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POR-6741
(WT-6741)

MIDDLE NORTH SERIES

DIAL PACK EVENT

PROJECT OFFICERS REPORT

PROJECT LN-318

TEST OF PRECAST CONCRETE UNDERGROUND STRUCTURE (U)

HEADQUARTERS
DEFENSE NUCLEAR AGENCY
WASHINGTON, D.C. 20305

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TEST OF PRECAST CONCRETE UNDERGROUND STRUCTURE (U)

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DEFENSE NUCLEAR AGENCY
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ABSTRACT

DIAL PACK Event of the MIDDLE NORTH Series, Bell Laboratories Project LN-318, involved the evaluation of the blast-induced response of the SA Manhole. The SA Manhole was a full-size, segmented, precast-concrete hardened structure, to be used by the Long Lines Department of American Telephone and Telegraph Company, to house electronic repeater equipment. Testing was designed to determine the extent of cracking, equipment environments, and overall structural response.

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INTRODUCTION

The primary objective of the DIAL PACK Event was to evaluate the blast-induced response of a full-size, segmented, precast-concrete hardened structure. Such a structure will be used by the Long Lines Department of American Telephone and Telegraph Company to house electronic repeater equipment on hardened L4 and L5 coaxial cable routes. In addition, this type of construction is being considered for use in larger underground buildings.

The existing L4 and planned L5 carrier systems are nationwide, high-capacity communication systems providing telephone circuits for civilian and military needs. These coaxial cable systems are hardened to survive the collateral effects of nuclear weapon attack. The communication system itself is not considered to be a target but is hardened to survive the effects of a nuclear weapon attack on nearby targets. The cable systems are routed to avoid targets by margins sufficient to preclude blast effects exceeding the design environment of the system.

The auxiliary repeater stations, or manholes, are all designed to survive 50-psi blast effects. The coaxial cable has a blast resistance exceeding 100 psi, even when buried at a shallow depth. These cables are buried at a minimum depth of 4 feet to reduce the likelihood of accidental dig-ups.

PROCEDURE

The structure tested in the DIAL PACK Event, the SA Manhole, was designed to survive a 50-psi blast loading due to the detonation of a megaton nuclear weapon with only minor plastic deformation.

A consideration of the impulse differences between the DIAL PACK Event and a megaton nuclear blast indicated the placement of the structure at a range corresponding to 60-psi overpressure in DIAL PACK Event (see figure 1). The test was designed to determine the extent of cracking, blast-induced deflections and relative motions, equipment environments, and overall structural response.

Figure 2 shows a model of the SA Manhole. The basic structure was made up of 12 precast concrete slabs, each 8-1/2 inches thick and roughly 9- by 13-feet in area. The interior dimensions of the structure were 12- by 24- by 8-feet. A structural steel frame supported the roof at mid-span, and a concrete collar section with a blast-hatch was mounted in the entry area and permitted a cover of 2 feet of earth over the roof of the structure. The blast-hatch, 2- by 6-feet in area, was made of cast aluminum in two parts; the sections folded to completely open the hatch area.

The principal data sought in this experiment were in the following areas: (1) load deflection and relative motion of the wall- and roof-slab sections, (2) accelerations on wall- and roof-locations to which equipment might be mounted, (3) shear-strength of the interlocking slab joints, and (4) performance of the new two-piece rolling blast-door, including information on rebound forces.

An elevation view of the installed manhole is shown in figure 3. An earth cover of approximately 2 feet was provided over the roof, sloping back to the original grade with about a 4 on 1 slope.

Figures 4 through 13 show the assembly of the manhole. Shown in figure 14 is the blast hatch used on the SA Manhole. Normally, the hatch was latched in place by means of four bars, activated either by handles from within, or from the outside by means of a special wrench. In the DIAL PACK Event, each hatch-half was bolted with four bolts. One set consisted of instrumented strain bolts which permitted determination of rebound forces.

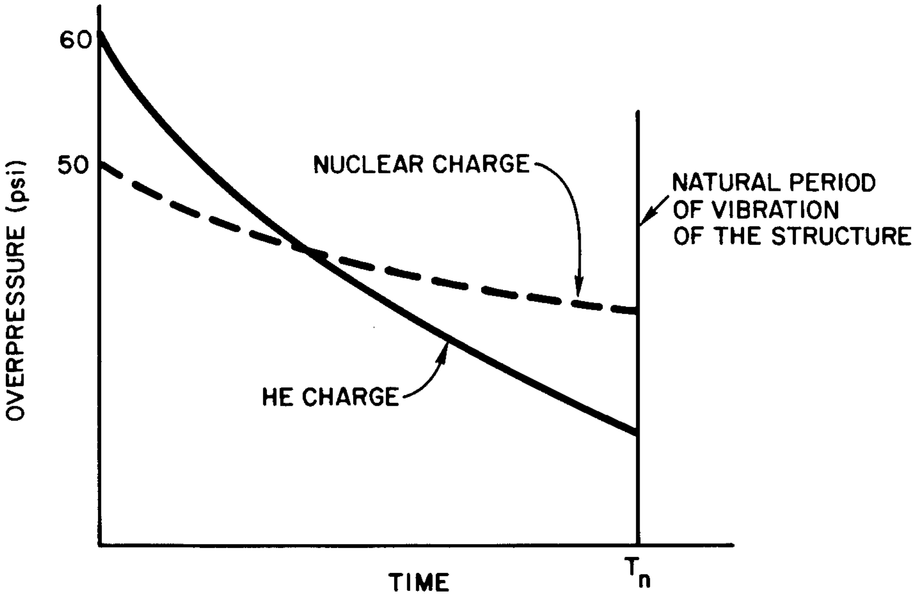


Figure 1. --Load impulse from impingement to natural vibration period.

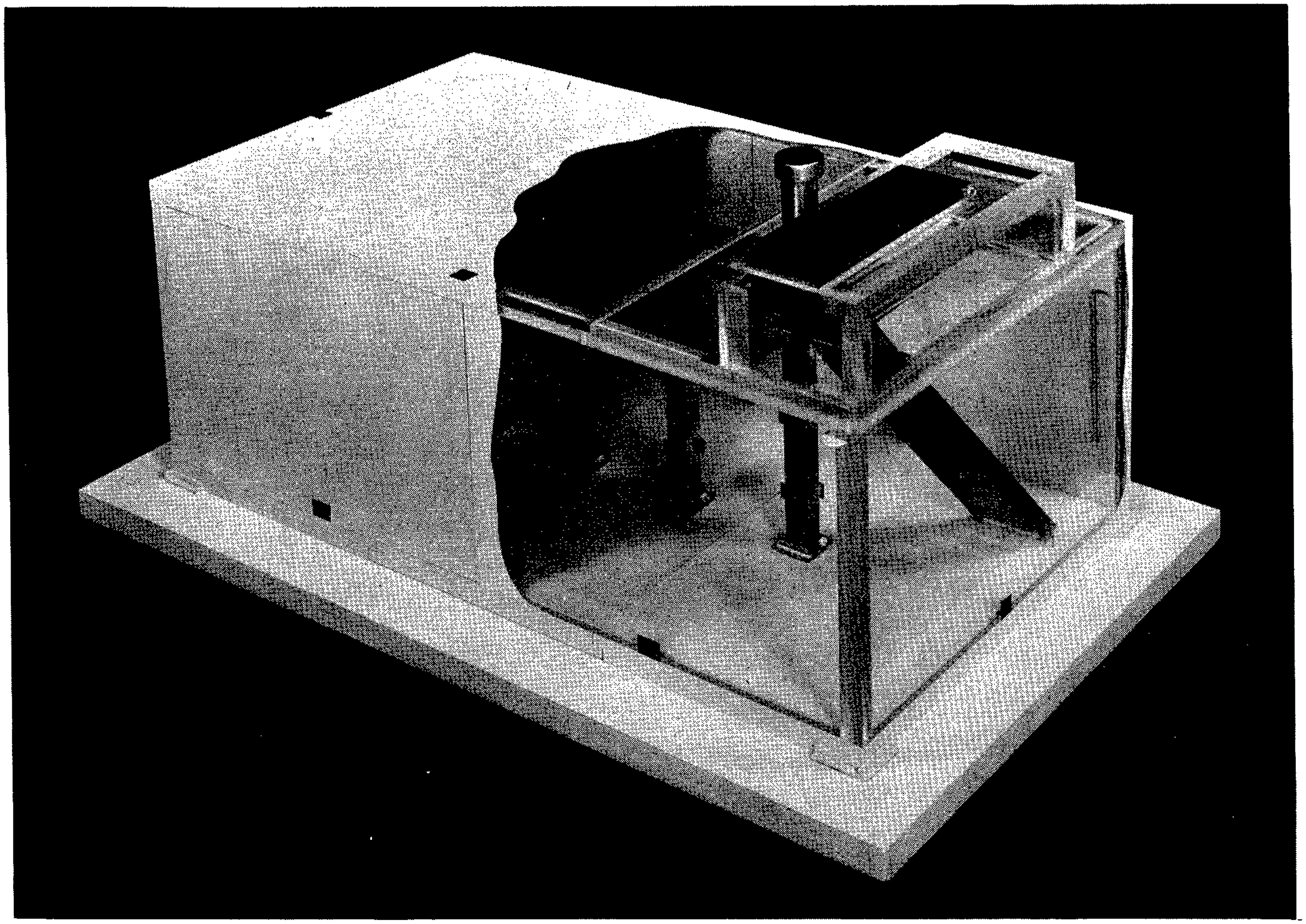


Figure 2. --Model of the SA Manhole.

