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Report to the Test Director

EFFECTS OF AN ATOMIC EXPLOSION ON UNDERGROUND AND BASEMENT TYPES OF HOME SHELTERS

By

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Federal Civil Defense Administration
Washington, D. C.
October 1953

CLASSIFICATION CANCELLED
DATE 4-10-63
For The Atomic Energy Commission
Chief, Declassification Branch

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ABSTRACT

This joint FCDA-AEC project was conducted to check the adequacy of several proposed home shelter designs.

Underground earth-covered shelters were exposed to a 16.4-kt, 300-ft tower shot at ranges of 1230 ft (one), 1450 ft (one), 1800 ft (five), and 3500 ft (one). Two types of basement shelters were constructed in each of the test houses at 3500 and 7500 ft (Project 21.2).

Instrumentation was by gamma-radiation badges, paraffin cubes, and nylon swatches. Attempts were made to measure permanent deflections of concrete roof slabs. Mannequins were placed in several shelters for purposes of demonstration and observation of blast-caused movement.

A weighted mannequin in the underground shelter at 1230 ft was broken in half; an unweighted one (child size) was thrown to the floor. All other mannequins remained in place, undamaged. Paraffin cubes and nylon swatches showed no evidence of thermal damage. Fallout conditions made it impossible to determine initial gamma-radiation quantities. There was no cracking or permanent deflection of the concrete roof slabs. Except for a wood-covered, trench type shelter, which partially failed because of faulty construction, the shelters showed no blast damage.

Thermal energy entering the shelters probably would not have caused skin burns to human occupants.

Adequacy of the shelters under full design loads could not be determined because pressures were lower than expected, but the shelter designs were structurally acceptable under test pressures received. Future tests are required under higher pressures. The basement shelters should be tested under masonry debris loads.

ACKNOWLEDGMENTS

L. A. Darling Company of Bronson, Mich., loaned, without charge to the Federal Civil Defense Administration (FCDA), all department-store mannequins used in the shelters.

North American Van Lines transported mannequins to and from Las Vegas, Nev., without cost to FCDA.

The Atlas Trucking Company of Las Vegas, as a public service, hauled mannequins to and from the Nevada Proving Grounds.

The J. C. Penney Company of Las Vegas, through the National Retail Dry Goods Association, donated clothing and dressed all mannequins used in this test.

The film and film holders used in the measurement of the gamma-radiation dose were supplied by the Radiation Instruments Branch of the U. S. Atomic Energy Commission, and the films were processed and read at the National Bureau of Standards.

Jack C. Greene of the Health and Special Weapons Defense Office of FCDA assembled and supervised the placing of the badges and interpreted the film readings.

Benjamin C. Taylor, Director of the Technical Division, and A. S. Neiman of FCDA reviewed this report.

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EFFECTS OF AN ATOMIC EXPLOSION ON UNDERGROUND AND BASEMENT TYPES OF HOME SHELTERS

1 INTRODUCTION

1.1 Objective

Eight outdoor and four indoor home type shelters, located at various distances from Ground Zero (Fig. A.1), were constructed at the Nevada Proving Grounds (NPG) and exposed to a 16.4-kt atomic device exploded at an altitude of 300 ft (Operation Upshot-Knothole, shot 1). The purpose of the test was to check the adequacy of several types of home shelters, proposed by the Federal Civil Defense Administration (FCDA), against gamma-radiation penetration and thermal and blast effects.

1.2 Background

Several types of home shelters, designed by Lehigh University Institute of Research for FCDA, were tested in the Buster series of October and November 1951, and the results were reported.[1] These tests showed weaknesses in the entrances. Since many of the underground shelters were constructed of wood which would have a comparatively short life in many parts of the United States, it was decided to use building materials of a more permanent nature. The covered trench was redesigned with reinforced concrete-block walls and with wood and concrete roofs; the basement corner room, the block-wall basement exit, and the concrete pipe were added as new types; and the Lehigh lean-to was modified for attachment to the basement wall. The Lehigh design for the reinforced concrete basement exit was selected as the most blast resistant. Since a manual on home shelters was being prepared, a field test of these shelters was considered necessary.

1.3 Instrumentation

No funds were available for instrumentation, and consequently it was necessary to improvise in an effort to determine thermal and blast effects. Eight gamma-radiation film badges were placed in each of the underground shelters, five in each of the two basement corner rooms, and two in each of the two lean-to's. Badges were attached to the walls of the shelters by nailing through adhesive tape slings or taping to studs driven into the concrete. Locations and total doses recorded by badges and distances of the shelters from Ground Zero are shown in Fig. A.1.

One treated-paper temperature-recording strip, mounted on 4- by 5- by $^{3}/_{16}$-in. plywood and furnished by the Quartermaster Research and Development Laboratory of Philadelphia, Pa., was nailed to the top of the bench in the reinforced concrete basement exit at 1230 ft from

Ground Zero; one was nailed to the top of the bench in the covered trench at 1450 ft from Ground Zero; and one was nailed to the top of the bench in the covered trench at 1800 ft from Ground Zero. These calibrated strips, white to gray in color, turn black when the temperature for which they are designed is reached (Fig. 1).

Half-inch cubes of ordinary household paraffin were mounted on 2- by 2- by $\frac{3}{4}$-in. wood blocks by means of a brad through the center. Olive drab nylon cloth swatches 6 by 6 in., donated by the Quartermaster Research and Development Laboratory, were mounted with tacks to $7\frac{1}{2}$- by $7\frac{1}{2}$- by $\frac{3}{4}$-in. wood blocks. One nylon and one paraffin sample were placed in each of the two lean-to's and in each of the two corner rooms. Three nylon and three paraffin samples were attached to the walls in the reinforced concrete basement exit and in the covered trench at 1800 ft. Two nylon and two paraffin samples were attached to the walls in the covered trench at 1450 ft. (See Fig. A.1.) The critical energy of the paraffin was estimated to be smaller than the 3 calories per square centimeter per second for the nylon cloth, but the actual value was to be determined later.

Attempts were made to measure permanent deflection of the concrete roof slabs in the reinforced concrete basement exit, in the covered trench at 1450 ft, and in the covered trenches at 1800 ft. A solid Monel wire, 0.020 in. in diameter, with one end connected to a small bolt and the other end attached to a $1\frac{1}{2}$-lb sash weight was used as a reference line for measuring deflection. This wire was detachable and was used in the shelters before and after the blast. The bolt end of the wire was threaded through a $\frac{3}{8}$-in. tiller guide, attached to the wall on one side, across the shelter, and through a flanged eye attached to the opposite wall at the middle of the shelter. The center point of the span on the bottom of the slab directly over the wire was marked. A steel scale graduated to $\frac{1}{64}$ in. was used to measure vertical distances from the center points to the wire.

2 TEST RESULTS

2.1 Gamma-radiation Penetration

At 5:20 A.M. on Mar. 17, 1953, the 16.4-kt device was detonated from the top of a 300-ft tower. Early reports by monitors indicated a heavy radioactive fall-out along a radial line from Ground Zero through the houses and shelters. Postoperation plans called for the entry of a recovery party at 7:30 A.M. Because of the high radiation level, postoperation plans were changed, and film badges in the basement shelters at 7500 ft were collected at 12:30 P.M. At noon on Mar. 18, 1953, a recovery party recovered badges in the basement shelters at 3500 ft and in all underground shelters except the wood-covered trench and the concrete pipe. Badges in the wood-covered trench were picked up at 12:15 P.M. on Mar. 20, 1953. No badges were recovered in the concrete pipe. Total gamma dosages are shown in Fig. A.1.

2.2 Thermal-radiation Effects

None of the paper temperature-recording strips turned black. There was no evidence that the nylon cloth swatches had melted. The paraffin cubes retained their sharp edges and showed no signs of melting, although some of them in the underground shelters changed in color to that of the surrounding soil, presumably caused by embedded dust.

2.3 Blast Effects

(a) Reinforced Concrete Basement Exit. For construction details of this shelter see Fig. A.2. Figure 2 shows the interior of the reinforced concrete basement exit at 1230 ft from Ground Zero. Sand weighing 28 lb was poured into the lower hollow half of the mannequin through an opening in the back at approximately waist level. Total dummy weight was about 60 lb. A child mannequin, weighing 7 lb, is not visible in the photograph. Gamma-radiation badges, nylon swatches, and paraffin cubes are shown in the background.

Figure 3 shows the same interior after the blast. The 2- by 12-in. leg of the bench near the entrance was removed by the blast. The child mannequin was undamaged, although thrown to the floor and partially covered with sand. The female mannequin was separated in two parts by the breaking of a wood dowel pin at the waist, used to connect the upper and lower parts.

Figure 4 shows the entrance to the reinforced concrete basement exit after the blast. A $\frac{1}{16}$-in. separation, not visible in the photograph, between the concrete steps and left entrance wall extended from the grade to the shelter floor. No other damage to the shelter was observed.

The roof slab showed no cracks. Measurements taken before and after the blast showed no permanent deflection of the roof slab.

(b) Covered Trench Shelter at 1450 Ft from Ground Zero. See Fig. A.3 for details of this shelter. Thirty-three pounds of sand was added to the lower part of the male mannequin in this shelter in the same manner as previously described. The total weight of the mannequin, fully clothed, was 84 lb. Marks were made on the bench and roof slab of the shelter before the blast to locate the position of the dummy.

The mannequin was not moved or damaged by the blast. No damage to the shelter was evident. The roof slab showed no cracks and had no permanent deflection at midspan.

(c) Covered Trench Shelter at 1800 Ft from Ground Zero. See Fig. A.3 for details of this shelter. Figure 5 shows the entrance to the covered trench shelter at 1800 ft from Ground Zero before the blast. Since no damage to the exterior occurred, the after-blast photograph was omitted.

The total weight of the male mannequin, fully clothed and with sand in the lower parts, was 84 lb. Marks were made on the bench and roof slab, as before, to locate the initial before-blast position of the mannequin.

The mannequin was not moved or damaged by the blast. No damage to the shelter was observed. The roof showed no cracks. Permanent deflection of the center of the slab measured $\frac{1}{16}$ in., but this may have been due to the limitations of accuracy of the method used.

(d) Wood-covered Trench Shelter at 1800 Ft from Ground Zero. For drawing of this wood-covered trench see Fig. A.4. Figure 6 shows the experimental shaft entrance to the wood-covered trench before the blast. Figure 7 shows the damage to the shaft entrance after the blast. This entrance was constructed only as a means of access to the shelter for test personnel and was not under test. Figure 7 is of interest, however, because it shows the movement of the bottom of the wall inward, probably due to the additional load resulting from the blast.

Figure 8 shows the failure of one of the longitudinal side walls of this shelter after the blast. The break occurred about midway between the end wall and the entrance. In Figure A.4 the roof joists are shown bearing on a 2- by 6-in. plate. This plate was to be attached to the block walls with $\frac{1}{2}$-in. round bolts about 2 ft 0 in. on center. Because of a misunderstanding of the drawing during construction, the plate was attached to the walls with a total of four bolts only, one near each corner. The roof joists suffered no damage.

(e) Covered Trench Shelter with Closed Shaft Entrance at 1800 Ft from Ground Zero. See Fig. A.5 for drawing. Figure 9 shows the closed shaft entrance to the covered trench before the blast. This shelter suffered no damage. No cracks were noted in the concrete roof slab. There was no permanent deflection of the roof slab.

(f) Block-wall Basement Exit at 1800 Ft from Ground Zero. See Fig. A.6 for plan. Figure 10 is a view of the entrance to the block-wall basement exit before the blast. Figure 11 shows the minor damage done to the exterior of this shelter by the blast. There was no interior damage. The roof slab showed no evidence of any cracking.

(g) Concrete-pipe Shelter with Closed Shaft Entrance at 1800 Ft from Ground Zero. For construction drawing of this shelter see Fig. A.7. Figure 12 shows the shaft entrance to the concrete-pipe shelter before the blast. The blast caused no damage to this shelter. A careful examination of the entire pipe interior disclosed no cracks.

(h) Covered Trench Shelter at 3500 Ft from Ground Zero. This is the same type shelter that was constructed at 1800 ft from Ground Zero. Figure 13 shows the entrance to the shelter before the blast.

An unweighted, dressed male mannequin of 37 lb was placed in this shelter and its position marked on the bench and roof slab. No movement of or damage to the mannequin by blast was noticeable. The shelter was undamaged. The roof slab was uncracked.

(i) Wooden Lean-to Shelter at 3500 and 7500 Ft from Ground Zero. See Fig. A.8 for the construction drawing. This shelter was built 6 ft 0 in. long instead of the 8 ft 0 in. shown. Figures 14 and 15 show the wooden lean-to in the basement of the house at 3500 ft before and after the blast. The mannequin in the shelter was removed after the explosion and before the photograph was taken.

Figure 16 shows the wooden lean-to shelter in the basement of the house at 7500 ft before the blast. The clothed female dummies weighed 30 lb each, and the child weighed 7 lb. All mannequins were undamaged and remained in their original positions.

No damage was caused to either shelter by the blast.

