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DIRECTOR'S DIVISION

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MORE EFFICIENT OPERATION OF KEARNY AIR PUMPS FOR MANUAL VENTILATION OF SHELTERS

by

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ABSTRACT

The following developments and tests pertinent to more efficient design and operation of Kearny Air Pumps (KAP's) when used to ventilate and cool shelters are described: (1) Demonstration of the unreliability of a KAP when operated in the doorway of a dead-end shelter room; (2) Development and tests of a technique for using an A-Frame Kearny Air Pump to efficiently ventilate a dead-end shelter; (3) Development and tests of improved handles and bridles with which to pull especially 6-foot KAP's that must be pulled directly, without the help of a pulley attached above the operator(s); (4) Perfection of illustrated written instructions to enable average Americans to operate KAP's efficiently, when guided only by these written instructions; (5) Determination of the preference of average citizens for pulling a 6-foot KAP with its pull-cord connected 15 inches from its hinge line, as compared with its pull-cord connected 3 feet from its hinge line; (6) Improvement of the durability of the flaps for KAP's; (7) Development of means for protecting homemade KAP's that are being operated inside shelters from being damaged by a moderate velocity shockwave and blastwind entering the shelter.

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MORE EFFICIENT OPERATION OF KEARNY AIR PUMPS FOR MANUAL VENTILATION OF SHELTERS

C. H. Kearny

In order to apply the principles of efficient air flow and of human engineering more effectively to the manual operation of the Kearny Air Pump (KAP) when used to ventilate and cool shelters, in the summer of 1971 Cresson H. Kearny made the following practice tests and improvements pertinent to the design and use of the Kearny Air Pump:

1. Made an estimate of the effectiveness of a 3-foot KAP,* when it was hung in a doorway that is the only opening of a dead-end shelter, to ventilate and cool this shelter.

The following three photographs (Fig. 1, 2, and 3) indicate that a KAP so operated in a doorway is an unreliable means of furnishing sufficient cooling air even to a small dead-end shelter room. Most of the exhausted air, being at slightly higher pressure than other air just outside this shelter doorway, flows to the relatively low-pressure region behind the swinging KAP, and then is pumped back into the shelter room in which it already has been heated and from which it has just been exhausted.

Recommendations: Provide additional means and instructions to enable occupants of dead-end shelter rooms to supply themselves with adequate volumes of outside air. These other means could include:

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*Kearny also tested a 6-foot KAP, as the means of adequately ventilating a dead-end shelter room having a doorway for its only opening, by operating a 6-foot KAP hung in this doorway, to pump air into the dead-end room. To permit air to be exhausted, he removed the flaps from the upper 3 feet of this pump. To his suprise, the air flow inside the shelter room (as proved by air velocity measurements in 21 different positions, using a Hastings Air Meter) was no better than when only a 3-foot KAP was used in the same doorway. And the exhaust air flowing outward through the upper half of the 6-foot KAP was "sucked" back into the shelter room fully as much as when using a 3-foot KAP.

PHOTO 1622-71

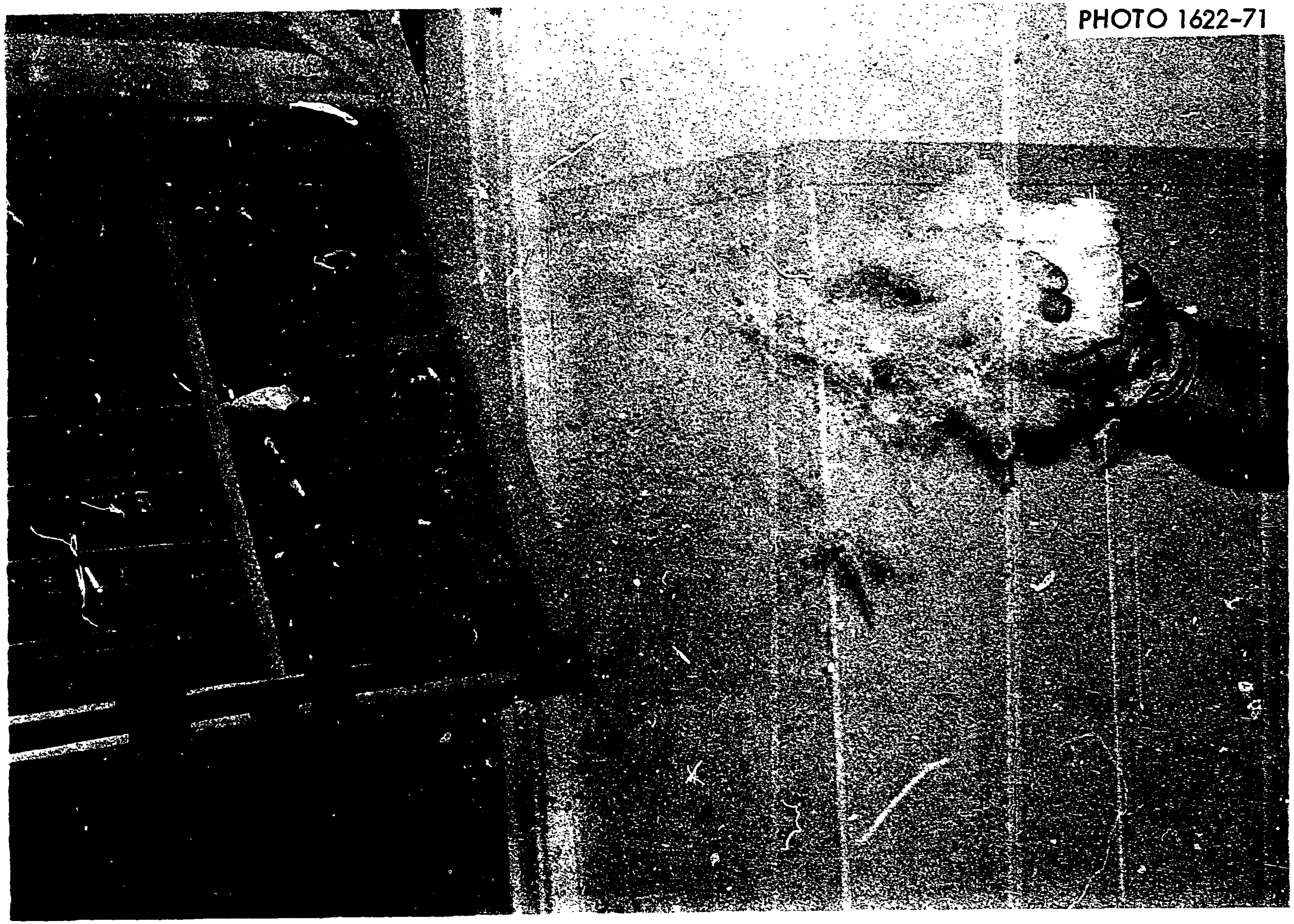

Fig. 1. Picture taken outside a shelter room having only this doorway for an opening. A 3-foot Kearny Air Pump is shown pumping air into the room, and sucking white smoke (titanium tetrachloride) into the shelter along with the air being pumped into the shelter room through the upper part of this doorway.

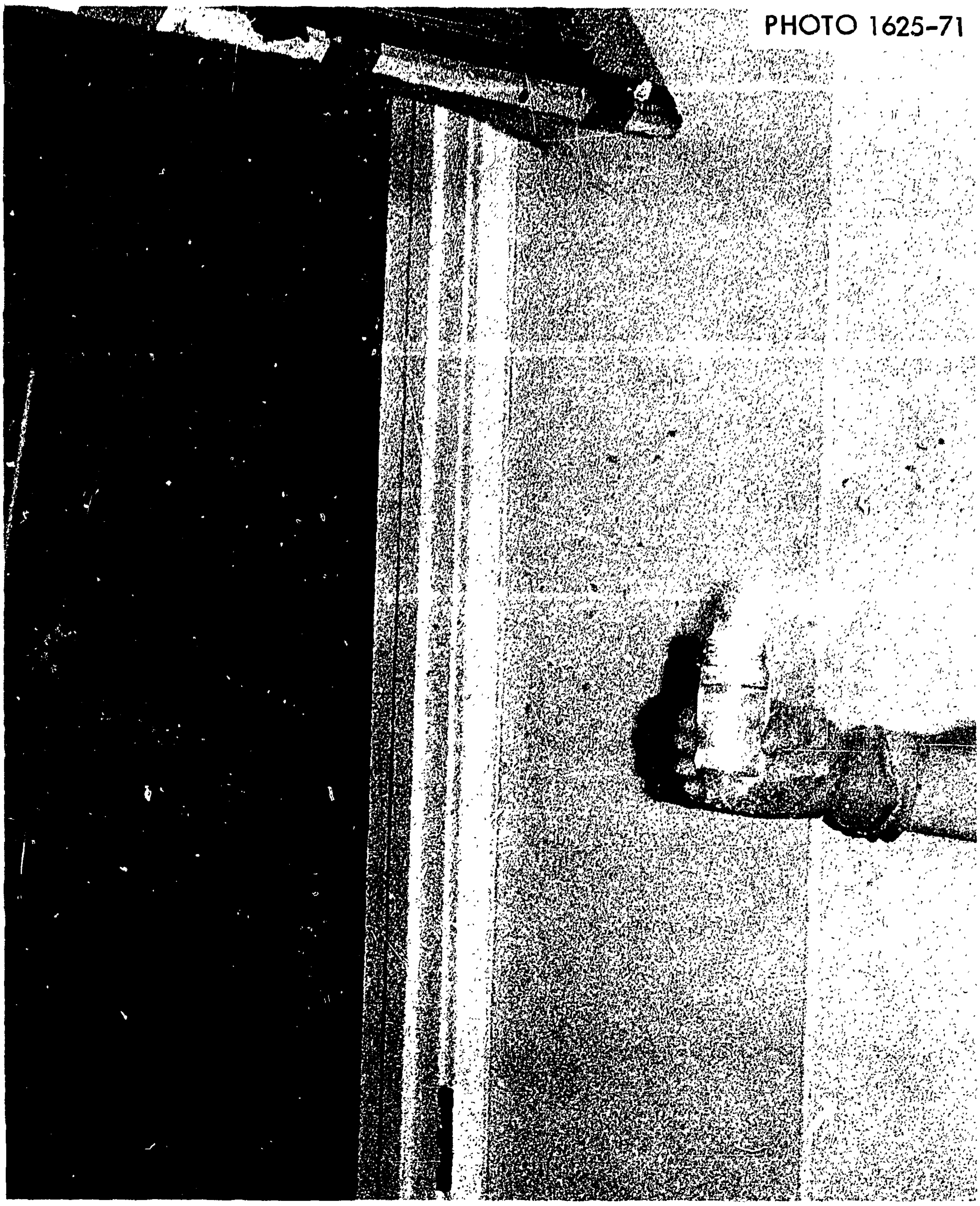

Fig. 2. About 2 feet outside the shelter doorway (the only opening to this shelter) and about 30 inches off the floor, the smoke flow shows that the outward (exhaust) air flow continues outward from the shelter a few inches more; then it rises toward the low-pressure region behind the Kearny Pump; and then the exhaust air is pumped back again into the shelter room. Thus the ventilating air flow into the shelter room is largely re-circulated air, that in a fully occupied dead-end shelter would already have been heated, and would rise the faster into the low-pressure region behind the inward-swinging pump.

PHOTO 1624-71

Fig. 3. In the shelter doorway (the sole opening), there is quite a strong outward (exhaust) flow of air along the floor. But only about 3 feet outside the doorway, the outward-flowing exhaust air is intermittently caused to rise upward at those times when the Kearny pump is pulling air into the shelter.

An air flow of about 50 feet per second had little effect on this very disadvantageous re-circulation of already exhausted air back into the shelter room.