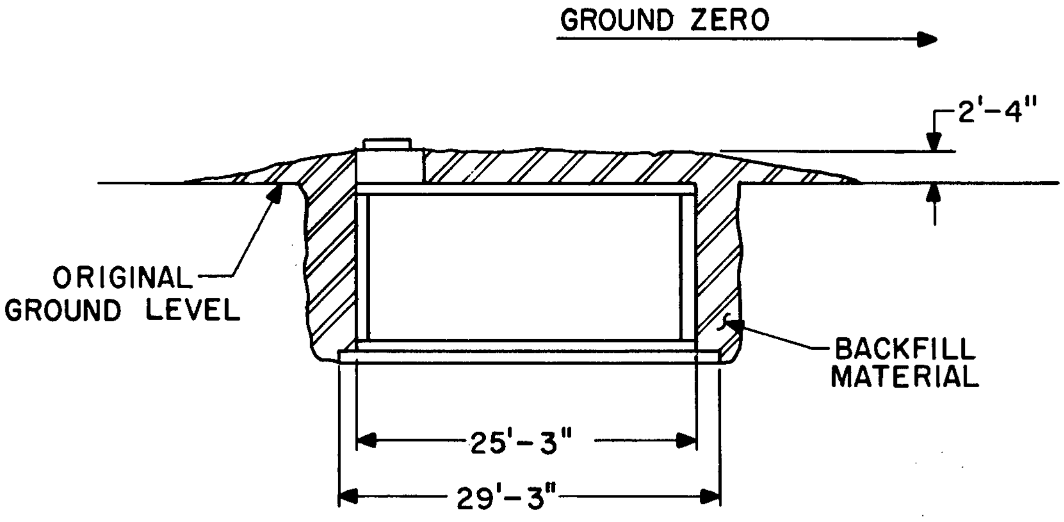


Figure 3. --Elevation view of the SA Manhole.

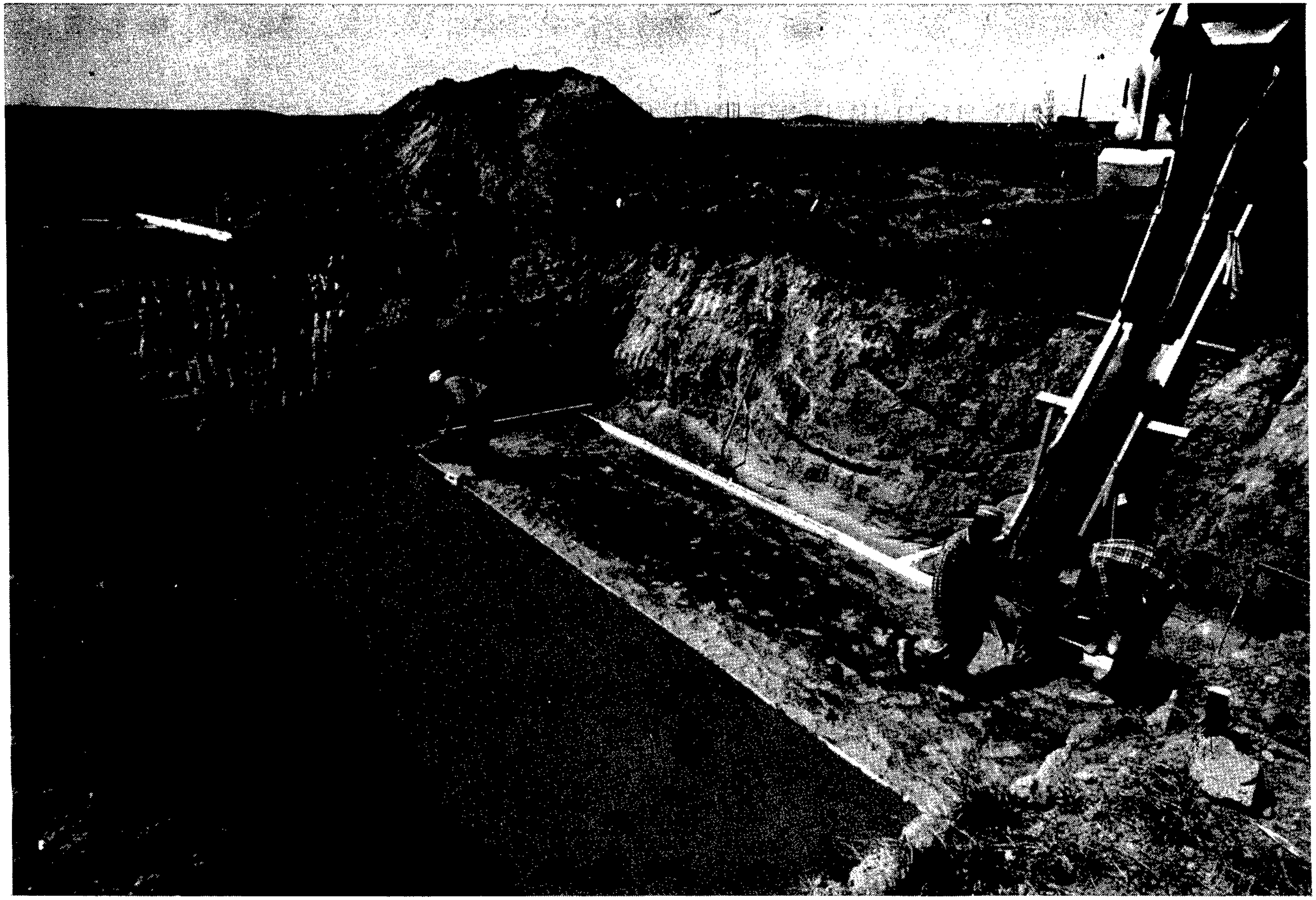
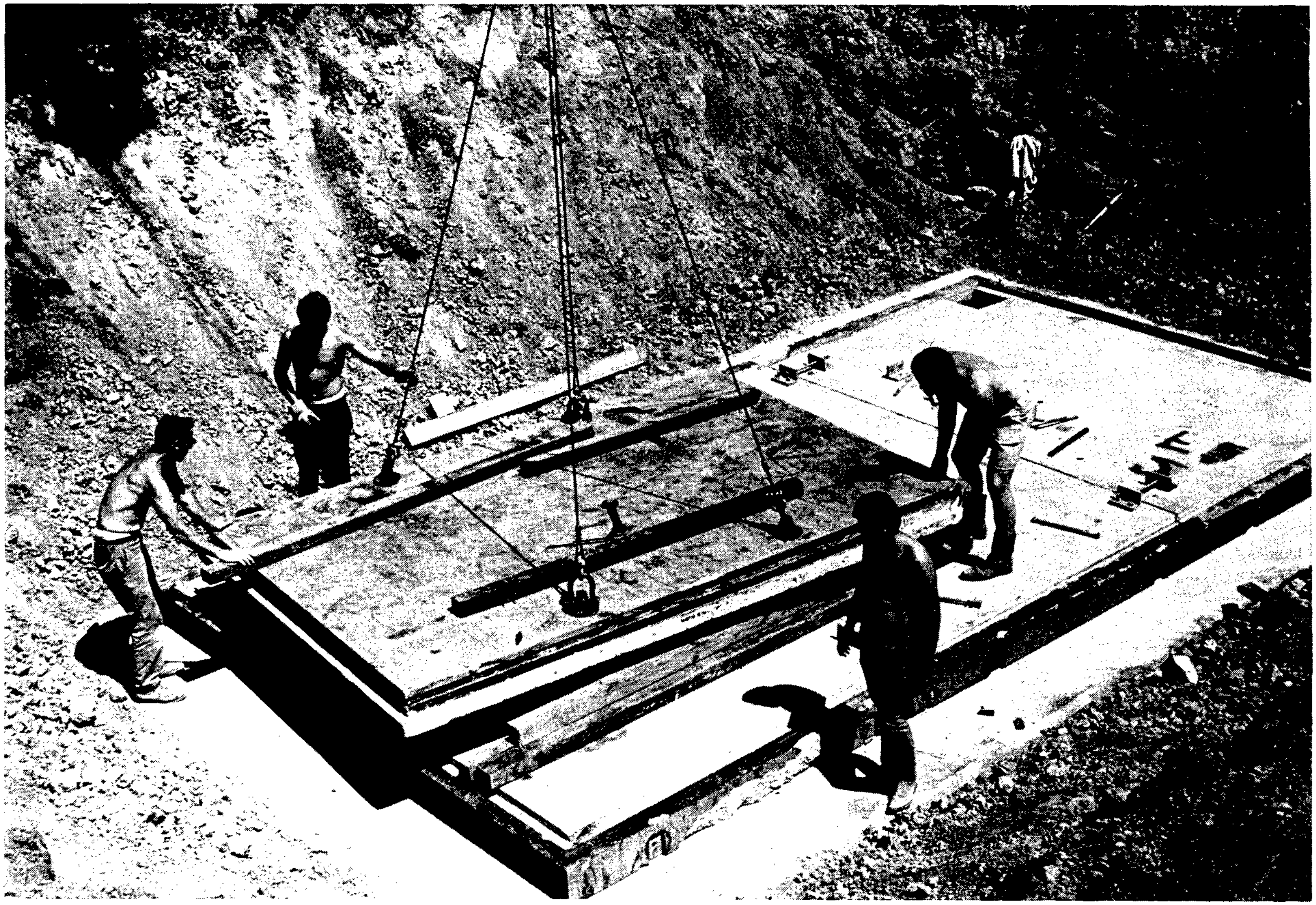


Figure 4. --Assembly of Manhole (page 1 of 10).