(j) Basement Corner Room Shelter at 3500 and 7500 Ft from Ground Zero. For drawing of this shelter see Fig. A.9. Figure 17 is a view of the interior of this shelter in the house at 3500 ft before the blast. Figures 18 and 19 show the interior of this shelter at 7500 ft before and after the blast. Male mannequins weighed 35 lb; females, 30 lb; and the child, 7 lb. None of these mannequins were damaged or moved by the blast.

Figure 20 illustrates the minor damage in the basement corner room at 3500 ft after the blast. Only one roof joist cracked under the debris load of the collapsed house above.

The basement corner room at 7500 ft was not damaged.

3 DISCUSSION

3.1 Analysis of Gamma-radiation Data

Badges were placed in all shelters to measure initial gamma radiation. Very little penetration was expected because of the relatively large mass of earth between the explosion and the interiors of the shelters resulting from the low incident angle caused by the 300-ft burst. Recovery of the badges was expected within 2 hr after the detonation. A severe fall-out in the area covered the shelters and houses and delayed postoperation plans. The badges in the basement shelters at 7500 ft were recovered 7 hr after the blast and most of the others 30 hr after. A few were collected as late as 78 hr after the explosion.

High residual radiation levels remained in the area for two days. Monitor reports showed wide fluctuations in readings, probably due to the shifting of the sand and dust under the action of the wind. Under these conditions it was impossible to differentiate between the amounts of initial and residual radiation to which the badges had been exposed.

3.2 Analysis of Thermal-radiation-effects Data

The paper temperature-recording strips in the shelters at 1230, 1450, and 1800 ft did not show discoloration. This would indicate that if there was any rise in temperature it did not increase sufficiently to reach 52°C or 94°F, the lowest temperature which the strips were designed to record.

Since there was no melting of the nylon swatches or paraffin cubes, the amount of thermal energy entering the shelters even at close ranges must have been small, probably not sufficient to cause even slight skin burns.

3.3 Analysis of Blast-effects Data

The pressure inside the reinforced concrete basement exit type shelter at 1230 ft was sufficient to break the bench. The actual pressure acting on the bench and mannequin is unknown. About 75% of the weight of the mannequin was located below the waist. It seems possible that the blast wave entering the shelter through the entrance may have exerted sufficient force between the wall of the shelter and the back of the mannequin to accelerate the light upper half forward, breaking the dowel pin connecting the two parts and twisting the upper part to its after-blast position. From the after-blast position of the lower part of the mannequin, it can be assumed that the dropping of the entrance end of the bench plus the force exerted in breaking the upper part loose were the causes of its displacement. The damage to the mannequin indicated that pressure inside this shelter should be studied.

The mannequins in the shelters at 1450 and 1800 ft did not move; yet the test pressure at the 1450-ft shelter was only 35% less than that at the reinforced concrete basement exit shelter. The entrances of the 1230- and 1450-ft shelters, however, had different orientations (see Fig. A.1), and this may have had some effect on the admission of pressure.

The concrete roof slabs of the underground shelters were designed to resist a dynamic load, with the maximum midspan deflection limited to about $\frac{1}{30}$ of the span. With this deflection, cracking of the slab was to be expected since the reinforcing steel was allowed to yield. However, no cracks were visible. Deflections must have been in the elastic range since no permanent deflections were observed.

At first it was believed that the design assumptions were in error: (1) that the mass of the earth cover acted with the slab, (2) that there was no attenuation of pressure on the roof slab through the soil, and (3) that pressure on the underside of the slab was zero. Later, when the actual pressures on the shelters were found to be much lower than anticipated, the behavior of the slabs was understandable. Under the test pressures listed below the slabs acted elastically.

Shelter	Distance to GZ, ft	Design pressure, psi	Test pressure, psi
R.C. basement exit	1230	50	23
Covered trench	1450	23	15
Covered trench	1800	23	10

No conclusions relative to the adequacy of the wood-covered trench should be drawn from the failure of the wall. If the proper number of anchor bolts had been used to anchor the plates to the walls, it is believed that the tops of the walls would have been sufficiently braced to cause the walls to span the distances between the roof and floor without failure.

The debris load on the basement shelters at 3500 ft was small; so these shelters were not tested to their maximum capacity, such as might be experienced in the collapse of a masonry house.

3.4 Conclusions

Thermal energy entering the shelters probably would not have caused skin burns to human occupants.

There is some evidence that pressure inside the shelters may cause injury to occupants and that their safety may depend upon the orientation of the entrances.

Although the adequacy of the shelters at full design pressures could not be determined, since the actual test pressures were about one-half the design value, the test nevertheless showed that the designs are structurally satisfactory at the pressures received. Since in any atomic attack the majority of residences in the attack area—and consequently the home type shelters—would not be in the regions of high pressure, the information obtained was of value to Civil Defense.

3.5 Recommendations

Future tests should be made to subject the reinforced concrete basement exit shelter and the covered trench shelter to blast pressures of about 45 and 25 psi, respectively.

[redacted]

The wood-covered trench, built according to plan, should be tested again at a blast pressure of about 25 psi.

Both types of indoor shelters should be tested under the debris load of a masonry house.

All future tests of shelters should include instrumentation to measure interior temperatures and blast pressures.

Future tests should include devices for reducing or keeping out the blast pressures.

REFERENCE

1. Archie P. Flynn, FCDA Family Shelter Evaluation, Buster Project 9.1a Report, WT-359, 1952.

[redacted]

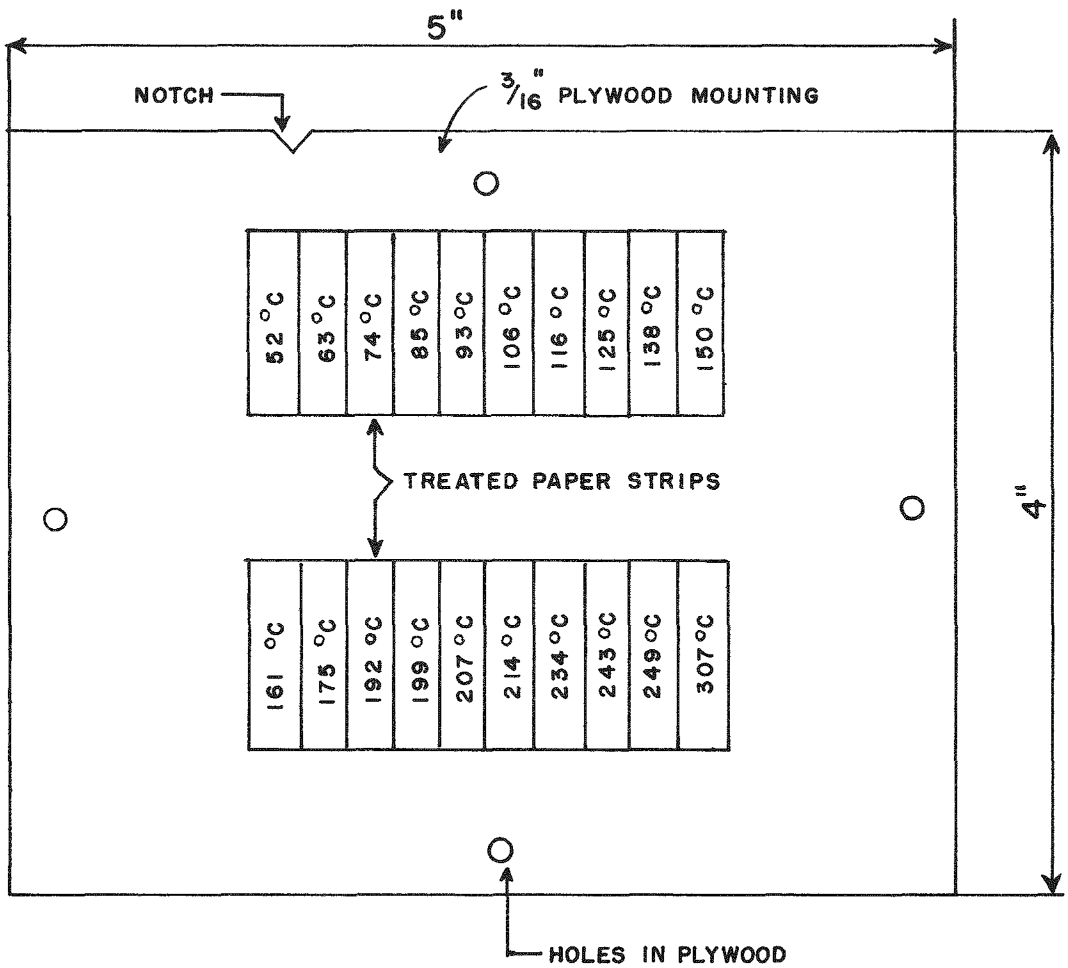

Fig. 1—Temperature-recording strips.

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Fig. 2—Reinforced concrete basement exit before blast.

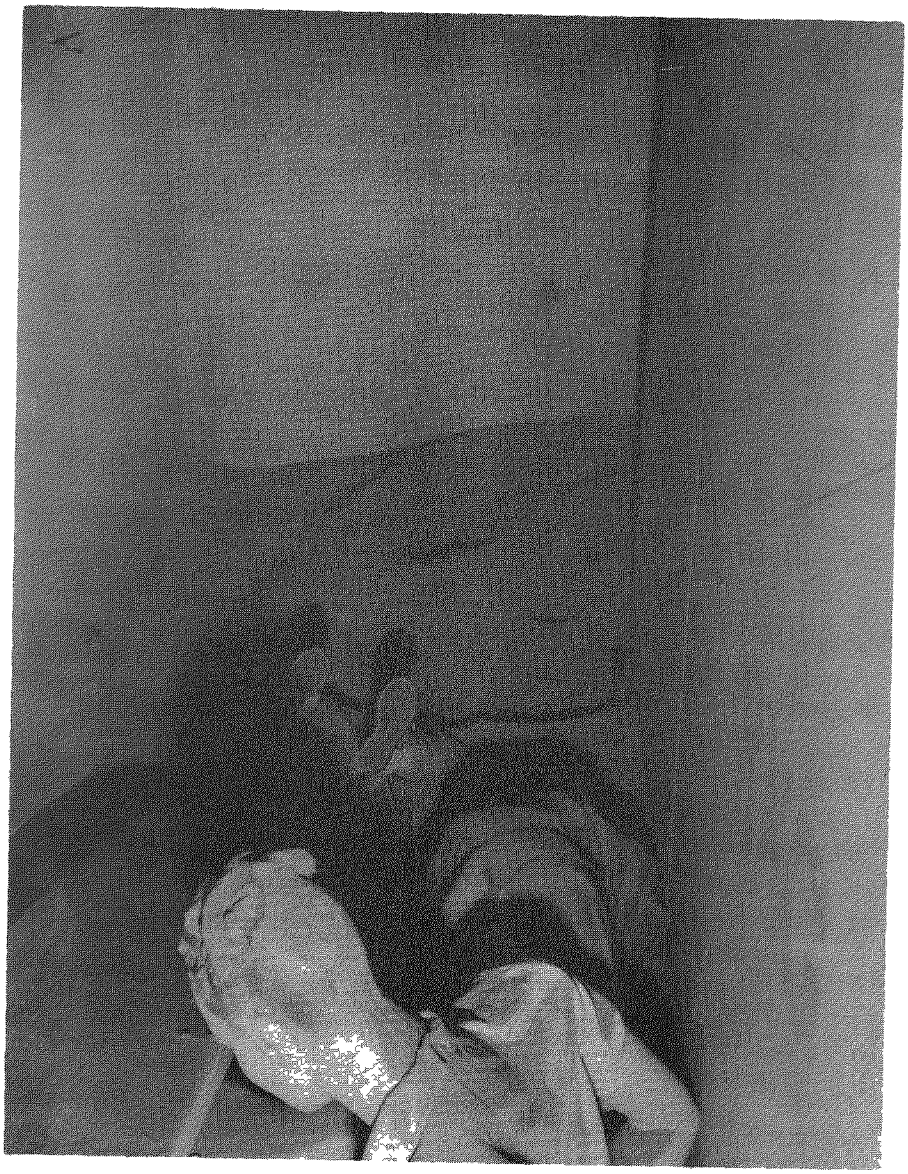

Fig. 3—Reinforced concrete basement exit after blast.

