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EXPEDIENT SHELTER CONSTRUCTION AND OCCUPANCY EXPERIMENTS

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Expedient Shelter Construction and Occupancy Experiments

Cresson H. Kearny

ABSTRACT

This report strongly indicates the practicality of tens of millions of Americans evacuating into rural areas and building and occupying high-protection-factor expedient shelters during an escalating international crisis. This concept was successfully tested by untrained families who built expedient shelters during winter in Colorado, summer in Utah, and spring in Florida. Their efforts are presented in this report primarily by the captioned photographs showing these typical American families evacuating their homes, driving to rural shelter-building sites, and then, with hand tools, constructing their own shelters.

These average, mostly urban, American families were *guided only by step-by-step, well-illustrated, written instructions* given to them at the start of each experiment. Crisis conditions were simulated, and adequate motivation was provided by the promise of a cash bonus for completion of the shelter within 36 or 48 hours, depending on the difficulty of construction. All families, or groups of families, succeeded in winning the bonus, with one exception.

The shelters built by the test families included the Door-Covered Trench Shelter, the Log-Covered Trench Shelter (which the building family occupied for 77 hours without emerging), and the Car-Over-Trench Shelter. Also, families are pictured while building four above-ground shelters designed for high-water-table or shallow-soil areas: the Above-Ground Door-Covered Shelter, the Crib-Walled Shelter, the Ridge-Pole Shelter, and the A-Frame Pole Shelter. These four above-ground shelters have protection factors (PF) in the range of 250 to 500.

The building in Alabama of a 50-occupant Log-Covered Trench Shelter, with 22-ft logs roofing a bulldozed trench, is illustrated and described, and the delays and inefficiencies of mechanized shelter-building during a rainy spell are noted.

1. Introduction

THE NEED FOR IMPROVED EXPEDIENT SHELTERS

The size of the strategic nuclear threat to the United States continues to increase. Therefore, there is increasing need for designs of improved expedient shelters that have been proven to be practical for average Americans to build for themselves during an escalating crisis. Furthermore, plans to build expedient shelters are a part of the ongoing Crisis Relocation Planning[1] that is an important element of U.S. civil defense.

The start of actual crisis-relocation preparations for Americans would be an embryonic counterpart of the extensive Soviet preparations[2] to evacuate, disperse, and shelter urban Russians within about 72 hours during some types of crises threatening nuclear war. An American crisis relocation capability might be able to reduce the probability of a major confrontation occurring or of a defeat befalling the United States. And in the event of a nuclear attack by the Soviet Union, prior implementation of crisis-relocation preparations would save many millions of American lives.

In most of the areas into which urban Americans might relocate (evacuate), there are not enough high-protection-factor (high PF) shelters for the permanent inhabitants. The need for shelters having protection factors much higher than 20 (typical of improved home basements) and, in addition, affording substantial protection against blast and fire, is a consequence of the large deliverable megatonnage of the Soviet Union.[1] Russian weapons such as the SS 9 and SS 18 have single warheads that, if surface bursted, would each be capable of destroying a large city. The fallout from one of these huge surface bursts is likely to produce such large radiation doses that, even a hundred miles downwind, they would prove fatal to persons remaining for two weeks inside PF 20 shelters. Figure 1.1 shows a two-week integrated dose of almost 10,000 roentgens (R) for above-ground locations 100 miles downwind from a 25-megaton surface burst; most persons in a PF 20 shelter would be killed by the 500-R two-week dose they would receive. Even some people in PF 100 shelters (who would receive a 100-R two-week dose) might die due to their resultant increased susceptibility to infections during the post-attack months when they would lack medical services, adequate sanitation, and a balanced diet while being subjected to additional radiation.

With one exception, all of the expedient shelters described in this report have protection factors higher than 200. These shelters also satisfy other requirements better than do most existing structures in the host areas for urban evacuees.

The protection factors stated for the shelters described in this report, especially for the below-ground ones having two to three feet of earth cover, are lower than commonly assumed. Calculations have shown that most of the radiation reaching the occupants comes through the shelter openings. Therefore, unless the designs of the entryways and exits are changed to ones more difficult and time-consuming to build, making the earth cover thicker than about 3 feet does not significantly improve the fallout radiation protection afforded by even the best of these shelters.

SCOPE AND BACKGROUND OF THIS REPORT

This report is a summary of some of the ORNL field experiments involving the building of improved expedient shelters by untrained American families. These families were guided only by step-by-step, illustrated instructions. Action photographs have been made the basis of this report in order to emphasize the fact that the families selected to follow the draft instructions and build these shelters were diverse, yet quite typical, American families, working with common home tools and widely available construction materials in a variety of environments.

These shelter-building experiments were funded by the U.S. Atomic Energy Commission (now the Energy Research and Development Administration) and the

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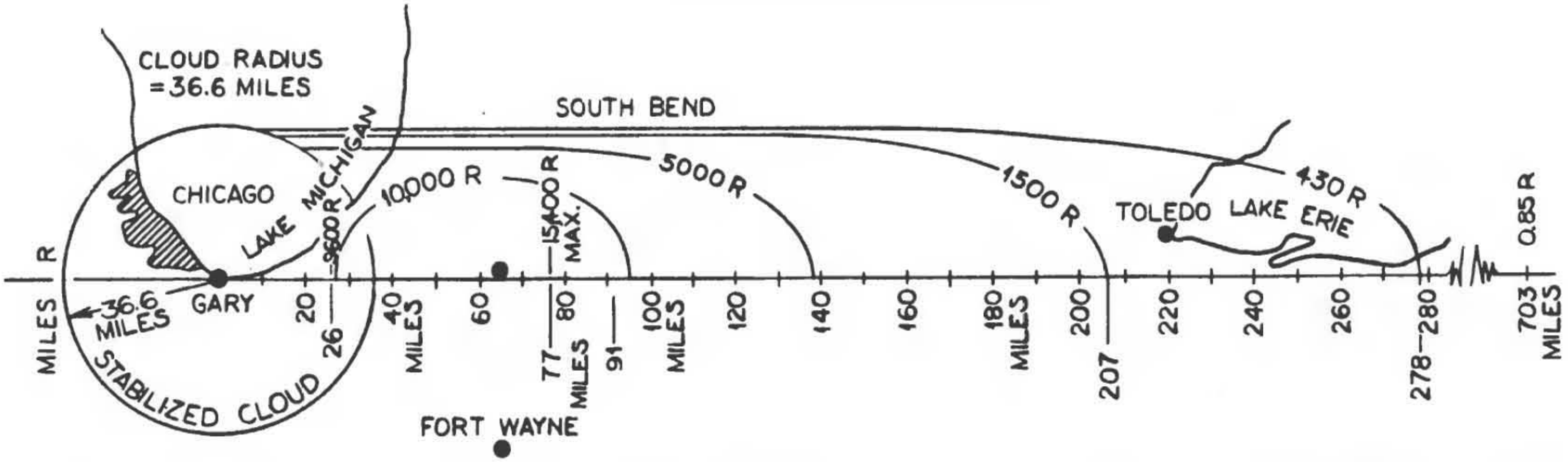
[1] See *Annual Defense Department Report, Fy 1976 and FY 197T*, by *Secretary* of Defense James R. Schlesinger; pages II-54 through II-57.

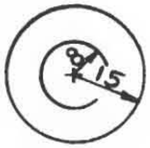
[2] See ORNL translations of authoritative Soviet civil defense handbooks: *Civil Defense* (Moscow, 1970), ORNL-TR-2793; *Civil Defense* (Moscow, 1974), ORNL-TR-2845.

ORNL-DWG 74-11138

CONTOURS SHOW THE DOSE (R) FROM TIME OF DEPOSITION UNTIL 14 DAYS AFTER THE DETONATION



BLAST AND FIRE EFFECTS OF 25 MT SURFACE BURST



8 MILE RADIUS:
5 psi OVERPRESSURE
200 cal/cm² THERMAL PULSE ON CLEAR DAY

15 MILE RADIUS:
1.8 psi OVERPRESSURE
50 cal/cm²

PARTICLE SIZE DISTRIBUTIONS:

AT DOWNWIND PEAK (77 MILES FROM GZ)	92μ 219μ
AT 136 MILES DOWNWIND	66μ 110μ
AT 278 MILES DOWNWIND	44μ 62μ

INTEGRATED DOSES (R) CALCULATED BY CRESSON H. KEARNY, ORNL, SO AS TO BE CONSISTENT WITH ASSUMPTIONS AND GEOMETRY OF MODEL AS DESCRIBED IN USNRDL-TR-639, DATED 21 MARCH 1963.

THIS UNITED STATES NAVAL RADIOLOGICAL DEFENSE LABORATORY FALLOUT MODEL ASSUMES A WIND SPEED AT ALL ELEVATIONS OF 15 MPH, AND INCLUDES NO RADIOACTIVITY FROM STEM OR THROW-OUT. THESE CALCULATED RADIATION DOSES (R) DO NOT TAKE INTO ACCOUNT ABNORMALLY HIGH CONCENTRATIONS OF FALLOUT DUE TO RAIN-OUTS, OR DUE TO ACCUMULATIONS AGAINST BUILDINGS AND IN GUTTERS ETC., NOR DO THESE CALCULATED DOSES REFLECT REDUCTIONS IN DOSES DUE TO WEATHERING AND ROUGHNESS EFFECTS.

Fig. 1.1. Fallout, blast, and fire effects from a 25-megaton (50% fission) surface burst.

Defense Civil Preparedness Agency. The work was conducted under the supervision of C. H. Kearny of the Emergency Technology Section, Health Physics Division, Oak Ridge National Laboratory.

PRIOR AND FUTURE ORNL WORK ON EXPEDIENT SHELTERS

The field experiments described in this report are a continuation of earlier work[3] done by Oak Ridge National Laboratory to develop and test high-protection-factor expedient shelters and to proof-test and improve illustrated instructions to enable untrained Americans to build such shelters in less than 48 hours. This report does not cover any of the extensive field tests of the most widely applicable of excellent expedient shelters, the Small-Pole Shelter. The Small-Pole Shelter is covered in earlier ORNL reports[3] and in a U.S. Army report.[4] Also, this ORNL report does not show the shelter-building families making their Kearny Air Pumps (KAP)[5] that supplied all of these crowded shelters (except those built during cold weather) with essential forced ventilation.

In the interest of brevity, only one example of step-by-step instructions for building an expedient shelter is given in this report (see Appendix). The *Expedient Shelter Handbook*[6] gives drawings and detailed instructions for building what the authors in early 1974 considered the 15 most practical designs of expedient shelters suitable for construction in the major environments of the United States. Unfortunately, four of these shelters have never been built, three have been built only by supervised U.S. troops, and only five have been built by untrained families guided solely by written instructions. Furthermore, 9 of these 15 shelters are built of lumber and other materials that during a rapidly escalating crisis would not be available in adequate quantities where needed to make expedient shelters for more than a small fraction of all Americans.

Improved step-by-step illustrated instructions building the most practical high-protection-factor pedient shelters and expedient life-support equipment will be given in a forthcoming ORNL survival handbook, *Nuclear War Survival Skills*.

EXPERIMENTAL PROCEDURES

Before untrained and unsupervised families built these shelters, the designs of expedient shelters that appeared to be the most promising for construction in each specified environment were built by supervised workmen. Next, the most promising design or designs for the specified environment were selected and improved. Then, step-by-step illustrated instructions for building each type of improved shelter were prepared. Finally, selected average-type families built each type of shelter under simulated crisis conditions, with no prior training and guided only by the written, well-illustrated instructions.

In some cases, as many as three shelters of the same design were built successively by three different families or groups of families. After each building experiment, the instructions and drawings were improved.

These experiments placed the shelter-building families under some disadvantages that they would be unlikely to face during an actual escalating crisis. For example, they were not permitted to borrow tools from or share tools with other families or even to observe how persons working nearby used tools. In an actual crisis, a demonstration on televison of the proper way to build the best designs of shelters for the area would save inexperienced builders much time and wasted effort, as would guidance from even a few persons with a little training.

To simulate crisis conditions during shelter construction, the agreement between the head of the family (or group of families) and the ORNL representative specified two unusual conditions. First, unless the builders completed their shelter in less than 96 hours from the time at which the head of the family (or group of families) first received the illustrated building instructions, they would receive no pay. Second, if they succeeded in completing their shelter in less than a specified time much shorter than 96 hours, they would earn a substantial cash bonus. A shelter had to be completed within 36 or 48 hours, according to the difficulty of construction, for the bonus to be earned. If the workers completed the shelter but failed to win the bonus, they earned the equivalent of good wages for this type of labor. If they succeeded in winning the bonus, they made excellent wages, calculated on an

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[3] C. H. Kearny, "Hasty Shelter Construction Studies," *Civil Defense Research Project Annu. Progr. Rep. March 1970–March 1971*, ORNL-4679, pp. 112–122; also "Construction of Hasty Winter Shelters," *Civil Defense Research Project Annu. Progr. Rep. March 1972*, ORNL-4784, pp. 78–89; also, *Blast Tests of Expedient Shelters*, ORNL-4905, January 1974.

[4] *Exercise Laboratory Shelter*, Hq. XVIII Airborne Corps & Fort Bragg, Fort Bragg, North Carolina, December 5, 1972.

[5] C. H. Kearny, *How to Make and Use a Homemade, Large-Volume, Efficient Shelter-Ventilating Pump: the Kearny Air Pump*, ORNL-TM-3916, August 1972.

[6] G. A. Cristy and C. H. Kearny, *Expedient Shelter Handbook*, ORNL-4941, August 1974.

hourly basis without consideration of overtime. In addition, the families were paid for all the materials they furnished.

After entering into a shelter-building agreement, families were not permitted to buy, acquire, or use any tools or materials that were not in their homes or on the shelter site at the time they first were contacted. Furthermore, builders could not receive any guidance or other help from anyone outside their specified group.

Each of these experiments began at the home of a shelter-building family when the head of the family was first given both the written instructions for building the shelter and an Evacuation Checklist very similar to the one included in this report (Table 1.1). Then, often before dawn, the families assembled the different categories of recommended items, selected some of each category to load into their car or cars, drove to the rural site, and built their shelters without guidance other than the illustrated, written instructions. The starting date was agreed upon in advance so that the builders could not select a time of good weather.

This experimental arrangement put the shelter-builders under considerable pressure. Since the author has observed in two wars that average Americans will work almost as hard to save their lives as they will to earn money, he believes that the successful outcomes of these shelter-building experiments indicate that most Americans in a nuclear war crisis would work hard and would succeed in building expedient shelters. These expedient shelters would provide them better protection than they could find available in existing structures. However, this belief is dependent on two hopes: (1) that in a desperate escalating crisis our highest officials would supply strong leadership, motivating Americans to work hard to improve their chances of avoiding nuclear war or of surviving if war befell and (2) that Americans would have received, before they would have immediate need of them, shelter-building and other survival instructions that have been proven to be practical.

Table 1.1. Evacuation Checklist

This is the final version, developed from four earlier versions that were improved in turn, after being used by different families that evacuated their homes preparatory to building shelters.

RECOMMENDED ITEMS FOR ~~URBAN~~ [illegible] EVACUEES TO TAKE WITH THEM IN THEIR CARS IF THEY PLAN TO BUILD OR IMPROVE EXPEDIENT SHELTERS DURING A WORSENING CRISIS:

Loading Procedure: Except for categories 1 and 2, first make separate piles of items, one pile for each category. Then load the car (leaving enough room for each crowded passenger), by taking items from each of categories 3 through 12.

A. THE MOST NEEDED ITEMS:

Category 1. Valuables: Money; credit cards; negotiable securities; valuable jewelry; checkbooks; and the most important documents at home.

Category 2. Survival Information: Shelter-building and other nuclear survival instructions; maps; battery-powered radio.

Category 3. Tools: Pick; shovel; file; knife; and any other tools specified in the building instructions for the type shelter you plan to make. Also take work gloves.

Category 4. Shelter-Building Materials: Rainproofing materials (plastic, shower curtains, etc.); cloth; etc. – as specified in the shelter-building instructions for the type shelter you plan to make.

Category 5. Water: Smaller water containers (filled), plus an empty cleaned and sterilized garbage can with plastic (bags or film) to use as liners before filling the larger container (or a water pit) in the shelter-building area; water-purifying material (like Clorox); and a teaspoon for measuring – one teaspoonful per 5 gallons.

Category 6. Light: Flashlights; candles; materials to improvise cooking-oil lamps (2 clear glass jars, cooking oil, and wick materials – see instructions*); matches and moisture-proof jar for matches.

Category 7. Clothing: Especially cold-weather boots, overshoes, and warm outdoor clothing (to be used in hot weather for padding and for sleeping); raincoats and ponchos; work clothes and work shoes.

Category 8. Sleeping Gear: A ~~C~~compact sleeping bag~~s~~ or two blankets per person.

Category 9. Food: Compact foods that require no cooking preferred. Include a pound of salt. Food for babies has highest priority. If other foods are available, take as much as the car or cars will hold in addition to passengers and the items listed above. Can and bottle opener; one spoon and one bowl per person; two cooking pots with lids (4 ~~quart~~ to 6 quart size preferred); large cooking spoon.

Category 10. Sanitation Items: Plastic or plastic bags in which to collect and contain excrement; bucket for urine; toilet paper; tampons; diapers; soap.

Category 11. Medical Items: Aspirin; first-aid kit and supplies; special prescription medicines (if essential to a member of the family); spare glasses and contact lenses.

Category 12. Miscellaneous: Two square yards of mosquito netting or screen wire to screen the shelter openings if insects are a problem; insect repellent; a favorite book or two; a few small toys for small children.

B. SOME USEFUL ITEMS – To take if car space is available:

1. Additional Tools: Saw (bow-saw best); ax; hammer; pliers.
2. Tent and some additional kitchen utensils.

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*These instructions for building expedient lights were given to the shelter-building families, but are not included in this report.

2. A Manless Family Building a Door-Covered Trench Shelter

BACKGROUND

One of the reasons why U.S. civil defense officials have not incorporated into civil defense plans the construction of high-protection-factor expedient shelters is the widely held belief that only Americans accustomed to hard physical work and having construction experience could build for themselves good shelters in a couple of days. The fact that millions of American families have the necessary tools and materials in their homes to build high-protection-factor expedient shelters is no proof that most of these untrained families could build such shelters quickly, especially if guided only by written instructions. Therefore, one of the main objectives of the ORNL shelter-building experiments has been to determine the capabilities of urban-type families that include no laborers to build expedient shelters under simulated crisis conditions.

Prior to the experiment described in this chapter, the practicality of a Door-Covered Trench Shelter had been indicated by this type shelter's having withstood blast effects accompanying a blast overpressure of 5 pounds per square inch (psi).[7] Furthermore, encouraging evidence of the practicality of this shelter had been derived from the success of a chiropractor and his family (who, until shortly before the experiment, were residents of Los Angeles) in winning the bonus for completing a Door-Covered Trench Shelter in less than 36 hours. The chiropractor, who had never before dug a ditch or trench, was handicapped by having an invalid wife and four children too young, with the exception of one girl, to work effectively. This experiment resulted in the addition of more details to the step-by-step building instructions. Such detailed instructions are especially needed by professional men not used to working with their hands and by manless families so common in the cities.

WINTER TESTS IN COLORADO

To perform an indicative experiment, the author recruited an urban-type family lacking any adult male member, having only the tools used in their home flower garden, and including no member with a background of construction experience, civil defense training, or hard manual labor. As described by the following captioned photographs, this untrained family, under winter conditions in Colorado, succeeded in following the step-by-step written instructions – first those in the Evacuation Checklist preparatory to evacuating their home and driving to a rural shelter-building site, and then the instructions for building a Door-Covered Trench Shelter. This family accomplished all this in 34 hours from the time the mother first received the instructions, thus winning the cash bonus for completion in less than 36 hours. Few of the officially designated shelters in buildings of the nearby shelter-short town of Montrose, Colorado, would have given better fallout protection than their shelter. This shelter had a protection factor of approximately 250 due to having less than the specified earth cover.

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[7] C. H. Kearny and C. V. Chester, *Blast Tests of Expedient Shelters,* ORNL-4905, January 1974.

Fig. 2.1. Start by an untrained, unskilled family of the second proof-testing of the written instructions for building a Door-Covered Trench Shelter. Starting at 6 AM on November 24, 1973, son Tad, age 14, and other children removed the doorknobs from one of the six interior doors that this fatherless family of six readied for use.

The six doors actually used were all new, inexpensive, hollow-core interior doors, 32 in × 6 ft 8 in. × $1\frac{3}{8}$ in., with $\frac{1}{8}$ in. mahogany veneer, and weighing $20\frac{1}{2}$ lb each.

The latter were purchased by the author, and of course lacked hinges or doorknobs.

PHOTO 3023-73

Fig. 2.2. Starting to stake out the shelter trench near Montrose, Colorado, at 7:17 AM. The six doors, some tools, water, etc., were carried in a station wagon. The ground was frozen only about an inch deep.

Pictured are the mother, a registered nurse and head of this family, Mary (14), Tad (14), Elizabeth (11), and David (8).

Julie (18), a student nurse, had to work at the hospital and was unable to join in the work until 3:45 PM. No man worked building this shelter.

PHOTO 3080-73

Fig. 2.3. The mother dug inefficiently with her dull shovel by pushing it with her foot. She dug the trench too narrow until it was almost completed – in spite of having read the instructions to the contrary. Until the second day, no member of this family learned to swing their dull old pick properly, by letting one hand slip toward the other as the pick descended. Nor did they know how to use their other tools properly.

Nevertheless, they won their bonus for completing their six-door shelter in less than 36 hours and received a total of $400.

Fig. 2.4. No member of this family was used to hard, physical labor. Within two hours of beginning digging, they were so tired they frequently sat down to dig! In an ill-conceived attempt to keep everybody working together, on the first day they mostly dug all at the same time while facing across their small trench, and all rested or ate at the same time.

PHOTO 3026-73

Fig. 2.5. Instead of sharpening their pick and using it, this family mostly pried and scraped away the dry, hard clay-loam with shovels, inch by inch.

Note how the trench narrowed downward, an error that later required several person-hours of work to correct.

All six workers quit for the day at 5:20 PM, tired.

PHOTO 3073-73

Fig. 2.6. Starting work at 7:33 AM on the second day, sore of muscle and low in spirits. It was snowing intermittently, at 25° F. All six workers were on the job the second day until completion of their shelter.

Fig. 2.7. At 8 AM on the second day, when the trench was about 3 ft deep, this family had the good fortune to get below the dry, hard clay-loam and into a slightly sandy clay-loam. The mother could dig this very stable but not-so-hard earth by standing on the shovel and slicing and prying off rows of chunks from the edge of a 6-in.-high earth step.

Fig. 2.8. Placing bedsheet coverings on the 4½-ft-high trench walls. Such coverings make the trench cleaner, warmer, and easier to illuminate.

At the far end of this 15-ft-long, 3-ft-wide, and 4½-ft-deep main trench, Tad is digging the steps in the 18-in.-wide, 24-in.-long entryway trench.

The trench was completed at 11:55 AM on the second day, 30 hours after Kearny handed this family the building instructions.

PHOTO 3037-73

Fig. 2.9. Placing the first of six interior, hollow-core doors over the completed trench. The earth on the wall-lining sheet was removed before the second door was positioned.

Although the trench was dug to be only 36 inches wide, in places some of the doors had to span more than a 48-in. width before they were covered with earth. The weight of the covering earth bowed some doors down almost an inch, until a part rested on the edge of the trench – thus reducing the effective span to about 40 to 42 inches.

PHOTO 3079-73

Fig. 2.10. Covering the water-shedding "buried roof." This family used a tent, due to a desire to save their shower curtains and most of their plastic table cloths, etc.

By far the worst error made by this family was putting the tent directly on top of the horizontal doors and starting to cover it as the "buried roof." At this point Kearny corrected them, for the first and only time, by asking the mother to reread the instructions.

The sandbags around the partially completed 18 × 20 in. entryway are earth-filled pillowcases, which, along with the tent, were recovered undamaged.

PHOTO 3041-73

Fig. 2.11. Completed Door-Covered Trench Shelter, with canopies made of plastic tablecloths inexpertly rigged over the two openings.

Because at this date Kearny did not realize what great depths of earth covering such hollow-core doors bridging a narrow trench would hold, the instructions given to this family specified only an 18-in. covering. This family, so tired by this time that they were shouting at each other, shoveled only about 15 in. of earth over the doors.

PHOTO 3042-73

Elizabeth, aged 11, asked Bettge (DCPA) and Kearny a pertinent question: "But how (in a crisis) would people know how to build shelters?"

Fig. 2.12. Inside their completed Door-Covered Trench Shelter, and all pepped up by their success in finishing an unexpectedly hard job. They completed their shelter at 3:50 PM on November 25, about 34 hours after first receiving the instructions on November 24.

CONCLUSION: Not only does this shelter afford fallout protection (about PF 250) in line with the current threats, but also it gives much better fire and blast protection than do most basements. In a Defense Nuclear Agency blast test, a Door-Covered Trench Shelter withstood 5 pounds per square inch blast overpressure. The shock and drag effects accompanying a 5 psi overpressure from a large nuclear weapon would topple a strongly built high-rise building.

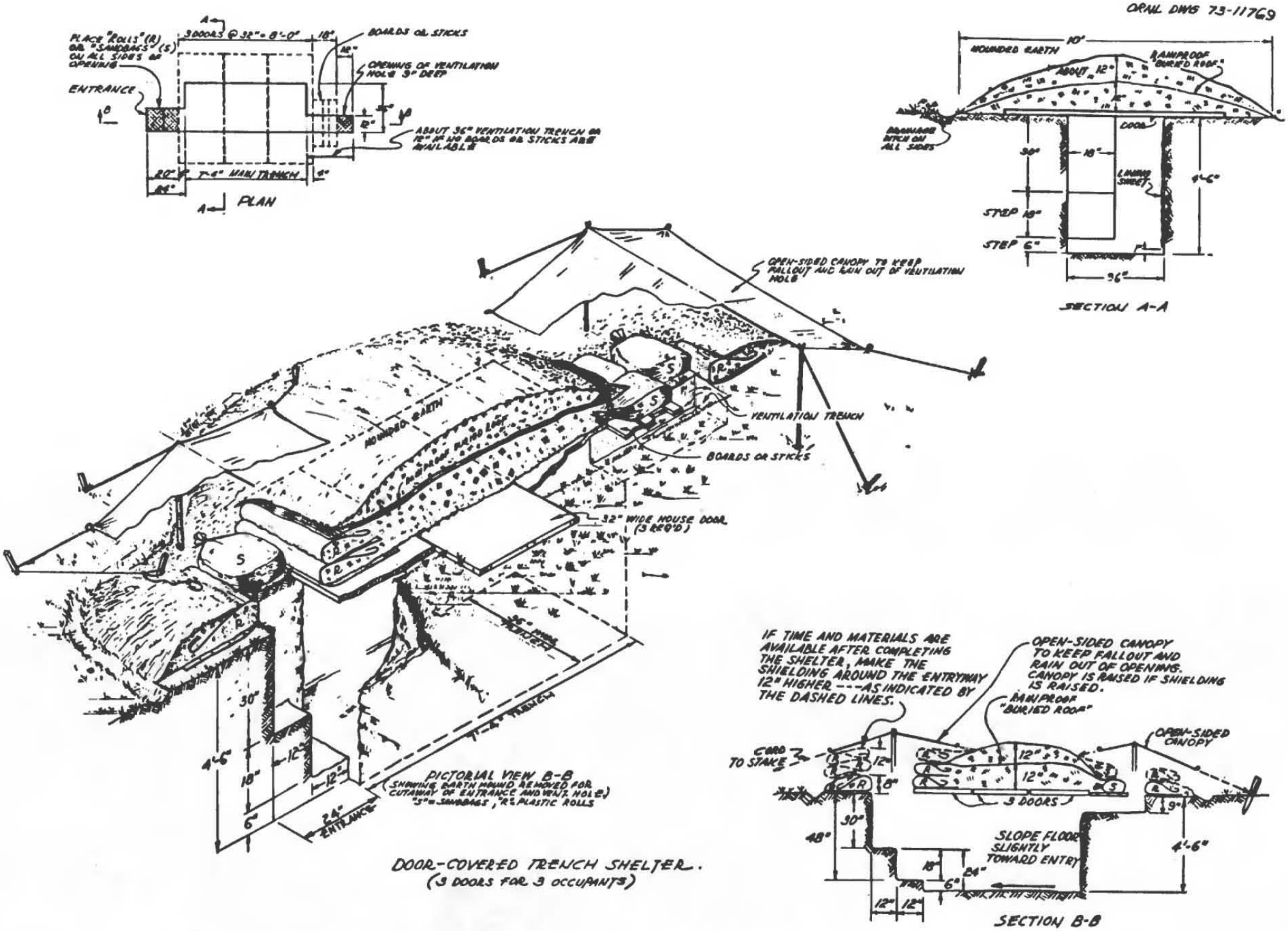

Fig. 2.13. Door-Covered Trench Shelter. Rolls substitute for sandbags and are made of bed sheets or other household materials rolled so as to hold earth, as described in the drawing of the Above-Ground Door-Covered Shelter (Fig. 5.13).

CONCLUSIONS

Even most unskilled, untrained urban families could build Door-Covered Trench Shelters within two days, provided they:

1. are adequately motivated;
2. have step-by-step illustrated instructions as good as the ones used by this family;
3. have one door per person at a shelter site with suitable earth; and
4. have a pick and shovel, or at least a shovel, the only tool essential for trenching in stable earth.

3. Stress Tests of a Door-Covered Trench Shelter and the Resultant Development and Testing of a Prototype Tarp-Roofed Trench Shelter.

BACKGROUND

In stable earth, covered-trench shelters without shored walls can be built to withstand quite severe blast overpressures by using the strength developed by earth arching in the overlying earth. The roof should be designed so that under blast pressure it will be depressed downward sufficiently to permit the overlying earth to be compressed to form an arch that carries most of the blast loading. Military foxhole covers, made of very strong plastic film such as Mylar and covered with earth, provide quite good blast protection by using earth arching in this manner.

No reports were found on shelters roofed with rugs or ordinary tarps, and none involving stress tests of Door-Covered Trench Shelters were found. Since rugs and interior doors are materials available to most Americans, it appeared important to investigate the practicality of using rugs (or canvas) and interior doors to roof trench shelters. The following experiments involved subjecting to heavy loads expedient shelters that were roofed with interior doors or cotton-duck tarps and covered with different thicknesses of shielding earth.

STRESS TESTS IN COLORADO

The following photographs give evidence of the unexpected effectiveness of the earth arching produced under pressure in the earth above trench roofs made of hollow-core, lightweight interior doors or inexpensive tarps of cotton duck (Figs. 3.1–3.15).

PHOTO 3065-73

Fig. 3.1. Six and one-half feet of earth piled on December 1 over the 6-door Door-Covered Trench Shelter built by the manless family on November 24 and 25, 1973.

Since this dry, crumbled clay-loam was not compacted except by its own weight, Kearny was surprised the doors did not break under such heavy loading.

Fig. 3.2. View of the same shelter from the entryway end. An observation trench had been dug out from the entryway, so that deflections of the roof doors could be observed safely.

The doors in the center were bowed down the most – about an inch. Most of this $6\frac{1}{2}$ ft of earth was supported by earth arching that resulted from the simultaneous downward bowing of the roofing doors and the settling of the piled-on earth. Prior static tests of similar interior hollow-core doors had shown that without arching such a door breaks under a load equivalent to about $3\frac{1}{2}$ ft of earth of this density.

PHOTO 3084-73

Fig. 3.3. An 8-ton backhoe on top of what was originally the $6\frac{1}{2}$-ft-deep pile of earth over the shelter. Before this picture was taken, this machine had been driven back and forth several times over the mounded earth. The roofing doors remained undamaged, and were not observed to be bowed downward any more than when only the $6\frac{1}{2}$-ft mound of earth was over them.

PHOTO 3083-73

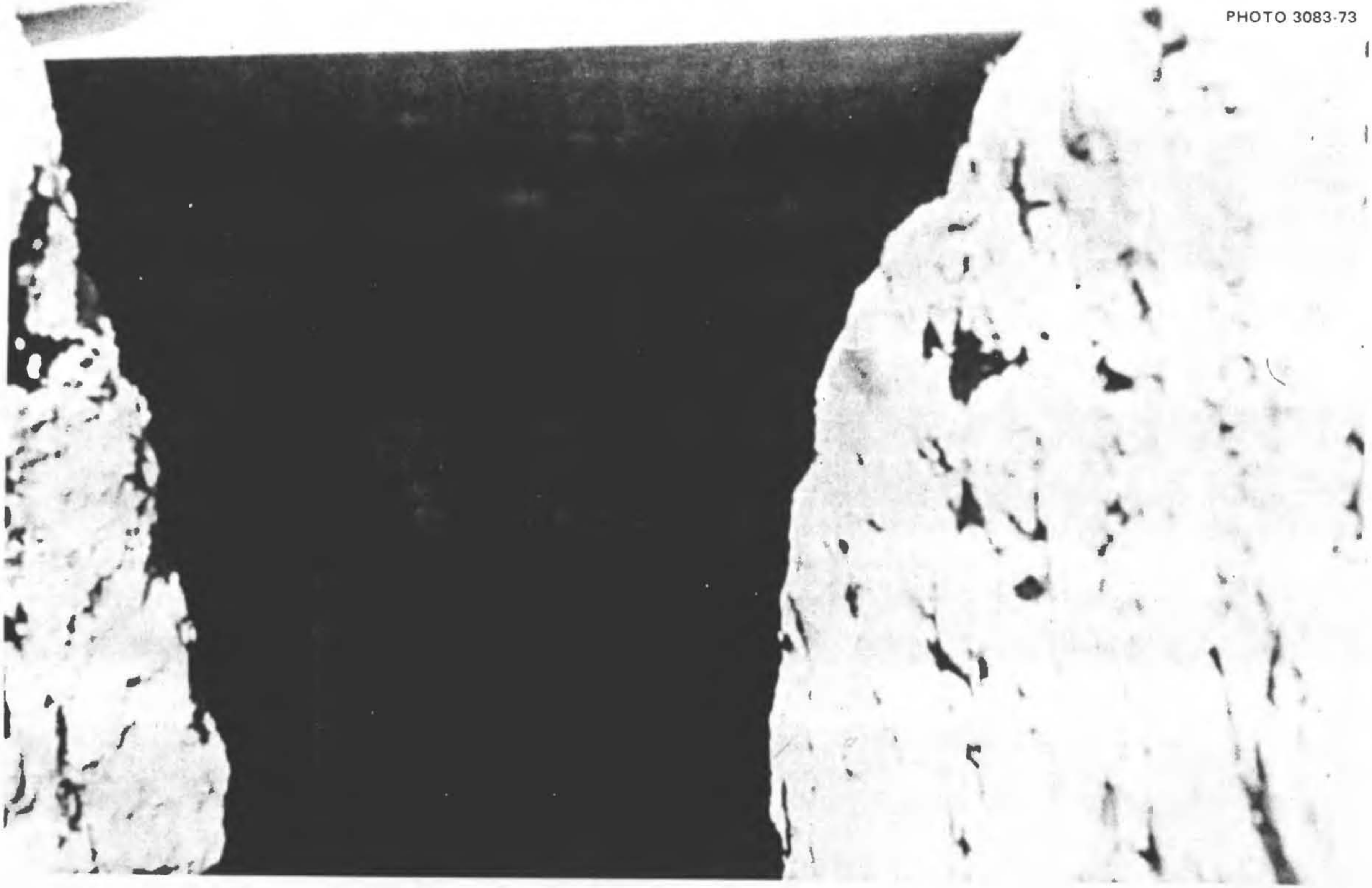

Fig. 3.4. View of interior doors after the successive loadings shown by the preceding photos. The center doors had been bowed downward a total of about 1 ½ in.

PHOTO 3070-73

Fig. 3.5. In order to break the roofing doors, the backhoe removed all but about a 2-ft thickness of the earth covering. Then the 8-ton backhoe was driven over the shelter; this compacted the earth under the wheels (reducing its thickness to $21\frac{1}{2}$ in.) and suddenly broke the $\frac{1}{8}$-inch mahogany veneer *on the lower sides of two doors.* But the $\frac{1}{8}$-in. veneer on the upper sides of the doors did *not* break!

The backhoe was driven back and forth several times over the shelter, which remained safe to occupy!

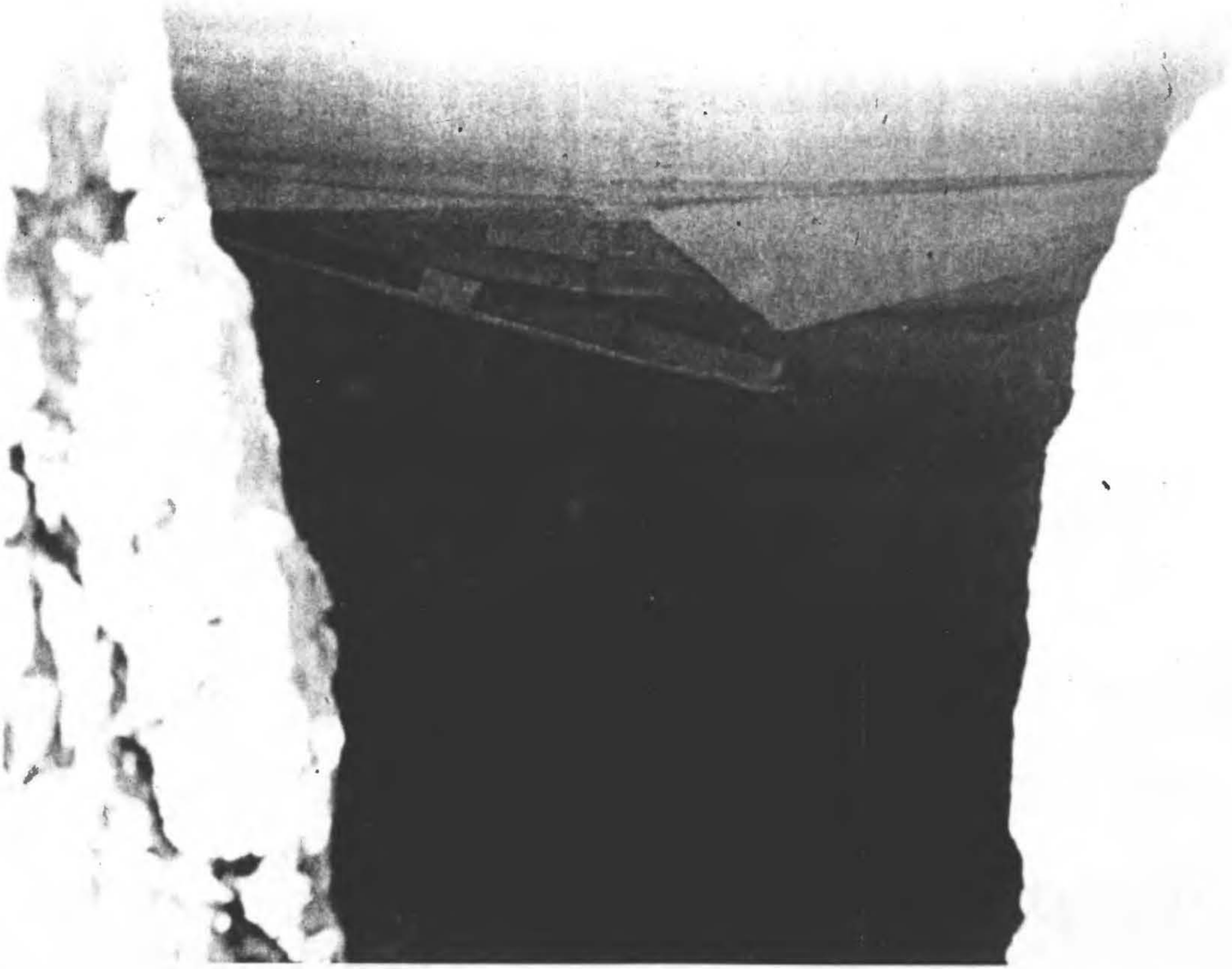

Fig. 3.6. Looking into the shelter after the rupture of the lower plywood-veneer sides of the doors. Since the veneer on the upper sides of the two partially broken doors and of two cracked doors remained intact, no earth fell into the shelter, and occupants would not have been injured by this unexpected type of failure of the most stressed of these very light hollow-core interior doors used for trench roofing.