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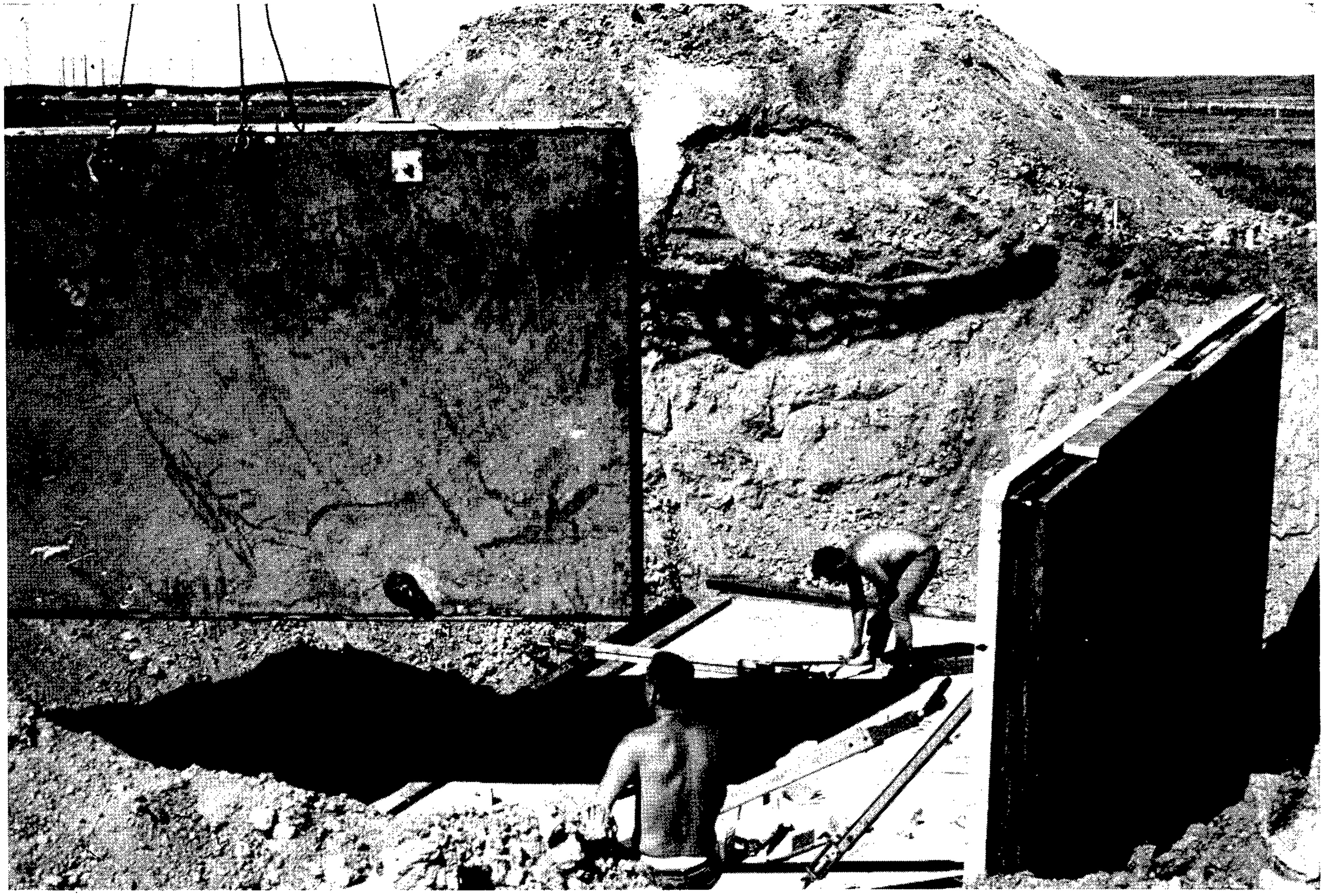
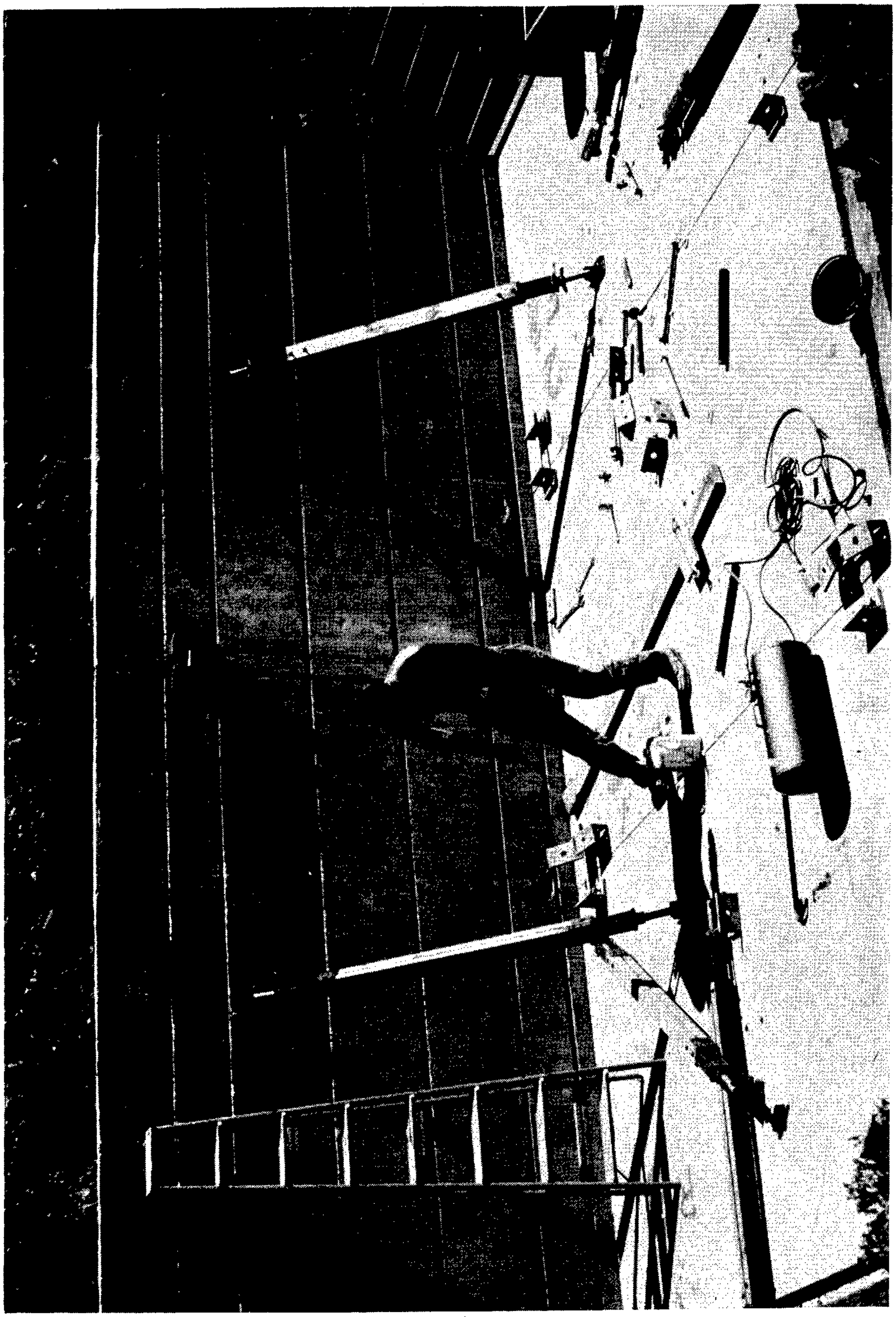


Figure 6. --Assembly of Manhole (page 3 of 10).

Figure 7. --Assembly of Manhole (page 4 of 10).



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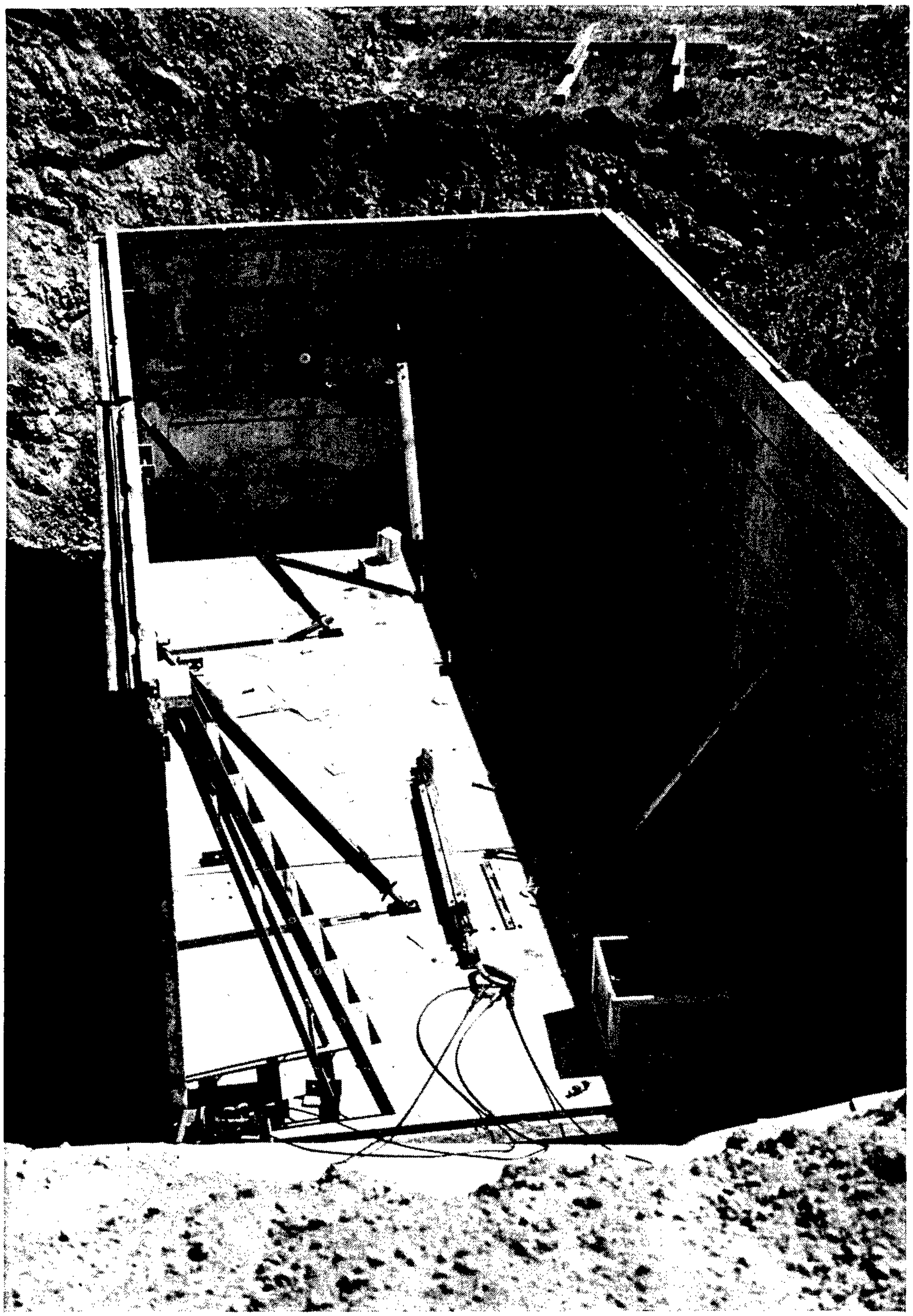

