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DESIGN AND CONSTRUCTION OF A TEST FACILITY TO SIMULATE THE EFFECTS OF A NUCLEAR DETONATION (ROCKTEST I)

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Los Angeles, California 90017

TECHNICAL REPORT NO. AFWL-TR-69-7

May 1970

AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base
New Mexico

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FOREWORD

This report was prepared by the Ralph M. Parsons Company, Los Angeles, California under Purchase Order 507 from the Bob Rutherford Construction Company, Albuquerque, New Mexico, and Contract F29601-68-C-0103.

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Inclusive dates of research were June 1968 through January 1969. The report was submitted 12 March 1970 by the Air Force Weapons Laboratory Project Officer, Capt Philip L. Madden (WLCD).

Former project officers were Capt Charles J. Lemont and Lt Robert R. Vergnolle.

Information in this report is embargoed under the U.S. Export Control Act of 1949, administered by the Department of Commerce. This report may be released by departments or agencies of the U.S. Government to departments or agencies of foreign governments with which the United States has defense treaty commitments, subject to approval of AFWL (WLCD).

This technical report has been reviewed and is approved.

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ABSTRACT

(Distribution Limitation Statement No. 2)

A method of simulating the effects of the static pressure of the airblast and airblast-induced ground motions was developed by Air Force Weapons Laboratory, and was designated High Explosive Simulation Technique (HEST). Proposed construction of new, more hardened weapon systems in rock sites made it desirable to apply the HEST method to full size and 1/4 scale models of missile facilities located in rock. This report describes the design and construction of this first ROCKTEST facility which covered a plan area of 160 by 208 feet. Design criteria are presented, some unique construction methods used are described, recommendations are made for application to future similar projects, and a complete set of design drawings and construction photographs is included.

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ABBREVIATIONS

ACI	American Concrete Institute
AFSWC	Air Force Special Weapons Center
AFWL	Air Force Weapons Laboratory
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
CERF	Civil Engineering Research Facility
GFP	Government Furnished Property
HEST	High Explosive Simulation Technique
TR	Technical Report
UBC	Uniform Building Code
WES	Waterways Experiment Station

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SECTION I

INTRODUCTION

The United States Air Force has been assigned the responsibility for conducting simulated nuclear tests on actual hardened systems for basic research on nuclear weapons effects and for providing information relative to these effects for use in designing future hardened systems. The Nuclear Test Ban Treaty made it necessary to develop a capability to simulate nuclear weapons effects. The Air Force Weapons Laboratory (AFWL) responded with a program that produced the High Explosive Simulation Technique (HEST), a technique that simulates the static pressure of the airblast and the air-blast-induced ground motions resulting from a nuclear detonation for certain overpressure ranges and for certain yield weapons.

In the development of newer, more hardened weapon systems, a program to apply the HEST technique to a rock test site was undertaken. This first project, designated the ROCKTEST I Development Experiment, was carried out in a test area, located in the Estancia Valley Test Area, approximately 45 miles east of Albuquerque, New Mexico. The effort was combined AFWL-Contractor effort in which the contractor designed and constructed the overall facility for the execution of the experiment by the Air Force Weapons Laboratory (AFWL). The test facility, including the construction and installation of 11 test structures, was designed and built to AFWL provided parameters. The objective was to produce an overpressure and an airblast-induced ground motion environment as specified by the Air Force Weapons Laboratory (AFWL).

The major simulated airblast parameters were peak overpressure level, shock-front velocity, overpressure duration and pulse shape. The achievement of specific blast effect phenomena required the construction of an earth supporting structure on limestone and shale. Earth material was compacted against the exterior walls and on top of the structure to a specified density. A framework of steel columns, beams and decking was designed to support the total surcharge load. The structure was instrumented with strain-gages to verify structural design and integrity of the facility prior to the test. Detonating cord was installed in the cavity of the structure in such amounts and configuration that when detonated, a shock wave would propagate throughout the cavity at the requisite velocity. The peak overpressure was contained by the overburden and cavity structure, which provided a reactive force to shape the resulting pulse wave and to lengthen its duration.

The end result of the test was the collection of data relating to blast and shock-wave effects on structures, materials and devices. Instrumentation in the form of sensors was located in and around the cavity to record the blast effects of the wave propagation through the rock materials. Sensors included displacement gages, velocity gages, pressure gages, stress gages, accelerometers, and time-of-arrival detectors. Instrumentation sensor data was transmitted to a centralized trailer area and recorded for later analysis by AFWL personnel. Instrumentation included approximately 800 active channels and passive measurements as specified by the AFWL document "ROCKTEST I Structural Measurements List", dated 8 July 1968. All instrumentation was designed, procured, and installed by the Air Force Weapons Laboratory (AFWL). Drilling services for instrumentation installation was provided by Mobile District, US Army Corps of Engineers, Mobile, Alabama, under AFWL direction.

This report covers only the design and construction phases of ROCKTEST I. Data obtained from the various instrumentation and the analyses of test results is contained in other AFWL technical reports.

SECTION II

DESIGN CRITERIA AND SERVICES PERFORMED

Drawings and specifications were provided for a test facility conforming to the following criteria and requirements:

1. The test bed consisted of a cavity 160 feet long by 208 feet wide with an interior height of 4 feet from the test bed floor to the bottom of support beams.

2. The roof was required to support 20 feet of earth surcharge at 100 pounds per cubic foot, and was designed for a total load of 2100 pounds per square foot. Lateral loads were based on an active earth pressure of 40 pounds per cubic foot equivalent fluid pressure.

3. The test facility was designed with a 1-foot-thick reinforced concrete perimeter wall, steel beams, columns, bracing, and roof deck. The corners of the perimeter were rounded to a 6-foot radius.

4. Surcharge and berm configuration were as shown on the drawings (see Appendix III).

5. The cavity was filled with approximately 2 million feet of 400 grain per foot detonating cord. The detonating cord (Government-furnished) was wrapped on wood racks at a specified weave angle and installed in the cavity in four layers. The perimeter wall and earth berm had 26 1-inch-diameter plastic pipe penetrations for a plane wave generator.

6. A layout of a surcharge dispersal system plan was as shown in Figure III-6. Charges were Government-furnished, Government-installed ammonium nitrate cannisters.

7. The instrumentation plan provided by AFWL was incorporated into the final design drawings. All instrumentation was furnished and installed by AFWL.

8. A trenching plan and cable protection system were provided by AFWL and included in the drawings.

9. An area excavation plan for the test structures was provided by AFWL and incorporated in the final drawings.

10. Drawings were provided covering a 3-module extension of the existing instrumentation trailer shelter.

11. Shop drawings of all structural steel and decking were submitted to AFWL for approval prior to fabrication and purchasing.

12. Preliminary and final design drawings were prepared in accordance with MIL-D-1000, Form 3, Category A. Approved final drawings were provided in reproducible chronoflex masters.

13. Preliminary and final specifications were prepared to normal construction specification format. Structural calculations were included as an appendix to the final specifications.

SECTION III

DESIGN PHILOSOPHY

Conservation in design was not desired because of the temporary nature of the facility. The requirement was to design a structure that would be just adequate to support the imposed loads with a reasonable factor of safety against failure. The following design techniques were used:

(1) Plastic design for steel beams with a load factor of 1.25.

(2) Elastic design for columns.

(3) Ultimate strength design for reinforced concrete with a load factor of 1.0.

(4) Elastic design for steel deck and miscellaneous steel items, using for the allowable design stress the yield stress of the material.

(5) A 25 percent increase over the allowable AISC values for high strength bolted connections and a 50 percent increase over the allowable UBC values for shear on anchor bolts.

All vertical and lateral loads were assumed to be uniform over and around the entire structure. No unbalanced vertical or lateral loads were considered.

To expedite erection, one-bolt connections were used on double angle struts and the roofdeck was welded to the steel beams by the "MIG Inert Gas Semi-Automatic Process" employing the "burn-through" method. All structural steel connections were bolted to minimize field welding.

Footings were not required under columns because the bearing capacity of the rock was sufficient to support the loads imposed. Columns were, therefore, grouted directly to the rock floor. They were supported laterally by grouted-in anchor bolts.

Base plate thickness required was much less than that used, based on an allowable bearing pressure of 10,000 psi. In the exercise of engineering judgment, however, a minimum thickness of three quarters of an inch was used.

Column design was most economical when based on the elastic method because the unsupported column length was so small. Plastic design would have required a thicker flange than on the proposed section merely to meet the flange width to thickness requirements of plastic design. Because the test bed floor was not level, a survey was required to determine the floor elevation at each column location. This information was incorporated in the final design drawings so that the steel fabricator could determine the required length of each column.

Beam design lengths were based on a 3- and a 5-span condition (24 or 40 feet, respectively). Splice points were located over columns in order to avoid complicated moment connections. Strut action was relatively small and did not reduce the plastic moment capacity of the section. Also, the two-bolt connection at the splice was sufficient to transfer the lateral load through the cap plate; therefore, beam continuity was not required. Compression flanges were supported laterally at plastic moment locations by the roofdeck at mid-span, and by the double angle struts and stiffeners at the columns. Beam stiffeners at the columns were required in plastic design because the section proposed fell just short of the flange width to thickness requirements. However, they did serve other functions such as transferring the double angle strut load and preventing lateral beam roll when placing fill over the subdeck. The failure mechanism occurs with the development of plastic hinges at the first interior support and at a distance of 3 feet 4 inches from the end support. This is true for both the 3-span and 5-span condition. Maximum shear occurs at the exterior side of the first interior support. At this location, the web shear capacity of the unreinforced section is reached prior to the full development of both plastic hinges. Neglecting the stiffeners at the supports, the factor of safety in shear would be 1.14. It was felt that this was too low and the section was reinforced at these critical shear locations by web doublers. This increased the factor of safety to the desired 1.25.

The subdeck was supported on the bottom flanges of the beams to provide a flush smooth ceiling in the cavity. No connections were provided at supports. The 10-inch earth fill was adequate protection for the detonating cord during the welding of the roofdeck to the structural beams.

Roofdeck design was based on a minimum deck length of 3 spans or 12 feet. However, 40-foot lengths were used to be more economical both in fabrication and erection. Analysis indicated that web crippling at supports was the governing factor in design. Design in this area was according to the AISI, with the allowable stress equal to the yield stress of the material.

Double angle struts were used to simplify the end connections (one high strength bolt in double shear). Although one-bolt connections are normally not good practice, it was considered justified because of the temporary nature of the structure. All high-strength bolts were designed as friction type to eliminate cumulative tolerances so that rigid lateral support was attained for the inflexible concrete perimeter wall.

A reinforced concrete perimeter wall 1 foot thick was more than adequate to support lateral loads. Reinforcing was kept to a minimum by using ultimate design. The walls spanned vertically from the test bed floor to a bond beam at the top, which was supported laterally at the north and south by the main steel beams, and at the east and west by the double angle struts. The lateral reaction at the bottom of the wall was resisted by friction and No. 7 dowels spaced 3 feet on center into the rock.

SECTION IV

CONSTRUCTION TASKS

The contractor provided all plant, labor, equipment, and materials (except those stipulated as Government-furnished) to perform the following construction tasks:

1. Excavation, filling, grading and compaction as required for the test bed.

2. Construction of the test facility and placement of the earth surcharge and berms as shown on Figures III-2 and III-4.

3. Construction, wrapping and installation of the detonating cord racks in the test facility as required.

4. Installation of plastic pipes (1-inch diameter) for protection of the planewave generator through the perimeter wall and earth berm.

5. Drilling of sixty-six 9-inch diameter holes approximately 9 feet deep into the surcharge for the surcharge dispersal system.

6. Excavation of approximately 600 linear feet of 3-foot-deep instrumentation cable trenches in the test bed. Trenches had a 1-foot-wide bottom with side slopes at 75 degrees to the horizontal. Trenches were field located for Government drill crews who drilled a series of 8-inch diameter holes on 2-1/2-foot centers with Government-furnished equipment along the center lines of the trenches. The contractor completed the excavation by drilling 1-inch-diameter holes at approximately 12 inches on center along the sides of the trenches and caving the sides inward by exploding detonating cord in the 1-inch holes.

7. Construction and installation of an instrumentation cable protection system in the trenches. Design responsibility for this system was borne by the Government. All materials for the system were provided by the Contractor.

8. Construction of test structures and supports in accordance with drawings provided by AFWL (see Figures III-12 through III-20).

9. Installation of the following Government-furnished structures:

a. One flush annular slot antenna

b. One end fire COMSAT antenna

c. Two "once tested" closures

d. One erectible antenna

Two pull-out tests were conducted on the erectible antenna; one prior to the completion of the test facility and the other after the test had been conducted and the debris removed. A 20-ton (minimum) capacity crane was provided, and by using a Government-furnished load ring, the antenna was lifted to a height at which the tip of the antenna was not more than 20 feet above the test bed level.

10. Removal of all rock material from the excavations for the test structures previously described. The perimeters of all excavations were drilled by Government-furnished and operated equipment prior to excavation.

11. Grouting of approximately 900 linear feet of 9-inch-diameter instrumentation holes of varying depths by using AFWL-furnished grout design mix. CERF performed the grouting with contractor furnished materials.

12. Filling of instrumentation cable trenches with a 12-inch sand cushion in the trench bottom and a concrete cap to the level of the test bed using concrete that was a 6-sack design (4000 psi) mix with high early strength cement.

13. Construction and installation of three sheet metal targets, 1 foot by 3 feet in size, painted with alternate 1-inch black and white horizontal strips across the 1-foot dimension. The targets were attached atop 20-foot long rods, the bottoms of which were welded to the steel decking. An outer

flexible conduit was placed around each rod to provide freedom of movement of the rod in the vertical direction through the surcharge. Two 2-inch-diameter, 20-foot-long steel pipes with outer flexible conduit were provided and installed. The bottom of each pipe was welded to a 1/2-inch-thick, 1-foot-square base plate, which was welded to the deck. A 3/4-inch diameter rod, 1-foot long, was welded to the top of each pipe.

14. Construction of a three module extension of the existing instrumentation trailer shelter in accordance with the provided drawings. Necessary connectors were available to extend the existing structure. This construction also included the placement of approximately 100 cubic yards of locally available soil in a 2-1/2-foot-thick layer on the top of the structure.

SECTION V

CONSTRUCTION METHODS

The following is a listing and description of some of the unique construction procedures employed by the construction contractor to expedite construction and maintain the tight construction schedule. Throughout the entire effort, time was economized and in some instances, production line methods were used to save time to achieve uniformity in construction and to minimize human error.

1. CONCRETE CURB

Because of the unlevel surface of the rock floor, a concrete curb was poured to provide a level surface on which to set the test facility wall forms.

2. CONCRETE PERIMETER WALL SHORING

Test facility perimeter walls were temporarily shored to allow premature backfilling behind the walls prior to erection of the lateral braces.

3. DETONATING CORD CUTTING AND SEALING

On previous HEST jobs, the detonating cords were cut one at a time with pocket knives and the cut ends were taped to prevent the loose powder from spilling out. This proved to be a costly and slow operation. On this job, the cords were cut four at a time with a paper shear and the cut ends were dipped into hot wax to seal them.

4. DETONATING CORD RACK FABRICATION

All detonating cord rack members were cut to length and spacing blocks stapled thereon in the contractor's yard. The racks were then assembled at the job site. Pneumatic tools were used to staple and nail the racks together.

5. DETONATING CORD RACK ASSEMBLY AND INSTALLATION

After individual racks were wrapped with detonating cord, they were put together into assemblies of the required number of layers and the cord ties between racks were installed. This was all done outside of the test facility. Rack assemblies were then transported to the test facility with a forklift and lowered into position with a crane. In previous HEST experiments, layers of racks and supports for racks were installed one at a time in the test facility.

6. PLACEMENT OF SUBDECK FILL

All of the subdeck fill could not be placed with a crane because of the large size of the test facility. The majority of the subdeck fill was placed with a bobcat (see Figure II-89).that had a tire track the same as the beam spacing. This allowed the bobcat to run down the beams and place fill in any location.

7. ROOFDECK WELDING

All of the roofdeck was welded to the support beams by the "MIG Inert Gas Welding" process. This is a machine welding process whereby puddle welding is automatically achieved with a welding "gun". A preset timer insures uniform welds. The "burn-through" method was employed, which allows welding in any location because pre-punched holes are unnecessary. This process proved satisfactory because both fabrication costs and welding time were minimized. Sections through test welds showed complete penetration using this technique.

8. ROCK EXCAVATION

A new method of rock excavation, which proposed to remove rock in large pieces, was tried. After perimeter drilling, wedges were driven into a center hole and a crane was attached to the wedges in an effort to snap the rock loose. This method was successful on the 1/4 scale model and the lined and unlined silos to a depth of approximately 4 feet.

Rock was excavated for the full scale closure model with the blasting technique as shown and described in Figure 5-1. Shallow excavation was accomplished with a Parsons' 18 unihoe. Deeper excavation was attempted with a crane by using an orange peel bucket. This was not successful, but only because of the poor condition of the orange peel bucket. Excavation was finally accomplished by lowering an Allis-Chalmers HD5 loader into the hole. The HD5 ripped and loaded loose rock into a dump truck bed suspended from a crane.

9. TRENCH EXCAVATION

Trench excavation was started by using the pre-split blasting method shown on Figure 5-2. The correct depth was attained, but there was excessive flare at the top (4 to 5 feet instead of 2 feet - 7-1/2 inches). In an attempt to correct this, the next length of trench was shot with no dynamite in the center holes and only the 8-inch pre-split charge at the bottom of the side holes. An even split was obtained in hard rock but a blasting effect resulted in the softer rock. Because of the inconsistency of the rock, this method was abandoned and the remaining trench was blasted with 400-grain detonating cord in the side holes. Excavation was then accomplished with a backhoe straddling the trench.

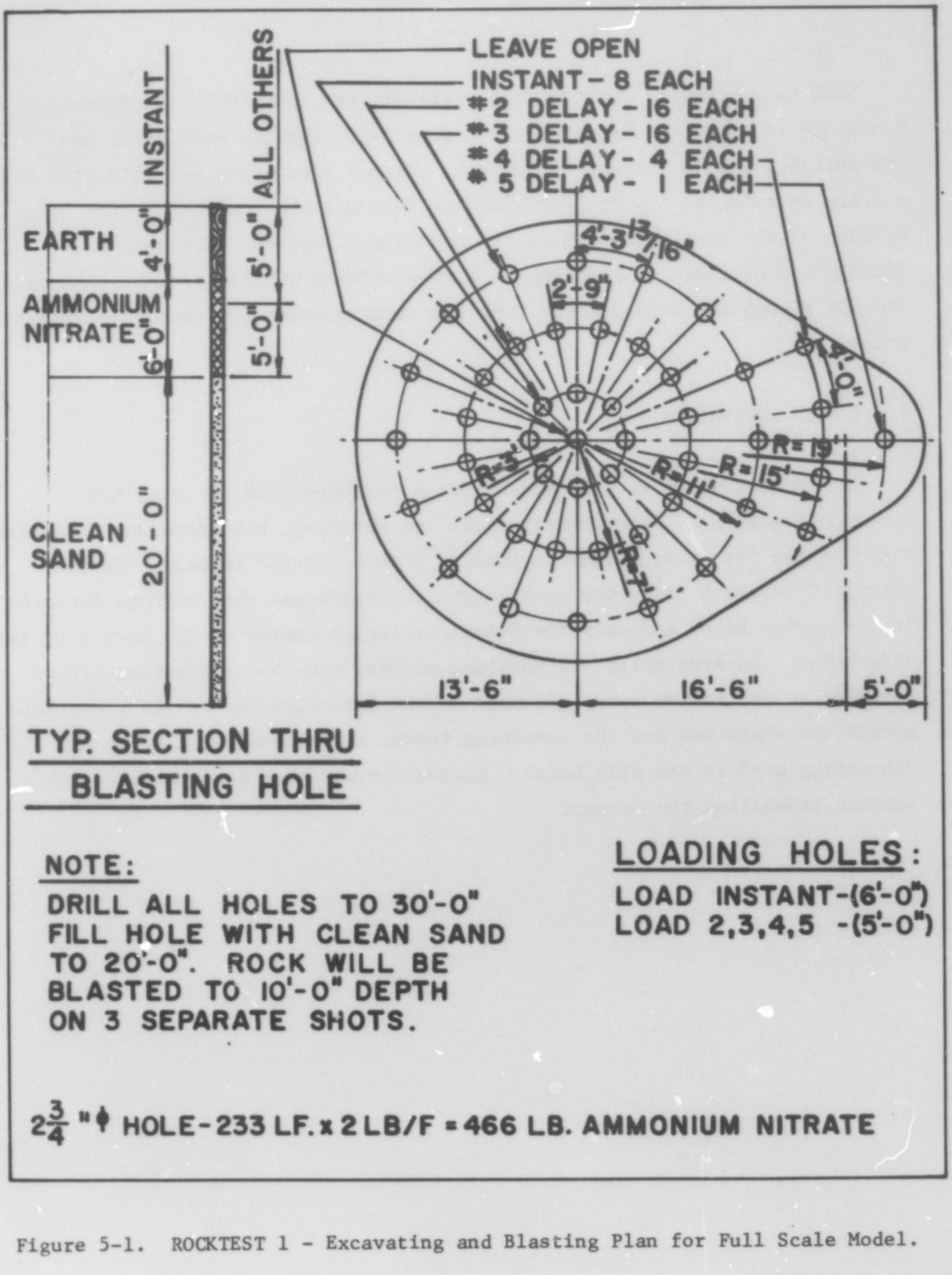

Figure 5-1. ROCKTEST 1 - Excavating and Blasting Plan for Full Scale Model.

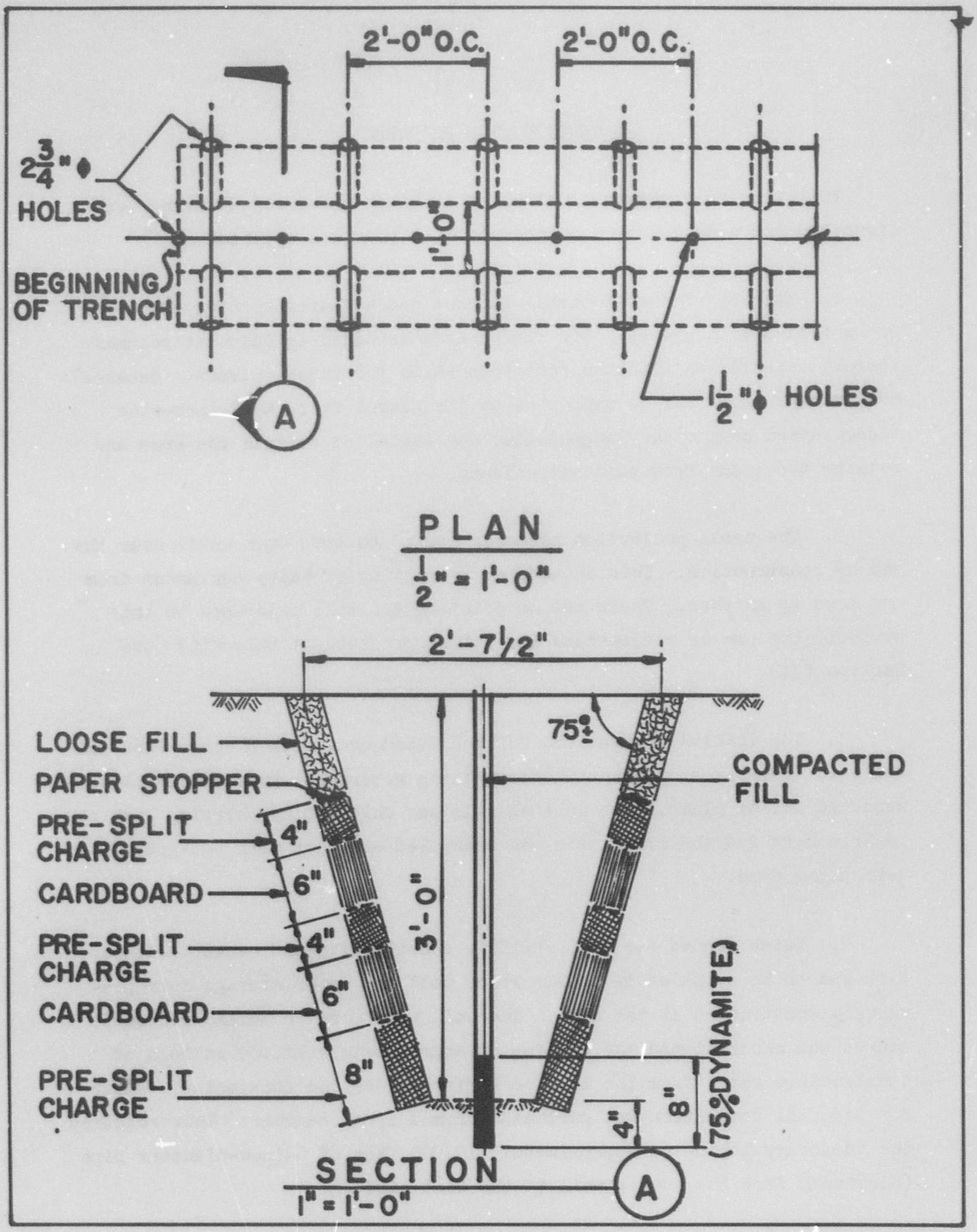

Figure 5-2. ROCKTEST 1 - Trench Blasting Scheme.

SECTION VI

CONSTRUCTION PROBLEMS

Following is a summary listing of problems encountered during construction and a description of the solution that was applied:

1. The top of the erectable antenna had a flared opening which had to be filled with gravel. The flared area extended to adjacent columns thereby interfering with the rock foundation for these columns. Because the columns could not be supported on the gravel fill, a 12-inch-wide flange steel beam with flange plates was installed to span the area and receive the loads from adjacent columns.

2. The cable protection trenches had to be left open until near the end of construction. This encumbered the moving of heavy equipment from one area to another. There was no solution for this hindrance on this project, but one is recommended for future projects of this kind (see Section VII).

3. The initial excavations for the lined and unlined silos were too small in diameter at the bottom because the government provided drill holes wandered out of plumb. The unlined silo was enlarged by chipping with paving breakers and the lined silo was redrilled and shot with 400-grain detonating cord.

4. Water needed for test facility construction and backfill compaction was to be supplied by an Air Force well and water storage lake previously constructed at the site. The well was found to be an inadequate source and necessitated the hauling of approximately 12,000 gallons of construction water from the town of Moriarity, by the contractor. Water for backfill compaction was purchased from a local rancher. This required the temporary laying of approximately 10,000 feet of 6-inch-diameter pipe (aluminum) from the source well to the test site.

5. Parking control of non-essential vehicles about the test site was not strict enough. Potential and actual hazard conditions arose, including one construction incident that resulted in minor damage to a government owned vehicle.

SECTION VII

CONCLUSIONS AND RECOMMENDATIONS

Based on the problems encountered and experience gained on this project, the following conclusions and recommendations are made for application to similar projects that may subsequently be undertaken.

1. DETONATING CORD RACKS

Where racks are required to be stacked in layers, it is recommended that they be assembled outside of the test cavity and so designed that the layers may be nailed together thereby eliminating the necessity for dowels. Also, additional lateral stability for the assembly should be provided. It is further recommended that all ties be made between racks within an assembly and all inter-assembly ties be attached before installation of the assembly in the test cavity. Also, it is recommended that the AFWL-designed detonating cord harness be used. This was proven to be a time saving device on this project and it facilitated the correct installation of cord ties.

2. PLANE WAVE GENERATOR

It would have been helpful to the contractor if the length and layout of the plane wave generator had been specified. It is recommended that this be done on future jobs as applicable.

3. SUBDECK

Although the 26 gage subdeck was structurally adequate, it was flexible, especially at the end spans adjacent to the concrete perimeter wall. Here the span was 4 feet 6 inches whereas the span between columns was 4 feet. In the future it is recommended that a minimum of 24 gage material be used.

4. INSTRUMENTATION CABLE TRENCHES

If possible, the excavation of cable trenches, the installation of pipes and cables, and the backfilling of trenches with concrete should be one of the first operations in the construction. This would eliminate debris from trench blasting and excavation from falling into free field instrumentation holes (even though plugged); but mainly, it would facilitate moving of heavy equipment within the test cavity. It is also recommended that instrumentation cables emerging from the test cavity be placed in ditches until they clear the berm. This would safeguard against damage to the cables during berm construction.

5. TEST STRUCTURES (MODELS)

If test model layout causes interference with column locations, it should be noted and considered in original design. All steel models fabricated from plate that is 3/8 inch or less in thickness should be poured on a solid level surface and well braced laterally to retain original shape. If the same method is used to bolt down the closure lid on the full scale model, it is recommended that the top of the bolts be drilled and tapped for insertion of guide rods. On this project, the test models were fabricated and shipped in accordance with the contractor's requests in consideration of such things as weight and size for handling and shipping, and minimization of field welding. This ensured that the contractor received the models at the time and in the configuration he wanted them, and it resulted in an orderly, unconfused sequence of construction enabling him to stay ahead of schedule. Close coordination between fabricator and contractor was required and achieved because the fabricator was directly responsible to the contractor. It is recommended, therefore, that this same delegation of responsibility be exercised in future work.