(a) Provide the duct-building materials and the instructions to use a KAP to efficiently ventilate a dead-end shelter room, as described in Section 2, <u>or</u>

(b) For dead-end shelter rooms where a sledgehammer can be used to break a hole (by working a few minutes making a hole in the shelter ceiling, by hammering on the floor above at a pre-selected, marked spot), provide a sledgehammer and instructions, along with a KAP. Thus, shelter occupants could secure for themselves an efficient ventilating air-flow clear through their shelter room -- in through the doorway and out through the broken hole -- that should have at least twice the area of the KAP.

2. Developed and tested a technique for using an A-Frame Kearny Air Pump to efficiently ventilate a dead-end shelter.

The class room shown in Fig. 4 was made to function as a dead-end shelter room, opening off a basement hallway, simply by closing all the windows and carefully taping shut all cracks. A 6-foot A-Frame KAP was positioned inside this shelter room with stiffened 4-mil polyethylene ducts that permitted the KAP to pump air into the room through the right half of the doorway. This intake half of the doorway was "upstream" in relation to the natural air flow (see Fig. 4) of some 4000 cfm down the "closed" school hallway--from right to left, as illustrated.

Each group of six numbers, in Fig. 4, gives air velocities (feet per minute) measured with a Hastings Air Meter, the upper line of the three numbers being the air velocities taken 6 feet above the floor level; the lower line of three numbers, air velocities taken 3 feet above the floor level.

The pair of numbers on the right of each group of six gives the air velocities when no air was being pumped, while the pair of numbers in the center are the air velocities when only the 6-foot primary KAP adjacent to the door was being operated, and the pair of numbers on the left, the air velocities when both of the two 6-foot A-Frame KAP's were being operated.

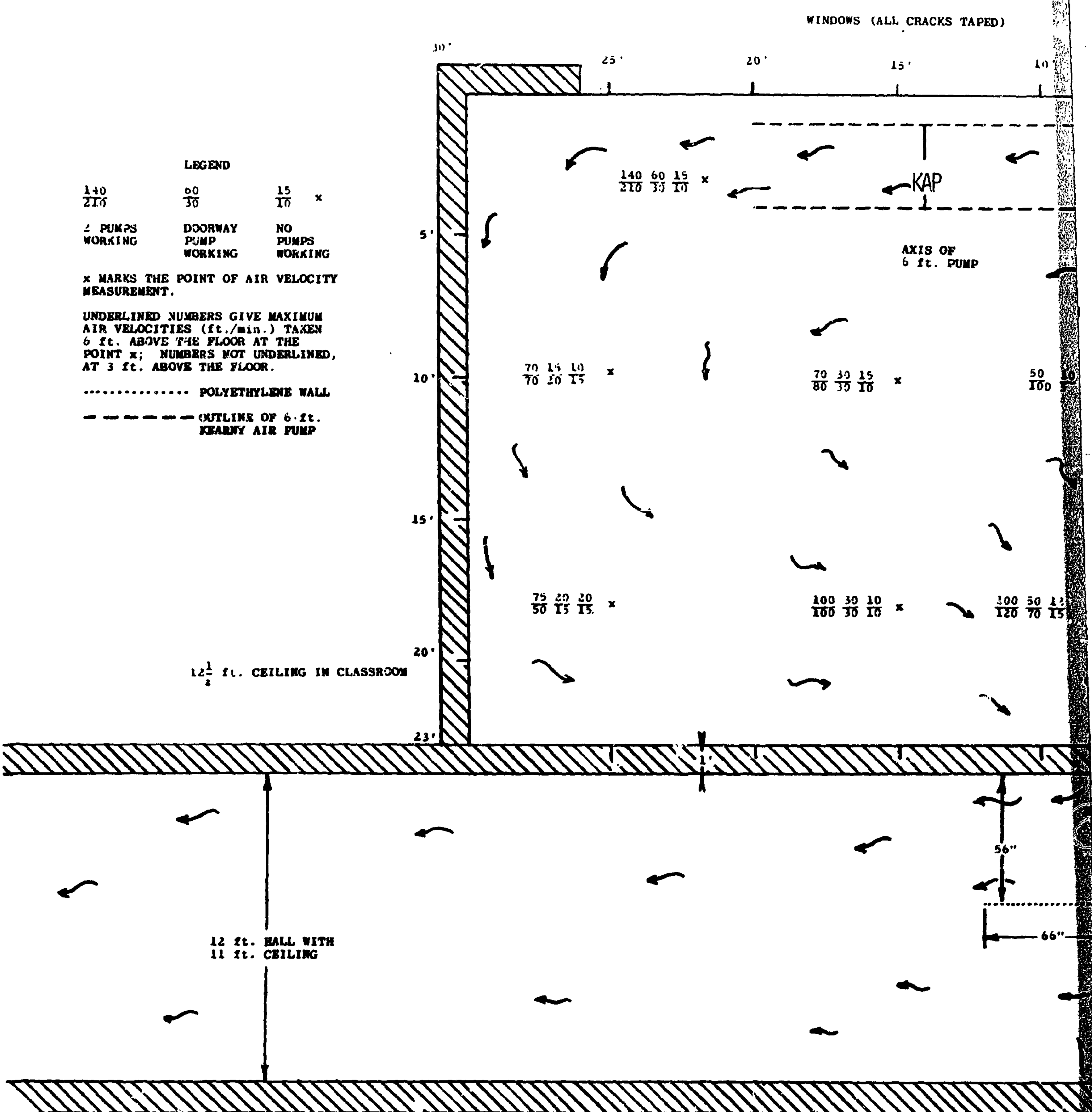

Fig. 4. 2000 cfm pumped into and around a dead-end shelter room by means o
Pump, using the right-hand half of the doorway as the intake opening. A large p
connected to the left half of the doorway, discharges the exhausted air 5-1/2 fe
hallway, and thus prevents already exhausted air from being repumped into the de

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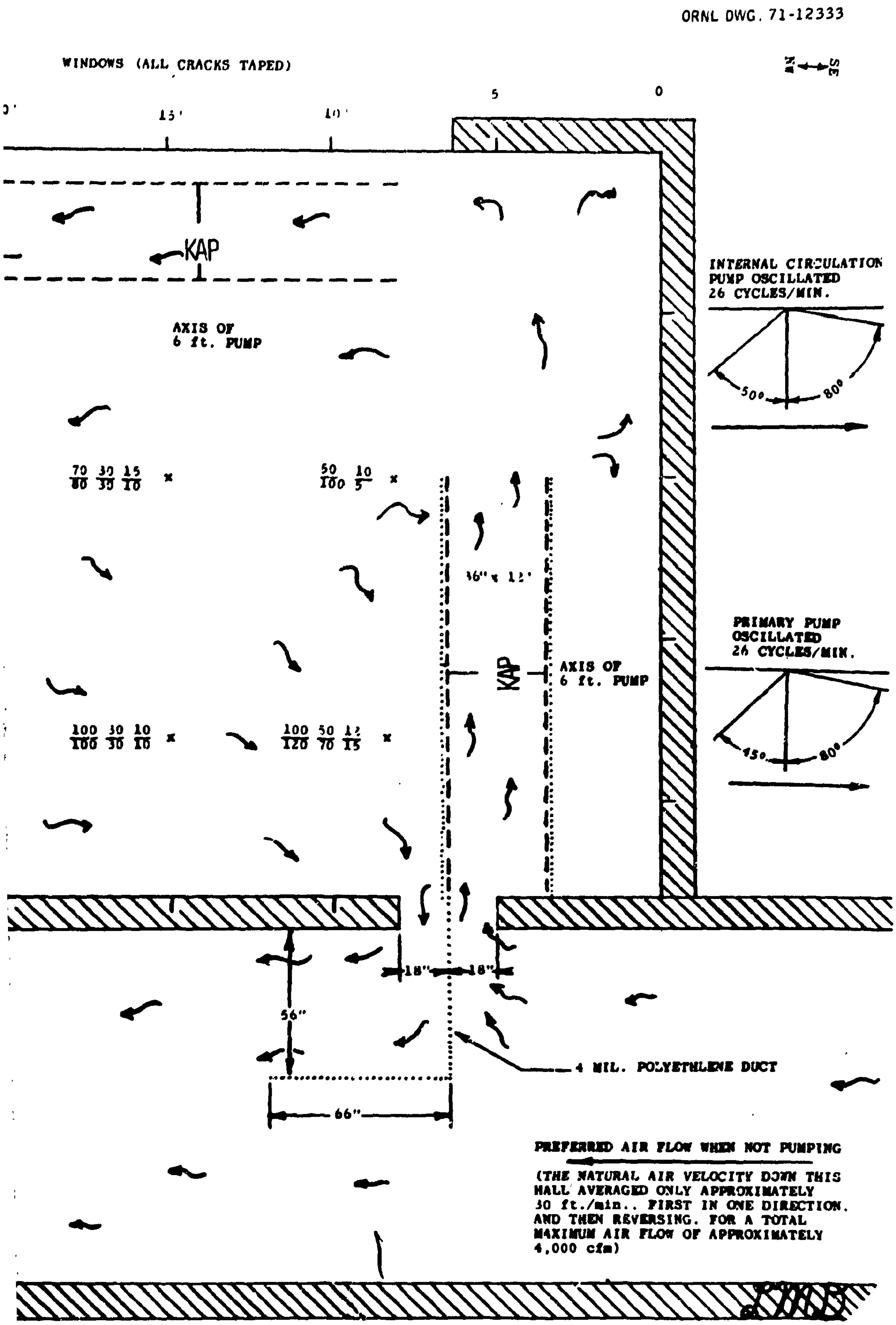

nd shelter room by means of a 6-foot Kearny Air
intake opening. A large plastic-film exhaust duct,
the exhausted air 5-1/2 feet "downstream" in the
being repumped into the dead-end shelter room.

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Fig. 5 gives air velocity measurements taken in the exhaust half of the doorway, from which the volume of air pumped through the room was calculated to be about 2000 cfm.

The following seven photographs (Figs. 6, 7, 8, 9, 10, 11 and 12) illustrate this first-trial setup--that was made by two boys following, not very accurately, Kearny's verbal instructions. Note that the "wings" (duct) surrounding the sides of the primary KAP were incorrectly made (by not completely covering the sides of the space in which the pump swung); thus much air already inside the shelter flowed into the low-pressure region of this pump, thereby preventing the pump from pumping its maximum volume through the dead-end shelter. (Since I was only trying to illustrate principles and had only a total of a few days of my time to devote to all these experiments, I did not make an improved setup and test. My summer assistant, engineering student L. M. Dickens, did much of the routine work connected with all these KAP developments and tests, except for this A-Frame KAP ventilation test).

Also note that when only the primary pump was operated, one corner of the room (the lower left, as illustrated) was inadequately ventilated. In contrast, with both pumps working, a fair breeze blew all around this room -- and the same two pumps would have produced an adequate round-the-room air circulation in a much larger room.

Finally, note that the large-cross-section, low-resistance duct "dumps" the exhaust air from the room over 5 feet "downstream" in the air flow down the hall -- far enough from the "upstream", half-doorway air intake so that no exhausted air was pumped back again into the shelter room--as was proven by air flow measurements, smoke tests and thin toilet-paper streamers hung from the ceiling.

Recommendations:

(a) Have a competent experimenter run tests involving ventilating dead-end shelter rooms with A-Frame KAP's used in the above-indicated manner, and determine the sizes of dead-end rooms that can thus be adequately ventilated for different effective temperatures of the "outside" pumped-through air. (Dilution of a known gas concentration in the room--such as CO_2 -- versus time of pumping, might give dependable information.)