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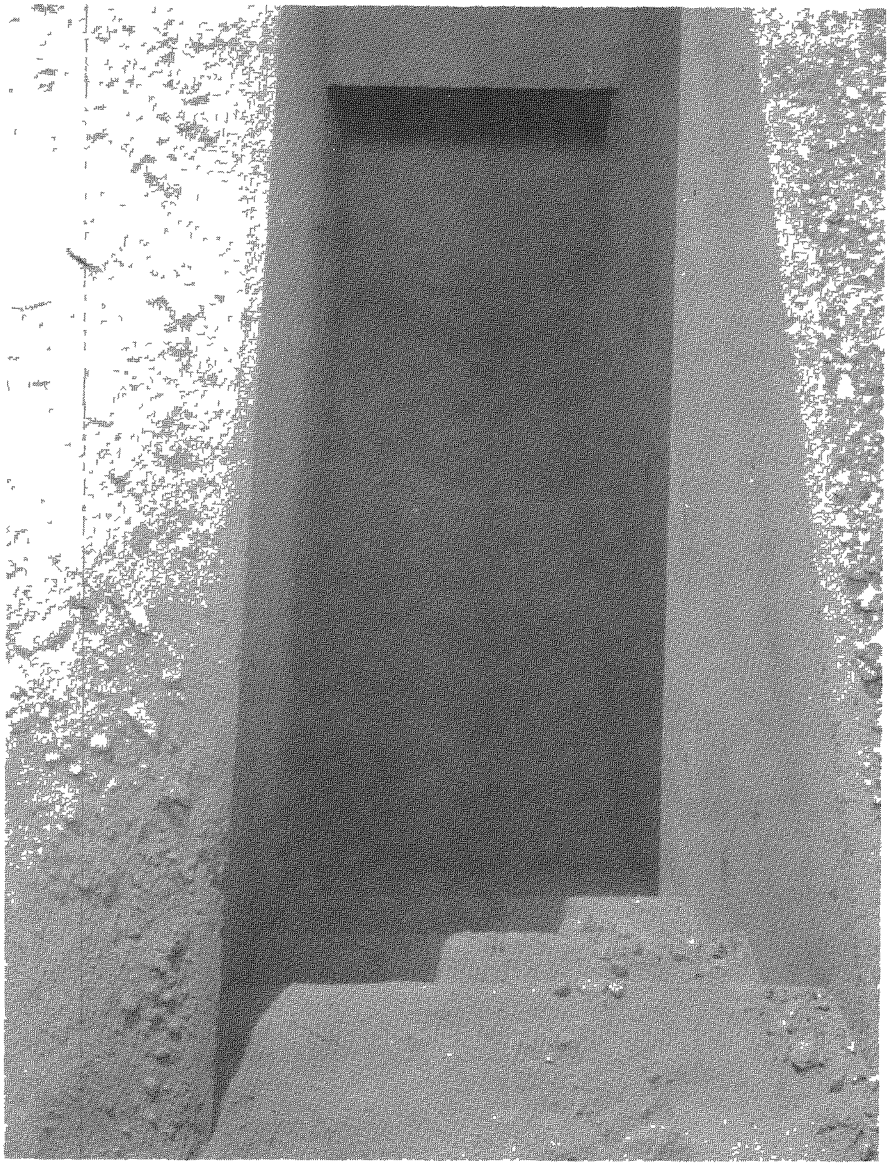

Fig. 4—Entrance to reinforced concrete basement exit after blast.

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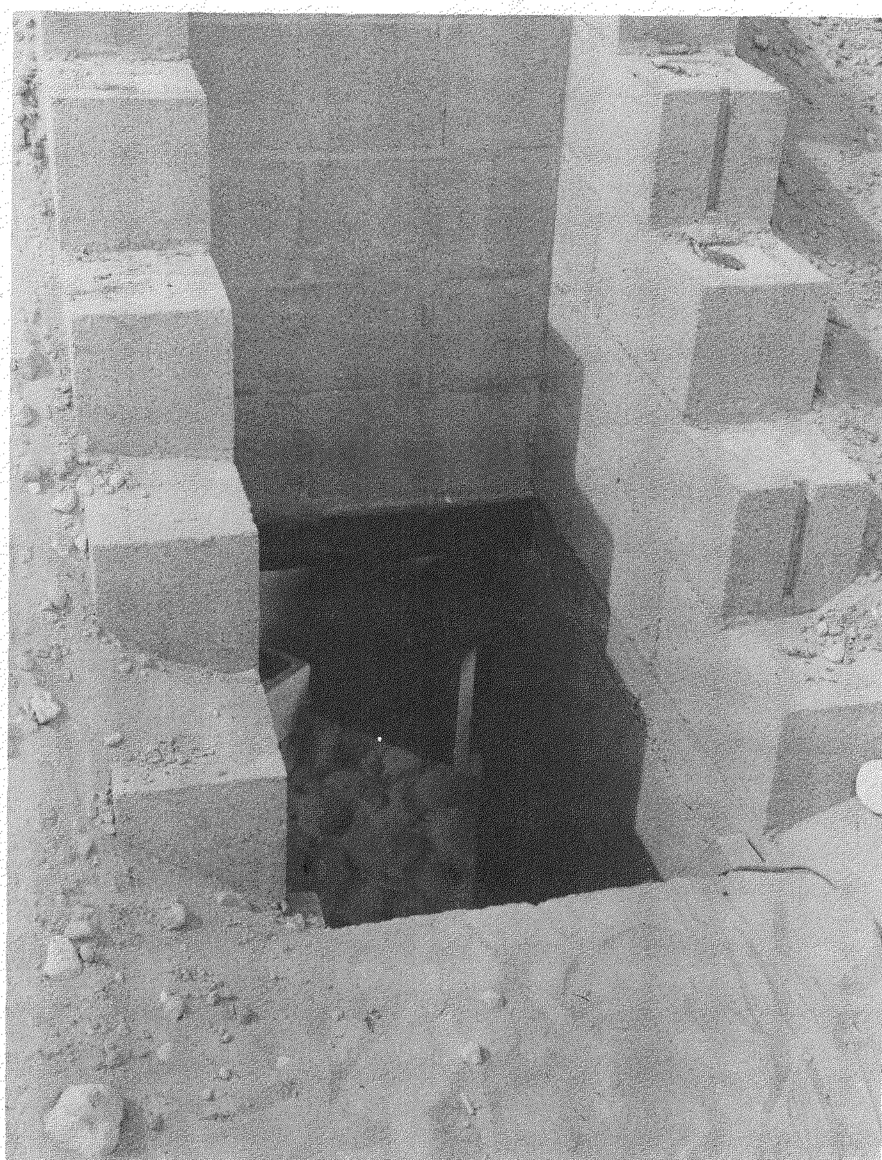

Fig. 5—Entrance to covered trench at 1800 ft before blast.

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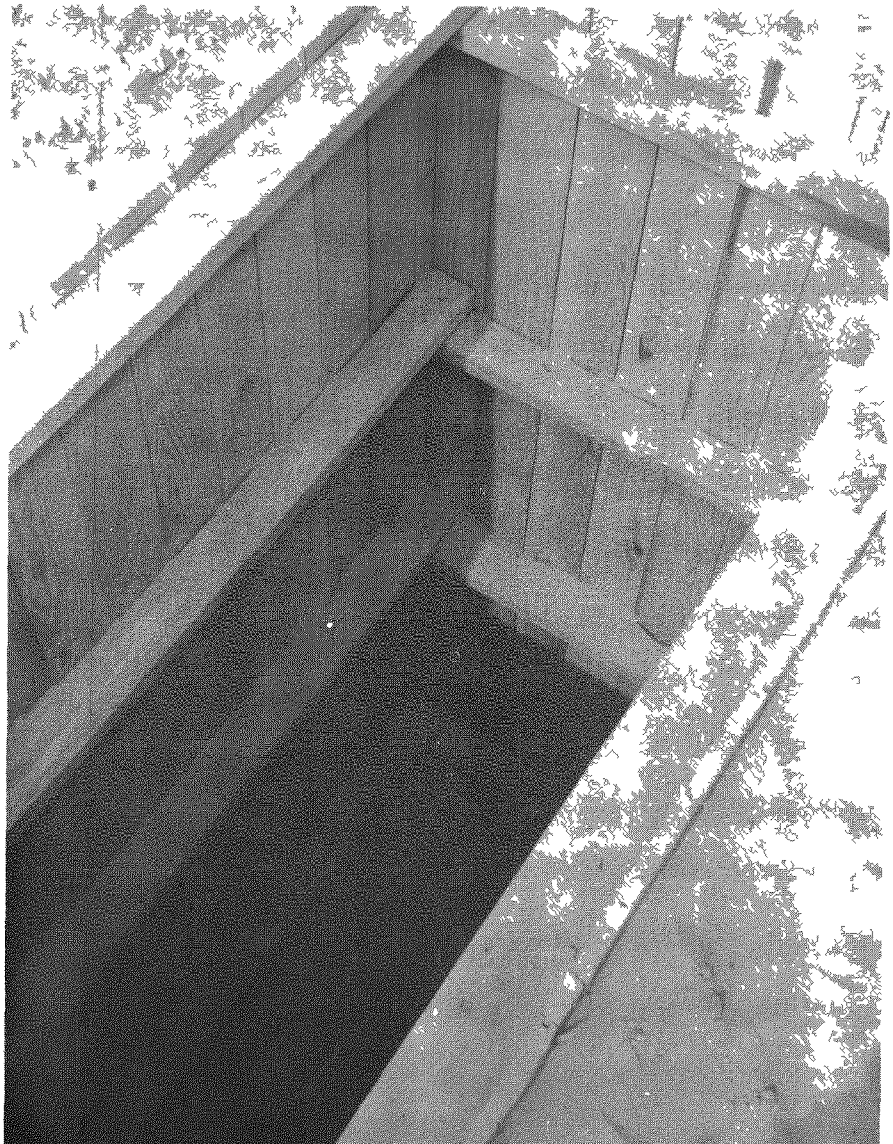

Fig. 6—Shaft entrance to wood-covered trench before blast.

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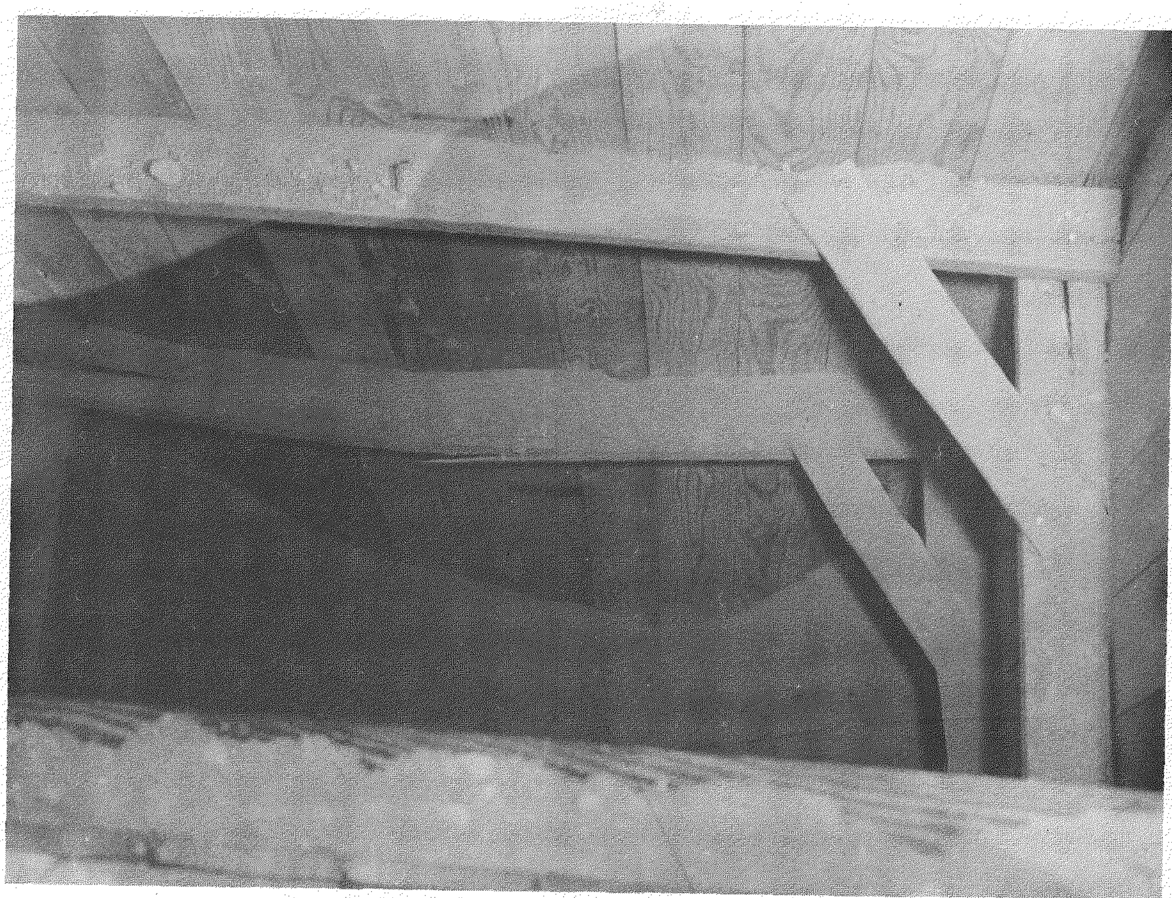

Fig. 7—Shaft entrance to wood-covered trench after blast.