Fig. 3.7. Looking at one of the partially broken doors after the removal of earth cover 21½ in. thick, measured from the man's hand to the center of the downward-bowed, unbroken upper veneer of a door. The maximum downward bowing – about 7 in. from the horizontal – occurred in the center parts of the two doors, directly under the wheels of the 8-ton backhoe.

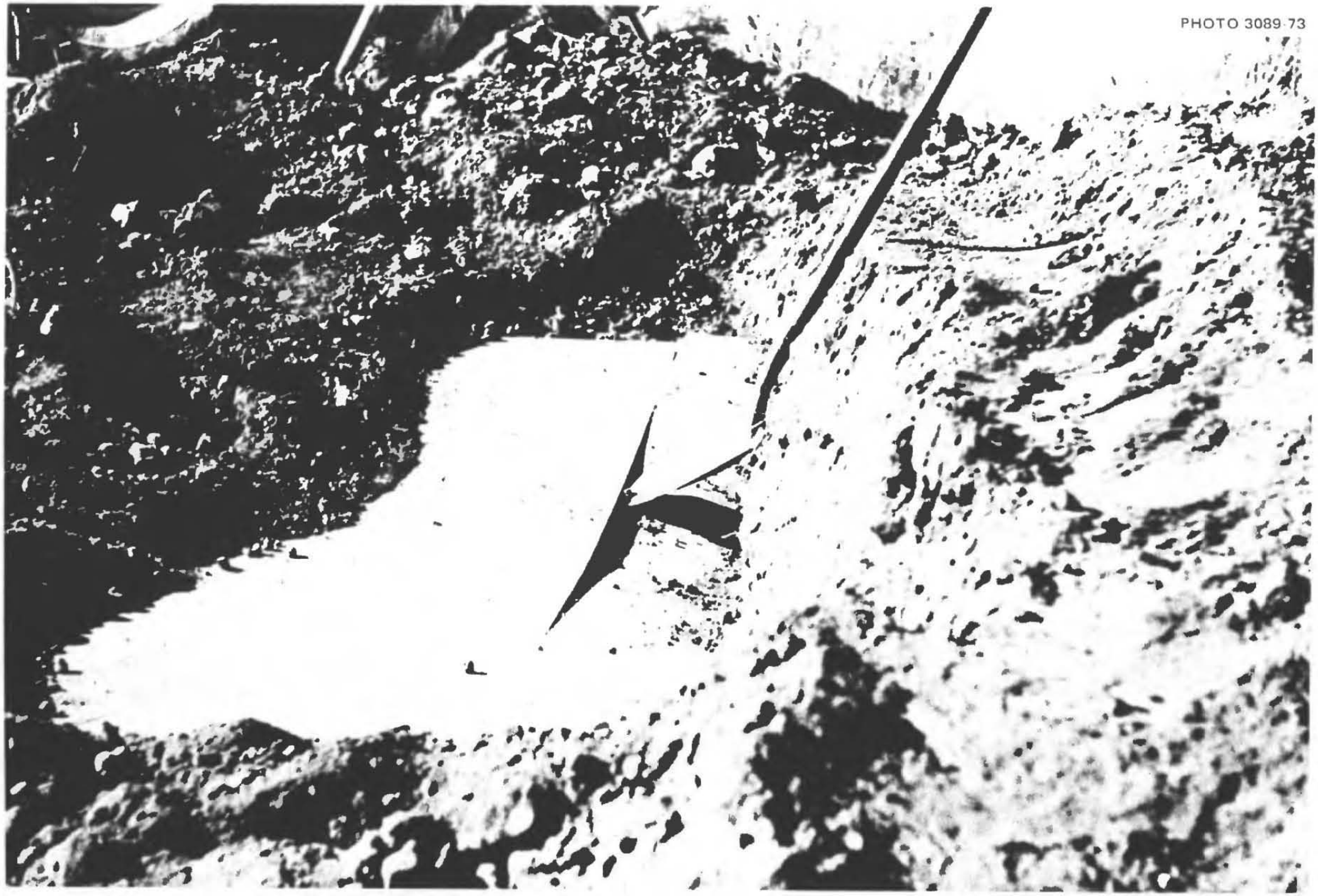

Fig. 3.8. Another view of the most downward-bowed upper veneer of a door. The ratio of earth cover to free span was 21½:40, that is, greater than ½. A ratio of ½, or greater, is usually required for the development of effective earth arching in the earth cover over a beam capable of being bowed downward sufficiently without breaking by the weight of the earth and/or downward pressures applied to the surface of the earth cover.


PHOTO 3068-73

Fig. 3.9. View of the most damaged door after the removal of the adjacent door. Removal of some of the weight on the $1\frac{1}{2} \times 1\frac{1}{2}$-in. pine board that formed the unbroken frame of this door resulted in its becoming less bowed. The dry-earth bank pictured above this door appears to be vertical but actually was not. Kearny concluded that all that is needed to build a blast shelter in areas with stable and adequately deep earth is: (1) a deformable membrane (such as a tarp or rug) strong enough to support the weight of earth between it and the bottom of the earth arch formed by downward stresses and strains in the earth above the membrane; (2) the earth itself plus some practical although uncommon knowledge of how to use merely such a deformable membrane and earth to build a blast-protective roof over a trench.

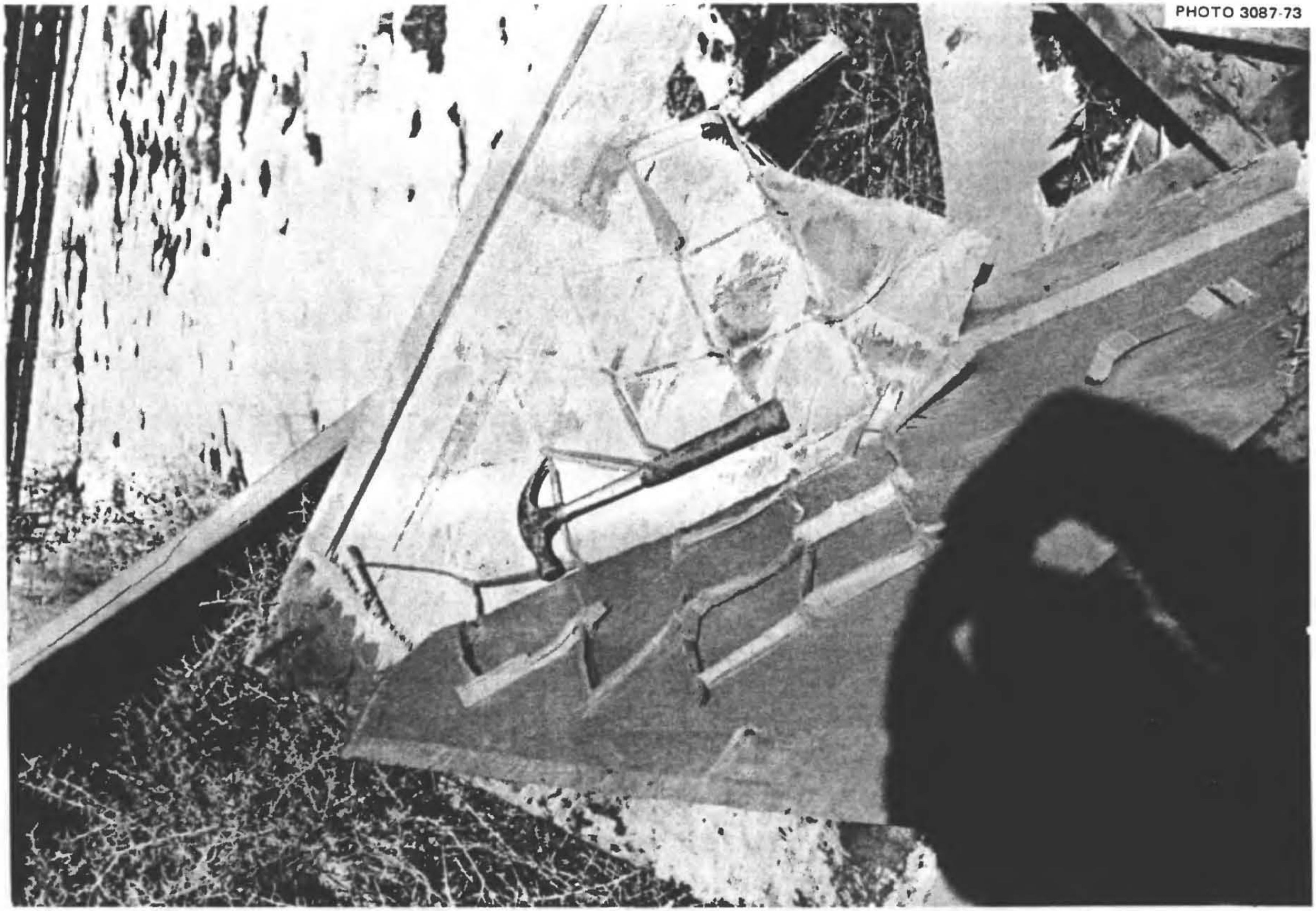

Fig. 3.10. View of the worst damaged door, taken after the shelter was demolished and some doors were torn apart. These 20½-lb hollow-core interior doors were of an inexpensive type with a coarse 6 × 6 in. honeycomb of cardboard strips (⅛ in. thick × 1⅛ in. wide) bonded with waterproof glue to the ⅛-in.-thick mahogany veneer of the two sides.

Fig. 3.11. Building the best of two successful Tarp-Roofed Trench Shelters constructed on Dec. 1, 1973, on the Kearny farm near Montrose, Colorado. C. H. Kearny designed this shelter after the November tests of the Door-Covered Trench Shelter had convinced him that, if the principles of earth arching and friction are used properly, then blast shelters can be built in many areas by roofing a trench with only a tarp or a strong rug, and then intelligently covering the tarp or rug with earth.

A workman is shown placing dry, crumbly clay-loam earth over one edge of the tarp. This edge had been placed in one of the two rectangular side trenches, as indicated by the sketch.

Fig. 3.12. **Compacting the earth over one edge of the tarp.** This edge has been placed in one of the two 16-in.-wide by 12-in.-deep rectangular trenches, each of which was dug parallel to and 3 ft from the vertical walls of the shelter trench. Packing with this wide-wheeled backhoe did not compact the earth as well as hand-tamping it with a pole.

The shelter trench was 3 ft wide. The tarp was of 12-ounce cotton duck and measured 11 ft 4 in. × 15 ft 4 in. This new, inexpensive tarp was laid with its length (which was the direction of its three-component stitched-together strips) across the trench. The downward bow, or sag,of the uncovered tarp, as pictured, was 6 to 8 in.

Where the tarp is shown starting to curve downward toward the center of the shelter trench, the edges of the trench were beveled off at 45°, as shown. With the side edges of the trench beveled thus, horizontal pressures (directed outwardly against both walls of the trench) are developed when the catenary section of the tarp (or other deformable membrane) is loaded with earth. These outwardly directed horizontal pressures help hold apart the two sides of the trench.

Fig. 3.13. Stressing the Tarp-Roofed Trench Shelter, a 6-ton backhoe, supported only by its buckets, pressed down repeatedly with its front bucket on a 62-in.-deep mound of loose earth. The mounding of loose earth caused the tarp to bow downward (sag) into a catenary curve. The compaction caused the tarp to stretch, resulting in an increase of the maximum sag from 8 to 14 in.

PHOTO 3092 73

Fig. 3.14. Stressing the Tarp-Roofed Trench Shelter, after the thickness of its earth cover had been reduced to about 3½ ft, by driving a 6-ton MF-30 backhoe back and forth across it. The downward bow, or sag, of the tarp catenary remained the same (14 in.).

Because Kearny wanted to see whether or not the tarp edges in the small earth-filled side trenches had moved, no more of the earth cover was removed preparatory to more severe loading tests. The tarp was unearthed by the backhoe and hand labor; the tarp edges in the small trenches had not been moved, nor had the compacted earth in the two small side trenches been disturbed by the inward pulls on the tarp produced by the loading tests.

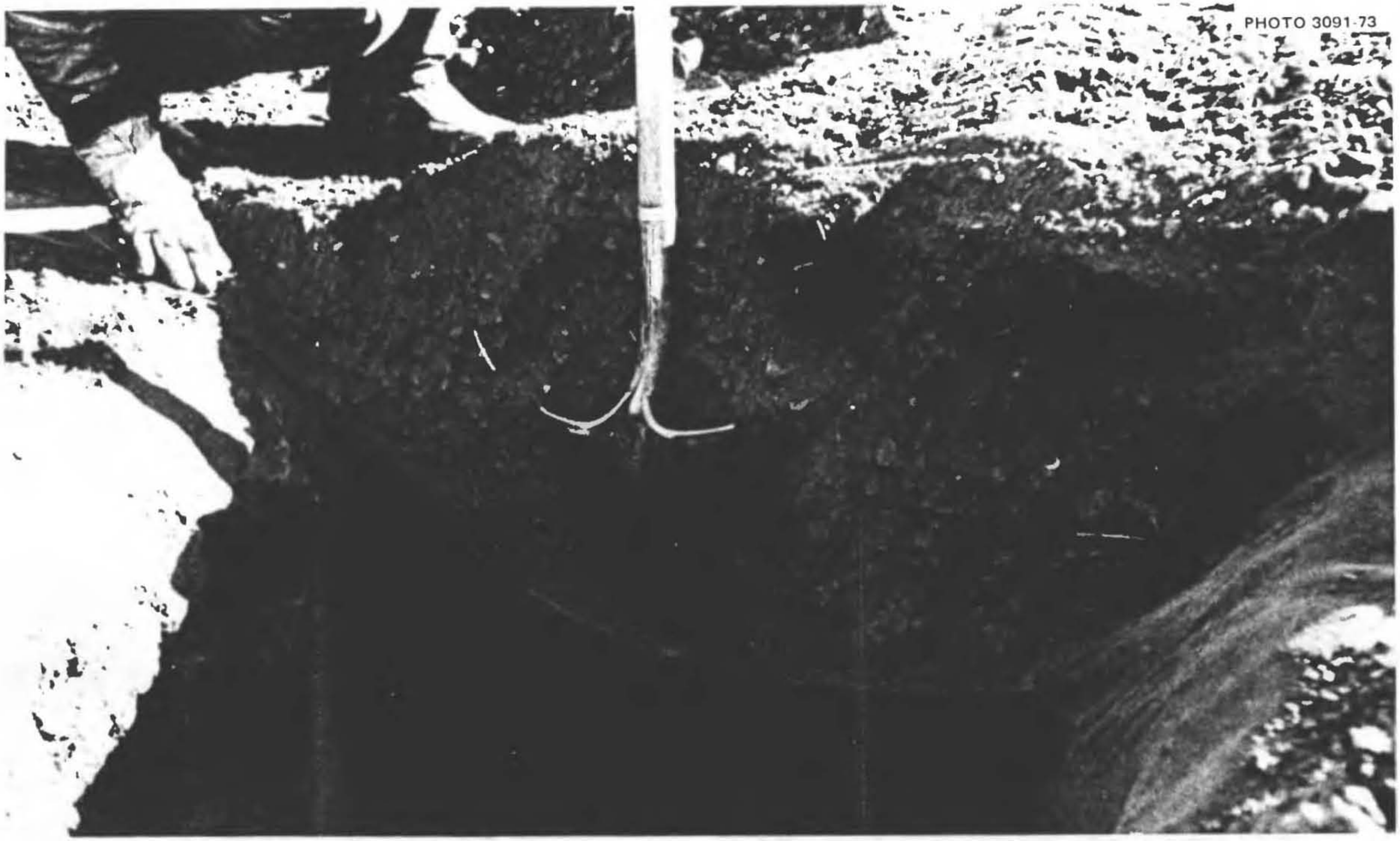

Fig. 3.15. View of the tarp catenary after the backhoe (that was removing the earth cover) had accidentally snagged part of the tarp and torn it. Note the 45° beveled edge of the trench.

Two-inch-wide strips cut from this 12-oz cotton duck tarp were subsequently stressed to failure in the Metallurgy Test Laboratory of ORNL. The ultimate strength was found to average only about 190 lb per 2-in.-wide strip, or 1140 lb per 12-in.-wide strip when subjected to ideal straight-pull stressing.

Calculations using these optimum figures show that without earth arching the Tarp-Roofed Trench Shelter would have failed under the loads it was subjected to on December 1.

Since Army units have many tarps and tents and many American homes have large rugs, further testing of Tarp-Covered Trench Shelters and Rug-Covered Trench Shelters is recommended.

CONCLUSIONS

1. The possibilities of suburban residents providing themselves with consequential blast protection, together with good fallout and fire protection, by roofing trenches with interior doors or rugs and covering them with earth should be more fully explored.

2. Rug-Covered Trench Shelters should be built and blast tested as part of the Defense Nuclear Agency's next large-scale blast test at White Sands Missile Range, and Door-Covered Trench Shelters should be tested at blast overpressures greater than 5 psi.

4. An Urban Family Evacuating, Building a Log-Covered Trench Shelter, and Occupying it Continuously for 77 hours.

BACKGROUND

Most good expedient shelters, if designed so that an average American family (or families) using only hand tools can build them in 48 hours or less, have such low roofs that an adult cannot stand erect inside them, except perhaps in a hole dug in the shelter floor deep enough to permit occupants the occasional luxury of standing erect to stretch. Preliminary overnight tests by the author had indicated that average Americans could live quite comfortably for many days in such small shelters if they are properly proportioned to use limited space efficiently and are equipped to provide forced ventilation, adequate water, dependable light, and furnishings to permit sitting and sleeping. However, no record could be found of any multi-day occupancy test by an American family of a high-protection-factor expedient shelter.

Families in Tennessee had built small, austere Log-Covered Trench Shelters[8] under simulated crisis conditions. These field tests had proven that even most rural families need detailed, step-by-step building instructions, illustrated with picture-like drawings. Therefore, additional details had been added to the shelter-building instructions before they were given to the urban family pictured in this chapter.

The blast protection afforded by Log-Covered Trench Shelters had been proven by tests that were part of Defense Nuclear Agency's million-pound TNT blast test.[8] Although the 7-foot logs used to roof one of these 42-inch-wide test shelters dug in stable earth were actually green pine poles only 4¼ to 5 inches in diameter, covered with about 25 inches of unpacked earth, this *closed* shelter was undamaged by a blast overpressure of almost 13 psi.

SUMMER TEST IN UTAH

The urban family selected for this pioneering shelter-occupancy test was above average in education and interest in survival. The father is an electrical engineer who for years has maintained his interest in civil defense.

Some of the comfort-promoting items that this family of six brought with them to the shelter-building site in their one small car were not on the Evacuation Checklist (Table 1.1). For a real crisis evacuation, it would have been more practical to have left the manually powered generator, TV set, toilet seat, electric clock, telephone, etc., at home and to have brought an equivalent weight of dry foods. However, in this experiment the main problem of this family was whether or not their six-year-old son, a high-strung child, would be content to remain continuously for at least 72 hours in a crowded "home" only 3½ feet wide, with a ceiling only 4½ feet high. So by providing their shelter with an odorless expedient toilet, a TV set, a clock, and other normal comforts of an American home, the parents thought that their small boy would be under less stress and that all members would have a better shelter experience.

This Log-Covered Trench Shelter has a protection factor of around 500 if covered with the specified 36 inches of earth (Figs. 4.8 and 4.9). As an example of the detailed step-by-step building instructions supplied to the untrained, unsupervised families that built this and other small shelters, the instructions used by this family for building this shelter are given in the Appendix.

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[8] C. H. Kearny, "Hasty Shelter Construction Studies," *Civil Defense Research Project Annu. Progr. Rep. March 1970–March 1971*, ORNL-4679, pp. 112–122; also "Construction of Hasty Winter Shelters," *Civil Defense Research Project Annu. Progr. Rep. March 1972*, ORNL-4784, pp. 78–89; also, *Blast Tests of Expedient Shelters*, ORNL-4905, January 1974.

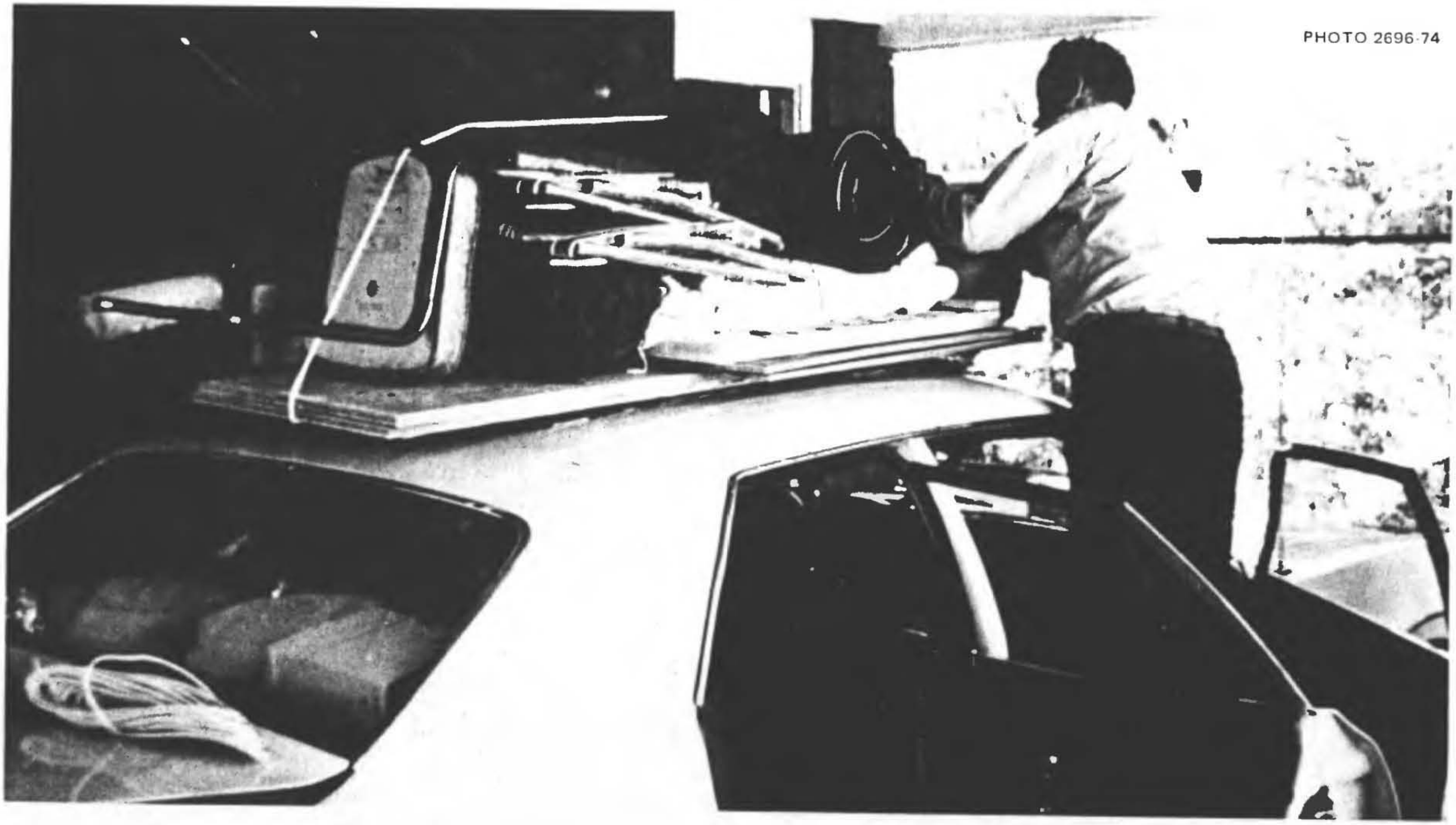


PHOTO 2696-74

Fig. 4.1. Loading the family car, a 4-door Maverick, preparatory to evacuating. Ten days before the agreed starting date (August 13, 1974) of this test, this 6-person family had agreed to build a trench shelter 3½ ft wide, 4½ ft deep, and 15 ft long, with an entrance trench 22 in. wide. No plans or instructions were supplied before the starting hour, 5 PM on August 13. Therefore, the prudent father of this family had built, before August 13, an essential ventilating pump (a KAP, 20 in. wide × 36 in. high) and prefabricated components of a 21-in.-wide, double-deck bunk. Also, he sawed plywood into several threshold boards to keep the edges of earth steps and ledges from being broken off. Furthermore, after having built a rough mockup of this small shelter in his home basement, he had decided to carry on top of the family car three folding chairs and one straight chair, to avoid getting sore backs from sitting for days with no good back support.

Between the car top and the plywood, the father sensibly placed a narrow shag rug. The sleeping bags also provided resiliency that kept the load on top from slipping after it was tied on.

Fig. 4.2. Food assembled ready for evacuation loading. Food was one of the 12 categories of items that the Evacuation Check List (Table 1) advised this family to take with them. The family planned to use the wooden boxes for bunk ends.

This family was given the Evacuation Check List and the detailed shelter-building instructions at 5 PM on August 13, 1974. They loaded their car by 6:16 PM and drove away from their home in Bountiful, a satellite town of Salt Lake City, and began the 64-mile drive to the shelter-building site near Spanish Fork.

This was the first expedient shelter exercise requiring an American family to evacuate with all tools, materials, and supplies needed to build an expedient shelter, build it, and then live in it for at least 72 hours. Therefore, Kearny had selected an above-average Mormon family, headed by an electrical engineer, a man long concerned with civil defense. This father is an inventor who had designed and made survival equipment -- a man likely to continue contributing practical ideas and insights.

PHOTO 2688-74

Fig. 4.3. The 6-person family just before reaching the shelter-building site on a farm near Spanish Fork, Utah, at 7:48 PM. Most of the 64-mile drive (evacuation) was on an interstate, moving with the traffic at 55 to 60 mph. To provide space in their crowded car, they left the back seat at home.

Note that the load on top of the car was first tied together with cord. Then, after being covered with a small piece of canvas, it was tied to the top of the car with two pieces of light rope. These ropes encircled the top of the car, before the four doors were closed. The father made a loop on one end of each piece of rope, so that he was able to cinch each of these ropes tightly around the purposely resilient load. Obviously, many city people would need to read and follow instructions to enable them to tie bulky loads securely on their car roofs.

Fig. 4.4. Expanding the shelter room to its full specified width of 3½ feet, and to its 4½-ft depth. This intelligent man made unnecessary work for himself by not following the instructions to cut a 3½-ft stick, and then use it repeatedly to be sure the trench was being dug full width.

Having only one shovel and no pick also slowed this urban family's digging, as did their failure to use their two 5-gal cans to carry earth, and their failure to have their 13-year-old daughter share in the work. An unavoidable handicap was that the mother had suffered for years from a heart condition, so she sensibly did nothing but prepare meals and help hold lights, until they stopped digging 15 minutes past midnight. They slept in their small camping tent, pitched beside the shelter excavation, after digging the main trench 3 ft 9 in. deep.

Fig. 4.5. The small ledgelike excavation on the side of the main trench was dug by Kearny to provide himself with a place to sleep and to observe the shelter-occupany test. This sleeping ledge was 2 × 8 ft, providing a height to the log roof of only 2 ft. After Kearny got a sore neck from turning around periodically on this sleeping ledge, with only a 24-in. ceiling, during the 77 hours of shelter occupany, he concluded that such sleeping ledges should be dug to provide a 30-in. ceiling.

The entry trench, 22 in. wide and 48 in. deep, is shown in the foreground. When this photo was taken, the 22 × 24 × 60 in. trench for the air exhaust-emergency exit had not yet been dug at the far end of the main trench. This main trench was $3\frac{1}{2}$ ft wide, $4\frac{1}{2}$ ft deep, and $16\frac{1}{2}$ ft long.

Fig. 4.6. Covering the main trench with 9-ft aspen logs. These logs were 4 to 6 in. in diameter at their small ends – thus being stronger than necessary to support the planned 3 ft of earth cover.

The uncovered narrow trench in the background is for the 22 × 24 × 60 in. ventilation duct-emergency exit. Note the plastic wall coverings, made of split-open garbage bags.

PHOTO 2689-74

Fig. 4.7. Placing the 9-ft roof logs, all 2 ft off center, over the 3½-ft-wide main trench. A shelter in firm earth such as this, with 9-ft roofing logs positioned 2 ft off center, would enable the builders to widen their shelter to a 5½- or 6-ft width and to deepen it to standing height. If their home and community were destroyed, the family could live in such a rainproof dugout for months, if necessary, while minimizing their radiation doses and being more comfortable, in cold weather, than if living in a tent or shack.

PHOTO 2699-74

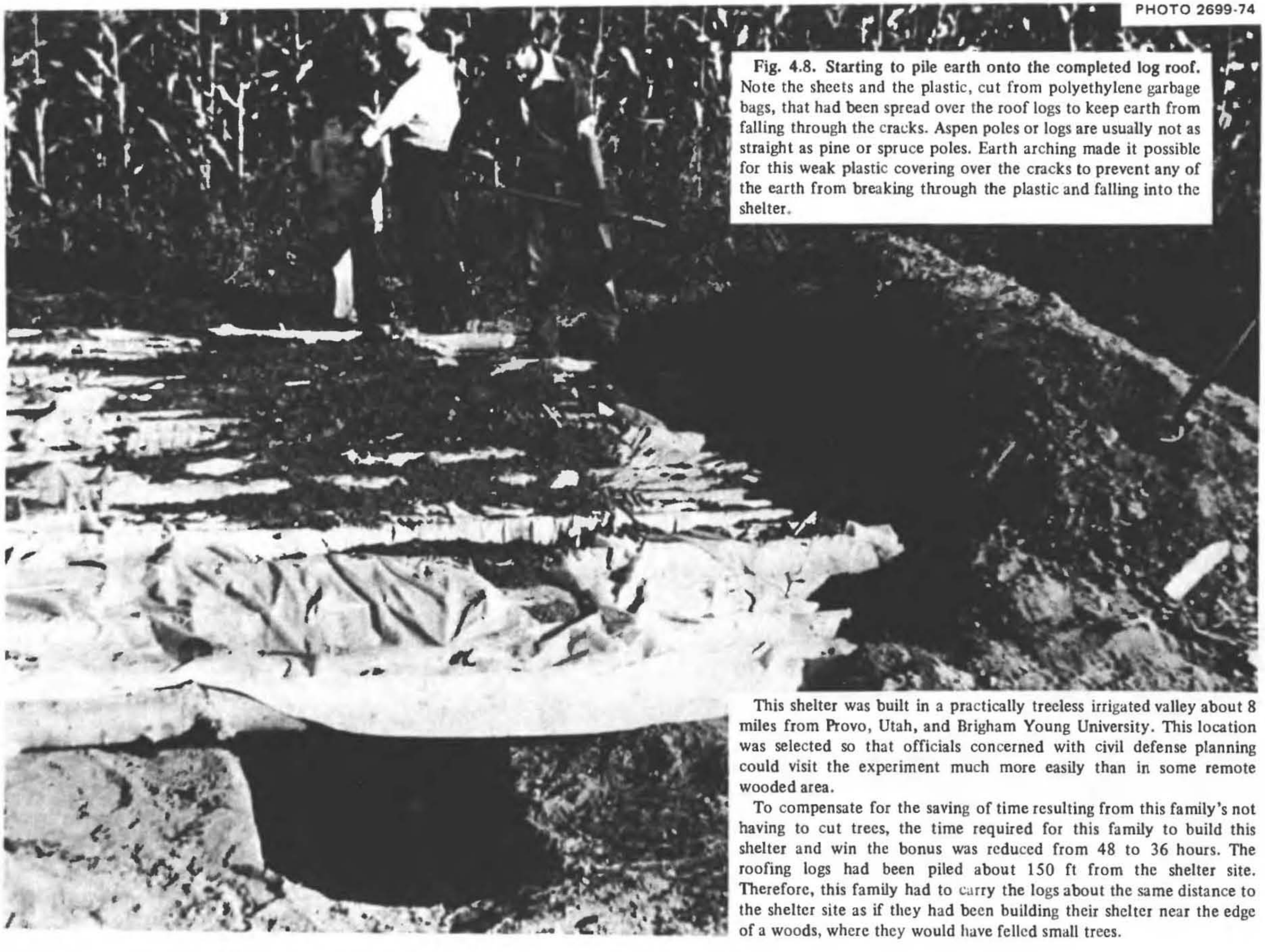


Fig. 4.8. Starting to pile earth onto the completed log roof. Note the sheets and the plastic, cut from polyethylene garbage bags, that had been spread over the roof logs to keep earth from falling through the cracks. Aspen poles or logs are usually not as straight as pine or spruce poles. Earth arching made it possible for this weak plastic covering over the cracks to prevent any of the earth from breaking through the plastic and falling into the shelter.

This shelter was built in a practically treeless irrigated valley about 8 miles from Provo, Utah, and Brigham Young University. This location was selected so that officials concerned with civil defense planning could visit the experiment much more easily than in some remote wooded area.

To compensate for the saving of time resulting from this family's not having to cut trees, the time required for this family to build this shelter and win the bonus was reduced from 48 to 36 hours. The roofing logs had been piled about 150 ft from the shelter site. Therefore, this family had to carry the logs about the same distance to the shelter site as if they had been building their shelter near the edge of a woods, where they would have felled small trees.

Fig. 4.9. Shoveling earth onto the "buried roof" made of a large piece of 4-mil polyethylene. After earth had been mounded onto the roof logs until it was about 18 in. deep along the centerline, the polyethylene sheet was spread over the entire roof area.

This Mormon family, as part of its preparation for possible disasters, not only had a year's supply of food in their home basement, but also had stored polyethylene, cooking utensils, and homemade devices for manually generating electricity. Their whole-grain wheat, skim-milk powder, etc., were stored in 5-gallon cans, rather than in the usual 55-gallon steel drums. These relatively small containers would make it possible for this family, if a crisis should begin to worsen, to move their emergency food supply out of their threatened home area, by carrying several loads in their small family car.

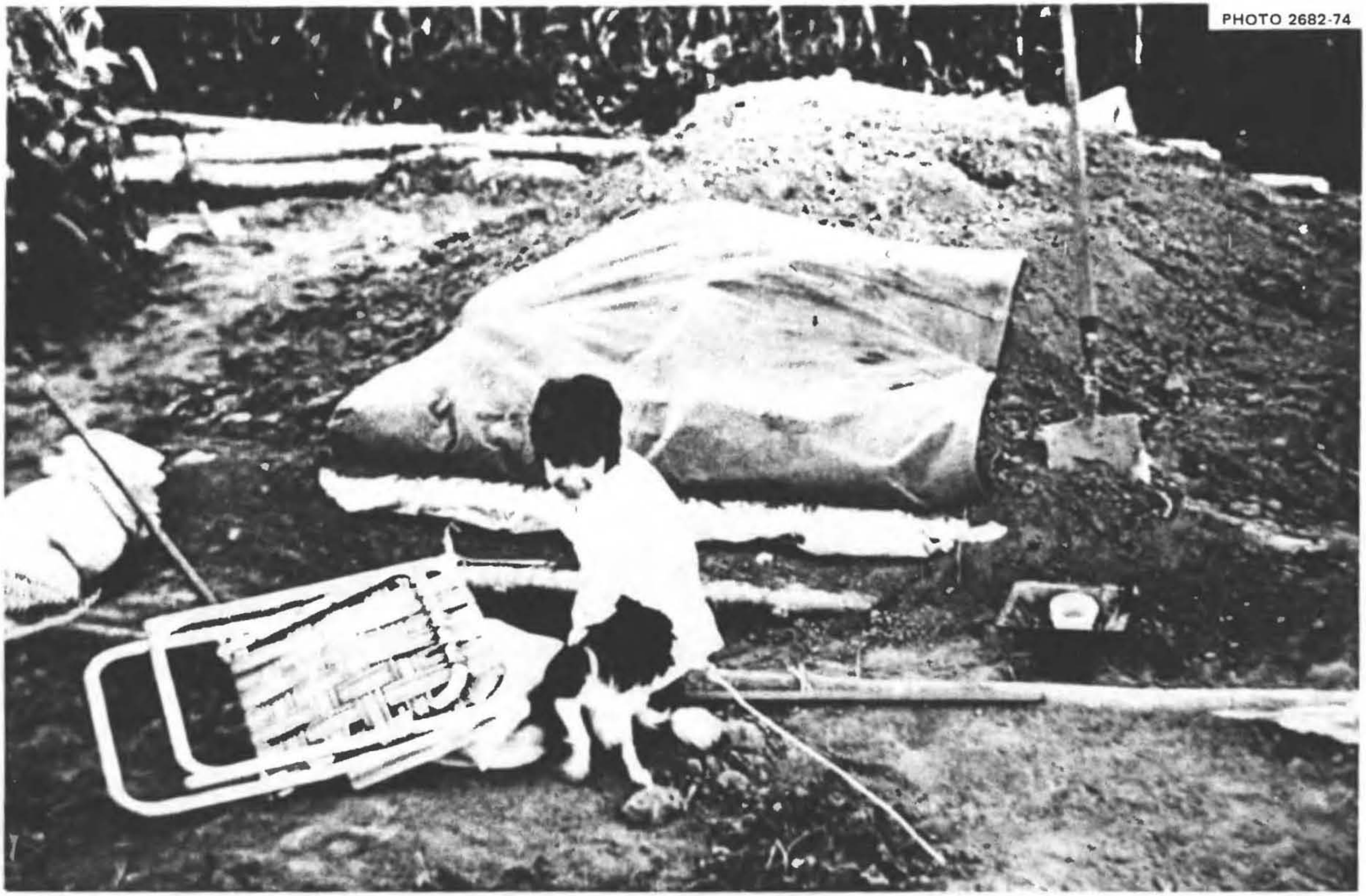


Fig. 4.10. Getting ready to carry a folding chair and the family dog into the shelter. The worst problem that this family anticipated, while living for at least 72 hours in this small expedient shelter, was the possibility of the 4-year-old son becoming so nervous or harrassed that he would want out. Therefore, they brought along his dog and some of his smaller toys.