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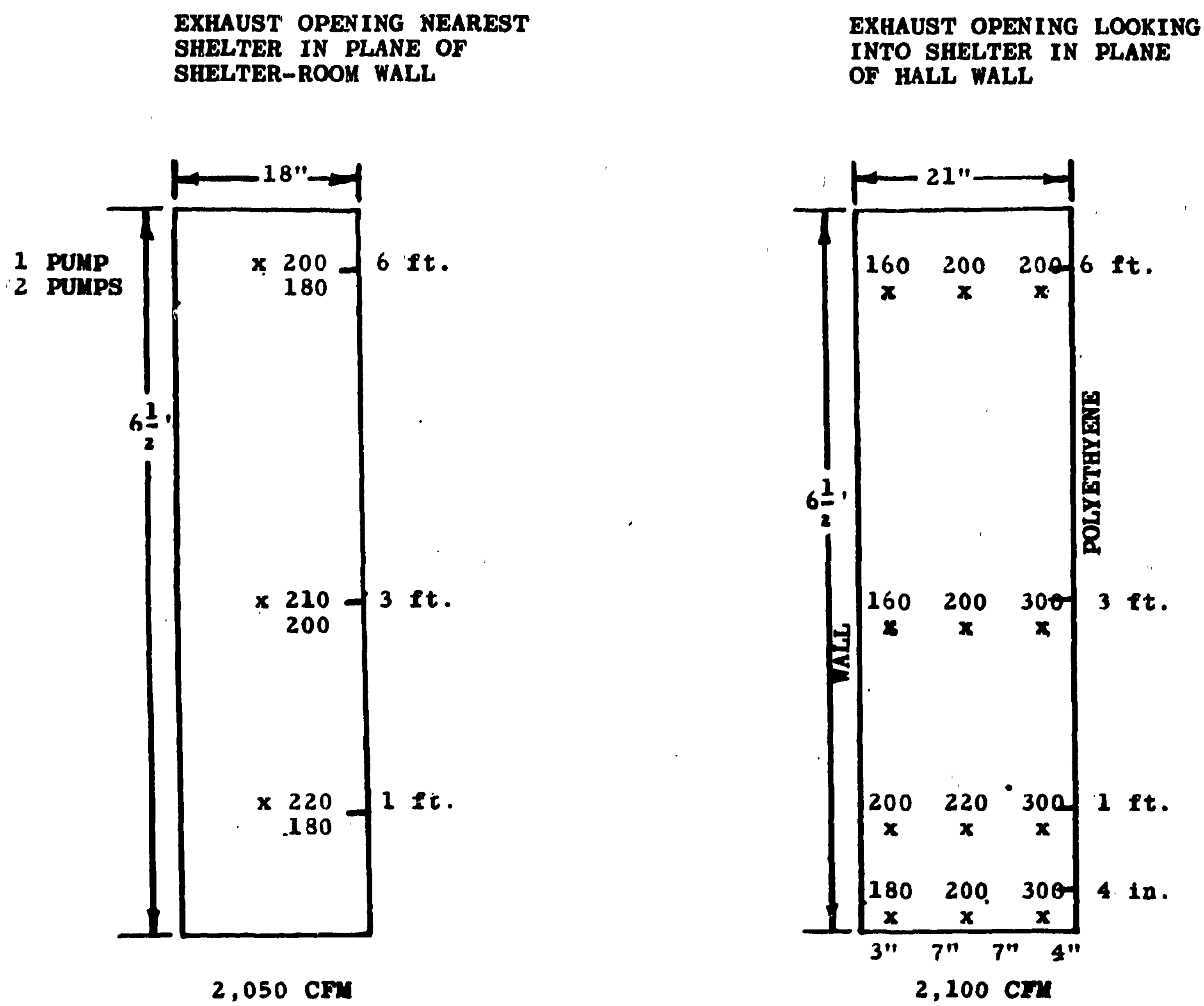

Fig. 5. Air velocities (feet per minute) in two parts of the exhaust half of the doorway to the dead-end shelter shown in Fig. 4, and total exhaust air flow (cfm).

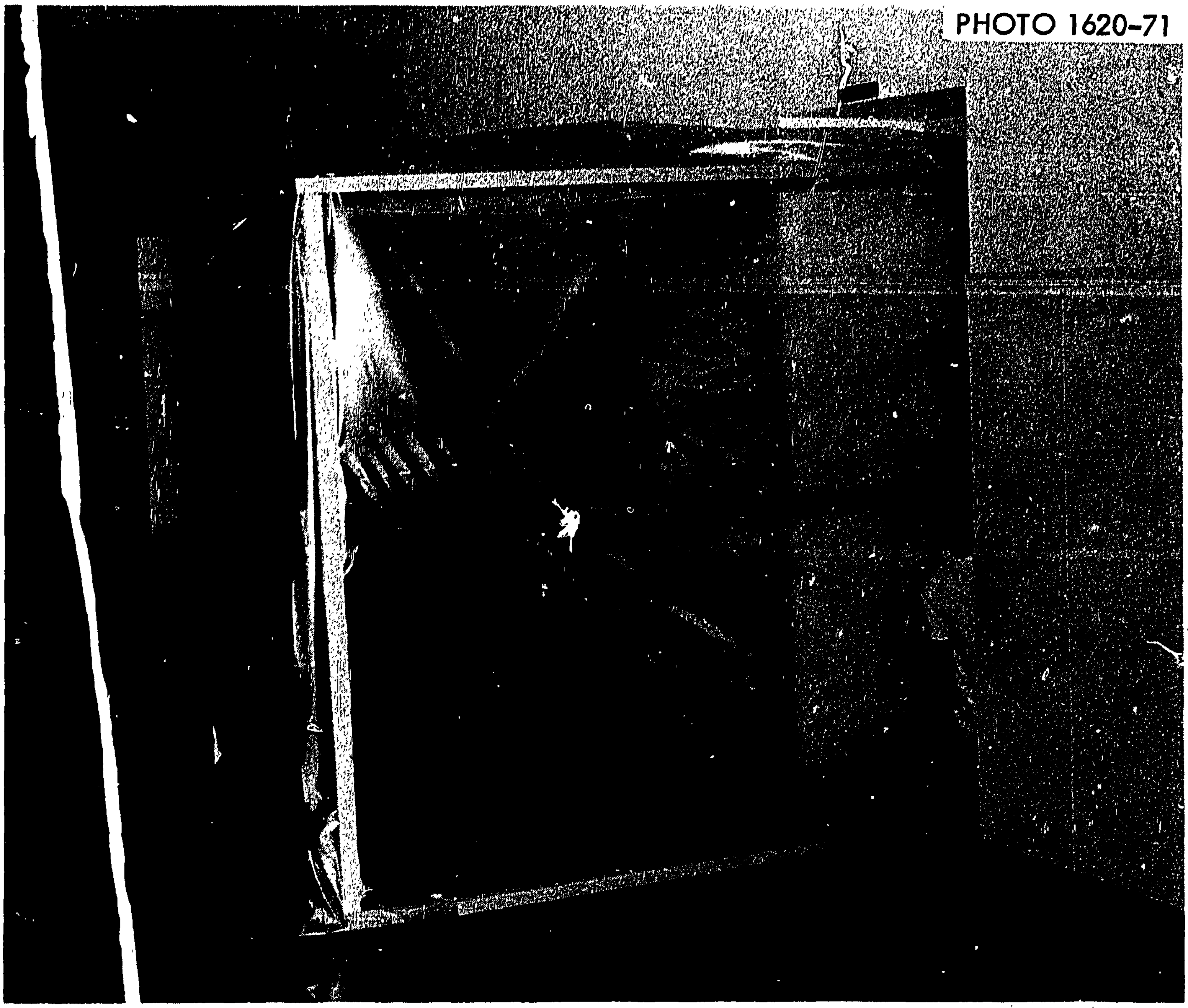

Fig. 6. Air intake opening ("upstream" half of doorway) of dead-end shelter room opening into wide school hallway, down which flowed approx. 4000 cfm, at an average velocity of about 50 feet per minute.

Large exhaust duct (stiffened by thin strips of wood connected to the A-frame of the 6-foot KAP pumping air into the shelter) "dumps" air exhausted from the room some 5 feet "downstream" in the hall—so that it is not pumped back into the shelter.

PHOTO 1618-71

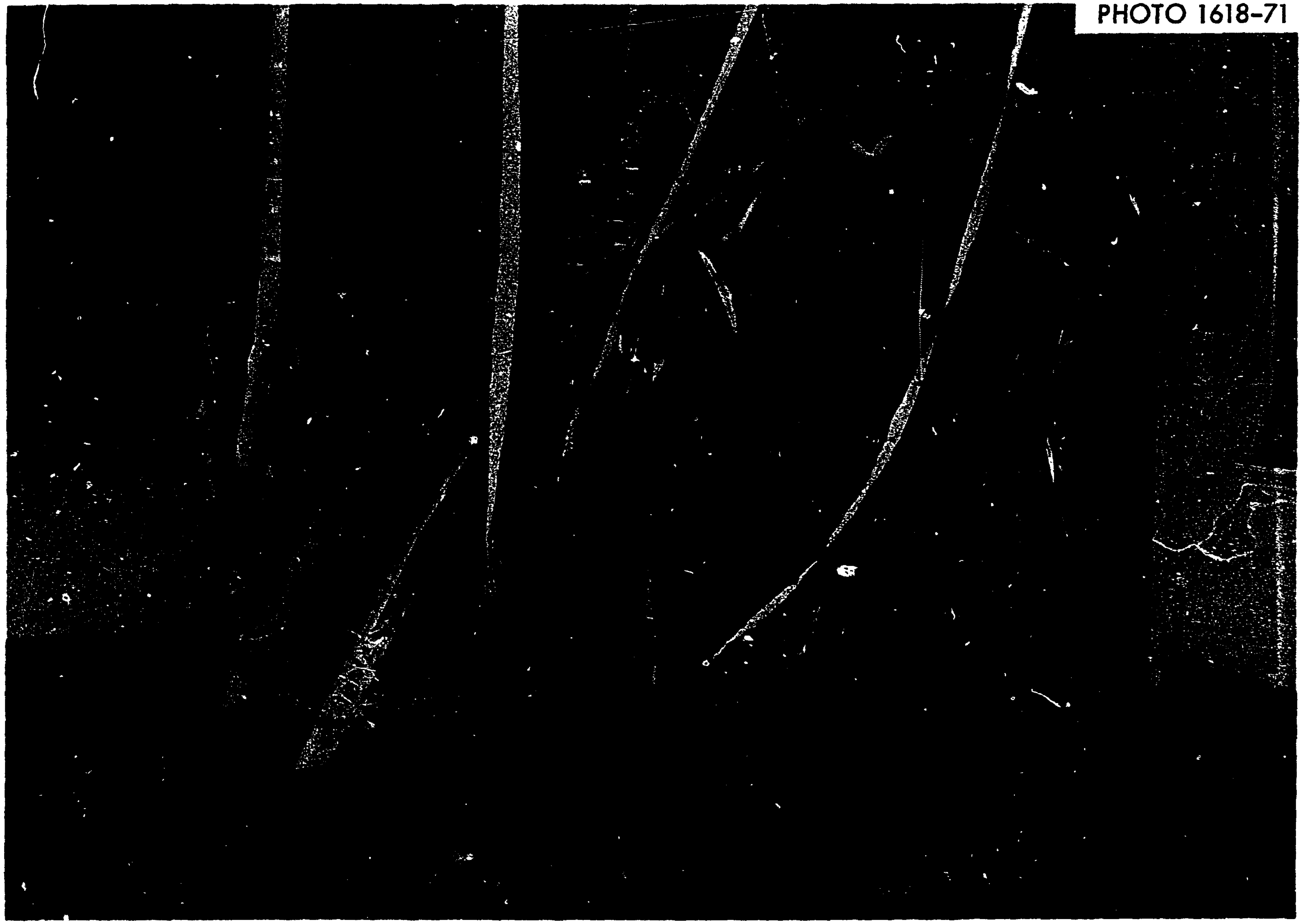

Fig. 7. 6-foot A-frame KAP positioned adjacent to intake half of doorway and covered with "wings" (duct) of 4-mil polyethylene on its top half nearest the doorway and over most of the sides of the volume in which this pump swings--so as to pump > 2000 cfm through a dead-end shelter room.

Note paper streamers indicating a strong exhaust flow out through the right (exhaust) side of the doorway, and the undesirable air flow toward the left (inner) end of the A-frame--that was inadequately covered with plastic film "wings" (duct) to prevent considerable air flow from the room into this low-pressure region.