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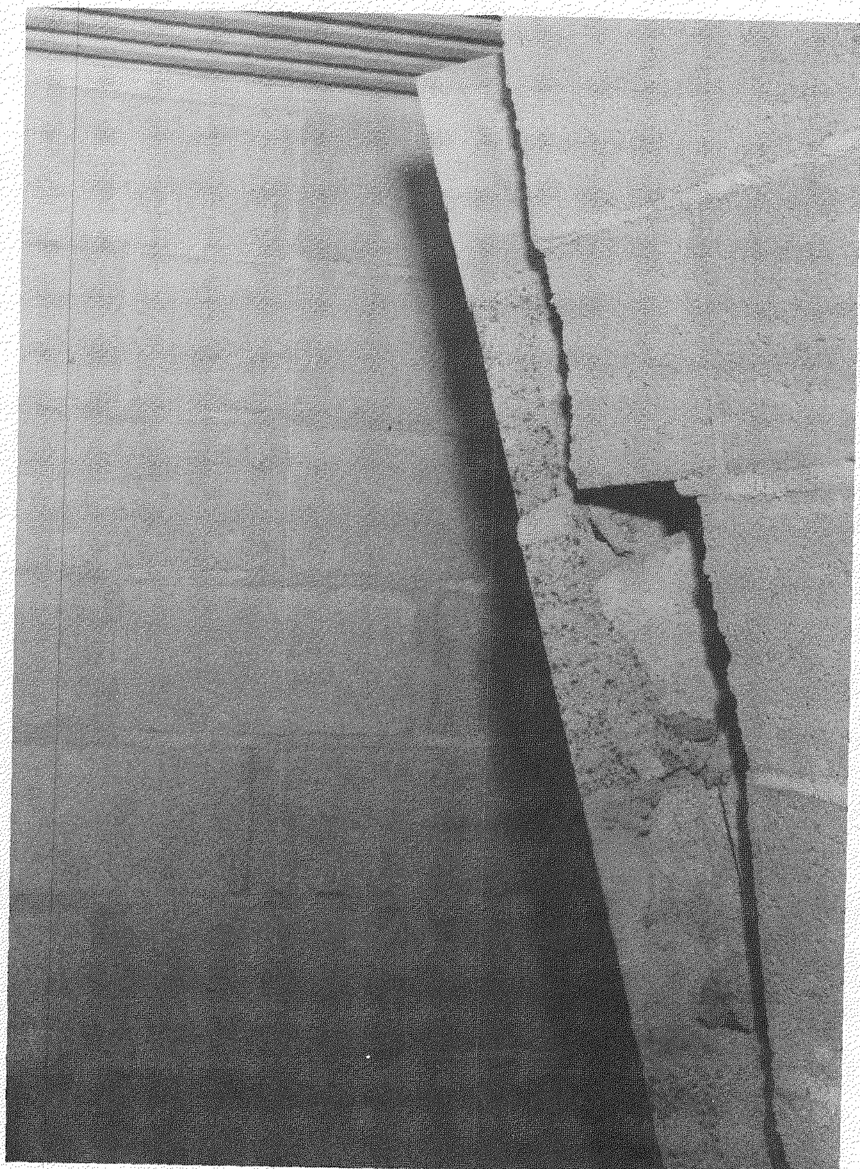

Fig. 8—Blast damage to wood-covered trench.

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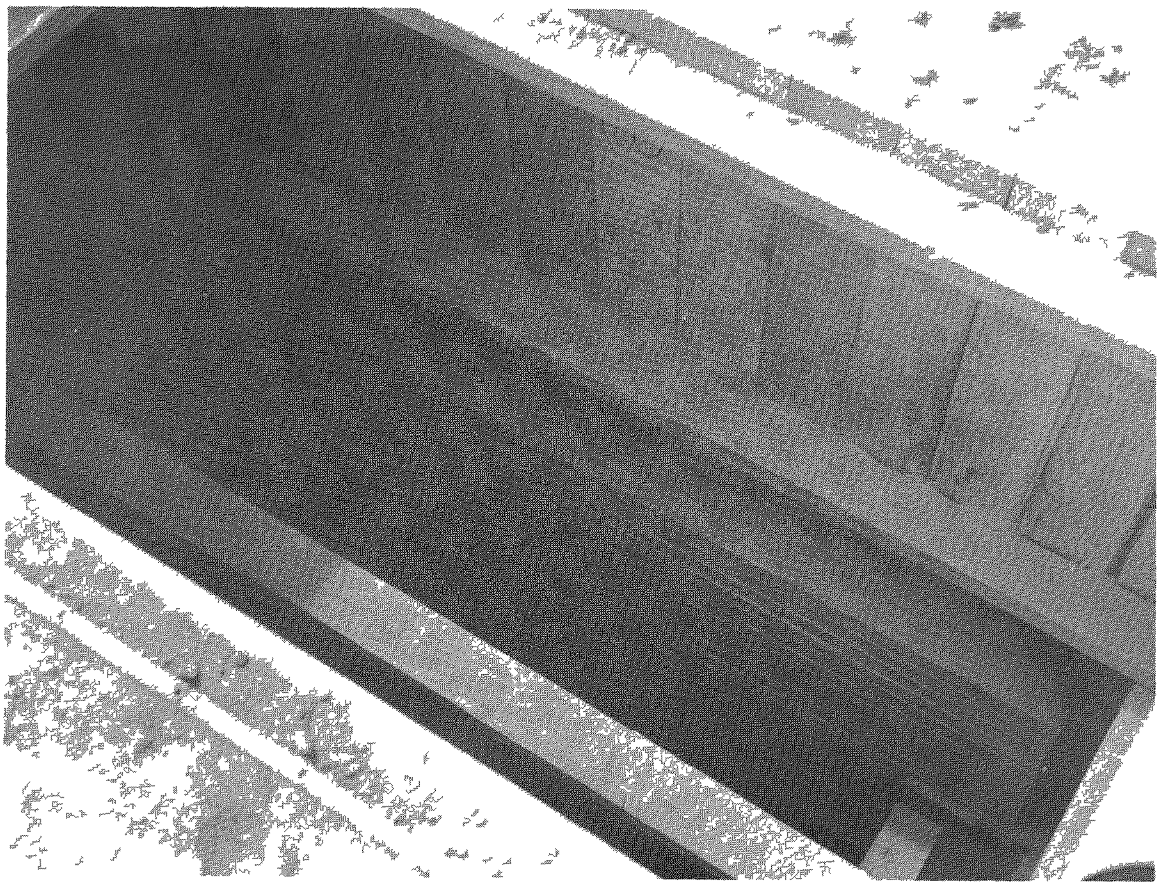

Fig. 9—Closed entrance to covered trench before blast.

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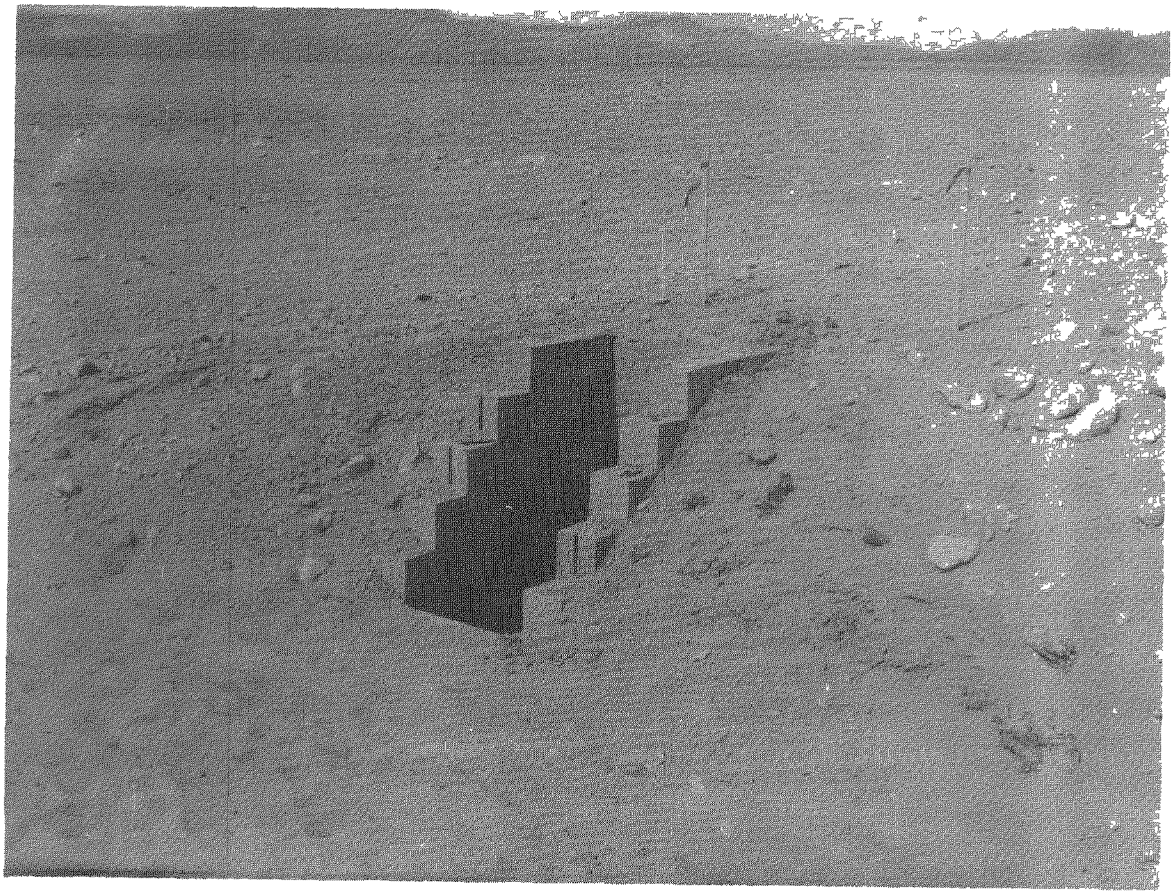

Fig. 10—Entrance to block-wall basement exit before blast.

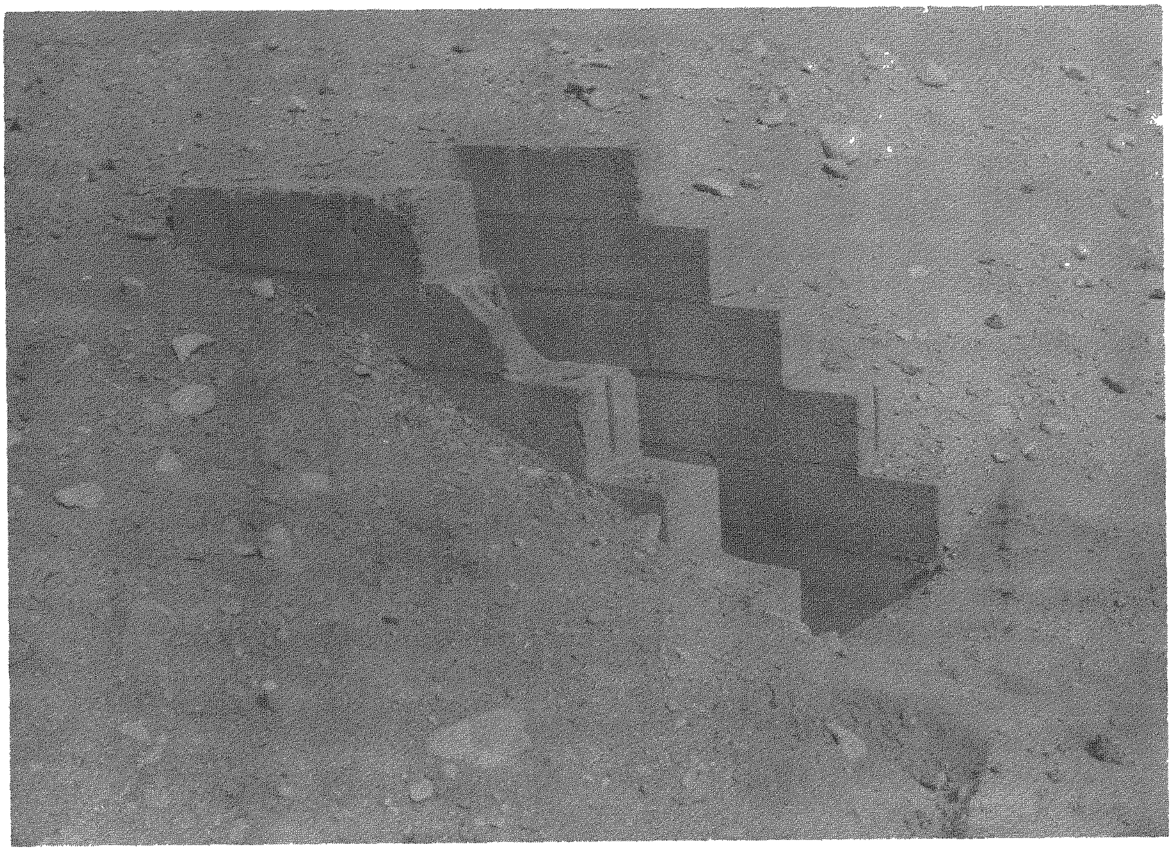

Fig. 11—Entrance to block-wall basement exit after blast.