6. PRESPLITTING

Presplitting was found to be impractical because the rock did not have a uniform hardness. The presplitting method gave desired results in hard rock formations, but in the softer rock formations the tops of the trenches flared out wider than desired. It is recommended on future work that presplitting experiments be conducted outside of the test cavity to determine its worth at each specific site. In this way an evaluation can be made without damage to the test cavity floor. It is believed that presplitting could be employed to excavate for the test models.

7. WATER SUPPLY

A definite source of water should be located and its output established in the early stages of contract negotiation.

8. PARKING AREA FOR VEHICLES

A parking area for vehicles and rules for the use thereof should be established and clarified early in the planning of future efforts.

9. ROOFDECK WELDING

Because of the savings in fabrication costs and welding time, it is recommended for future work that the roofdeck be welded to support beams by the "MIG Inert Gas Semi-Automatic" process.

APPENDIX I

RESUME OF BI-WEEKLY PROGRESS LETTERS

During the contractual period of performance, bi-weekly progress letters were submitted to the AFWL Project Office and AFSWC Procurement Division by the contractor. These reports provided a summary of the project status with respect to schedule, problem areas, trips, meetings, conferences and program funding.

The contents of each of the bi-weekly letters are summarized below to provide the reader with a chronological account of the major events occurring during the performance of this project. If more detailed information is desired, reference should be made to the specific progress letter for the period concerned.

1. FIRST BI-WEEKLY PROGRESS LETTER (4 June 1968 to 18 June 1968)

Design activity consisted of the preparation and submittal of preliminary design drawings, specifications, and calculations for review. Several shop drawings were received, reviewed, and submitted to the subcontractor. Additional information was requested in order to facilitate completion of design. Construction activity consisted of drilling holes in test facility floor to receive perimeter wall dowels, drilling perimeter holes around test structures, pouring concrete curb for perimeter wall and excavation for and pouring of concrete footings for instrumentation trailer shelter.

2. SECOND BI-WEEKLY PROGRESS LETTER (19 June 1968 to 3 July 1968)

Preliminary design drawings and specifications were returned and design continued incorporating comments made thereon. Shop drawings were received, reviewed, and returned. Additional design information was requested. Construction work consisted of establishing column elevations, forming, and pouring pedestals on instrumentation trailer shelter footings, drilling test structures, setting forms for the test facility perimeter wall, and drilling and blasting for the full scale closure.

3. THIRD BI-WEEKLY PROGRESS LETTER (4 July 1968 to 17 July 1968)

Final design drawings, specifications, and calculations were completed, submitted and approved. Shop drawing review was completed and all shop drawings returned to the vendors. Rock excavation of test structures and drilling of instrumentation and explosive shot holes were being performed. Sections of the cable protection trench were blasted as per the proposed scheme; however, this method of trench excavation (pre-split method) seemed inadequate because of irregular fractures due to rock inconsistency.

4. FOURTH BI-WEEKLY PROGRESS LETTER (18 July 1968 to 31 July 1968)

Cable protection trench and test structures were drilled and excavated. Forming, rebar placement, and pouring was accomplished on portions of perimeter wall. An on-site meeting determined antenna placement.

5. FIFTH BI-WEEKLY PROGRESS LETTER (1 August 1968 to 14 August 1968)

Test structure excavation and work on concrete perimeter wall continued. Column anchor bolt holes were drilled, anchor bolts set, and columns grouted in place on west side of test facility. Portions of some test structures were poured. Fabrication of detonating cord racks was started at the contractor's yard.

6. SIXTH BI-WEEKLY PROGRESS LETTER (15 August 1968 to 28 August 1968)

Additional cable protection trench was drilled, blasted, and cleaned, and work on cable system was started. Work on test structures continued with rebar placement and concrete pours. Access road and storage areas were graded. More columns were grouted and instrumentation of test structures began. Fabrication of detonating cord racks was started at job site.

7. SEVENTH BI-WEEKLY PROGRESS LETTER (29 August 1968 to 11 September 1968)

Fabrication of detonating cord racks continued and approximately 50 percent of the racks were wrapped with cord. The lightning protection system was installed. Excavation of cable trenches continued and some trench piping was assembled and installed. Construction of test structures continued and horizontal instrumentation holes were drilled. Some instruments were grouted in place in instrumentation holes. The setting and grouting of columns continued.

8. EIGHTH BI-WEEKLY PROGRESS LETTER (12 September 1968 to 25 September 1968)

Construction and instrumentation of test structures continued. Cable trench piping was completed and portions of trenches were backfilled with sand and concrete. Wrapping of detonating cord racks continued and approximately 20 percent of total racks were placed in the test cavity. Erection of steel beams was started and a test facility survey was made. Structural steel for instrumentation trailer shelter was erected and five instrumentation trailers arrived at the site. The setting of columns continued with approximately 60 percent complete.

9. NINTH BI-WEEKLY PROGRESS LETTER (26 September 1968 to 9 October 1968)

Assembling and wrapping of detonating cord racks and concrete filling of cable trenches was completed. Work continued on construction of test structures, erection of beams and columns, and cable and instrumentation systems. Subdeck placement was started, followed by placement of earth fill on subdeck and placement of roofdeck on steel beams. Forms were set for the remaining portion of the perimeter wall that was left open for access to test cavity.

10. TENTH BI-WEEKLY PROGRESS LETTER (10 October 1968 to 23 October 1968)

The following work was accomplished, thereby completing the construction activity except for the remaining earth placement:

a. Poured last section of concrete perimeter wall.
b. Placed steel deck and earth cover on trailer shelter.
c. Completed detonating cord installation.
d. Completed column and beam erection.
e. Completed placement of subdeck and subdeck fill.
f. Completed installation of roofdeck.
g. Installed plane wave generator.
h. Erected targets.
i. Placed approximately 4 feet of earth surcharge.

11. ELEVENTH BI-WEEKLY PROGRESS LETTER (24 October 1968 to 6 November 1968)

Surcharge and berm construction was completed, and surcharge dispersal holes were drilled. All members of the instrumentation trailer shelter were painted with identifying marks to facilitate reassembly. General clean-up of the area continued.

12. TWELFTH BI-WEEKLY PROGRESS LETTER (7 November 1968 to 20 November 1968)

The pump was removed on the water well east of the instrumentation trailer shelter. Targets were placed on the earth surcharge and general clean-up continued.

13. THIRTEENTH BI-WEEKLY PROGRESS LETTER (21 November 1968 to 4 December 1968)

The test event was conducted at 1430 hours on 21 November 1968. Started removing steel, earth berms, and earth surcharge from the test facility. Began removing earth cover from instrumentation trailer shelter.

14. FOURTEENTH BI-WEEKLY PROGRESS LETTER (5 December 1968 to 31 December 1968)

Completed clean-up and removal of steel, earth berms, and earth surcharge from the test facility.

APPENDIX II

CONSTRUCTION PHOTOGRAPHS

This appendix contains a collection of construction photographs selected to present a pictorial record of the significant and/or unique construction events and to illustrate the progress of the job.

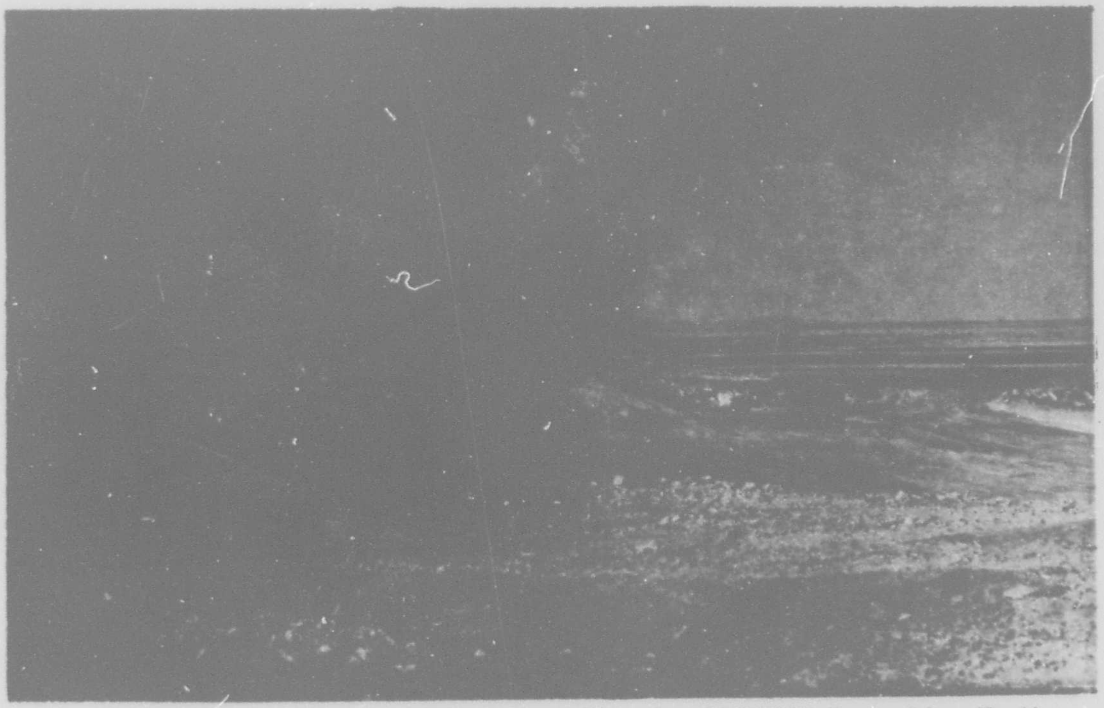

Figure II-1. Estancia Valley Test Site for ROCKTEST I, Looking North, Prior to Construction.

Figure II-2. Corps of Engineers Drilling Perimeter Holes for Full Scale Model.

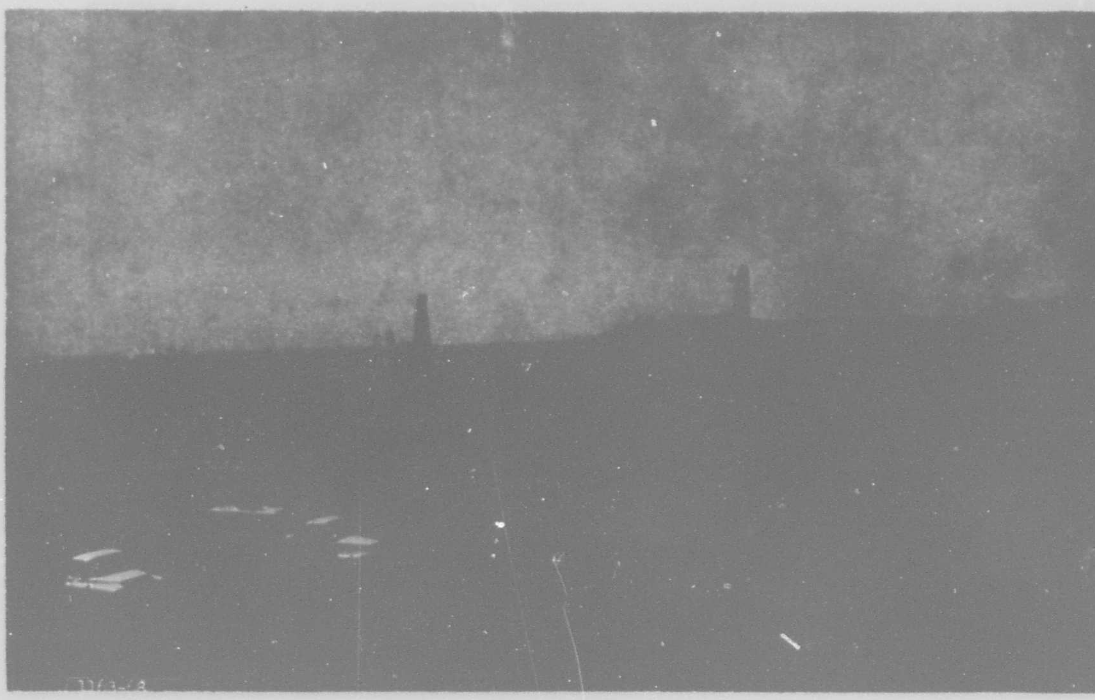

Figure II-3. Test Site in Early Stages Showing Corps of Engineers Drilling Rigs and Contractor's Equipment.

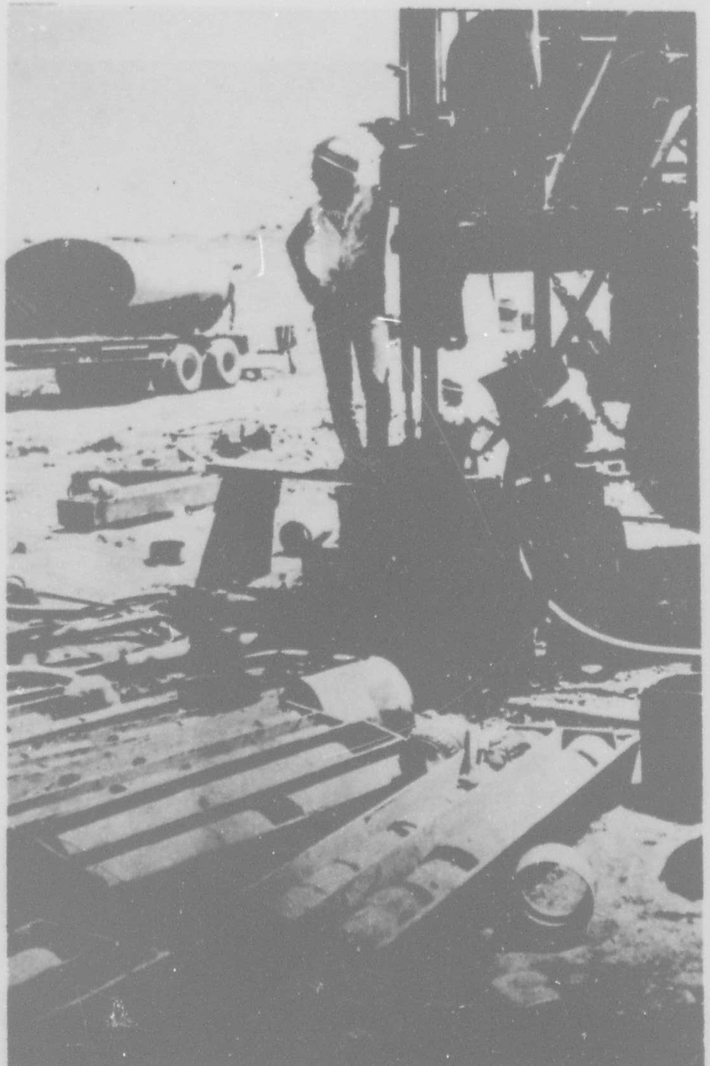

Figure II-4. Rock Drilling by Corps of Engineers.

Figure II-5. Contractors Air Track Rig Drilling Shot Holes for Instrumentation Trenches.

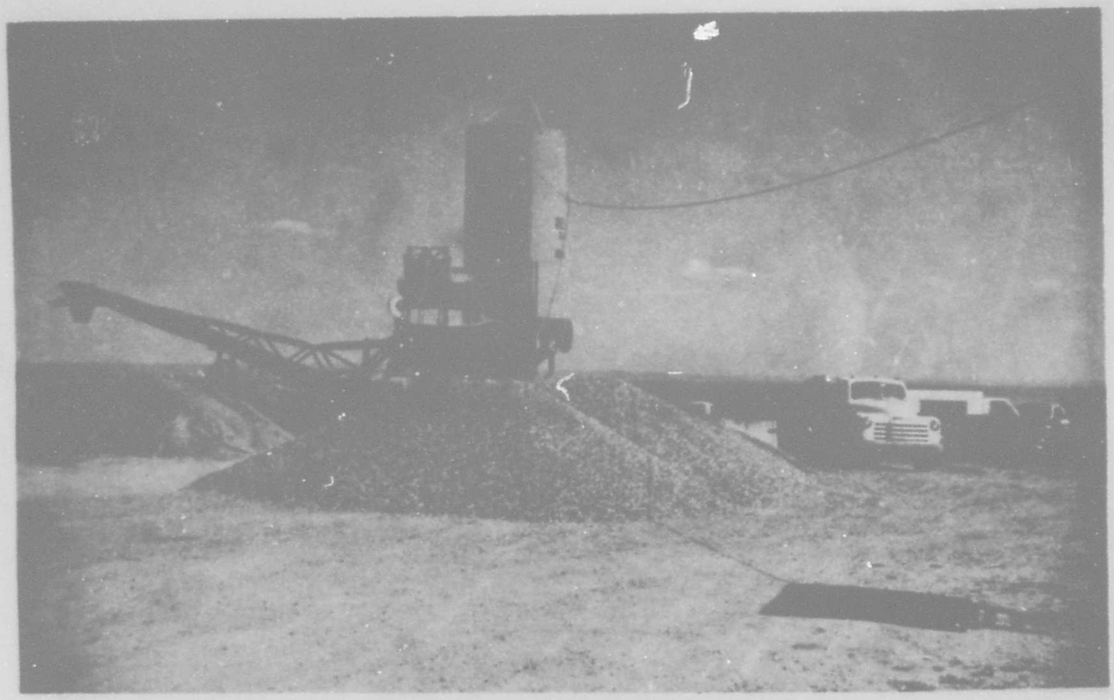

Figure II-6. On-Site Concrete Batch Plant.

Figure II-7. Placing Concrete Curb Around Perimeter of Test Bed to Provide Level Surface for Concrete Wall Forms.

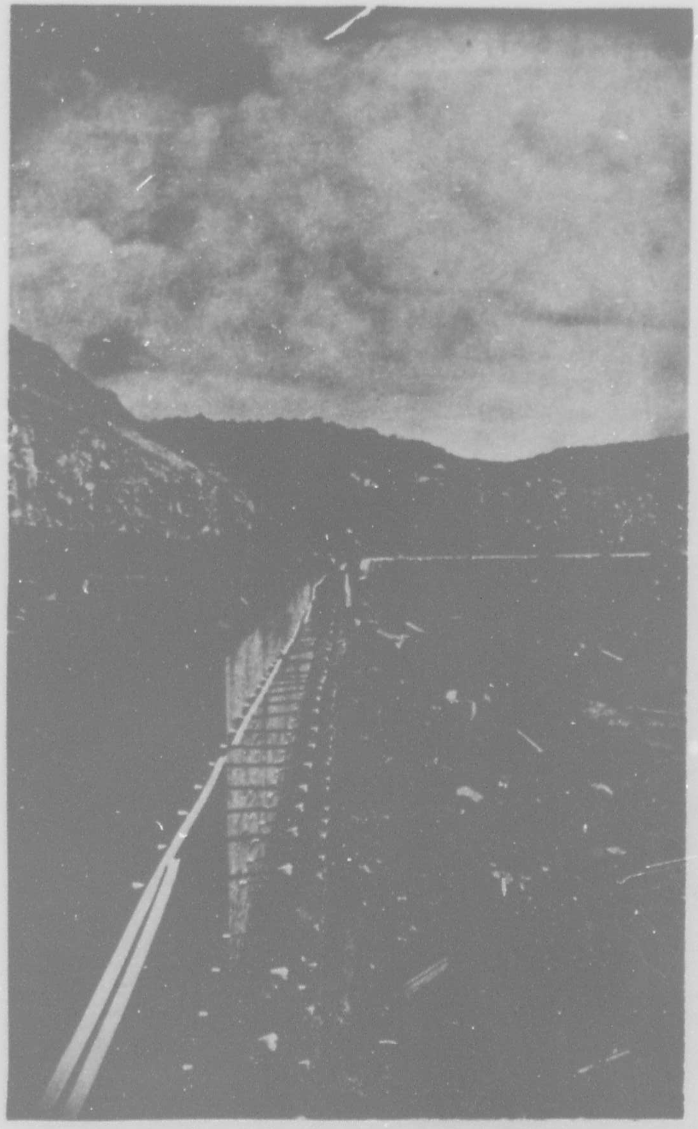

Figure II-8. Forming for Perimeter Walls.

Figure II-9. Reinforcing Steel Placement for Concrete Perimeter Walls.

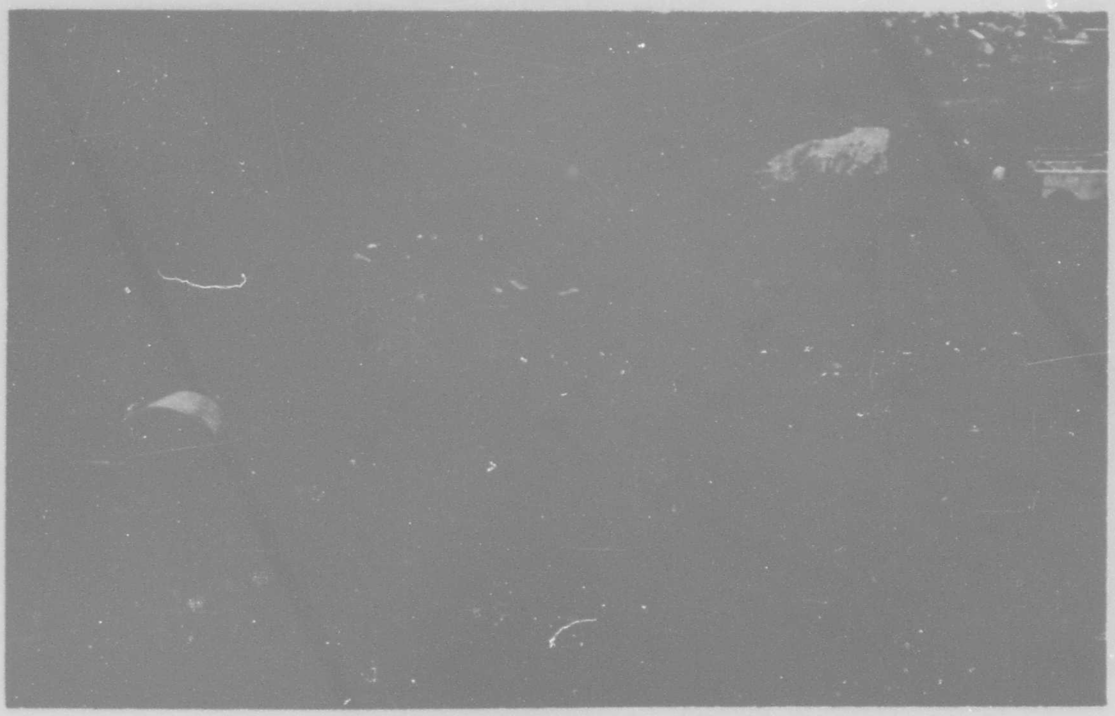

Figure II-10. Rock Excavation for Test Structures.
Pouring Concrete Perimeter Walls.

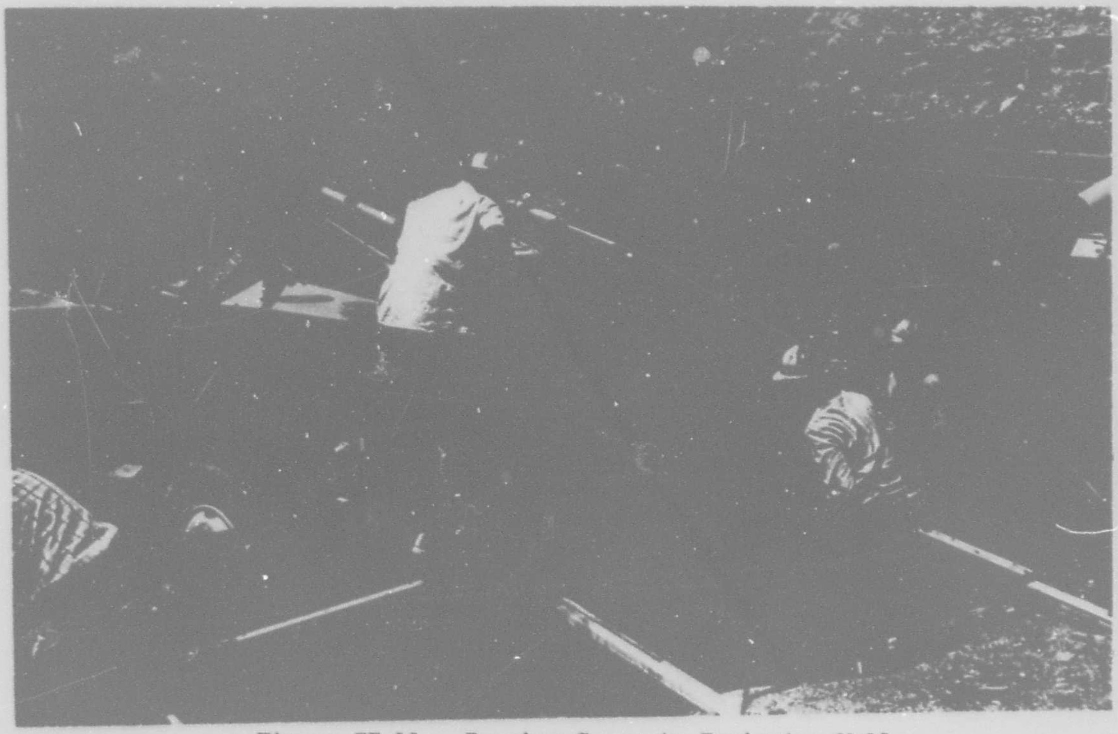

Figure II-11. Pouring Concrete Perimeter Walls.

Figure II-12. Concrete Perimeter Walls, Anchor Bolts and Leveling Plates.

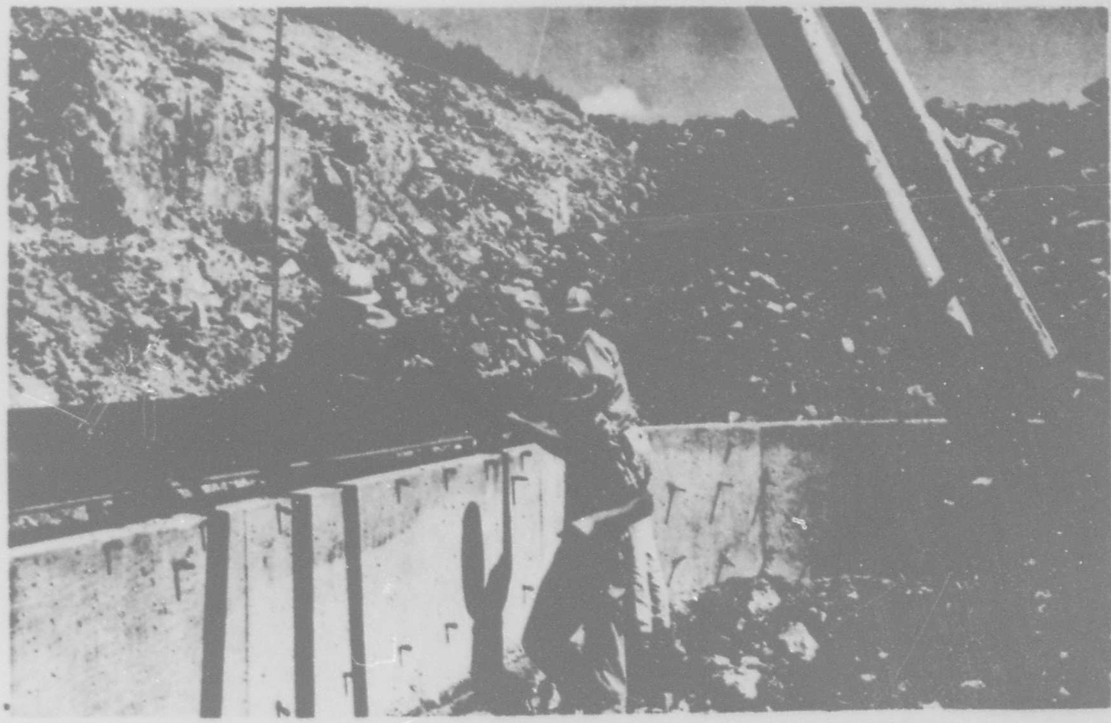

Figure II-13. Placing Steel Beam on Concrete Wall.

Figure II-14. Aerial View Showing Test Bed and Excavation for Test Structures in Progress.

Figure II-15. Solid Mass of Rock Removed from Quarter Scale Model.