Fig. 8. View inside tne dead-end shelter room. The paper streamers to the left of the A-Frame KAP indicate undesirable airflow into the low-pressure region behind the 6-foot KAP pumping air from the hallway into the dead-end room.

Note continuing strong exhaust air flow out of the right side (the exhaust side) of the doorway.

Also note the upper wooden stiffeners (of the large polyethylene duct around the A-Frame KAP) are connected both to the top of the A-Frame and to an adjustable metal exercise-bar fixed in the top of the doorway.

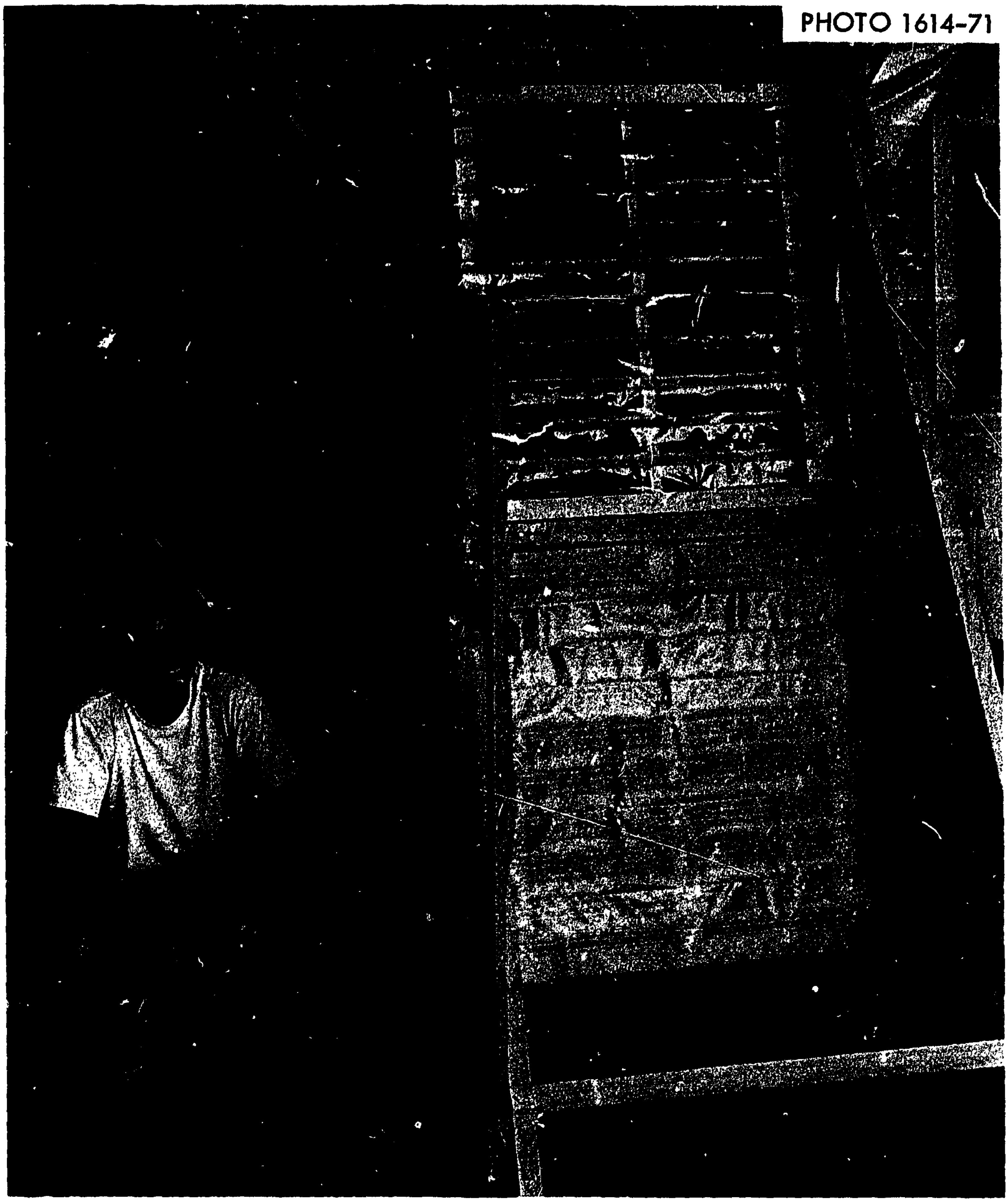

Fig. 9. Note incomplete, inefficient "wings" (side ducting) built by this boy and another boy around the inner end of this primary KAP ventilating a dead-end shelter room.

Fig. 10. Paper streamers indicate the strong air flow around the simulated dead-end shelter (note taped windows) when both the primary KAP and the pictured KAP are pumping.

The boy shown holding the "Y" bridle, has just pulled the primary KAP through its power stroke pulling it about 90° from the vertical. If the two boys operating these two 6-foot KAP's has less efficient pull-handles and if the pumps' pull-cords had been connected to the pumps 3 feet from their hinge lines (rather than an efficient 15 inches) then they would not have pulled them through such efficiently wide angles of swing, nor would they have succeeded in pumping as much air through and around this shelter.

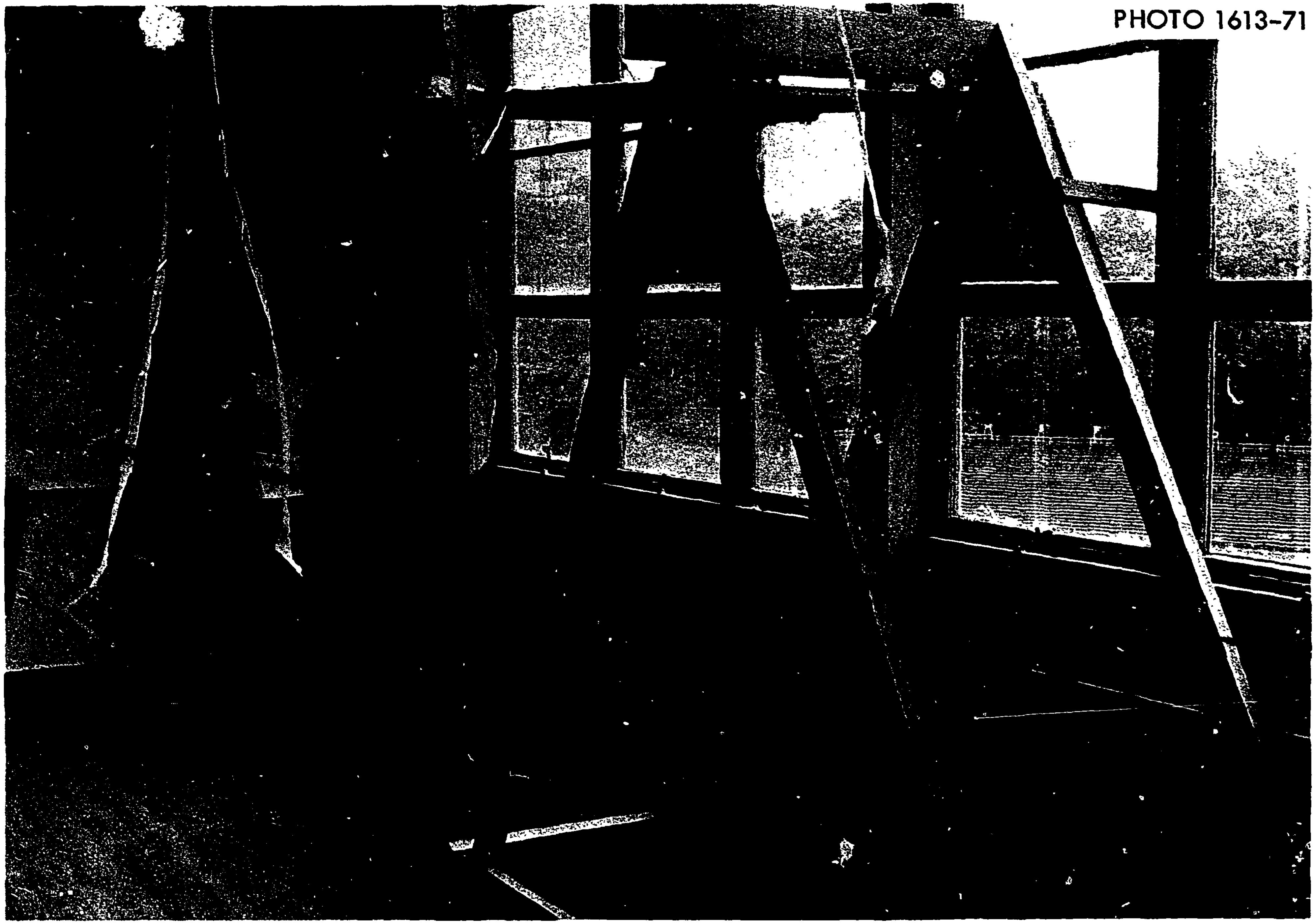

Fig. 11. 120-pound boy completing a short, efficient power-stroke pull of a 6-foot KAP swinging a full 90 degrees from the vertical, largely by rocking his body backward and using primarily his leg and back muscles efficiently.

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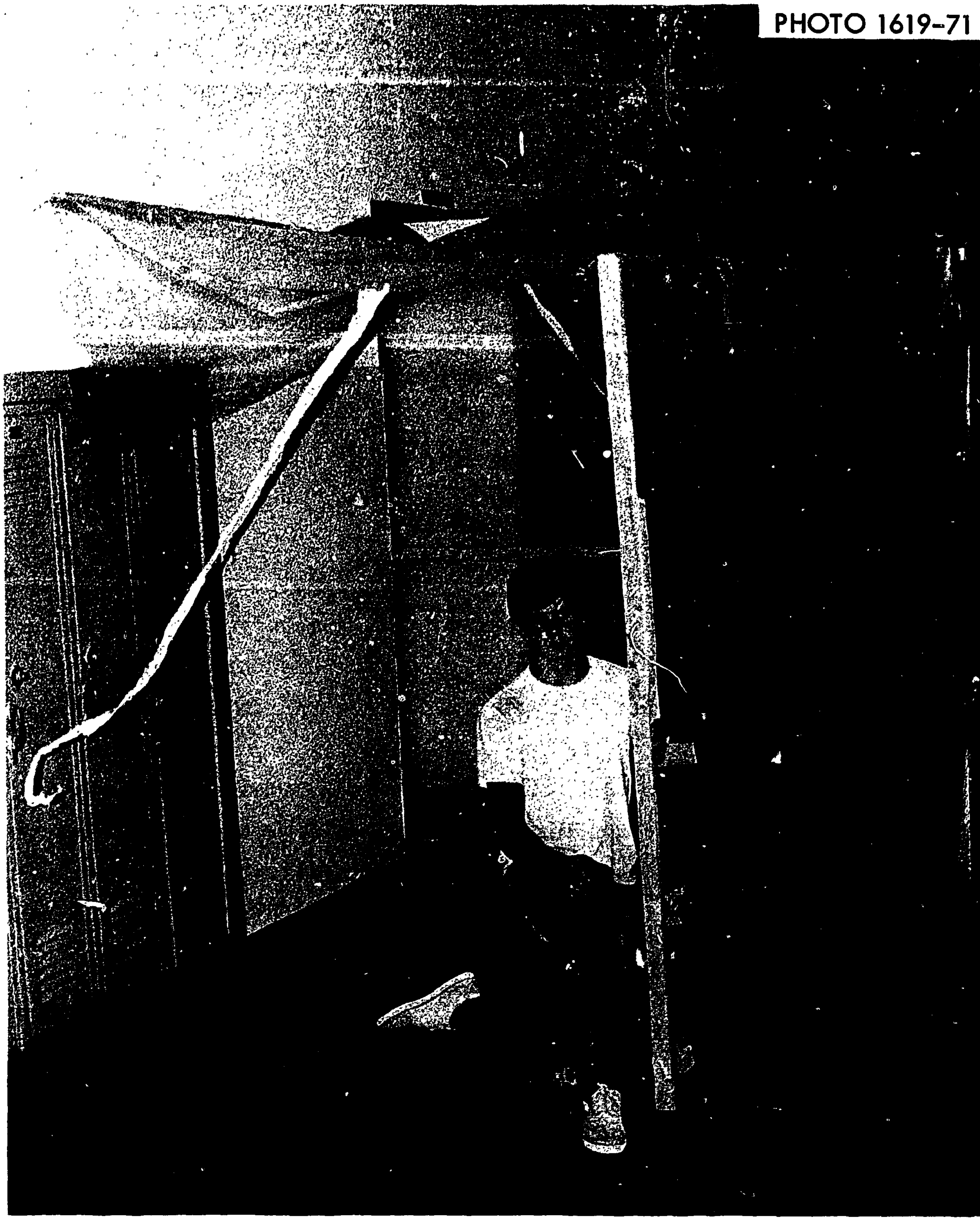


Fig. 12. Wide exhaust duct that "dumps" exhaust air 5 feet "downstream" in school hallway. The paper streamer indicates the strong and continuous flow of exhaust air--about 2000 cfm.