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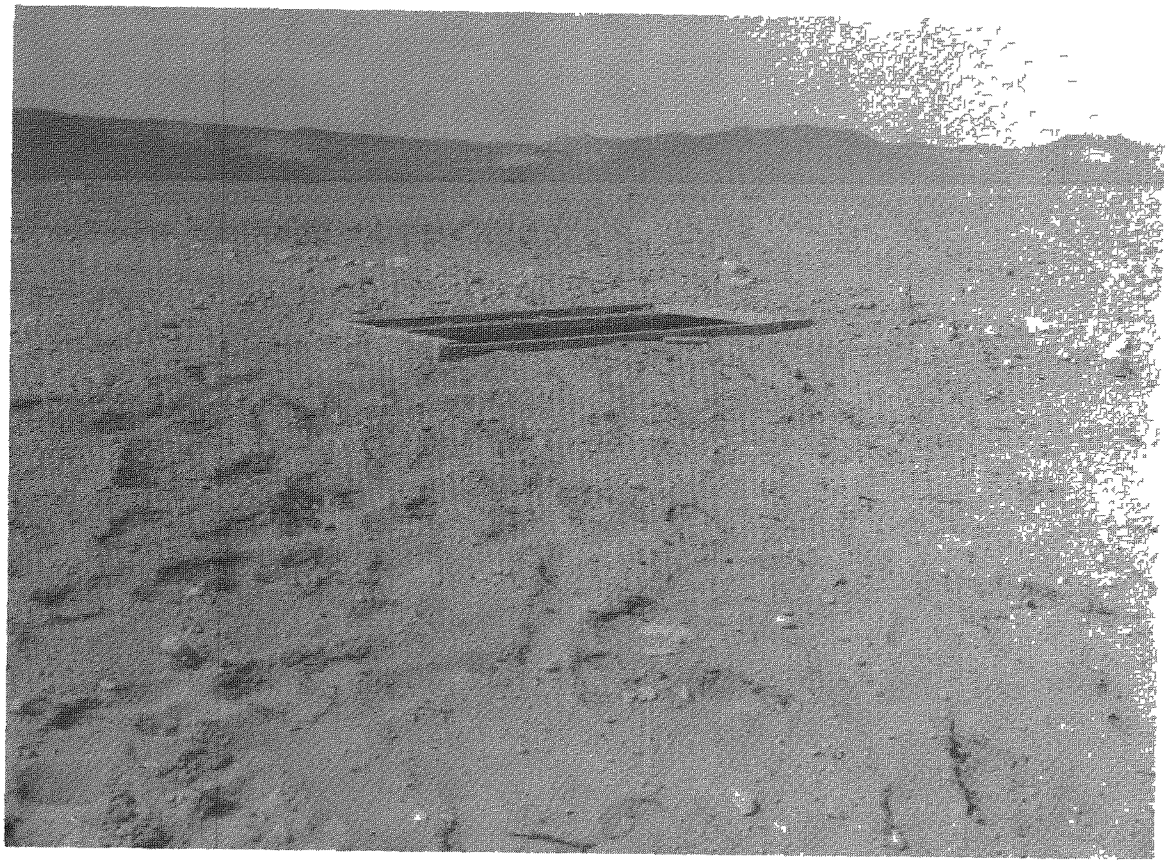

Fig. 12—Shaft entrance to concrete pipe before blast.

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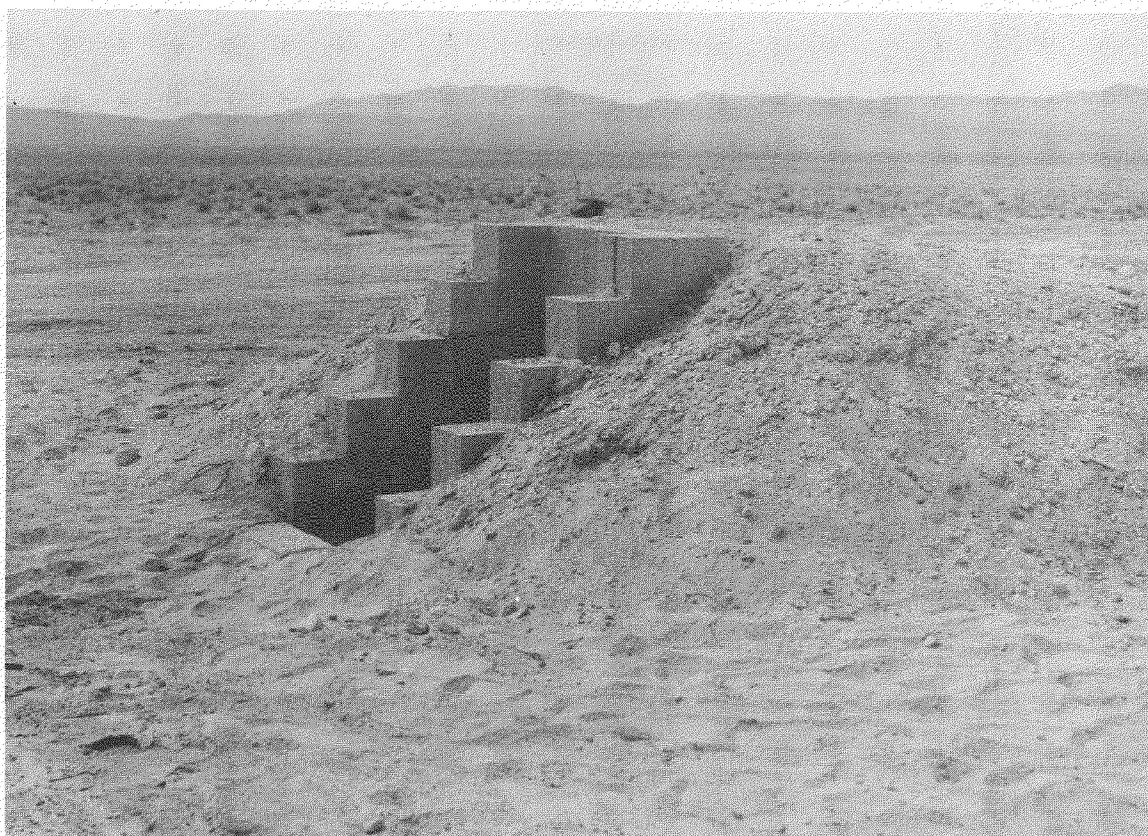

Fig. 13—Covered trench at 3500 ft before blast.

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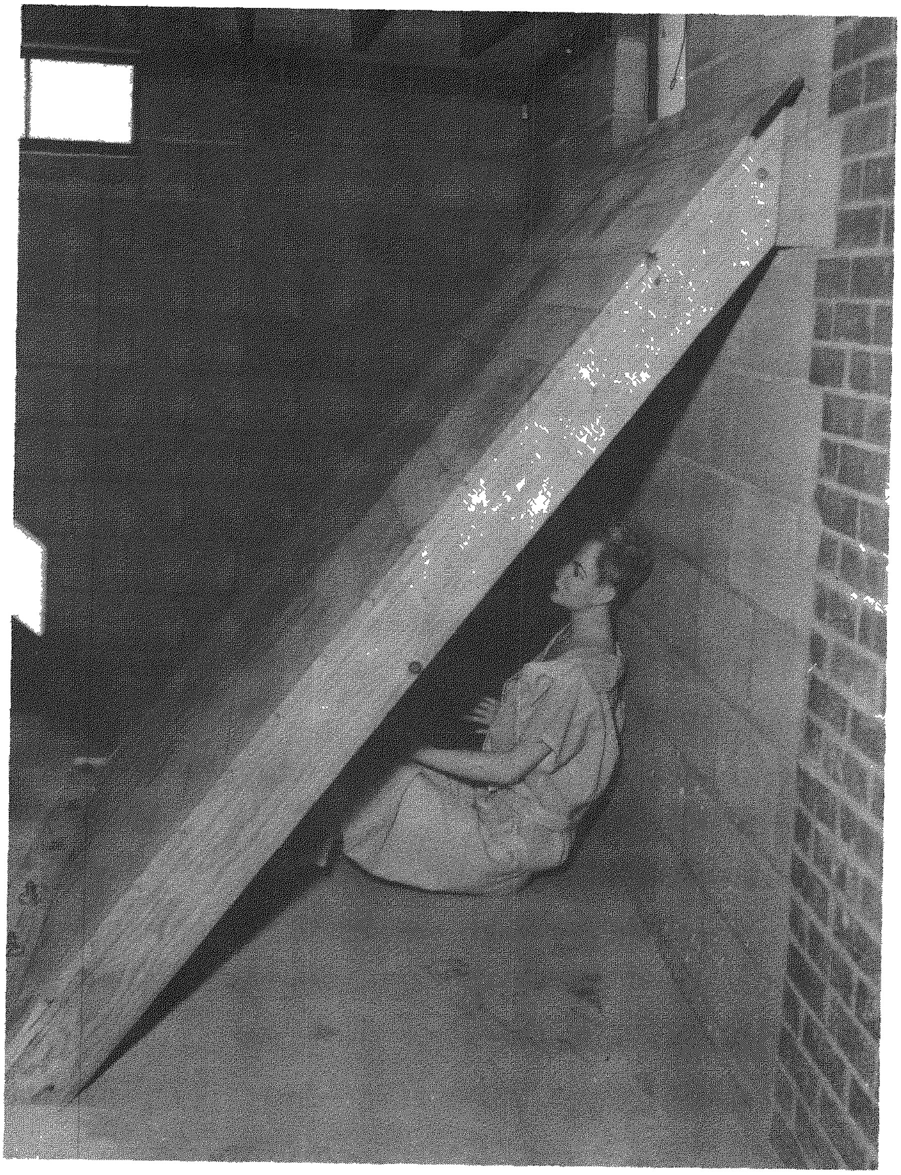

Fig. 14—Lean-to at 3500 ft before blast.

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Fig. 15—Lean-to at 3500 ft after blast.

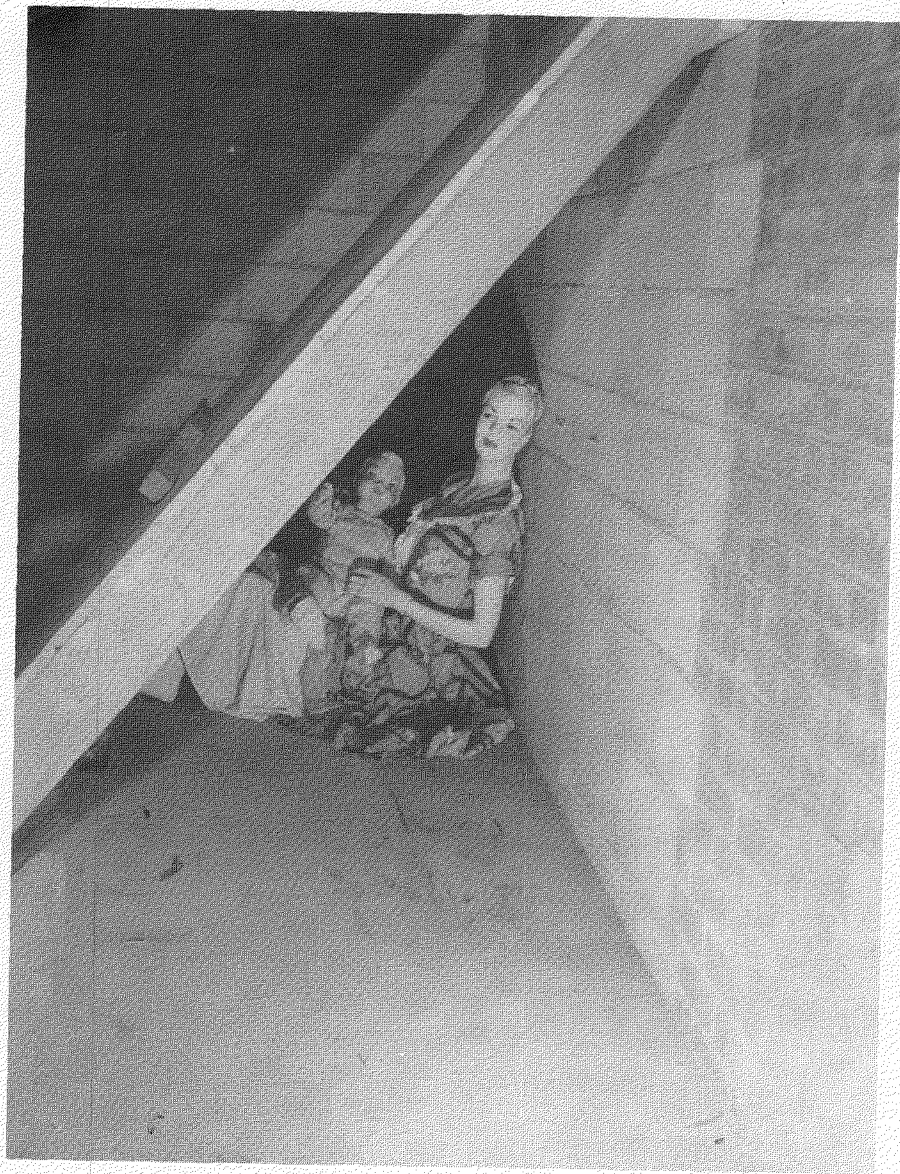

Fig. 16—Lean-to at 7500 ft before blast.