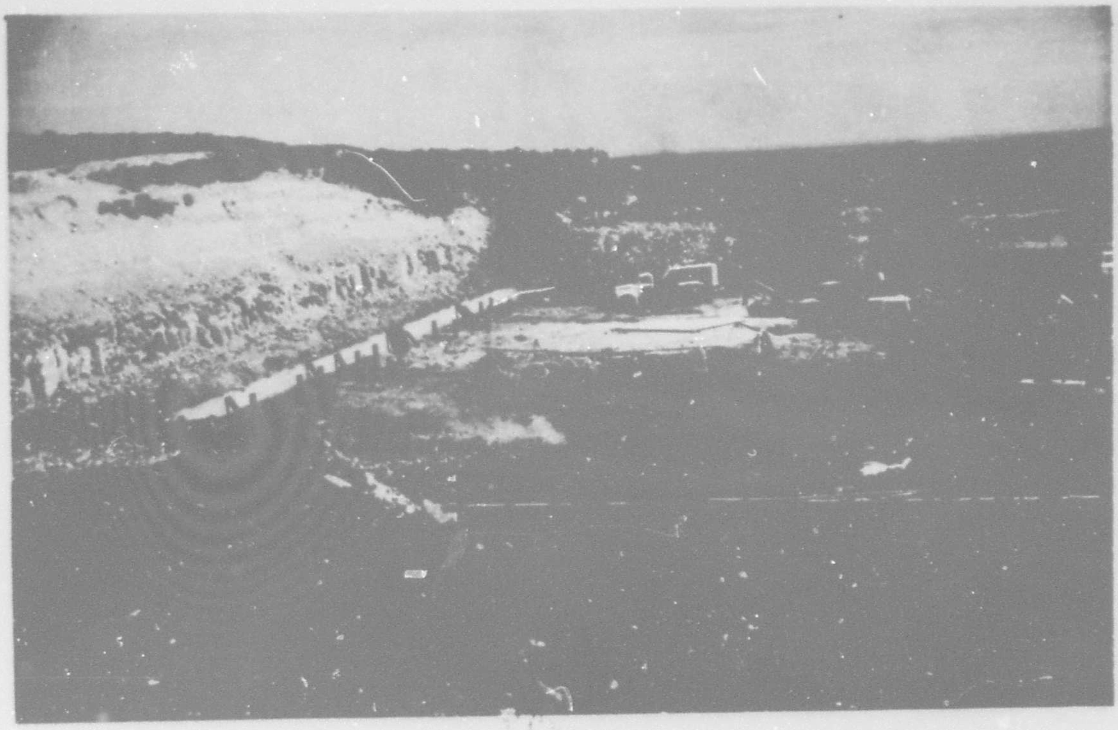

Figure II-16. Test Bed Showing West Wall Looking North.

Figure II-17. Test Bed Showing East Wall Looking North.

Figure II-18. Rock Drilling for Column Anchor Bolts.

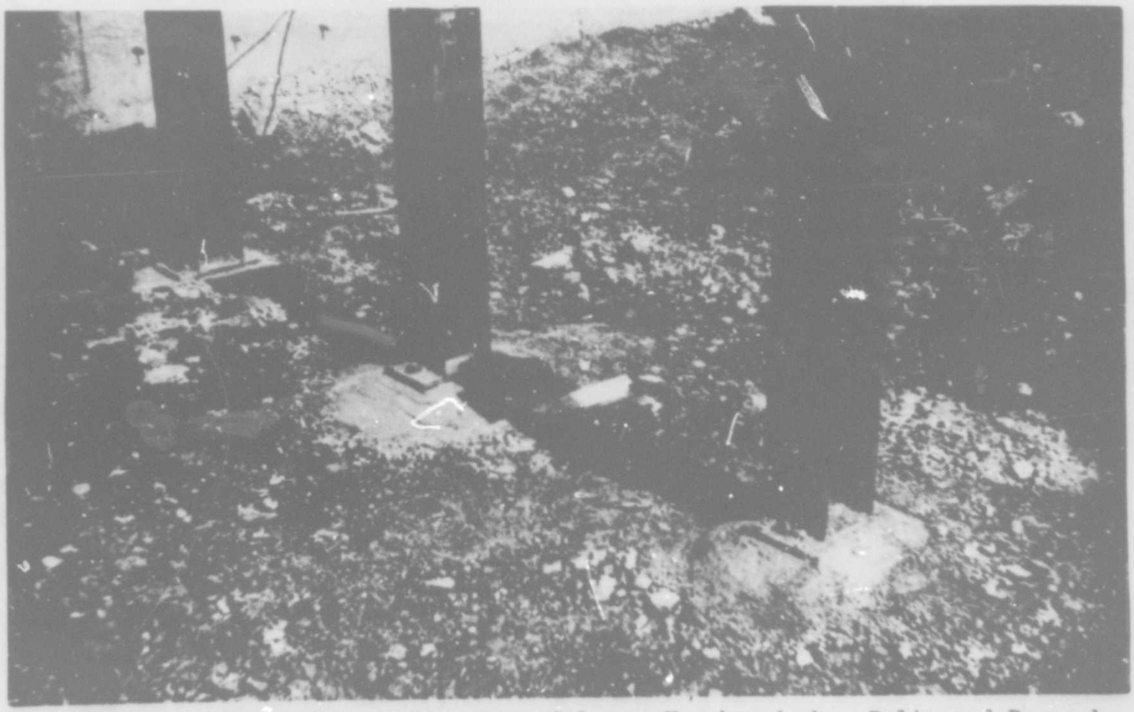

Figure II-19. Overpressure Structure Columns Showing Anchor Bolts and Drypack.

Figure II-20. Instrumentation Trench Immediately after Pre-Splitting Shot.

Figure II-21. Measuring Instrumentation Trench Excavated by Pre-Splitting Method.

Figure II-22. Jack-hammering for Instrumentation System. (Results of pre-splitting attempt shown beyond construction worker).

Figure II-23. Instrumentation Trench Excavation.

Figure II-24. Rock Excavation for Government Installed Splice Cases.

Figure II-25. Couplers and Sleeves for Instrumentation Cable Protection System.

Figure II-26. AFWL Personnel Installing Instrumentation.

Figure II-27. Instrumentation Cables Emerging from Test Facility in Background.

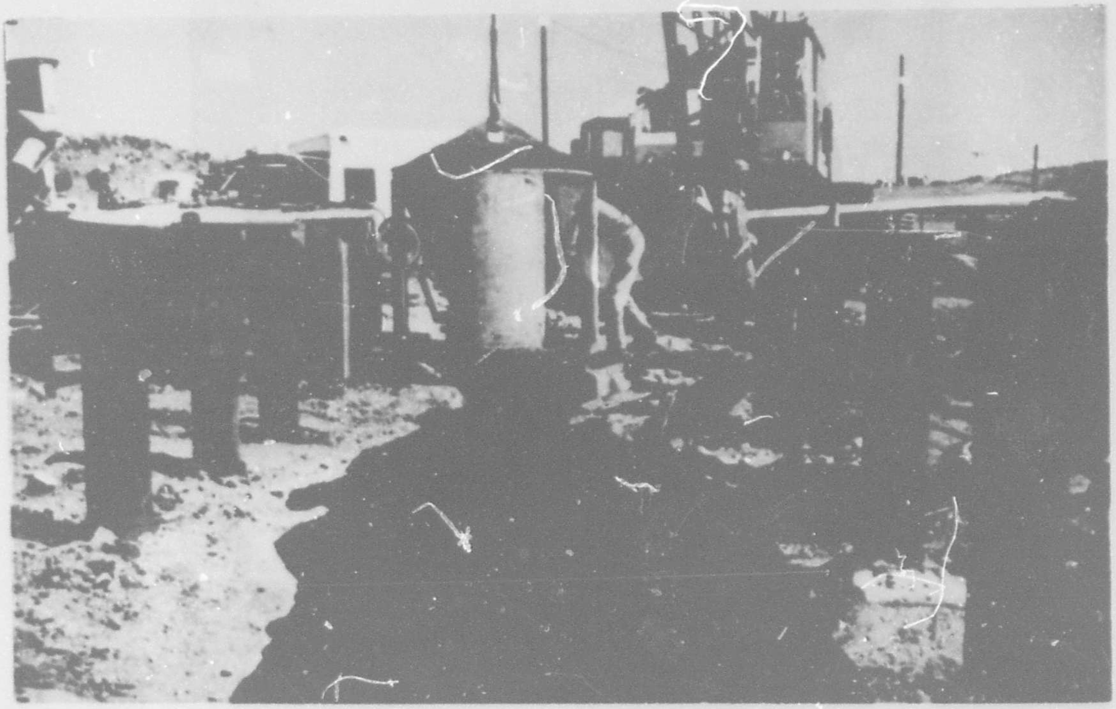

Figure II-28. Placing Concrete over Instrumentation Cable System.

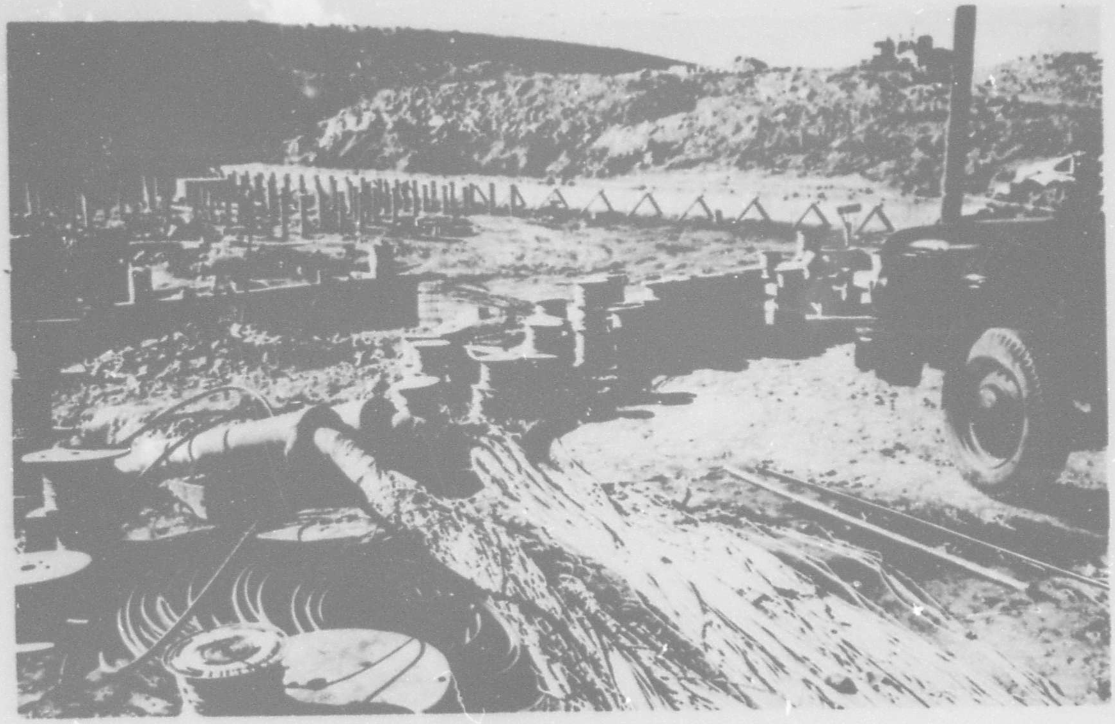

Figure II-29. Instrumentation Cabling.

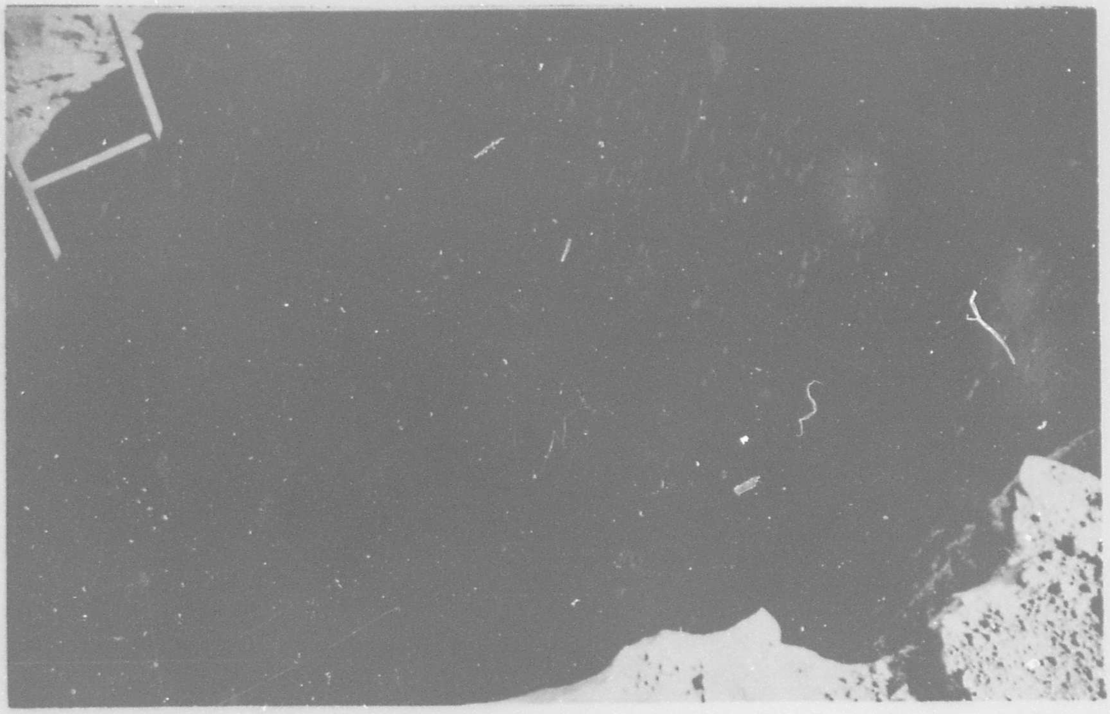

Figure II-30. Loading Holes with Dynamite on Unlined Silo.

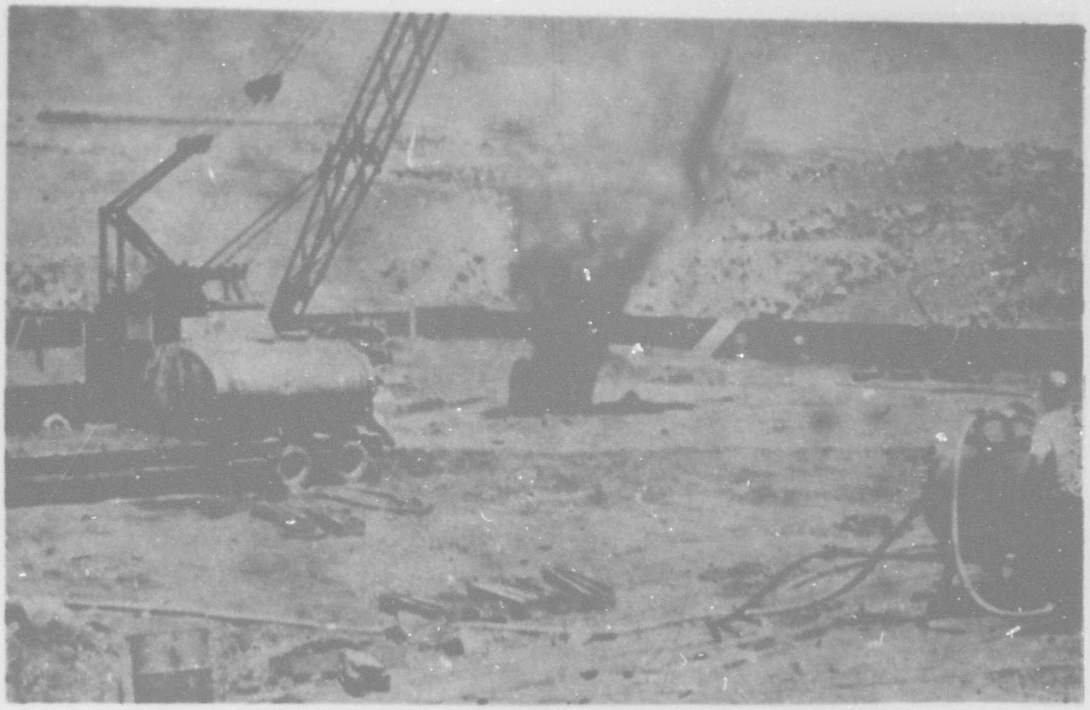

Figure II-31. Blasting Rock for Unlined Silo.

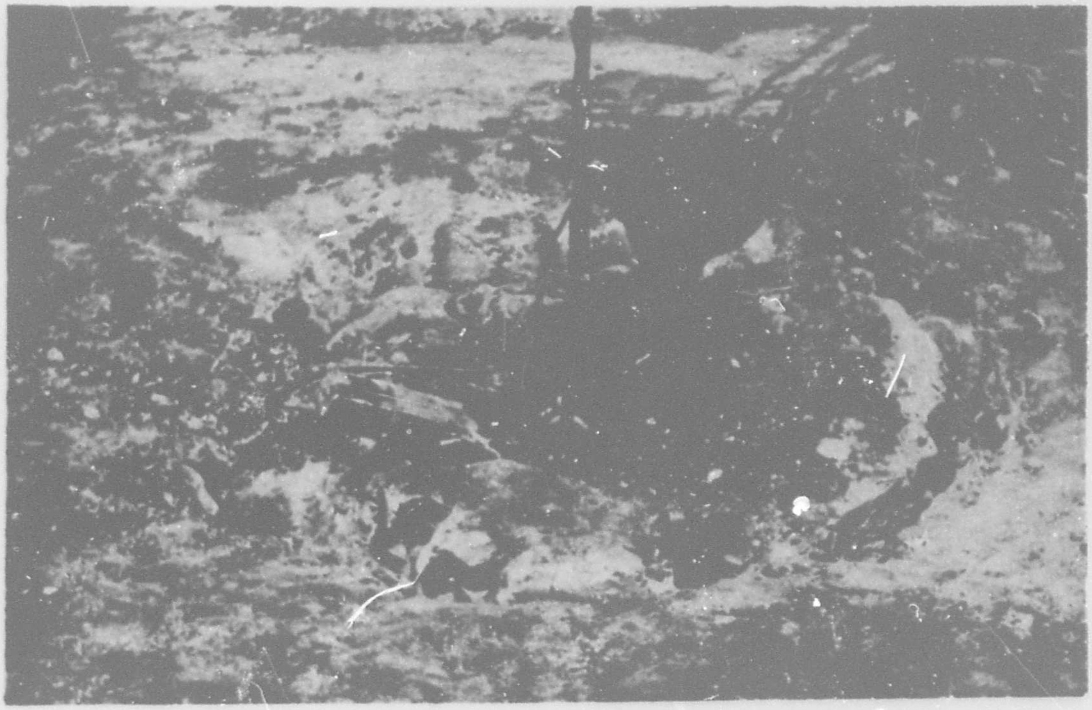

Figure II-32. Rock Excavation of Large Pieces.

Figure II-33. Rock Removal from Lined and Unlined Silo with 55-gallon Drum.

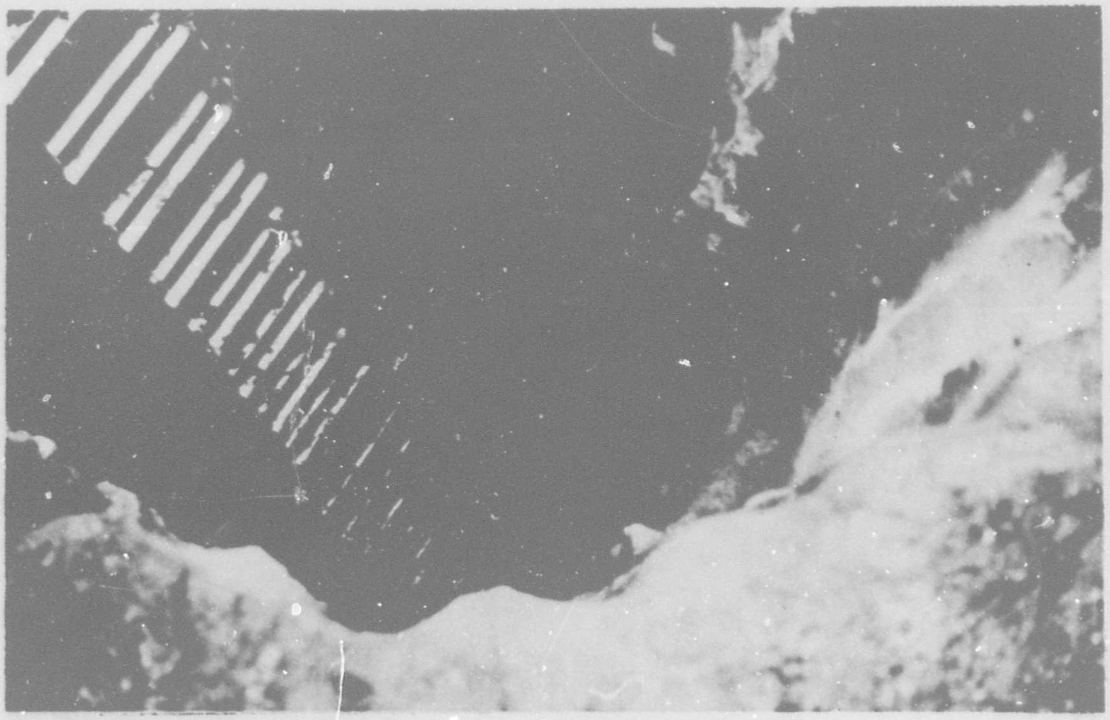

Figure II-34. Water in Bottom of Lined Silo (Rain and rock seepage).

Figure II-35. Lined Silo Number 02. Leveling Air Track to Re-drill the Lined Silo.

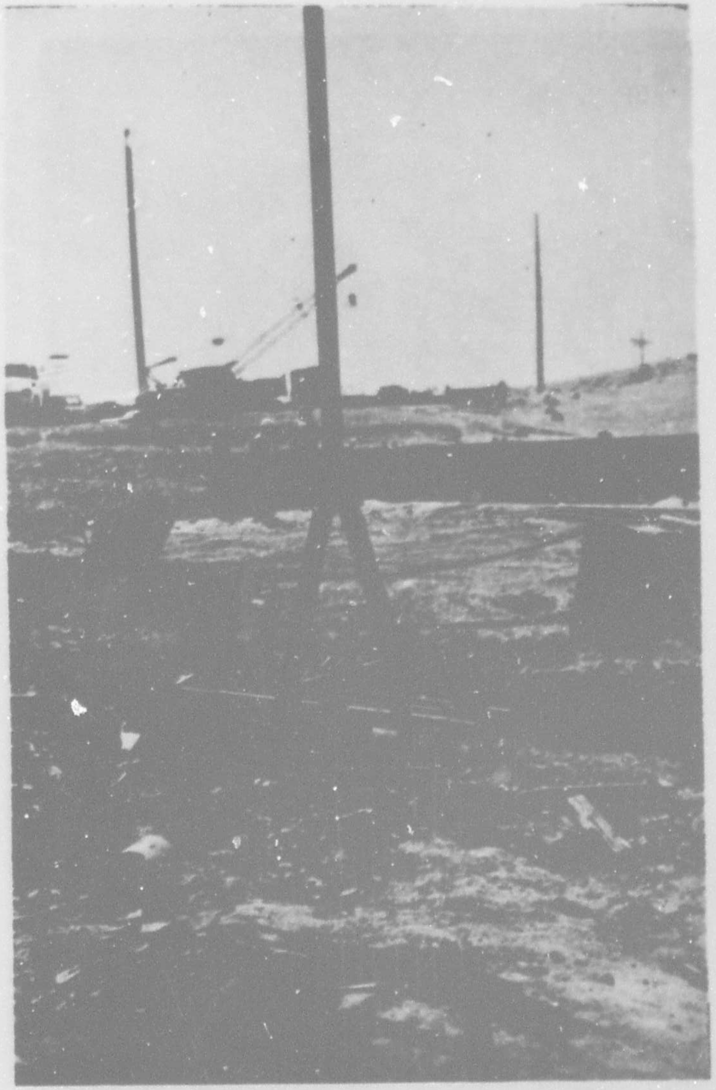

Figure II-36. Drill Rig for Drilling Horizontal Instrumentation Holes.

Figure II-37. Lined Silo Number 02. Installation of Reinforcing Steel prior to Liner Placement.

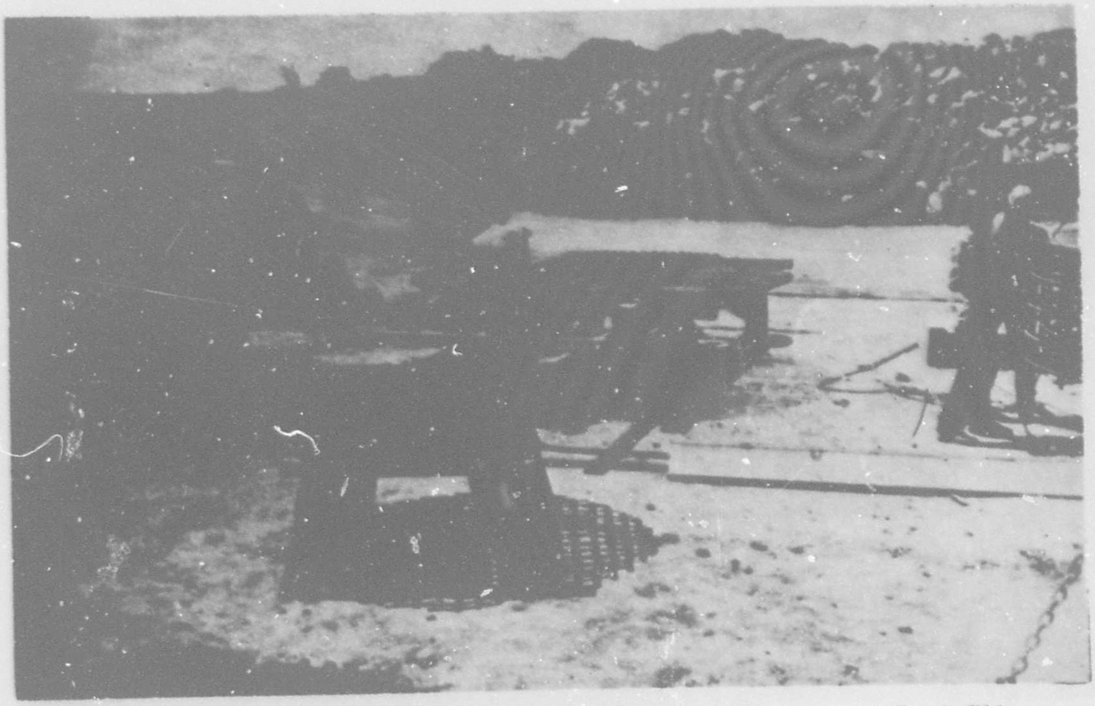

Figure II-38. Tying Steel Reinforcing Mats for Closures at Test Site.

Figure II-37. Lined Silo Number 02. Installation of Reinforcing Steel prior to Liner Placement.

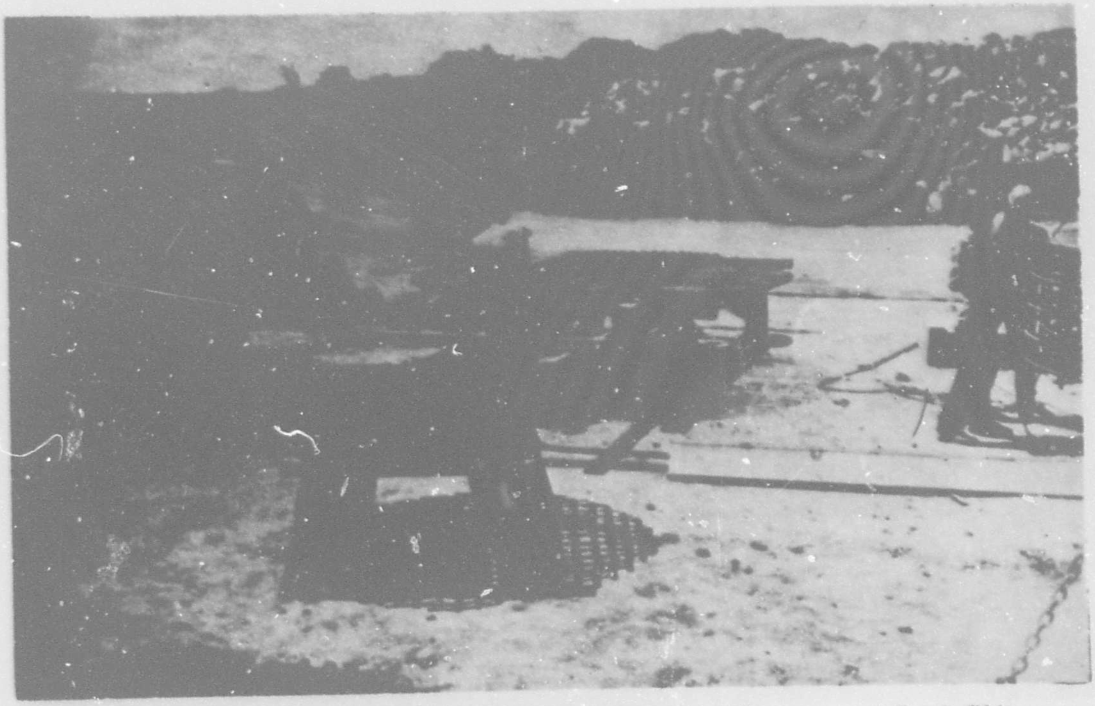

Figure II-38. Tying Steel Reinforcing Mats for Closures at Test Site.

