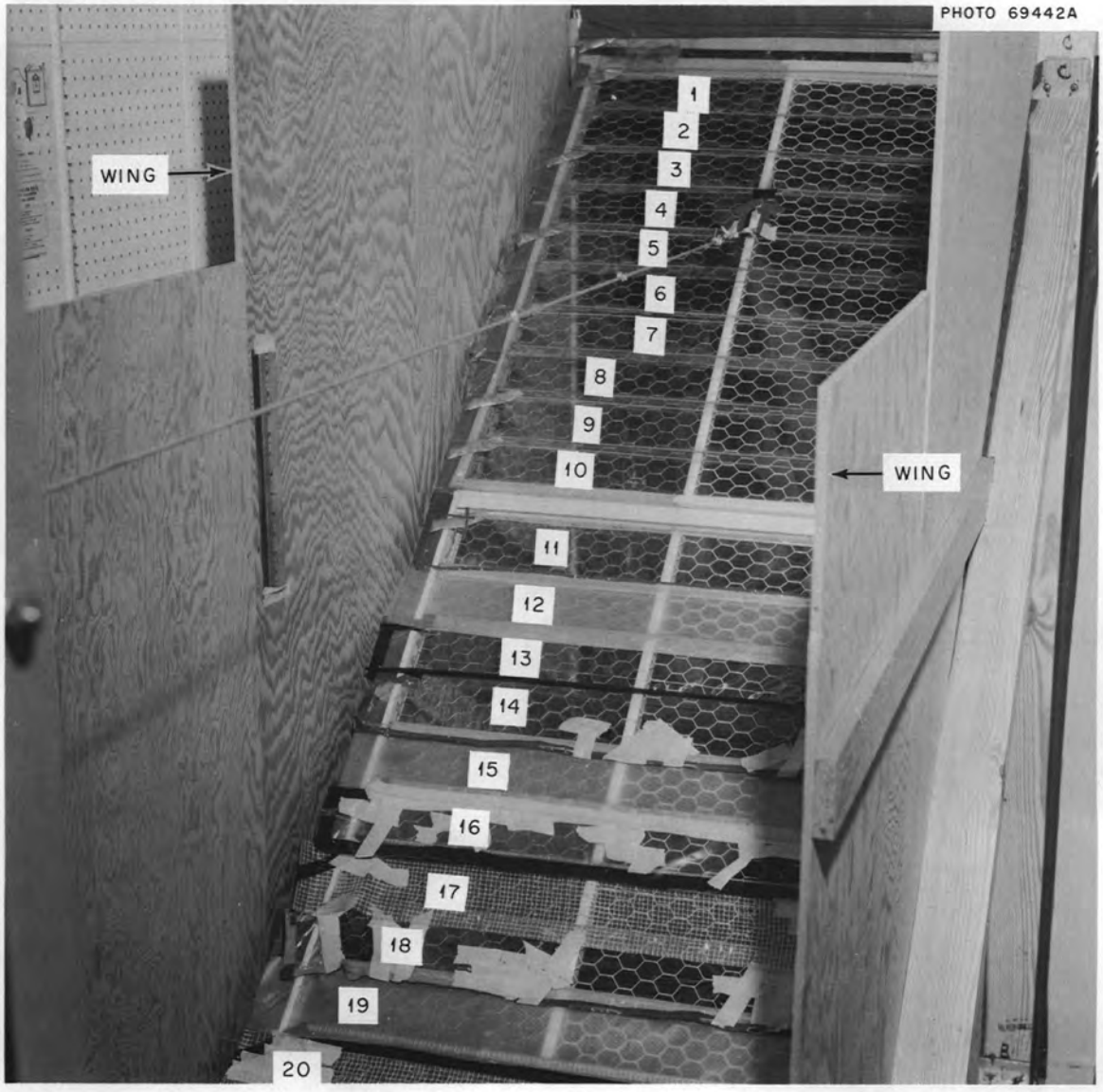


Fig. 4. After over 1000 hours of testing, the punkah-pump is shown with flap-valves closed during its inward power stroke. Note that the only flap-valves made of material such as probably would be used for mass-produced models (flaps 12, 15, and 19) are in good condition.