[redacted]

Fig. 17—Basement corner room at 3500 ft before blast.

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Fig. 18—Basement corner room at 7500 ft before blast.

Fig. 19—Basement corner room at 7500 ft after blast.

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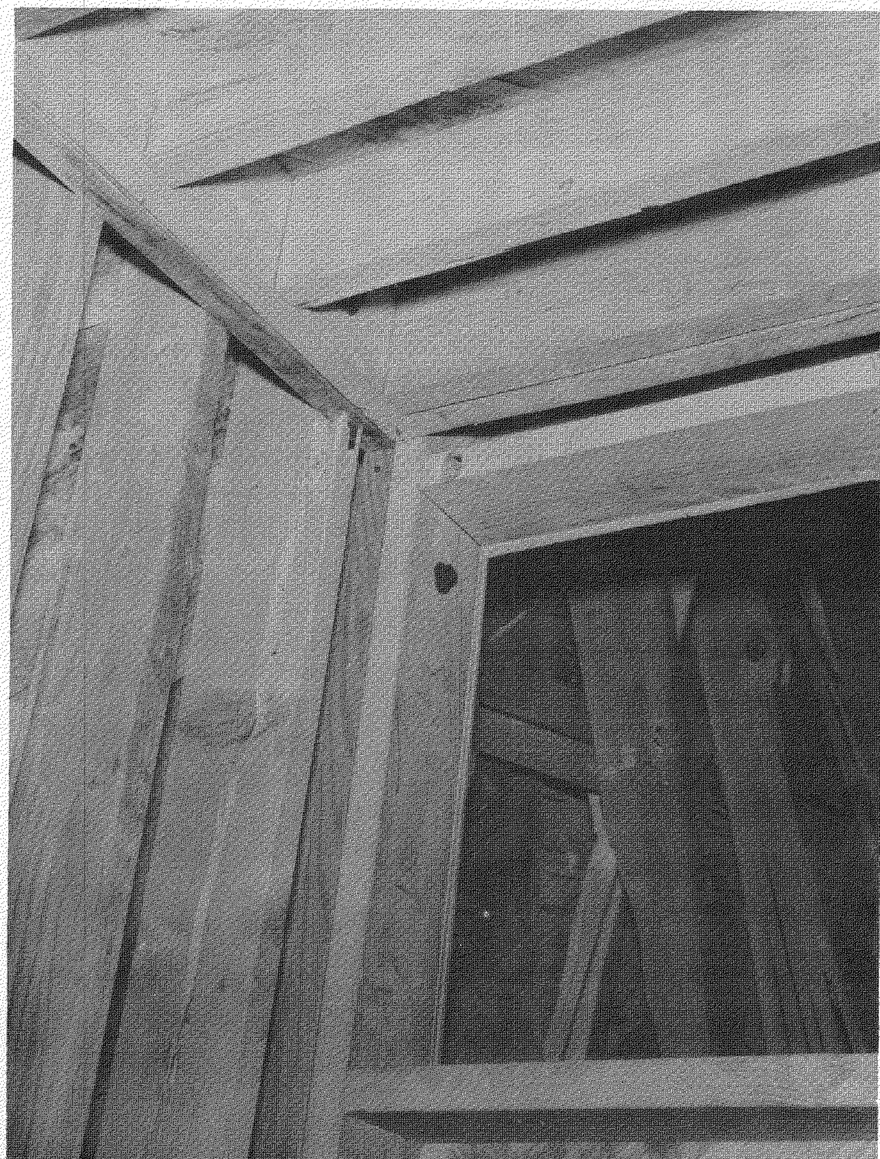

Fig. 20—Damage to basement corner room at 3500 ft.

APPENDIX

LOCATIONS AND STRUCTURAL DETAILS OF SHELTERS

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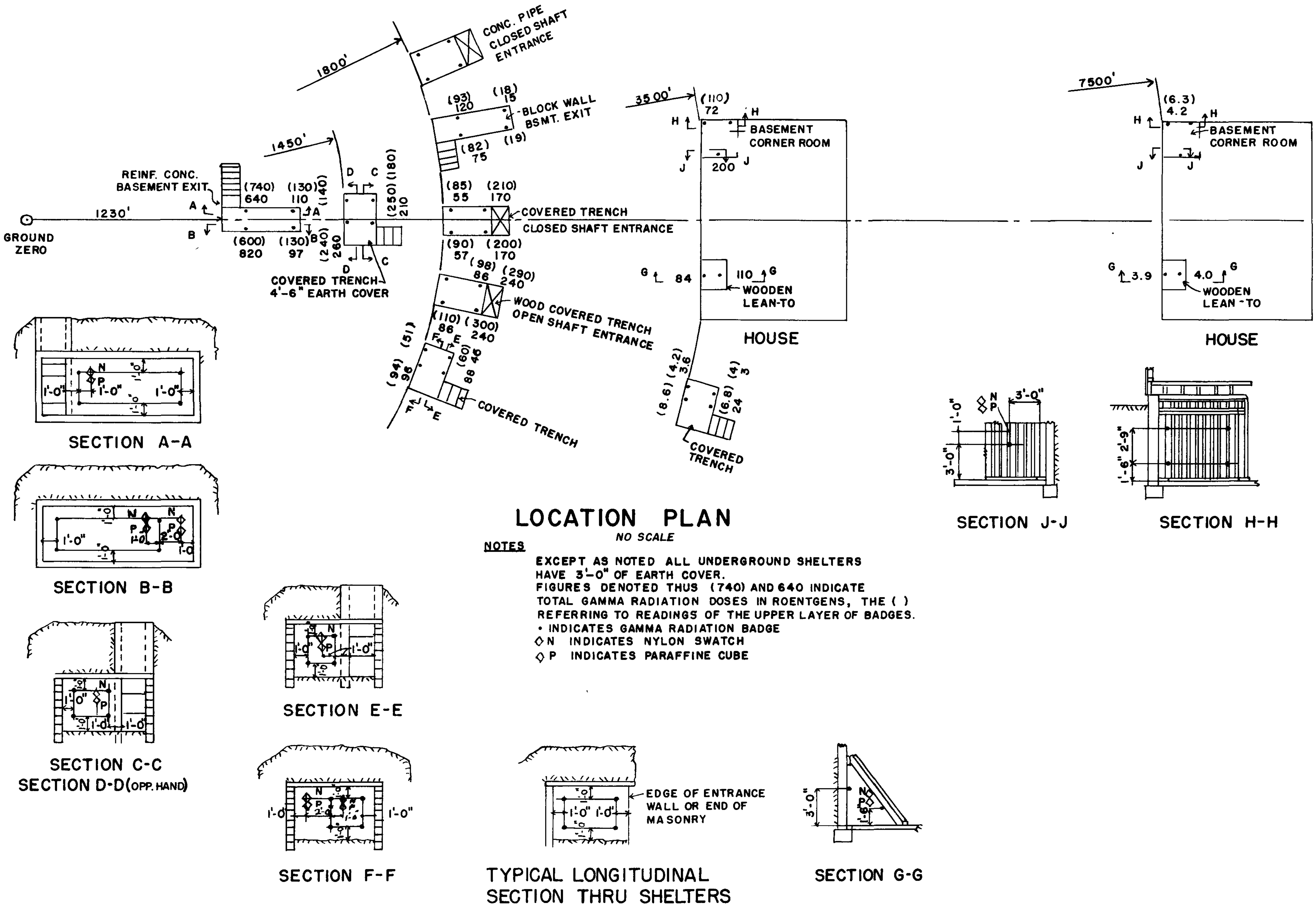


Fig. A.1—Location plan.

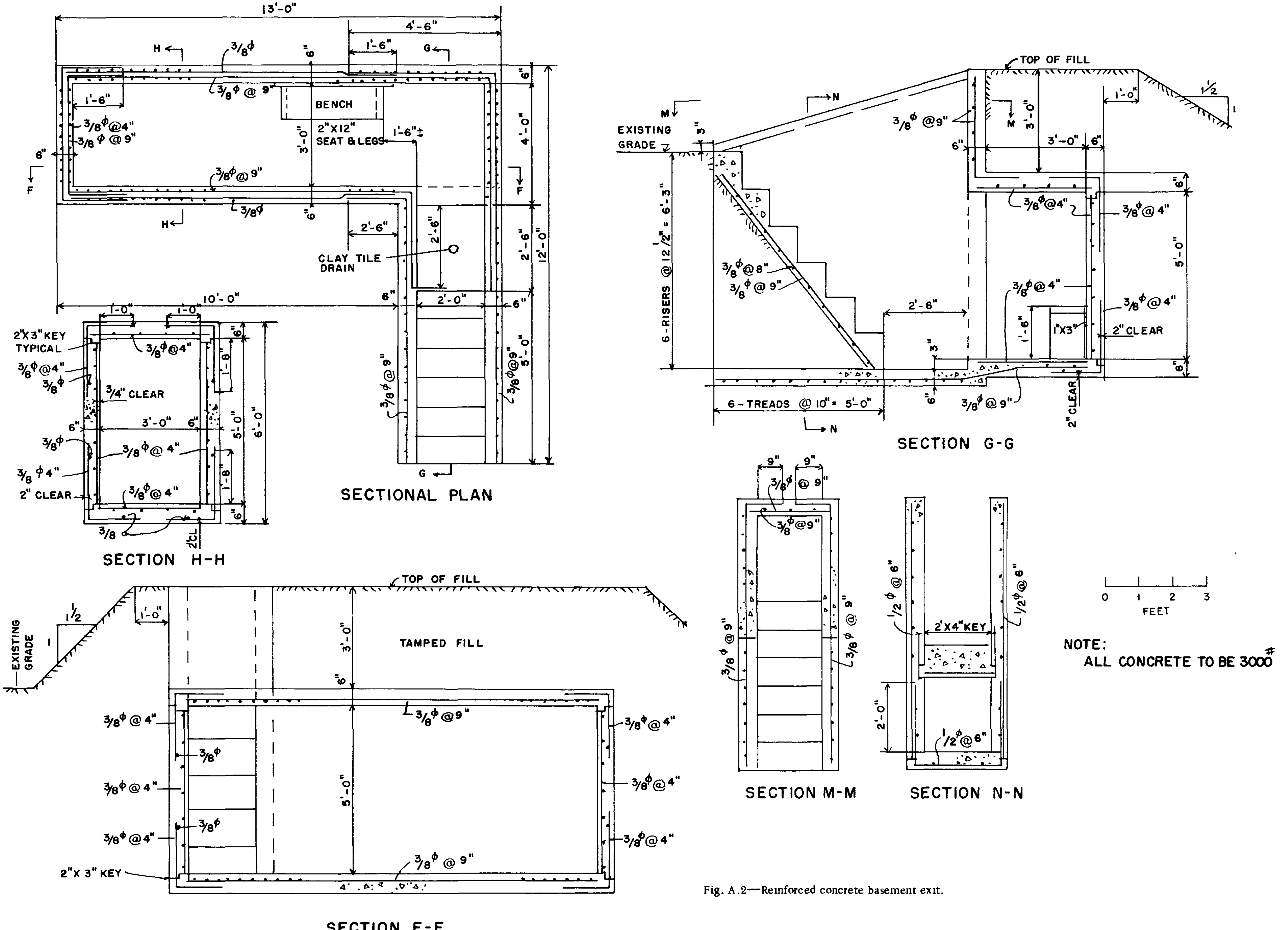
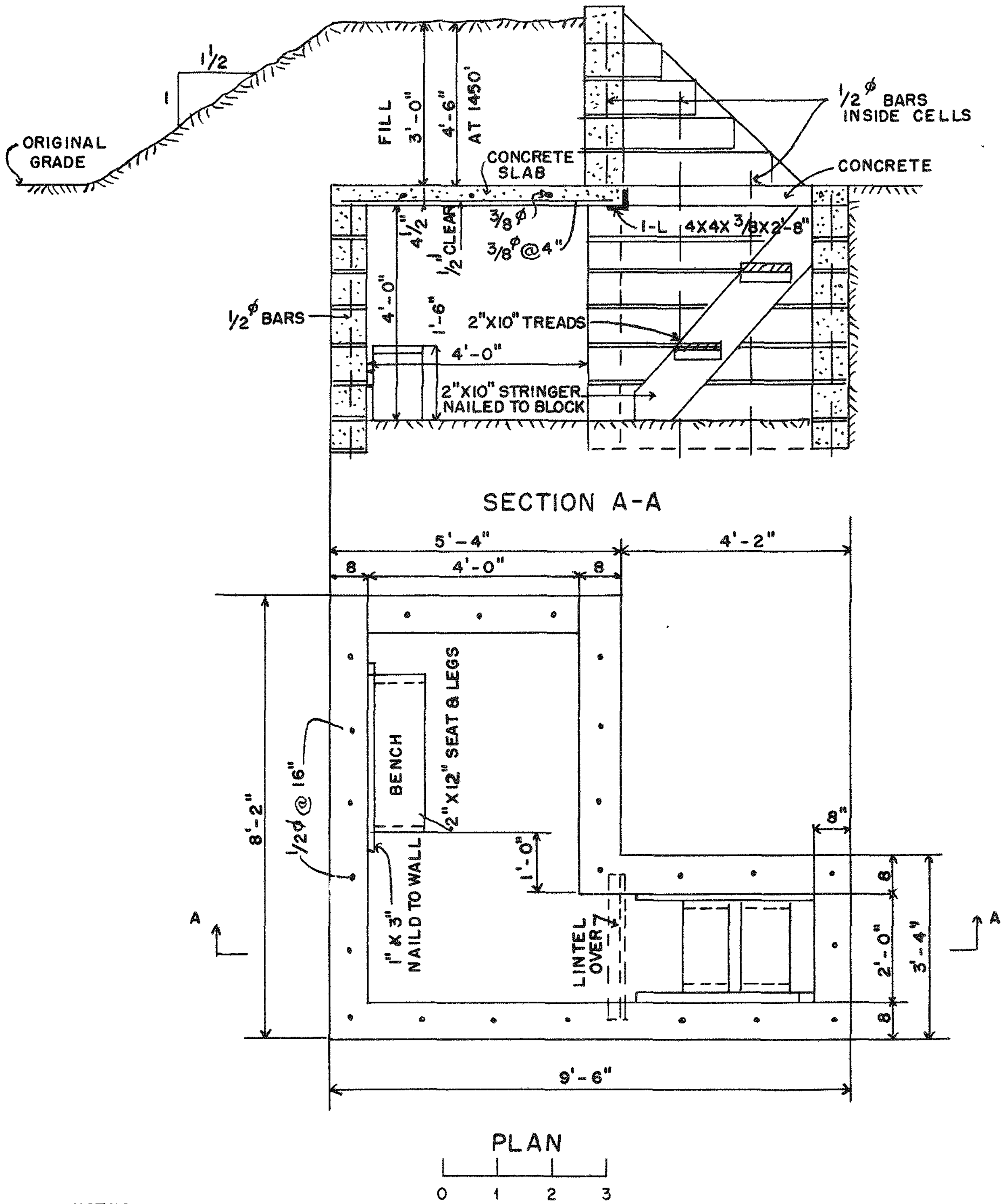