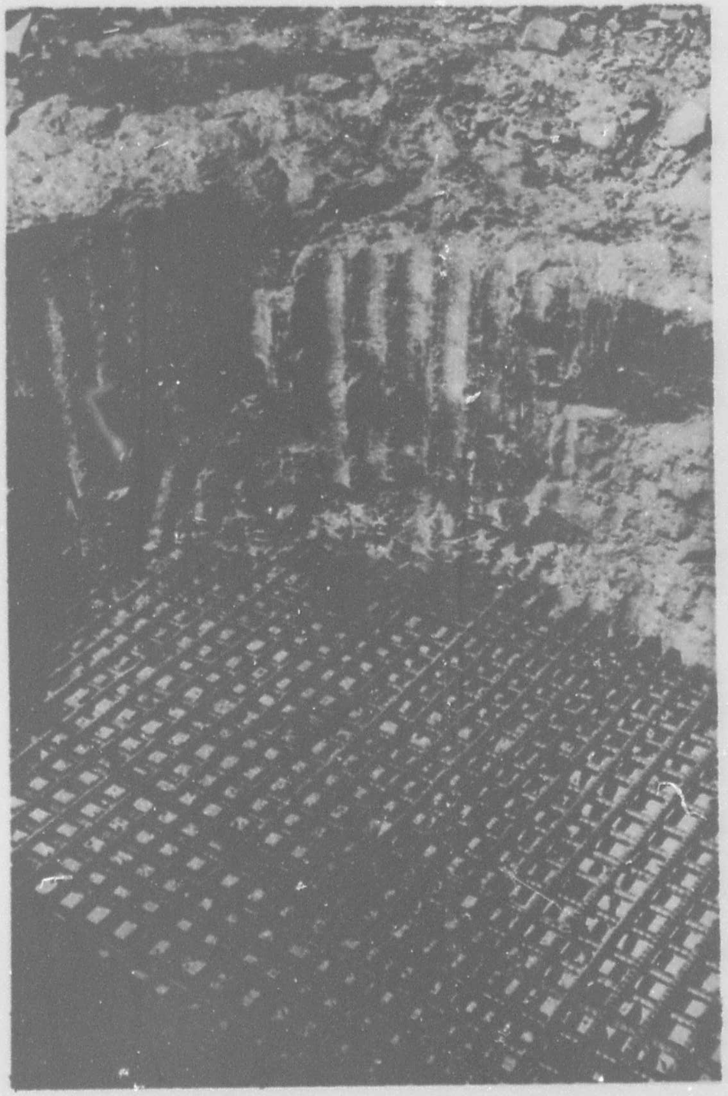

Figure II-41. Research Closure Number 05.
Reinforcing Steel Prior to Concrete Pour.

Figure II-42. Excavating Full Scale Model.

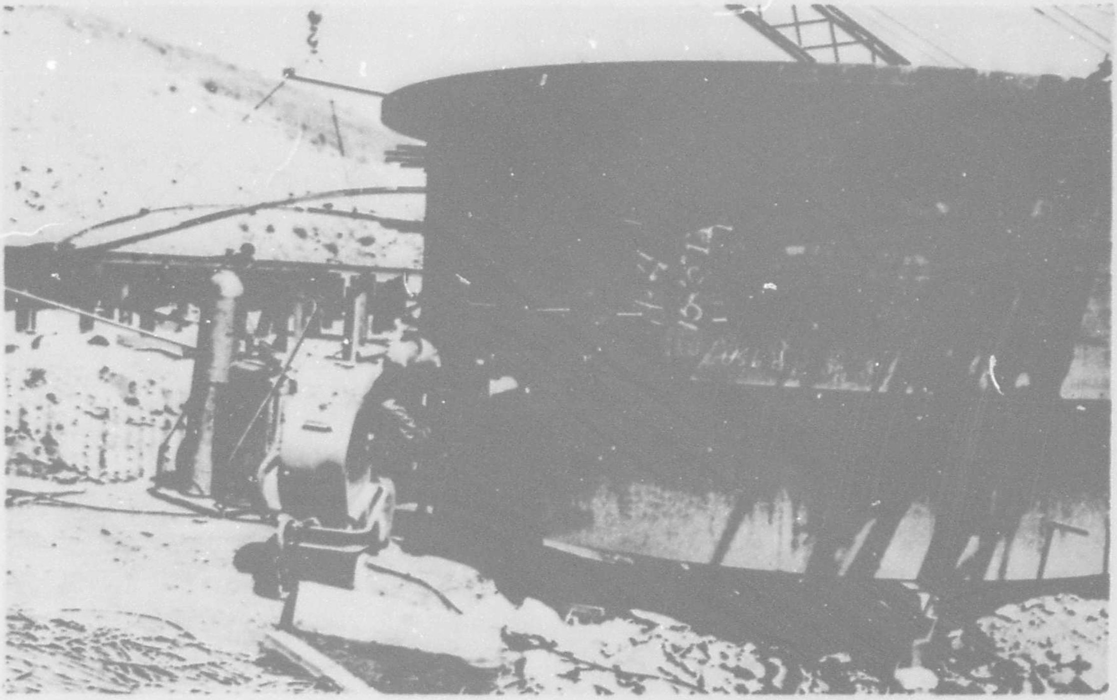

Figure II-43. Full Scale Closure Liner at Test Site
Showing Welding in Progress.

Figure II-44. Rock Removal from Full Scale Model.

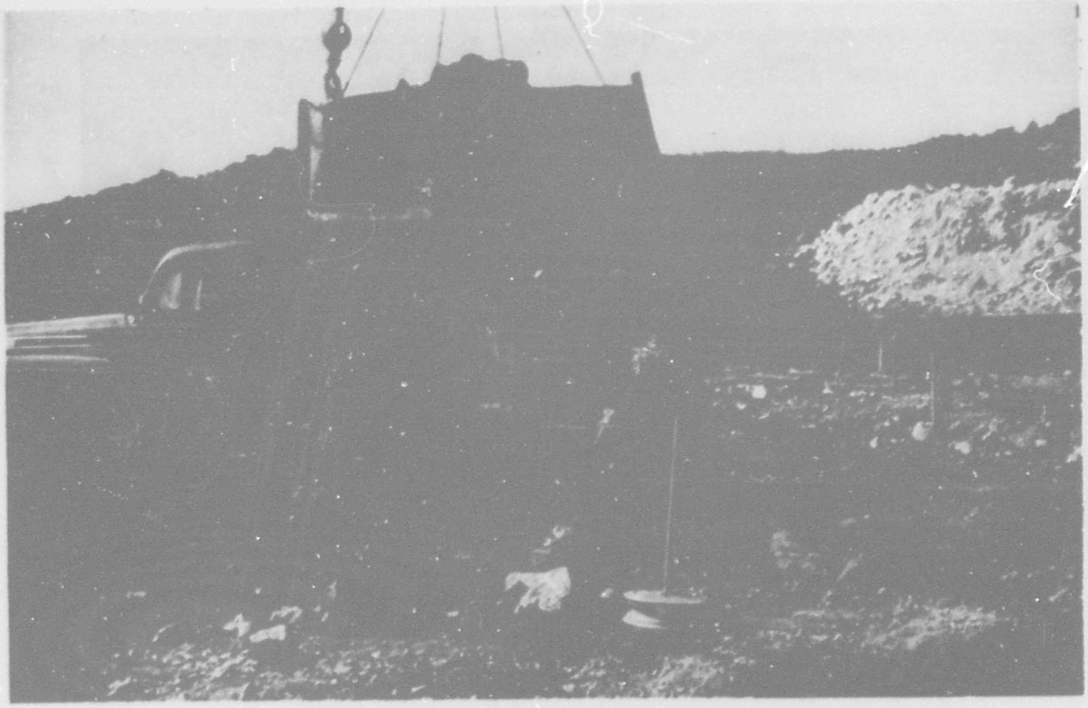

Figure II-45. Rock Removal from Full Scale Model.

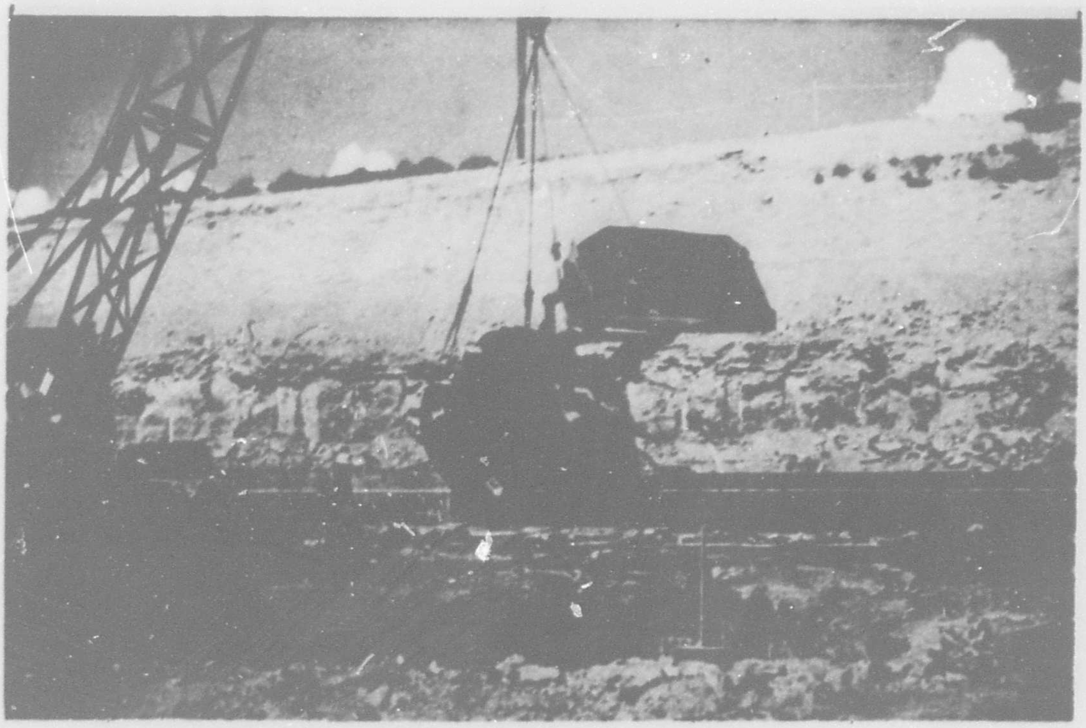

Figure II-46. Lowering HD-5 Track Loader into Full Scale Model.

Figure II-47. HD-5 Track Loader Ripping Rock on Full Scale Model.

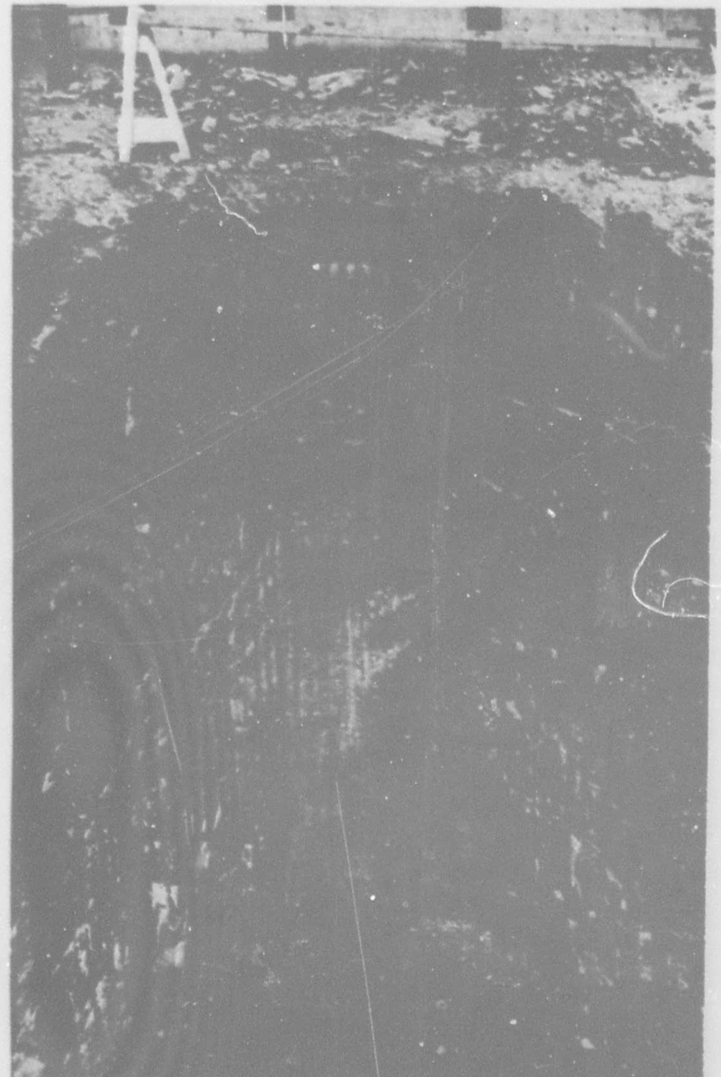

Figure II-48. Completed Excavation for Full Scale Model.

Figure II-49. Pouring Concrete on Full Scale Model.

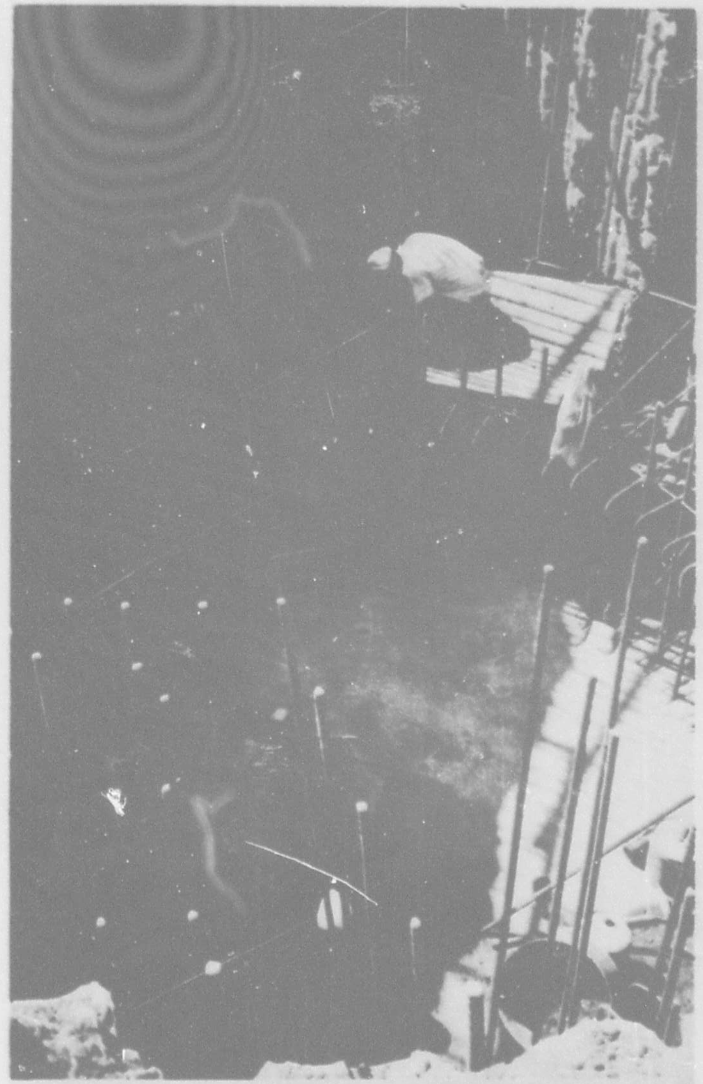

Figure II-50. Full Scale Model Reinforcing after First Pour.

Figure II-51. Vibrating First Pour of Concrete on Full Scale Model.

Figure II-52. Access Shaft Liner for Full Scale Model.

Figure II-53. Reinforcing Placement for Full Scale Model.
Access Shaft Liner In Place.

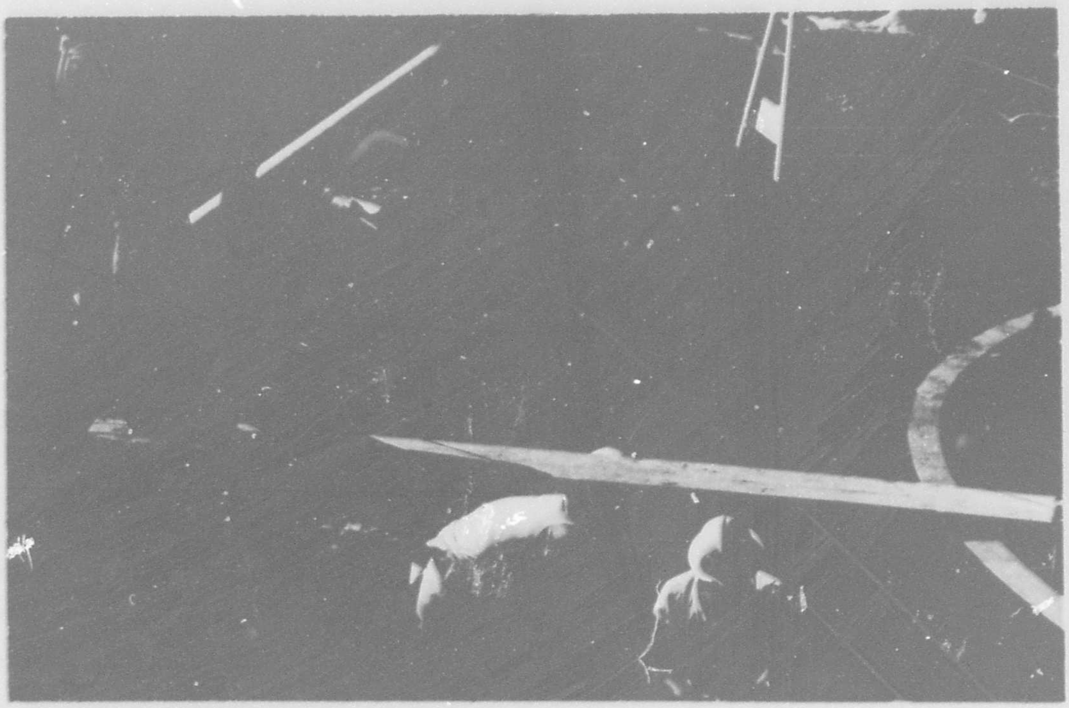

Figure II-54. Installation of Instrumentation on Full Scale Closure.

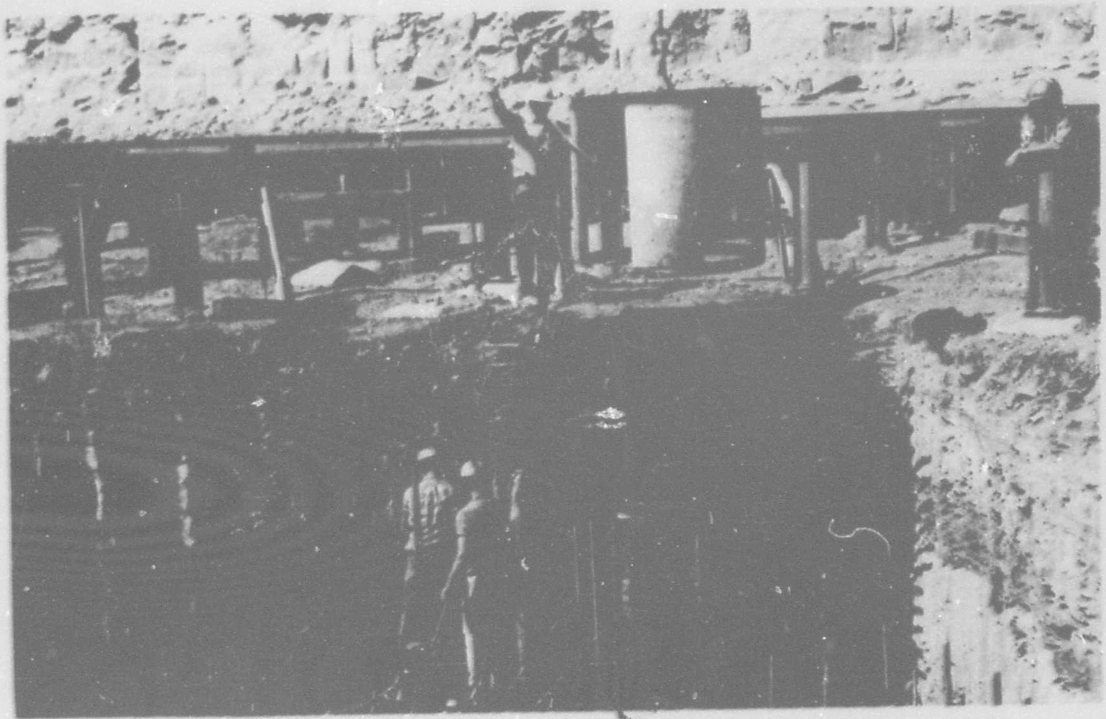

Figure II-55. Concrete Pour on Full Scale Closure and Access Shaft.

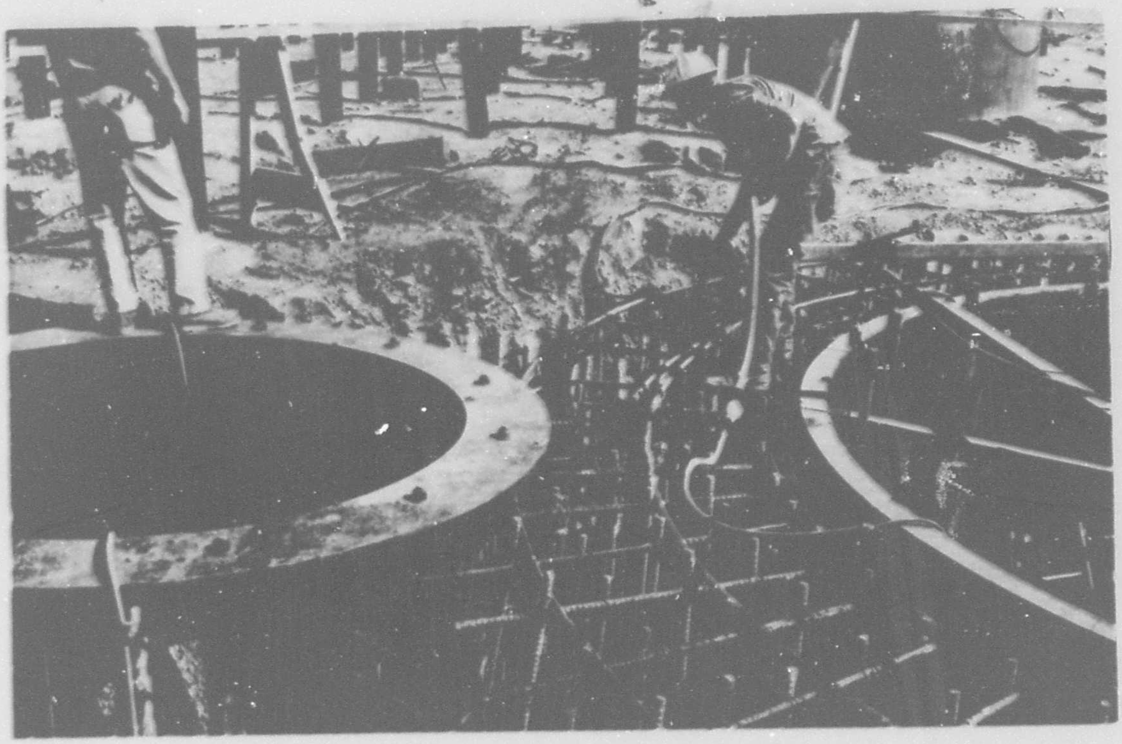

Figure II-56. Vibrating Concrete for Full Scale Closure and Access Shaft.

Figure II-57. Test Bed Area Showing Final Concrete Pour on Full Scale Model.

Figure II-58. Full Scale Closure Showing Stirrups and Top Layer of Reinforcing Steel.

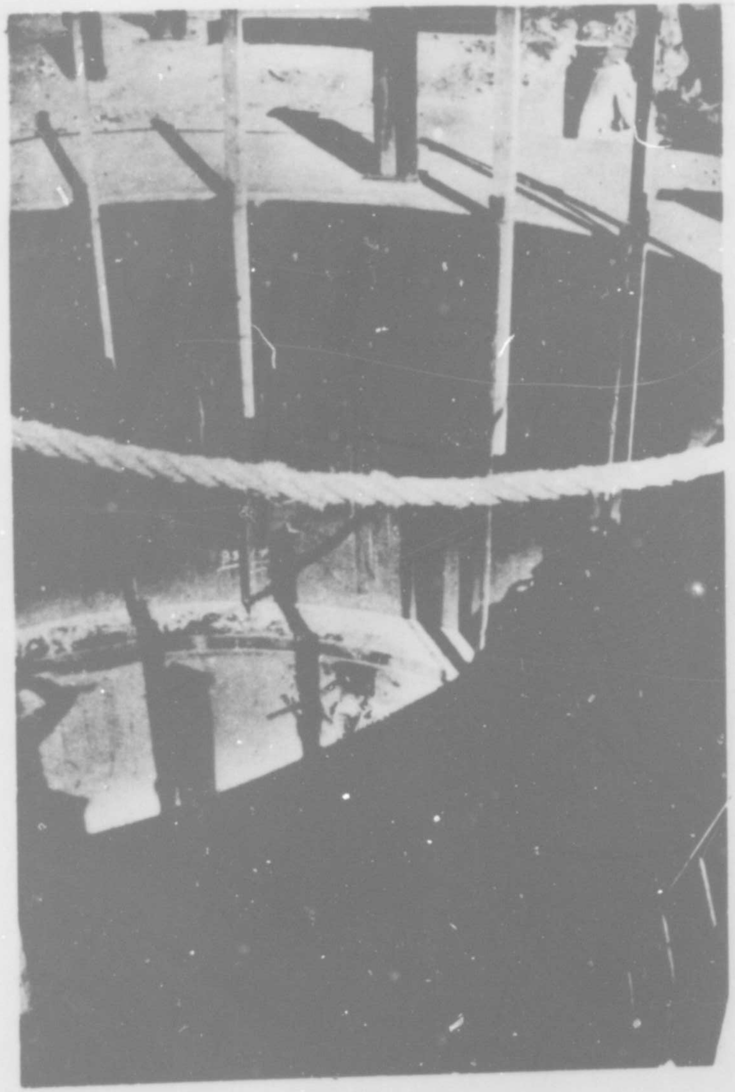

Figure II-59. Full Scale Liner Showing 1-1/2 inch Diameter H. S. Anchor Rods for Closure.

Figure II-60. Final Concrete Pour on Full Scale Closure.

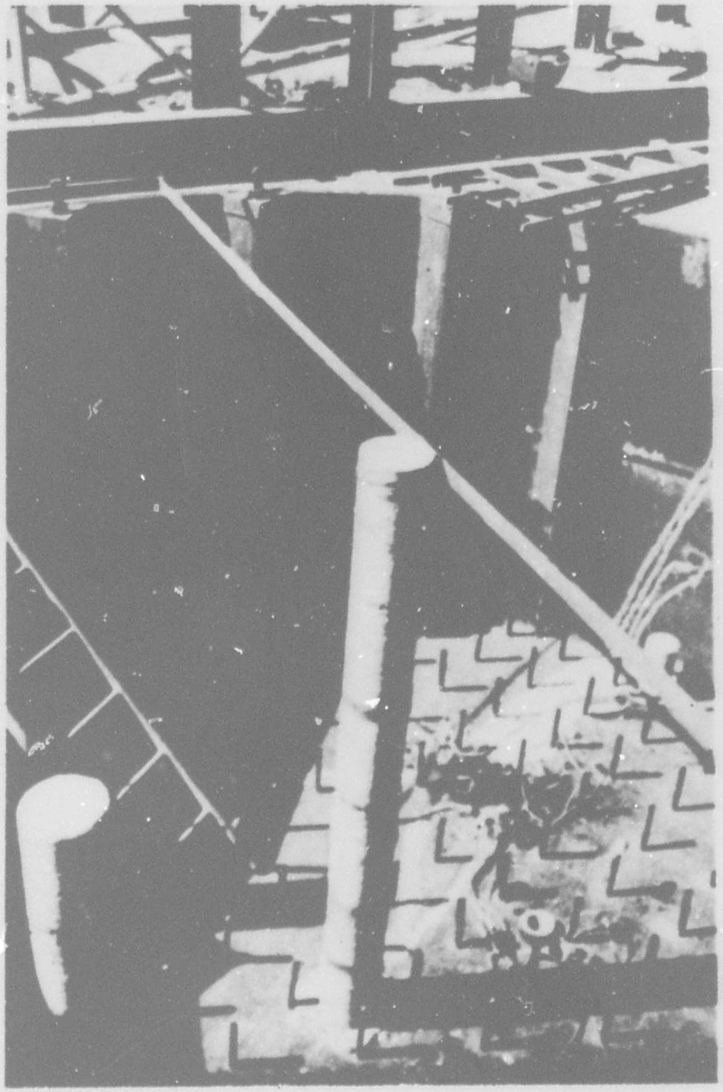

Figure II-61. Full Scale Closure Liner In Place Prior to Pouring Concrete. Instrumentation Being Installed.