(b) Develop and test the assembly and use, by average citizens, of pre-fabricated, stiffened ducts that could be attached easily and quickly to a factory-built, metal A-Frame KAP, so as to enable occupants of a dead-end shelter room to ventilate their room within a few minutes with decidedly more than 2000 cfm. (The rapid erection of a large, stiffened polyethylene duct -- such as is shown in Fig. 8, -- is facilitated by having an adjustable exercise-bar positioned near the top of the doorway. In Fig. 8, the upper two wooden stiffeners of the large polyethylene duct were quickly tied to the top of the A-Frame KAP and to the adjustable exercise-bar near the top of the doorway.)

3. Developed and tested improved handles and bridles with which to pull especially 6-foot KAP's that must be pulled directly, without the help of a pulley attached above the operator(s).

(a) Under hot, humid Tennessee-summer conditions, for 30 minutes I pulled a 6-foot KAP via a 6-inch-long, approximately 1-inch diameter handle connected in its center directly to the pull-cord; this handle is very similar to the handle of the mil. spec. KAP developed by GATX for OCD.

I frequently shifted the pull-cord between different fingers, and changed hands about every two minutes, in order to reduce the amount of rubbing of the pull-cord on skin between my fingers at any one point. In spite of these precautions, however, at the end of 30 minutes I had rubbed an open blister on the middle finger of my left hand. This blister took over a week to heal, in spite of medication with an antibiotic ointment and the avoidance of infection or additional irritation. I also rubbed a small blister on the inside of the pointer finger of my right hand.

The other test subject made a 30-minute test using this same overly simple pull-handle. This man is a 240-pound weight lifter with heavily calloused hands; he did not hold the handle in such a way that the cord went between his fingers, and as a result was not blistered. But few Americans have heavily calloused hands.

Because ORNL regulations prohibit tests (other than by a professional initiating his own tests) in which physical injury to test subjects is likely to result, these were the only tests conducted with this handle.

If such tests are carried out under cool conditions, when the test subjects' skins are not wet and softened with sweat, blistering of the fingers when using this handle would not be as serious a problem. However, shelters occupied during a real war fallout period are likely to be hot, humid and decidedly unsanitary. I know, from years of experience in jungle explorations and with jungle infantrymen, that even small open blisters on the hands can rapidly lead to serious infections. Therefore, I am sure that any manually operated shelter device should be designed to minimize the chances of the operators blistering their hands, and that this overly simple handle should not be advocated, produced or used.

(b) In preliminary tests, a number of different types and sizes of pull-handles and pull-bridles were made and evaluated to determine the best handle with which to pull a KAP directly. (A knotted, thick strip of soft cloth -- the handle that tests both in the U.S. and in Israel have shown is the best handle to pull a Kearny Air Pump via an overhead pulley with a bell-toller's motion -- definitely is not the best handle with which to pull a KAP directly.)

The best handle developed and tested is illustrated by each of the two handles shown in the following dimensioned drawing (Fig. 13). All test subjects preferred this type handle, that permits a pump operator easily to avoid rubbing his skin with any cord and that minimizes the turning of the handle in the hand while pulling the pump.

The "Y" bridle enables either one or two persons to pull a 6-foot KAP with maximum ease and efficiency. The illustrated dimensions are the most advantageous -- for men, women and large children -- of the several "Y" bridles tested.

Fig. 14 through 19 show some of the eleven final test subjects who operated a 6-foot KAP. Each of these eleven final test subjects worked both as a single operator using this "Y" bridle and also as one of a pair of operators each of whom pulled on half of this "Y" bridle.

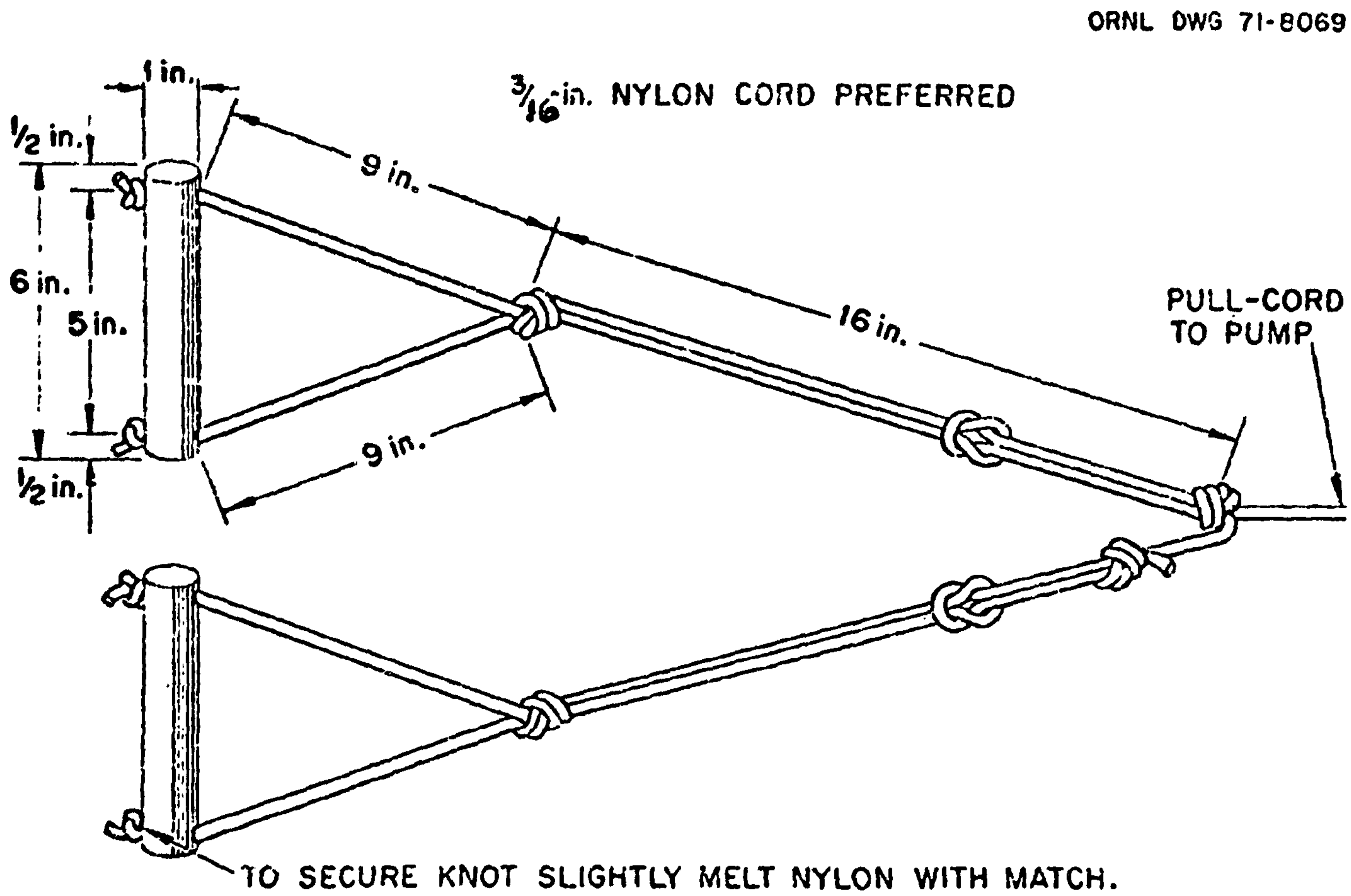


Fig. 13. Y-Bridle for Pull-Cord on Kearny Air Pump.

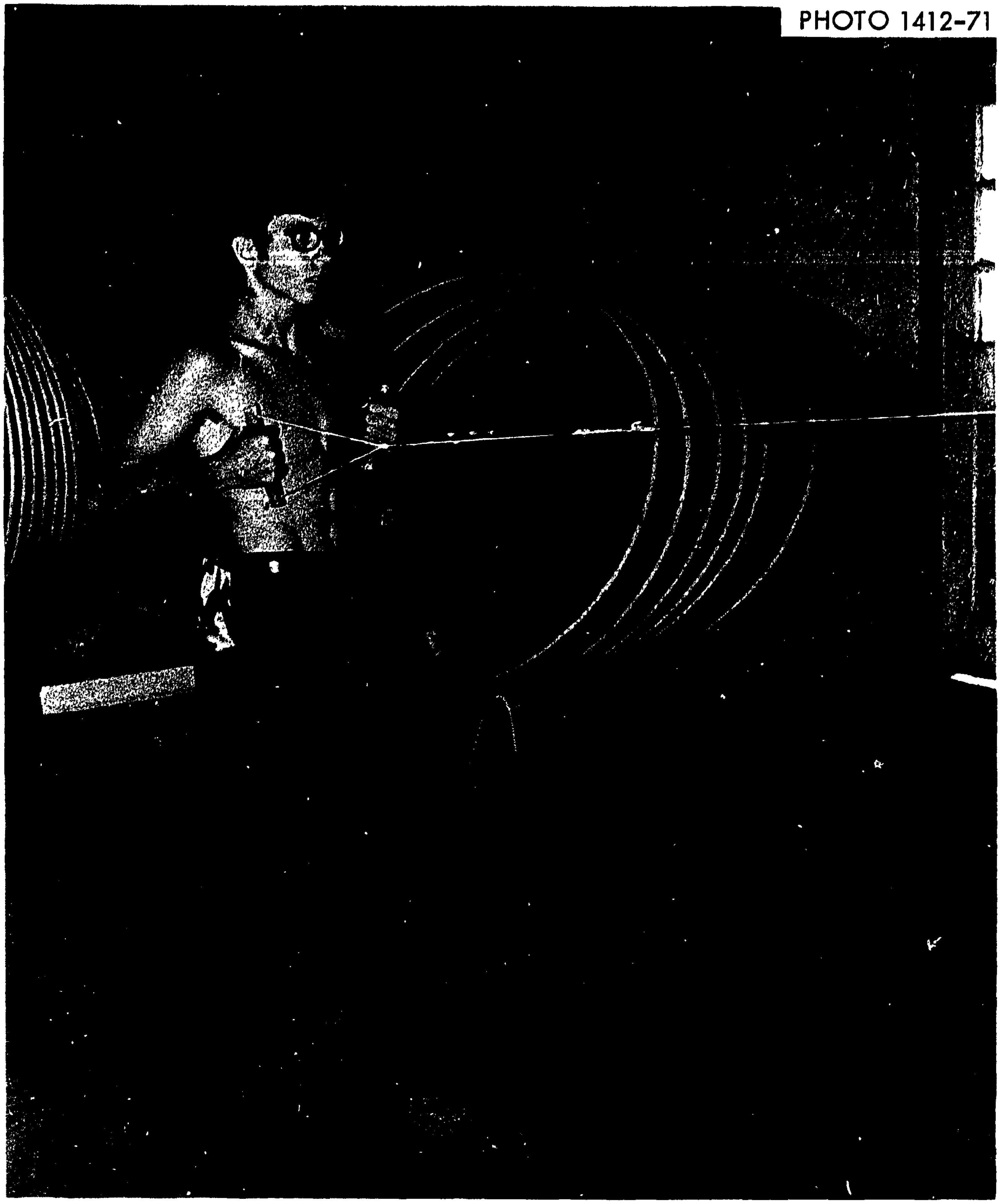


Fig. 14. Boy easily operating 6-foot KAP in partition doorway, using "Y" bridle and pulling a distance of only about 30 in. on the power stroke. He used mainly his leg and back muscles. The pull-cord was connected 15 inches from the hinge line.