Fig. A.2—Reinforced concrete basement exit.



NOTES

BLOCK WALLS LAID UP WITH MORTAR.
FILL CELLS OF ALL BLOCKS WITH CONCRETE.
USE 3000# CONCRETE IN ROOF SLAB.
SLAB REINFORCING BARS TO BE STRAIGHT STANDARD A-305 OR ORDINARY DEFORMED WITH HOOKED ENDS.

Fig. A.3—Covered trench at 1450, 1800, and 3500 ft.

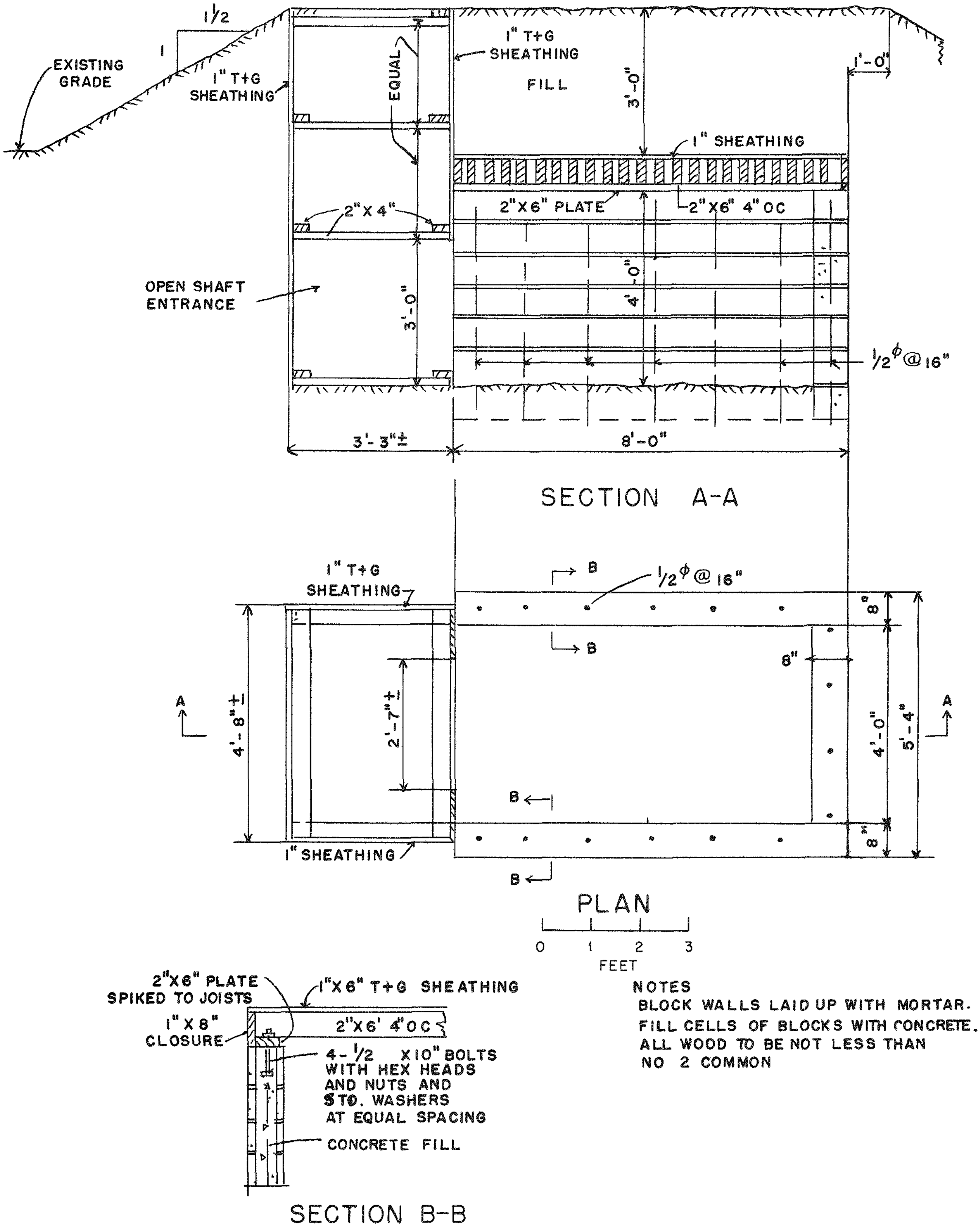


Fig. A.4—Wood-covered trench.

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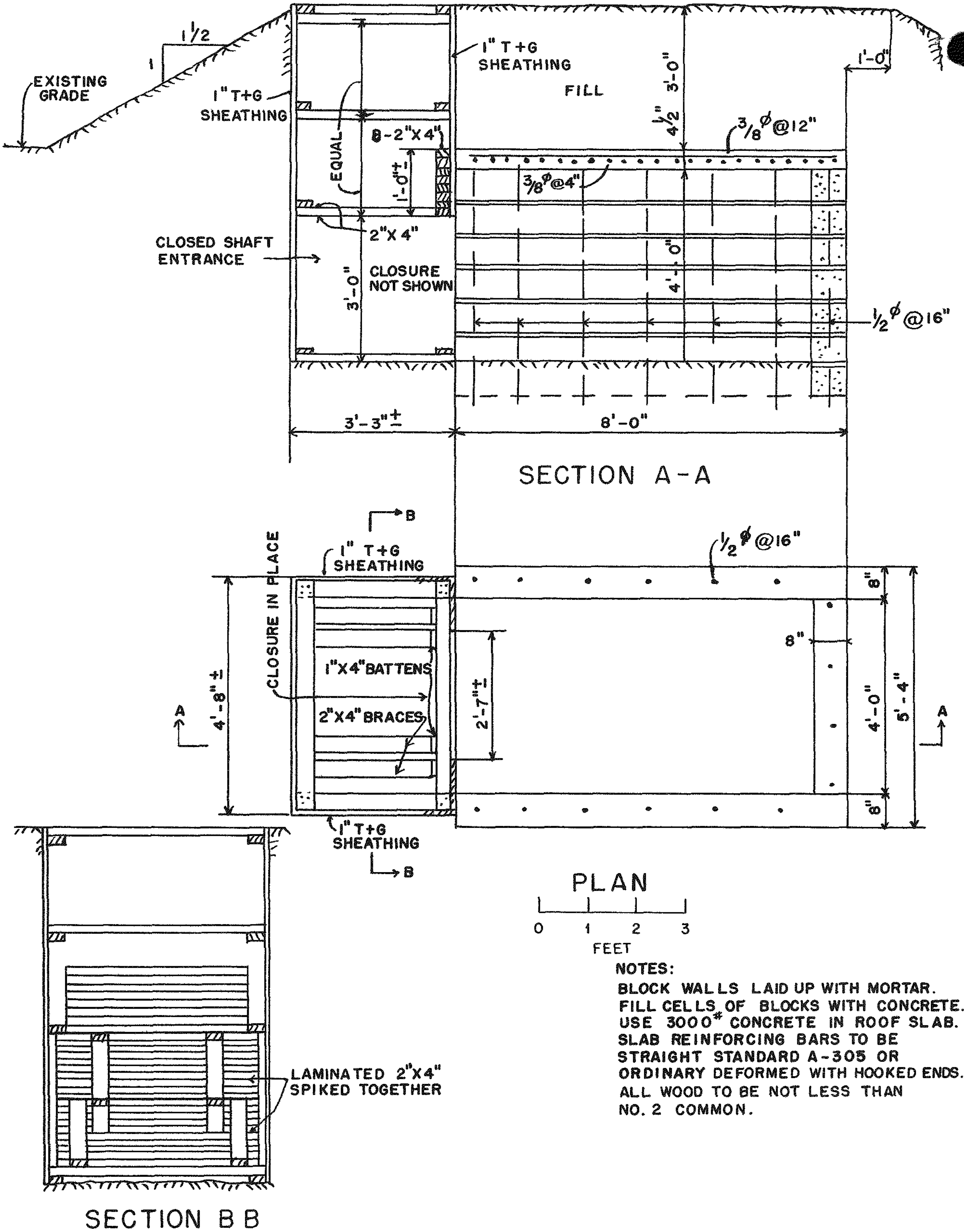

Fig. A.5—Covered trench with closed shaft entrance.

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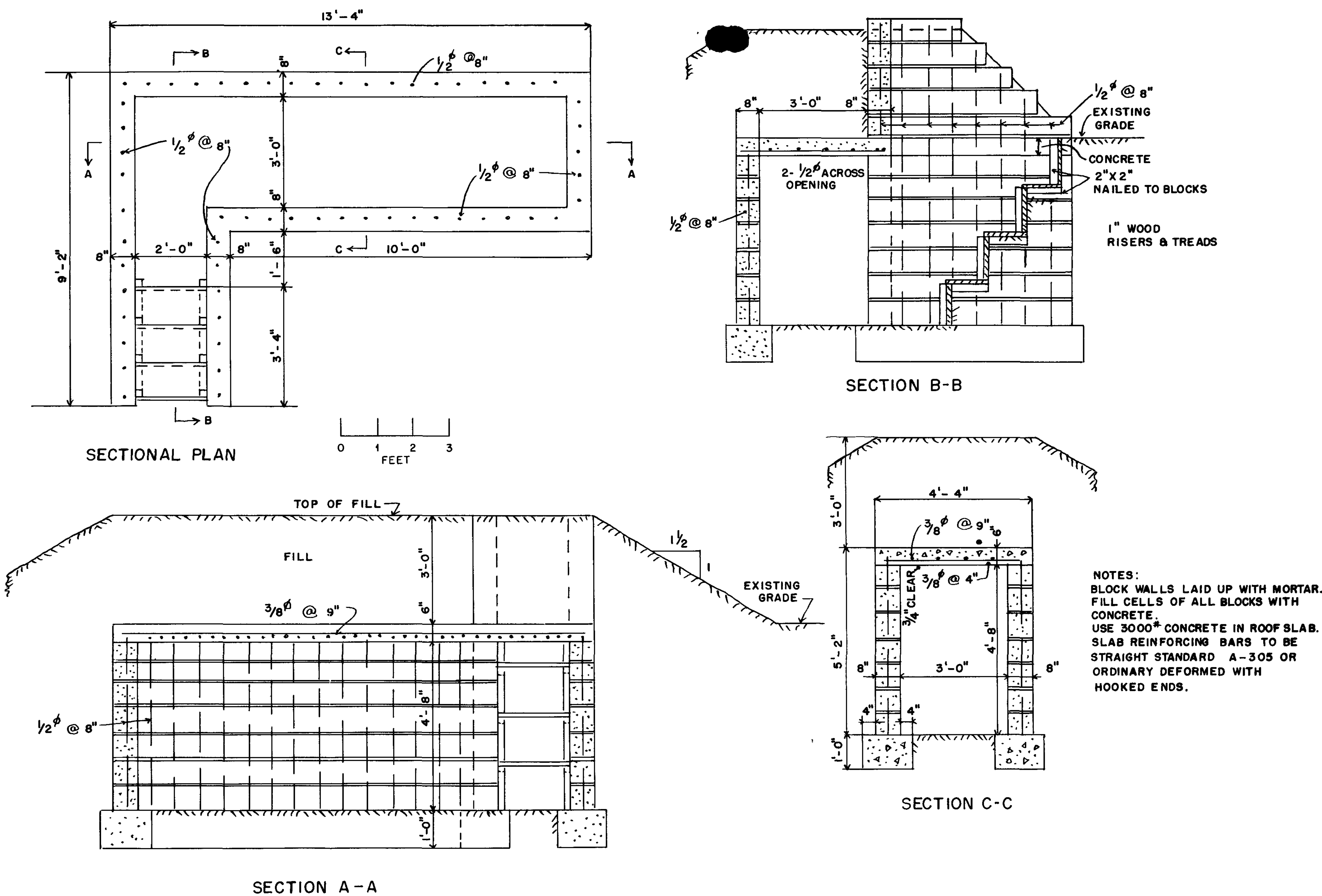

Fig. A.6—Block-wall basement exit.