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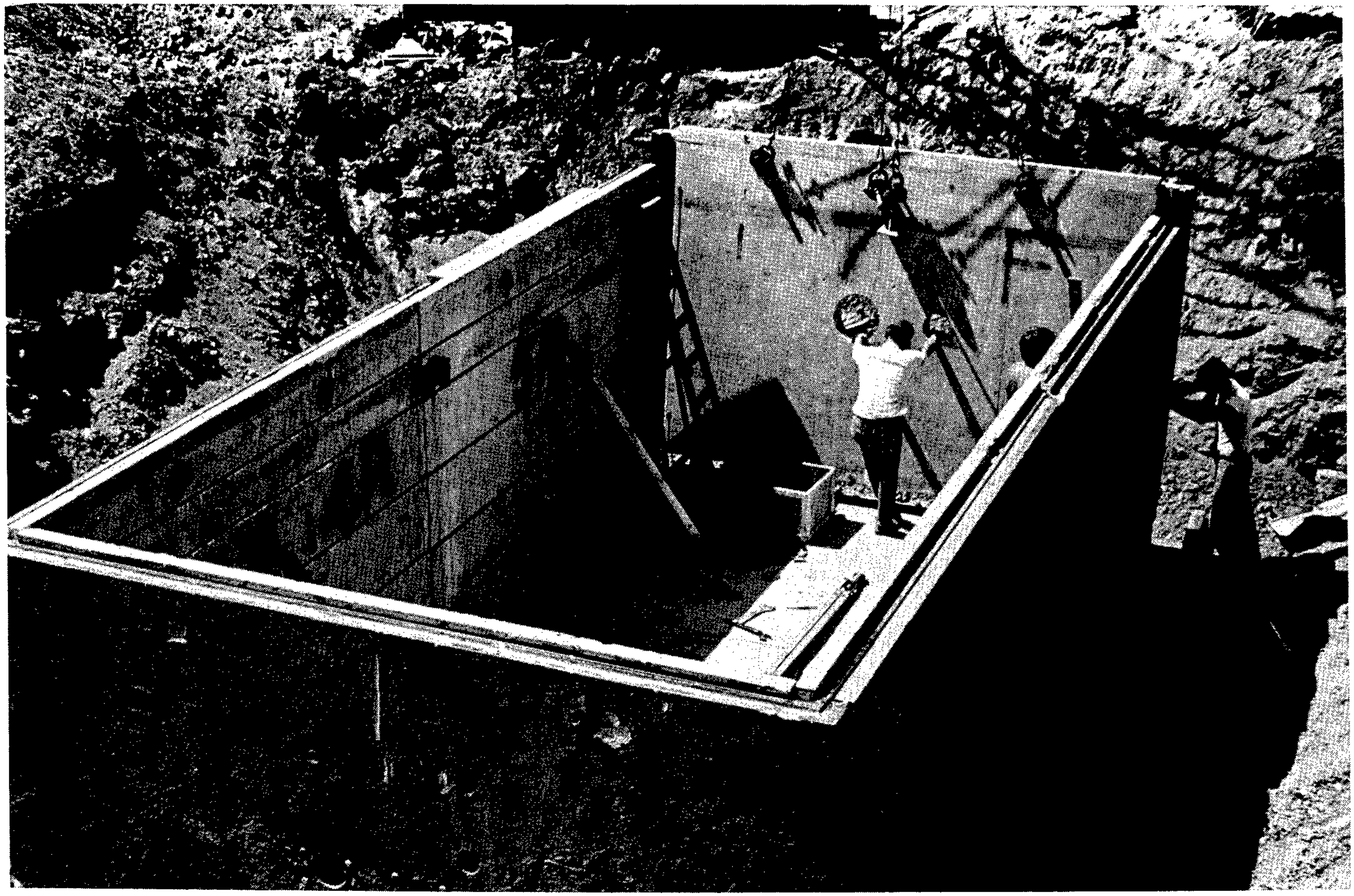


Figure 10. --Assembly of Manhole (page 7 of 10).

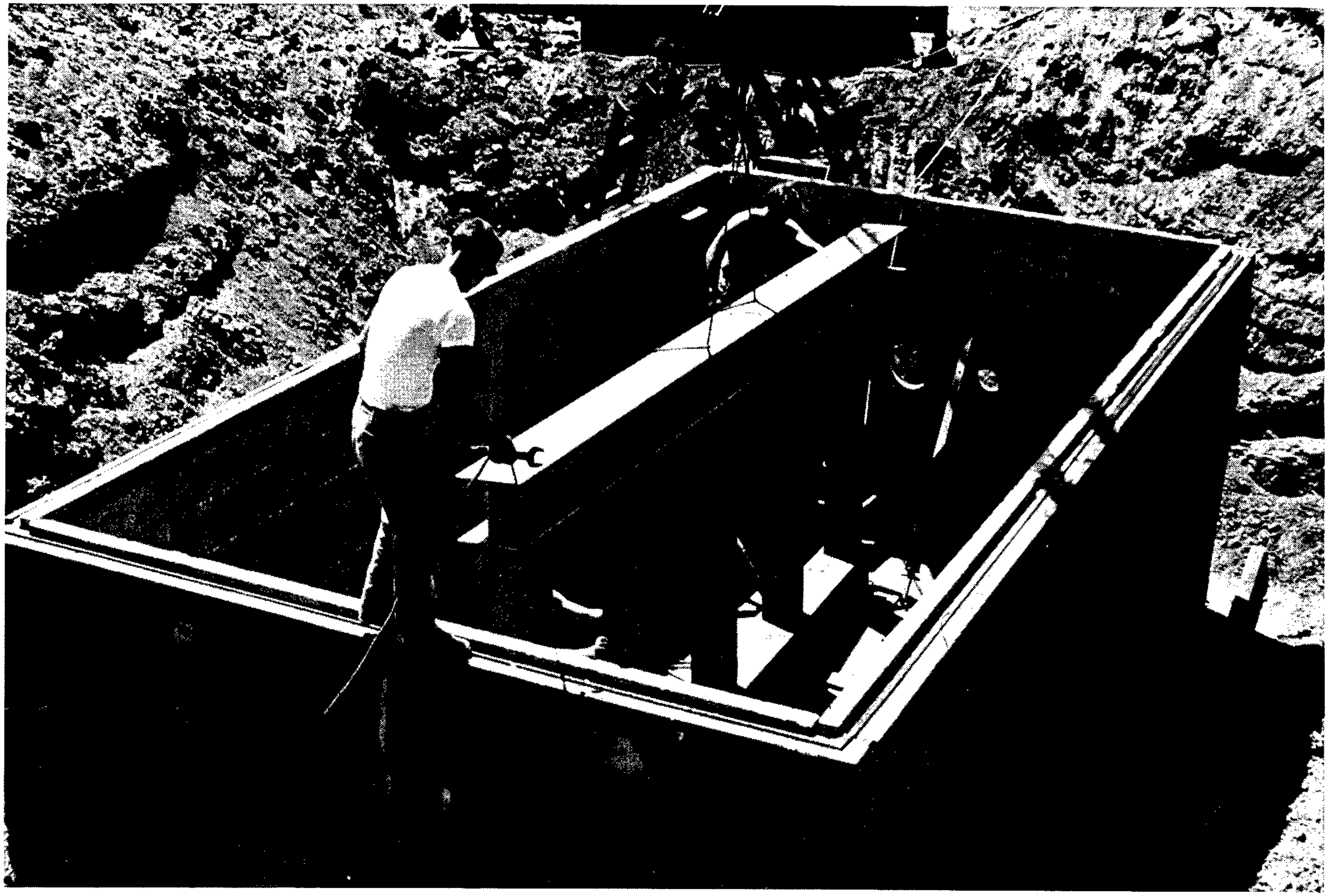


Figure 11. --Assembly of Manhole (page 8 of 10).