Note the canvas tarp, with one of its edges secured to the outermost roof log, ready to be erected as a canopy over the 22 × 24 in. entry hole.

PHOTO 2679-74

Fig. 4.11. Outside the completed shelter, with the family of six – and their dog – inside. Thirty-two and one-half hours elapsed from the time this family received an Evacuation Check List and the shelter-building instructions at their home in Bountiful, to the hour they completed their shelter near Spanish Fork and began the continuous occupancy test.

The small plastic canopy over the air-duct-emergency exit at the rear of the shelter is obscured by the mounded earth and the standing man. Window screens, one over each opening, kept out mosquitoes, numerous in this irrigated area.

PHOTO 2962-74

Fig. 4.12. Inside the completed shelter, showing the double-deck bunk, 21 in. wide and 6 ft long, in the 42-in.-wide shelter room. Most of the time two of the six shelter occupants slept or rested on the two bunks, while the remaining four sat in the four chairs along one wall. The walls were covered with 1-mil polyethylene sheets cut from garbage bags. This plastic was also placed under the shag rug on the floor, to keep the damp earth from dampening the rug.

Note the suspended transistor radio. Reception is good in all types of expedient shelters tested to date.

Fig. 4.13. The *essential* shelter-ventilating pump, a homemade KAP 20 in. wide × 36 in. high. This KAP, which swung on two cabinet hinges, was operated by pulling on its pull cord. The pull cord was attached to the left side of the KAP frame, about 9 in. below its hinges. The pull cord was connected to the opposite end of the shelter, to enable anyone in the shelter to pump fresh air through the shelter without moving to another location.

PHOTO 2959-74

Fig. 4.14. Kearny, on his sleeping ledge, pulling the pull cord of the homemade KAP, to demonstrate to Dian Thomas, in the foreground, how a KAP forces an abundant flow of air through a crowded shelter.

Only a few visitors, persons actively concerned with survival problems, were permitted to go inside the shelter, and only for brief periods. Dian Thomas works for the Mormon Church and teaches food storage, emergency cooking, etc., in many states.


PHOTO 2961-74

Fig. 4.15. The shared-bunk sleeping system proved to be a hardship in this small shelter. Even the two smallest children could not sleep together on a 21-in.-wide bunk. And when a 4-year-old boy is awake and very close to a person who is trying to sleep, going to sleep is difficult, especially in the daytime.

Fig. 4.16. Comfortably asleep on the fourth night, in an expedient Bedsheet-Hammock. At 1:30 AM on the fourth night (the hour at which this family won their bonus for occupying their shelter for 72 hours during which no person could emerge) this family had planned to leave the shelter, give three cheers, and sleep the rest of the night outside in their tent.

However, before the fourth night Kearny had shown them how to improvise boatlike, comfortable Bedsheet-Hammocks and how to suspend them from the roof logs. So on the fourth night all six were sleeping so comfortably (three in hammocks, two in the double-deck bunk, and one on the rug-covered floor) that they did not awake at 1:30 AM, and slept soundly until sunup

PHOTO 2684-74

Fig. 4.17. Sleeping under a flowered blanket on a bunk, and resting in a hammock during the chill of a desert night. In the early morning hours, outside temperatures as low as 45° F were recorded, with effective temperatures as low as ET 66.5° F inside. The occupants wished they had brought more blankets, since they used their sleeping bags for mattresses.

Fig. 4.18. Enjoying the occasional luxury of bright shelter illumination from a 25-watt bulb. A homemade manual generator o an extra car battery supplied electricity. The battery could have been recharged efficiently with this generator, if it had not had som faulty cells. Furthermore, both the original small 12-volt bulb and a spare bulb of this family's standard auto trouble light (operate off a 12-volt car battery) blew out while being used to provide light. Work progressed on most of two nights, before the shelter wa completed at 1:30 AM on the second night. As a result, when the shelter-occupancy test started, this family was already using thei spare flashlight batteries, and these batteries no longer gave a bright light.

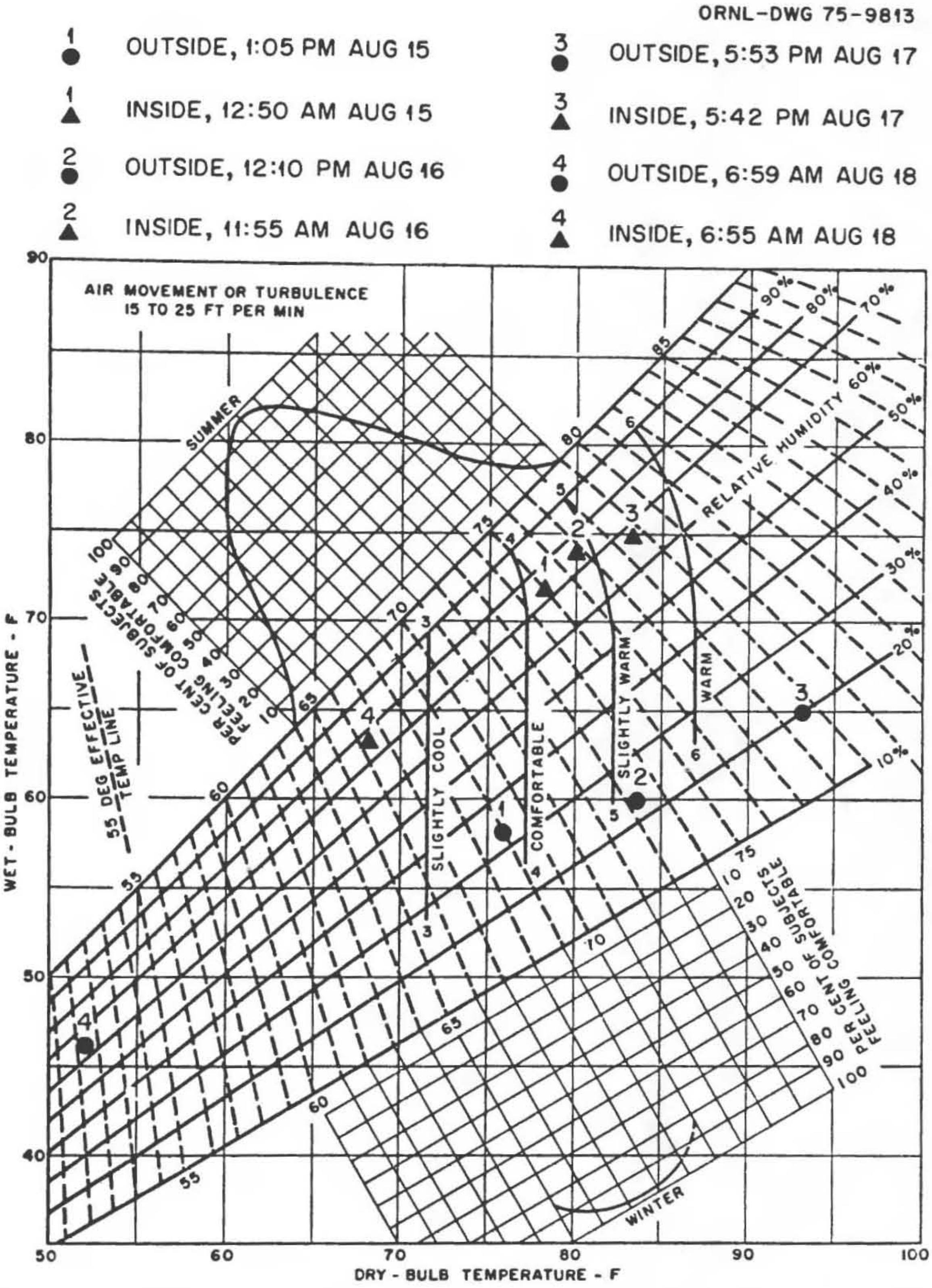


Fig. 4.19. Eight approximately paired temperatures (°F), four outside and four inside the Log-Covered Trench Shelter with seven occupants.

This family operated its shelter ventilating pump (a 20 × 36 in. homemade KAP) intermittently when the effective temperature *inside* the shelter rose above about 72°F effective temperature (ET). They operated their KAP almost continuously when the *outside* temperature was higher than about ET 75°F. When the *outside* temperature was above ET 75°F, pumping about 50 cubic feet per minute *per person* through the shelter kept the ET inside the shelter essentially the same as the ET outside.

All air had to pass through the insect screens over the two shelter openings. (Effective temperature is a combination of wet and dry bulb temperatures equivalent in sensation to the given temperature at 100% relative humidity.)

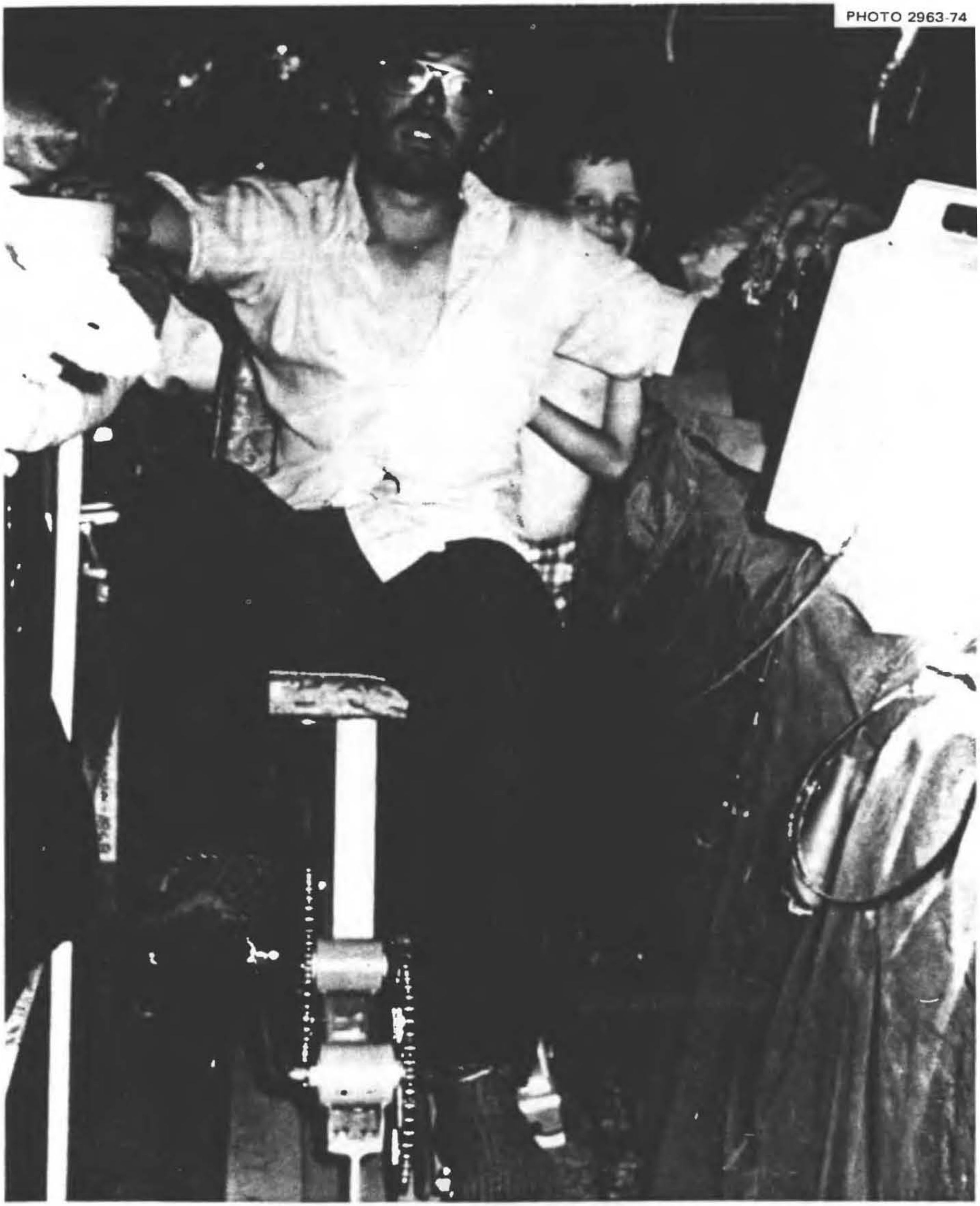


Fig. 4.20. The 18-year-old son getting good exercise by peddling his father's homemade generator to operate their portable TV set. Several years ago the father made this manually powered generator, which uses the sprockets and chains of two bicycles, mounted on a steel frame, to rotate the alternator from a car. The alternator is mounted on a bracket. Only a few minutes were required to remove the alternator and attach it securely to the bracket.

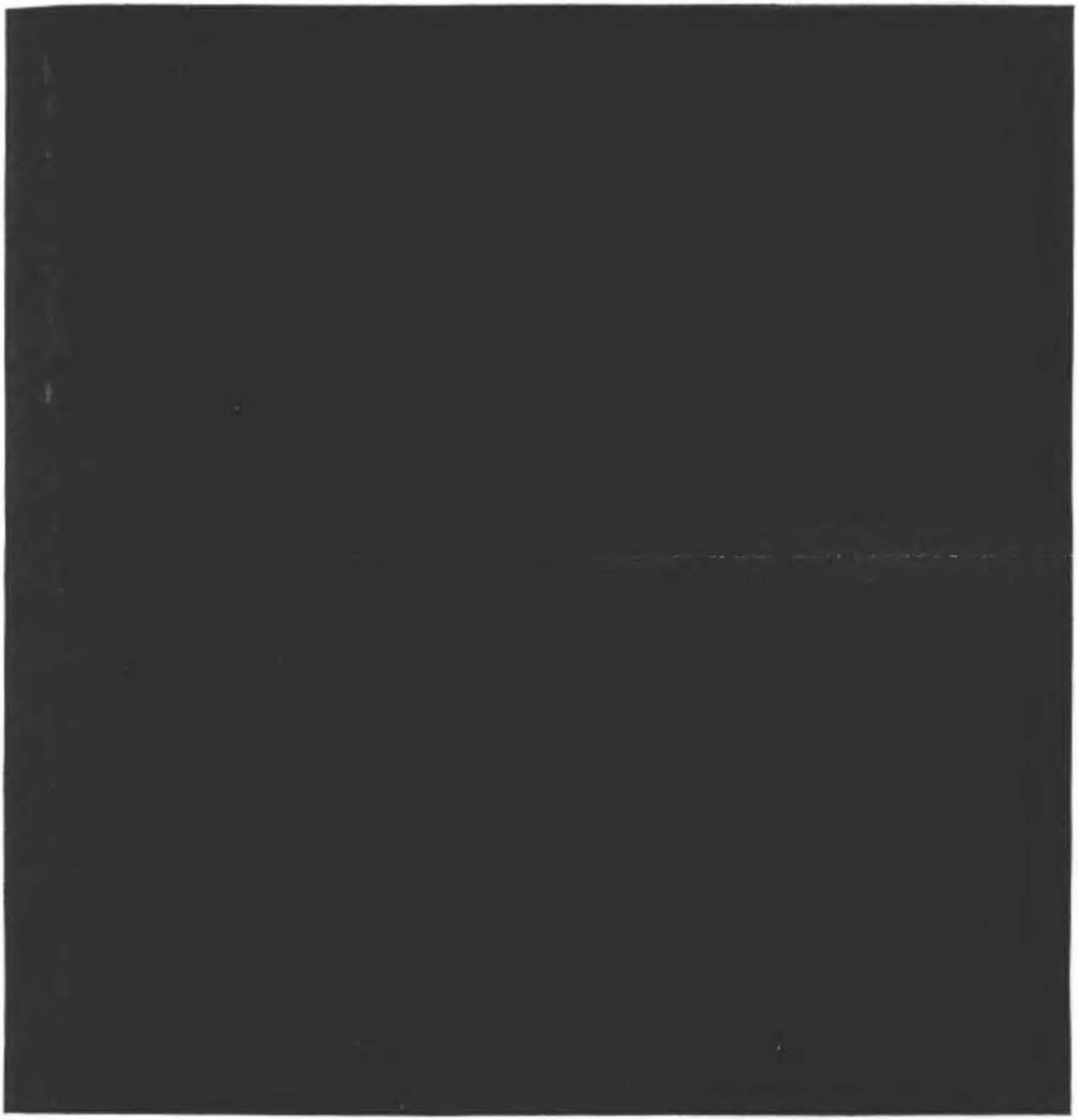
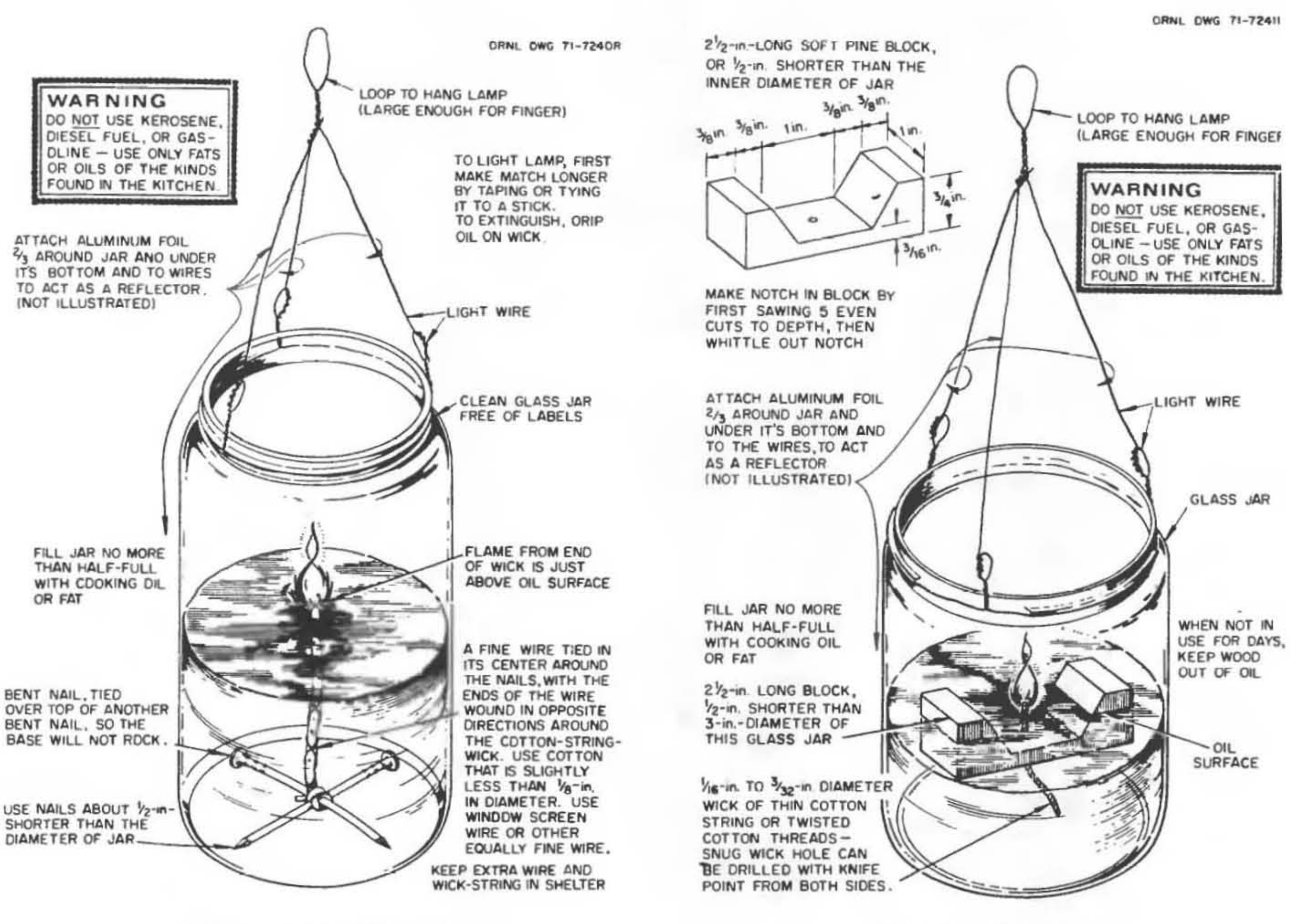


Fig. 4.21. This family's electrical sources of low-level nighttime lighting had failed them, and they had failed to follow the Evacuation Check List and bring from their home the handful of household materials needed to make and fuel an expedient lamp. Therefore, during most of the first three nights of the shelter-occupancy test, this family slept and sat in blackness. The 4-year-old boy objected to it being so dark that he could not even see his foot in front of his face; to make him feel secure enough to go to sleep, someone had to sit so close to this resting or sleeping little boy that he could reach out at any time and touch a reassuring human body.

On the third night of blackness inside the shelter, a potentially serious incident occurred. Kearny for a moment thought the planned 72-hour shelter-occupancy test was going to be aborted, when he heard the mother say, in a disciplined but tense voice, "I have to get out of here. I can't orient myself." She went on to say that she knew where she was, but had to get out of the lower bunk in which she had been sleeping, and sleep on the floor near the entrance. After doing so, with the help of their dim flashlight, all was quiet again.

This decidedly stable woman had never before experienced claustrophobia.

Conclusion: It is bad not to be able to see at all.



WIRE-STIFFENED-WICK LAMP

FLOATING WICK LAMP

Fig. 4.22. These are the instructions this family had received and should have followed to provide their shelter with dependabl light, at a cost of less than one ounce of oil or fat per night.

On the fourth night, Kearny provided a lamp of the type having a wire-stiffened wick, complete with a reflector of aluminu foil. All agreed that this little light, which burned only about one ounce of cooking oil in a summer night, greatly improved th habitability of the shelter. This light also killed all the mosquitoes inside the shelter. The glittering aluminum foil attracts an confuses mosquitoes, and they fall into the oil.

Fig. 4.23. The mother standing in the 18-in.-deep stand-up hole next to the toilet. Note the air-duct-emergency exit, shown above the mother's shoulders, with a piece of toilet paper hanging from its roof to indicate air movement.

At times when there was no breeze outside, readings with a hot-wire Hastings Air Meter showed an air flow through the shelter of around 300 cubic feet per minute when the KAP was pulled gently, as it usually was.

The stand-up hole also served for a place to take sponge baths, using water brought into the shelter by 40 ft of $^1/_2$-in.-diam. garden hose. This hose was used as a siphon to bring water from a 120-gallon, covered water-storage pit (Fig. 4.35).

The blanket, shown drawn to one side, gave privacy to the members of this family when they were using the toilet or bathing.

Fig. 4.24. The 13-year-old daughter brushing her teeth while sitting on a water container placed on the plywood threshold board. The stand-up hole, pictured just below the girl's toes on the edge of the threshold board, was also used by this family when taking their daily sponge bath.

The electric clock was powered by a flashlight battery. The telephone was brought along as a playful gag, to make nontechnical visitors think this family had all the conveniences of home in their 42-in.-wide shelter.

Fig. 4.25. The father starting work, with cold chisel and hammer, on his clever design of an odorless expedient toilet. In order to determine how long it would take to build and install this toilet under field conditions, he brought from his home the two 5-gallon cans, a 5-gallon plastic water jug (shown upside down), a garden hose, a complete toilet seat, an uncut piece of plywood, a tube, some cord, and freezer tape – all the materials needed to build this toilet.

The photo illustrates the cutting of a circular hole in what was to be the uppermost part of the 10-gallon vented space provided for holding human wastes.

The father worked 70 minutes to build his odorless expedient toilet. His son worked about an hour to dig a hole for this toilet, install it with the seat at ground level, and then dig an 18-in.-deep stand-up hole next to the seat, so that occupants could both sit normally on the toilet and could occasionally stand erect and stretch in what otherwise was a $4\frac{1}{2}$-ft-deep covered trench.

Fig. 4.26. Using a sharp knife to cut off the lower part of the 5-gallon plastic water jug, in order to make the bowl of the toilet. The bottom of the 5-gallon can shown on the right was cut out so that when this can was used to form the bottom of the 10-gallon vented space provided for the wastes, the liquid fraction could run into permeable earth or sand below.

Although this is an excellent expedient toilet, Kearny believes that most builders of expedient shelters should use simpler, less time-consuming means for disposing of human wastes.

One simpler means is to urinate in a bucket, and occasionally pour the urine outside. If plastic is available, shelter occupants can defecate in a piece of plastic or in a plastic bag. The plastic containing the excrement should be tied shut so that flies cannot reach the filth to lay their eggs or to spread infections. These packages can be tossed outside occasionally, best into a pit. The gases produced will attract flies away from the shelter.

A simpler expedient toilet has been made merely of a 5-gallon can vented near its top through a 10-ft length of garden hose. The can was covered with a piece of plastic, tied tightly over its top, when no one was sitting on it. This toilet was found to be almost odorless when it was not being used. If the can is placed at the exhaust end of the shelter and a pumped flow of air is produced with a shelter-ventilating KAP whenever a person is using the toilet, the rank odor released into the shelter from the temporarily uncovered toilet can is minimized.

Fig. 4.27. View looking into what was to become the uppermost 5-gallon can of the 10-gallon vented space. The toilet bowl is on the ground, below this can and attached to it. The mouth of the shortened, plastic water-jug bowl is shown extending through the hole cut into the bottom of this can. Freezer tape had been used to seal the cracks between these parts.

An ordinary aluminum cake pan had been hinged with a single coat-hanger wire, so that it could be pulled by its attached cord. This pull cord is shown in front of the mouth of the plastic water-jug toilet bowl. A little water was then poured into this horizontal cake-pan valve, to make a gastight seal and thus to prevent malodorous gases from rising into the shelter.

Fig. 4.28. The assembled toilet, except for its vent hose, the toilet seat, and the plywood base of the toilet seat. The pull cord (that operated the hinged water-sealable cake-pan valve) is shown extending out of the small rubber tube, which kept the pull cord out of contact with the earth.

Later, earth was packed around the plastic toilet bowl and the two 5-gallon cans below it. A weight was attached to the end of the pull cord, to keep the cake-pan valve closed, except when the weight was lifted.

The uppermost of these two cans was vented to the outside of the shelter through a 10-ft length of garden hose that was run through a hole chiseled through the side of the uppermost can near its top. The vent hose extended out through the surrounding earth, to let gas escape outdoors.

Fig. 4.29. View looking straight down on the installed toilet and its seat. The two assembled 5-gallon cans and the toilet bowl had been placed in a hole dug in the bottom of the shelter. A piece of $\frac{1}{2}$-in. plywood, in length equal to the 42-in. width of the shelter room and about 20 in. wide, served as the horizontal surface to which the toilet seat was attached. An appropriately sized, roughly elliptical hole had been cut in this plywood with a brace and bit and a cold chisel. The plywood base of the toilet was at floor level. Note the vent hose.

The 42-in.-wide threshold board is seen on the far edge of the stand-up hole. This and other threshold boards were installed on the edges of earth steps, and prevented the earth edges from being broken off, even after having been used for days.

PHOTO 2695-74

Fig. 4.30. Healthy and clean, on emerging at sunup after the fourth night of continuous shelter occupancy. The only member of this family that suffered during this test was the family dog, who, remarkably, held in everything for the 77 hours of shelter occupancy.

One of the two metal-framed window screens (that this family had carried from their home) is pictured on the left. These screens had been placed over the entrance hole and served well. Only a few of the many mosquitoes outside got into the shelter.

The garbage bags, shown in the foreground, contained empty cans, waste paper, and other refuse accumulated during the shelter occupancy. These bags had been thrown outside from day to day.

Behind the family are the earth

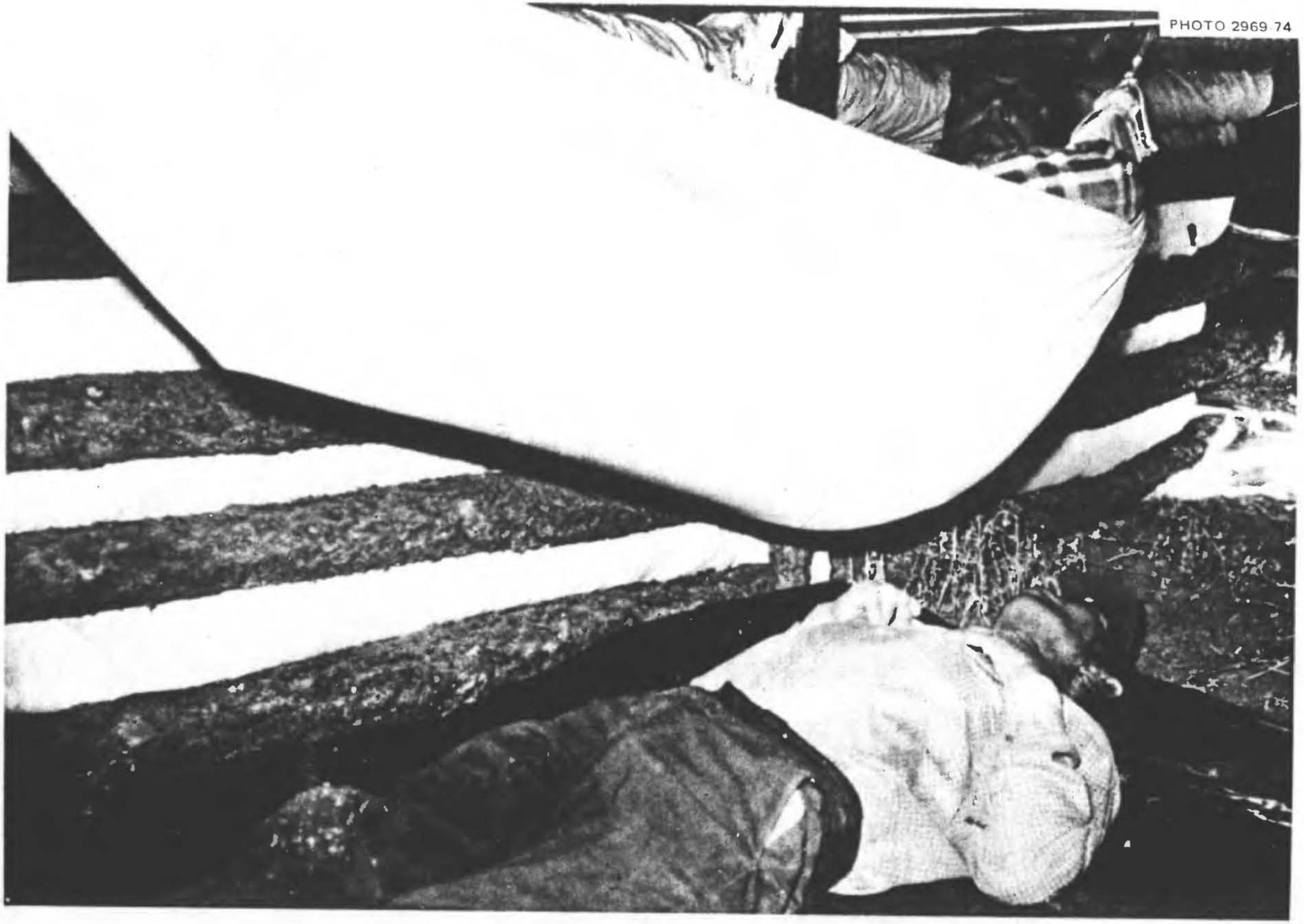


Fig. 4.31. Using an expedient Bedsheet-Hammock, to enable two persons to sleep over the same floor space. Otherwise, only one person could sleep in this space in an Above-Ground Crib-Walled Shelter. The ceiling was only 40 in. above the floor.

Fig. 4.32. Two Bedsheet Hammocks, one above the other, slung in the entrance end of a lumber version of a Russian-type Small-Pole Shelter. On the right is seen the end of one side of the typical Russian-style benches with overhead boardbunks. The Russian sitting-sleeping system is a "hot-bunk" system that enables only one-third of the occupants to lie down at the same time.

By using this new design of short, space-saving hammocks, all occupants can lie down and sleep at the same time – even in the austere stoop-in Log-Covered Trench Shelter. Furthermore, all occupants can sit comfortably together in suspended Bedsheet-Chairs, that they can quickly make from their Bedsheet Hammocks.

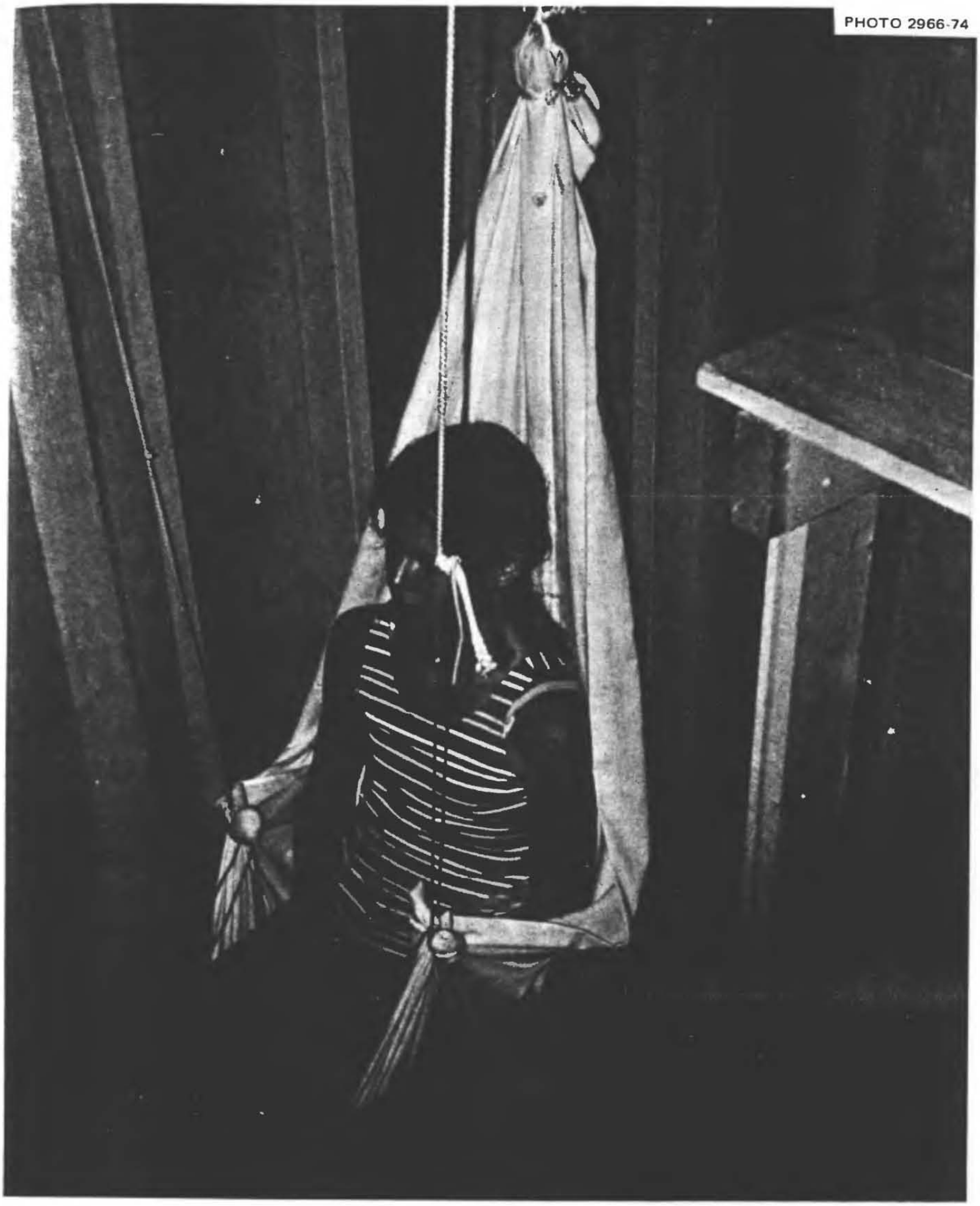


Fig. 4.33. Sitting comfortably in an expedient suspended Bedsheet-Chair, easily made by converting a Bedsheet-Hammock. This design was developed after the August 1974 shelter occupancy test.

Two stones, or lumps of earth, each about $1\frac{1}{2}$ in. in diameter, are tied in the edges of a Bedsheet-Hammock, so that two cords (or strips of sheet serving as cords) can be securely connected as supports.

Fig. 4.34. Placing a sheet of 4-mil polyethylene in a 120-gallon water-storage pit. Unlike previous water-storage pits dug and tested by Kearny, this pit was not first lined with cloth or other material to keep sharp roots, etc., from puncturing the waterproofing plastic. All root ends were merely cut off with a knife. The edges of the plastic were folded into the small side trenches, and then held by packed earth. Six days after being filled, no leaks had developed.

Kearny dug this pit about 35 ft from the far end of the family's test shelter. The father used 40 ft of $\frac{1}{2}$-in.-diam. garden hose to make a syphon, so that, when the end of the hose inside the shelter was lowered, water ran from the pit into the shelter. Sometimes the hot Utah sun heated the water in the hose as hot as 125° F.

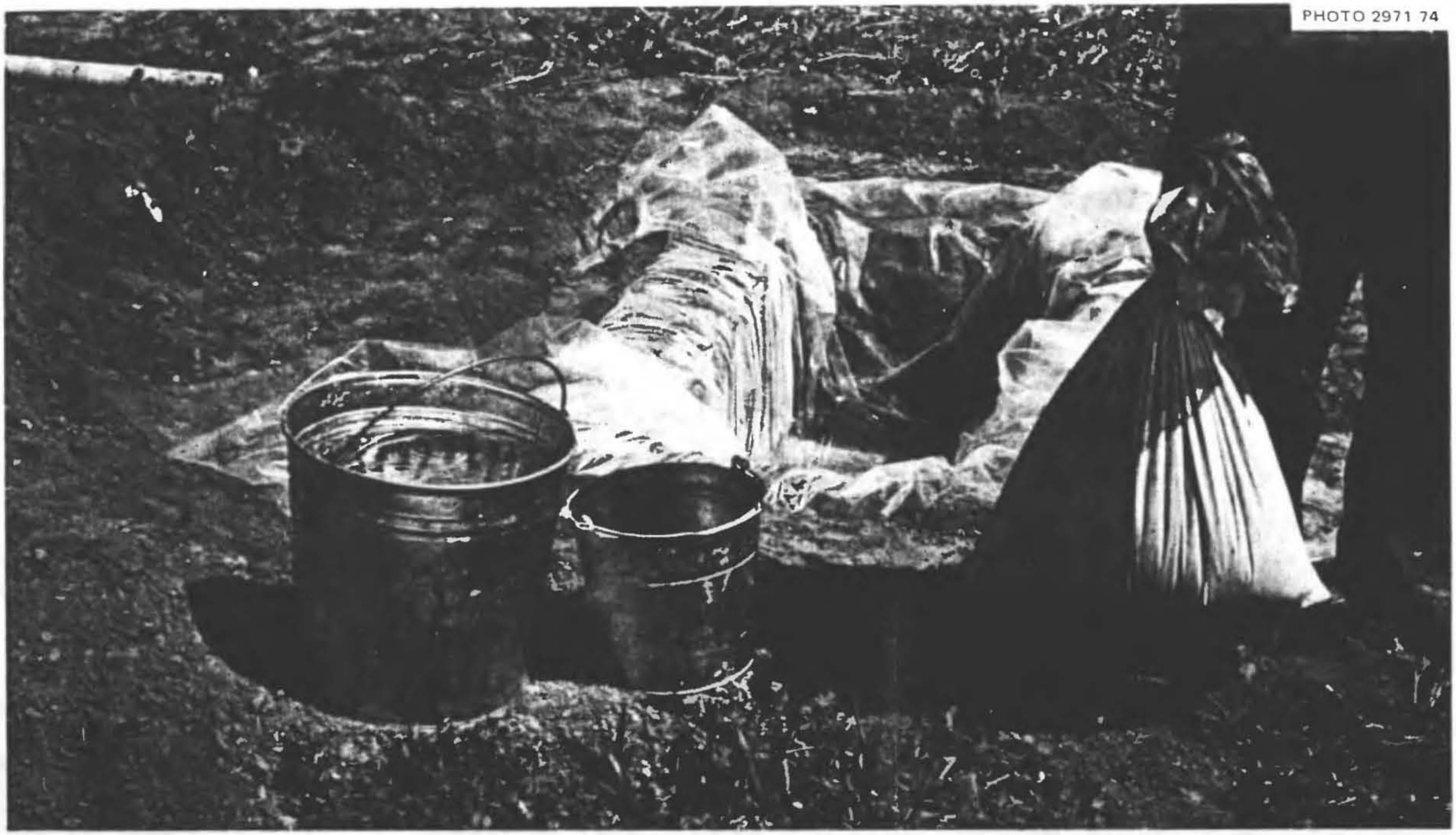


PHOTO 2971 74

Fig. 4.35. **The 120-gallon water storage pit of thin plastic being filled.** This pit was later covered with boards, over which thin plastic was placed, and then earth was mounded over the boards, about 6 in. deep in the center. Next, a waterproof, outward-sloping "buried roof" of the plastic was laid on top of the mounded earth. Finally, about 4 in. of earth was mounded on top of the buried roof.