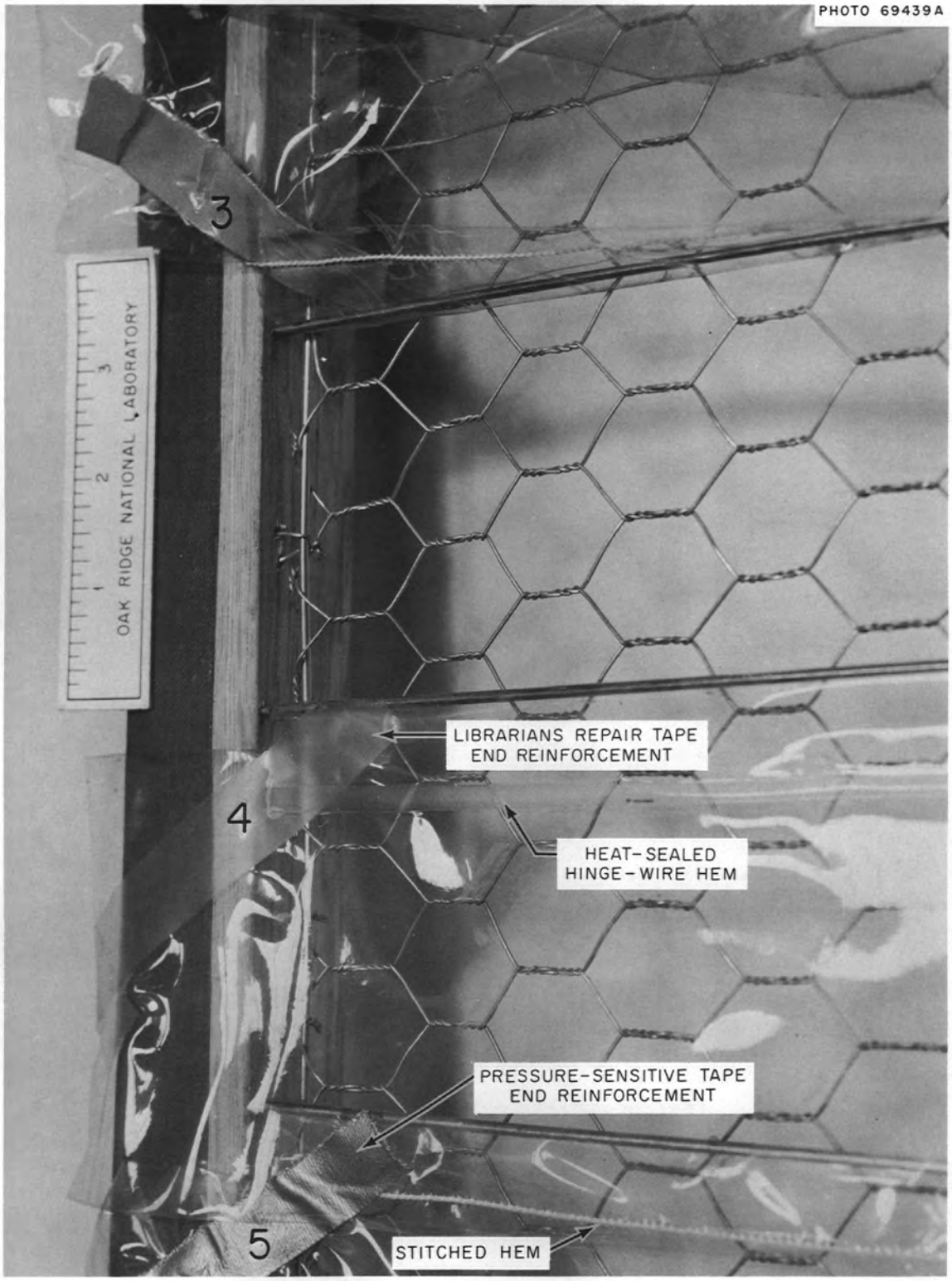


Fig. 5. Detail of Flap-Valves, After 1000 Hours of Testing, and Flap-Stop Wire Mesh, of Upper Half of the Six-Foot Punkah-Pump. The plane of stop-flap wire mesh is 3/16-in. behind the plane of the face of the oak frame.

2. Test 2 (23 hours and 40 minutes)

A loop of nylon-coated 3/32-in.-diam stainless steel steering cable was used to connect the end of the pull-cord to the oak pump frame. At some time during the second or third day of testing, repeated flexures caused this cable to break where it passed through a 1/8-in.-diam hole in the oak frame. This failure ended the test.

Because of increased tearing of the pure polyethylene flap-valves on the lower half of the pump (these tears started on the cut edges and worked inward), it was concluded that, for the bottom half of the 6-ft pump, the cut edges of plastic film flap-valves must be reinforced, and this was done before Test 3 began.