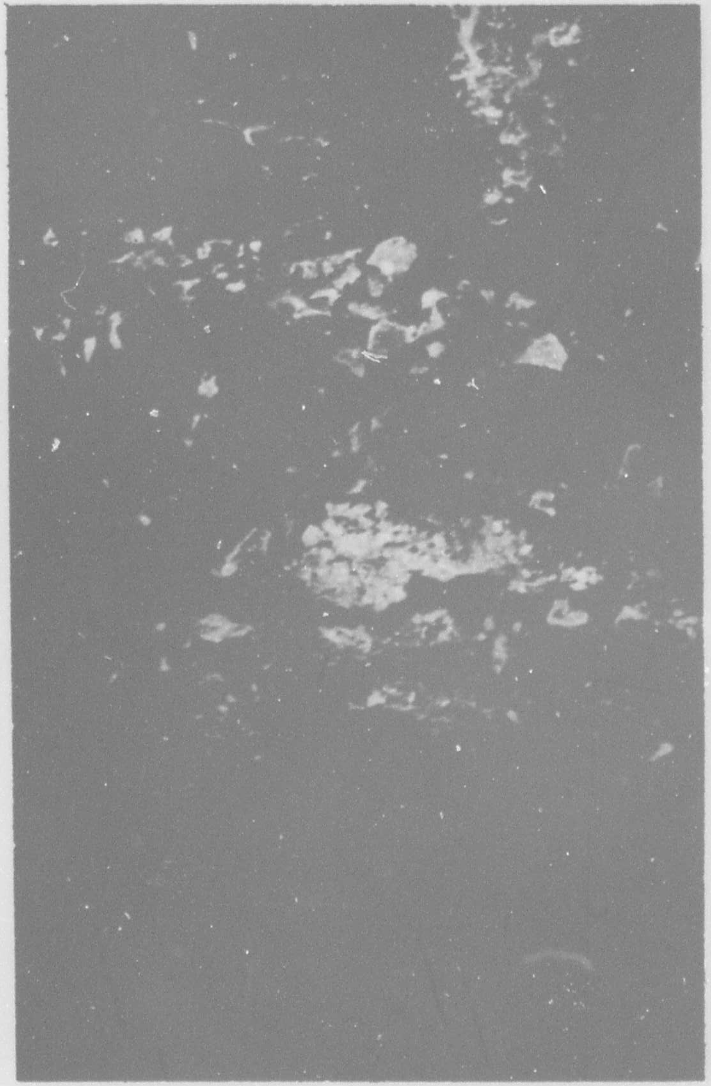

Figure II-62. 2' 4" Diameter Core Drilled Hole for Erectable Antenna.

Figure II-63. Erectable Antenna Prior to Placement.

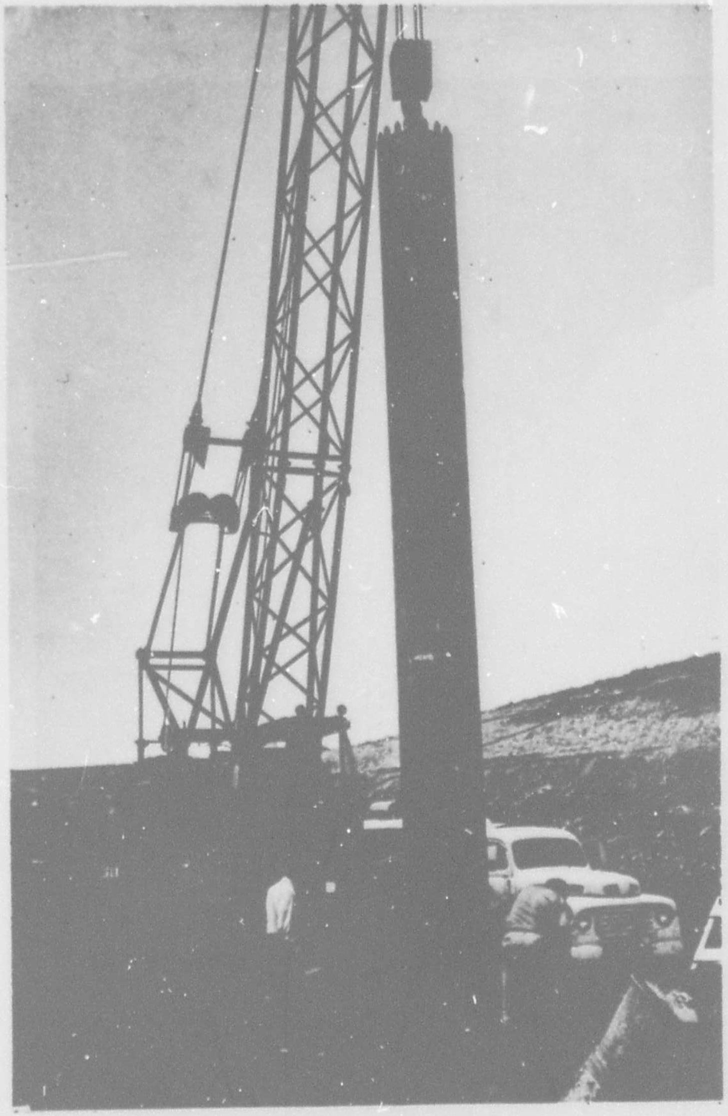

Figure II-64. Placement of Erectable Antenna (GFP).

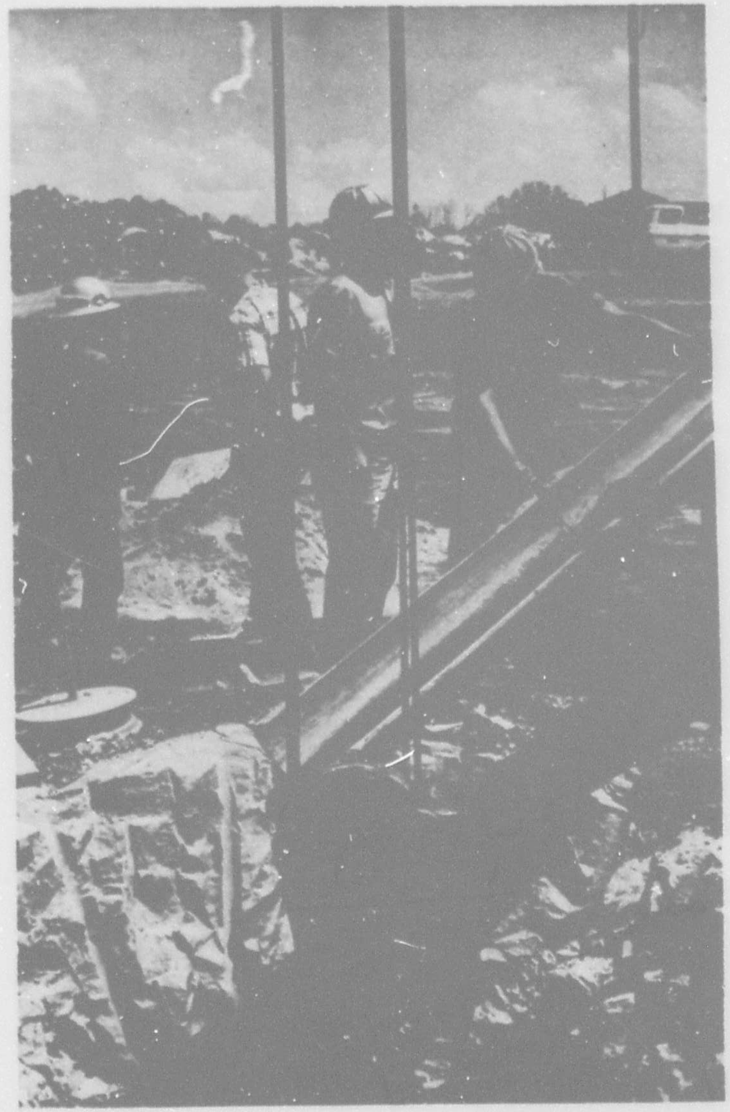

Figure II-65. Placing Concrete for Erectable Antenna (Number 10).

Figure II-66. Top View of Erectable Antenna after Grouting.

Figure II-67. Placement of Bottom Portion of End Fire COMSAT Antenna.

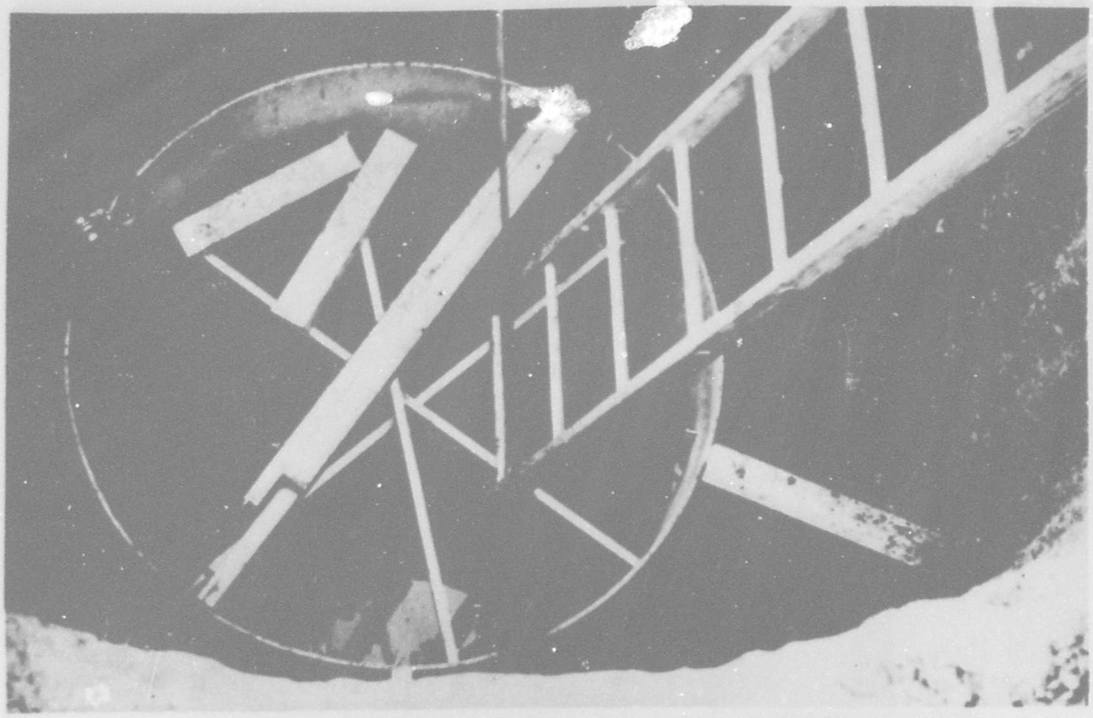

Figure II-68. Installation of Bottom Portion of End Fire COMSAT Antenna (Number 12).

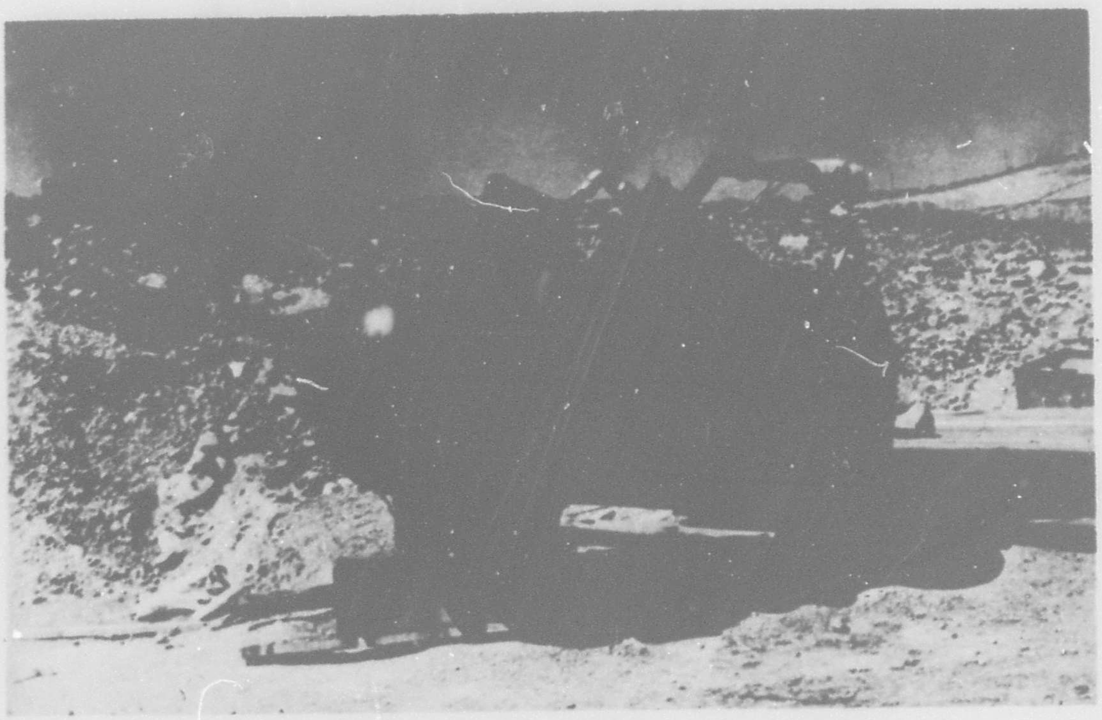

Figure II-69. End Fire COMSAT Antenna (GFP).

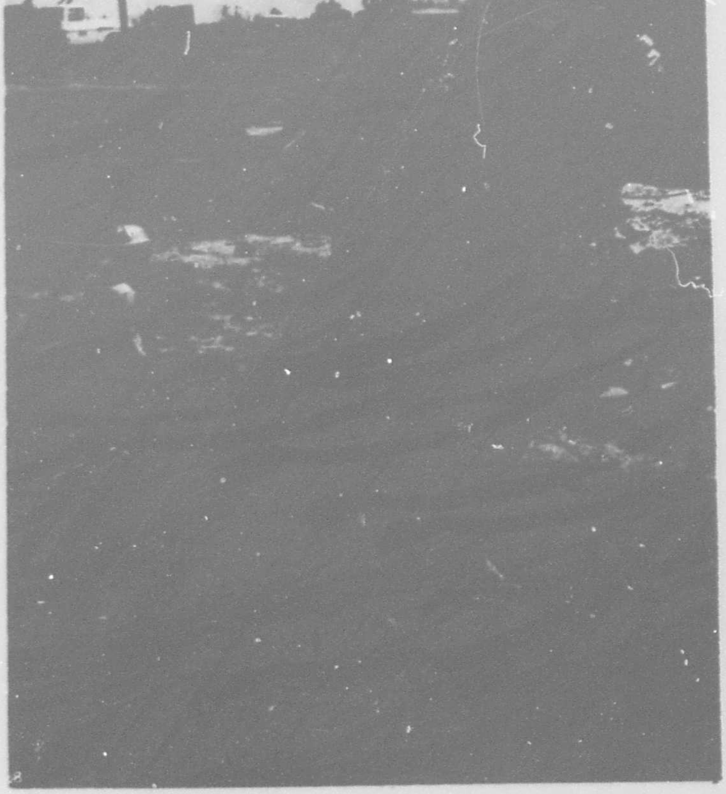

Figure II-70. Placing End Fire COMSAT Antenna (Number 12).

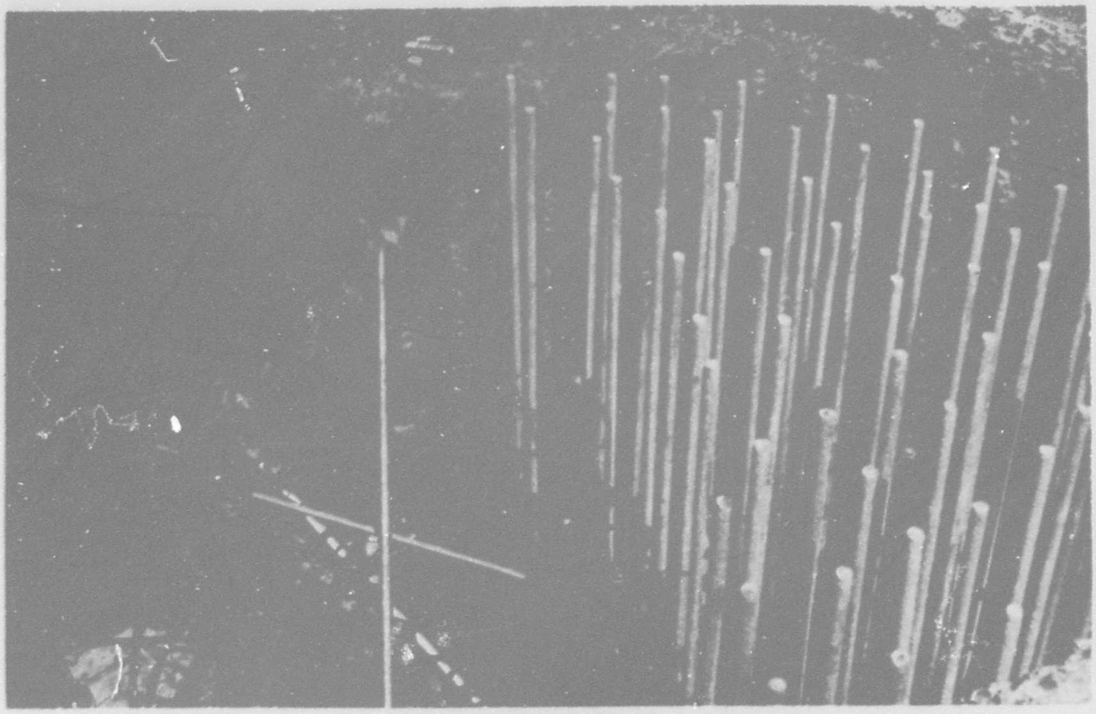

Figure II-71. Reinforcing Steel and Fiberglass Rods for Flush Annular Slot Antenna (Number 04).

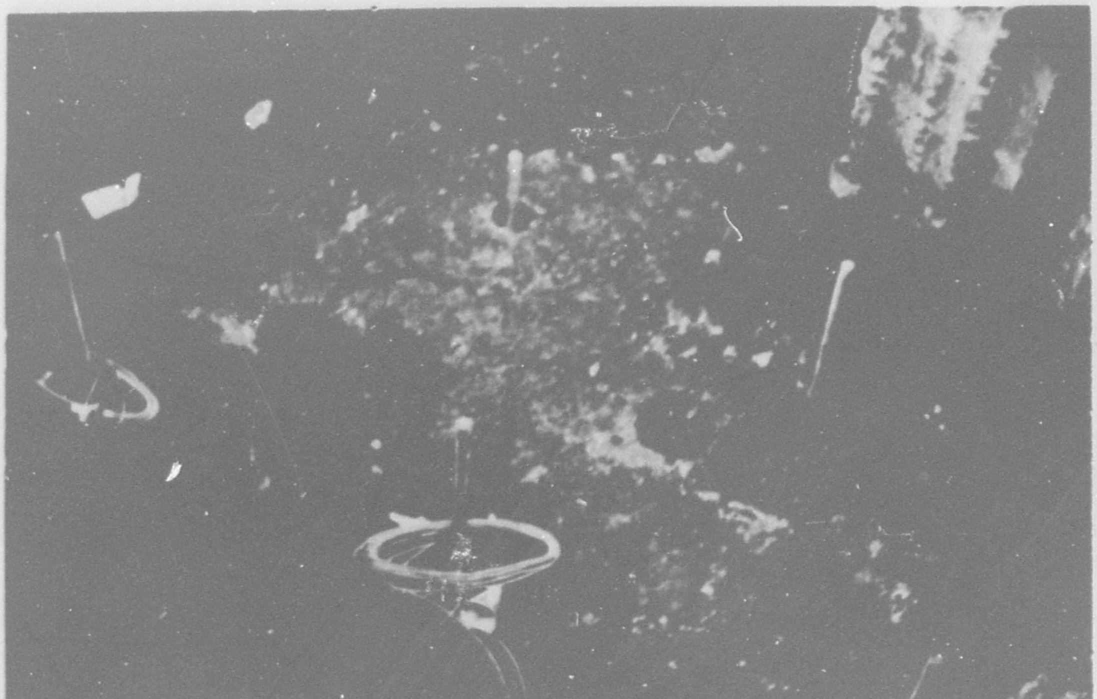

Figure II-72. Flush Annular Slot Antenna after First Concrete Pour.

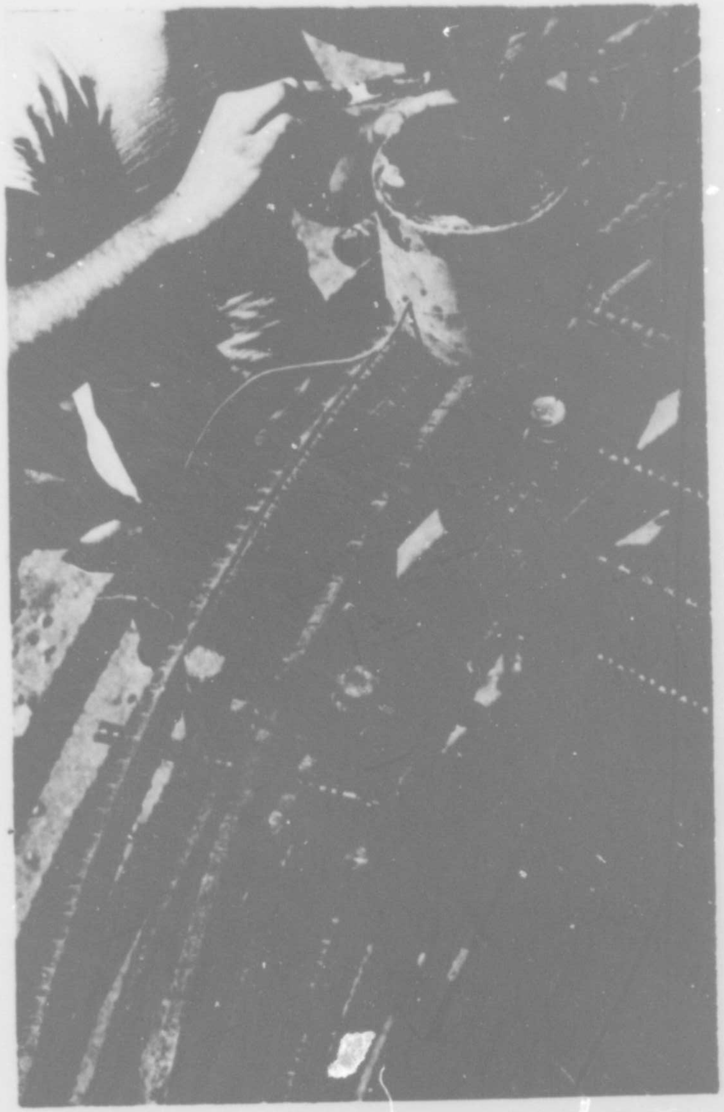

Figure II-73. Instrumentation Installation on Upside Down Closure Support.

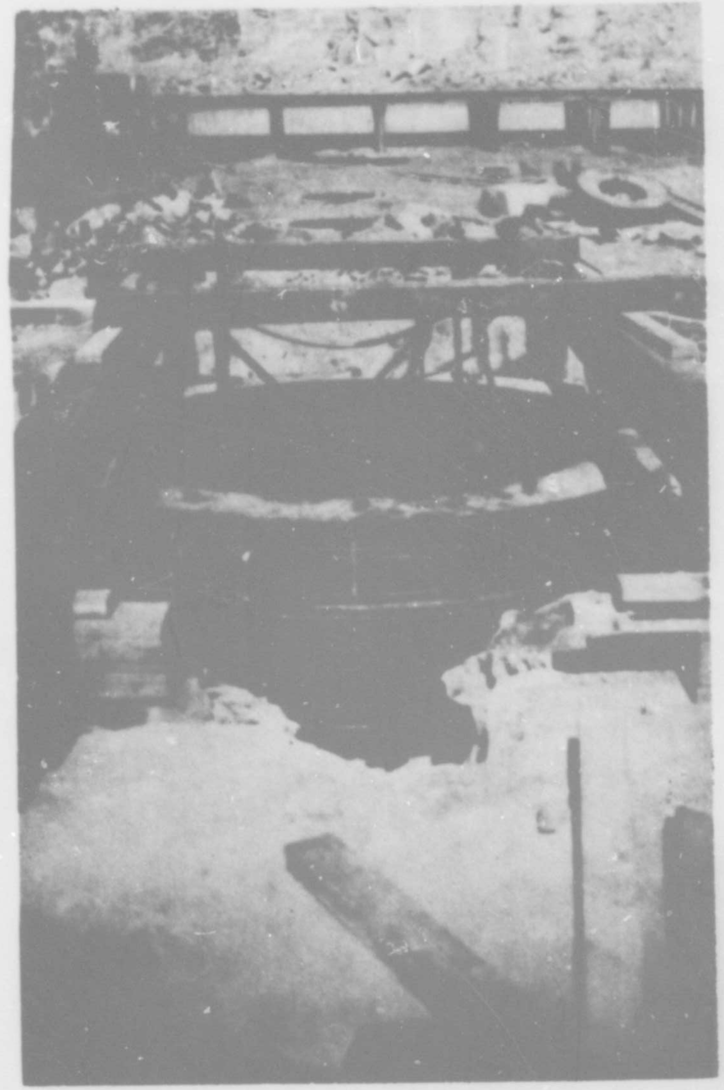

Figure II-74. Unlined Silo Model (Number 03). Cribbed In Place Prior to Concrete Pour.

Figure II-75. Turning Structural Models Upside Down for Instrumentation Placement.

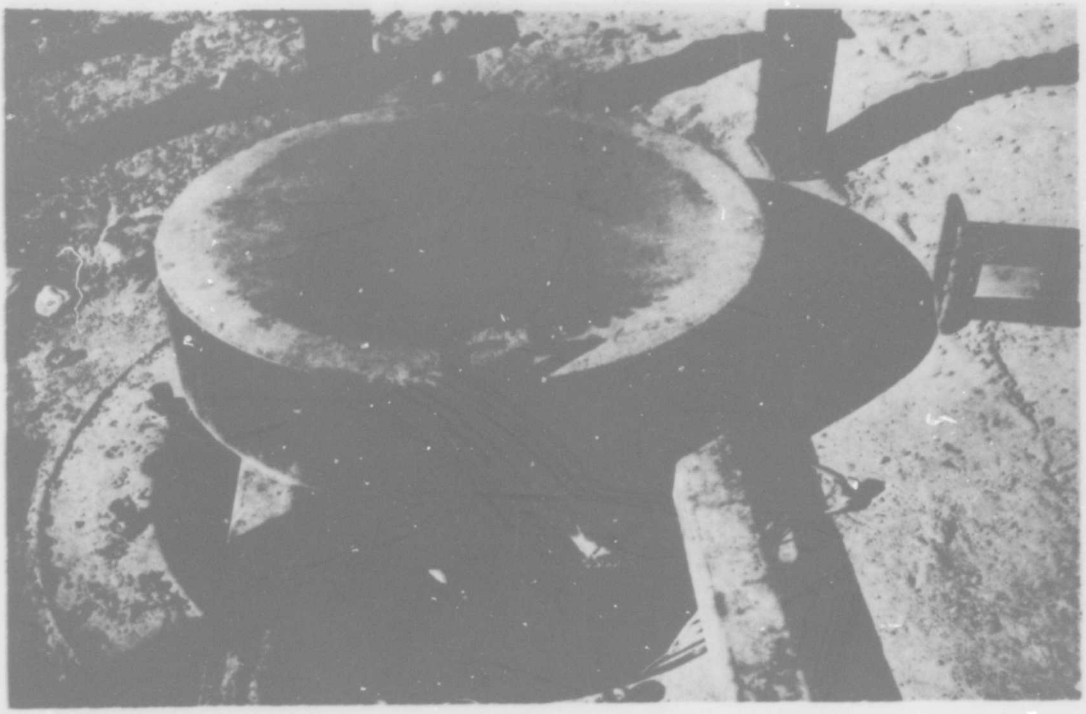

Figure II-76. Once Tested Closure and Support Showing Instrumentation Leads.

Figure II-77. Research Closure (Number 04) and Support.

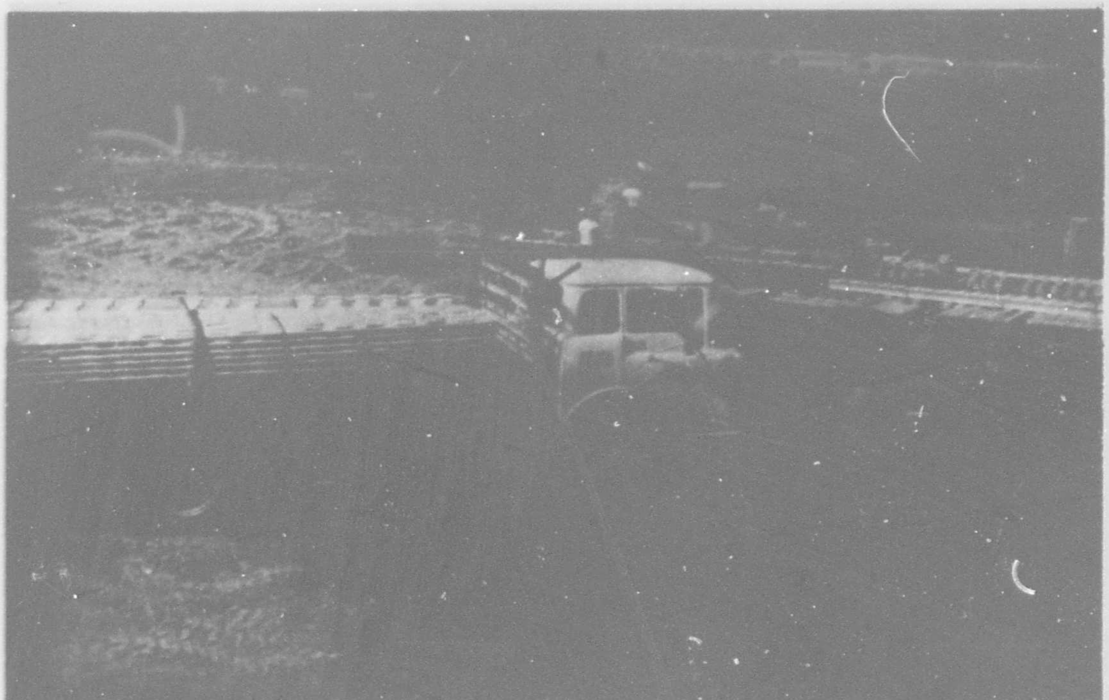

Figure II-78. Detonating Cord Rack Storage at Site.