Water was readily carried to the pit inside an ordinary polyethylene trash bag, placed inside a smaller pillowcase. Thus the thin polyethylene bag did not have to carry the stresses, since the water merely pressed the thin waterproof bag against the cloth.

By securing the mouth of such a lined water container so that the mouth remains above the level of the water, quite large volumes can be both carried and/or stored.

Adequate water is more essential than food for the first several weeks of possible shelter occupancy, and most Americans have had no experience with serious water shortages or thirst. Therefore, descriptions of expedient methods to carry and store adequate water are an essential part of all practical instructions for building and using expedient shelters.

PHOTO 2970-74

Fig. 4.36. A water storage pit lined with plastic bags, photographed 6 days after having been filled and covered. None of the approximately 25 gallons of water in this pit had leaked through the two 30-gallon trash bags (each about 1¼ mils thick) placed one inside the other for a pit lining.

The hole was dug so as to have a diameter about 2 in. less than the diameter of a filled 30-gallon bag. This hole was not lined, but all protruding roots had been cut off, to prevent the thin polyethylene from being punctured.

A circle of wire, 2 in. larger in diameter than the diameter of the hole, had been taped inside the upper edges of the plastic bags, to prevent the edges from slipping down into the hole.

All water in storage pits was disinfected, by using one teaspoonful of Clorox per 5 gallons.

CAUTION: OPERATE THIS STOVE ONLY NEAR OPENINGS WHERE EITHER NATURAL OR PUMPED VENTILATION IS CAUSING AIR TO LEAVE THE SHELTER. DO NOT OPERATE IN A CLOSED SHELTER.

Fig. 4.37a. Expedient Bucket-Stove, made of a bucket, coat-hanger wire, about 2 ft of finer wire, and metal from an ordinary juice can. This is the most efficient expedient stove tested to date.

No chimney is required; a Bucket-Stove is used in the shelter opening that is serving as the air-exhaust outlet at that time.

When this stove is used with a covered-lid pot having a diameter about 2 in. less than the diameter of the bucket (or large can) at the height of the bottom of the pot, 3 quarts of water can be raised from 60°F to boiling by burning only about 7 ounces of dry wood or paper.

If an expedient fireless cooker is also available, then 3 quarts of soaked beans, wheat, or tough meat can be cooked by burning only about half a pound of dry wood or paper.

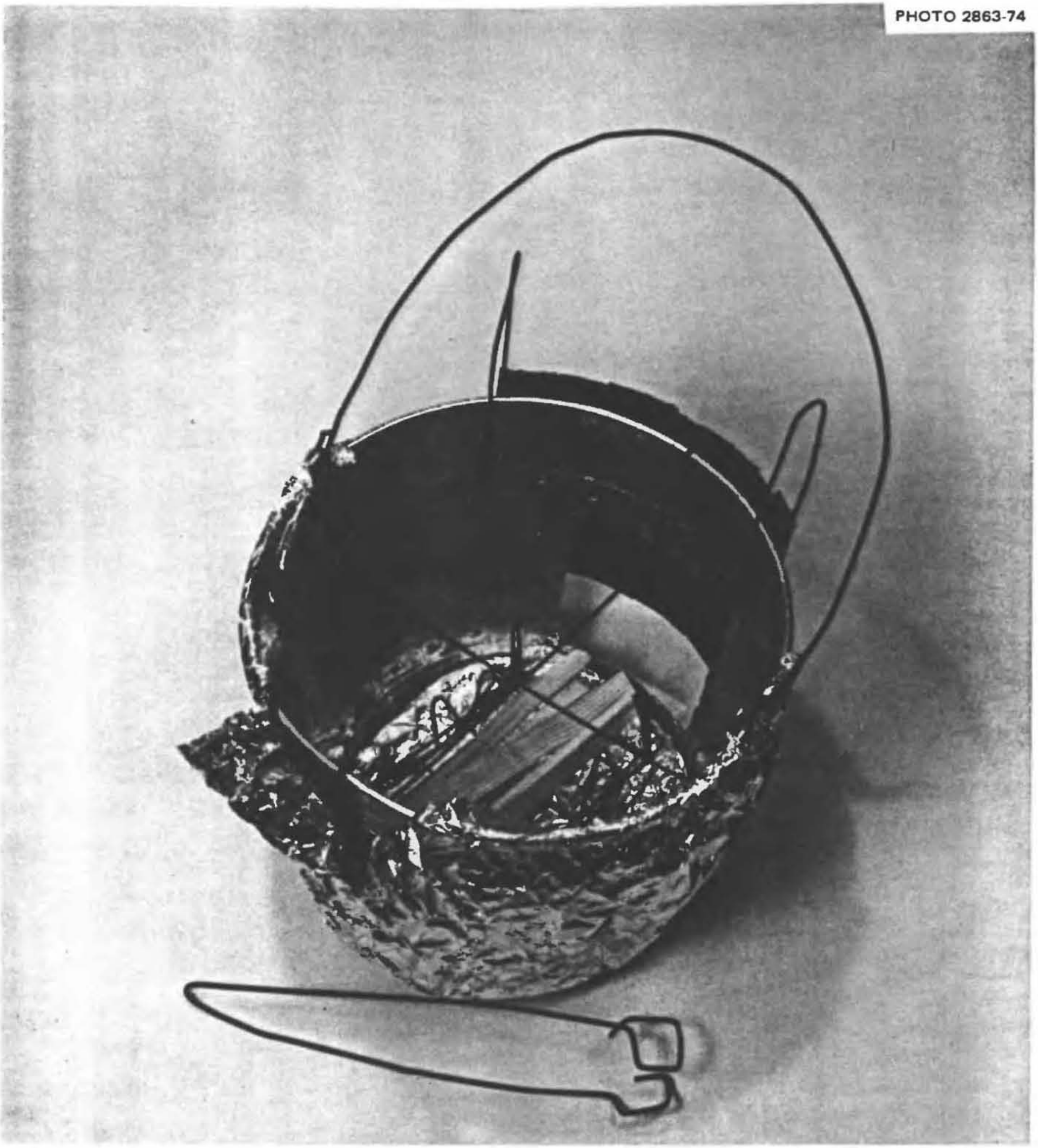


Fig. 4.37b. Bucket-Stove, showing its adjustable sliding damper partly closed, and the two coat-hanger wires that serve as pot supports. The ends of these wires are bent over the top of the bucket to form protruding springs to center and secure the pot by pressing against its sides. Pieces of wood about ½ × ¾ × 6 in. are best.

An equal weight of newspaper is as efficient for fuel, if half pages are crumpled and twisted into 5-in. "sticks," and one stick is fed into the fire about every half minute. The 12-in. tongs are made of coat-hanger wire.

This stove can be quickly carried to whichever end of the shelter is serving as the exhaust opening. If a KAP is supplying forced ventilation, even in windless weather all smoke is blown out of the shelter, away from the occupants.

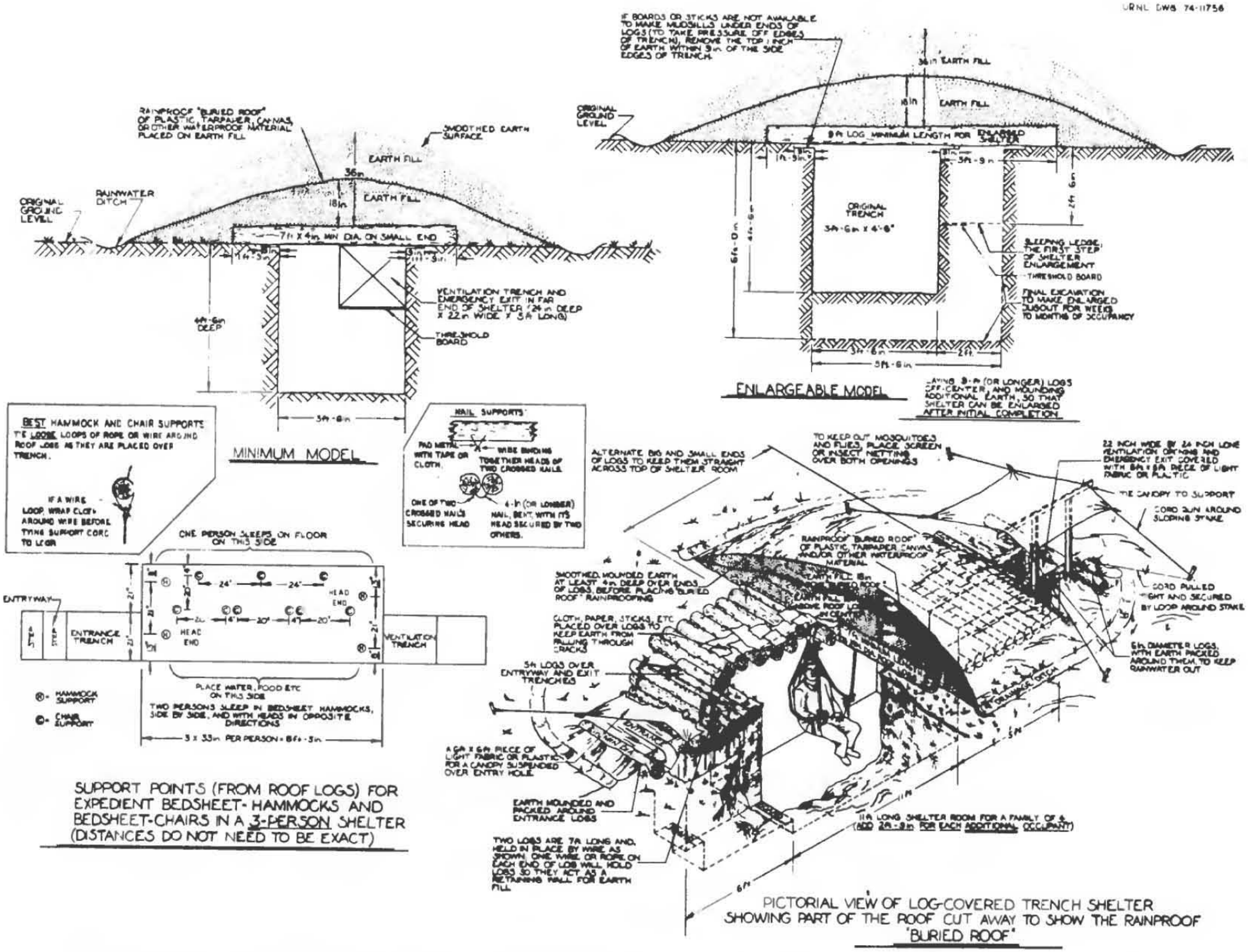
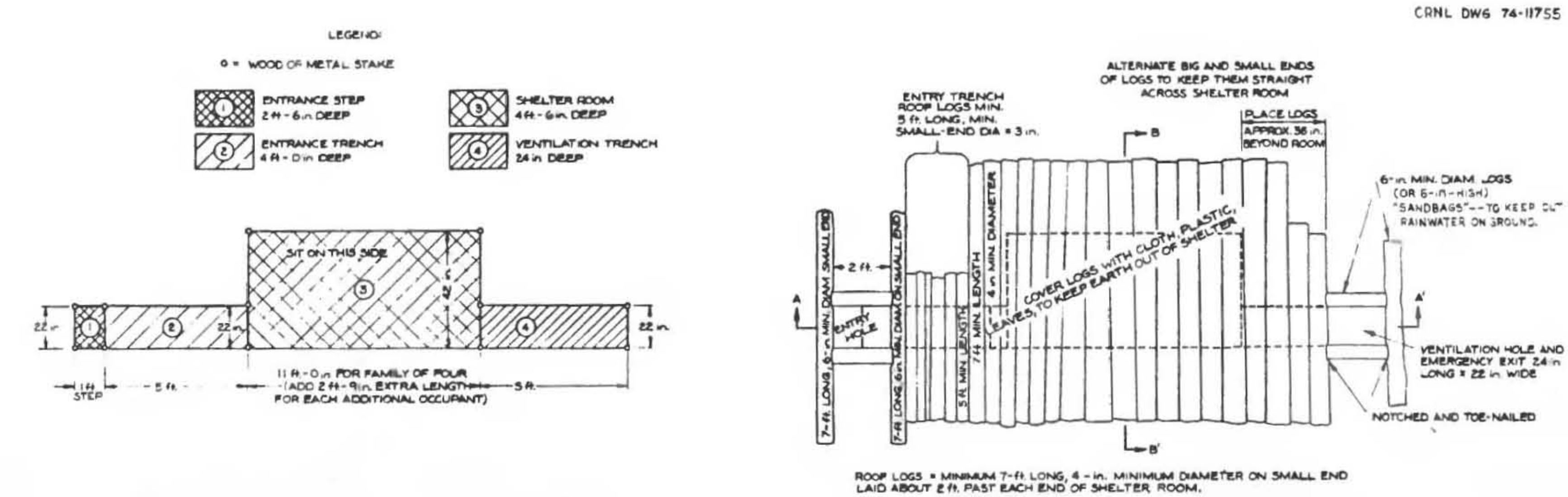
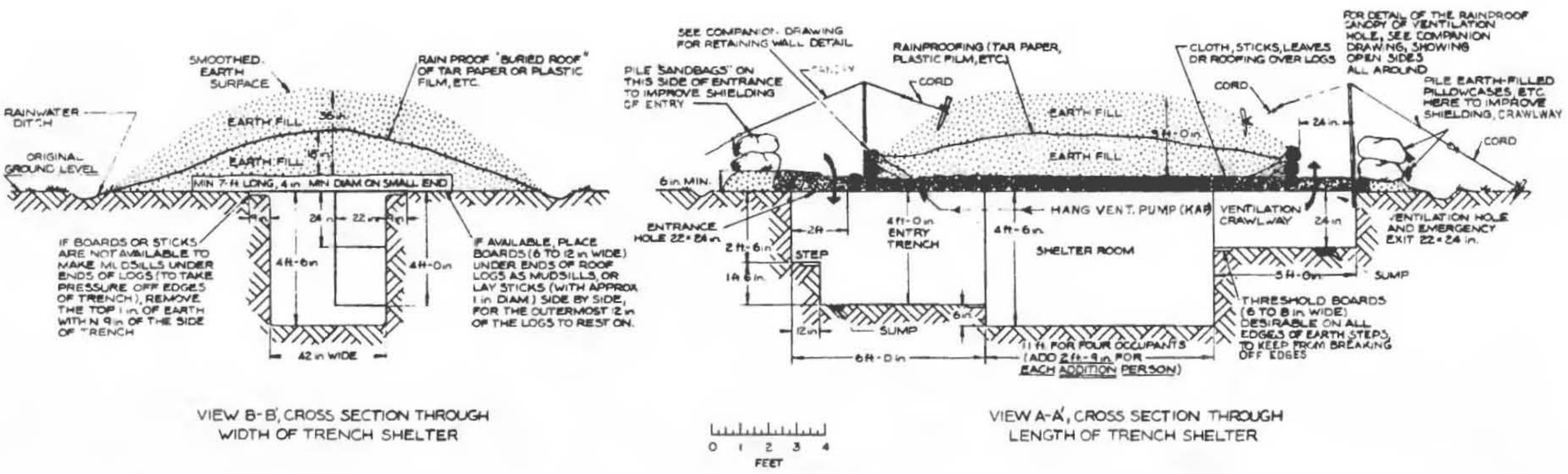


Fig. 4.38. One of the pair of proof-tested drawings of the Log-Covered Trench Shelter. Picture-like detailed drawings like this are needed by most Americans to enable them to build good expedient shelters. The drawings actually given to the family were to a scale about 50% larger than these drawings, which are too small for efficient use.



PLAN FOR STAKING OUT TRENCH ON TOP OF GROUND
(SEE LEGEND FOR 4 DIFFERENT DEPTHS OF TRENCH)

PLAN VIEW OF TOP OF SHELTER- SHOWING PLACEMENT
OF LOGS FOR ROOF- EARTH FILL NOT SHOWN



VIEW B-B', CROSS SECTION THROUGH
WIDTH OF TRENCH SHELTER

VIEW A-A', CROSS SECTION THROUGH
LENGTH OF TRENCH SHELTER

Fig. 4.39. The other detailed drawing needed to minimize the inefficiencies of untrained Americans building even this simple an expedient shelter. Most untrained Americans also need accompanying step-by-step detailed instructions (see Appendix) to build a good expedient shelter. The drawings and instructions used by this Utah family had been used successfully by two separate groups of Tennessee families, in less perfected form, to build two Log-Covered Trench Shelters. In well-wooded Tennessee, these families cut all of the required logs, using only hand saws, and completed their shelters in less than 48 hours.

CONCLUSIONS

1. A sizable fraction of urban American families could evacuate their homes during an escalating crisis, drive to wooded rural sites outside areas of probable blast damage (carrying all essential materials and tools with them), and build Log-Covered Trench Shelters if these people were sufficiently motivated and were given field-tested instructions specifying in detail what they should take with them and how they should build their shelter.

2. How to persuade some educated, overconfident people to follow all needed instructions (for example, to bring with them the few common household materials needed to make a dependable shelter light) is a still unsolved problem.

3. Since most evacuated urban citizens would be homeless after a massive nuclear attack, the fact should be recognized that in wooded areas many builders, mostly unskilled, could make expedient shelters with protection factors of about 500 which provide good protection against blast and fire and which can be enlarged subsequently into habitations more livable than were many of the dugout homes of American pioneers.

5. Above-Ground Expedient Shelters Built by Families after Evacuating.

BACKGROUND

In areas where the water table or rock is close to the surface, building high-protection-factor expedient shelters is more difficult than in any other environment except cold regions with deep-frozen earth. To build adequately protective above-ground shelters, more materials and labor are required than to build below-ground shelters. The quantities of lumber required are so great that in all but a few areas only a small fraction of the people would have enough lumber at the building sites. Therefore, especially for above-ground shelters studied by Oak Ridge National Laboratory, designs have been limited to those that can be built using the small trees available at or near many sites and using the doors, bed sheets, and other materials found in sufficient quantities in most homes.

Improving the shielding provided by existing houses can be a practical solution in some areas. However, the protection factors thus attainable, as well as the blast and fire protection afforded, usually are not as good as those provided by separate above-ground expedient shelters capable of being built with equivalent effort.

Soviet civil defense publications are not of much help in providing designs for above-ground expedient shelters. Perhaps the causes of this deficiency are that a smaller fraction of Russians than Americans live in extensive areas where the water table is very close to the surface and that the potential fallout dangers that Russians face may not be as severe as those that Americans may suffer. Furthermore, Soviet civil defense plans logically call for the evacuation of areas subject to possible flooding, apparently feared downstream if nuclear weapons were to break big dams. A recent Russian civil defense handbook[9] shows this deficiency: of the 22 fallout shelters described, all of which were planned for improvement or construction within a few days, only two are expedient types suitable for above-ground construction.

American civil defense publications supply even less information on above-ground expedient shelters. This American deficiency was remarked upon by Florida civil defense officials. They had been unable to obtain designs of above-ground expedient shelters suitable for large numbers of average Florida citizens to build within a few days in areas with high water tables. Therefore, these officials requested from the author the illustrated building instructions for the four best designs of above-ground expedient shelters built by untrained families. These four shelters are described in this chapter.

TESTS IN FLORIDA

All of the shelters illustrated in this chapter were built in a wooded part of northern Florida, about 60 miles south of Jacksonville and some 25 miles northwest of Daytona Beach. In this sparsely inhabited area of hundreds of thousands of acres, the water table is only a foot or two below the surface. This experimental construction was done in February, March, and April of 1974 in an area where even the store buildings lack basements. Yet, if the inhabitants of Jacksonville or Daytona were to evacuate in the event of an all-out enemy attack, high-protection-factor shelters probably would be needed in this and similar areas, both for the present residents and the relocated urban evacuees.

CAUTION: The large amounts of soft earth excavated by these families with hand tools in a few hours and then hand-placed on their above-ground, low-roofed shelters should not be used in estimating the cubic yards or tons of soft earth that could be manually dug and hand-placed on the roofs of houses and around houses in other areas of the country. And, if the above-ground expedient shelters described in this chapter were to be built in a typical area with rock near the surface, the work of covering them with harder-to-dig earth would be more time-consuming than these experiments in sandy Florida might indicate.

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[9] V. I. Molodykh et al., *Antirradiation Shelters in Rural Areas*, (Moscow, 1972), ORNL-TR-2745, October 1973.

A. Above-Ground Door-Covered Shelter

This austere shelter is designed to be built within a day or two in areas with high water table or with little earth above rock, by unskilled families that have for tools and building materials only a shovel, buckets or pots, interior doors, bed sheets, bedspreads, other fabrics, and waterproof materials found in most single dwellings. If built as specified by the drawing, its protection factor is in the 200 to 300 range.

PHOTO 1051-74

Fig. 5.1. One of the prototype above-ground shelters built by a contractor's laborers in Flagler County, Florida, under the direction of C. H. Kearny, preliminary to the building of shelters by inexperienced family groups. Several prototype shelters of different types were built toward the end of an abnormally dry winter, during a time when a backhoe was able to excavate earth to a depth of about 15 in. without getting stuck too often. The water pictured is in one of the excavations after rains ended the dry spell, showing the normal height of the water table. The water table in most parts of Flagler County is only 1 to 2 ft below the surface.

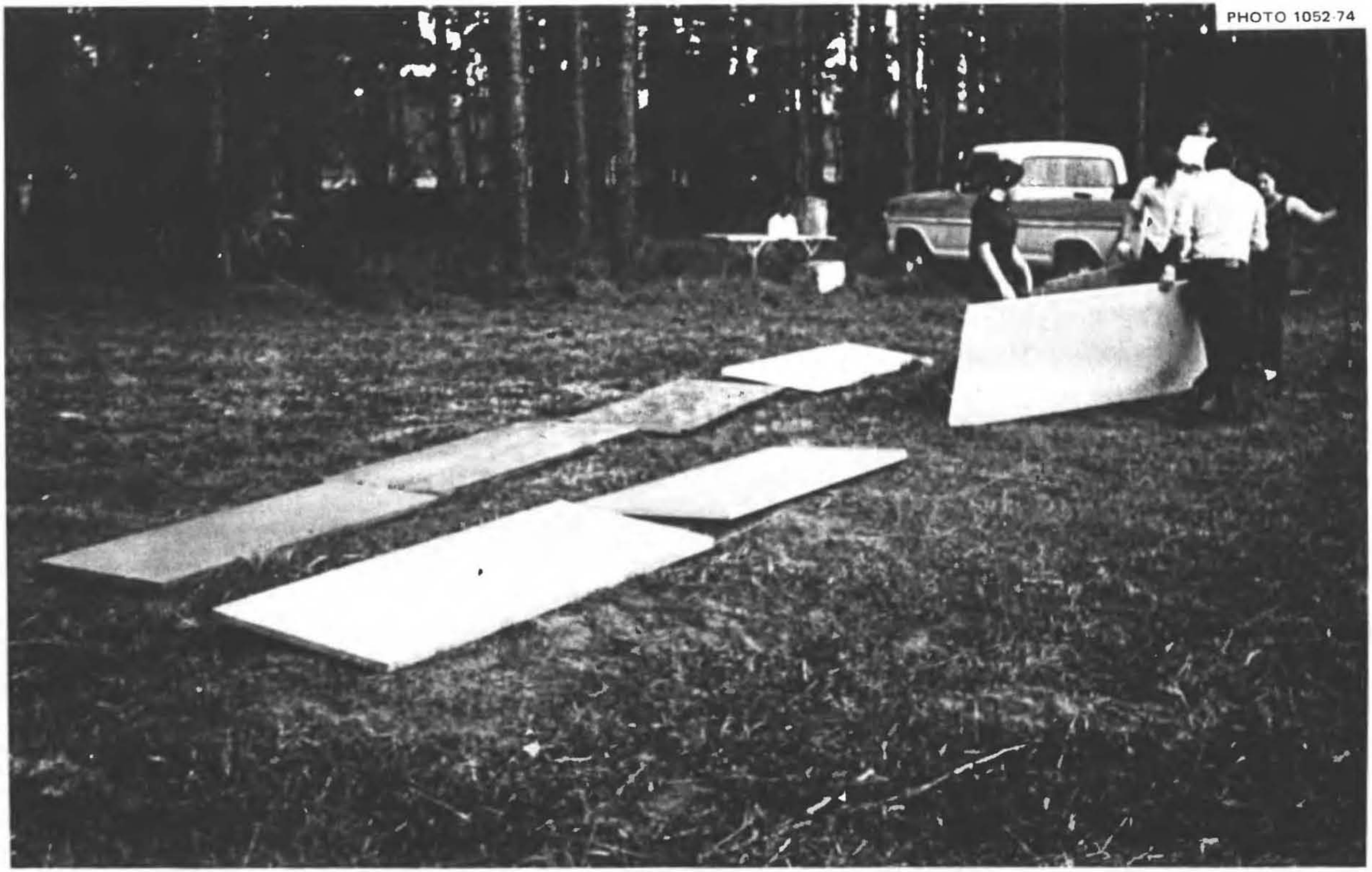


PHOTO 1052-74

Fig. 5.2. The start of an expedient-shelter-building test by a family from Bunnell, Flagler County. In this test an inexperienced family, guided only by illustrated written instructions, built an above-ground shelter using interior hollow-core doors for the roofing material. The walls were made of earth-filled rolls made of bed sheets, as detailed in the drawing for this shelter. Only materials found in most urban homes were used.

The pictured site was about 10 miles from this family's home in Bunnell, in an area where the water table was 15 to 18 in. below the surface. The earth is extremely sandy.

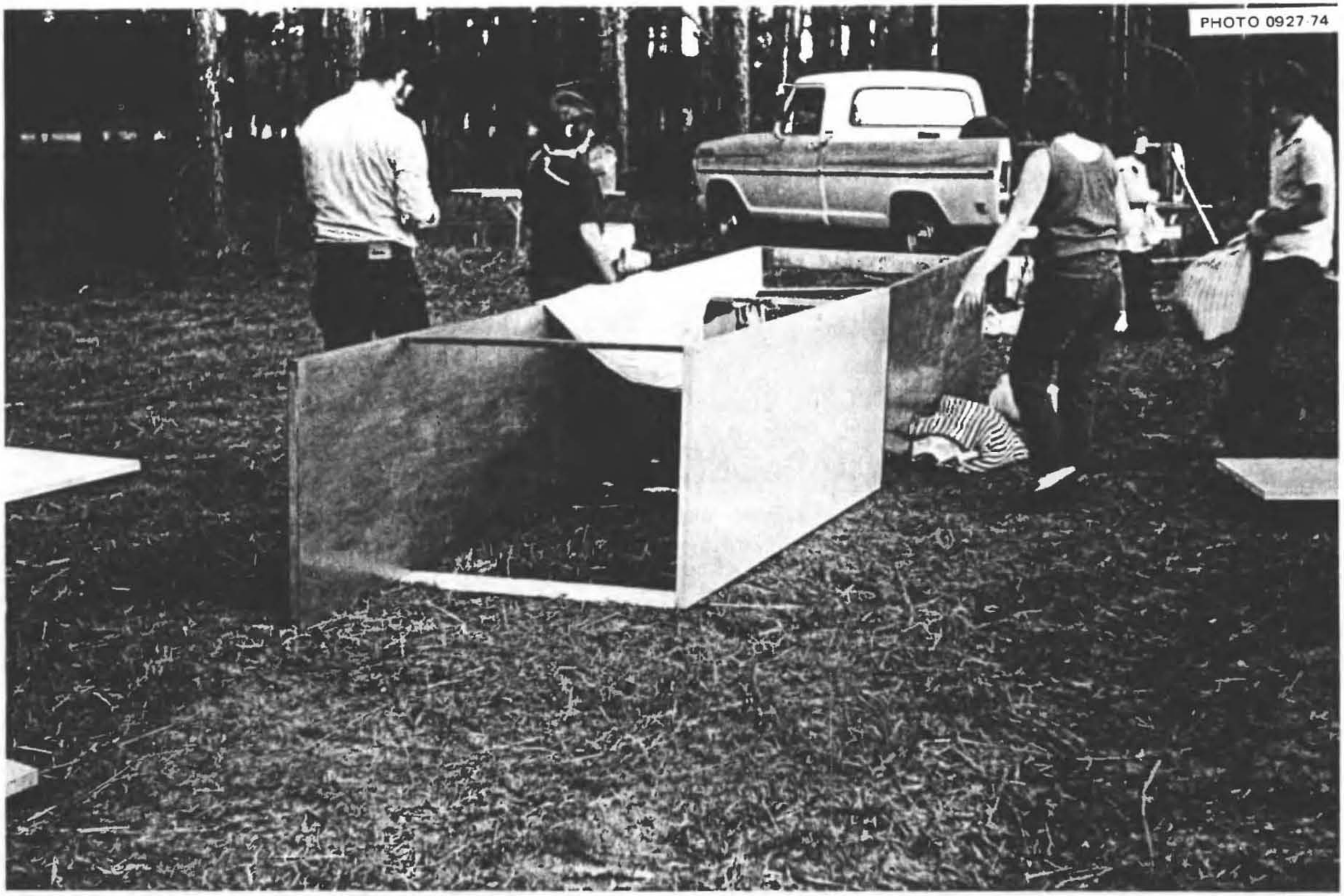


Fig. 5.3. Some of the doors set up as forms around which the earth-filled rolls were built to make the above-ground walls of the 7-person shelter built by this postal clerk, his secretary-wife, their 14- and 12-year-old sons, and their 13- and 9-year-old daughters. Note the cross bracing tacked to the inner edges of the hollow-core doors. These same doors were used for the roof, after the walls made of rolls had been completed.

Fig. 5.4. Starting to make the first roll by shoveling earth onto bed sheets that had been placed with 2 ft of their long sides on the ground, with the rest of the sheets temporarily draped over the doors used as forms. This sandy earth could be dug quite easily with shovels.

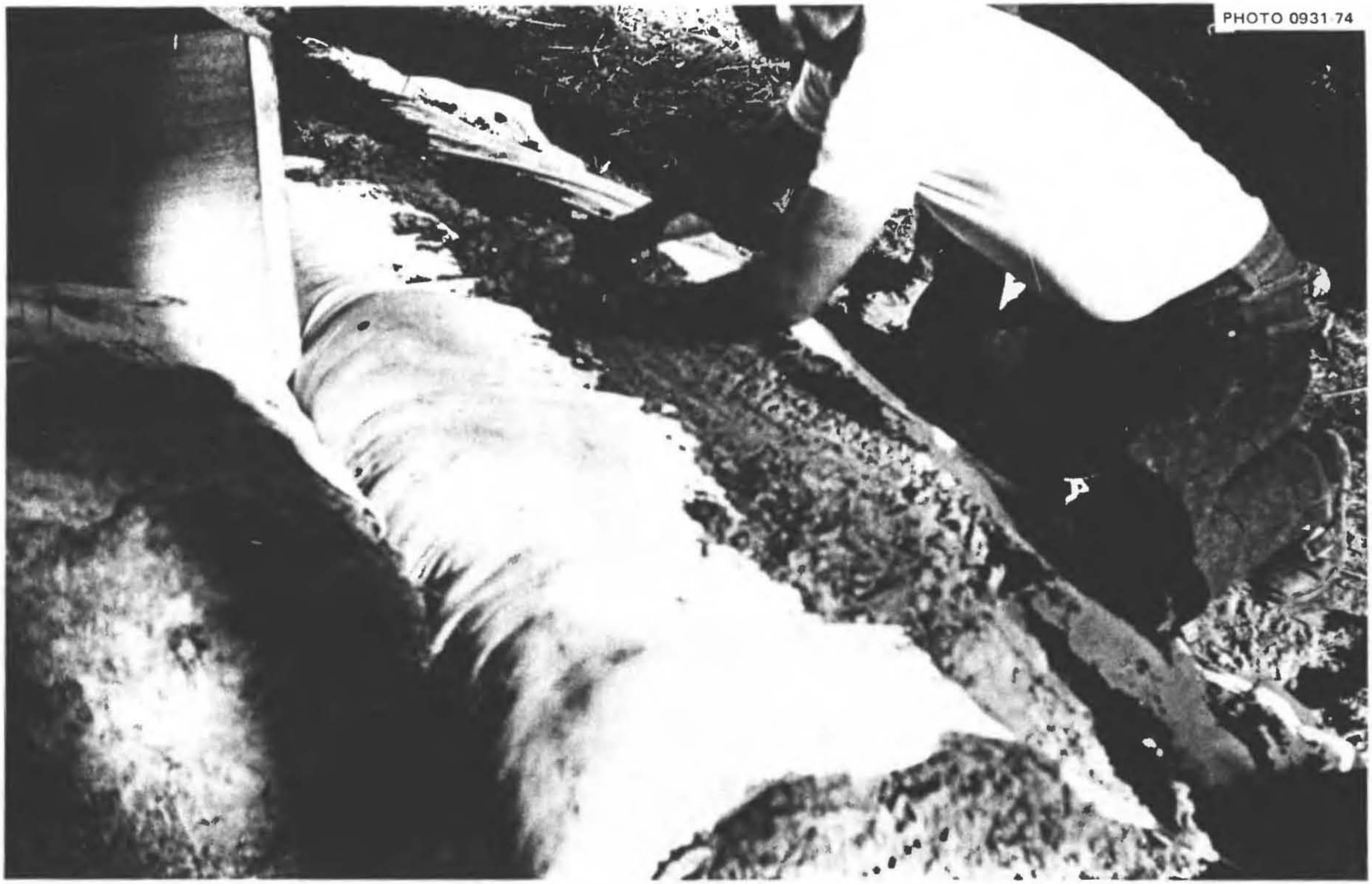


Fig. 5.5. Packing earth into what soon would be the hook of a roll. This photo was taken after the upper, free part of the sheet had been pulled down and over the earth that had been piled on part of the sheet while part of it was supported by the form made of an interior door. A part of this sheet had been folded down into a shallow ditch dug in the mounded earth; this ditch was below the line of packed-in earth on which the father's hands are pressed.

To complete the hook, the upper, outer edge of the sheet was folded over this earth packed into the shallow ditch.

One layer of a wall made of rolls was then completed by placing earth both on top of the hook and on the rest of the sheet-covered roll of earth, until the surface of the earth was as high as the

Fig. 5.6. Starting to make the lowermost roll to form the wall at one end of the shelter. The striped sandbag is made of a child's pillow case, one of several used to form the outside supports of one entryway wall.

PHOTO 0932-74

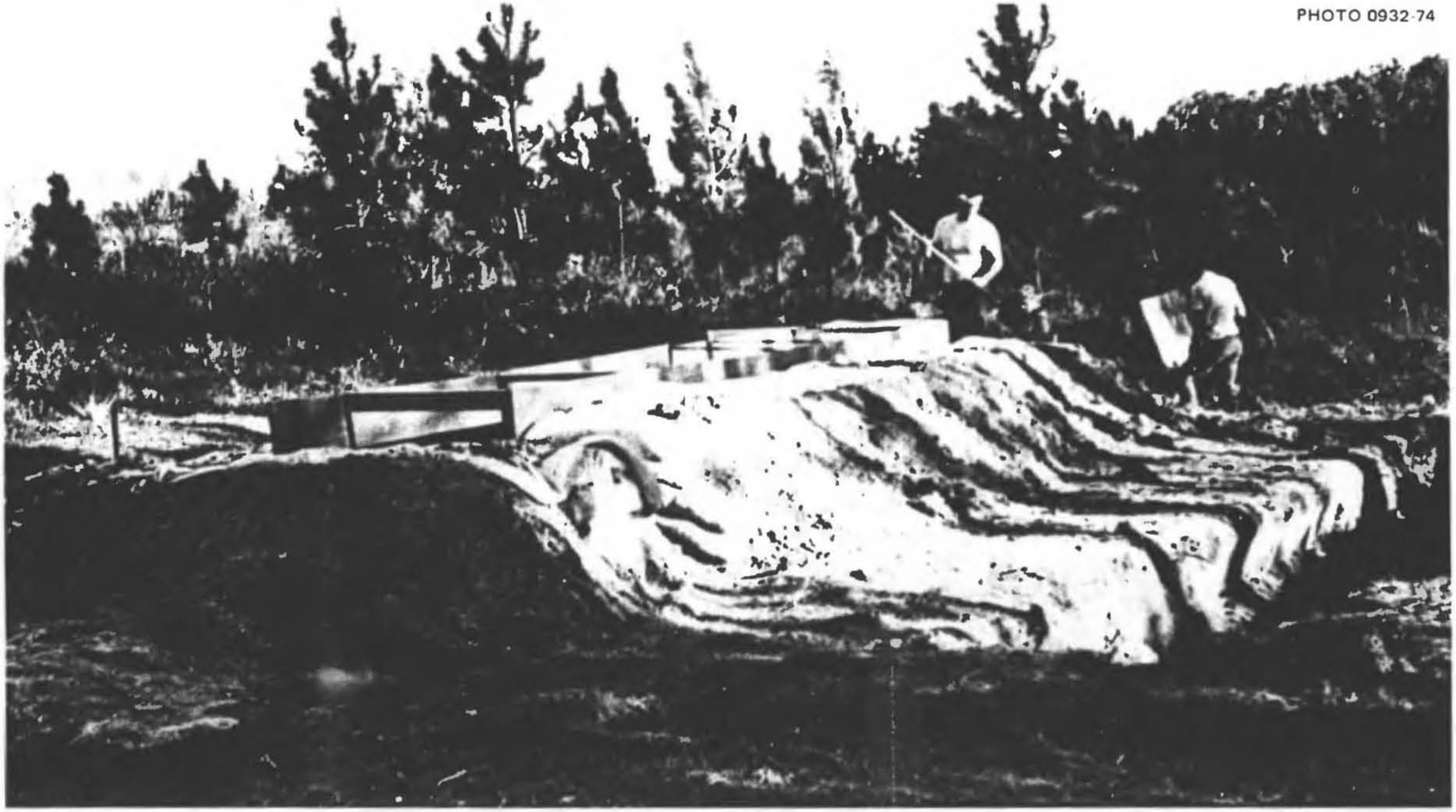


Fig. 5.7. One of the side walls, made of three rolls placed one on top of the other, pictured shortly before the door forms were removed.