3. Test 3 (986 hours and 42 minutes)

The following modifications were made before the start of Test 3.

Flap-Valves Numbers 1 through 10 (Fig. 4)

On the top half of the pump the flap-valves were left untouched. All 10 were of pure 4-mil polyethylene film (4-mil clear polyethylene film; Warp Brothers, Chicago, "Coverall," which meets government specification MIL-P-3803, as revised). All had diagonal end reinforcements (see Figs. 4 and 5) of pressure-sensitive cloth tape or of librarian's repair tape. Their hinge-hems were either sewed or heat-sealed (see Fig. 5). None had their cut edges reinforced, except for the edges of a slot cut in flap number 4, where the pull-cord connections rubbed against it (see Fig. 4).

As is indicated by Fig. 4, a photograph taken after over 1000 hours of testing, none of these upper ten flap-valves were damaged or repaired in any way, except for two small tears near the center of flap number 4.

Flap-Valves Numbers 11 through 20

On the lower half of the pump, every valve (except 12 and 15) had diagonal end reinforcements of cloth tape, plastic tape, or plastic; all proved satisfactory.

(1) Valve 11: 4-mil polyethylene (Warp Brothers), with all cut edges reinforced with 1/4-in. strips of pressure-sensitive cloth tape. The hinge-hem was stitched with dacron thread. No damage at the end of Test 3.

(2) Valves 12 and 15: Made of Sun Chemical Company's 6-oz clear nylon-reinforced plied vinyl (called "Facilon," 6-oz, "nylon-reinforced vinyl fabric," Style No. 618; meets MIL Spec. C-43006 Type III). No end or edge reinforcements. Hinge-hem heat-sealed. No damage noted at end of Test 3, except for a few threads which were broken at the re-entrant corners of the ends of the flaps.

(3) Valves 13 and 14: 4-mil polyethylene (Warp Brothers) with heat-sealed hinge-hem and plastic diagonal end reinforcements. All cut edges reinforced with 1/2-in. tape. Several inches of interior tears occurred during testing; these were repaired with paper masking tape.

(4) Valve 16: Common utility covering polyethylene 4-mil film (Warp Brothers) with heat-sealed hinge-hem and plastic diagonal end reinforcements. Cut edges were reinforced with 3/4-in. plastic electrician tape. The entire hem was repaired before the end of the test. An 8-sq-in. piece of one end was torn away, and other smaller tears were repaired before the end of the test. The hem was probably sealed at too high a temperature; stitching is preferable to inexpert heat-sealing.

(5) Valves 17 and 20: Nylon-reinforced polyethylene (an inexpensive grade), about 6-mil. Hinge-hem and diagonal end reinforcements of 3/4-in. electrician's tape. No damage suffered except for holes near ends.

(6) Valve 18: Same as valve 13, except that greater stresses near bottom of pump resulted in more interior tears, including the loss of 4 sq in. of polyethylene near one end.

(7) Valve 19: Same as valves 12 and 15, except it had vinyl heat-sealed diagonal end reinforcements. These came off, but there was no damage to this excellent nylon-reinforced vinyl flap-valve.

Pulleys and Pulley-Ropes (Fig. 2)

A good pulley greatly facilitates manual operation of a punkah-pump, although one is not necessary for emergency operation. In order to minimize costs and possible deterioration problems, the pulleys tested were all of plastic with simple stainless steel shafts; in chronological order, they were:

(1) Two-in. nylon pulley (an old model of Allen Marine, Inc.--a "Tiller Block" for a 1/4-in. or 5/16-in. rope). The shaft was a 3/16-in. stainless steel rod, and the bearing area was 1/2-in. long. A braided dacron rope ran over this pulley and was tied to the pull-cord of the pump. After 351 hours of testing, this pulley was about to fail. The cause of failure was slow plastic flow of the solid nylon in contact with the shaft, causing enlargement of the hole and eccentricity of the bearing area. This finally led to overheating and to irregular movement, which wore the rope more during the last day than during the preceding 13 days of use.

(2) New 2-in. nylon pulley (same model as before). After 190 hours of testing, the shaft hole of this pulley sheave was worn about 1/8-in. oversize and was running hot, although still smoothly. It appeared unlikely that it would last even two weeks. Therefore, it was replaced by (3).

(3) One-in. swivel block (Seaboard Marine Supply Co.) of machined phenolic resin, with 1/4-in. stainless steel shaft. This pulley caused the old pull-rope (which still was strong and appeared useful for more service with the previous 2-in. pulley) to break in a few hours. It was concluded that with braided dacron rope, pulley sheaves should have diameters of at least 2 in. and should have rounded edges in order to avoid overflexing the rope and cutting it.