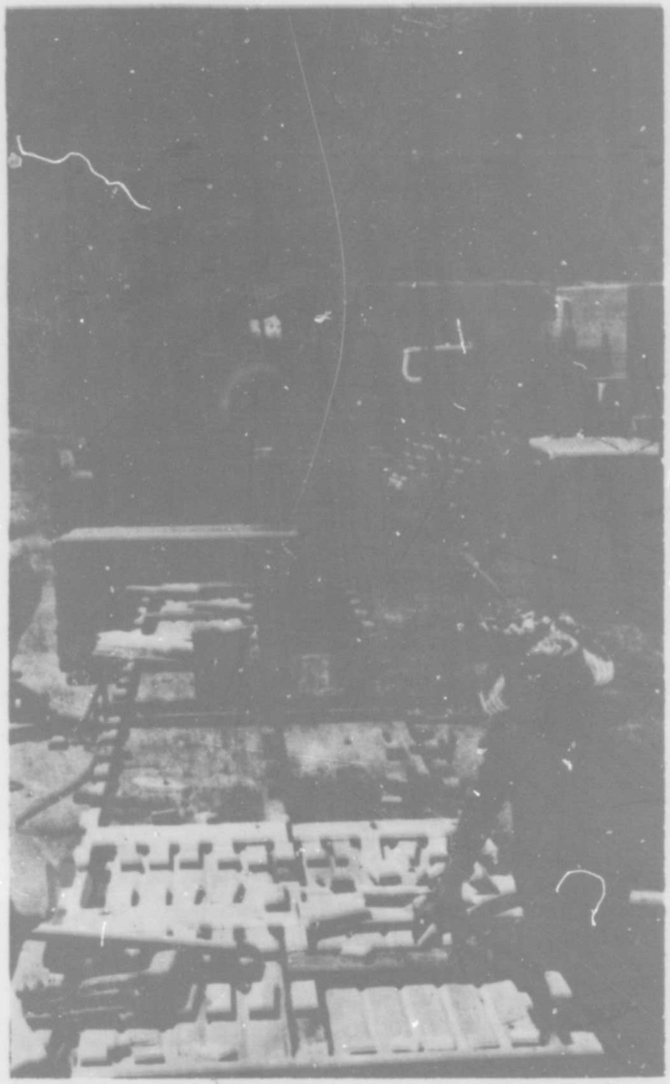

Figure II-79. Jigs for Detonating Cord Racks in Contractors Yard.

Figure II-80. Ends of Detonating Cord Racks and AFWL Designed Plane Wave Generator Bridle.

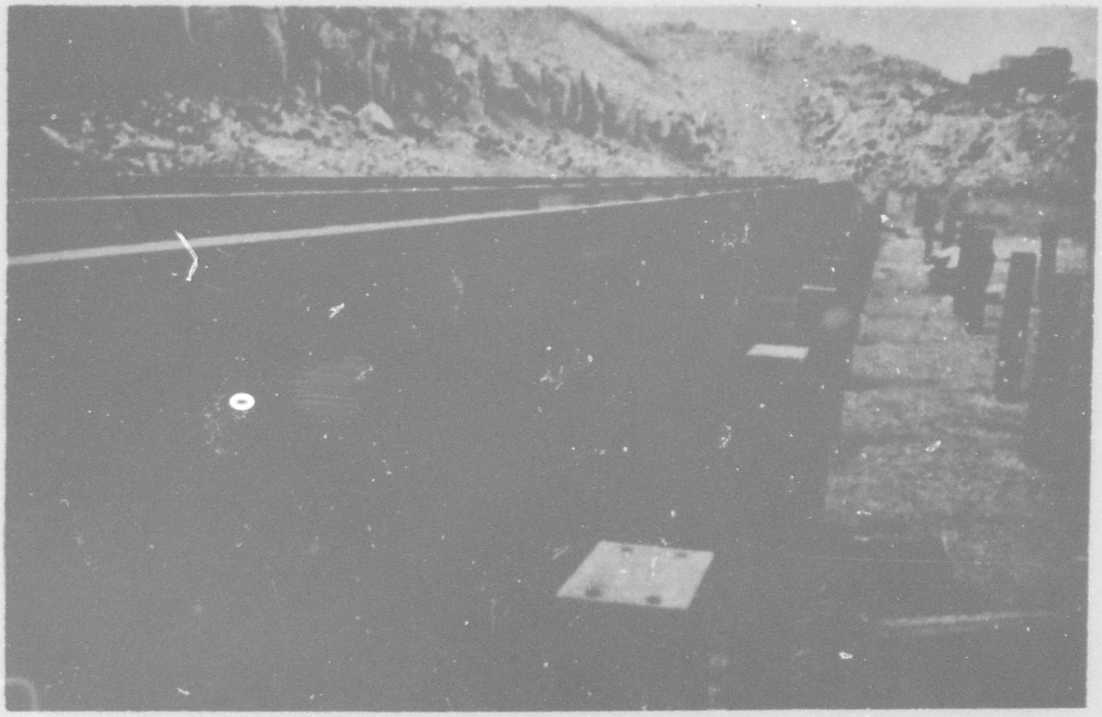

Figure II-81. Steel Beams Showing Stiffeners and Web Doublers.

Figure II-82. Beam Spanning Erectable Antenna (GFP).

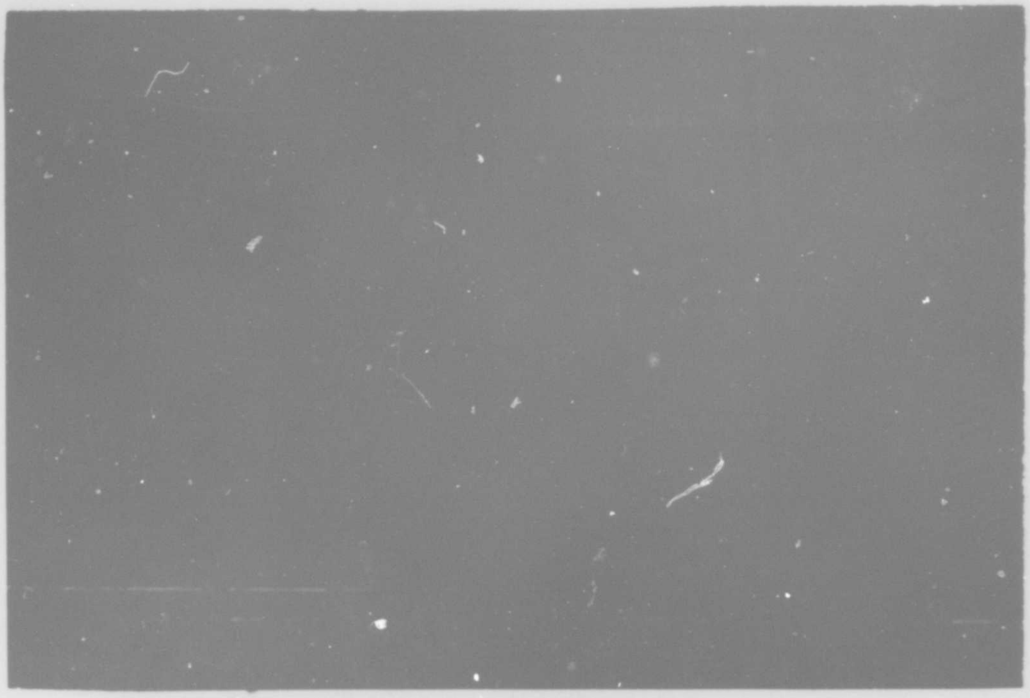

Figure II-83. Overpressure Structural Steel Framing Detonating Cord Racks In Place.

Figure II-84. Erection of Structural Steel for Overpressure Structure Showing Installation of Double Angle Struts.

Figure II-85. Overpressure Structure Beams and Subdeck Showing Grouting Along Sides of Beams.

Figure II-86. Overpressure Structure Showing Subdeck and Subdeck Earth Fill Prior to Placing Roofdeck on Top of Wide Flange Beams.

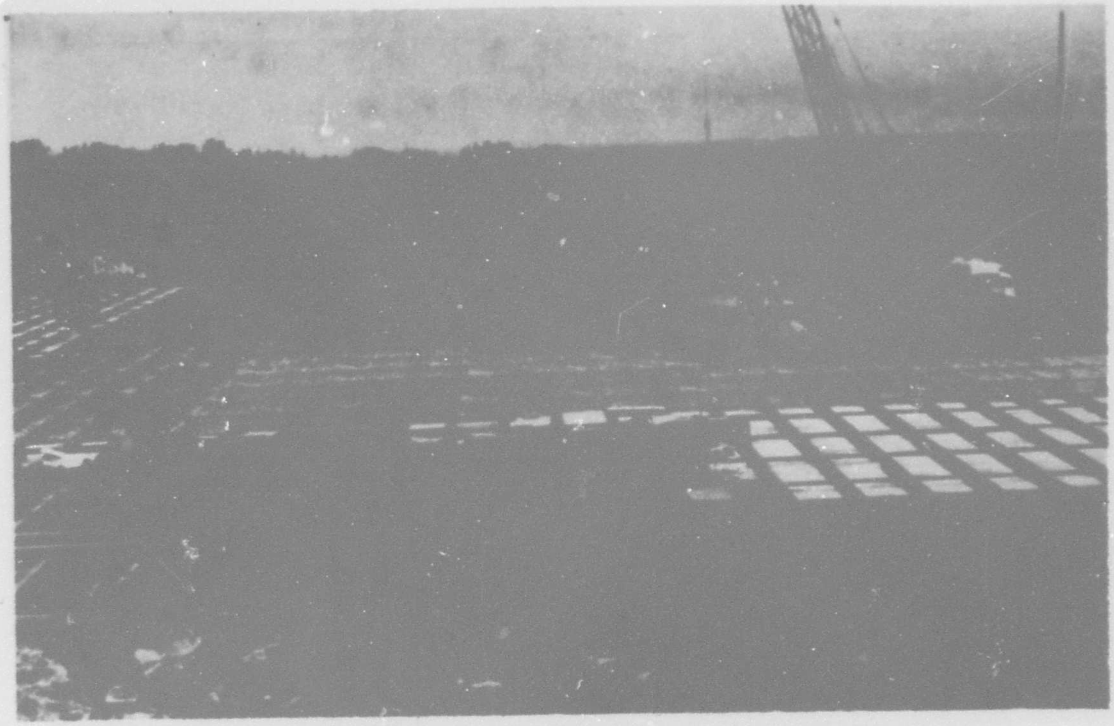

Figure II-87. Test Pit View Showing Detonating Cord Racks In Place, Columns, Beams, Subdeck, Earth Fill and Roofdeck.

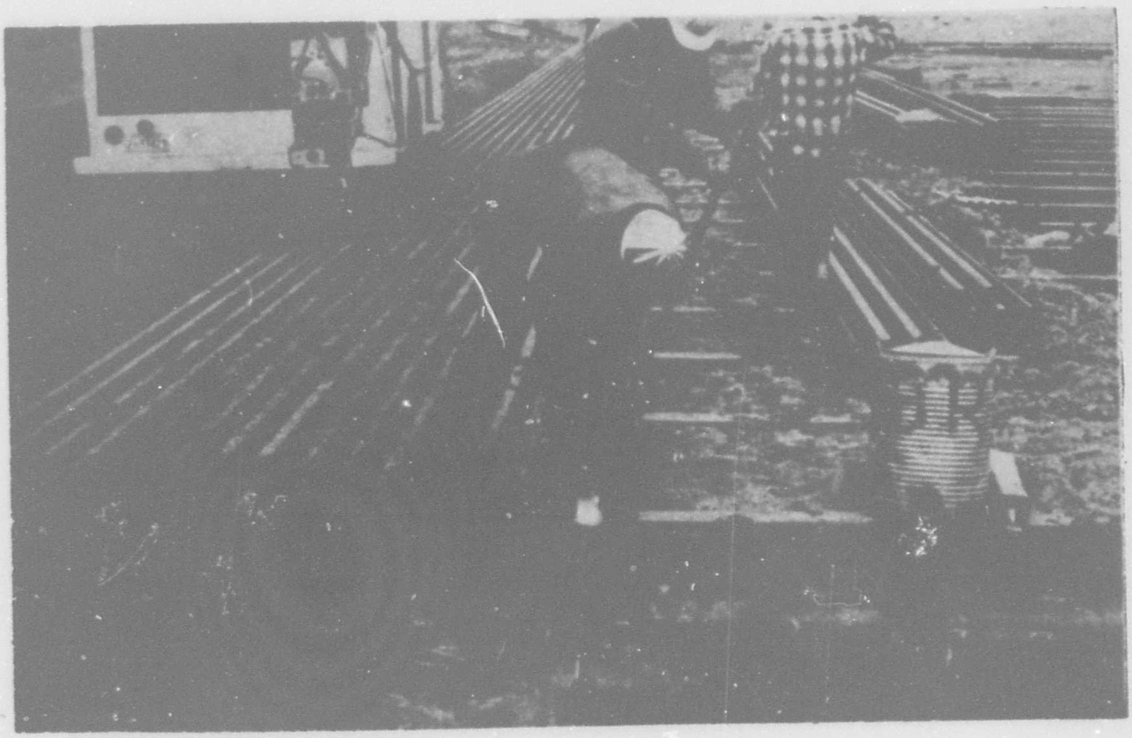

Figure II-88. "Mig Inert Gas Welding" Process for Spot Welding Roofdeck to Wide Flange Beams.

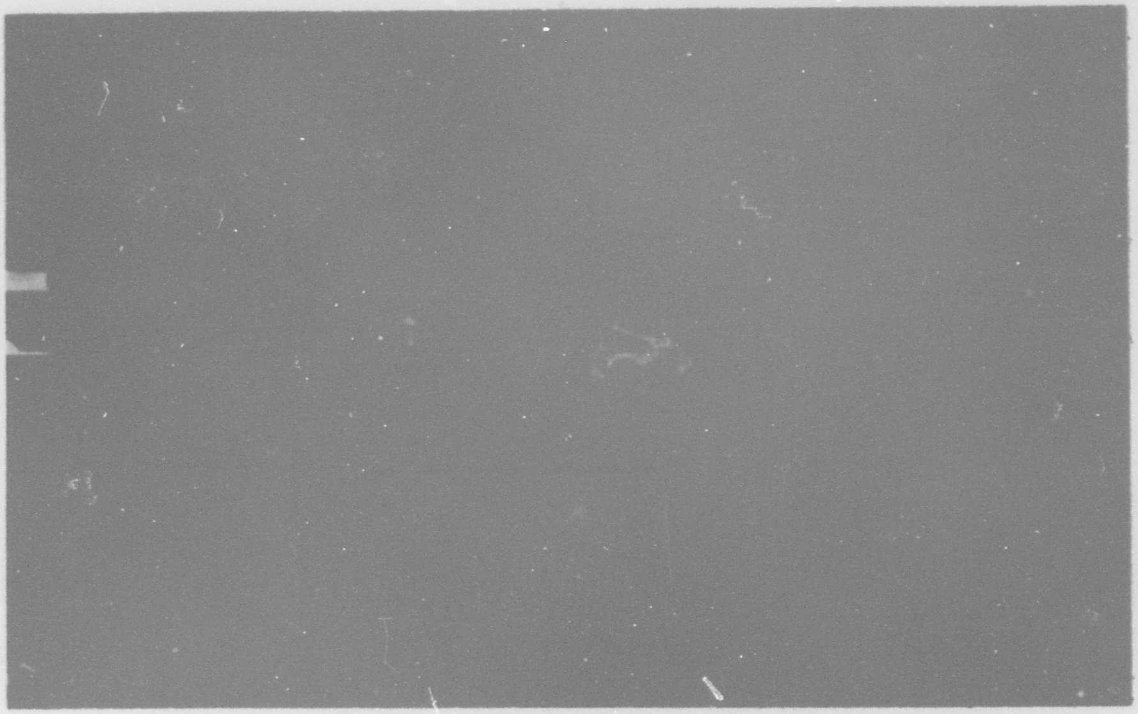

Figure II-89. Bobcat Riding Wide Flange Beams to Place Earth Fill on Subdeck Before Roofdeck Placement and Welding.

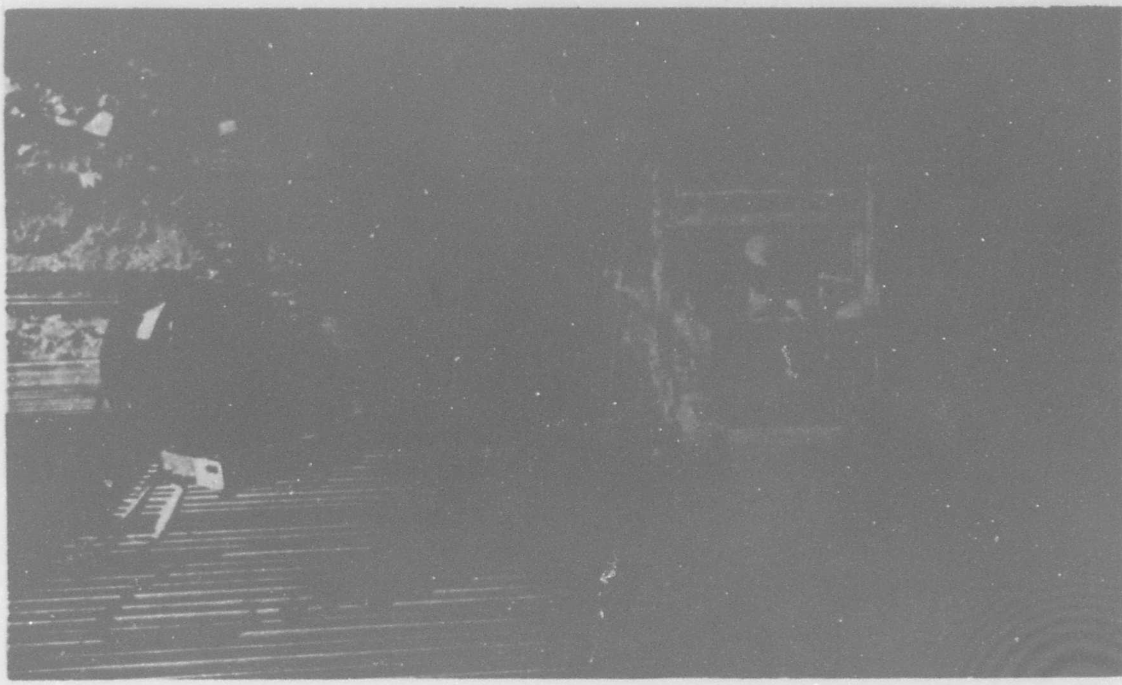

Figure II-90. Deck Welding Using Bobcat to Provide Bearing.

Figure II-91. Deck Welding Using Farm Tractor to Provide Bearing.

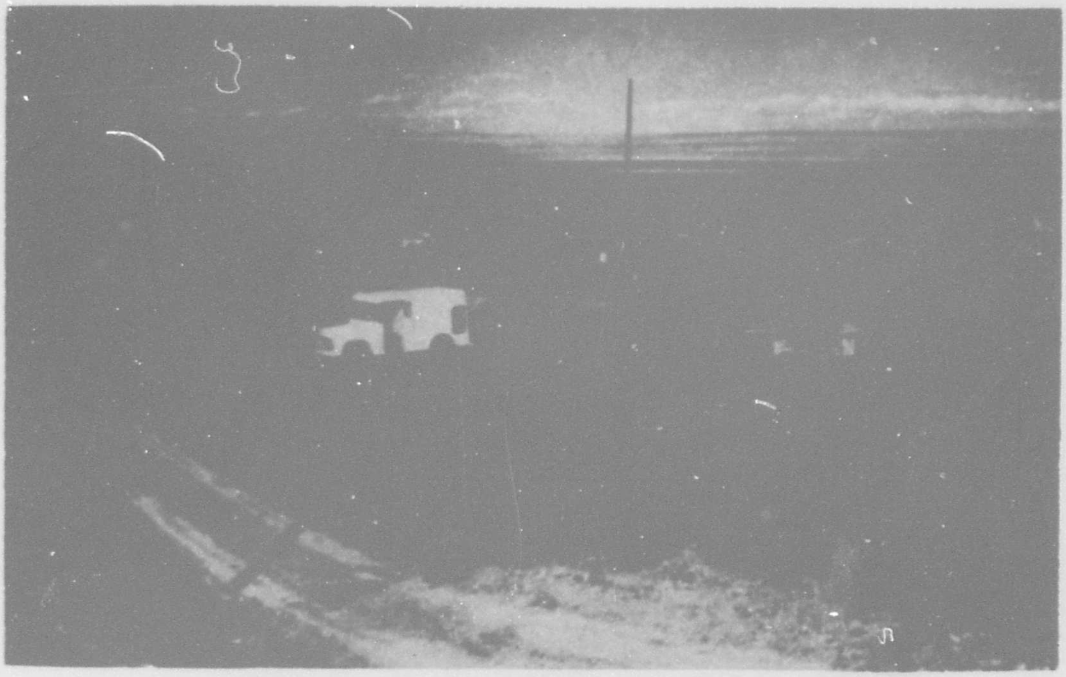

Figure II-92. Covering Roofdeck with Earth Fill.

Figure II-93. Start of Surcharge Placement. Plastic Conduits for Plane Wave Generator in Foreground.

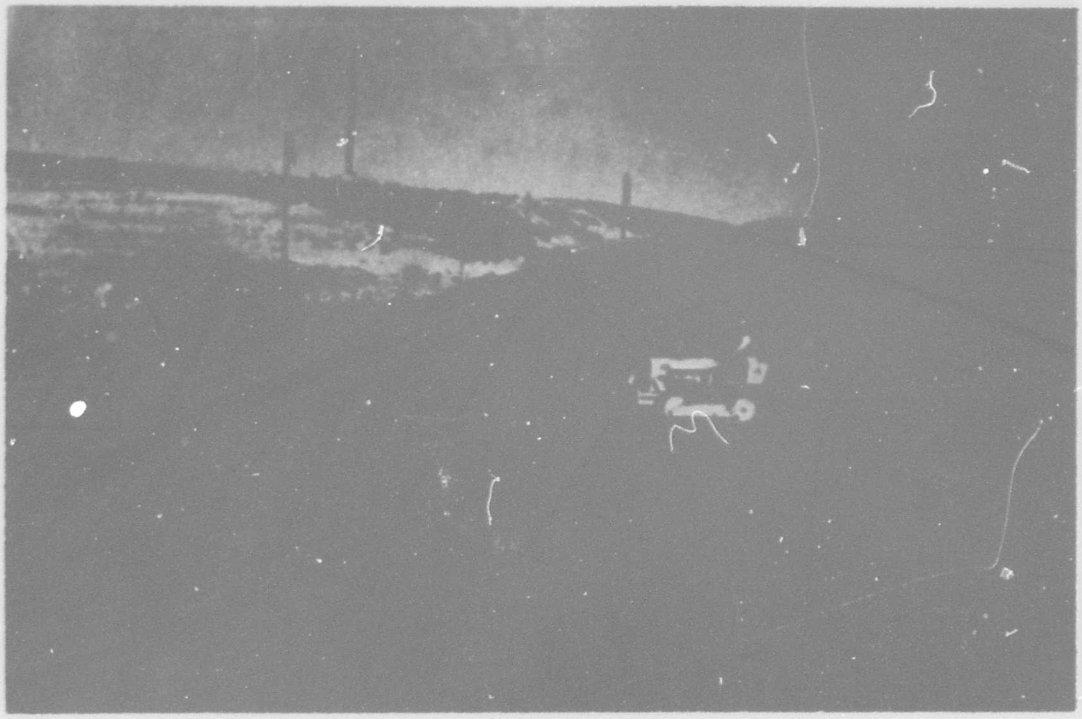

Figure II-94. Surcharge (Earth Fill) Being Placed on Structure.

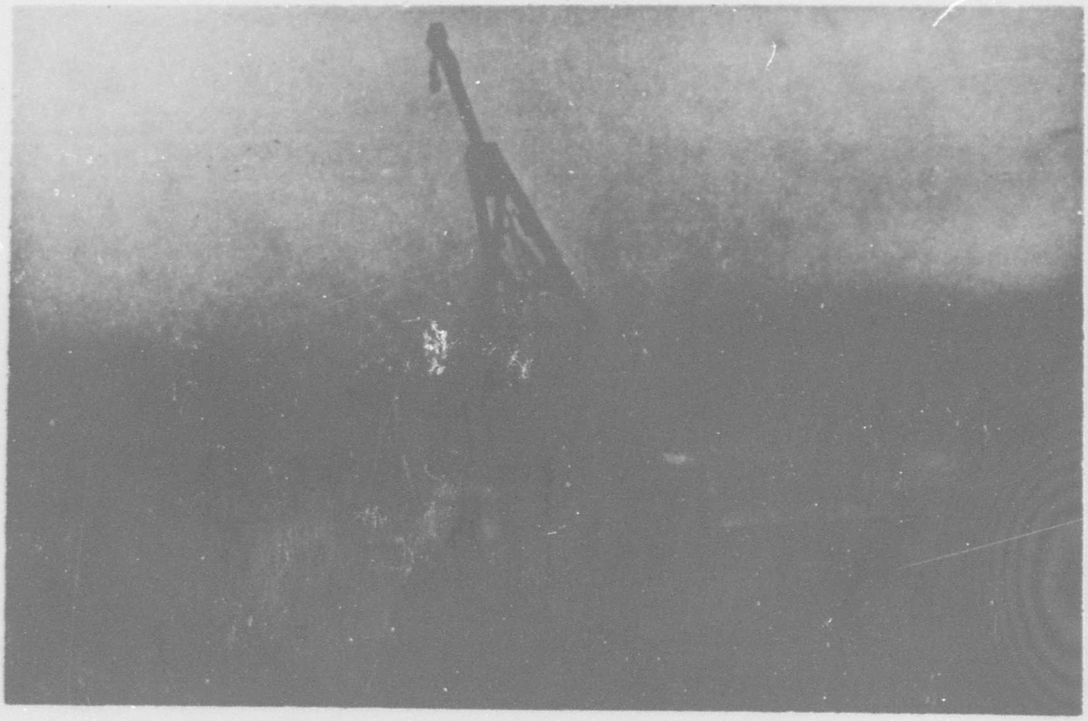

Figure II-95. Contractor Drilling Holes for Surcharge Dispersal System. Holes are 9-inch Diameter 9-feet deep.

Figure II-96. Instrumentation Trailer Shelter (3-Bay Extension on Left).

Figure II-97. Instrumentation Trailer Shelter Showing 3-Bay Extension.