Note the pits from which earth was excavated. Due to the high water table and underlying wet clay, these workers removed earth from only the uppermost 12 to 15 in.

Fig. 5.8. Placing an interior door over one end of the shelter and part of an entryway. The wall of this entryway consisted of 7 small rolls which were made by using pieces of sheets and other cloth, with the outer ends tucked in.

The man was standing on the main part of the shelter, over which other doors were soon to be placed, all parallel to the pictured door.

Fig. 5.9. The completed shelter, after a full 15 in. of heavy, wet, sandy earth had been piled on top of the roofing doors. These doors had all been painted or varnished with two coats, to simulate the interior doors from an average home. As an additional means to keep dampness from weakening the cardboard honeycomb inside these hollow-core doors, the walls made of earth-filled rolls were made about 3 in. higher on one side than on the other. Then waterproof materials (shower curtains, plastic film, and plastic clothes bags) were placed directly on these sloping doors. Finally, earth was piled 15 in. deep on top of these waterproof door coverings.

Fig. 5.10. A closeup view of the same entry pictured previously, showing the sandbags used to finish the ends of the entryway walls and to reduce radiation from fallout on the ground, which otherwise would enter the shelter.

This shelter, like the other above-ground shelters designed for use in a hot, humid climate, had two entryways, facing in opposite directions, one at each end.

PHOTO 1057-74

Fig. 5.11. The other entryway of the same shelter. In previous tests hollow-core interior doors used as previously described had supported at least this thick an earth covering for more than a month, during which extremely heavy rains had fallen.

This family of six built this 7-person shelter in 13 hours and 43 minutes of a single day, starting at 8:40 AM, the time Kearny handed them the building instructions after they had reached the rural site about 10 miles from their home. Only the father worked essentially the whole time. At the finish, all were tired but not exhausted.

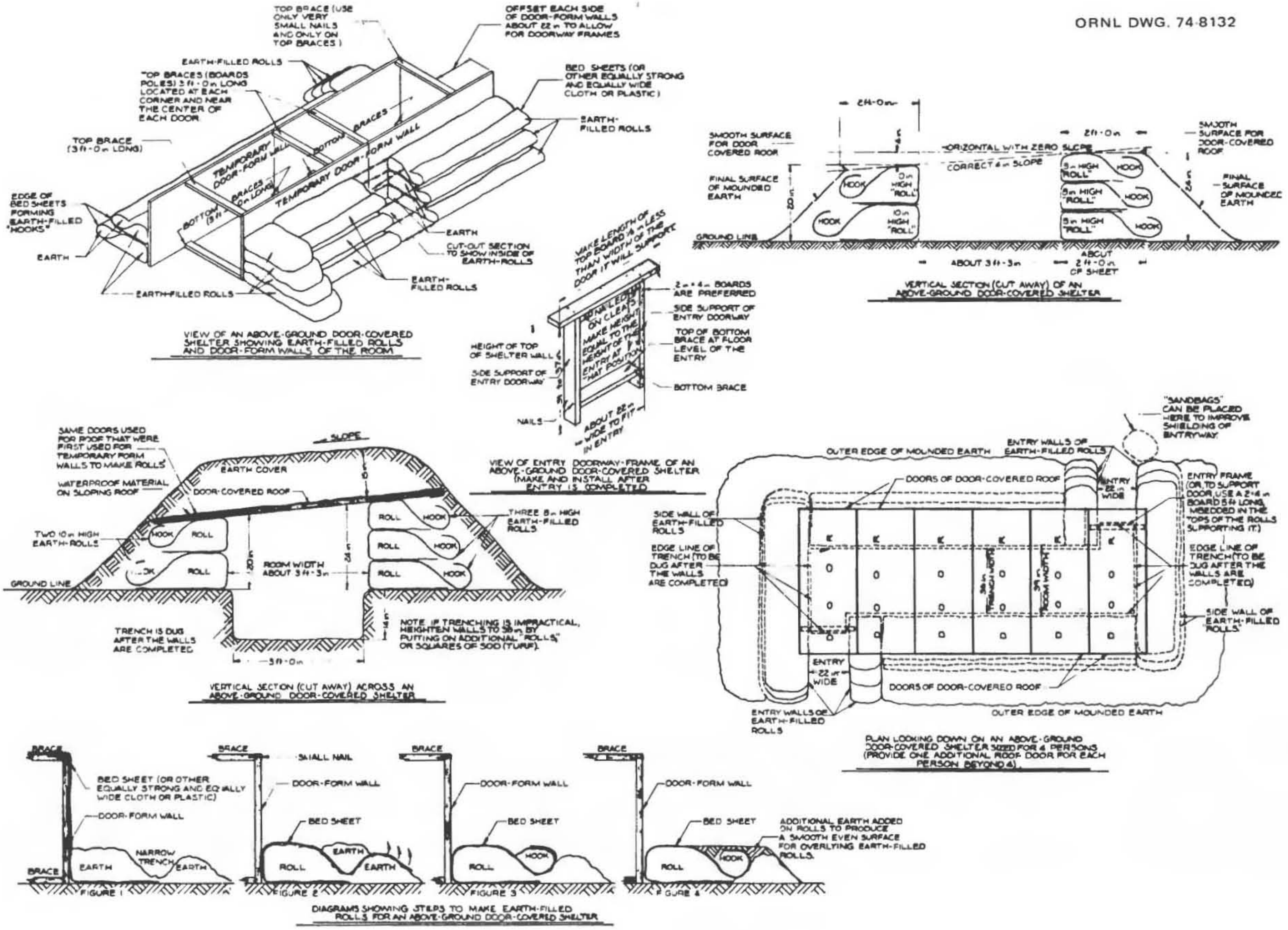
The previous evening they had built an excellent KAP to fit either of the two entryways of this shelter, guided only by written instructions that did not include the instructions for building any shelter. Although natural ventilation through an above-ground shelter with two opposite-facing entrys is much more effective than through a below-ground shelter with two entrys of the same size, nevertheless in still, hot weather the forced ventilation provided by a KAP is essential.

PHOTO 1059 74

Fig. 5.12. Interior of the shelter, showing the roofing doors sloping from the right to the left, and bowed downward about 1 in. due to the 15 in. of wet earth covering them. This bowing occurred as soon as the doors were covered and did not increase during the following days.

Note how the walls near the woman have remained quite vertical, whereas the walls nearest the camera have sagged. The nearer parts of the rolls forming the walls were the first rolls made by the inexperienced builder, who was guided only by written, illustrated instructions. At first the builder failed to pull upward on the sheets before he folded them back over the mounded earth, preparatory to forming the hook.

Also note the foot-deep trench dug in the sand; this trench was dug to within about 3 in. of the quite stable water table. In many areas, squares of turf could be cut from a lawn and placed on top of above-ground walls made of rolls, thus producing enough head room inside the shelter without the necessity of excavating a shallow trench to enable occupants to sit upright, and without requiring more bed sheets, bedspreads, drapes, and other fabrics than possessed by the average family.


VIEW OF AN ABOVE-GROUND DOOR-COVERED SHELTER SHOWING EARTH-FILLED ROLLS AND DOOR-FORM WALLS OF THE ROOM

VERTICAL SECTION (CUT AWAY) OF AN ABOVE-GROUND DOOR-COVERED SHELTER

VIEW OF ENTRY DOORWAY-FRAME OF AN ABOVE-GROUND DOOR-COVERED SHELTER (MAKE AND INSTALL AFTER ENTRY IS COMPLETED

VERTICAL SECTION (CUT AWAY) ACROSS AN ABOVE-GROUND DOOR-COVERED SHELTER

PLAN LOOKING DOWN ON AN ABOVE-GROUND DOOR-COVERED SHELTER SIZED FOR 4 PERSONS (PROVIDE ONE ADDITIONAL ROOF DOOR FOR EACH PERSON BEYOND 4).

DIAGRAMS SHOWING STEPS TO MAKE EARTH-FILLED ROLLS FOR AN ABOVE-GROUND DOOR-COVERED SHELTER

Fig. 5.13. Above-Ground Door-Covered Shelter.

B. Crib-Walled Shelter

This above-ground expedient shelter is designed to be built within 48 hours by untrained citizens who lack the skill to cut and fit poles or other materials with some accuracy, who can build in an area where they can cut or obtain numerous poles, and who have common tools found in most rural and suburban homes, plus bed sheets, pillow cases, bedspreads, and some waterproof materials. No nails are needed. Its fallout protection is good – at least PF 400.

About twice as many poles are needed to build this shelter as are required to build a Ridge-Pole Shelter of equal capacity (see the following section of this chapter). Also, in a group of families totaling 12 to 20 members, there would usually be at least one person with the modest skill needed to build a Ridge-Pole Shelter; and the few nails required to build this shelter are likely to be available from one of the cooperating families. Thus a Crib-Walled Shelter is primarily a backup design of high-protection-factor expedient shelter for use in wooded areas with very high water tables or very shallow soil above rock, especially for single families lacking nails.

Fig. 5.14. A Florida family cutting a small pine tree to build an above-ground Crib-Walled Shelter in Flagler County. This family had hard luck in that the months-long drought was broken by a 3-in., all-day rain lasting what would have been the first 12 hours of their shelter-building effort.

To fell trees, the father and his 16-year-old son used an old crosscut saw that they had sharpened before this experiment began officially.

Fig. 5.15. Cutting a small felled tree into one of the specified lengths needed to build pole cribs. Later the cribs were lined with bed sheets and then filled with earth. Instead of following the instructions and pulling long poles to the shelter-building site, where they should have been cut to the desired lengths, this family chose to have the children carry small poles one at a time to the site.

With only homemade kerosene torches made by filling pop bottles with kerosene and twisting pieces of cloth into the mouths for wicks, this family worked from sundown until 3 AM, felling trees and packing poles to the site at the edge of the woods. At 3 AM more heavy rain forced them to take cover under pieces of plastic and in the cab of their pickup truck, in which they had driven some 12 miles from their home near Bunnell to the rural site.

Fig. 5.16. Building the cribs forming the entrances and ends of this shelter, and also making the connecting spaced-pole walls of the main room. This family of 6 consisted of a father, aged 55, who is a painter and odd-job handyman; a mother, aged 50, who is a school custodian; a son and daughter, both 16; and two small but strong sons, aged 13 and 11.

Note that each pole is notched only on its upper side – all that is necessary to build this frontiersman-type crib, or hog pen, as modified to served as an earth-filled wall.

Fig. 5.17. The outside of one of the spaced-pole walls of the shelter room, after it had been readied for mounding earth against it by guying vertical poles against the inside of this wall to stakes driven outside the wall. Note the guy ropes made of foot-wide strips of bed sheets, twisted and pulled tight by the twist-sticks near the inner line of stakes. These twist-sticks are kept from unwinding by being positioned so that their lower ends could be pressed against the ground. Later these guy ropes and sticks were completely covered by the earth mounded against this wall until the 2-ft-wide top layer was about 3 in. higher than the top of the spaced-pole wall. The bed sheets (with the help of earth arching) kept the earth from falling through the spaces between the poles.

Although this family successfully followed the instructions for building, lining, and filling the cribs and for roofing the shelter, they were unable to stake and guy the walls without some verbal guidance from C. H. Kearny. Kearny concluded that a shelter built entirely of earth-filled cribs is a more practical design for unskilled builders, and would take no more time even for quite skilled builders.

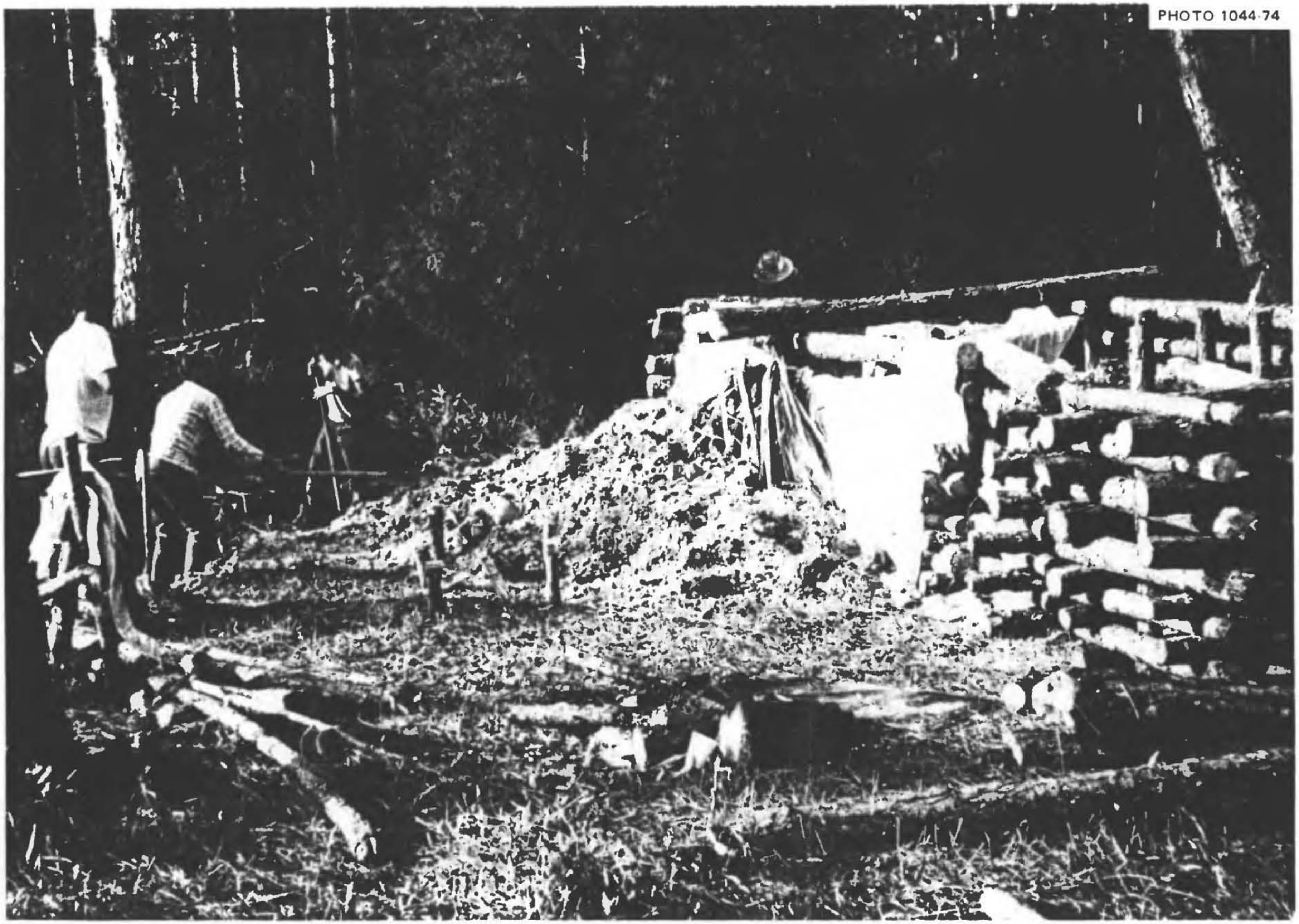


Fig. 5.18. View showing earth being mounded against one of the spaced-pole walls of the shelter. The crib nearest the camera had not yet been lined with a bed sheet, preparatory to filling with earth.

Fig. 5.19. One of the two entryways of this Crib-Walled-Shelter, showing a sheet-lined, earth-filled end crib almost filled with earth. The two entryways, one at each end of the shelter, faced in opposite directions, assuring adequate cooling except in very still, hot, humid weather.

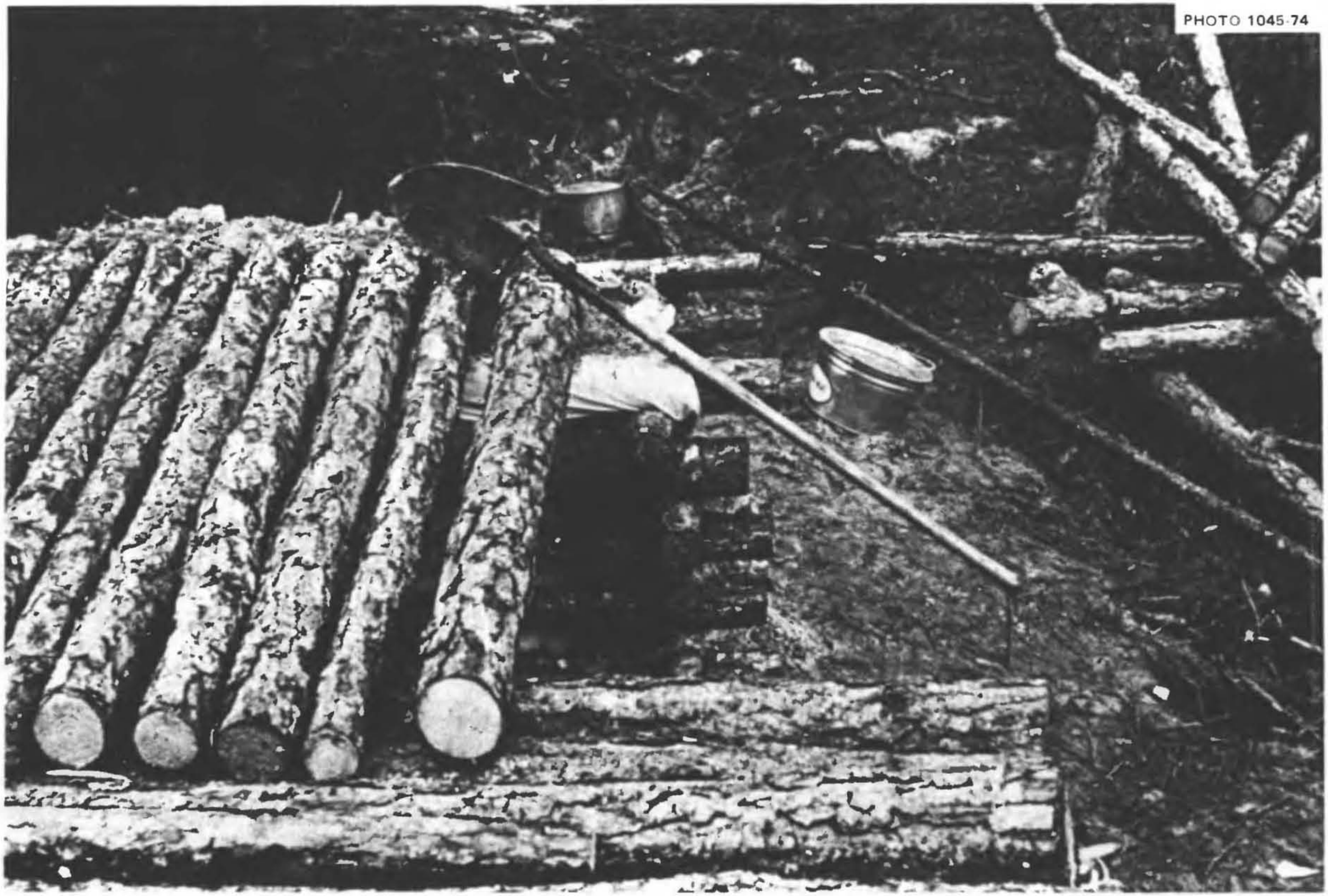


Fig. 5.20. View looking down on the same entryway, after it had been filled with earth to a height of about 3 in. above the uppermost poles of the crib, and roofing poles had been placed in position. Note that the roofing poles across the entryway rest with their ends on the earth that fills the crib, and also on the outermost poles that rest on earth in a crib (not shown in this view) forming the inner side of the entry. The outermost roofing pole of the entryway had not yet been placed.

Fig. 5.21. Since this family lacked newspaper, cardboard, or other material to keep sand from sifting through the cracks between the roofing poles, they used palm leaves for this purpose. Grass or pine needles could have been used, but would have required more work, and might have contained ticks and chiggers.

Fig. 5.22. Using an old bedspread to form an earth-filled roll along an upper edge of the essentially flat shelter roof of poles. The father is pouring earth out of a large bucket. These rolls made it possible to increase the stability of the earth covering around the edges of the roof, and also prevented heavy rains from washing any appreciable amount of shielding earth off the shelter roof.

Fig. 5.23. After mounding earth over the shelter roof so that the earth was about 1 ft deep over its centerline, this family made a rainproof "buried roof" out of waterproof material. Since they had part of the north side of their home covered with a big piece of polyethylene film to keep the winter wind from blowing through cracks, they had enough waterproof material to bring with them to the shelter-building site to cover this entire shelter roof.

Fig. 5.24. The successful builders outside their completed shelter, with a full 2 ft of earth on the roof. Note one of the shallow barrow pits, from which they had shoveled and carried earth, in buckets and a wheelbarrow, to the adjacent building site.

Due to the heavy rains that fell during the first 26 hours of this shelter-building experiment, this family was unable to win the bonus offered for completion within 48 hours. However, they quite easily earned the base sum of $500 for completion within less than 4 days, without working very hard except on the first day. Kearny also paid them for their 14 bed sheets, 6 bedspreads, and the plastic film used to complete this shelter.

5.25. Resting in the completed shelter, which inadvertently was built with its roof high enough to have permitted the occupants to sit on benches or boxes. The floor was carpeted with palm leaves. This family of six concluded their shelter was large enough for several additional persons, although the floor area of the well-shielded interior room was only 45 square feet.

5.26. A different crib design that requires no notching of poles. Note the two vertical, small-diameter poles tied into each corner, one inside the crib, and the other outside. Each pair of vertical small poles was tied together (top, center, and bottom) with three "ropes" made of foot-wide strips of bed sheet, or (at only two points) with rope.

Later this crib was lined with a piece of polyethylene film only 4 mils thick (not as strong as bed sheet), and filled with earth to a height about 4 inches above the uppermost poles. The small vertical poles were cut off about 3 inches above the uppermost horizontal poles of the roof. Then a 5-ton backhoe lifted itself off its wheels by pressing down with its bucket against the earth inside the crib. Only after the backhoe shoved back and forward repeatedly, while in this position, did this crib start to come apart from the top. Kearny concluded that probably average or subaverage families could build this type of crib more rapidly than a crib requiring notching of its poles. This conclusion was confirmed by the later success of a Colorado family (Fig. 5.27).

PHOTO 1815-74

Fig. 5.27. A Crib-Walled Shelter completed in Colorado. This family finished 29 hours and 53 minutes after receiving the building instructions at their suburban-type home about 9 miles away from this site. All six members were at this site, working over 90% of the time, for 10 hours and 13 minutes on May 26th, and for 5 hours and 11 minutes on May 27th. If they had built near a woods and had cut all the poles specified for this shelter, Kearny believes this family could have finished it by working as hard for two full days, 10 or 12 hours each day.

The father (43) is a dispatcher for a power company. The mother (40) is a housewife. The children are a girl (18) and three boys (16, 15, and 14). All are healthy.

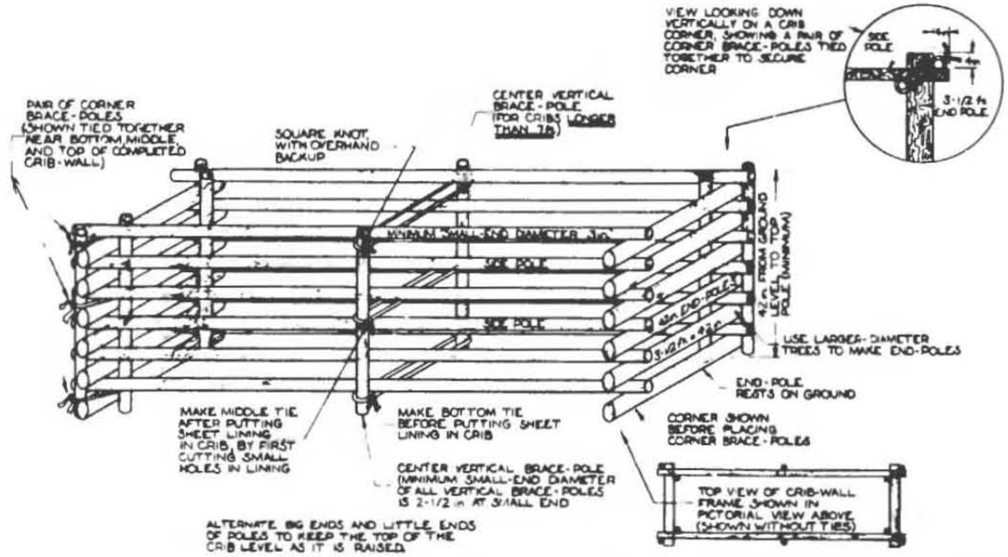
Note the entryway in which the boy is kneeling. A second entryway, opening in the opposite direction, and also having a 90-degree turn, is near the diagonally opposite corner of the shelter.

Fig. 5.28. A 20 × 24 in. KAP being used on a still day to pump an average of about 600 cubic feet per minute through an Above-Ground Crib-Walled Shelter. This shelter had an entrance at each end, each providing about 5 sq ft of effective cross-sectional area.

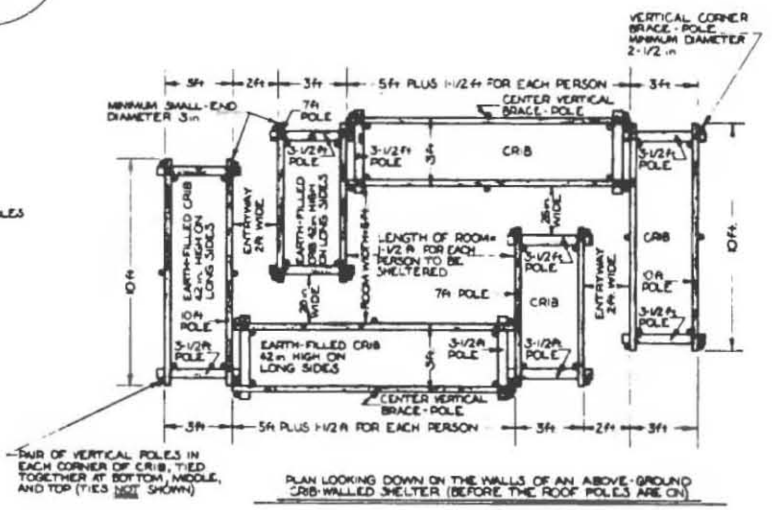
Six hundred cubic feet per minute is enough outdoor air to restrict the rise in the *effective temperature* of the shelter air, measured as it leaves the shelter, to only about 2° F for a larger shelter of this type occupied by 24 persons.

This pump was built by two young Florida women, who were about to have babies. Therefore, while other members of their families did the heavy manual work building an A-Frame Pole Shelter, these untrained women built the ESSENTIAL shelter-cooling KAP. Yet to date no instructions have been given to the American people to enable them to build KAPs, or any other kind of expedient air pump.

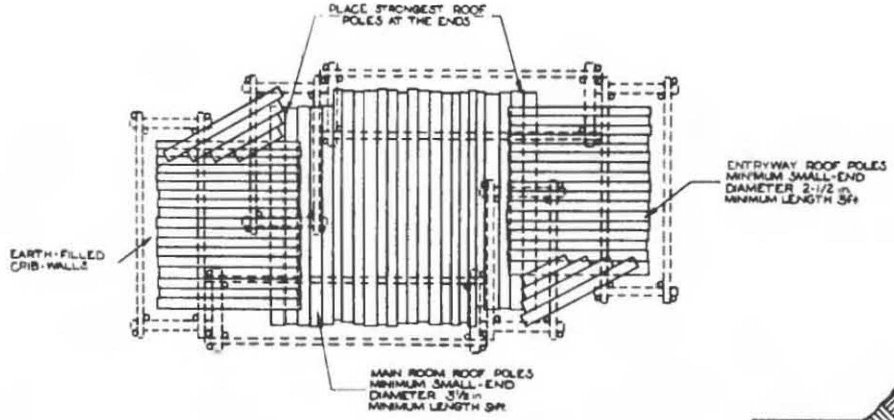
ORNL DWG. 74-8130



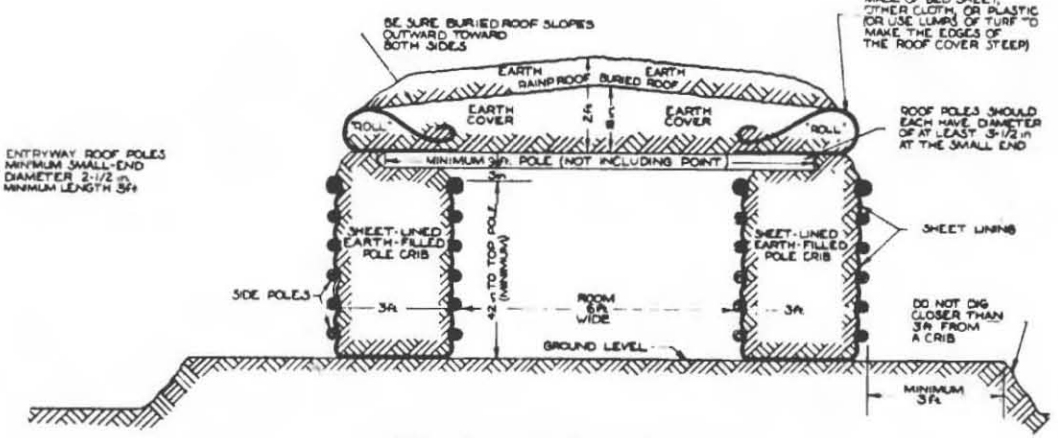
VIEW OF CRIB-WALL FRAME, (BUILT LIKE A POLE-PEN) TO BE LINED WITH CLOTH AND FILLED WITH EARTH



PLAN LOOKING DOWN ON THE WALLS OF AN ABOVE-GROUND CRIB-WALLED SHELTER (BEFORE THE ROOF POLES ARE ON)



PLAN LOOKING DOWN ON SHELTER ROOF SHOWING PLACEMENT OF ROOFING POLES ON THE EARTH-FILLED CRIBS OF CRIB-WALLED SHELTER



VERTICAL CROSS-SECTION (CUT-AWAY) OF ROOM OF A COMPLETED ABOVE-GROUND CRIB-WALLED SHELTER

Fig. 5.29. Crib-Walled Shelter.

C. Ridge-Pole Shelter

This above-ground shelter is designed to be built without requiring any exact cutting except for the few posts that support the ridge-pole. No boards and only about 100 nails (3 inches or longer) are needed. The sides require only half as many poles as do the sides of an A-Frame Pole Shelter. Most American homes contain all the other materials needed to make this strong shelter, which millions of Americans in wooded areas with high water tables or little depth of earth above bedrock could build in less than 48 hours.

The protection afforded by this shelter against fallout radiation is good (about PF 500); against fire hazards, also good; against blast effects, better than most buildings provide.

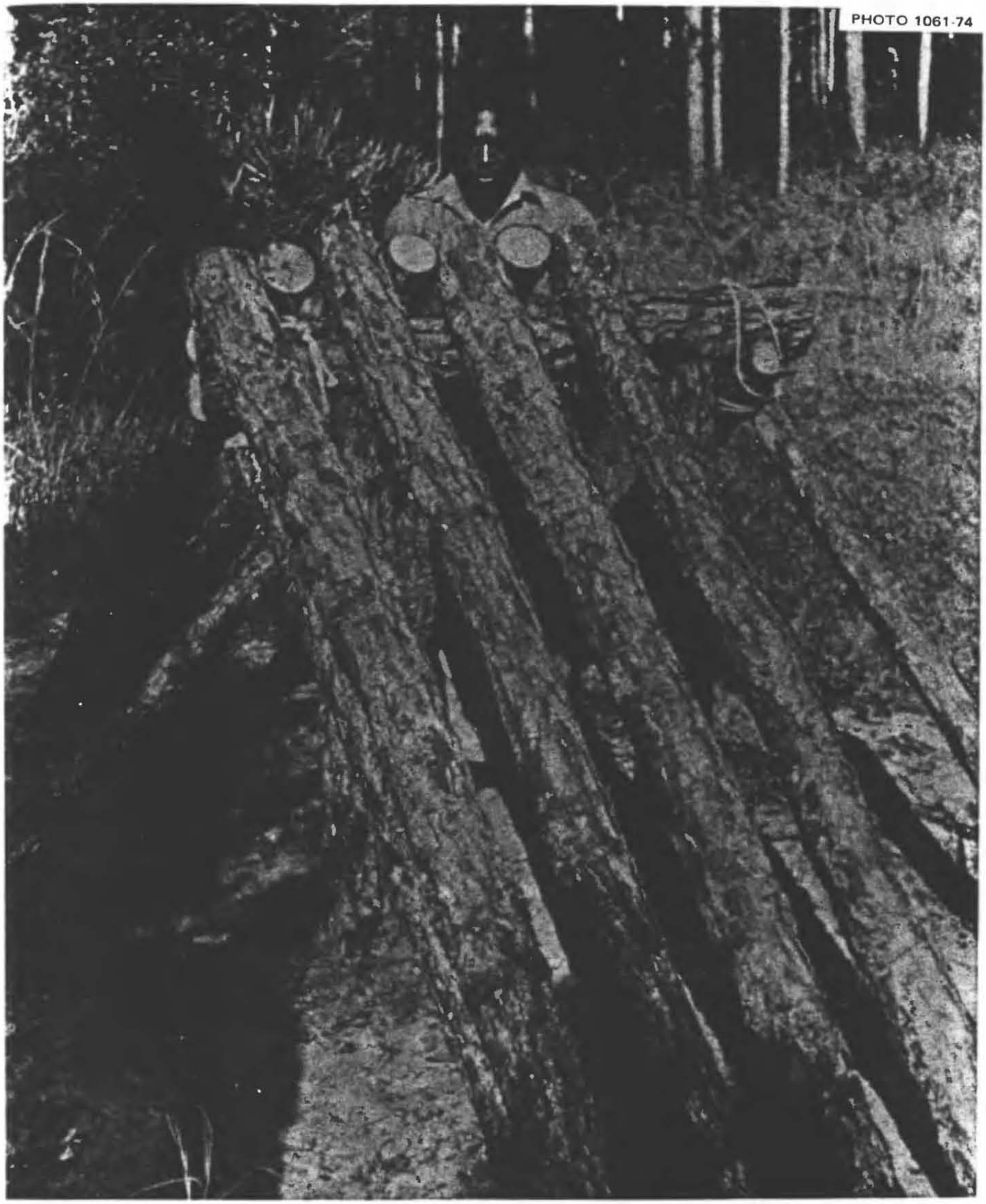


Fig. 5.30. The first prototype of a Ridge-Pole Shelter built by Kearny and a contractor's workmen. The ridge pole of this prototype was supported by 2 vertical posts, each of which had a shallow notch in its upper end, in which the ridge pole rested. This first prototype had cross-braces with their ends under the ridge pole to steady it; subsequent loading of this structure with over 2 ft of earth indicated that this cross bracing was unnecessary.

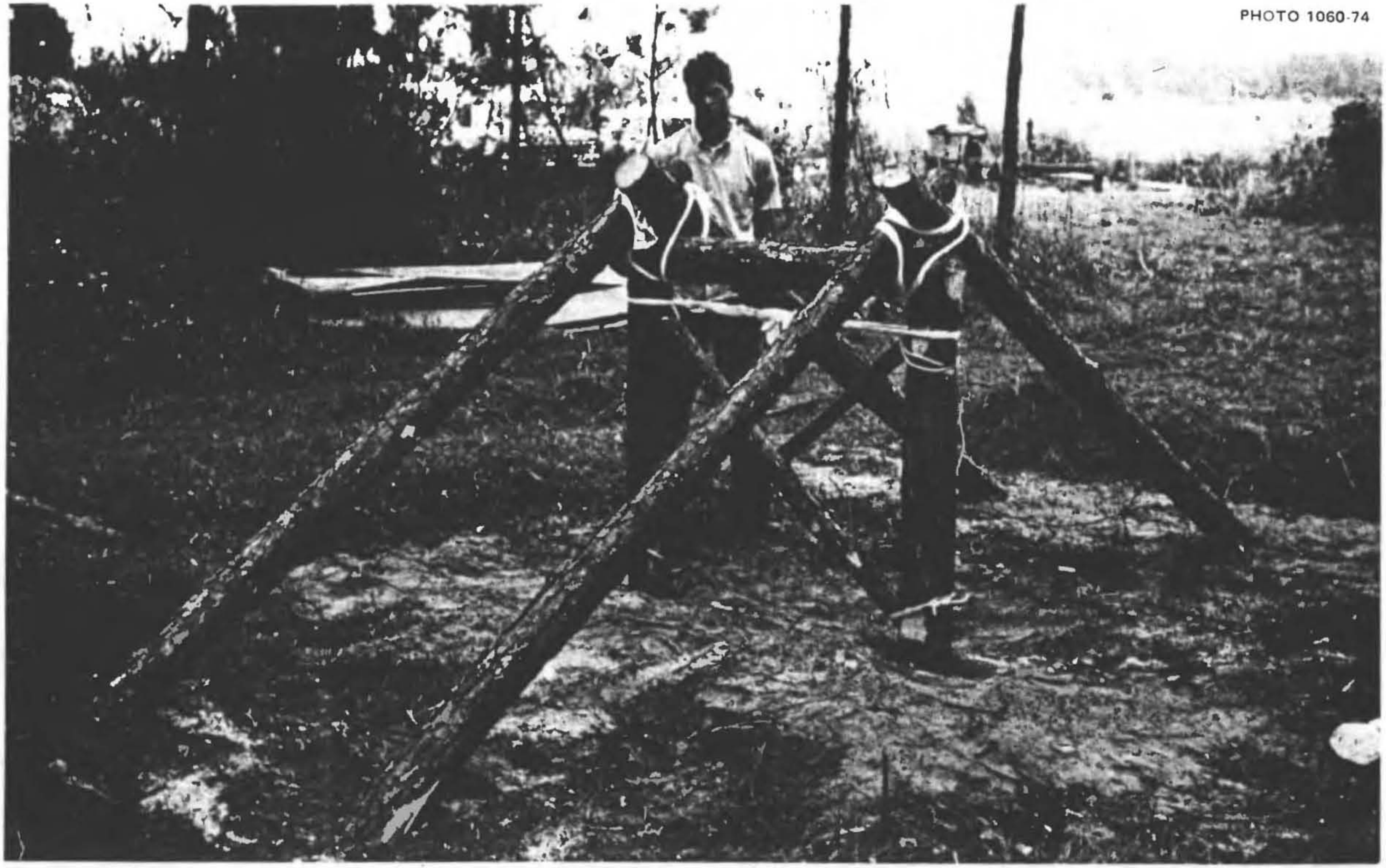


PHOTO 1060-74

Fig. 5.31. A second prototype of the frame of a Ridge-Pole Shelter, built without using a single nail. Slightly twisted strips of bed sheet, 1 ft wide, were used to hold this simple yet very stable structure together, and three pieces of rope were used to secure the notched cross-braces between the two vertical posts supporting the ridge pole. These vertical posts rested on flattened small areas cut on the upper side of a slightly below-ground footing log. Small poles on the outer side of the vertical posts, just below ground level, prevented any sideward movement of the bottoms of the vertical posts.