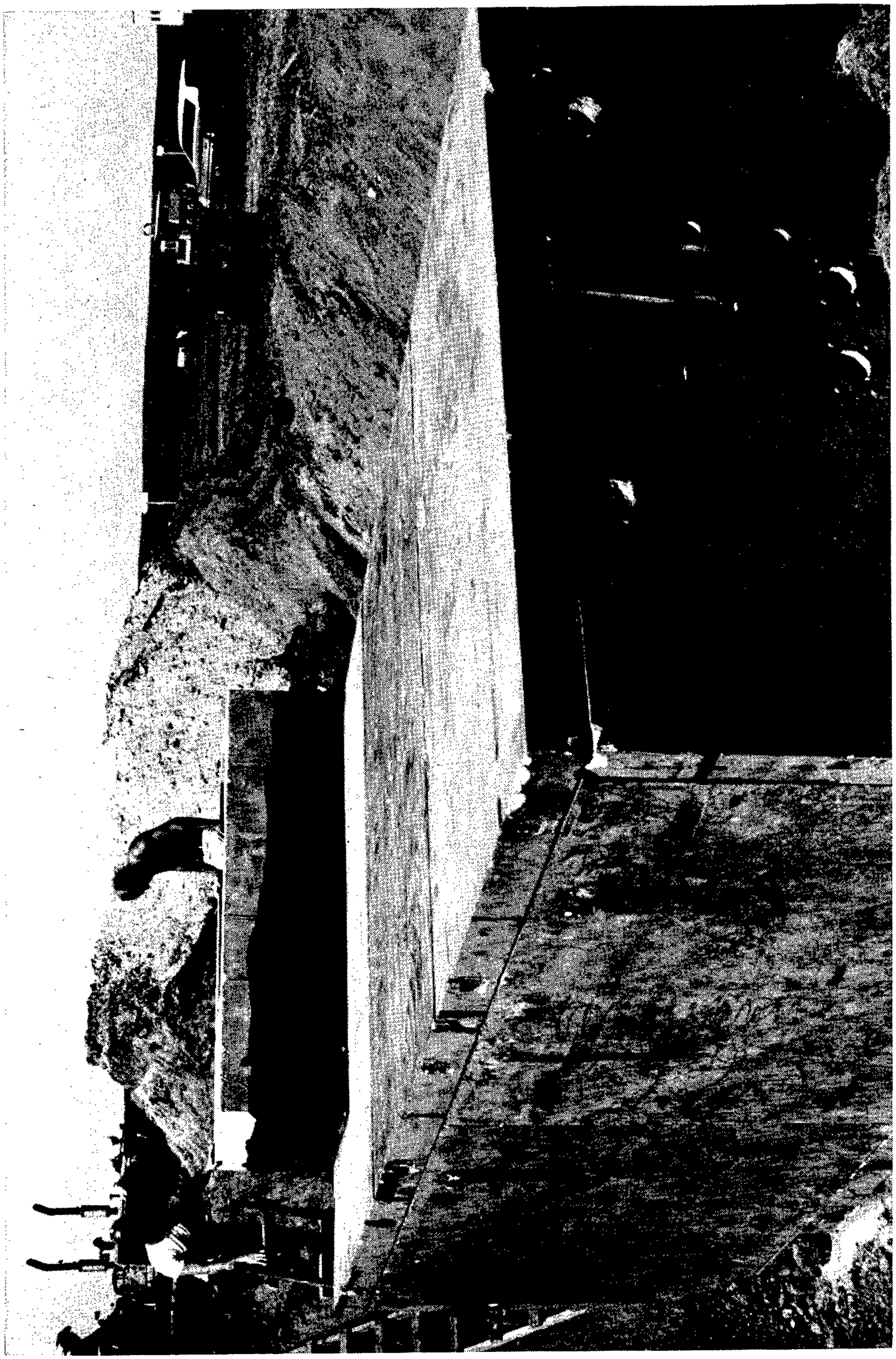


Figure 12. --Assembly of Manhole (page 9 of 10).

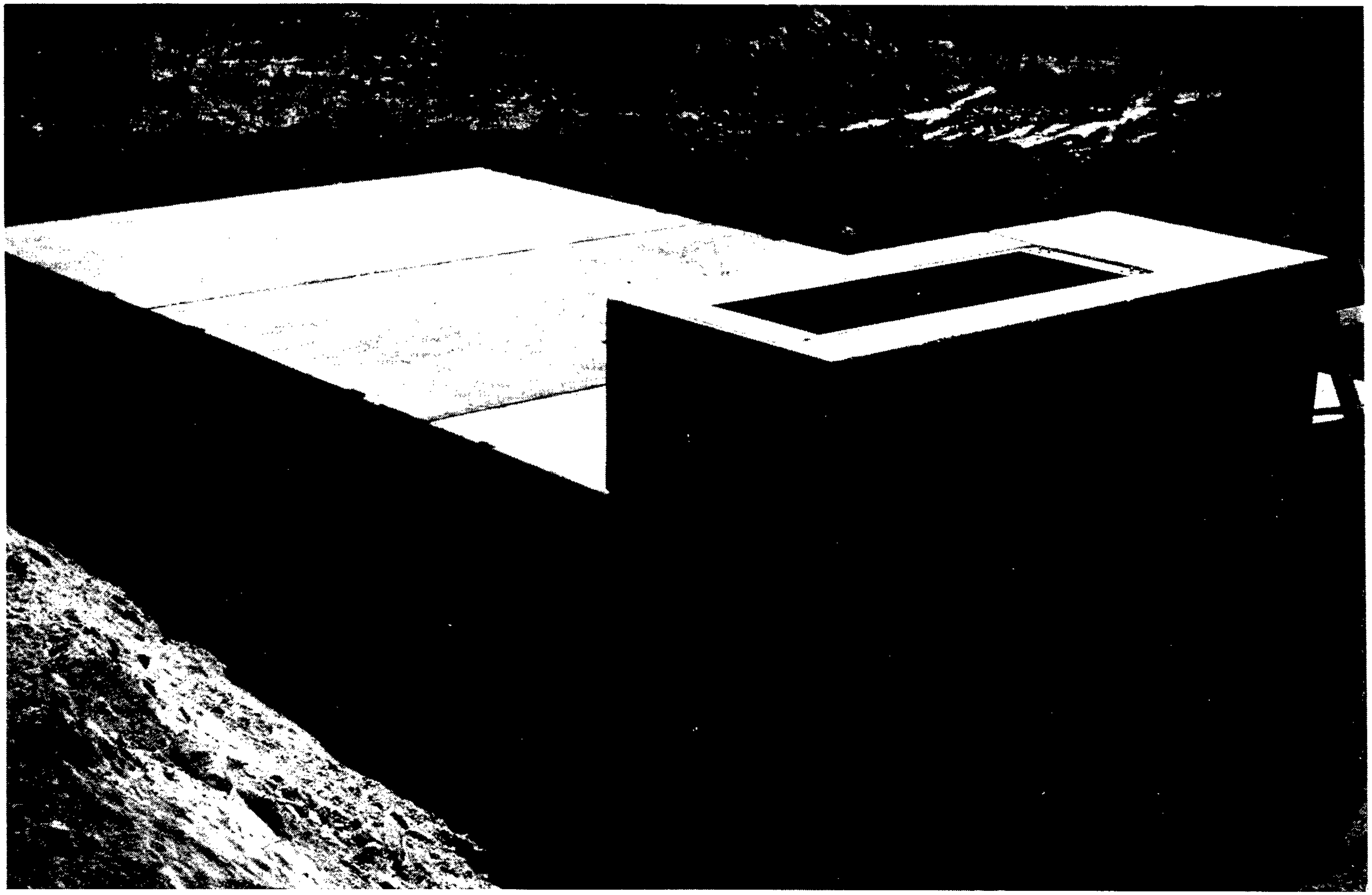


Figure 13. --Assembly of Manhole (page 10 of 10).