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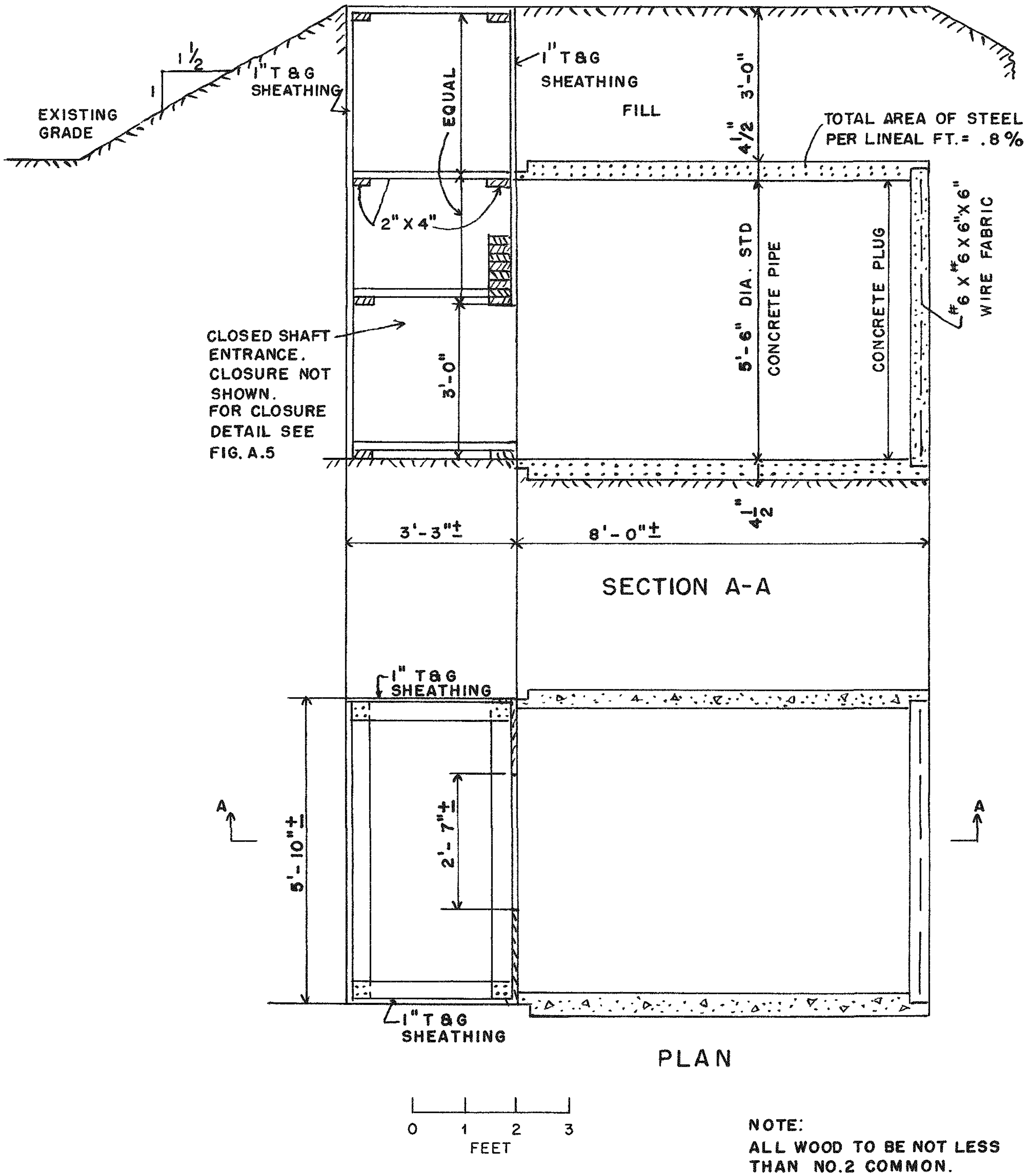

Fig. A.7—Concrete pipe with closed shaft entrance.

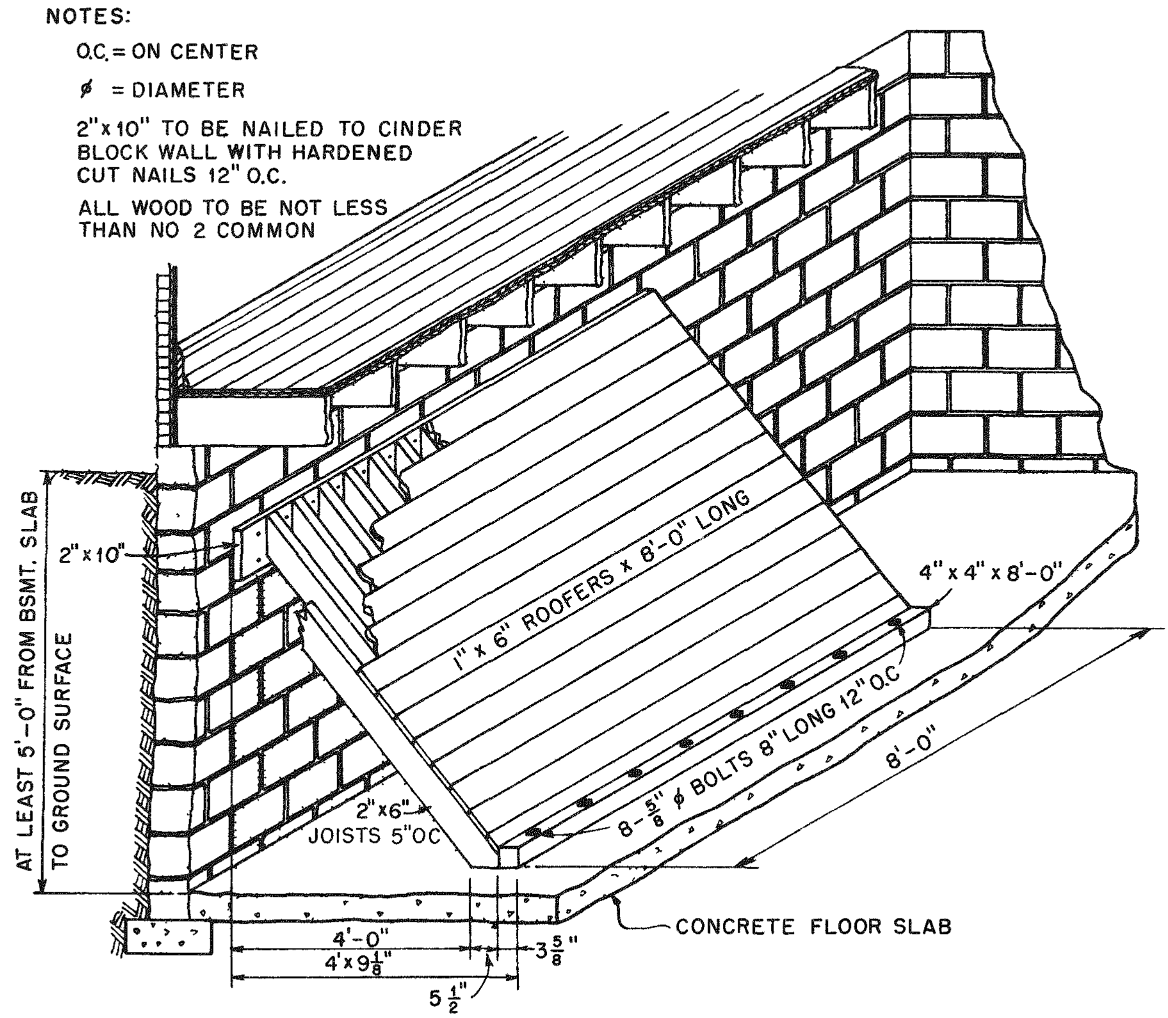

Fig. A.8—Wooden lean-to at 3500 and 7500 ft.

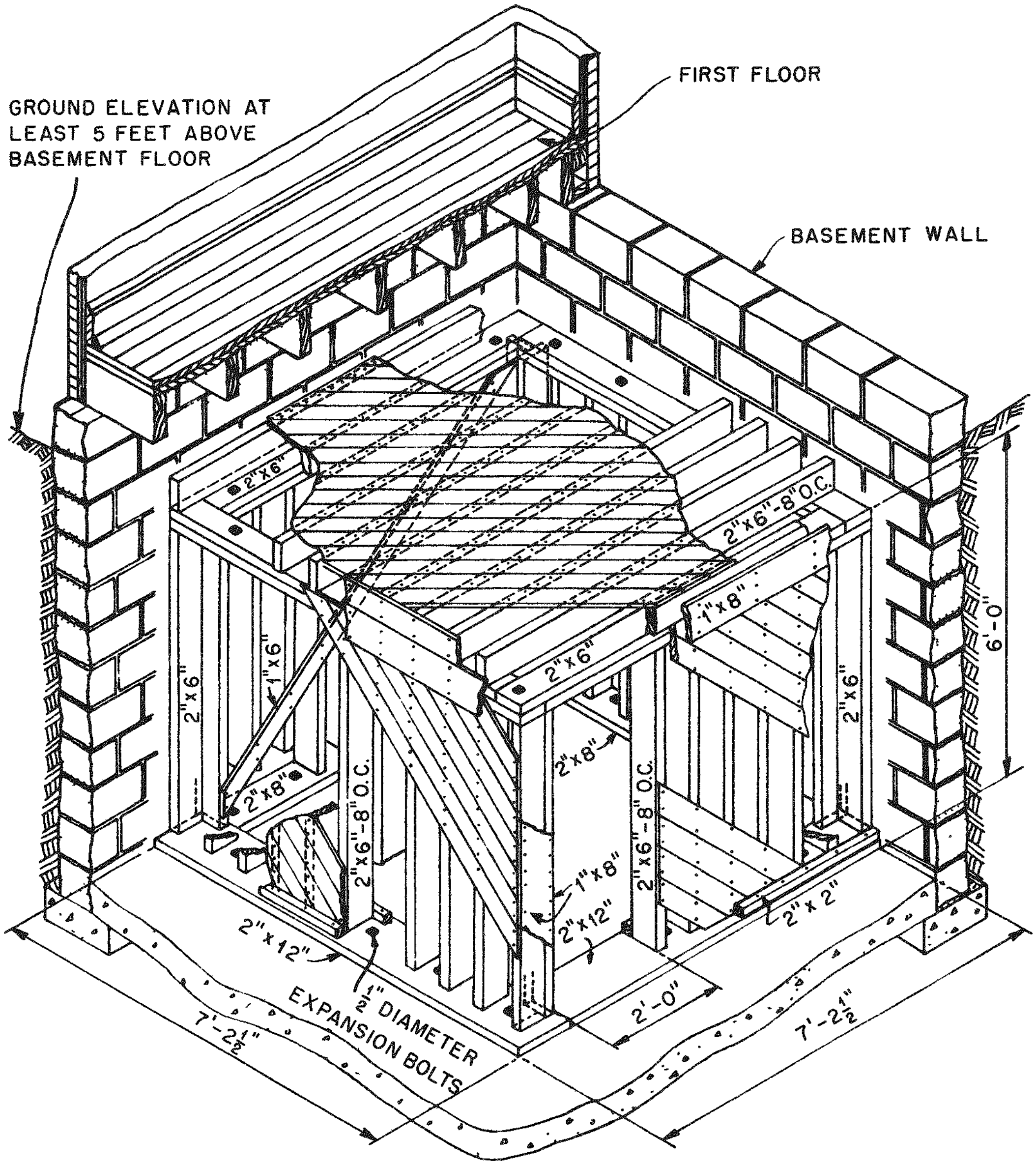

Fig. A.9—Basement corner room at 3500 and 7500 ft. All wood to be not less than No. 2 common. Roof to be prefabricated and erected as a unit.

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