Kearny concluded that this design is too complicated for some unskilled families to build, because of the notching and fitting required if no nails are used.

Fig. 5.32. The Walden families (in the senior father's home at 7:18 AM on March 16) reviewing the Evacuation Check List that Kearny handed to them at 7 AM. They had assembled the recommended tools, shelter-building materials (other than poles) with which to build a Ridge-Pole Shelter large enough for all 15 members of these families. They also assembled water containers, food, blankets, a tent, etc., to take with them.

Led by Kearny in his car, the Walden families moved some 12 miles in their four cars and on one motorcycle to the rural building site in a high-water-table area.

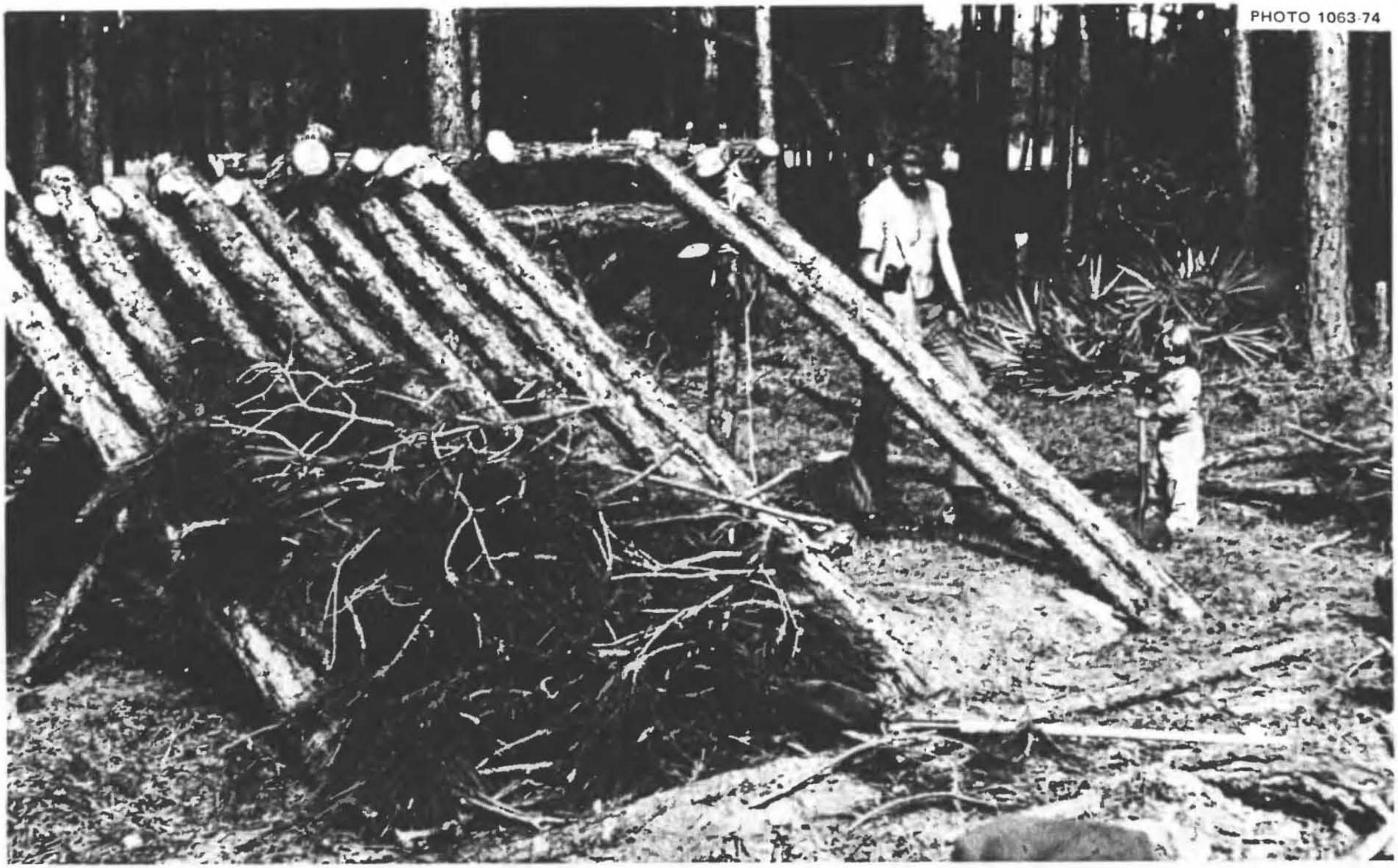


Fig. 5.33. The Waldens' Ridge-Pole Shelter had a ridge pole 16 ft long, supported by 4 vertical posts, each with a shallow V notch in its upper end. The roof poles on the sides were each 9 ft long; their lower ends rested in a V trench only 4 in. deep. In these very shallow trenches were placed poles only about 3 or 4 in. in diameter, with one side flattened. The lower ends of the 9-ft roofing poles pressed against the flattened sides of these small poles that probably were unnecessary.

Preparatory to covering the sides with bed sheets, the Waldens piled more sticks and small limbs across the roofing poles than specified in the instructions. Prior tests in Flagler County had shown that small branches placed crosswise to the roof poles at 4- to 6-in. intervals and covered with bed sheets or 4-mil plastic film prevented even a 3-ft-thick sand covering from falling between the widely spaced roofing poles, probably in large measure due to small-scale earth arching.

Fig. 5.34. Placing bed sheets over the pine limbs that had been placed crosswise over the roofing poles of the shelter. After the whole shelter had been covered in similar fashion, earth was shoveled or carried so as to cover the entire shelter. This covering was done from ground level upward.

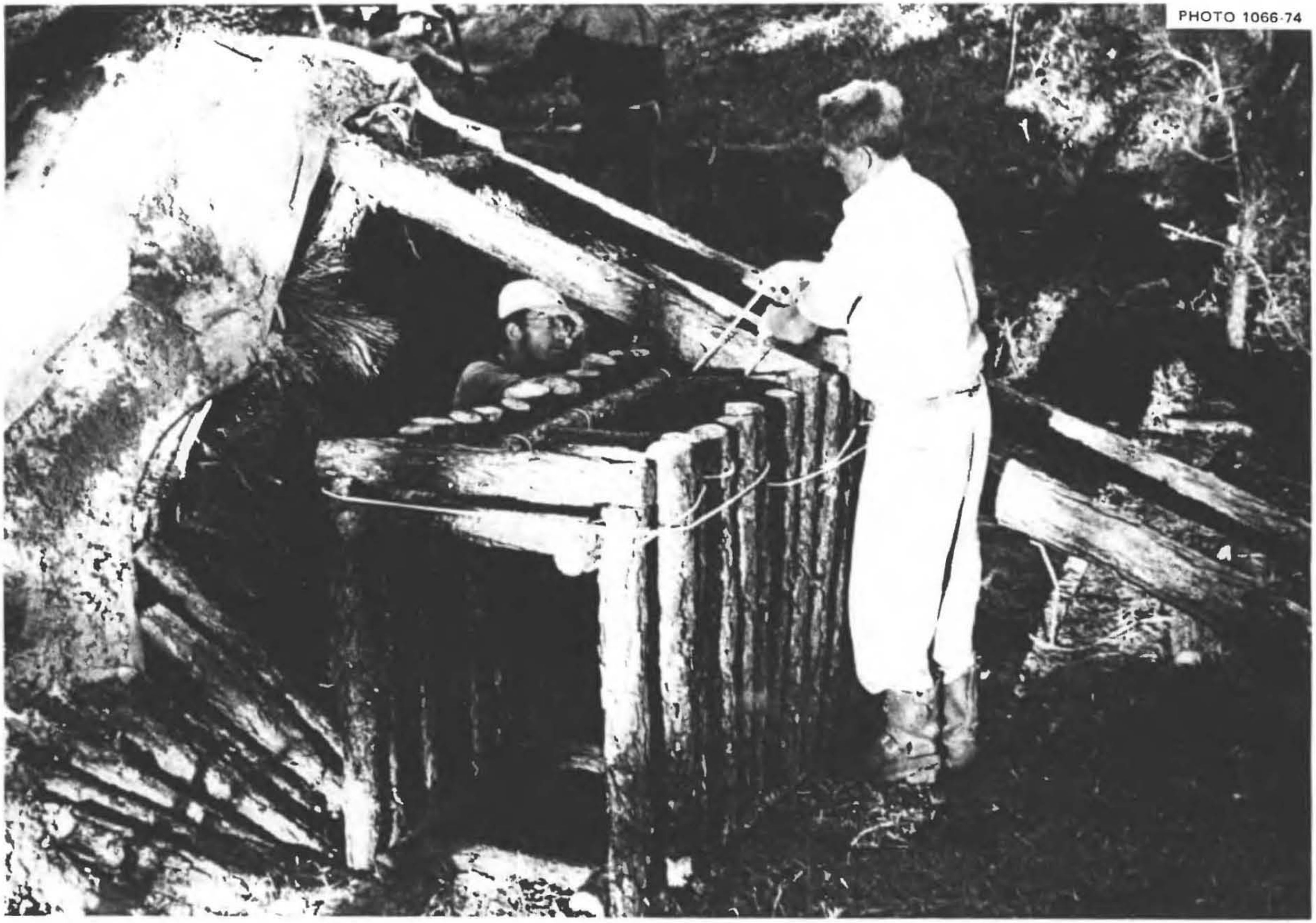


PHOTO 1066-74

Fig. 5.35. Securing the side walls of the outer part of an entryway that had a right-angle turn before it reached the main shelter room. This entryway was built like a miniature Small-Pole Shelter. When this photo was taken, the horizontal roofing poles of this entryway had not been placed on the upper ends of the vertical wall poles of the entryway. The vertical wall poles could have been held in place by piling earth against them.

Fig. 5.36. Two teenagers carrying earth in a 5-gallon bucket, from one of the shallow barrow pits. These builders found that carrying earth in this manner enabled even children to move earth effectively, all the way to the top of the shelter.

Fig. 5.37. The just-completed shelter at 6:40 AM, 23 hours and 40 minutes after the Walden families had been given the Evacuation Check List and the building instructions at their homes 12 miles away from the building site. Several of the adults worked essentially all night to complete this shelter in less than 24 hours, although they could have won the full bonus if they had completed it in 47 hours 59 minutes. They moved over 50 tons of earth by manual labor. The earth over the sheet-covered limbs across the wall poles was a full 2 ft thick.

Fig. 5.38. View inside the Waldens' Ridge-Pole Shelter, showing a part of one side. This shelter had a main room 13 ft wide and 16 ft long. The Waldens concluded that it was big enough to shelter at least 20 people, with plenty of room for food and other possessions. The four centerline posts were not objectionable.

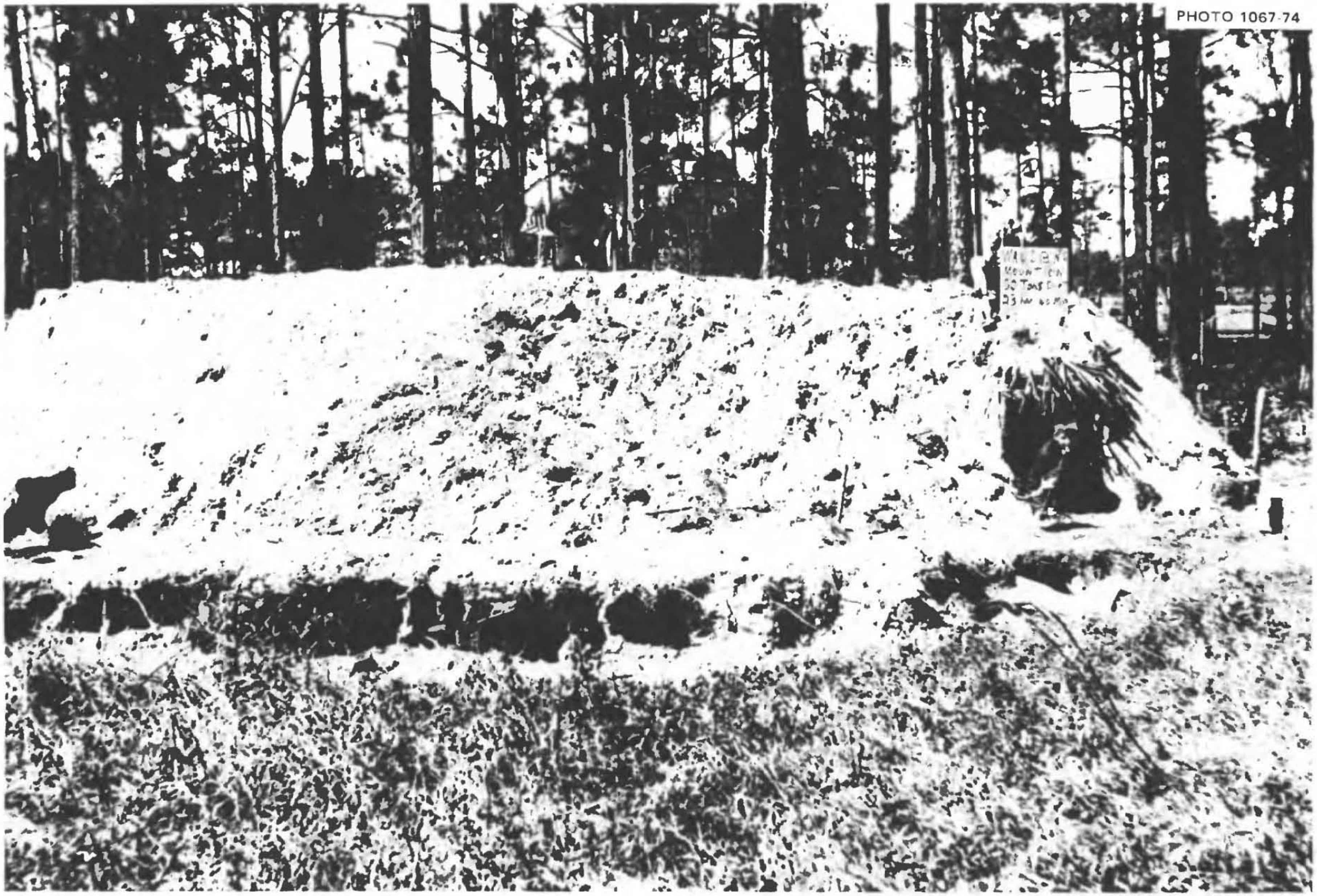
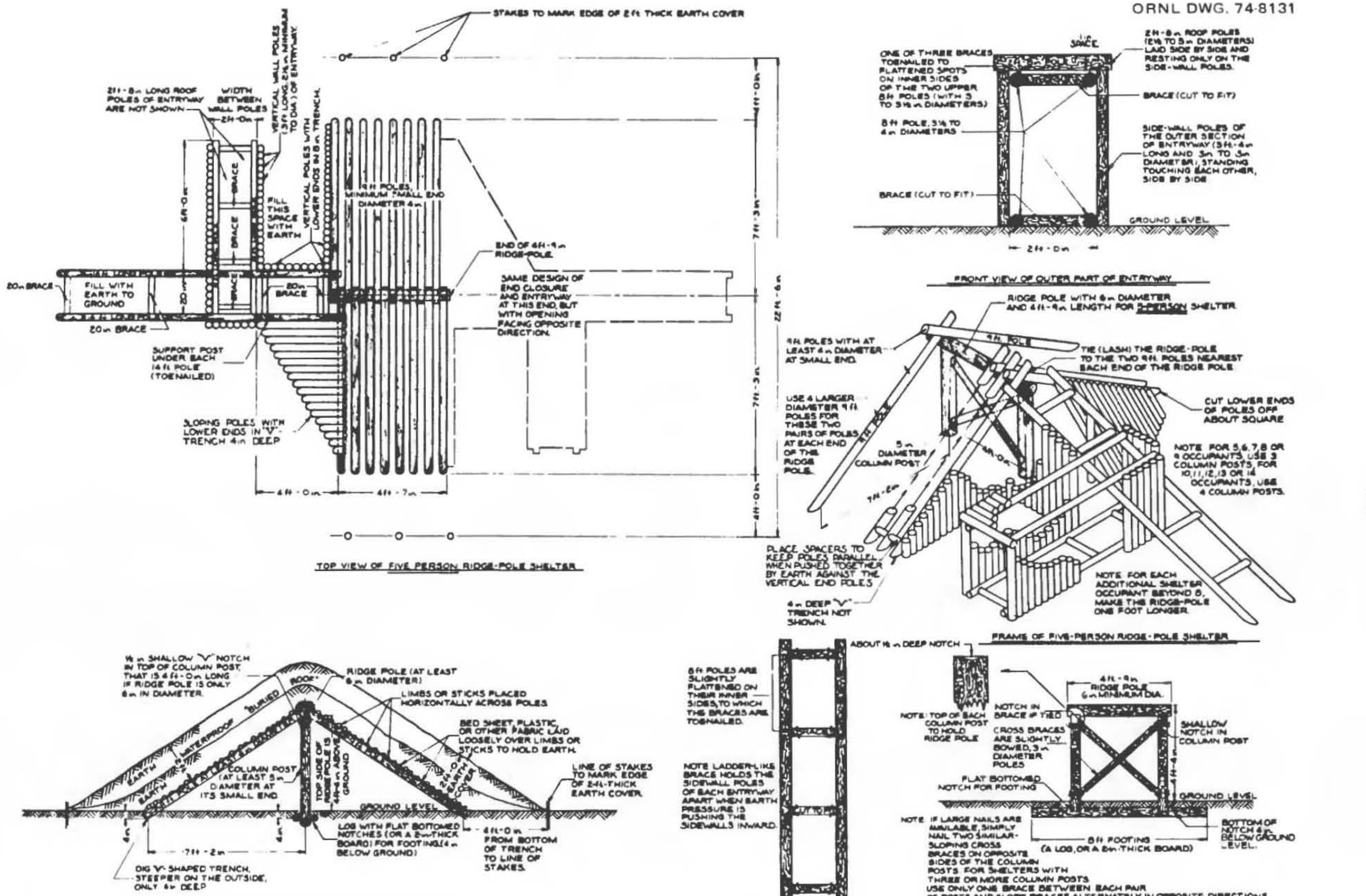


Fig. 5.39. View of the completed shelter, showing one of the two opposite-facing entryways. Even when there was only a very light breeze outside (less than 2 miles per hour), air movement through this shelter was several hundred cubic feet per minute.

As was the case with other shelters built by family groups in Florida, the Waldens were required to build a Kearny Air Pump, which would have been necessary to maintain tolerable conditions inside the fully occupied shelter during hot, humid, still weather.

Fig. 5.40. View after a backhoe had started to demolish the Waldens' Ridge-Pole Shelter, which proved to be decidedly sturdy. Note that some of the wall poles were broken before they were moved off the ridge poles, or the ridge pole had been moved significantly.

This shelter was built with its sides sloping approximately 36°, the smallest angle of a 3,4,5 triangle. The instructions were written so the builders did not have to be concerned with angles. Unlike the roof sloping 45°, a uniformly thick earth cover can almost always be placed on a roof sloping 36° – thus saving many hours of laborious work putting on tons of earth cover that, of necessity, is much thicker near the ground than near the top of a more steeply sloping shelter roof.



TOP VIEW OF FIVE PERSON RIDGE-POLE SHELTER

FRONT VIEW OF OUTER PART OF ENTRYWAY

FRAME OF FIVE-PERSON RIDGE-POLE SHELTER

CUT-AWAY END VIEW OF FRAME OF RIDGE-POLE SHELTER

TOP VIEW OF HORIZONTAL LADDER-LIKE BRACE

SIDE VIEW OF THE CENTER SUPPORT

Fig. 5.41. Ridge-Pole Shelter.

D. A-Frame Pole Shelter

This versatile shelter can be built above ground, semi-buried, or below ground. As proven in Defense Nuclear Agency's Mixed Company blast test,[10] the above-ground version with 3 feet of earth cover can withstand blast overpressures of at least 16 psi, even if closed with blast doors. Since its green poles are completely covered with earth except for a few poles near its two openings, this shelter is difficult to set afire. And, if built entirely above ground, it would be less endangered by smoke and carbon dioxide than a below-ground shelter.

An A-Frame Pole Shelter requires more skill to build than is needed to construct either a Ridge-Pole Shelter or a Small-Pole Shelter of equal capacity. It is more suitable for above-ground construction than is the vertical-walled Small-Pole Shelter, which, if built above ground, requires over twice as much earth to provide equivalent shielding.

If intended to afford blast protection in the 10 to 16 psi overpressure range against nuclear weapons smaller than about one megaton, 5 feet of earth cover would be needed to give adequate protection against the penetrating initial nuclear radiation.

Its protection factor against fallout is superior to the other above-ground shelters, due largely to its relatively long entry passageways; with the illustrated 2 feet of earth cover, the PF is about 500; with 3 feet or more of earth cover, the PF is about 1000 except near the entrances.

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[10] See C. H. Kearny and C. V. Chester, *Blast Tests of Expedient Shelters*, ORNL-4905, January 1974.

Fig. 5.42. Starting to build a 21-person above-ground A-Frame Pole Shelter. Five families, having 22 persons in all (including two babies and three adults unable to do heavy work) built this shelter with a main room 21 ft by 13 ft wide. The roof poles (not shown) had a minimum small-end diameter of $3\frac{1}{2}$ in. and sloped approximately 36°. This photograph shows one of the 6-in.-deep, "V"-shaped trenches being dug to secure the lower ends of the 9-ft roof poles, that measured 9 ft on their short sides.

All of the adults in these families either had rural jobs or had previously worked in the country. Kearny had concluded that the skill required to build this type of shelter would prevent many able-bodied urban Americans from constructing it, even if they had the necessary tools, unless there were at least one moderately skilled person in the group.

Fig. 5.43. This was the only group of families permitted to use any motor-powered equipment: a chain saw and a pickup truck. The young man pictured was expert with a chain saw. He made a road into the nearby woods, making it practical to use the pickup truck to carry some 10,000 lb of poles most of the distance from where they were cut to the building site.

Fig. 5.44. Erecting a 16-ft-long section of the ridge board that later was extended to a 21-ft length. These decidedly competent rural people were so overconfident of their building abilities that they failed to read the instructions carefully. As a result, they made several errors that they had to correct. One of these errors was initially using a 5-in.-wide board for the first part of the ridge board; they found that the upper ends of some of the wall poles would not fit properly against a board so narrow.

Fig. 5.45. **Chain saw operator using a templet to cut an upper end of a wall pole at the specified 54° angle and 9-ft length on its short side.** The templet was made from a wide 10-ft board, with one end cut at 54°. A nail was driven 9 ft from the end of this 54° angle; the squared-off base of the pole was placed against this nail.

Such templets make it unnecessary to measure any angles. Average rural people have no difficulty making the templets if they read the instructions.

PHOTO 1018-74

Fig. 5.46. Nailing a 9-ft roof pole to the ridge board. This photograph is misleading as regards the lower ends of the ridge poles; actually the ends rested against a 1 × 6 board placed against the outer side of the 6-in.-deep V trench that marked the edge of each shelter side wall.

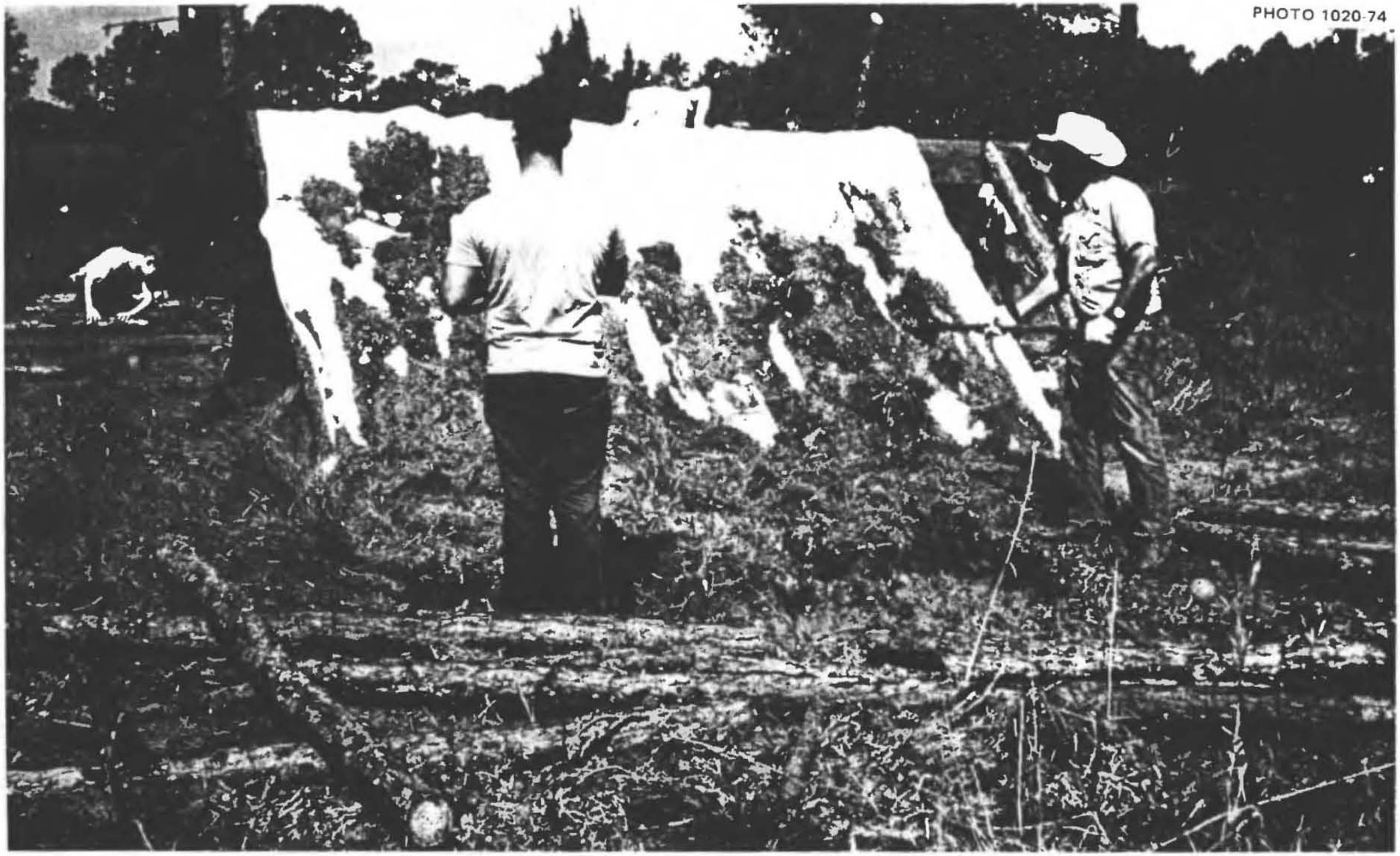

Fig. 5.47. Starting to cover part of the completed side walls with earth. Since these families had plenty of sheets and bedspreads, they placed some directly on the wall poles to keep sand from falling through the cracks.

This group of families failed to follow the instructions that recommended the building of the entryways at the same time the main shelter room was being built.

Urban Americans in Florida were not attracted to the hard work of building good shelters, even when they had the necessary tools and were offered incentives equivalent to about $10 per man-hour of hard work. Several poor families with urban backgrounds turned down Kearny's offer to pay them for building shelters. The workers of the successful rural families earned about $150 each for construction that was completed in 12 hours and 14 minutes.

The man with the shovel is a multimillionaire rancher and a Mormon.

Fig. 5.48. Erecting a tripod made of three 24-ft poles. Kearny's agreement with these mechanized rural Americans specified that they could only use two motor-driven pieces of equipment. To his surprise, they chose to rig a manually operated earth conveyor system, utilizing this tripod, nylon rope, two 5-gallon cans, and pulleys to move earth from the shallow barrow pits to the shelter roof.

Fig. 5.49. Unnecessary work and delay resulted because these families failed to follow some of the instructions, especially as regards placing earth on the shelter starting from ground level and working upward. While Kearny was going to his car to get some food (the mud prevented his driving his station wagon to this site), the ridge of this shelter shifted lengthwise about 4 in. The builders stopped this move with the board brace pictured and then pulled the whole shelter back into its correct position with a chain and powerful hand-operated winch.

Since few families have this equipment, and it would not have been feasible to have built this skewed shelter with the specified horizontal entrances in one end while the necessary emergency braces remained in position, Kearny ruled that these families should build a different type of ventilation opening at this end of the shelter.

PHOTO 0930-74

Fig. 5.50. The simplified, but not as protective, ventilation opening constructed in what had been the end of the shelter toward which the skewing movement occurred. Seven-foot poles were placed on the roof poles, parallel to the ridge board and extending 3 ft beyond the outermost wall poles. Those 7-ft poles formed the overhanging gable shown in this photo. Later, the earth cover was thickened.

Fig. 5.51. The pulley conveyor system actually wasted energy and time, since earth had to be lifted in a 5-gallon paint can up to the hook on the movable pulley; then the earth-filled can was pushed up the upward-sloping nylon rope to a position several feet above the top of the shelter. Then most of the earth rolled down below the top of the shelter, obviously wasting thousands of foot-pounds of work.

The entryway pictured is a miniature version of two small-pole shelters, joined so as to produce a 90° turn. The opening of this entryway faced away from the camera.

Fig. 5.52. The properly completed entryway of the A-Frame Pole Shelter, pictured on the day following its completion. These hard-working rural families built this 21-person shelter in 12 hours 14 minutes, from the time they received the instructions on a farm about 2 miles from the shelter-building site.

The construction included moving and mounding some 80 tons of earth, using only manually powered tools to produce a covering having a minimum thickness of 2 ft.

PHOTO 0934 74

Fig. 5.53. Entrance of the A-Frame Pole Shelter which had a main room 21 ft long and 13 ft wide. If rated a 21-person shelter (as Kearny rated this shelter), this gives each person 13 sq ft of floor space. Both builders and civil defense officials who inspected these shelters agreed that people could get by with 10 sq ft per person of floor space, even though the roof was low and sloping.

Air flow measurements showed that even when there was very slight air movement outdoors, as in the calmest weather observed, the opposite-facing crawlway entrances at each end of this type of shelter resulted in air movements through the shelter of 300 cubic feet per minute or more. Only in very hot, calm weather would natural ventilation be inadequate for the cooling of 21 people in this shelter.

Two young wives in these families were in an advanced stage of pregnancy and therefore were given the job of building the required Kearny Air Pump. They built an excellent KAP to fit the entryway, while guided only by illustrated written instructions.

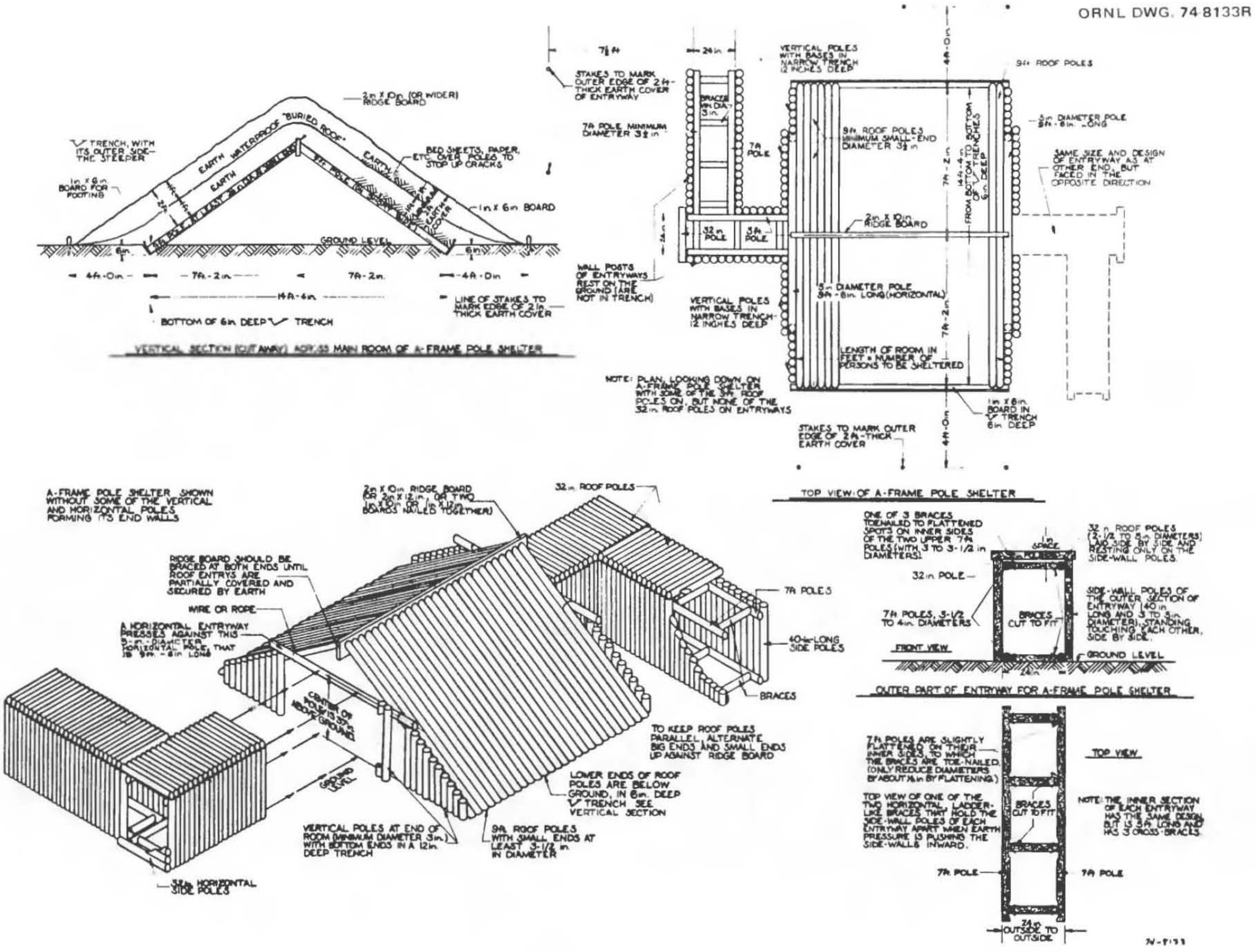

Fig. 5.54. A-Frame Pole Shelter.

E. Other Florida Experiments

The following captioned photographs (Figs. 5.55–5.70) indicate some of the reasons why the preceding above-ground expedient shelters were designed as described and were selected from among a number of designs using the same materials. Shelter designs were rejected which required more material and labor than competitive designs that were adopted, which were more difficult to ventilate and cool adequately, or which were unsafe.

PHOTO 0908-74

Fig. 5.55. The first of the hollow-core doors used to roof the initial prototype of an above-ground, door-covered shelter using earth-filled rolls for its walls. Since at this time Kearny did not realize that earth-filled rolls made of bed sheets or 4-mil plastic film could be used to form strong and stable *vertical* walls, these rolls were made sloping inward. This resulted in the free span of the roofing doors being about 5 ft wide. When the single-thickness doors of this roof were loaded with 15 in. of heavy, sandy soil, they broke within 1 to 3 days, although the earth was dry and no rain fell. Humidity, however, was high.

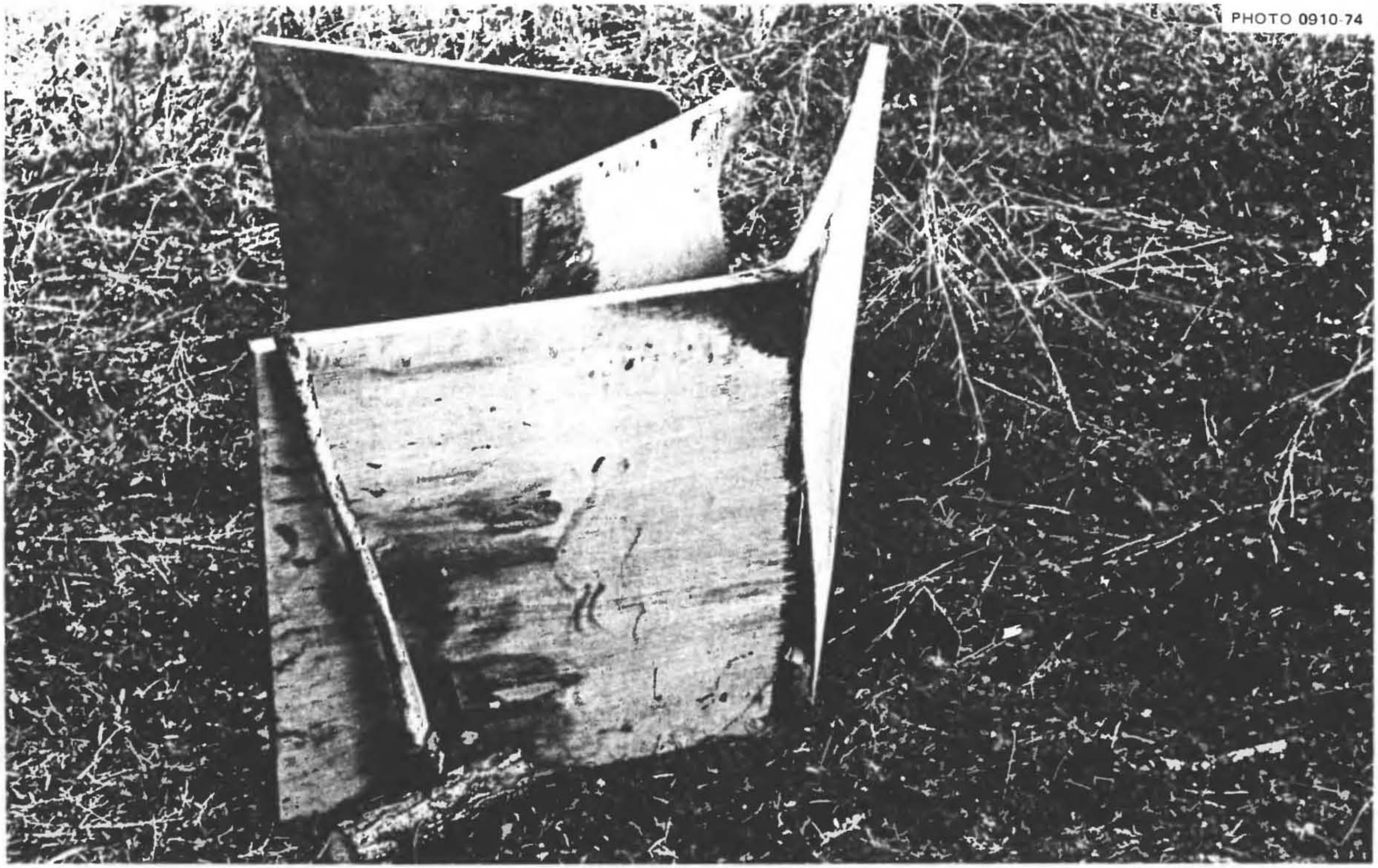

Fig. 5.56. Two of the broken roof doors after they were moved from the previously described shelter. Because the ratio of the depth of earth cover over these doors to the width of free span was too small, the centers of these broken doors fell to the floor of the shelter.