PHOTO 1411-71

Fig. 15. Boy holding his arms forward and letting the pull-cord go slack during the entire return swing of a 6-foot KAP. Note that with this efficient setup he does not have to move his feet or get into any awkward, strained or inefficient position.

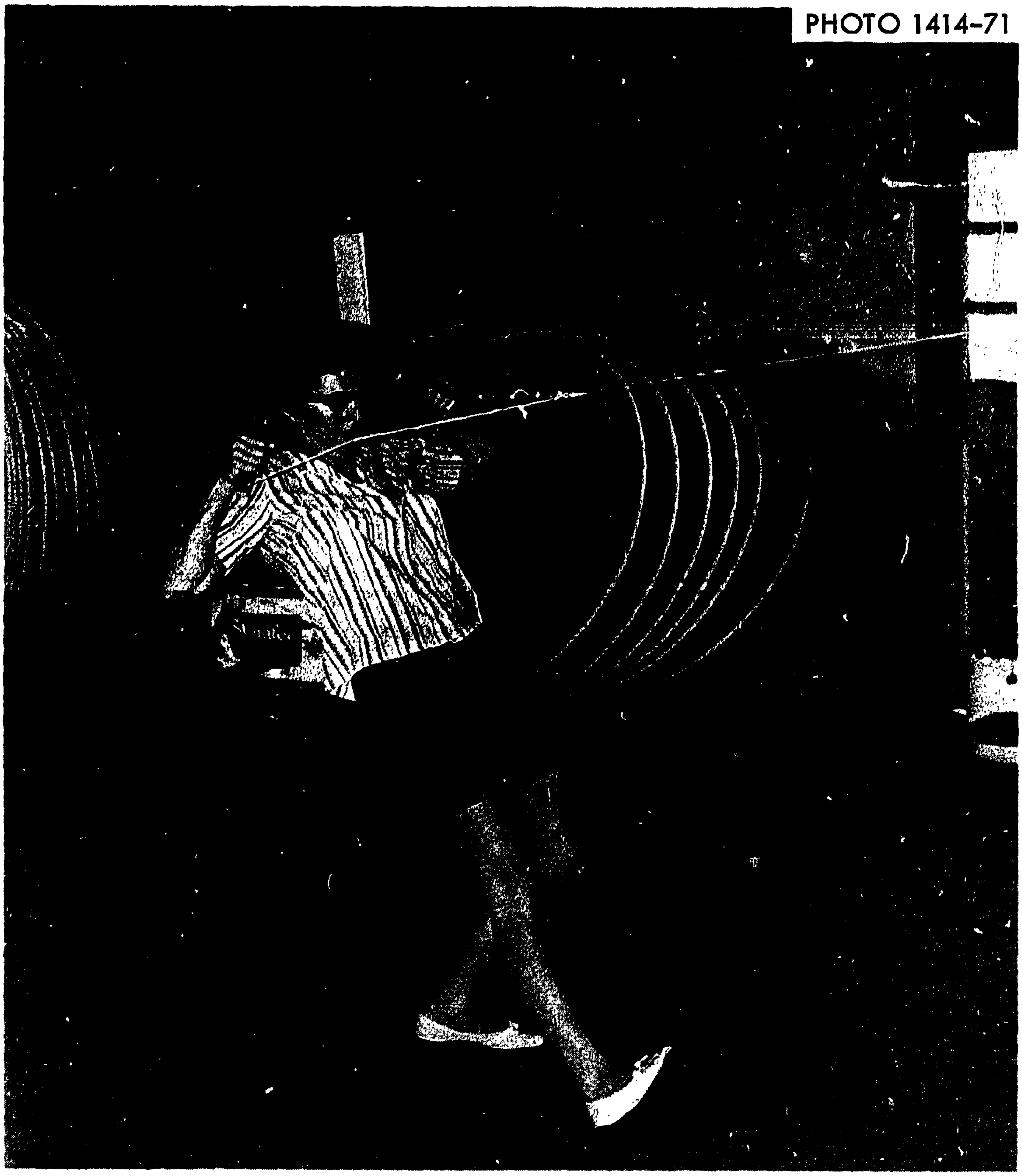


Fig. 16. Exceptionally energetic woman pulling a 6-foot KAP through the same amplitude of swing as the boy did, pictured in Figs. 13 and 14.

This woman, however, was pulling a pump with its pull-cord connected 3 feet from its hinge line (as in the mil. spec., GATX-OCD model), so that in order to swing the pump to produce maximum air flow, the operator must pull through a horizontal distance of almost 6 feet, and get into strained, inefficient body and arm positions.

Fig. 17. Same energetic woman correctly holding her arms forward at the beginning of the pump's return swing, so that the pull-cord remains slack and does not restrict the entire return swing. Note that she has been obliged to step forward, in order to move her hands through the necessary 6 feet of horizontal movement.

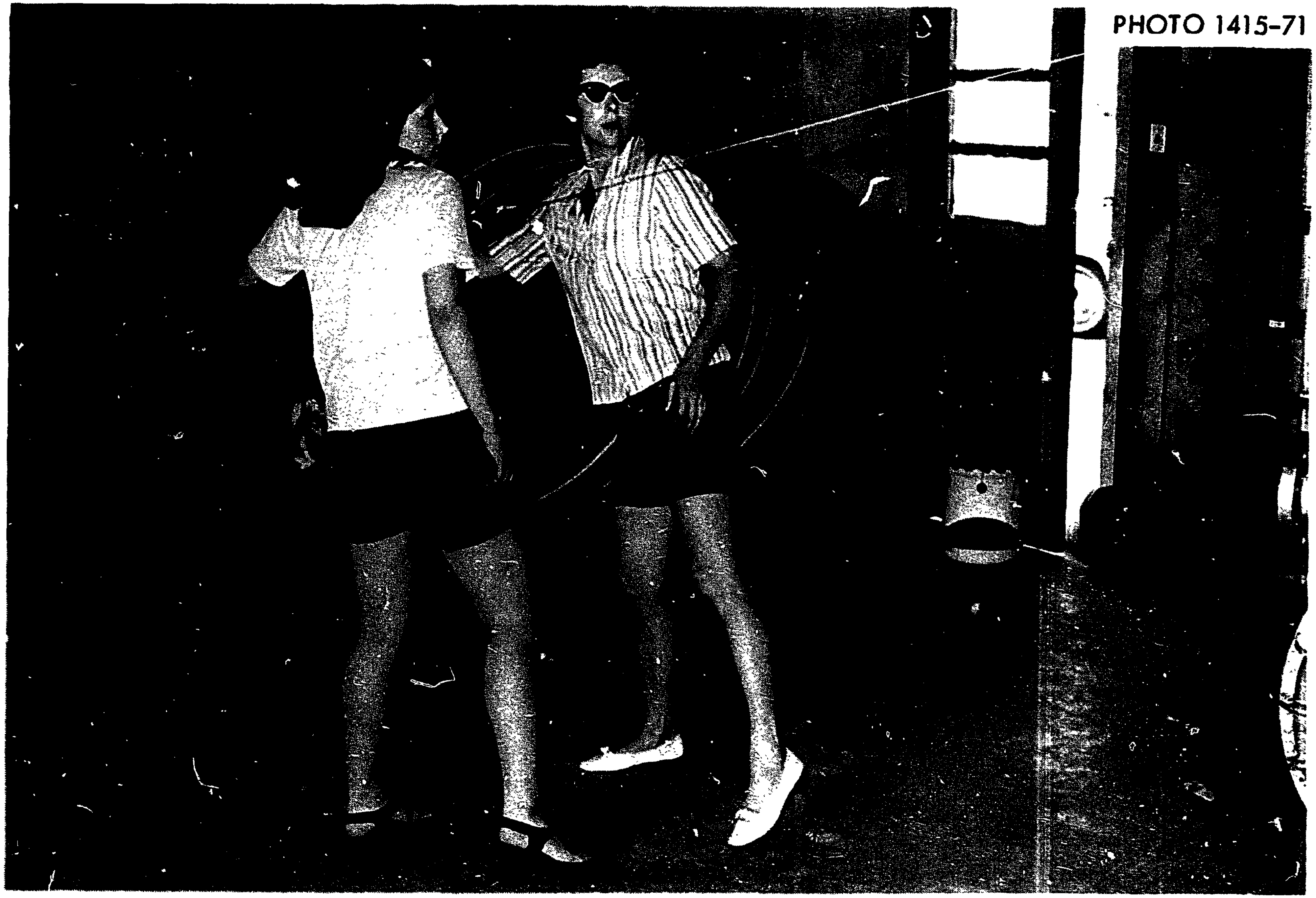


Fig. 18. Two women using "Y" bridle to operate a 6-foot KAP with its pull-cord attached to it 3 feet from its hinge line. Note the strained, inefficient positions they must assume as they near completion of a full-amplitude power stroke.

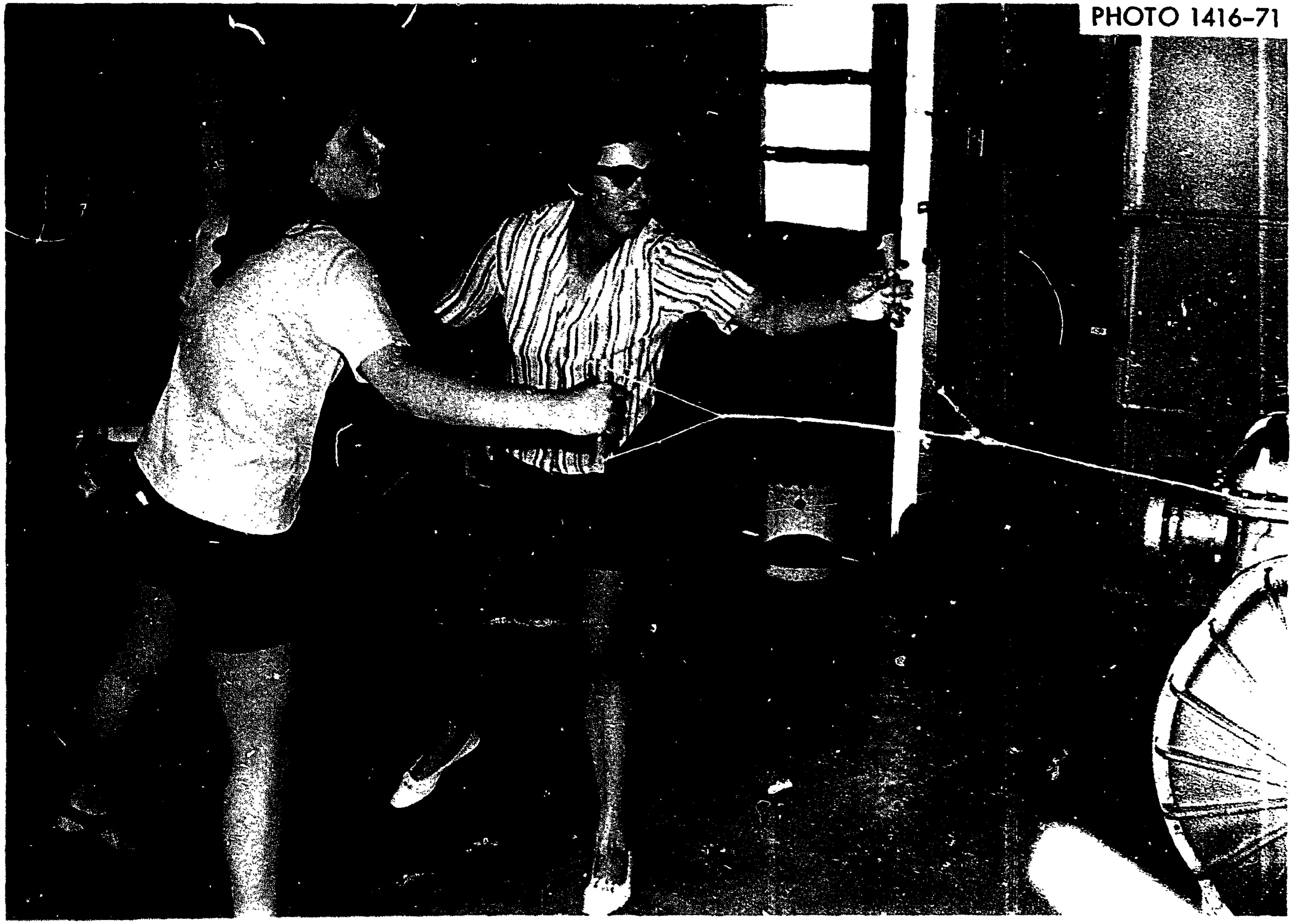


Fig. 19. Note the operators, in spite of their reaching far forward, do not have the pull-cord efficiently slack at the end of the pump's back swing--because the pull-cord is connected to the pump 3 feet from its hinge line.