APPENDIX III

CONSTRUCTION DRAWINGS

This appendix contains the following drawings:

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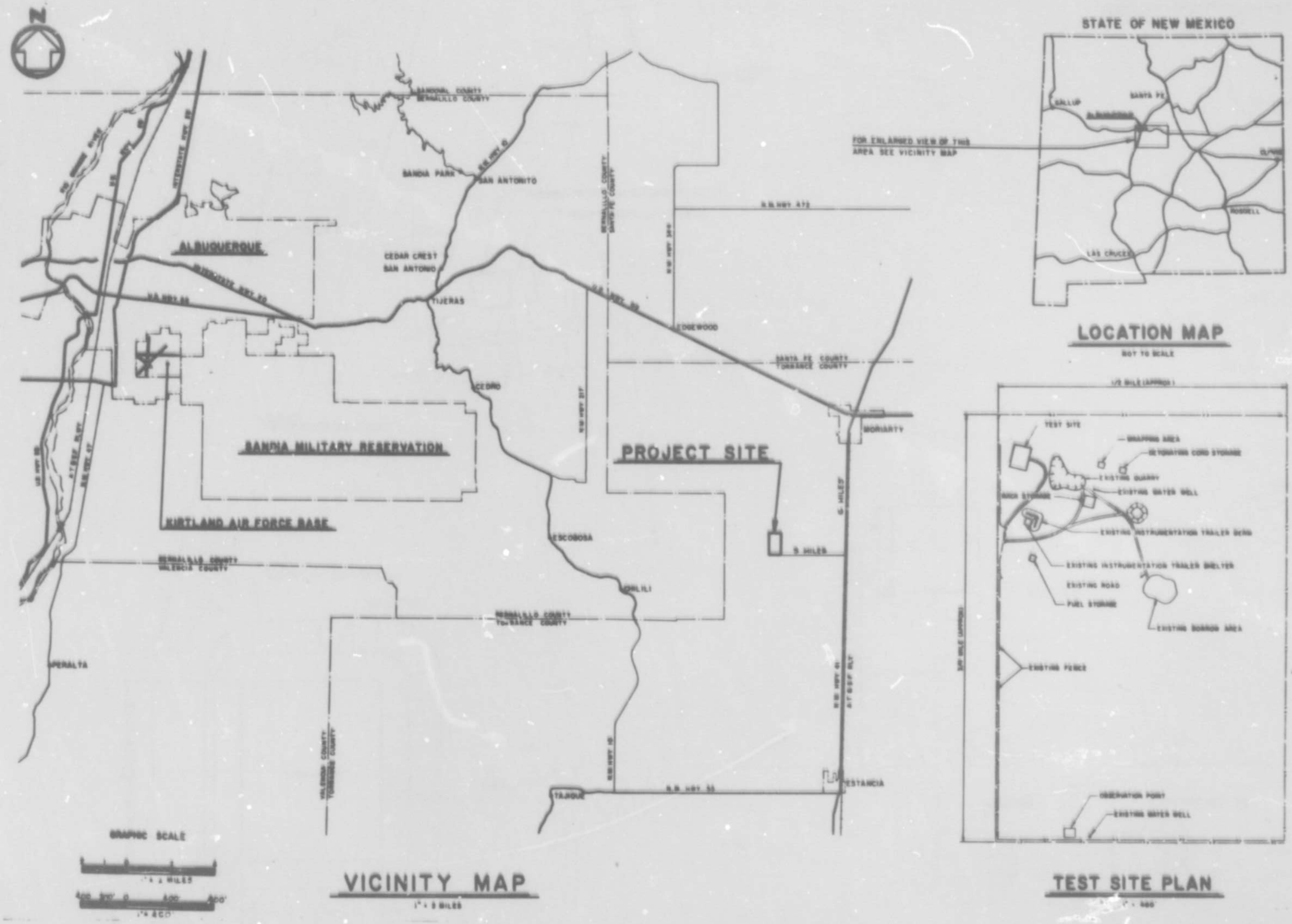
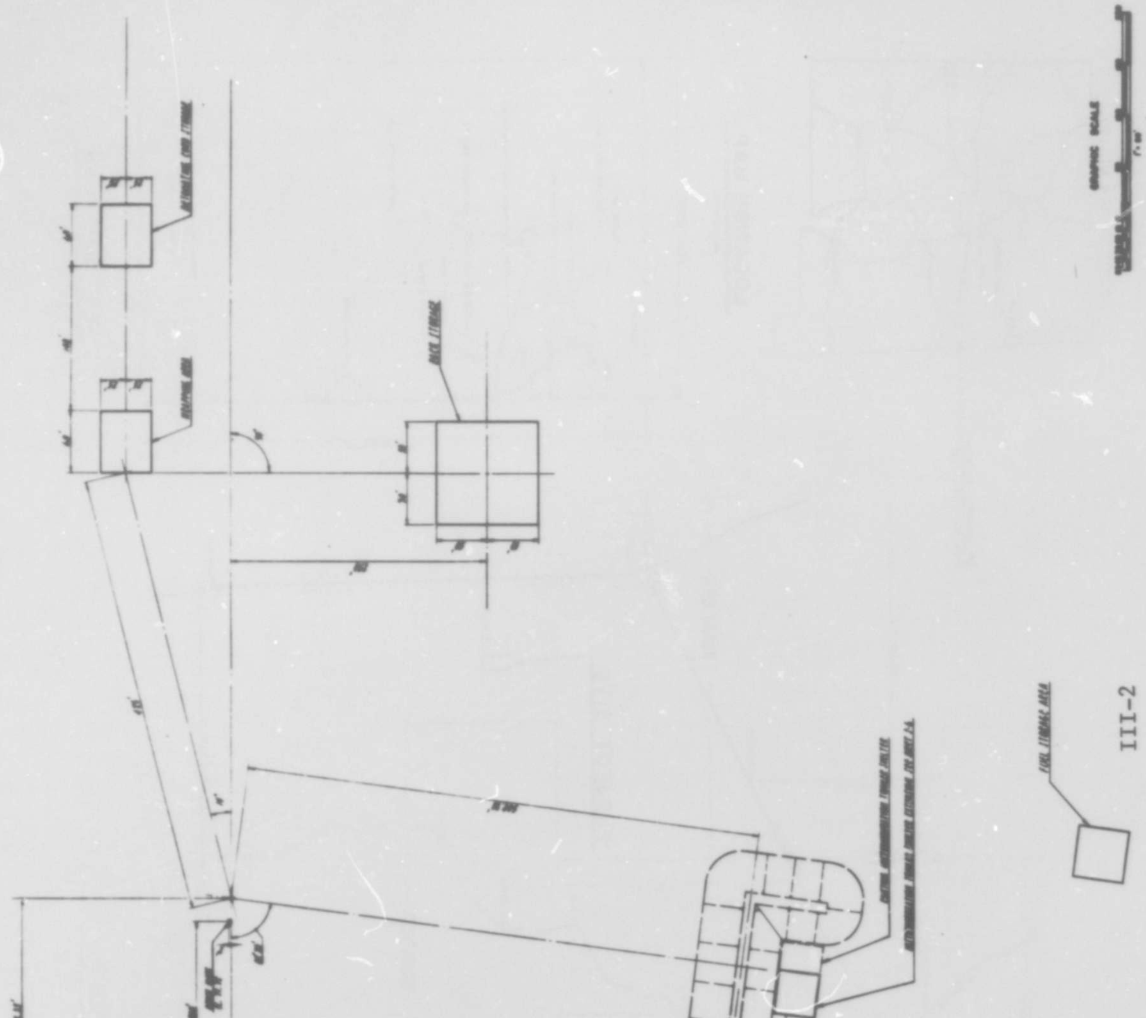
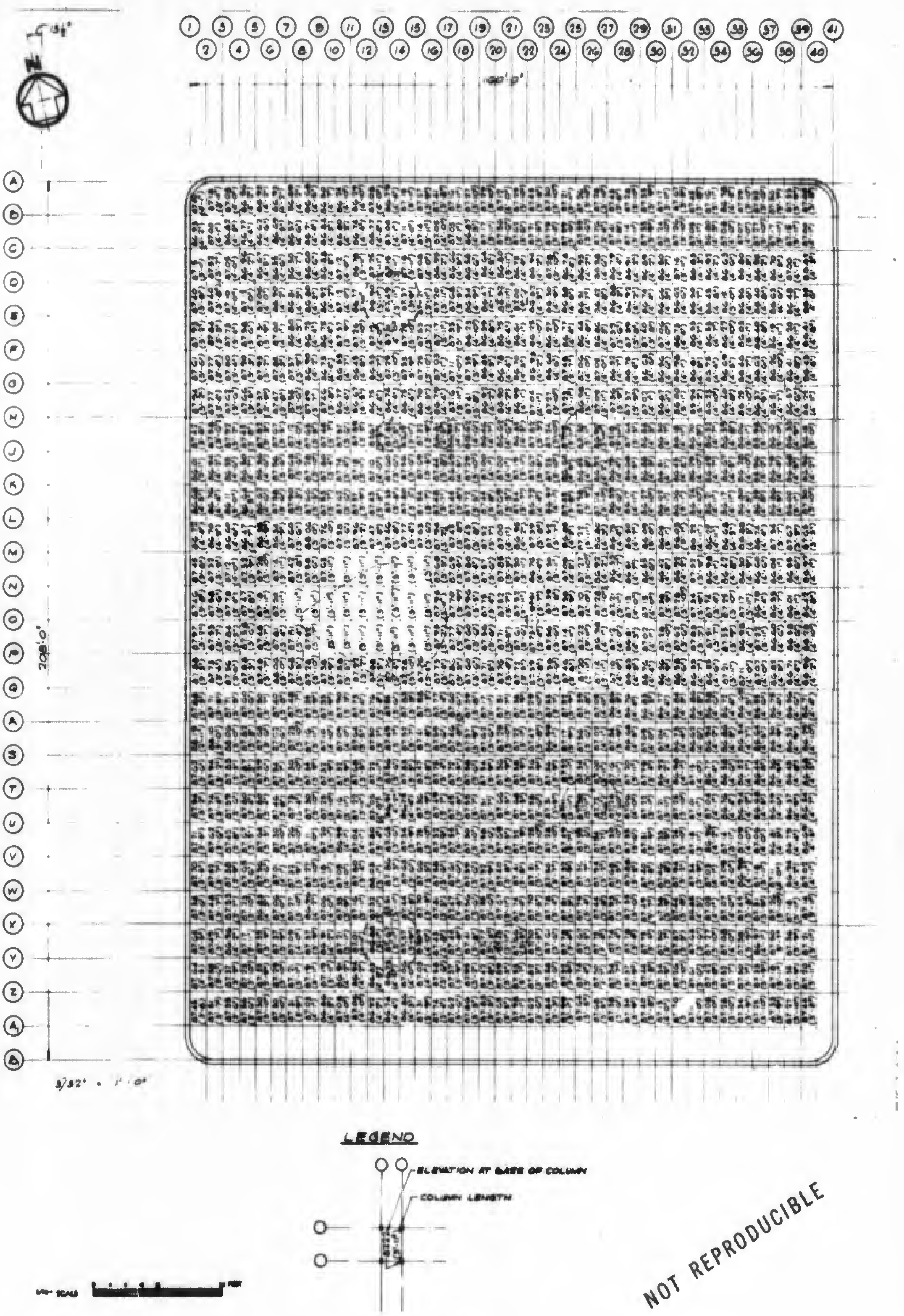

N
ALBUQUERQUE
SANDIA MILITARY RESERVATION
KIRTLAND AIR FORCE BASE
PROJECT SITE
SANDIA PARK
SAN ANTONITO
CEDAR CREST
SAN ANTONIO
TIJERAS
CEDRO
ESCOBOSA
CHILILI
EDGEWOOD
MORIARTY
ESTANCIA
TAJIQUE
PERALTA
SANDOVAL COUNTY
BERNALILLO COUNTY
SANTA FE COUNTY
TORRANCE COUNTY
VALENCIA COUNTY
9 MILES
6 MILES
GRAPHIC SCALE
VICINITY MAP
STATE OF NEW MEXICO
GALLUP
SANTA FE
ALBUQUERQUE
ROSWELL
LAS CRUCES
FOR ENLARGED VIEW OF THIS AREA SEE VICINITY MAP
LOCATION MAP
NOT TO SCALE
TEST SITE
EXISTING QUARRY
EXISTING WATER WELL
EXISTING INSTRUMENTATION TRAILER BERM
EXISTING INSTRUMENTATION TRAILER SHELTER
EXISTING ROAD
FUEL STORAGE
EXISTING BORROW AREA
EXISTING FENCE
OBSERVATION POINT
EXISTING WATER WELL
TEST SITE PLAN

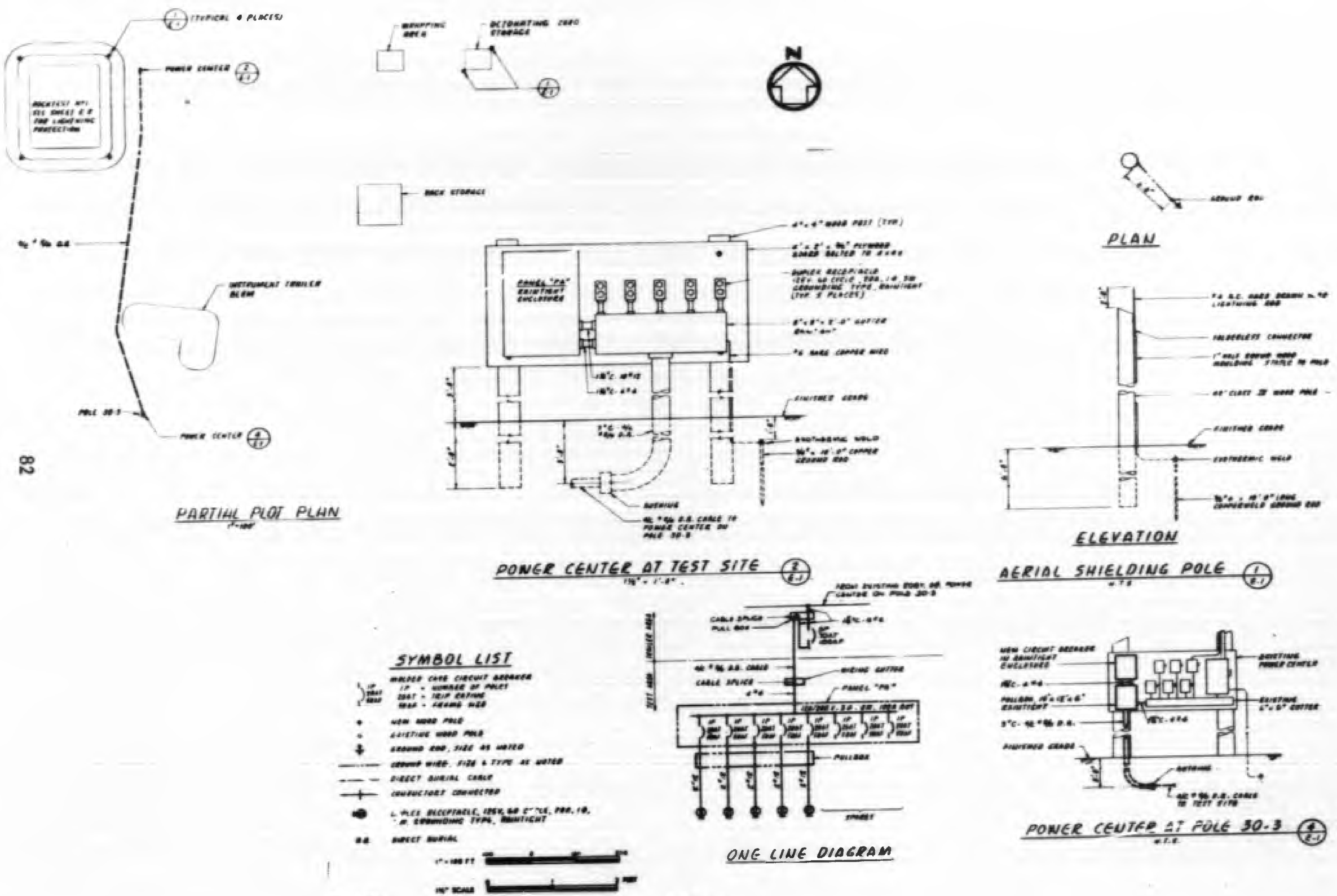
III-1



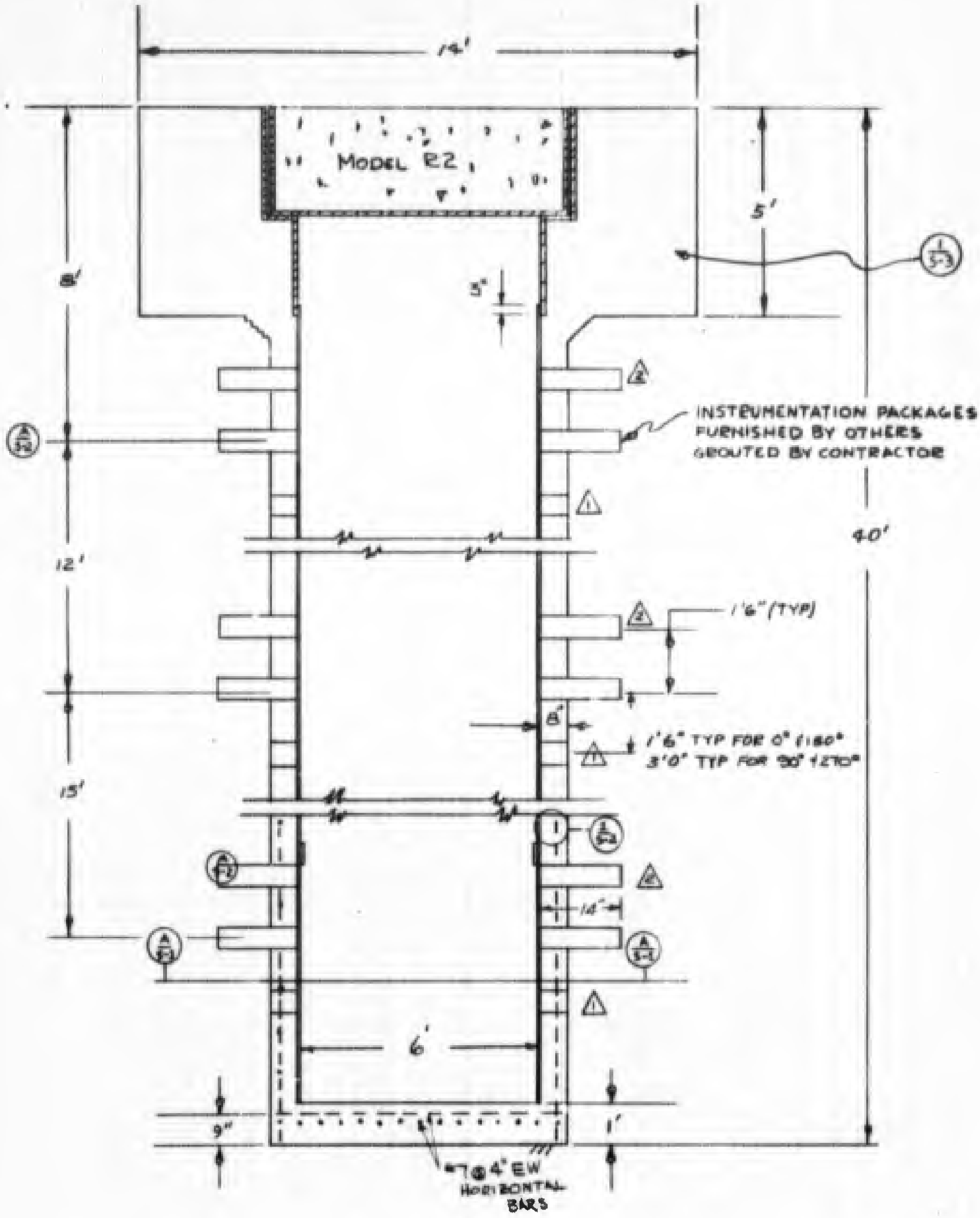
III-2

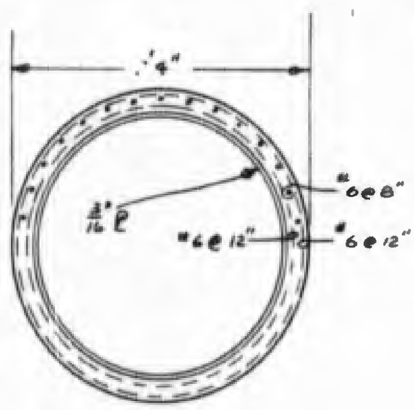


208'0"
3/32" = 1'-0"
LEGEND
ELEVATION AT BASE OF COLUMN
COLUMN LENGTH

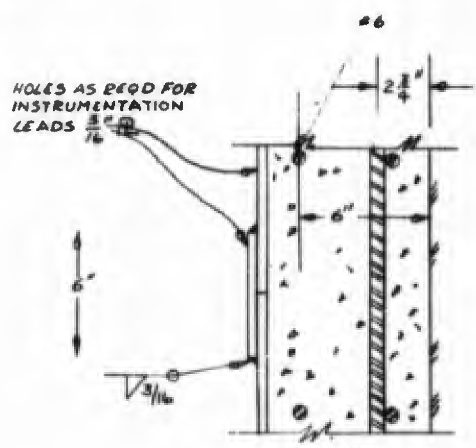


PARTIAL PLOT PLAN
POWER CENTER AT TEST SITE
PLAN
ELEVATION
AERIAL SHIELDING POLE
SYMBOL LIST
ONE LINE DIAGRAM
POWER CENTER AT POLE 30-3
N



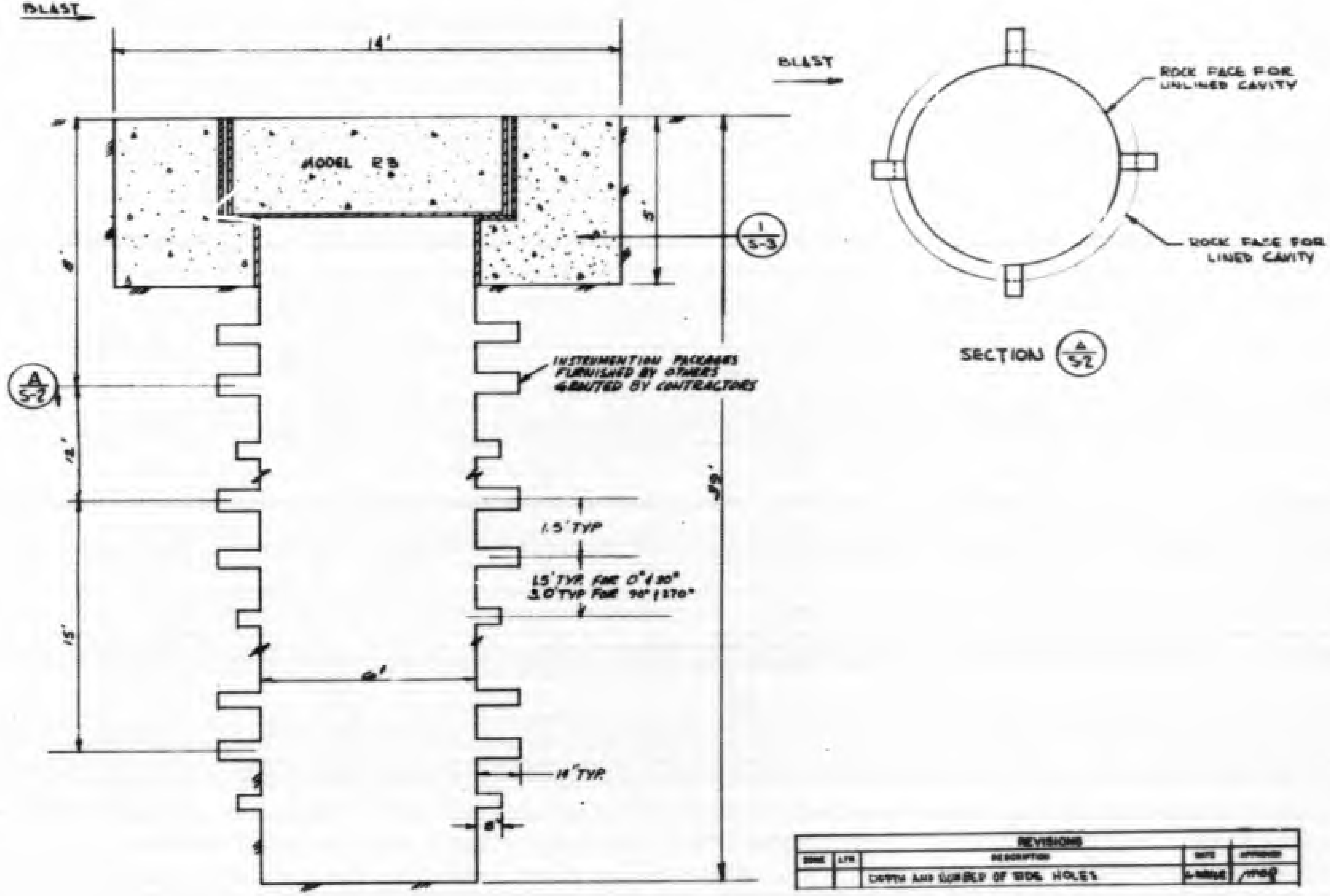


SECTION (A/5-1)

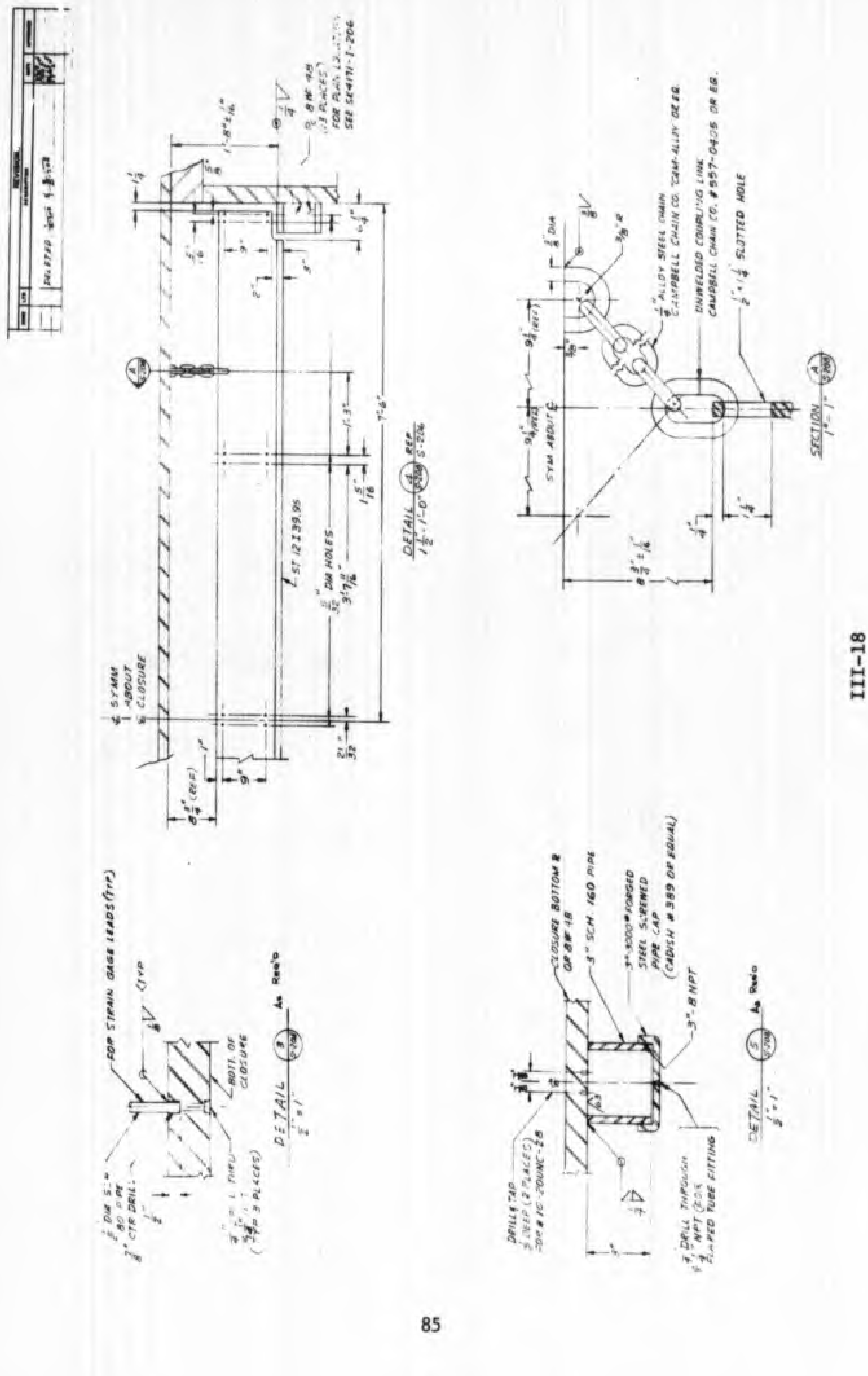


DETAIL (A/5-1)
FIELD SPLICE FOR LINER-USE AFTER EACH CONCRETE POUR

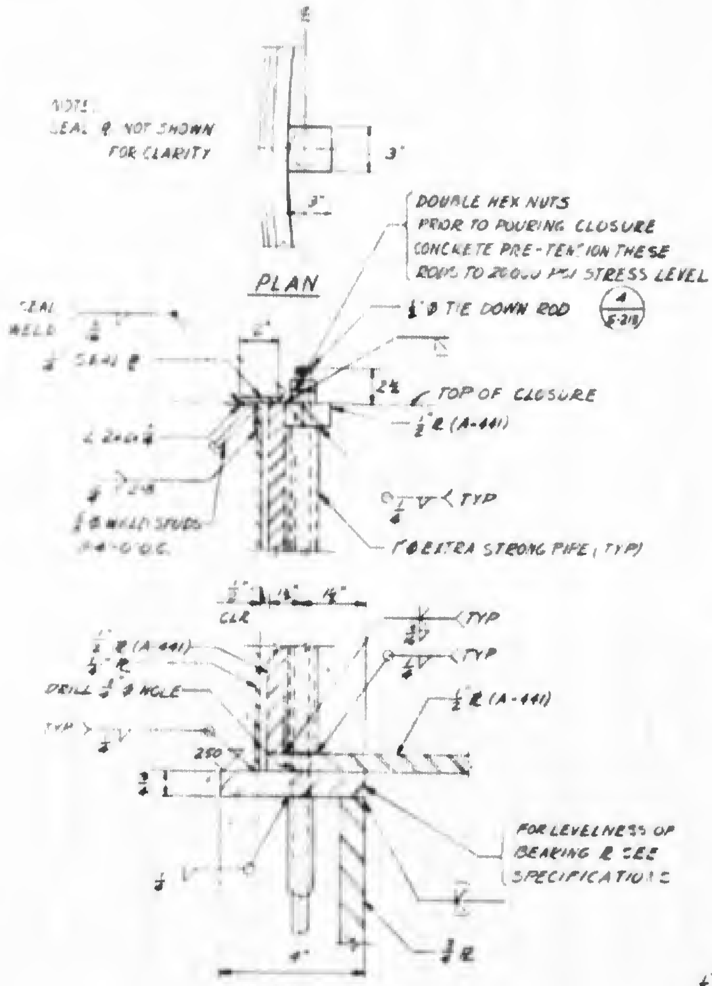
REVISIONS			
SYM	DESCRIPTION	DATE	APPROVED
1	ADDITIONAL MEASUREMENT PACKAGE LOCATION	6 MAY 68	map
2	CHANGE DEPTH OF SIDE HOLES	6 MAY	map


BLAST
14'
MODEL 23
5'
1/S-3
A/S-2
12'
15'
39'
6'
INSTRUMENTION PACKAGES FURNISHED BY OTHERS GROUTED BY CONTRACTORS
1.5' TYP
1.5' TYP FOR 0° & 180°
3.0' TYP FOR 90° & 270°
14" TYP
8"
ROCK FACE FOR UNLINED CAVITY
ROCK FACE FOR LINED CAVITY
SECTION A/S-2
REVISIONS
DESCRIPTION
DEPTH AND NUMBER OF SIDE HOLES

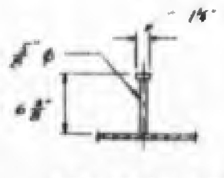
III-13



FOR STRAIN GAGE LEADS (TYP)
DETAIL
CLOSURE BOTTOM
3" SCH. 160 PIPE
3"-8 NPT
DETAIL
SYM ABOUT CLOSURE
DETAIL
UNWELDED COUPLING LINK
SLOTTED HOLE
SECTION
III-18

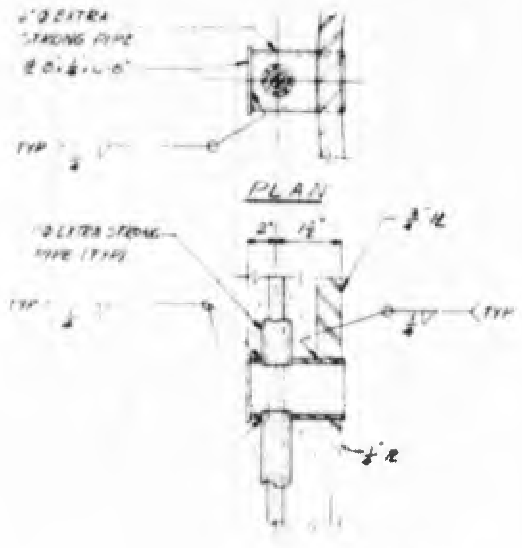


DETAIL (1/S-213) REF S-212
N.T.S.