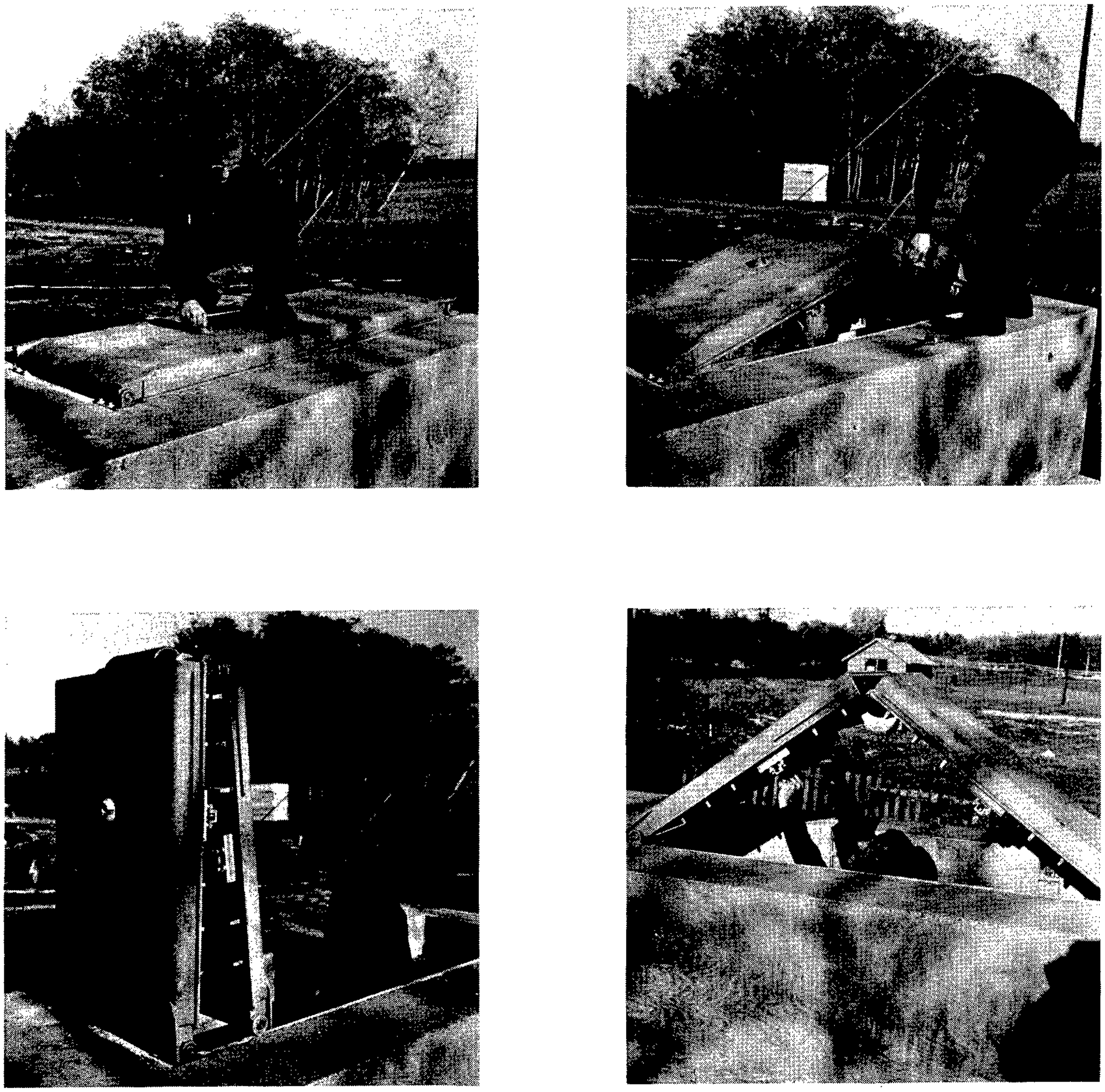


Figure 14. --Blast hatch used on SA Manhole.

The test installation is shown in plan in figure 15. As noted previously, the center of the manhole was located at the 60-psi range, with the long axis of the manhole oriented radially from GZ.

On the end of the manhole toward GZ, two 20-tube coaxial cables were installed to simulate a long cable run entering the manhole. Two types of cable entry pipes were installed: a 5-foot length of 4-inch ID PVC pipe (proposed for use), and an 8-foot length of 4-1/2-inch ID steel pipe. Each cable entry pipe penetrated the manhole wall and was grouted in place and bolted to the outer surface by means of a flanged connection. The cables were anchored externally to a deadman and were tied inside the manhole to the center structural steel frame to simulate the normal cable termination at a splice. The cables were installed at a depth of 4 feet below the original grade.

Two 40-foot lengths of conduit, one constructed of cement-asbestos, and the other of poly-vinyl-chloride (PVC), were located on the end of the manhole away from GZ. Both conduits had nominal inside diameters of 6 inches. The wall thickness of the relatively rigid cement-asbestos conduit was 0.70 inch, while that of the PVC conduit was 0.34 inch.

Shear protection for the transite conduit was provided by a nominal 12-inch diameter outer steel jacket, 6-feet long. The space between the jacket and conduit was filled with soft polyurethane foam. Shear protection for the PVC conduit consisted of a foam padding surrounding only the portion of conduit that projected through the wall.

The purpose of these tests was to evaluate the change due to blast in the alignment of conduit installed in a trench and at the interface with a manhole.

Bell Laboratories is currently engaged in the development of a waveguide transmission system for transcontinental communications. Unlike coaxial cables, low-loss performance of the waveguide requires a low level of geometric imperfection. Whereas failure in coaxial cables occurs only if the cable tears apart or an outer coaxial tube collapses, failure of the waveguide system could occur if the residual soil displacements are highly irregular, causing excessive curvature of the waveguide axis.

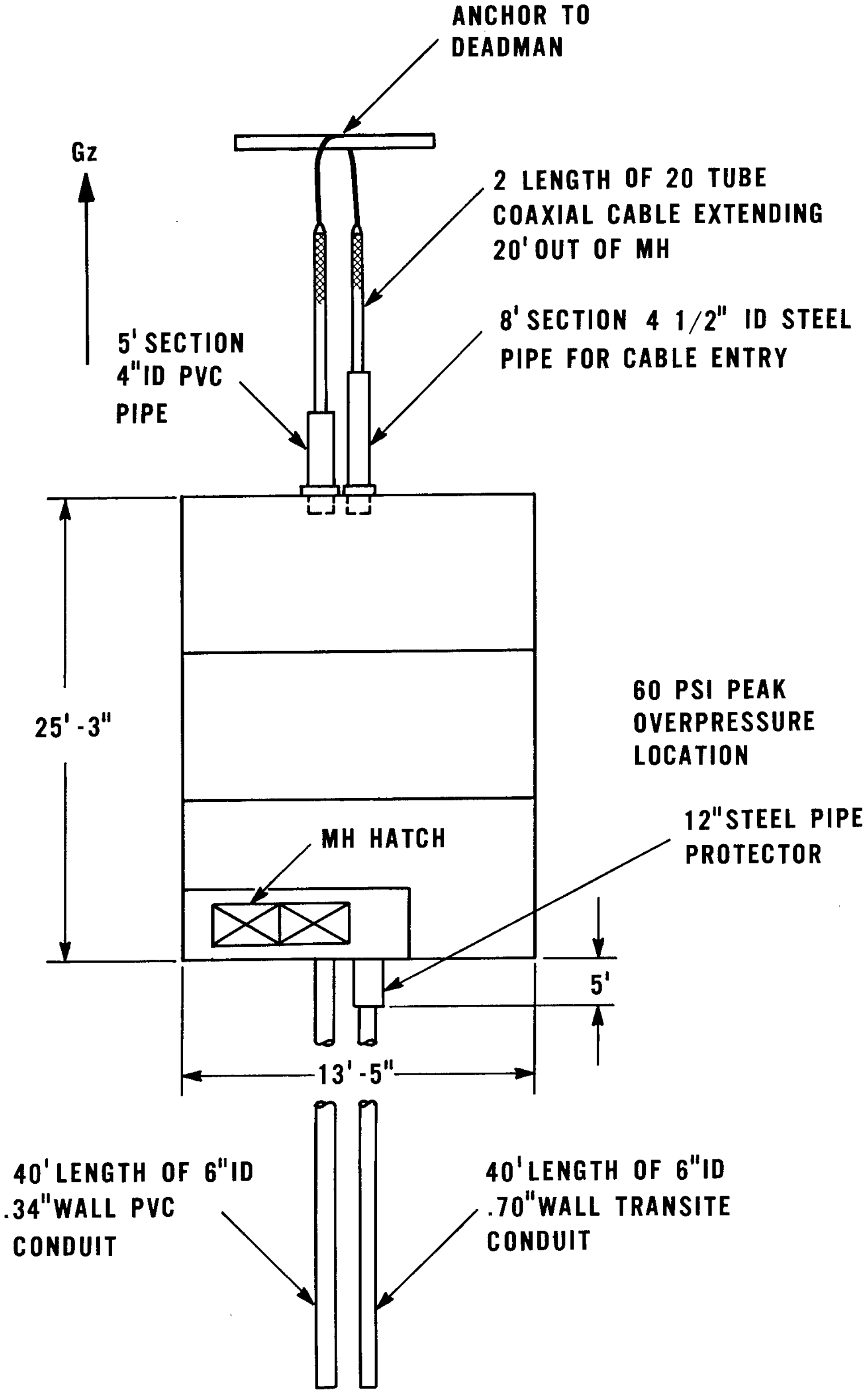


Figure 15. --Test installation.

Although the configuration of the buried installation has not yet been determined, it is likely that the waveguide will be housed in a conduit in a manner which isolates it from a certain amount of distortion of the conduit.

Some distortion will occur during initial installation, and this must be accounted for in the selection of repeater spacings. It is important to have an estimate of the distortions which may occur during the life of the installation or under blast loading, so that adequate compensation can be provided in the repeaters.

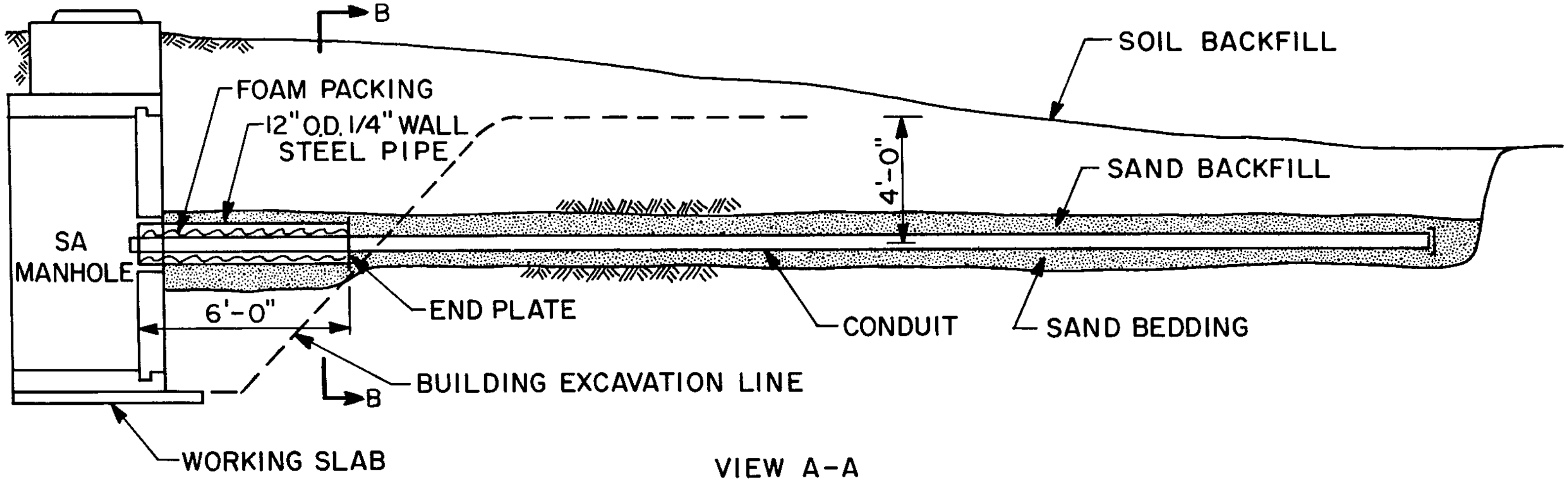
Figure 16 shows an elevation view of the conduit installation. The excavation region surrounding the building was somewhat larger than originally anticipated. In the area where the conduits and cable crossed the excavation region, the backfill under the conduits and cables was compacted. The natural soil was pushed into the void against the manhole end-walls to a height just below the entry holes for the conduit and cable (about a 3-foot depth), after which about 1,000 gallons of water were used to partially compact the soil by "puddling." Then, a few inches of additional soil were added on top of the wet soil to permit additional compaction by means of an impact-type motor driver-compactor. The result of this process was less than an optimum soil compaction but modeled a situation likely to occur in actual practice.