(4) Two-in. nylon pulley, modified by an ORNL machine shop so as to have a 1-in.-long rather than a 1/2-in.-long bearing area on its 3/16-in. shaft. A new braided 1/4-in. nylon rope with a dacron core was used. After 23 hours, this pulley was removed since it was painfully hot to the touch and not turning on the return stroke.

(5) Two-in. Delrin (DuPont) swivel-eye pulley (Allen-Jervis Marine, Inc., Hicksville, New York), with 3/16-in. stainless steel shaft having a 1/2-in.-long bearing area. This pulley ran hot at first (apparently because there was not quite enough clearance around its shaft) but later ran cool and gave excellent service for a total of 324 hours. It showed a final clearance of about 0.03 in. around its shaft and appeared good for hundreds of hours more use.

(6) Special 3-in. pulley made by an ORNL machine shop with a sheave of machined Nylatron GS-M (nylon with MoS_2 lubricant, by Polymer Corp.). The steel shaft was 0.500 in., with the bearing surface 0.75-in. long. Surprisingly, this pulley ran painfully hot from the start and was removed after only 103 hours, because it was binding against its sides. The 1/4-in. rope continued to be in good condition.

(7) Two-in. nylon pulley, with same rope as before. It was in good condition after 41 hours, at the end of all testing.

Connection of the Pull-Cord to the Pump Frame

Simply tying either a 1/8-in. or a 3/16-in. braided nylon pull-cord to the central oak stick of the frame results in a connection (as indicated by two tests) which lasts about 24 hours before wearing through. This would constitute no particular problem for manual operations.

A connection which lasted for nearly 1000 hours, and appeared likely to last several thousand, was made with a special clevis. This clevis had a 3/16-in. steel pin which fitted tightly in the hole through the oak center stick, 3/8 in. from its inner face. (The cotter pin through the end of this clevis pin was wired to prevent any rotation of the pin in the hole in the oak stick.) The distance from the clevis pin to the U-shaped end of the clevis was 1-3/4 in., and the clevis was 1/8 in. wider than the oak center stick. This clevis was conveniently connected to the end of the pull-cord with a snap hook.

IV. HOME-WORKSHOP MODEL PUMPS

These mechanized durability tests indicate that mechanically similar, but simpler, models--which could be made more easily in a home workshop--would also be serviceable. Figure 6 illustrates some details of one such design.

Frame

The frame can readily be made like a narrow windowscreen frame of 3/4-in. lumber, except that a vertical central stick (3/4-x-1-in.) should be added. So that the frame will swing back farther during its return stroke, an equal weight of metal or wood should be connected to the frame after the pump is otherwise completed. In Fig. 6, metal is taped to the wood frame.

Pivot Wires

For the wires which serve as pivots for the flap-valves, straightened coat-hanger wires can be stapled to the inner face of the swinging frame and the central vertical stick.

Stop Wires

To stop the flap-valves when they reach their closed positions, thin wires or strings can be fixed to the inner face of the frame about 3/4 to 1 in. apart and parallel to the pivot wires.

Flap-Valves

Ordinary polyethylene film, preferably 4- to 6-mils thick, can be used as previously described, with care being given to the reinforcements (not shown in Fig. 6) of ends and cut edges. Many other common household materials can be used successfully, such as coated fabric tablecloths, raincoats, or even tightly woven cloth. Sewing the hinge-hem is usually best, but taping (preferably with a waterproof tape) often serves well if long storage is not involved.