If Kearny Air Pumps are made with designs and connections that do not permit as efficient operation as do Kearny's original models, the pressure differentials and air flows that they can produce inevitably will not be as great as measured for more efficiently designed pumps tested by Kearny and by engineers at the Protective Structures Development Center, Fort Belvoir, Virginia.

All eleven concluded they preferred pulling a 6-foot KAP while working as one of a pair of operators. All eleven also preferred working in pairs, whether pulling a KAP of Kearny's most efficient design (with the pull-cord connected to the pump 15 inches below its hinge line), or pulling a KAP of the GATX-OCD type, with its pull-cord connected to the pump 3 feet below the hinge line.

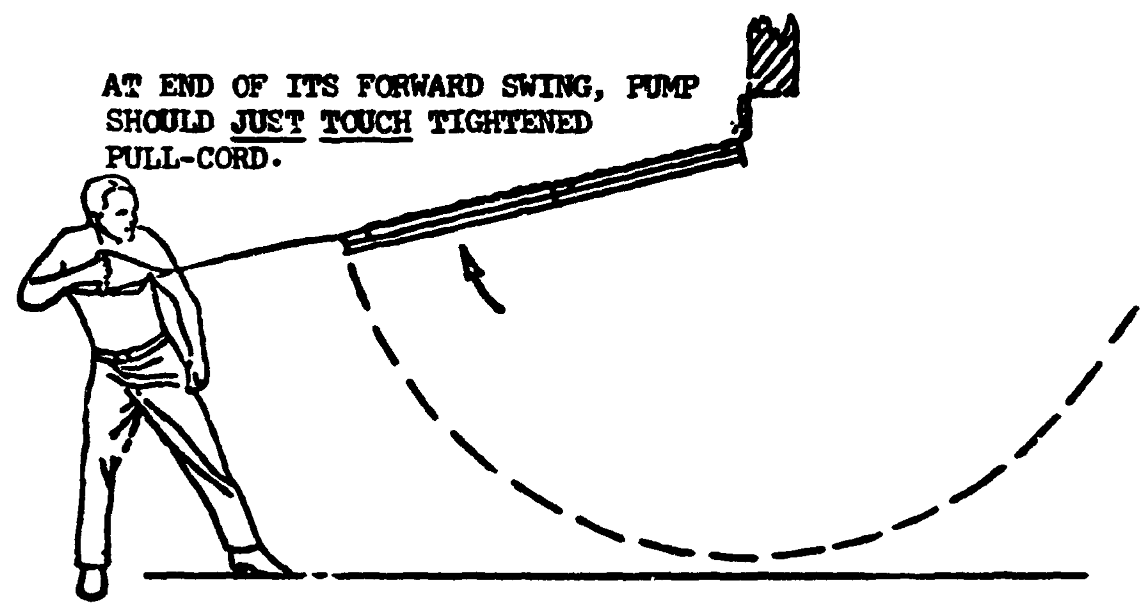
Recommendation: Unless some other design of pull-handle and pull-bridle is proved superior by realistic tests, the pull-handles and "Y" bridle illustrated in Fig. 13 should be adopted for pulling KAP's intended to be operated directly, without the use of an overhead pulley.

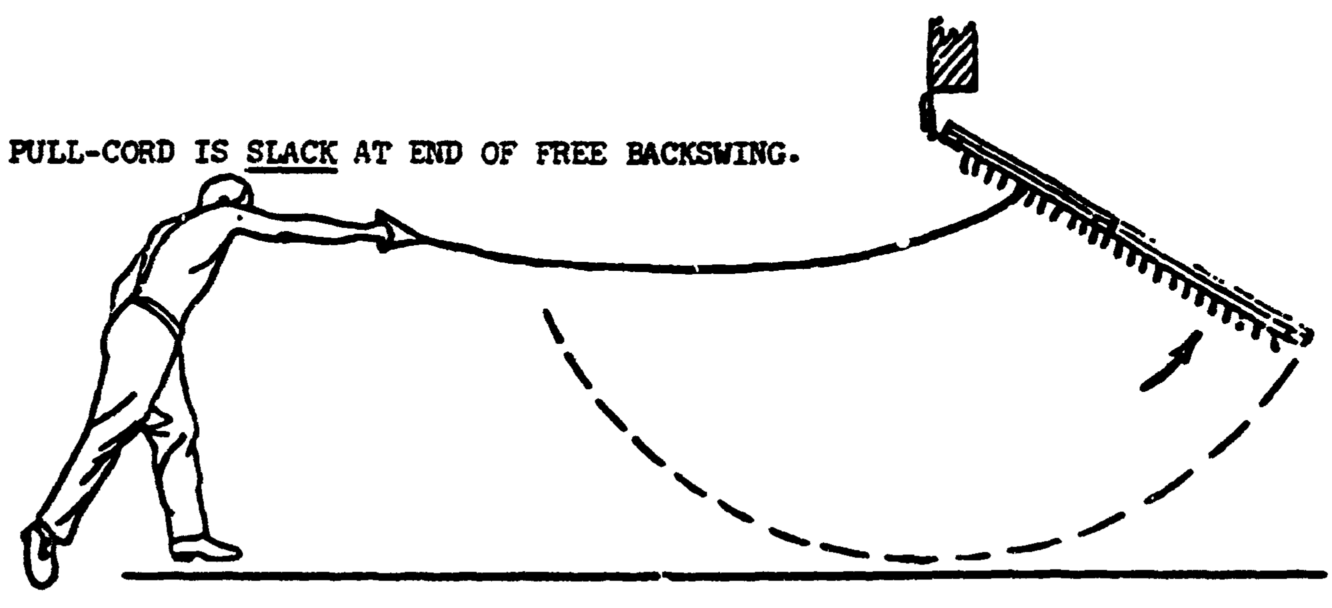
4. Perfected illustrated written instructions to enable average Americans to operate KAP's efficiently, when guided only by these written instructions. Unexpectedly, this turned out to be the most time consuming part of the work covered by this report. Finally, however, after successive tests and resulting improvements in the instructions and illustrations (based on the experience gained from nine preliminary test subjects, plus other informal tests) the final instructions (see Fig. 20, 21 and 22) enabled all the last eleven test subjects to operate efficiently a KAP with its pull cord connected to it 15 inches from its hinge line.

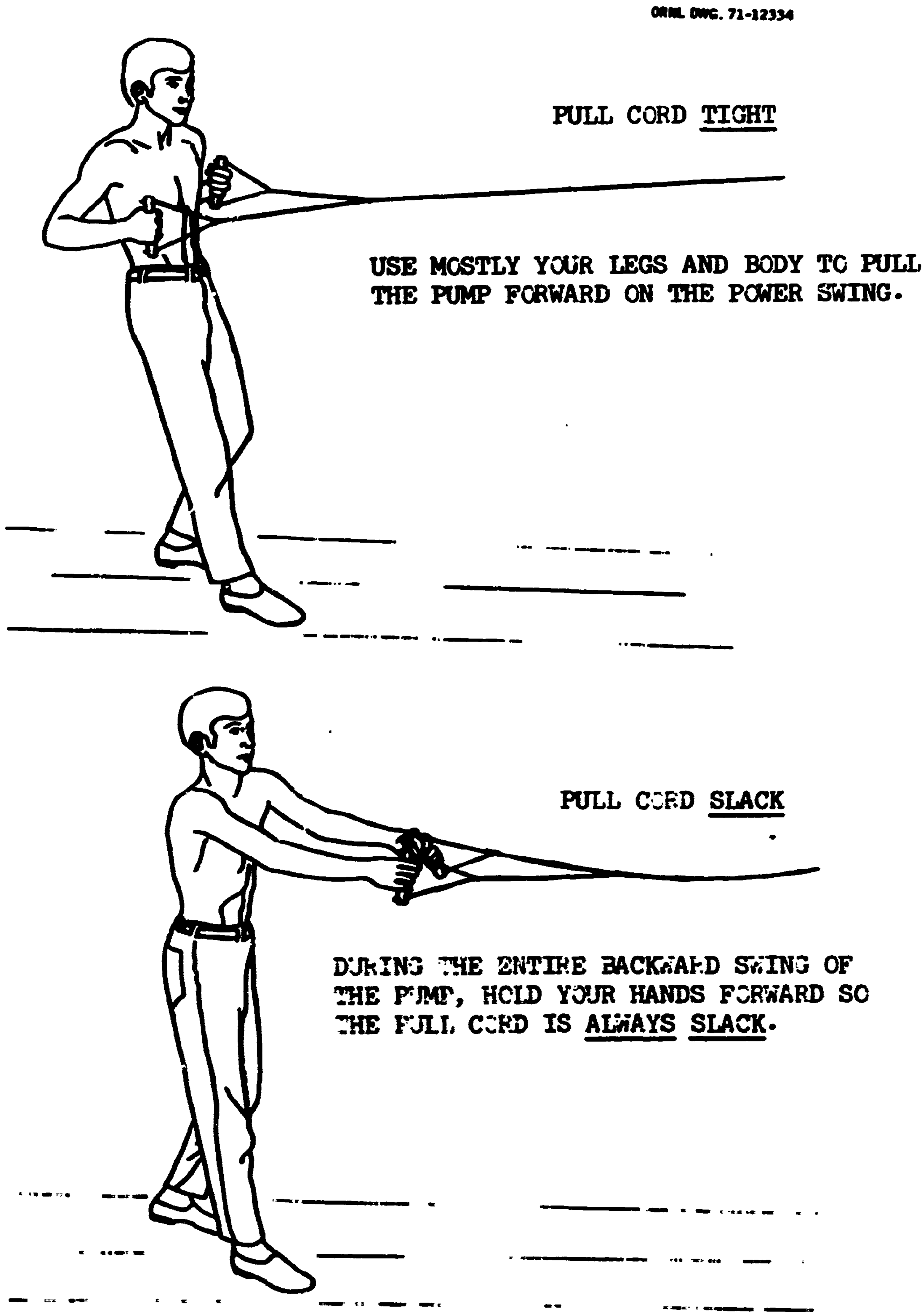
The difficulty in using only written instructions to teach average citizens to operate a KAP efficiently stems from the fact that none of the test subjects had ever even heard of this type air pump before, and most of them had difficulty understanding why they should pull this pump in the manner described in the instructions. Also, when more detailed instructions than these perfected ones were given, many test subjects did not read them. Furthermore, as the Army has found, average Americans get the intended message better from simple sketches of real people (made by an artist from action photographs) than from "stick" figures shown doing the same tasks.