To make measurements of the distortions of the conduit tubes before and after the blast, a small target was sighted through a telescope located inside the manhole. The target was pushed along the conduit bore from inside the manhole.

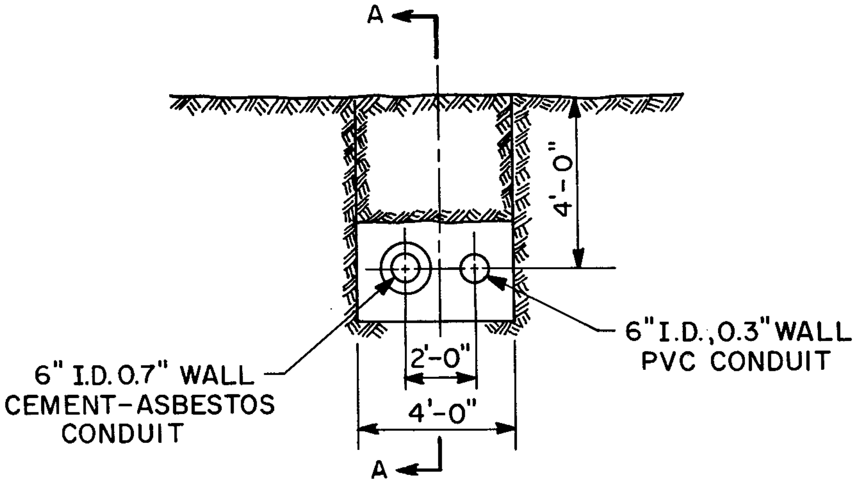
Figure 17 shows a view of the installation of the PVC conduit.

Two separate tests were performed adjacent to the large structure. A new design cast-aluminum manhole cover was installed on a cast-aluminum frame and fiberglass collar at the same overpressure range as the center of the precast concrete SA Manhole. Five 10-foot long sections of conduit of various stiffnesses were installed at a depth of 4 feet and at a range equal to that of the center of the 40-foot lengths of conduit. The objective of both of these experiments was to determine blast resistance and ability to survive the applied blast overpressure.

Included in this latter installation were three cement-asbestos conduits of 0.40-inch wall thickness, a PVC conduit with a 0.18-inch wall thickness, and a flexible, corrugated plastic conduit of nominal thickness 0.02 inch, corrugation



VIEW A-A



VIEW B-B

Figure 16. --Elevation view of the conduit installation.

Figure 17. --Installation of the PVC conduit.

depth 0.2 inch, and corrugation pitch or "wavelength" of 0.25 inch. One of the cement-asbestos conduits had a nominal 5-inch inside diameter, but the rest were 6-inch conduits.

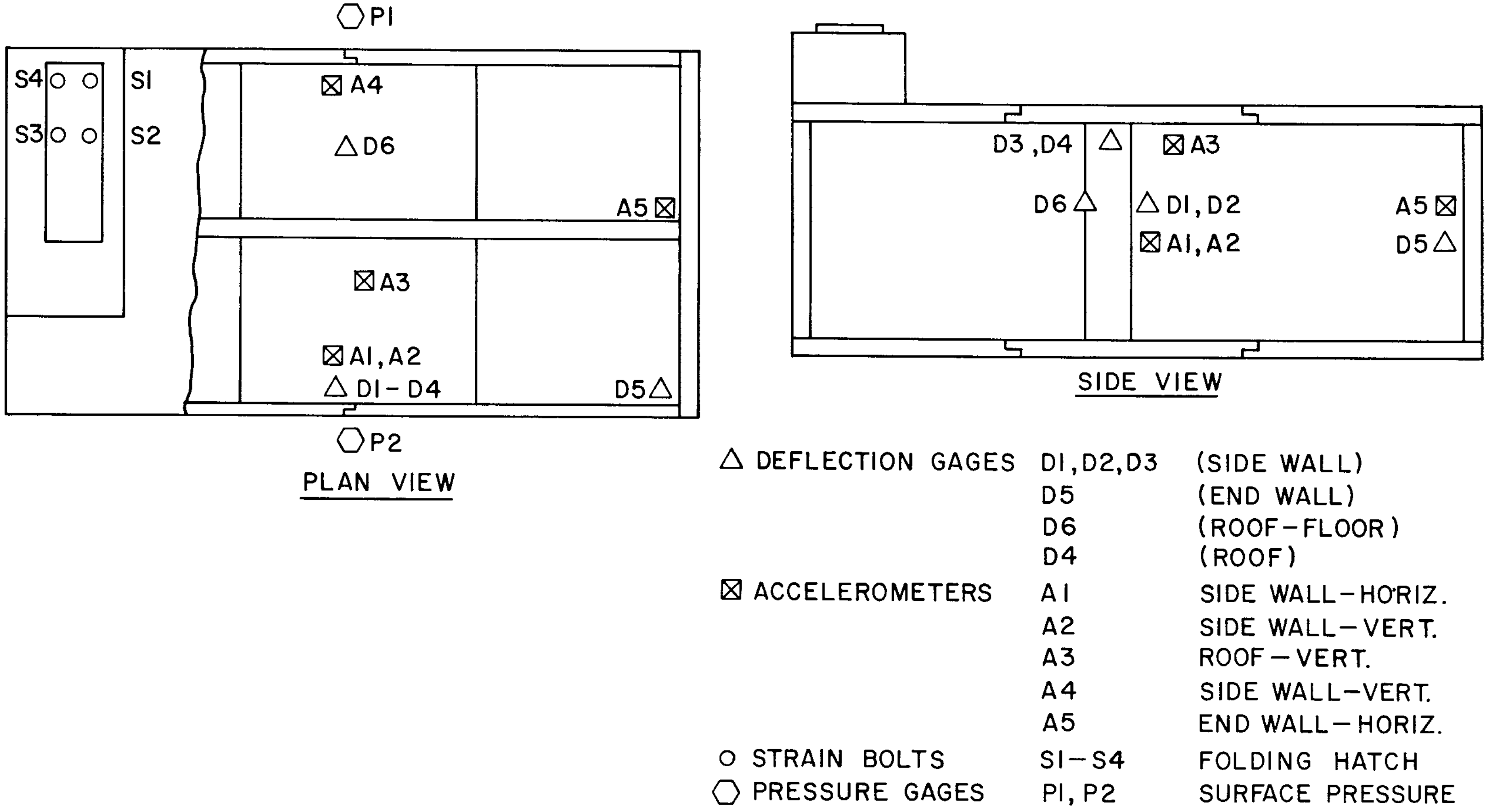
Although a great deal of care was exercised in the installation of the main conduit runs, the short, thin-walled conduits were installed using standard pipe-laying procedures. Sand was used as a bedding material in both cases, and sand backfill was placed over the conduit to a height of 12 inches for the main runs and 6 inches for the others. The bedding and backfill sand of the main runs was tamped with an impact type of soil compactor.

The location of all instrumentation for this project is shown in figure 18. The deflection gages in the structure were used primarily to determine relative movement between the side wall, end wall, roof, and base slabs. Gages D1 through D5 were of the cantilever beam type with two SR-4 strain gages cemented on the top and underside of the beam. One end of the beam was fixed securely on a slab, while contact to the adjacent slab was made by means of an adjustable screw with a pointed tip through the free end of the beam. The pointed tip engaged a blued steel plate which also provided a scratched record of deflections perpendicular to the movement of the cantilever beam. Gage D6, which measured displacement between the floor and roof of the structure, was of a slide-wire potentiometer type. Prior to the detonation, all deflection gages were calibrated and initial deflections applied to permit both positive and negative movements of the slabs to be recorded.

The following notation was employed for the deflection measurements:

D1, D2	Horizontal deflection of side walls in two directions.
D3	Vertical roof deflection relative to side wall.
D4	Horizontal side wall deflection relative to roof.
D5	Horizontal deflection of end wall relative to side wall.
D6	Vertical displacement between roof and floor.

Accelerations A1 through A5 were measured at the locations and in the directions shown. Surface pressure gages P1 and P2 were placed along the expected 60-psi overpressure range and about 5 feet from each side wall of the structure.



△ DEFLECTION GAGES	DI, D2, D3	(SIDE WALL)
	D5	(END WALL)
	D6	(ROOF-FLOOR)
	D4	(ROOF)
☒ ACCELEROMETERS	AI	SIDE WALL-HORIZ.
	A2	SIDE WALL-VERT.
	A3	ROOF-VERT.
	A4	SIDE WALL-VERT.
	A5	END WALL-HORIZ.
○ STRAIN BOLTS	SI-S4	FOLDING HATCH
⬡ PRESSURE GAGES	PI, P2	SURFACE PRESSURE

Figure 18. --Instrumentation.

Strain bolts S1 through S4, used to fasten the folding hatch in place, were secured with an initial load of approximately 1,000 pounds per bolt.