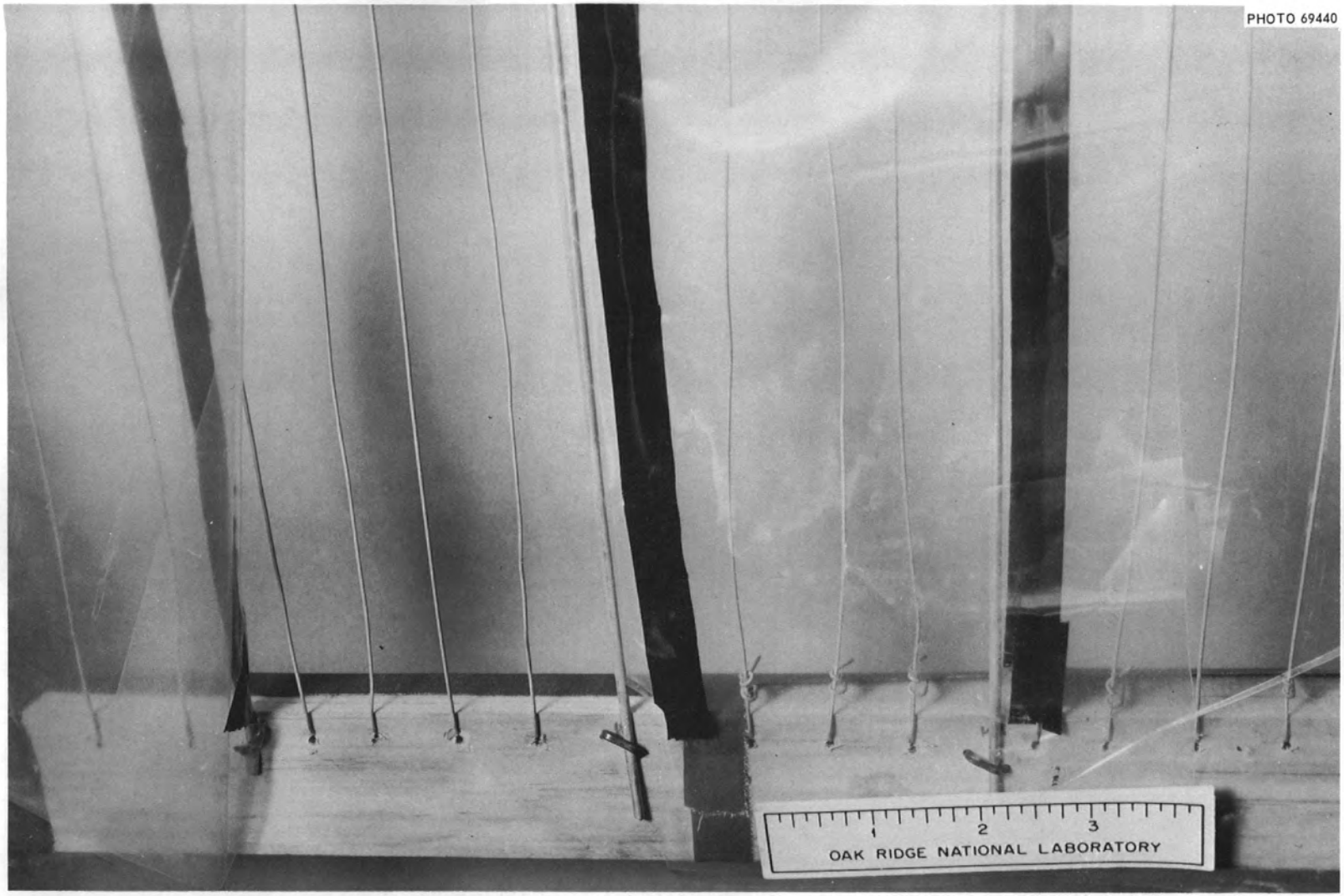


Fig. 6. Details of a Punkah-Pump Which Could be Easily Constructed in Home Workshops. Flap-valves are of ordinary 4-mil polyethylene with taped hinge-wire hems. To increase the amplitude of the pendulum-like return swing, a steel bar is taped onto the back of the frame.

Hinges

If door hinges are not available, leather or fabric strap hinges will serve if more than 3/4-in. clearance is provided between the swinging frame and the doorway or "wings" within which it swings.

Pull-Cord

If a pulley cannot be obtained, the pull-cord which is connected to the center vertical stick of the frame can be run over a smooth greased groove cut in a piece of wood. However, a straight pull is more efficient, preferably through a large guide-hole, which helps the operator always to pull the pull-cord in the proper line.

V. CONCLUSIONS AND RECOMMENDATIONS

1. Punkah-pumps of the type tested in this program probably will last for 1000 hours or more of manual operation. However, like any manual shelter ventilating pump upon which the lives of many people may depend, punkah-pumps should be subjected to realistic testing, powered by average people during a shelter test of more than two weeks duration. Even though an initial sheltering period might end after two weeks, shelter occupants would often find it advantageous to reduce their radiation exposure by using well-ventilated shelters for barracks for considerably longer periods.

2. In order for average citizens during an escalating crisis to be better able to build punkah-pumps, improved building instructions should be prepared. This can best be done by giving written instructions to average home workshop owners who have never heard of such pumps and by having them use locally obtainable materials to build punkah-pumps. Thus, pump-building instructions can be checked and improved until they are proven practical means for enabling average people to build serviceable pumps.

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