Fig. 20. INSTRUCTIONS FOR PULLING KEARNY AIR PUMP
(Original Model, with Pull-Cord tied 15 inches from hinge-line)

1. TO PULL A 6-FOOT PUMP MORE EASILY, TWO PERSONS SHOULD PULL TOGETHER, USING A "Y" BRIDLE.
2. GRADUALLY START THE PUMP SWINGING BACK AND FORTH, MOVING YOUR ARM AND BODY AS ILLUSTRATED, AND PULLING MOSTLY WITH YOUR LEGS AND BODY.
3. STAND AT SUCH A DISTANCE FROM THE PUMP THAT YOU CAN PULL THE THE PUMP TOWARD YOU UNTIL THE FORWARD-SWINGING PUMP 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.
4. TO BE SURE YOU DON'T REDUCE THE AMOUNT OF AIR YOU PUMP, RAPIDLY MOVE YOUR PULLING ARM FORWARD AS SOON AS THE FORWARD-SWINGING PUMP TOUCHES THE TIGHTENED PULL-CORD--AND HOLD YOUR ARM FORWARD UNTIL THE PUMP AGAIN STARTS TO SWING TOWARD YOU.



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PULL CORD TIGHT
USE MOSTLY YOUR LEGS AND BODY TO PULL THE PUMP FORWARD ON THE POWER SWING.
PULL CORD SLACK
DURING THE ENTIRE BACKWARD SWING OF THE PUMP, HOLD YOUR HANDS FORWARD SO THE PULL CORD IS ALWAYS SLACK.

Fig. 21

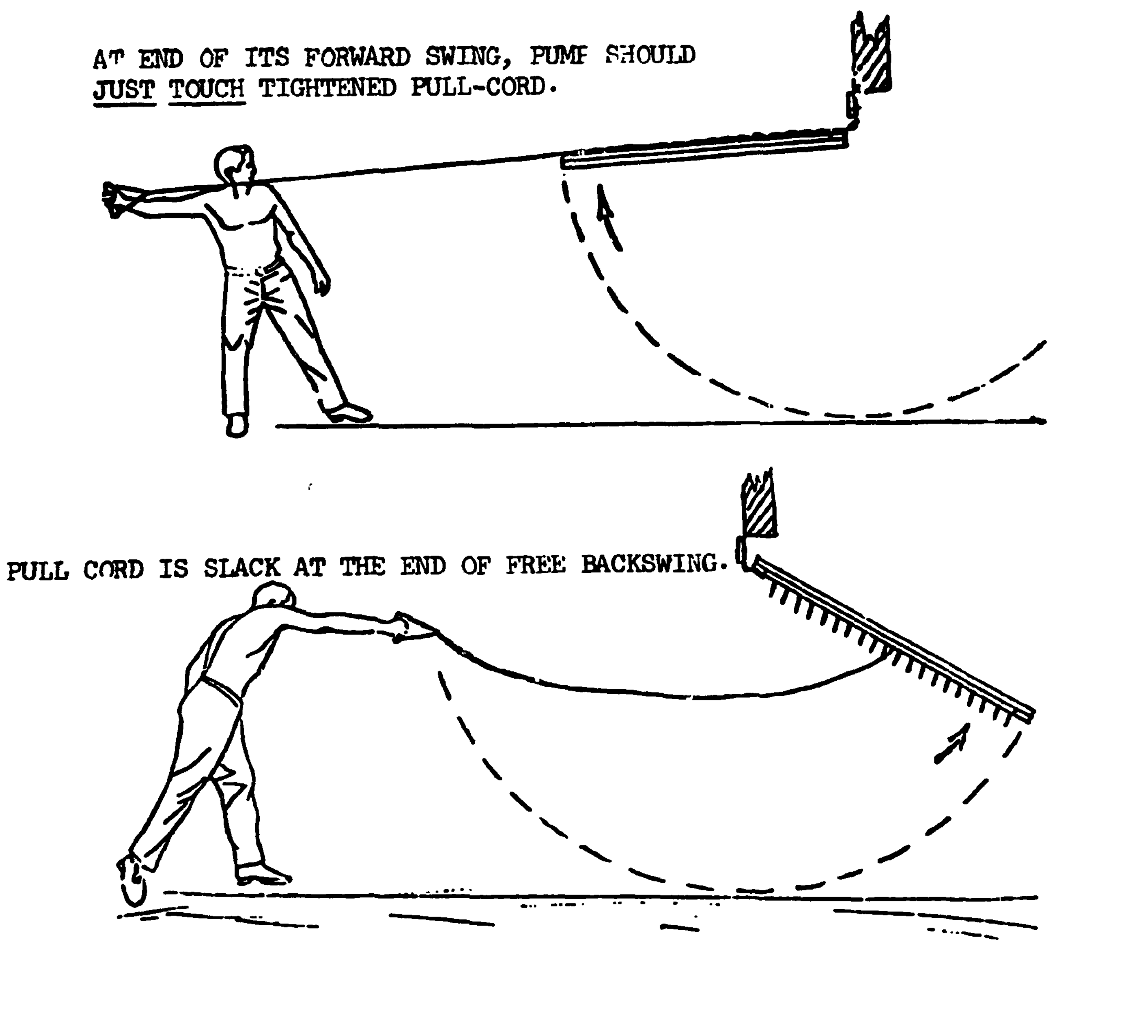
Fig. 22. INSTRUCTIONS FOR PULLING KEARNY AIR PUMP
(OCD Model, with Pull-Cord tied 3 ft from hinge-line)

1. **TO PULL A 6-FOOT PUMP MORE EASILY, TWO PERSONS SHOULD PULL TOGETHER, USING A "Y" BRIDLE.**

2. **GRADUALLY START THE PUMP SWINGING BACK AND FORTH, MOVING YOUR ARM AND BODY AS ILLUSTRATED.**

3. **STAND AT SUCH A DISTANCE FROM THE PUMP THAT YOU CAN PULL THE PUMP TOWARD YOU UNTIL THE FORWARD-SWINGING PUMP 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.**

4. **TO BE SURE YOU DON'T REDUCE THE AMOUNT OF AIR YOU PUMP, RAPIDLY MOVE YOUR PULLING ARM FORWARD AS SOON AS THE FORWARD-SWINGING PUMP TOUCHES THE TIGHTENED PULL-CORD--AND HOLD YOUR ARM FORWARD UNTIL THE PUMP AGAIN STARTS TO SWING TOWARD YOU.**



Recommendation: Make tests -- using average men, women and large minors for test subjects -- comparing the effectiveness of these written, carefully illustrated instructions for efficiently pulling a KAP directly, with other instructions, and adopt the instructions proved best by these recommended tests.

5. Determined the preference of average citizens for pulling a 6-foot KAP with its pull-cord connected 15 inches from its hinge line, as compared with its pull-cord connected 3 feet from its hinge line.

The final eleven test subjects, when working alone pulling a 6-foot KAP through its most effective total angle of swing (about 140 degrees), all preferred the connection of the pull-cord 15 inches from the hinge line. When working in pairs, nine of these eleven test subjects preferred the connection 15 inches from the hinge line.

Recommendation: Manufacture KAP's so that the pull-cord can be, and is, connected 15 inches from the hinge line.

6. Improved the durability of the flaps for KAP's. The findings of a recent study* funded by OCD confirm my ORNL findings,** that were based on more than 1000 hours of testing a variety of flap materials -- including confirmation of my finding that all pure polyethylene flaps on the lower half of a 6-foot KAP will not last for even 2 weeks of continuous use. However, if a good grade of pressure-sensitive tape (cloth, or electrician's plastic tape) is available to shelter occupants, for them to use for making diagonal-end reinforcements, taping all raw edges of flaps and repairing any holes that develop, then even flaps made of 4-mil polyethylene film can be made to last over 1000 hours, when used in the lower half of a 6-foot KAP.

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*Shelter Ventilator Studies, GARD Final Report 1477-1, Jan. 1971.

**Mechanized Durability Tests of a Six-Foot Punkah-Pump, by Cresson H. Kearny, ORNL-TM-1155, July 1965.

For a commerically-produced KAP, an inexpensive nylon-reinforced, 6-mil polyethylene (see ORNL-TM-1155) appears to be the most cost-effective flap material. Furthermore, considering the heavy fallout over much of the U.S. that would result from a Soviet attack, it appears prudent to spend a few dimes more per KAP, and thus provide flaps that will last at least 1000 hours. Many shelter occupants would find it at least advantageous to their health to continue sleeping and resting for weeks in shelters after the end of the first two weeks following such an attack.

If shelter occupants have a roll of good-grade pressure-sensitive tape, they can:

(a) Repair the flaps of KAP's and thus maintain the capability of KAP's to pump at their fully developed capacities, and

(b) Use this tape, along with cardborad, etc., to stop up disadvantageous openings. Disadvantageous openings include those around the exercise-bar on which a KAP swings in a shelter doorway, and unnecessarily wide spaces between the sides of a KAP and the sides of its doorway. Through such openings, air escapes in the opposite direction from that in which the pumped air flows.

GARD Final Report 1477-1 correctly concludes that if part of any KAP flap is torn away, the volume of air that this damaged KAP can pump decreases, because of this disadvantageous opening. Any equally large opening around the sides of the vertical plane through which the pump swings in a doorway (or other "duct) can cause equally serious decreases in the volume that a KAP can pump.

Recommendations:

(a) Use inexpensive nylon-reinforced polyethylene flaps, and supply some spare flaps and/or sheet polyethylene.

(b) Supply a roll of good-grade pressure-sensitive tape with each KAP and instructions to enable shelter occupants ot use it effectively--including instructions for covering the space above and around a pump hung in a doorway.

7. Developed means for protecting homemade KAP's that are being operated inside shelters from being damaged by a moderate velocity shock-wave and blastwind entering the shelter.

Since most Soviet weapons are in the megaton range, most fallout shelters that are far enough away from ground zero so as not to be destroyed, would be subjected to blast effects several seconds after the detonation. For example, for one megaton groundburst, at a distance of 2.7 miles from G.Z. (where the maximum unreflected overpressure outside is 5 psi), 8 seconds elapse between the flash and the arrival of the shockwave and blastwind. At 7.5 miles from G.Z. (where the maximum unreflected over-pressure outside is 1 psi), 30 seconds elapse. An OCD supported study* has confirmed not only the vulnerability to blast damage of a KAP placed in a doorway, but the danger due to parts from a KAP hit by blast being blown into the shelter and injuring occupants.

If shelter occupants had a KAP designed so that it could be jerked out of a doorway (or other exposed position) and within a few seconds placed in a much more protected location inside the shelter, and if occupants were informed by the KAP instructions that they should post a warning lookout (while he kept under cover) for the flash accompanying a relatively nearby detonation, then shelter occupants could save most KAP's in those fallout shelters that would survive the blast effects, and lessen the chances of occupants being injured.

Therefore I have developed ways to hang homemade KAP's so that when pump operators inside a shelter see the flash of a detonation, they can jerk down KAP's without damaging them, and, in a few seconds, place them in locations in the shelter where KAP's are unlikely either to be seriously damaged by blast effects, or to endanger anyone.

I have made no quick-disconnect designs for thus hanging a manufactured model of a KAP.

Recommendations:

A manufactured KAP should be designed so that it remains securely attached in its operating position when pulled normally, but so that it

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*Ventilation Kits, GARD Final Report 1477, November 1969.

immediately separates from its exercise-bar (or from another "fixed" attachment to the shelter) if its frame is jerked strongly sideways. Any competent gadgeteer should be able in a few days to make and test several different designs of such quick-disconnects for a KAP, and to select the two most practical designs. Final selection should be based on practical shelter tests by average citizens guided only by illustrated written instructions.

General Conclusion

In view of the importance of furnishing adequate cooling ventilation for millions of shelter spaces -- and at minimum cost -- it is desirable to produce the most cost-effective KAP's that can be developed, and to issue illustrated written instructions to enable average citizens to use them to their maximum advantage.