In addition to dynamic instrumentation, diagonal measurements were made inside the structure before and after the blast to determine if racking occurred. This was accomplished by using telescoping aluminum tubes with specially prepared ends. The tubes were graduated to facilitate measurement.

RESULTS

Figure 19 shows a postshot view of the blast hatch. The hatch cover did not sustain damage and was still secured in place after the blast. The strain bolts, which had been preloaded to 1,000 pounds each, indicated very little rebound loading due to the blast. See table 1 for recorded measurements.

The structure developed some hairline cracks and some minor spalling. The damage was superficial, however, and would not be considered as having caused any weakening of the structure.

Surface pressure-gages P1 and P2 recorded pressures of 56 psi and 38 psi, respectively. These gages were checked after the blast and were found to be accurate. The recorded pressures were therefore considered to be actual pressures.

All deflection gages and accelerometers performed satisfactorily. The recorded tapes indicated the peak values noted in table 3.

Diagonal measurements of the structure interior indicated some slight changes which could be attributed to a compression of the butyl rubber gasket; however, racking of the structure did not occur. See table 2 for diagonal measurements before and after the shot.

In figure 20 the vertical axial deformations of the main conduits are shown. It was found that there were virtually no changes in the configurations of the two conduits over the full length in the horizontal plane (not shown) and over all but the first 10 feet in the vertical plane. Not only did substantial vertical deformation changes occur in the excavation region due to the blast, but initial alignment there was much more irregular. A circumferential crack was noted in the cement-asbestos conduit about 6-1/2 feet from the inside end. Beyond the 10-foot position, any changes that might have occurred were generally small and less than the estimated 0.10-inch possible error inherent in the measuring method. From 28 to 36 feet out, the measured deformations differed slightly from the initial readings for the cement-asbestos conduit, but the changes were upward, a movement which would not be expected. Thus, the data there were considered suspect on initial investigation.

Figure 19. --Postshot view of the blast hatch.

Table 1. --Recorded measurements of rebound forces

Bolt Number	Load	
S1	2,400 pounds	Hatch cover rebound forces
S2	1,400 pounds	
S3	2,400 pounds	
S4	1,400 pounds	

Table 3. --Recorded peak values

Gage	Expected Reading	Actual Reading
D1	0.0625 inch	0.013 inch
D2	0.0625 inch	0.010 inch
D3	0.125 inch	0.087 inch
D4	0.125 inch	0.110 inch
D5	0.125 inch	0.125 inch
D6	0.250 inch	0.220 inch
A1	25 g's	±6 g's
A2	25 g's	±8 g's
A3	50 g's	+9 g's through 15 g's
A4	25 g's	±9 g's
A5	50 g's	±9 g's

Table 2. --Diagonal measurements of structure interior

Position	Initial Reading	Final Reading
1	14 feet - 4-7/8 inches	14 feet - 4-3/4 inches
2	14 feet - 4-7/8 inches	14 feet - 4-3/4 inches
3	14 feet - 5-3/16 inches	14 feet - 4-15/16 inches
4	14 feet - 5-1/16 inches	14 feet - 4-7/8 inches
5	14 feet - 5-3/8 inches	14 feet - 5-1/8 inches
6	14 feet - 5-3/16 inches	14 feet - 5 inches
7	14 feet - 5-1/2 inches	14 feet - 5-1/2 inches
8	14 feet - 5-1/4 inches	14 feet - 5-1/16 inches

(Diagonal measurements averaged 1/8 inch to 1/4 inch shortening.)

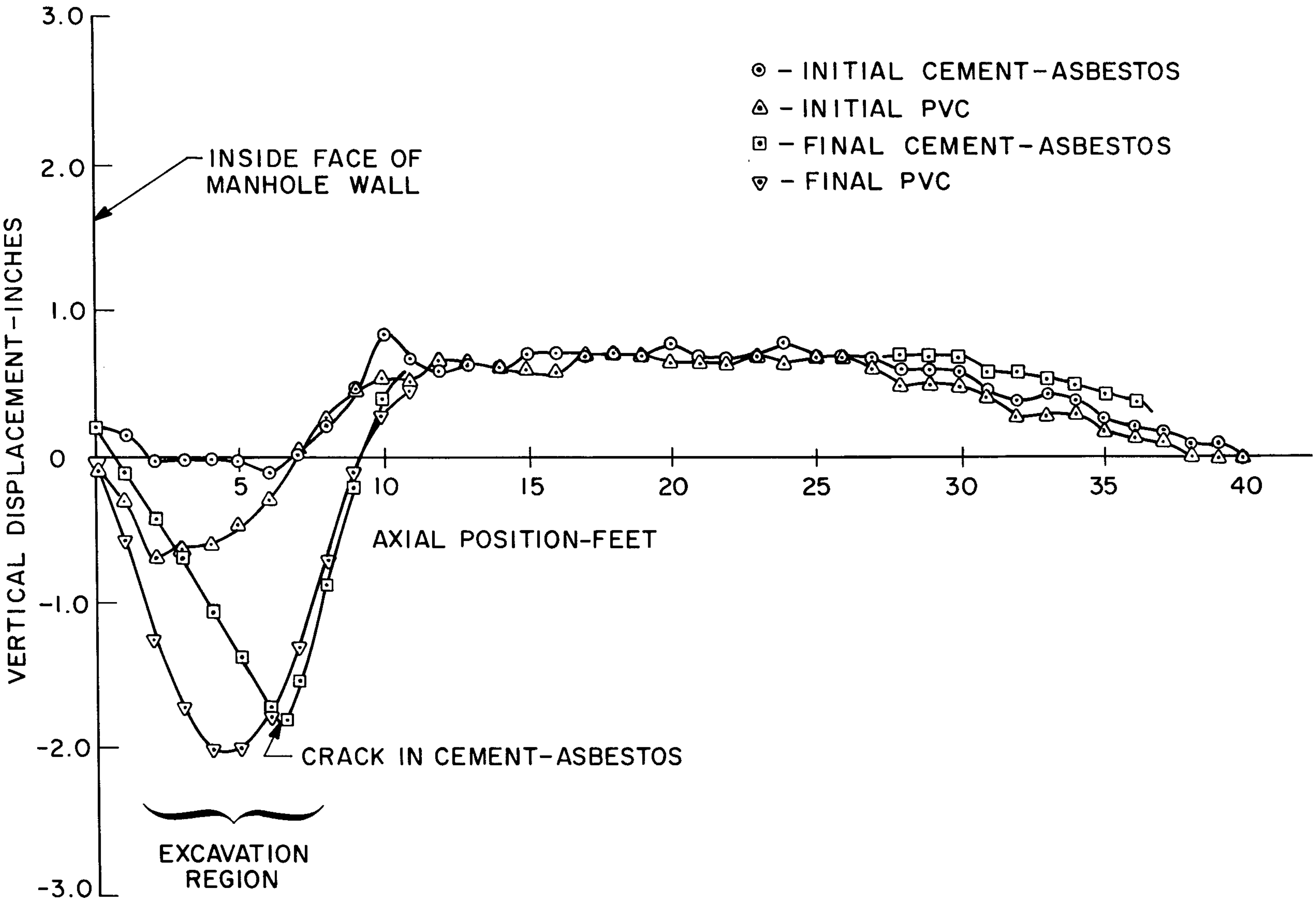


Figure 20. --Main conduit vertical axial deformations.

All of the thin-walled conduits survived, as was ascertained by inspection, looking into the ends of the conduits. It was not possible to determine whether there had been any appreciable ovalling except at the inspection ends. There was some ovalling at the end of the PVC conduit, with a major- to minor-diameter ratio of approximately 1.1. The other conduit ends appeared circular. A hairline circumferential crack appeared in one of the 6-inch cement-asbestos conduits. This may have been due to an imperfect bedding and was not related to collapse phenomena.

The large coaxial cables survived the blast with no apparent damage. Both the PVC plastic and the steel pipes were bent downward on their outward ends by 3 to 5 inches; at the junction with the concrete wall, each had buckled slightly due to the high bending moment at that location.

CONCLUSIONS

Three basic conclusions were drawn from the conduit experiment:

1. No appreciable vertical deformations occurred in the trenched conduit 4-1/2 feet below the surface at the nominal 50- to 40-psi region.
2. Commercial conduit in the 5- to 6-inch diameter range can survive this environment using standard installation procedures.
3. Some special treatment of the backfill in the excavation region under entrance pipes is required to limit conduit deformations.

Deflections and relative motions of adjacent wall slab or roof sections were small; they were on the order of 1/8-inch or less minimum to 1/4-inch maximum. Accelerations were somewhat lower than expected, ranging from 5 to 15 g's. Racking, or change in diagonal dimensions across the manhole, was minimal, with noted changes of 1/4 inch or less. It is apparent that this type of structure, with individual flat slabs interlocked together with only minimal ties and no moment carrying ability at joints, can survive the applied blast loading with very little relative motion between slabs.

Both cable entry protection designs survived the blast loading, but the deflections and buckling of the pipe indicate that such protection is needed and, if not provided, such loading would very likely damage the coaxial cables.

Although both the two-part folding blast hatch and the smaller one-piece cast-aluminum manhole cover survived the blast as installed, the low rebound forces recorded in the hold-down bolts of the blast hatch were unexpected. The rebound behavior of this blast hatch should be studied further.

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DIAL PACK Event of the MIDDLE NORTH Series, Bell Laboratories Project LN-318, involved the evaluation of the blast-induced response of the SA Manhole. The SA Manhole was a full-size, segmented, precast-concrete hardened structure, to be used by the Long Lines Department of American Telephone and Telegraph Company, to house electronic repeater equipment. Testing was designed to determine the extent of cracking, equipment environments, and overall structural response.

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