Note that the upper, $\frac{1}{8}$-in.-thick plywood of these hollow-core doors was not broken. If the earth cover had been thicker in relation to the free span (with a thickness-to-free-span ratio of $\frac{1}{2}$ or more), earth arching would have prevented these roof doors from being depressed sufficiently to injure occupants of the shelter, even if the plywood on the lower sides of these doors had been completely broken.

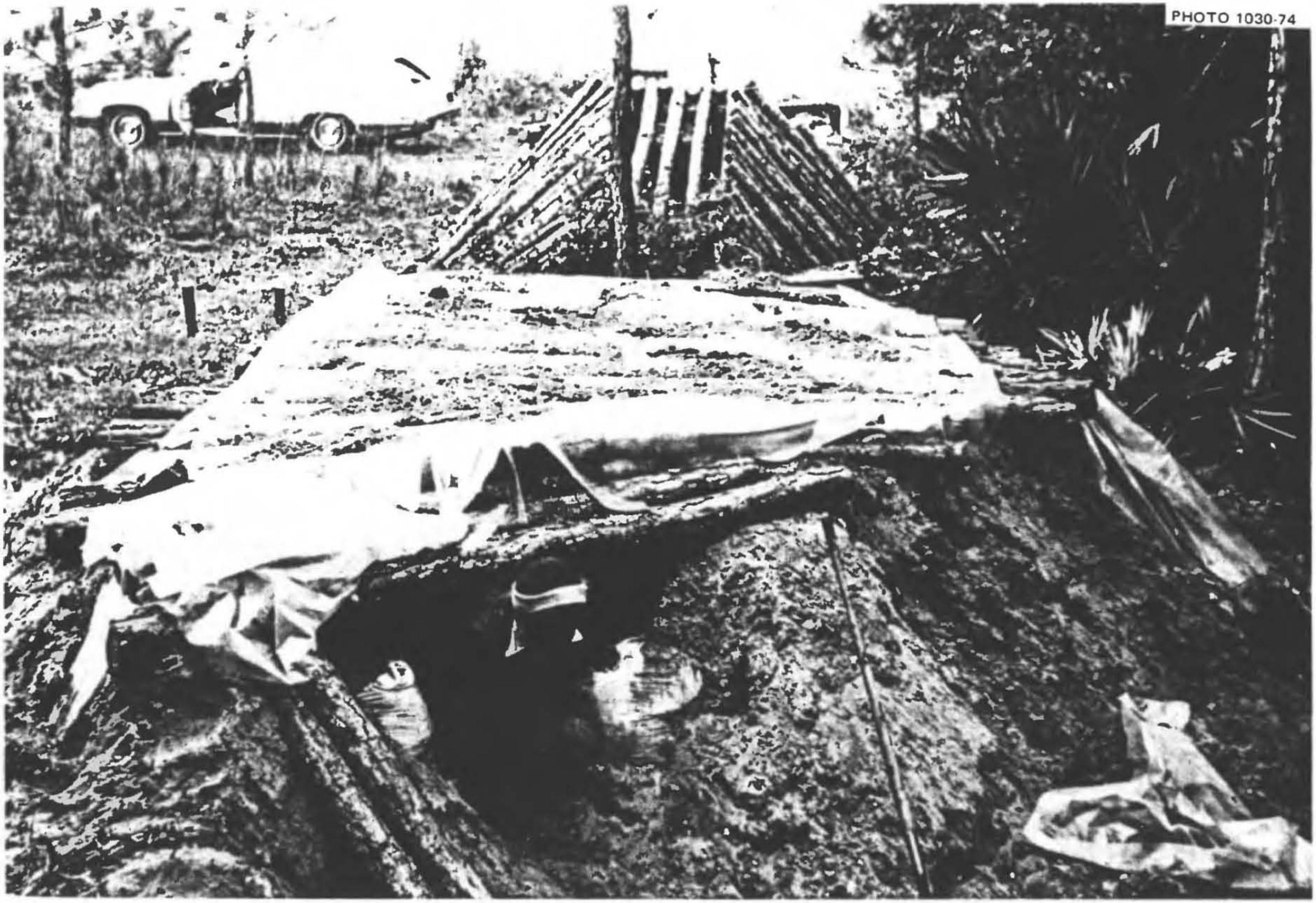

Fig. 5.57. The same shelter after being roofed with substantial pine poles placed on the walls made of undamaged rolls. Later, 2 ft of earth was mounded over these roof poles. At the time this shelter was completely demolished, almost one month later, the sheet-covered rolls were still in satisfactory condition. However, where black organic matter was in contact with cotton sheets, the fabric was beginning to rot.

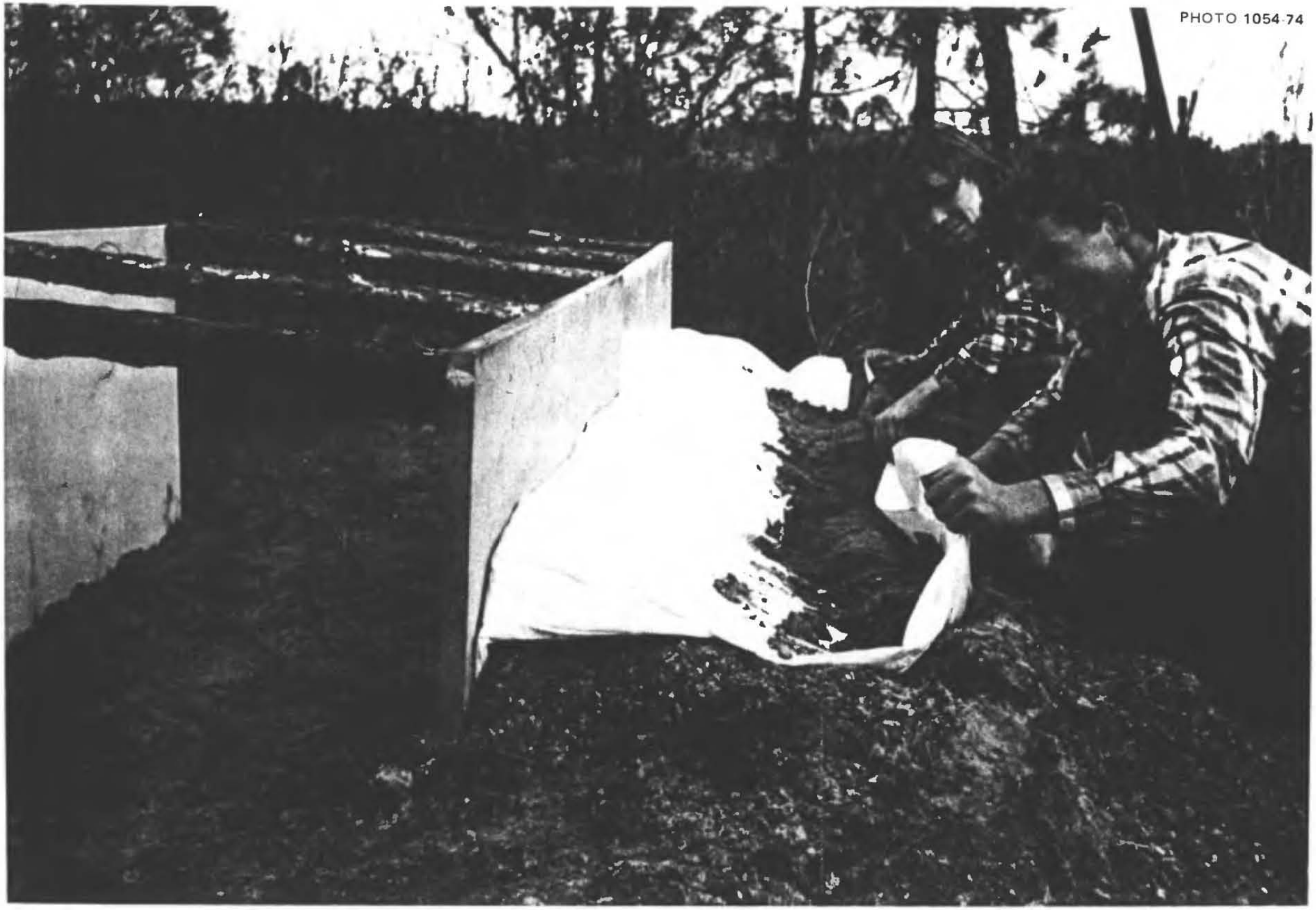

Fig. 5.58. Workmen building the first prototype of a shelter with vertical interior walls consisting of 2 or 3 rolls, stacked one on top of the other. This photo shows the workers forming an earth-filled "hook," which holds the part of a sheet forming the upper side of a roll in place, so that especially the vertical inner side of the roll will remain in place when the door form is removed.

PHOTO 1031-74

Fig. 5.59. A view of one end of an experimental setup designed to test the strength and dependability of hollow-core doors used to roof an above-ground shelter with vertical walls made of earth-filled rolls, under humid, wet conditions. Two doors that had been painted with two coats of interior-type latex paint were only slightly bowed after being subjected to the pictured loading for almost a month. The doors were protected from moisture by a sheet of 4-mil polyethylene placed directly on them. Note that this roof slopes to the right, so that water will not leak through the plastic.

Heavy rains fell during the test period, but the cardboard honeycomb structures inside these painted doors were found to be only slightly damp at the end of this successful test. The earth at the edge of the pictured door was held almost vertical by being contained in an earth-filled roll extending the full length of the door.

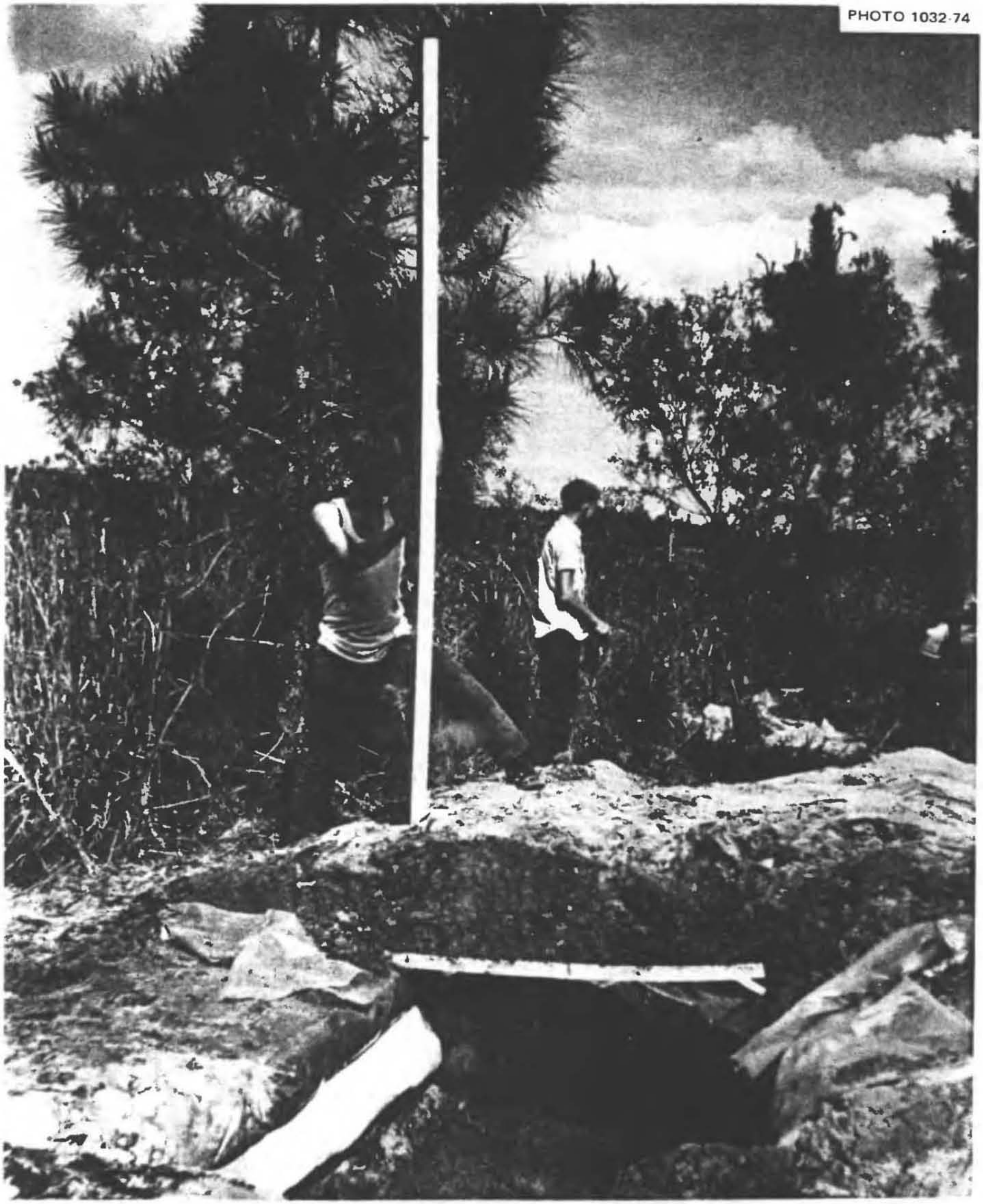

Fig. 5.60. The painted hollow-core door previously pictured, soon after it had been uncovered and removed from the walls made of rolls. Note how slight was its permanent warp or bow.

The second painted door is pictured in test position.

Fig. 5.61. The opposite end of the roof-door experimental setup, photographed almost one month after the beginning of this experiment. This broken-in door was unpainted. The same type of polyethylene film covered all the doors in this test. The unpainted door absorbed more moisture and was broken by the same thickness of wet earth cover that the painted doors survived. However, if the roof broke in this manner, occupants of a shelter would not have been injured, due to the fact that earth arching prevented the broken door from being dangerously depressed into the shelter.

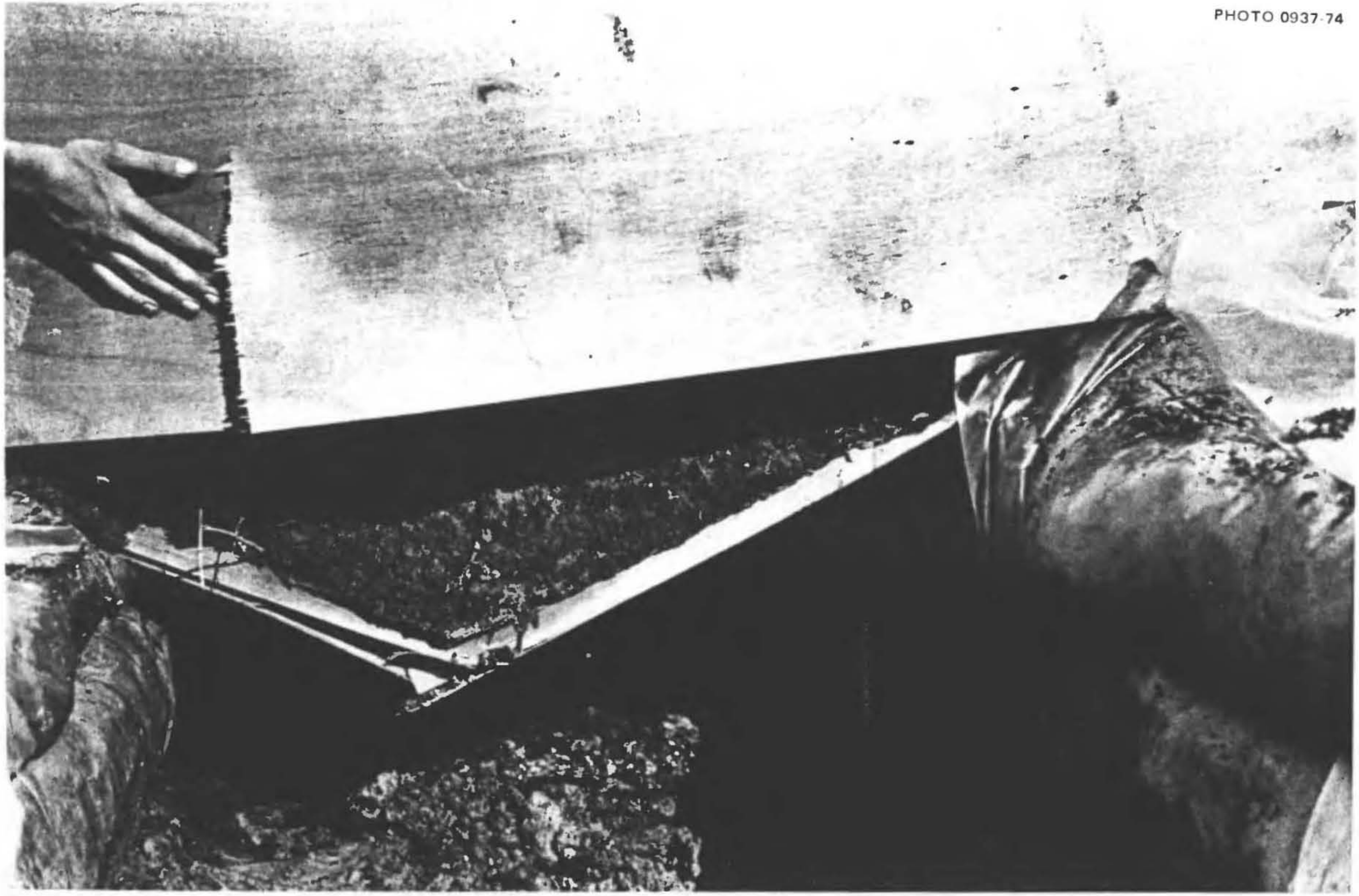

Fig. 5.62. The same unpainted and broken door, showing its upper $\frac{1}{8}$-in.-thick plywood still intact.

The partly broken and upturned door (against which the man's hand rests) was an interior door with two coats of varnish. It was subjected to the same earth loading and other conditions as were the other three doors in this experiment. Its partly broken condition indicates that varnished doors may not be as satisfactory as are painted doors for use as roofs under rainy, humid conditions.

Fig. 5.63. Preparing to test a hollow-core interior door used as a roof door of an expedient Tilt-Up Shelter, built following instructions received from Donald A. Bettge, DCPA. The plywood (that was nailed to the horizontal 2 × 4s connecting the two pine trees) represented the side of a house. The door slopes 45° and is secured at its base by stakes.

No trench was dug below the door, since the water table in this area is only about 1 ft below the surface.

The shelf nailed to the door was made of the specified lumber. Careful nailing with small box nails was required to connect it to the thin side-reinforcements of the hollow-core door, to avoid weakening the door.

Fig. 5.64. The door was loaded with about half the specified average thickness and weight of earth, due to earth falling off the sides.

Note the protective covering of 4-mil polyethylene film placed directly on the door. Prior tests in this humid part of Florida showed that if waterproofing material is not placed directly on a hollow-core door, the cardboard honeycomb of the door becomes damp, and the door fails much sooner than if the damp, wet earth is not in direct contact with it.

When this single roof door was thus loaded with approximately half the weight per square foot of earth specified for a double-thickness door roof, this door was not over-stressed, and the downward bow did not increase for the three days of testing before the earth was removed.

Fig. 5.65. A single hollow-core door simulating a section of the roof of a Tilt-Up Door Shelter. The unnecessary shelf had been removed; an earth cover approximately equal to the specified weight of earth for the double-thickness roof doors of the DCPA shelter was positioned. The door had been covered with 4-mil polyethylene, and earth-filled rolls were placed along both its sides. These rolls made it possible to place steep-sided earth cover on the door.

This experiment was set up shortly before sunset and photographed. Note that the single door was dangerously bowed. At some time before the following morning, this door broke through. If a person had been below it, he would have been injured.

A Tilt-Up Door Shelter necessitates using a double thickness of doors to build a shelter that affords radiation, fire, and blast protection inferior to that provided by a Door-Covered Trench Shelter or by a Door-Covered Above-Ground Shelter with earth-filled rolls for walls. These door-covered shelters, which have essentially rectangular cross sections and much shorter free spans, require: (1) only a single-thickness door roof; (2) a number of doors that a far larger fraction of families have available in their homes; (3) more work but less skill to build than do Tilt-Up Door Shelters; and (4) much better protection against blast and fire.

Fig. 5.66. An above-ground Small-Pole Shelter with an interconnected room on each side, beneath 9-ft side-wall poles that slope at 36°. This prototype shelter had 200 sq ft of floor space in its three rooms, was built by a contractor's workmen, and later was covered with a full 2 ft of earth by a backhoe.

Kearny concluded this shelter was impractical for even average *rural* Americans to build because: (1) The two doorways near the ends of the two side rooms were quite difficult to build, yet did not result in a measurable volume of air flowing through the side rooms even when a KAP was forcing a pleasant breeze through the center room; and (2) Ridge-Pole and A-Frame Above-Ground Shelters are easier to build and cover with earth, and permit straight-through, efficient ventilation, both natural and forced.

Note the vertical entryway, which requires too much earth to cover when built above ground.

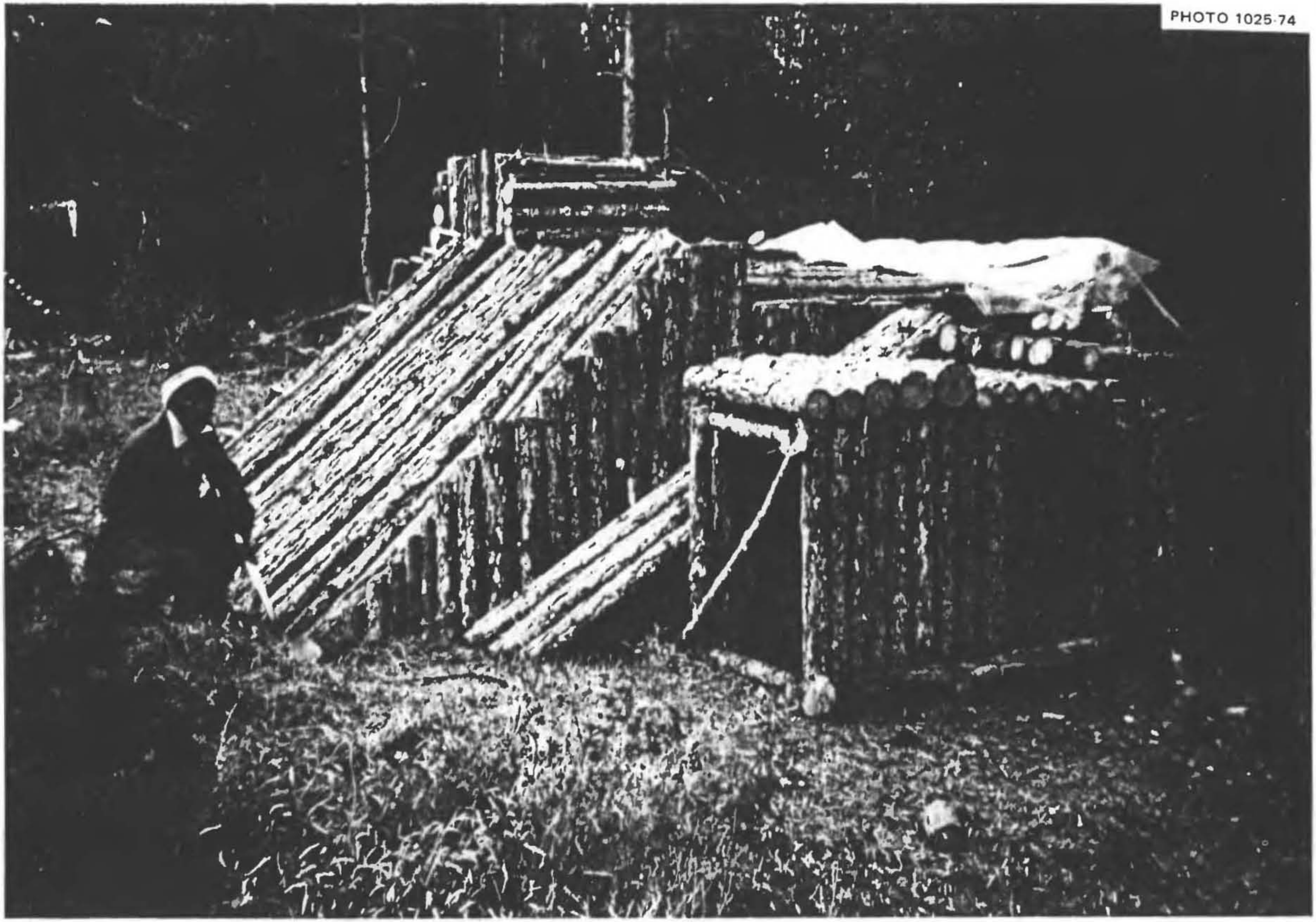

Fig. 5.67. The horizontal crawlway entry of the three-room shelter consisted of two miniature Small-Pole Shelters connected so as to form a 90° turn. This type of horizontal entryway, built at each end of an above-ground shelter, proved the most practical type of entryway, especially as regards requiring less earth to cover with a 2-ft minimum thickness.

Fig. 5.68. Backhoe covering the unsuccessfully modified Small-Pole Shelter with three rooms built entirely above ground. The backhoe worked for almost 5 hours to place earth on this shelter to a minimum depth of 2 ft, because it could excavate only a little over a foot deep without getting stuck. The backhoe repeatedly had to lift itself out of the mud on both its buckets, although this work was done toward the end of a long dry spell.

Machines in areas with high water tables are relatively more handicapped than are men working with hand tools.

Kearny concluded that above-ground, stoop-in, single-room shelters with roofs that slope upward rather gently on both sides to a ridge line are more practical for builders to cover with shielding earth than are shelters with rectangular cross sections that have equal maximum ceiling heights and equal floor areas. The former shelters require less than half as much earth to cover to a minimum depth of 2 ft than do the latter shelters, with their vertical sides.

Fig. 5.69. An experimental, partially completed, prototype stoop-in pole shelter designed by Kearny with horizontal wall poles, in order to minimize the cutting of poles needed to build a given area of walls. After the level of the earth mounded around this shelter had been raised about 3 in. higher than the uppermost poles, the 6-ft-wide shelter was roofed with 9-ft poles resting on the mounded earth. Then 2 ft of earth cover was placed on the roof.

Kearny concluded that this shelter is not as practical as the Small-Pole Shelter (which has short vertical wall poles) because:

(1) The workmen needed repeated supervision to select and lay the long poles properly (short vertical poles are easier to fit together).

(2) The bracing tended to be forced out of square when earth was mounded onto and over this shelter. (The ladder-like horizontal bracing of a Small-Pole Shelter does not have this tendency.)

(3) If this type of shelter were built much longer, the problems of hauling and/or splicing the long wall poles would be quite difficult.

Fig. 5.70. A shallow well for drinking water, dug into the free-flowing sand below the water table. Note the rectangular board shoring, which was forced downward as the free-flowing sand was dug out from inside and below this shoring frame. Twigs and leaves were stuffed in behind the frame, to help check the inward flow of sand, that otherwise would have led to the collapse of the sides of this well. Without instructions, average Americans would not be able to dig a well inside their shelter, from which they could dip water repeatedly without causing disastrous caving.

Kearny successfully dug another shallow water well in this area, by driving eight 3-ft pole stakes in a circle 18 in. in diameter. He drove these stakes from the bottom of a 2-ft-diameter hole after first digging to the top of the water table, which was 15 in. below the surface. He placed thin saplings and grapevines behind the eight stakes, as the well was dug deeper, to prevent sand from flowing into the well.

CONCLUSIONS

1. In areas where water or rock near the surface prevent the building of below-ground expedient shelters, most families could build for themselves above-ground expedient shelters affording much better fallout, blast, and fire protection than do most existing buildings.

2. The building of even the least protective of the shelters described in this chapter, the Above-Ground Door-Covered Shelter, would often be justified because:

a. If an all-out nuclear attack occurs, 2-week fallout doses of 5,000 to 10,000 R are quite likely (Fig. 1.1).

b. The lightly constructed homes typical of areas with high water tables lack basements and afford fallout protection in the PF 2 to 4 range.

c. An Above-Ground Door-Covered Shelter, with PF 200, requires less work and time to build than is needed to improve the shielding of part of a lightly constructed home so as to make much more comfortable shelter giving perhaps PF 20 protection.

3. Because citizens vary so greatly in their shelter-building abilities and in what materials and tools they could obtain during a rapidly escalating crisis, field-tested instructions for building several types of expedient shelters, in areas with very high water tables or where rock is near the surface, at least should be readied for distribution during a possible crisis.

6. An Urban Family Building a Car-Over-Trench Shelter

BACKGROUND

The Car-Over-Trench Shelter affords by far the least protection of all the expedient shelters built to date as part of ORNL civil defense research. However, for some urban Americans who might have to evacuate into practically treeless, sparsely inhabited country such as the area inland from San Diego, a Car-Over-Trench Shelter would afford better fallout protection than an open trench or a lightly constructed house improved by piling earth around the walls. Except for cars so constructed that it is impractical to provide adequate shielding above the area under the back of the back seat, the protection factor is in the PF 80 to 100 range.

Prior summer tests of Car-Over-Trench Shelters built in Tennessee and Colorado had proven that, especially in warm, still weather, forced ventilation is essential to keep the shelter habitable. A homemade small KAP will supply sufficient outside air. But in near-zero weather, there appears to be no practical expedient way to keep this shelter from becoming too cold for most Americans.

Car-Over-Trench Shelters, even if carefully built, leak a little in a heavy rain – another disadvantage of this almost last-resort shelter.

WINTER TEST IN COLORADO

The following captioned photographs describe how an urban mechanic from Los Angeles, with inconsequential help from his diabetic wife and no help from their nine-year-old daughter, evacuated in his car, built a Car-Over-Trench Shelter, and stocked it for prolonged occupancy.

PHOTO 3059-73

Fig. 6.1. The mother of an urban family assembling the recommended categories of items (see Evacuation Check List, Table 1), preparatory to simulating evacuating a city in their family car and building a Car-Over-Trench Shelter. This family had recently come to Montrose, Colorado, from Los Angeles and had not yet finished settling into their small apartment in the town of Montrose.

On receiving the check list for evacuees and the shelter-building instructions at 8:03 AM on Nov. 24, 1973 (simulating their receiving this survival information in a crisis edition of the local newspaper), they first spent 12 minutes reading, then started assembling the various categories of recommended items to be taken in their car.

Fig. 6.2. The father washing three plastic garbage disposal cans (each about 5-gallon capacity) preparatory to disinfecting them with Clorox. He followed the instructions for providing large-volume water containers. One of these lidded cans was filled with water and, nested inside the two empty cans, was carried in the car to the building site.

Before starting to load their car, this family did a good job of repeatedly consulting the Evacuation Check List and piling the different categories of items in separate piles in their apartment.

Fig. 6.3. **Taking all of, or some of, each category of evacuees' survival items from their apartment.** These items included, for lack of a shower curtain or plastic table cloth, a piece of plywood about 4 × 4 ft.

Fortunately, this family had a practically new pick and shovel, with which the father had recently started to dig the foundations of a house he plans to build on a small piece of land some miles out of town. Without a pick and shovel, or at least a heavy hoe and a shovel, no family in two or three days could dig even this smallest of expedient shelters in

Fig. 6.4. Reading over the Evacuation Check List for the last time, to be sure nothing had been overlooked, before driving their heavily loaded Maverick to the rural shelter-building site.

This family drove away from their home 1 hour 43 minutes after first receiving the instructions. This was the first family to simulate evacuating while being guided by this type of Evacuation Check List, and the second family to build a Car-Over-Trench Shelter guided only by written instructions.

PHOTO 3062-73

Fig. 6.5. Unloading tools, food, and water at the building site on the Kearny farm about 5 miles from Montrose. Work on the shelter began at 10:11 AM. This family brought along two items that were not on the Evacuation Check list (and will not be), but which they said they would carry with them in a real evacuation: their .38 automatic with extra ammunition and their toy poodle. Both the pampered poodle and daughter stayed in the car almost all of the time.

The mother, a diabetic with poor circulation, wore typical snug-fitting women's rainboots in the melting snow and near-freezing mud on the surface. (About 3 in. down, as a result of an abnormally dry fall, the earth was dry and hard.) She soon had painfully cold feet, and did nothing sensible, like wrapping and tying towels or other cloth around her feet to keep them warm. Kearny, fearing she would get sick, shortly before noon had his assistant drive her home to her apartment

Fig. 6.6. The father swung his pick properly, a result of his learning to use an ax as a boy of 12, when his family spent a while in rural Oregon. However, he tied unnecessary strings between the stakes, and left them tied, and dug the trench too narrow. Later, he spent about two hours inefficiently widening it.

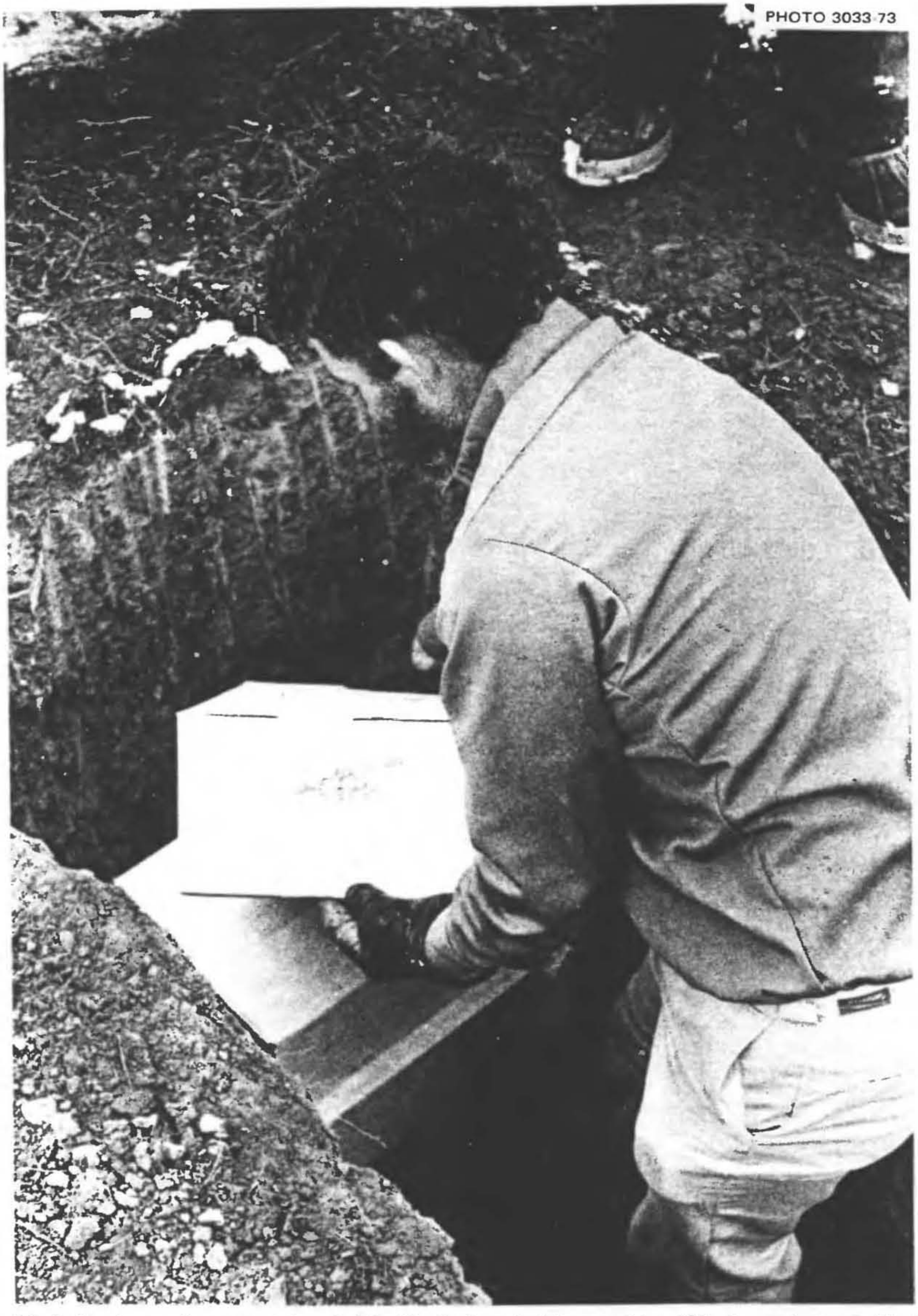

Fig. 6.7. Putting boxes of concentrated survival food in the far end of the completed, 40-in.-deep main trench. The father, a Mormon, is a salesman for a Mormon-owned company that makes survival foods and health foods. As a result, he was able to stock this trench shelter with enough food for at least two weeks on full rations for these three provident Mormons and their dog.

Fig. 6.8. Some of each category of survival items stored for the night in the completed and very dry main trench. The family was parked for the night over the stocked trench. The father, tired, quit at 5:33 PM, and was driven to his apartment in town to join his half-sick wife and daughter.

PHOTO 3034-73

Figure 6.9. At 10:05 AM on Nov. 25, the father drove the car, on which a light snow had fallen during the previous night, evenly over the trench. Just before this, he had turned too sharply, and had come close to slipping a rear wheel into the trench – another reason for not making such trenches wider than 28 to 30 in.

After arriving on the site at 8:20 AM, the father laboriously dug the entryway trench and steps, and widened the main trench – work that should have been done concurrently with digging the main trench to its specified depth. He worked a total of 8 hours 45 minutes digging this shelter.

PHOTO 3035-73

Fig. 6.10. Putting a foot of earth inside the car and in the trunk. Unfortunately, before loading the car with about 2 tons of earth, the father and mother put many of their possessions under their car and on the surface of the ground around the edges of the trench. As a result, when the car body was depressed by its earth load, potatoes in a bag were crushed and cans were pushed into the wet earth near the surface.

For want of a second shovel, the mother used an empty can to help dump earth inside the car.

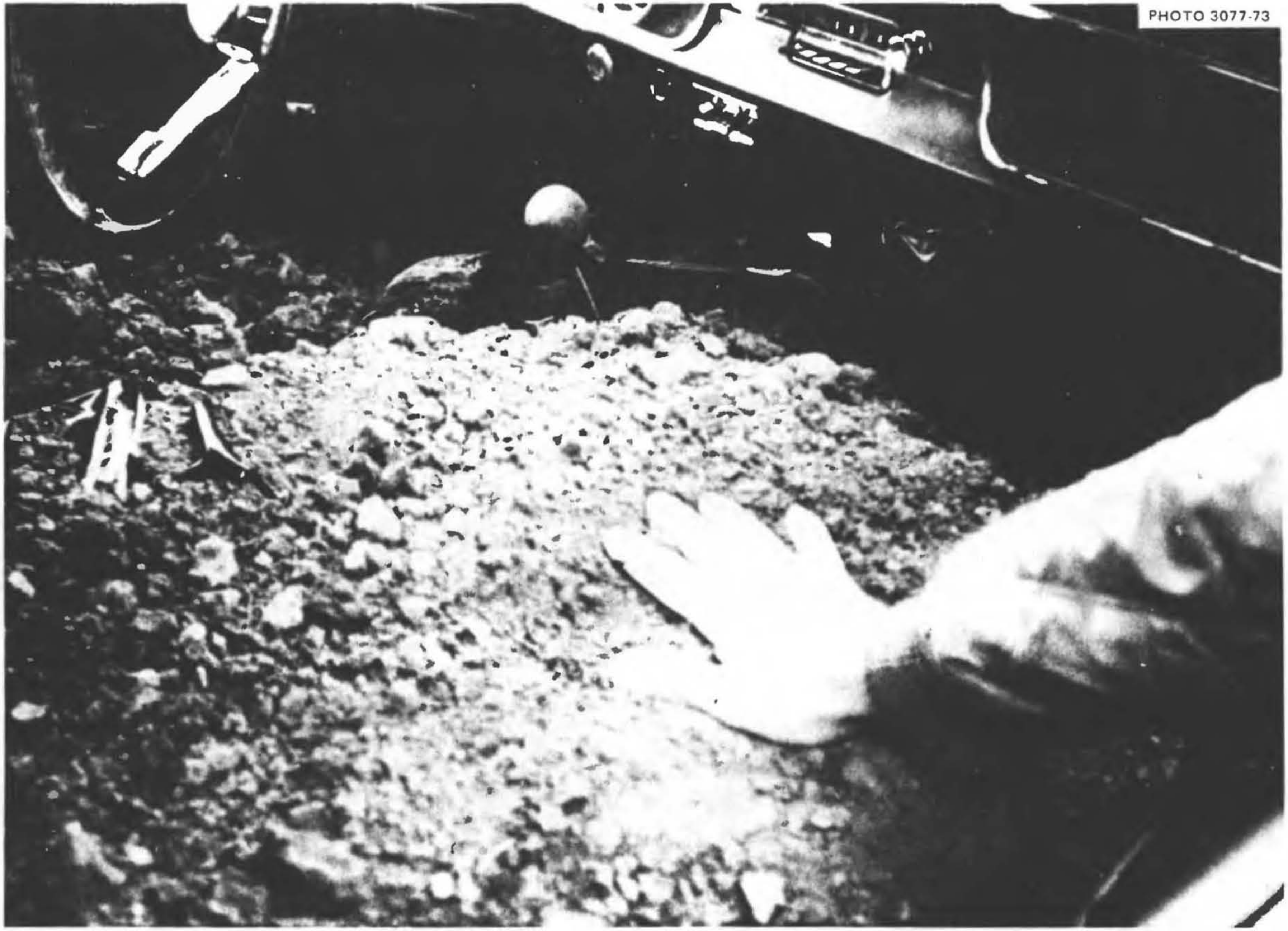

Fig. 6.11. About a foot of earth inside the car. Note the black plastic lining under the earth. Kearny, after several families had refused his offer of $250 to build a Car-Over-Trench

Fig. 6.12. Taping split-open plastic garbage bags to the sides of the car, for want of other waterproof material to keep some of the dry earth to be mounded around the car from running under the car onto the storage "shelf" areas around the edges of the trench, or into the trench. Fortunately, the father had some waterproof duct tape, and cleaned the dirt off the spots on the car to which he planned to tape the plastic. However, because he did not tape all of the upper edges of the pieces of plastic, if water had run down the sides of the car, much of it would have run under the upper edges of the plastic and into the shelter space under the car.

PHOTO 3040-73

Fig. 6.13. Placing earth-filled plastic garbage bags around the edges of the entryway trench.

The mother was able to remain on the site all of the second day and do some work – thanks to a borrowed pair of insulated boots that kept her feet from getting painfully cold.

PHOTO 3044-73

Fig. 6.14. The Car-Over-Trench Shelter was completed at 4:15 PM on the second day. The father did about 95% of the work; 14 hours and 27 minutes were spent working at the site. This family did not win the bonus for completion within 24 hours from the time work began.

The mother said she found the experience "quite exciting."

Note the plywood "awning" over the entryway opening, used for want of better rainproof material to be found in this family's modest apartment.

Fig. 6.15. The father (sitting on a box) and the mother in their 40-in.-deep, 28-in.-wide shelter. Enough room remained (occupied by the photographer's leg when this picture was taken) for the small daughter and the family poodle. All of their supplies had been placed under the car.

Fig. 6.16. A 17 × 19 in. KAP being used to pump about 100 cubic feet per minute through a Car-Over-Trench Shelter, and out through the 110 square inch exhaust opening. Especially during hot, sunny weather, temperatures inside a Car-Over-Trench Shelter would become intolerable without adequate forced ventilation.

This small pump was built by a boy who was guided only by the well-illustrated, written instructions. He used sticks cut from bushes for the frame, and polyethylene cut from trash bags for the seven flaps. The pull cord runs through the greased fork of the forked-stick "pulley" suspended in front of the KAP. Thus pulled, the KAP swings evenly on its looped-wire hinges.

CONCLUSIONS

1. A Car-Over-Trench Shelter affords better fallout protection than do most existing structures that could be used as shelters in areas lacking trees or other obviously appropriate materials for roofing a trench shelter.

2. Since most Americans – if given proper detailed instructions – could build better expedient shelters in almost all areas, expending no more time and effort than required to build a Car-Over-Trench Shelter, the disadvantages of this shelter should be clearly explained to potential builders.

3. For use in treeless areas by urban evacuees who would have to carry shelter-roofing material with them in small cars, trench shelters roofed with rugs and other fabrics should be thoroughly investigated.

7. Large Log-Covered Shelters in Bulldozed Trenches

BACKGROUND

Since digging the excavations needed for high-protection-factor expedient shelters is the most laborious part of manual construction, an *apparently* quick and easy way to build shelters for thousands of urban Americans would be to use bulldozers to excavate big trenches and then to roof these trenches with logs capable of supporting the shielding earth. Although this design is an old one, the author has been unable to find any record of log-covered shelters in bulldozer-width trenches actually having been built, other than the two large shelters constructed under his supervision.

If skilled loggers, specialized log-handling machines, and tools and suitable trees are available, in 48 hours log-covered trench shelters utilizing typically wide bulldozed trenches can be built to shelter about ten times as many occupants as the number of skilled loggers* involved in construction. However, only a very small fraction of the shelter spaces that would be needed in a rapidly escalating crisis could be constructed by the relatively small number of men and machines that work in the timber.

FIFTY-OCCUPANT LOG-COVERED TRENCH SHELTER BUILT IN ALABAMA

To make a better evaluation of the practicality of building large log-covered shelters in bulldozed trenches during a crisis, a non-logging contractor was employed to build a 50-occupant shelter of this type on a gently sloping wooded hillside near Gadsden, Alabama. The length of its 12-ft-wide room was 42 ft; its ceiling height was 7 to 8 ft. Because its two entrys lacked horizontal passageways leading to the shelter room, its protection factor varied from about PF 300 near its entrys to at least PF 1000 near its center.

The contractor who built this shelter specialized in pipeline work. His men were not accustomed to handling logs, nor did they have cant hooks or other specialized equipment needed to handle 22-ft logs efficiently. The following complications beset the building of this apparently simple expedient shelter, which required *two weeks to complete:*

1. For several days, rains kept the logging trucks of the subcontractor out of the woods. (Workers with hand tools could have continued working during these warm summer rains.)

2. The first load of logs trucked to the building site were mostly too short; somehow, in the chain of orders, the men who actually felled the trees did not understand that all the large-diameter logs had to be 22 ft long.

3. The backhoe could not reach the shelter site, which was slippery with wet clay, in time to dig the drainage ditch from the bulldozed trench. As a result, over 2 ft of rainwater collected in the excavation, which was on the side of a small hill.

4. The workmen wasted much time waiting for equipment and materials and for the completion of parts of the job.

5. The workers took time off on holidays and on days when it rained. However, if they had worked positioning the heavy logs in the slippery wet clay while it was raining, the chances of a serious accident would have been quite high.

6. A few days after completion of this shelter, several tons of earth fell off the vertical wall of the wet, uphill side of the shelter. If the shelter had been occupied at the time, serious injuries could have resulted. To make this Alabama shelter safe for a shelter-occupancy exercise, the fallen earth had to be removed by hand, and the wet, uphill wall had to be shored with poles and boards.

7. The total construction cost of this 50-occupant shelter built in 1972 was about $7180, or about $143 per occupant-space provided. This is almost three times the cost per occupant-space of the similar large shelter built in 1972 by expert loggers in Colorado. The cost

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*C. H. Kearny, "Construction of Hasty Winter Shelters," *Civil Defense Research Project Annu. Prog. Rep. March 1971*, ORNL-4784. Experienced loggers (using chain saws, a D-6 bulldozer equipped with a ripper and log-winch, cant hooks, etc.) completed a 45-man shelter in 129½ man-hours of work, without building the ventilating KAP need for temperate or warm-weather occupancy.

was at least 50% more, the author estimates, than what would have been the cost per occupant-space if these same Alabama workers had built two Small-Pole Shelters, each accommodating 25 persons, with these two shelters placed side by side in a 15-ft-wide bulldozed trench. (Russian-type Small-Pole Shelters are built of small poles, most of which are only 7 ft long, and need be of diameters no greater than $4\frac{1}{2}$ inches. Their boxlike construction makes them safe to construct even in unstable sand.)

SOME OTHER DISADVANTAGES OF LARGE EXPEDIENT SHELTERS

The larger the shelter and the more numerous the people who are supposed to build it, the less each worker tends to work and the more the workers get in each other's way.

If an expedient shelter has more than about 25 occupants, problems of management and hygiene become more difficult.

An even more serious disadvantage is the probable lack of dependability of plans for having contractors' workmen build large expedient shelters during a desperate crisis period. The author has questioned contractors' workmen in Tennessee, Alabama, Florida, and Colorado regarding what they would do if during a crisis the President urged Americans lacking good shelters to build shelters for themselves in two days. With few exceptions, these workers said they would build shelters for their own families.

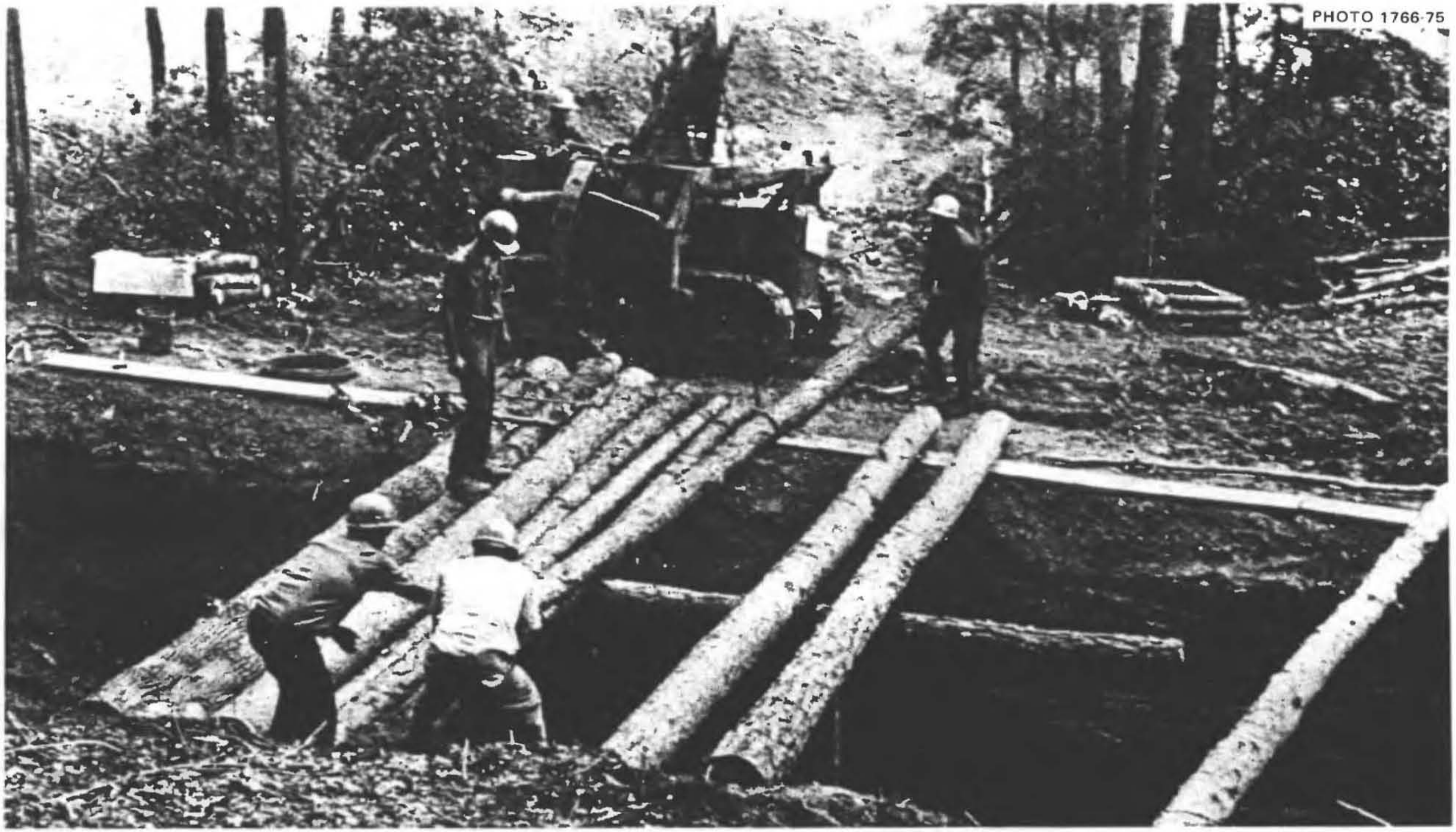

Fig. 7.1. Workmen of a pipeline contractor laying 22-ft logs across a 12-ft-wide bulldozed trench. This trench was bulldozed 7 to 8 ft deep into firm, weathered-in-place Alabama clay. The sides of the trench were vertical.

Note the 2 × 12 in. footing boards, on which the 22-ft roof logs rest, one beside the other. The inner edges of these footing boards were placed 20 ft apart, so that the weight of the roof, with its 3 to 4 ft of earth cover, would not tend to shear off the sidewalls of the vertical-walled trench.

If dug in this type of earth, unsupported sidewalls of such an unshored trench are safest if sloped almost up to the inner edges of the footing boards. Pick-and-shovel workers can slope trench walls quite readily in this manner, but a bulldozer cannot.

A few days after the completion of this shelter, several tons of wet earth sheared off part of the uphill vertical sidewall. In one place, this earth fall extended to the inner edge of a footing board. No movement of roof logs occurred. This was the only potentially dangerous failure of any of the several dozen expedient shelters built or supervised to date by the author.

Fig. 7.2. Starting to erect one side of an entryway, after all of the 22-ft roofing logs had been positioned. A vertical entryway was placed at each end of the 12 × 42 ft shelter room.

Note the line of log columns down the center of the trench. These log columns, which rested on a plank footing and were spaced 4 ft apart, supported a horizontal center log. The centers of all the roof logs rested on this horizontal center log.

When even experienced workmen are building a large shelter of this type, frequently only a few men can work productively at any one time, because one part of the structure must be completed before other parts can be built.

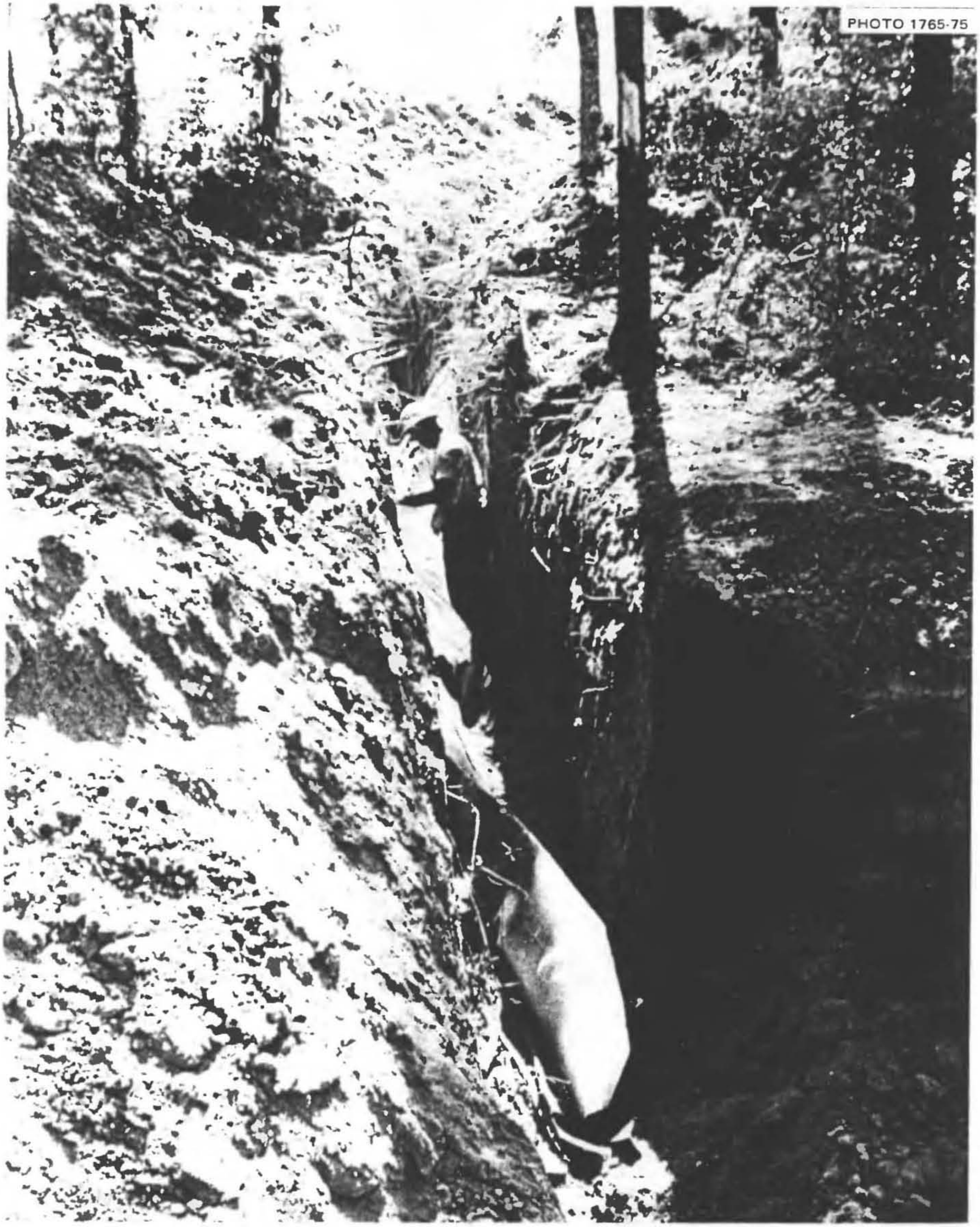

Fig. 7.3. Expedient drainage "pipe" being made of a pile of sticks about 6 to 8 in. deep. The clean sticks were placed along one side of the gravity-drainage ditch leading from the lowest corner of the shelter excavation. To keep earth from getting between the sticks and preventing them from functioning like a pipe, plastic was placed over the continuous pile or bundle of clean sticks. Then earth was backfilled on top of this protective plastic covering.

When completed, this "pipe" of covered sticks drained away over 2 ft of water which had been standing in the bulldozed trench and kept the shelter dry during the following weeks while a little water continued to seep out of the uphill sidewall.

Fig. 7.4. One of the two completed vertical entries, with its expedient blast door made of 2-in.-thick rough lumber. Its hinges were made of strips of worn auto tires, spiked to each of the vertical entryway posts on the hinged side. A door of this type successfully withstood a blast overpressure of 17 psi.* The other blast door was made of 3-in. planks and may have been able to withstand higher blast over pressures than would collapse the earth walls of this covered-trench shelter.

The roof logs had been covered with roofing to keep earth from falling through the cracks. Then about 2 ft of clayey earth had been packed over the whole roof, on which a sloping "buried roof" of 4-mil polyethylene film had been laid for waterproofing. Finally, another 1 to 2 ft of earth had been placed and packed over the "buried roof."

For adequate protection against the initial nuclear radiation from smaller warheads, producing overpressures in the 10- to 20-psi range, a minimum of 5 ft of earth cover should have been placed on this very strong roof. Furthermore, for better protection against this most severe threat, each entry should also have a horizontal passageway, built like a longer version of that of the Small-Pole Shelter.**

**Blast Tests of Expedient Shelters,* by Cresson H. Kearny and Conrad V. Chester, ORNL-4905.

**"Hasty Shelter Construction Studies," by C. H. Kearny, Chapter 21 of the *Annual Progress Report, Civil Defense Research Project,* ORNL-4679.

PHOTO 1763-75

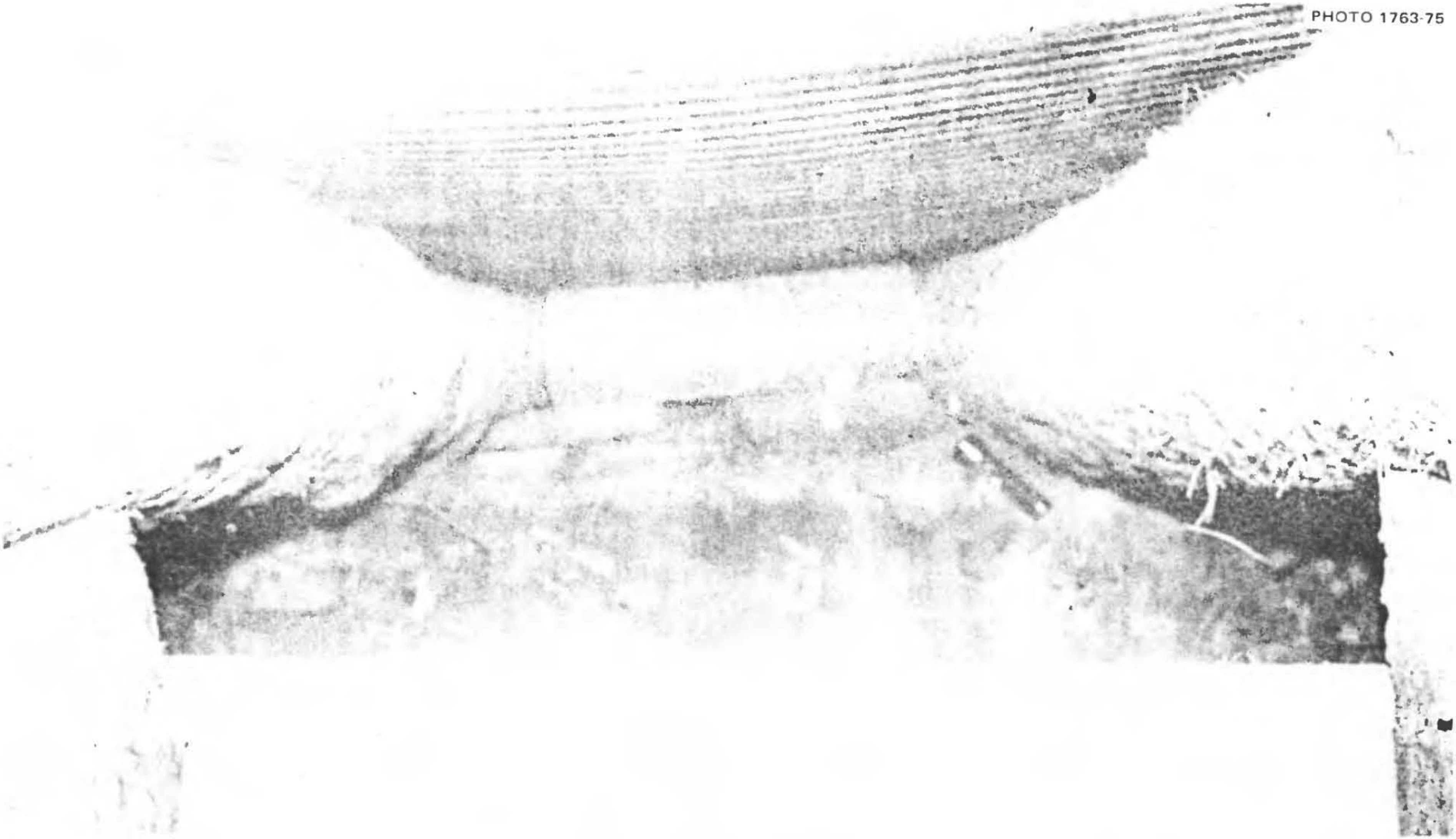

Fig. 7.5. Parts of the roof-boards and two roof-logs, each with its supporting column-log, of the large Log-Covered Trench Shelter built in Colorado in 1972. This 45-occupant Colorado shelter had a different roof design than that of the 50-occupant Alabama shelter; its 22-ft roof logs were of larger diameters, were spaced $2\frac{1}{2}$ to 4 ft apart, and were covered with 2-in. boards or heavy corrugated iron roofing laid parallel to the length of the bulldozed trench. Each of the thick 22-ft roof logs was supported in its center by a column-log. Each column-log was notched with a flat V on top, as illustrated by the tops of the two column-logs shown in this picture.

To make the upper sides of these heavy roof logs all approximately in the same plane, so that the boards would not be bent too sharply and broken by the thick earth covering, most of the ends of the roof logs had to be lifted to the proper heights and blocked up.

CONCLUSIONS

1. If plans for building expedient shelters during a rapidly escalating crisis involve some of them being built by contractors' workmen or municipal workers, the chances of these mechanized workers reporting for work will be improved if they are given credible assurance that they and their families will be the occupants of the first shelters they complete.

2. To provide high-protection-factor expedient shelters for the majority of a population, the shelter-building plans should be based on designs for small shelters requiring only components so light that one or two average Americans can carry a component. Good designs should enable the maximum number of able-bodied citizens – men, women, and children – to work efficiently and without dependence on mechanized equipment while building most of the required expedient shelters.

3. In a mass shelter-building effort intended to provide shelters in a few days, earth-moving machines should be used primarily to excavate trenches, or move the earth needed to cover aboveground shelters. The citizens needing shelters, working if need be with buckets and pots, can move loosened earth and quite readily cover the shelters with a thick earth shielding.

8. Overall Conclusions and Recommendations

1. Tens of millions of Americans – if adequately motivated and given field-tested, step-by-step, illustrated instructions appropriate to their building sites – could build for themselves, in 48 hours or less, expedient shelters with protection factors better than 200. In most areas, PF-200 shelters would provide fallout protection that would greatly improve the chances of surviving the fallout dangers from an all-out nuclear attack.

2. The field experiments described in this report prove – as do other shelter-building experiments in which average, untrained Americans were required to build high-protection-factor, livable shelters under simulated crisis conditions – that most Americans need detailed, step-by-step, illustrated instructions to build good expedient shelters.

3. These field tests have shown that quite modest cash incentives sufficiently motivate average Americans to work very hard building shelters. Therefore, it appears likely that average Americans would work at least as hard to improve their chances of surviving a nuclear attack – provided the highest officials furnish strong leadership during a crisis and support credible survival measures.

4. These shelter-building tests indicate that a large percentage of American families could build and equip high-protection-factor expedient shelters within 48 hours, even if these families were handicapped by:

a. a lack of members having pertinent civil defense training, construction experience, or physical conditioning for hard manual labor;

b. several members being incapable of working effectively;

c. having available to them only common materials and tools found in millions of American homes – especially doors, bedsheets and other home fabrics, waterproof films and materials, plastic bags, and gardening tools;

d. being obliged to evacuate their homes and drive tens of miles to shelter-building sites outside areas of probable blast damage, carrying all shelter-building necessities and supplies with them, as specified in the detailed Evacuation Check List.

5. To enable the majority of people who may occupy expedient shelters (or most good shelters in existing buildings) to stay sheltered long enough to allow adequate decay of heavy fallout, citizens need to receive field-tested instructions for building a KAP shelter-ventilating pump, improvising expedient means for carrying and storing water, and making and using a homemade (yet accurate) fallout meter, expedient lamps, portable cooking stoves, expedient shelter sanitary equipment, shelter furnishings, etc.

6. Realistic multiday occupancy tests of the principal types of expedient shelters should be conducted, after average families have built the shelters under both summer and winter conditions. A number of these field tests should also require average families to evacuate their home areas, preparatory to building and occupying shelters. Some of these shelters should be designed for later enlargement into high-protection-factor habitations in which the occupants could live for months.

7. The ORNL field-tested instructions for building and equipping high-protection-factor expedient shelters should be made available to local civil defense officials. Then, in the event of a crisis, mass distribution of the instructions could be made quickly.

8. The credibility of the U.S. nuclear deterrent forces would be improved if the following conditions were attainable and if the fact that they were attainable were known worldwide:

a. tens of millions of Americans could build and equip high-protection-factor expedient shelters quickly under crisis conditions;

b. these expedient shelters would afford consequential blast and fire protection;

c. most of these shelters would be located outside U.S. cities.

The knowledge of the improved American posture most certainly would contribute to the likelihood of preventing possible major confrontations or the outbreak of nuclear war.

Appendix

These are the instructions (except for a few subsequent minor improvements) used by the urban family that evacuated, built a Log-Covered Trench Shelter. and then lived in it continuously for 77 hours, as described in Chapter 4. Before this experiment, two somewhat inferior. shorter versions of these instructions had been used by rural families to guide their successful efforts to build Log-Covered Trench Shelters.

Experienced builders do not need instructions this detailed. However, very few modern Americans are experienced builders, especially of specialized structures that are designed to provide protection against dangers about which most Americans know very little. Unexpectedly, some of the most highly educated builders of expedient shelters under simulated crisis conditions have made the worst mistakes. These overly confident builders merely look at the drawings. They do not "waste time" reading all of the step-by-step instructions that cover design features having no counterparts in common structures.

INSTRUCTIONS FOR BUILDING A LOG-COVERED TRENCH SHELTER

I. PURPOSE

This simple shelter is designed to give excellent protection against fallout radiation. With 3 feet of earth on its roof, the amount of radiation that comes through the roof is reduced to about 1/1000th of what would come through a canvas or plastic roof. Less than 1/300th of the outside radiation reaches people inside this shelter if the roof is covered with 3 feet of earth. Most of this radiation comes through the two openings, something like ricocheting bullets.

If built outside a flammable woods and sufficiently far from houses to avoid carbon monoxide and smoke dangers, this shelter gives good protection against fire hazards. And if built in very stable earth, blast tests have proven this type shelter is undamaged by blast effects accompanying overpressures of at least 12 pounds per square inch – blast effects severe enough to demolish most buildings.

Construction tests have shown that an average family, using only muscle-powered tools, with no prior instructions and guided only by written instructions can build this shelter for themselves in a wooded area in 48 hours or less, including felling the trees. Using only hand-powered tools and starting with standing trees, only 12 to 18 person-hours of work per person sheltered are required in average-to-hard stable earth.

CAUTION: This shelter should be dug only in very firm earth that will stand in vertical banks about 5 feet high, provided the bank soil is not soaked. Make sure that the earth is firm and stable enough so that the walls of the trench will not cave in. As a test, dig a small hole about 18 inches deep. Remove all loose earth from the bottom of the hole and then try to push a bare thumb into the undisturbed (natural state) earth in the bottom of the hole. If the thumb can be pushed into the earth no further than one inch, the earth should be suitable for this type of shelter. If the earth does not pass this test, move to another location and try the test again. Continue to relocate and repeat until suitable earth is found. (Or, if the earth is not stable, build a Small-Pole Shelter or an A-Frame Pole Shelter.)

II. CHECK LIST FOR BUILDERS

1. Before beginning work, study the drawing and read all of the following instructions. *THEN CHECK OFF EACH STEP WHEN COMPLETED.*
2. *TOOLS AND MATERIAL NEEDED:*
   - A. *Essential Tools and Materials* (for the illustrated *4-person* shelter, with a room 11 ft long).
     - (1) Saw (bow-saw or crosscut preferred) and/or ax – to cut logs and poles, of the lengths and diameters illustrated.
     - (2) Shovels (one shovel for each two workers is desirable).
     - (3) Pick (if the ground is hard).
     - (4) Knife
     - (5) At least 2 square yards (3 sq. yds are better) per person of rainproof roof materials (shower curtains, plastic table cloths, plastic mattress covers, etc.). Rainproofing is almost essential in rainy, cold weather. Also 2 pieces of plastic, or tightly woven cloth, each about 6 X 6 ft, to make canopies over the two shelter openings.
     - (6) Materials for building a simple Shelter-Ventilating Pump, a KAP 22 inches wide and 30 inches long. See attached instruction booklet for building a KAP. Only in cold or continuously breezy weather can tolerable temperatures and humidities be maintained for days in a crowded underground shelter that lacks an air pump.
   - B. *Useful Tools and Materials*
     - (1) Materials for making expedient lamps. See page 18 of attached instruction booklet for building a KAP, that should be 20 in. wide and 36 in. high.

(2) Large cans, buckets and/or pots with bail handles – in which to carry earth and later to store drinking water and/or human wastes.

(3) Two bed sheets and two pillow cases per person – to cover cracks between roofing logs, to make "sandbags", and to improvise bedsheet-hammocks and bedsheet-chairs.

(4) File

(5) Measuring tape, yardstick, or ruler

(6) Rope, or strong wire (100 ft) – to make log retaining walls close to the shelter openings, hammock supports, etc.

(7) Chain saw, pick-mattock, hammer, hatchet, pliers.

(8) Kerosene, turpentine or oil – to keep hand saws from sticking in gummy wood.

3. To save time and work, *SHARPEN ALL TOOLS AND KEEP THEM SHARP.*
4. Wear gloves from the start – even tough hands can blister after hours of chopping and digging, and become painful and infected.
5. If possible, select a location for the shelter that is in the open and at least 50 feet from a building or woods. Remember that on a clear day the thermal pulse (flash of heat rays) from a large nuclear explosion may cause fires even 20 or 30 miles away.
6. If on steeply sloping ground, locate the shelter with its length crosswise to the direction of the slope.
7. Stake out the outlines of the trench, driving stakes as indicated in the two accompanying drawings. If more than about 10 persons are to be sheltered, build 2 or more separate shelters, allowing $2\frac{3}{4}$ ft of shelter-room length for each person.
8. Clear the ground of saplings and tall grass within 10 feet of the staked outlines so that later the excavated earth can be easily shoveled back onto the completed shelter roof.
9. Start digging, throwing the first earth about 10 feet beyond the staked outlines of the trench. Less able members of the family should do the easier digging, near the surface, while the best ax and saw men cut and haul logs.
10. Pile all excavated earth at least 3 feet beyond the edges of the trench, so roofing logs can be laid directly on the ground. To make sure that the trenches are dug to their full widths all the way down, cut and use two sticks, one 42 inches long and the other 22 inches long, to check trench widths repeatedly.
11. Get only fresh-cut, green logs, or, as a second choice, sound dry logs. Use no logs smaller in diameter than those specified in the accompanying drawings. For ease in hauling, select logs no more than 50% larger in diameter than those specified.
12. Follow the advice of the attached suggestion sheet, *How to Cut and Haul Logs and Poles More Easily.*
13. To provide essential ventilation and cooling, at the far end of the shelter dig the illustrated, ventilation trench-emergency exit 22 inches wide; make it 30 inches deep if the weather is warm. In cold weather or when fallout is descending, canvas or plastic curtains should be hung in the two openings to control, but not cut off, air flow essential to prevent a hazardous concentration of exhaled carbon dioxide.
14. Unless the weather is cold, build a shelter-ventilating pump, a KAP 20 inches wide × 36 inches high following the attached instructions. If the weather is cold, you can safely delay building a KAP until after the shelter is completed.
15. Lay the logs side by side over the trench. Alternate their large and small ends in order to keep the logs straight across the trench.

    If roof logs 9 ft long are being used to roof a 42-inch-wide trench, be sure to place the roof logs so that their ends extend two feet farther beyond one side of the trench than beyond the other side. This will enable shelter occupants, after the stoop-in shelter is completed, to widen the shelter room 2 ft on one side – first to provide a 2-ft-wide sleeping ledge, and/or later to make space for additional expedient hammocks, or for double-bunk beds of poles or boards built on each side of the shelter.

16. For ease and safety when later hanging expedient bedsheet-hammocks and bedsheet-chairs in the completed shelter, place *loose* loops around roof logs, in the approximate locations given by the diagram on the shelter drawings. Make these *loose* loops of rope, or strong wire. or 16-in.-wide strips of strong cloth, such as 50% polyester bedsheet rolled up to form a "rope". (Unlike provisions for adequate water for prolonged shelter occupancy, hammocks and seats are not essential, although decidedly useful.)

17. Cover the cracks between the logs with cloth, leaves, or any other material that will keep dirt from running down between the cracks.

    CAUTION: DO NOT try to rainproof this flat roof, and then simply cover it with earth – because water will seep straight through the loose earth cover, puddle on the flat roofing material, and leak through the joints between pieces of roofing material or through small holes in the roofing material.

18. Place 6-ft-long logs. one on top of the other, next to the entrances to keep earth to be placed on top of the entryway trench from falling into the openings. Secure these logs with wire or rope. (See View A-A^1.) If wire or rope is not available, make earth-filled cloth "rolls" to hold the earth nearly vertical on the trench roof next to each opening.

19. Mound earth about 18 in. deep in the center over the shelter roof (as shown in View B-B^1), to form the surface of the future "buried roof." Smooth this mounded earth surface. removing sharp roots and stones that might puncture thin rainproofing materials to be placed upon it.

20. Place the waterproofing material of the "buried roof" in shingle-like fashion, starting at the lower sides of the mounded earth.

21. Cover the "buried roof" with another 18 inches of mounded earth in the center, and smooth this final earth surface.

22. Finish the entrances by putting some shorter logs between the two longer logs next to entryway. and bank and pack earth at least 6 in. deep around the sides of the entrances. so that rain water on the ground cannot run into the shelter entrances.

23. Dig surface drainage ditches around the outside of the mounded earth and around the entrances.

24. Place a piece of water-shedding material over each of the entrances like an open-ended canopy. to keep fallout and rain from falling into the shelter openings. Almost all fallout would settle on these suspended canopies, or fall off their edges. rather than fall. like sand. into the shelter openings.

25. Hang the KAP from the roof of the entry trench. However, if an inadequate natural flow of air is coming in through the emergency exit. hang the KAP in the exit trench. so that the KAP will pump air in the direction of its natural flow.

26. As time and materials permit, continue improving the shelter by:

    A. Filling all available water containers, including dug pits lined with cloth and plastic and roofed with available materials. Be sure to disinfect water taken from streams or ponds, using one teaspoon of a chlorine bleach such as Clorox, for each 5 gallons of water.

    B. Making expedient lights. as also described in the attached instructions.

    C. Making and hanging expedient bedsheet-hammocks and bedsheet-chairs, following the attached instructions and the installation diagram on a drawing of this shelter.

    D. Installing screens or mosquito netting over the two openings, if mosquitoes or flies are a problem. But remember that screen or netting reduces air flows through a shelter – even when the air is pumped through with a KAP.

    E. Making and installing threshold boards, to keep the edges of earth steps and ledges from being broken off. (In damp earth, it is best to install threshold boards before roofing the shelter.)

    F. Digging a stand-up hole near the far end of the shelter – about 15 inches in diameter, and if practical, deep enough to permit the tallest of the shelter occupants to stand erect.

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