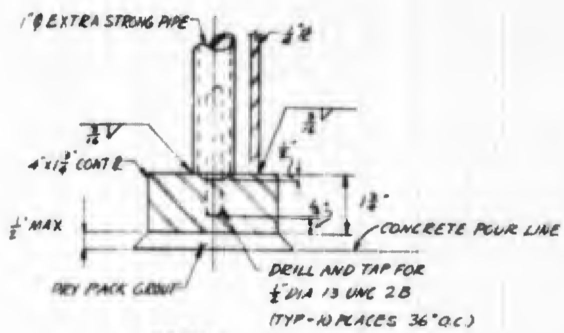


TYP WELD STUDS (3/S-213) REF S-212
N.T.S.

TIE DOWN ROD DETAIL (4/S-213)
N.T.S.



DETAIL (2/S-213) REF S-212
N.T.S.



DETAIL (5/S-213) REF S-212
N.T.S.

APPENDIX IV

SURVEYS

Two surveys were performed by the contractor using a fixed point inside the test cavity (see Figure IV-1). The first survey (Tables I and II) was performed and recorded after completion of the test structures and instrumentation holes. The second survey (Tables III and IV) was performed and recorded after the test bed had been cleared for inspection.

TABLE I

SURVEY DATA
STRUCTURE BEFORE BLAST

POINT	ANGLE	DIST.	ELEV.	Y COORD.	X COORD.
POINT B				200.00	200.00
A-B	0°00'	5.0'			
B-1A	0°00'30"R	125.25'	87.21	324.250	200.018
B-1B	1°47'18"R	120.36'	87.21	320.301	203.756
B-1C	1°48'00"L	120.49'	87.22	320.431	196.215
B-2A	0°00'	113.71'	87.23	313.710	200.00
B-2B	4°20'41"R	100.65'	87.21	300.361	207.625
B-2C	4°26'47"L	100.95'	87.24	300.646	192.174
B-3A	22°24'11"R	115.84'	87.09	307.097	244.149
B-3B	23°21'15"R	112.15'	87.08	302.962	244.458
B-3C	22°02'50"R	112.57'	87.07	304.338	242.256
B-4A	35°41'00"R	133.32'	87.16	308.289	277.766
B-4B	36°55'02"R	126.17'	87.16	300.873	275.785
B-4C	34°42'50"R	126.75'	87.19	304.189	272.181
B-5A	25°37'00"R	102.07'	87.09	292.037	244.129
B-5B	26°59'00"R	98.54'	87.09	287.813	244.711
B-5C	25°02'24"R	99.10'	87.08	289.786	241.944
B-6A	38°39'00"R	74.38'	87.13	258.089	246.455
B-6B	41°45'00"R	69.59'	87.14	251.918	246.339
B-6C	35°32'37"R	69.76'	87.13	256.762	240.553
B-7A	21°42'33"L	115.15'	87.17	306.983	157.407
B-7B	21°43'06"L	112.23'	87.17	304.263	158.470
B-7C	23°33'46"L	115.06'	87.15	305.466	154.004

TABLE I (Continued)

SURVEY DATA
STRUCTURE BEFORE BLAST

POINT	ANGLE	DIST.	ELEV.	Y COORD.	X COORD.
B-8A	35°57'10"L	133.34'	87.17	307.939	121.714
B-8B	34°14'43"L	128.46'	87.17	306.190	127.711
B-8C	37°32'39"L	128.13'	87.17	301.592	121.921
B-9A	38°40'43"L	74.10'	87.17	257.847	153.691
B-9B	35°51'14"L	68.26'	87.14	255.326	160.019
B-9C	41°44'36"L	69.40'	87.17	251.782	153.794
B-(6X)-A	45°46'07"R	108.41'	87.17	275.622	277.679
B-(6X)-B	46°27'29"R	106.06'	87.18	273.063	276.880
B-(6X)-C	44°50'53"R	105.76'	87.18	274.982	274.585
B-10A	46°04'00"L	110.71'	87.24	276.813	120.273
B-10B	43°24'07"L	108.22'	87.23	278.627	125.641
B-10C	45°57'47"L	102.96'	87.23	271.570	125.983

TABLE II

SURVEY DATA
CLOSURES BEFORE BLAST

POINT	ANGLE	DIST.	ELEV.	Y COORD.	X COORD.
POINT B				200.00	200.00
B-2A	1°01'10"R	112.50'		312.462	202.002
B-2B	3°28'33"R	100.07'	87.25	299.886	206.067
B-2C	3°26'05"L	99.92'		299.740	194.012
B-1A	0°00'	124.56'		324.560	200.000
B-1B	1°28'38"R	120.48'	87.25	320.440	203.106
B-1C	1°17'58"L	119.78'		319.749	197.284
B-3A	22°26'46"R	115.64'		306.880	244.153
B-3B	23°52'53"R	113.95'	87.09	304.194	246.132
B-3C	22°02'00"R	112.85'		304.608	242,335
B-4A	35°06'29"R	131.78'		307.805	275.789
B-4B	37°18'00"R	129.88'	87.22	303.316	278.706
B-4C	35°33'42"R	126.48'		302.890	273.558
B-5A	25°40'29"R	101.82'		291.767	244.115
B-5B	27°06'04"R	98.94'	87.09	288.077	245.073
B-5C	25°07'25"R	99.08'		289.706	242.067
B-6A	36°52'32"R	73.42'		258.732	244.058
B-6B	41°38'00"R	70.99'	87.19	253.059	247.163
B-6C	36°53'33"R	67.37'		253.880	240.443
B-7A	21°42'33"L	114.25'		306.147	157.740
B-7B	21°43'06"L	112.88'		304.867	158.230

TABLE II (Continued)

SURVEY DATA
CLOSURES BEFORE BLAST

POINT	ANGLE	DIST.	ELEV	Y COORD.	X COORD.
B-7C	23°33'46"L	113.20'		303.762	154.748
B-8A	35°22'45"L	132.38'		307.934	123.354
B-8B	37°11'20"L	127.20'	87.21	301.334	123.115
B-8C	34°53'30"L	130.98'		307.434	125.076
B-9A	38°42'10"L	73.91'		257.679	153.786
B-9B	35°59'16"L	68.31'		255.273	159.860
B-9C	41°38'10"L	69.41'		251.876	153.884

TABLE III

SURVEY DATA
STRUCTURE AFTER BLAST

POINT	ANGLE	DIST.	ELEV.	Y COORD.	X COORD.
POINT B				200.00	200.00
A-B	0°00'	5.0'			
B-1A	0°00'45"R	125.31'	87.16	325.3099	200.0273
B-1B	01°46'35"R	120.42'	87.15	320.3621	203.7328
B-1C	01°48'42"L	120.54'	87.16	320.4797	196.1893
B-2A	00°00'58"L	113.75'	87.18	313.7499	199.9681
B-2B	04°20'36"R	100.72'	87.16	300.4307	207.6278
B-2C	04°27'03"L	101.03'	87.19	300.7253	192.1598
B-3A	22°23'15"R	115.90'	87.02	307.1645	244.1426
B-3B	23°23'31"R	112.28'	87.02	303.0517	244.5772
B-3C	22°02'08"R	112.71'	87.02	304.4766	242.2867
B-4A	35°40'18"R	133.43'	87.11	308.3947	277.8083
B-4B	36°54'22"R	126.25'	87.12	300.9747	275.8005
B-4C	34°42'15"R	126.84'	87.15	304.2754	272.2149
B-5A	25°35'52"R	102.01'	87.04	291.9976	244.0734
B-5B	26°57'55"R	98.54'	87.03	287.8268	244.6830
B-5C	25°01'18"R	99.12'	87.02	289.8173	241.9238
B-6A	38°37'17"R	74.42'	87.04	258.1434	246.4508
B-6B	41°42'03"R	69.61'	87.04	251.9728	246.3074
B-6C	35°30'50"R	69.79'	87.02	256.8072	240.5410
B-6XA	45°45'29"R	108.43'	87.14	275.6504	277.6792

TABLE III (Continued)

SURVEY DATA
STRUCTURE AFTER BLAST

POINT	ANGLE	DIST.	ELEV.	Y COORD.	X COORD.
B-6XB	46°26'27"R	106.08'	87.14	273.1000	275.8722
B-6XC	44°50'25"R	105.81'	87.13	275.0272	274.6101
B-7A	21°43'45"L	115.16'	87.12	306.9772	157.3656
B-7B	21°43'45"L	112.31'	87.10	304.3297	158.4207
B-7C	23°32'26"L	115.14'	87.10	305.5577	154.0134
B-8A	35°57'05"L	133.41'	87.13	307.9974	121.6752
B-8B	34°15'30"L	128.50'	87.12	306.2062	127.6642
B-8C	37°33'25"L	128.22'	87.12	301.6461	121.8436
B-9A	38°42'23"L	74.14'	87.12	257.8559	153.6381
B-9B	35°51'37"L	68.25'	87.09	255.3130	160.0185
B-9C	41°45'00"L	69.41'	87.12	251.7838	153.7812
B-10A	46°04'34"L	110.77'	87.21	276.8413	120.2166
B-10B	43°24'40"L	108.29'	87.20	278.6663	125.5801
B-10C	45°59'12"L	103.05'	87.19	271.6017	125.8887

TABLE IV

SURVEY DATA
CLOSURES AFTER BLAST

POINT	ANGLE	DIST.	ELEV. CENTER OF LID	Y COORD.	X COORD.
POINT B				200.00	200.00
B-1A	00°00'45"L	124.67'	87.19	324.6699	199.9729
B-1B	01°27'45"R	120.54'		320.5007	203.0765
B-1C	01°18'40"L	119.84'		319.8086	197.2580
B-2A	00°59'40"R	112.55'	87.19	312.5330	201.9533
B-2B	03°27'30"R	100.12'		299.9376	206.0395
B-2C	03°27'01"L	99.94'		299.7588	193.9854
B-3A	22°25'00"R	115.95'	NO LID	307.1882	244.2162
B-3B	23°52'55"R	114.09'		304.3217	246.1897
B-3C	22°00'39"R	112.71'		304.4949	242.2416
B-4A					
B-4B	NO LID				
B-4C					
B-5A					
B-5B	NO LID				
B-5C					
B-6A	36°49'10"R	73.50'	87.08	258.8388	244.0482
B-6B	41°39'19"R	71.05'		253.0855	247.2231
B-6C	36°51'50"R	67.40'		253.9242	240.4343
B-7A	21°43'20"L	114.28'	87.10	306.1648	157.7042

TABLE IV (Continued)

SURVEY DATA
CLOSURES AFTER BLAST

POINT	ANGLE	DIST.	ELEV. CENTER OF LID	Y COORD.	X COORD.
B-7B	21°44'00"L	112.96'		304.9304	158.1724
B-7C	23°35'00"L	113.30'		303.8370	154.6707
B-8A					
B-8B	NO LID				
B-8C					
B-9A	38°42'25"L	74.00'	87.12	257.7462	153.7251
B-9B	35°59'00"L	68.35'		255.3079	159.8410
B-9C	41°35'02"L	69.49'		251.9371	153.8331

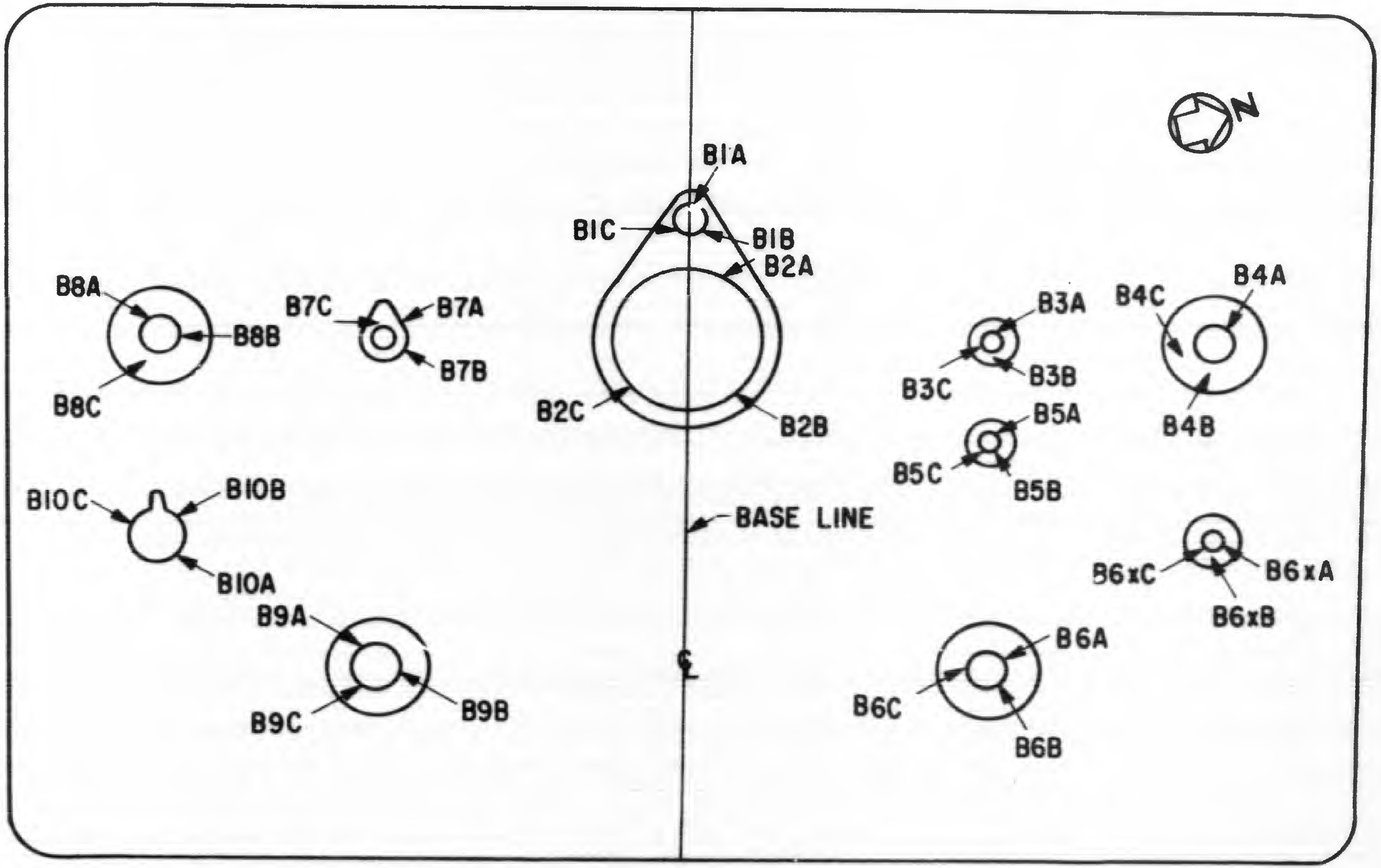


Figure IV-1. ROCKTEST I Survey Points

REFERENCES

AFWL TR 65-11 April 1965	Simulation of Airblast-Induced Ground Motion (Phase I)
AFWL TR 65-26 April 1965	Simulation of Airblast-Induced Ground Motion (Phase II)

Air Force Manuals

AFM 127-100 20 April 1964	Explosive Safety Manual
AFM 127-101 30 December 1965	Accident Prevention Handbook
AFTO 11A-1-58 15 January 1966	Demolitions

Specifications

MIL-D-1000	Drawing, Engineering, and Associated List

Corps of Engineer's Manual

EM-385-1-1 13 March 1958	General Safety Requirements

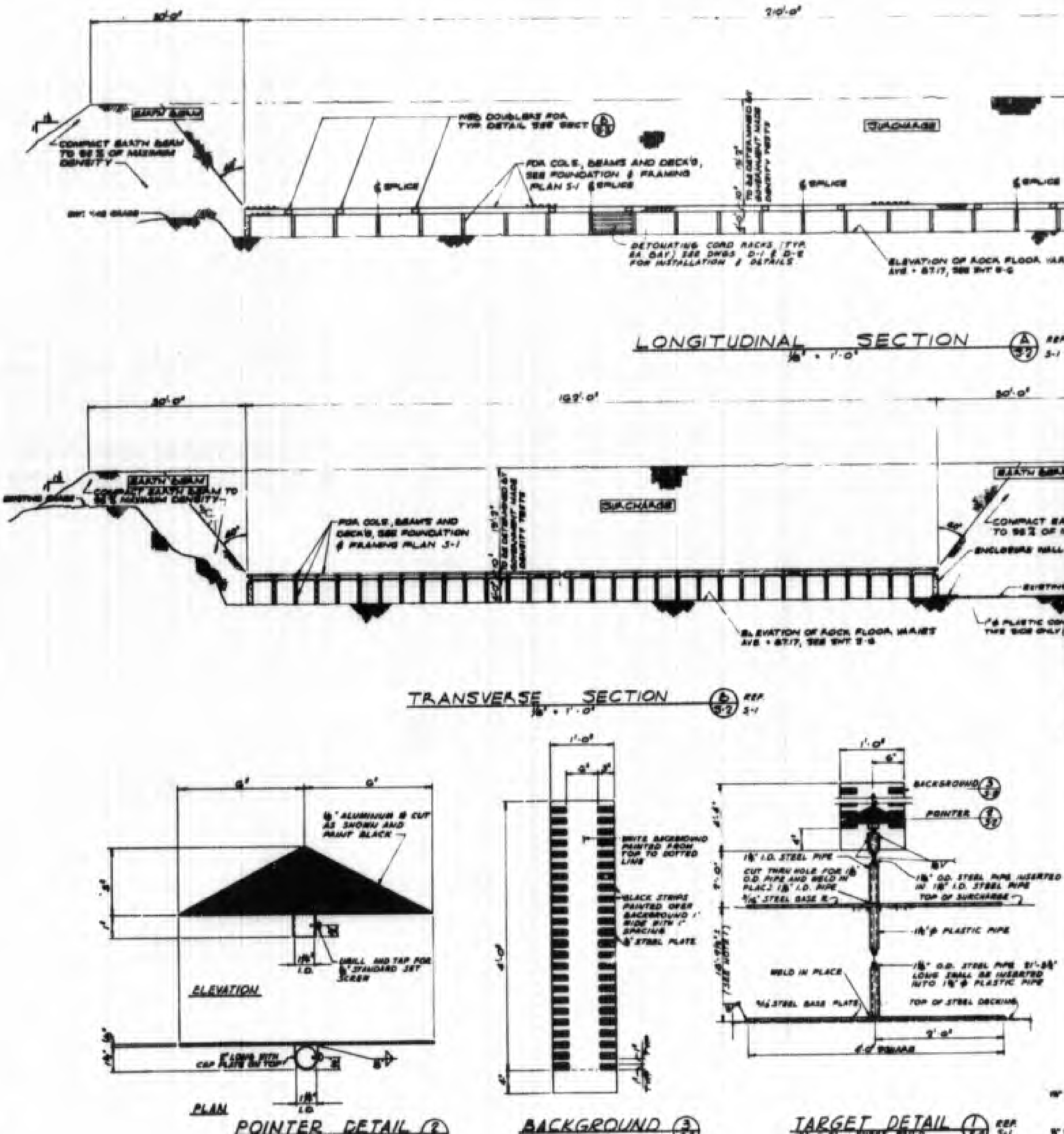
AFWL Generated Safety Documents (SOP's)

Appendix "E" to the Test Plan	Safety Plan
Appendix "D" to the Test Plan	Security Plan

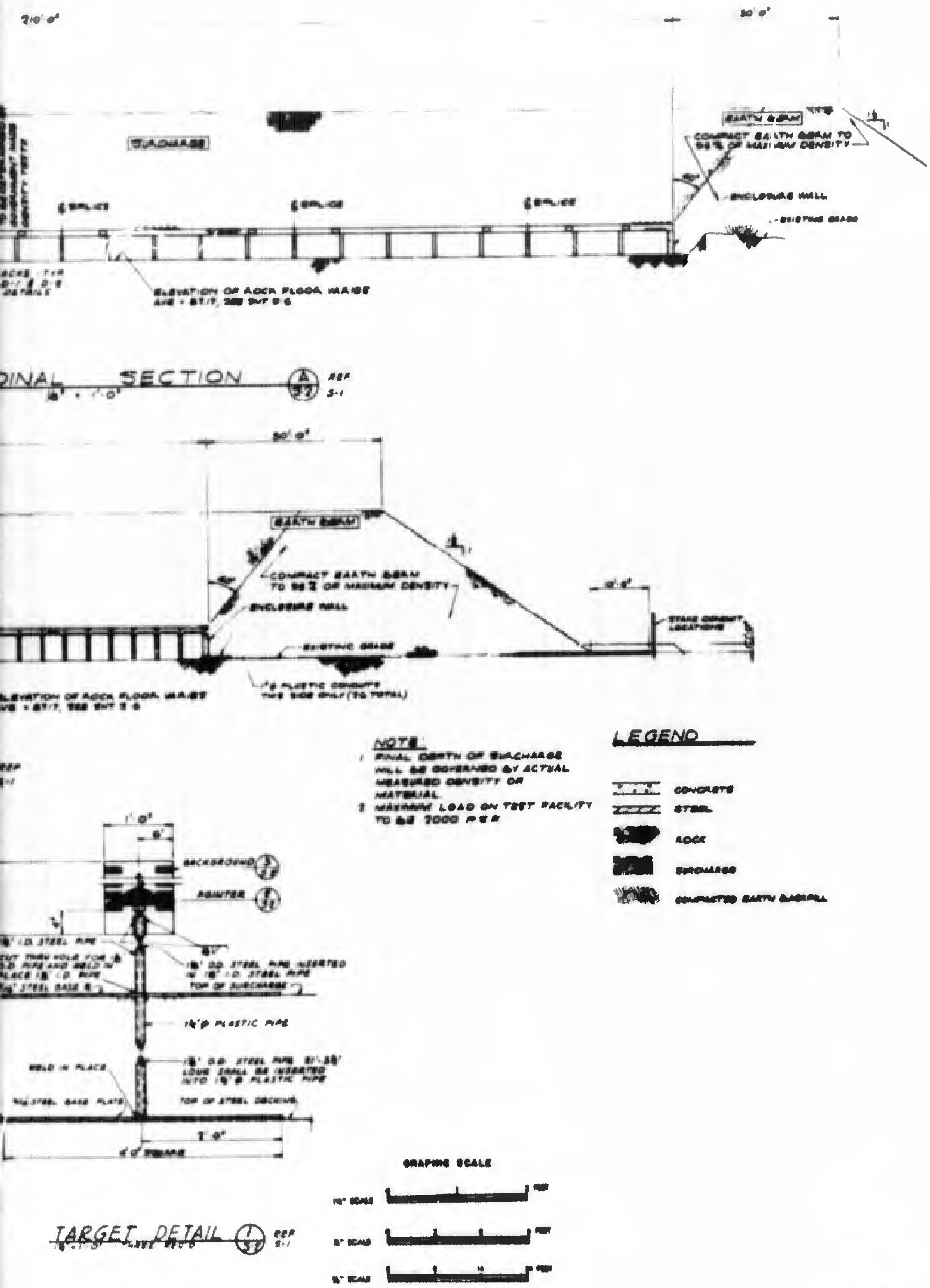
Drawings

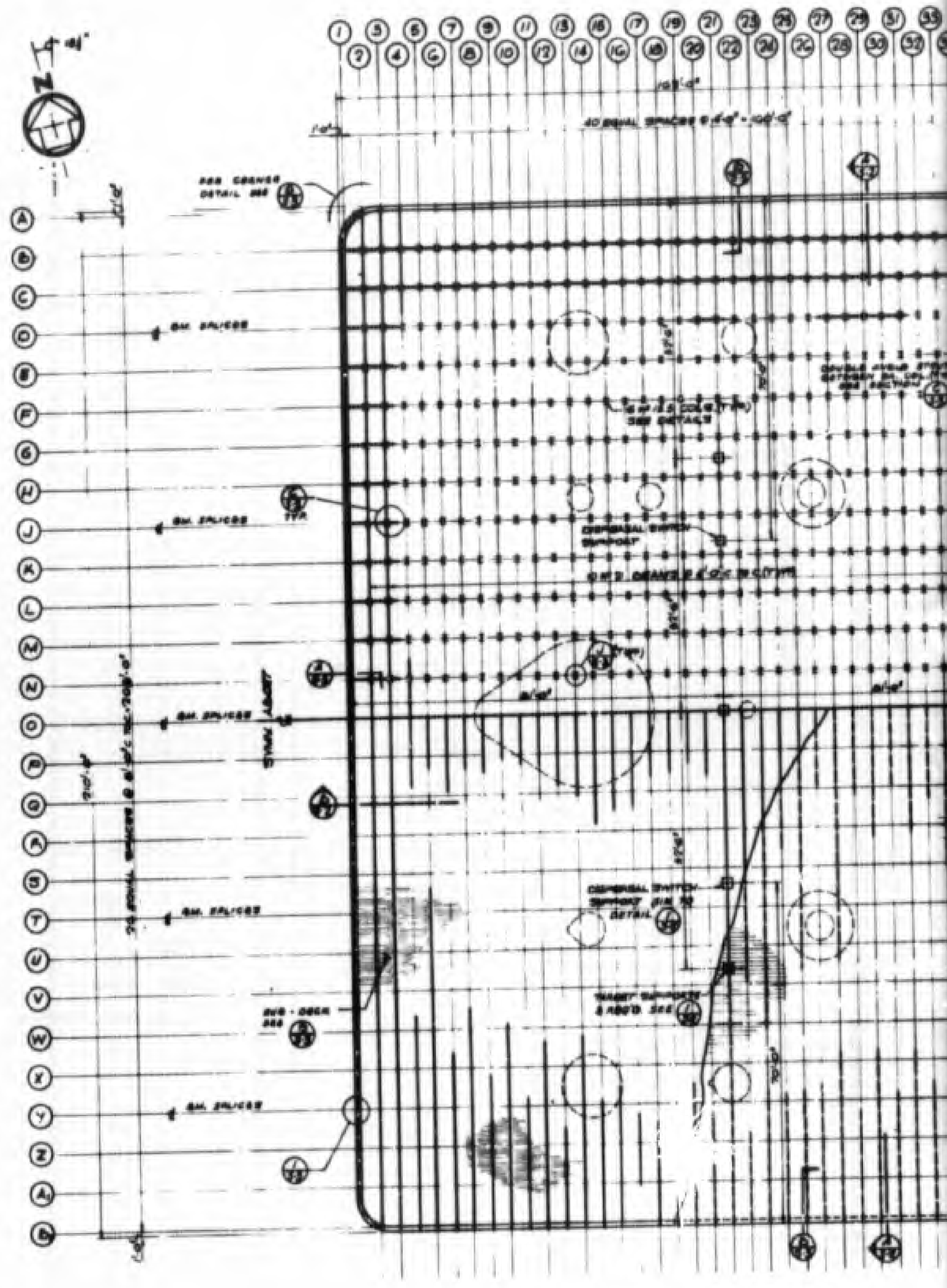
WLDC 68-1	Test Site Location
WLDC 68-2	Test Site Plan
S-1 through S-9	Test Structures Drawings
Sheet 17	Cord Rack Support Plan
Sheets 21 and 22	Steel Framed Trailer Shelter

AISC	Manual of Steel Construction
AISI	Light Gage Cold-Formed Steel Design Manual
Lynn S. Beedle	Plastic Design of Steel Frames
International Conference of Builder Officials	Uniform Building Code (1964 Edition)
ACI	Building Code Requirements for Reinforced Concrete



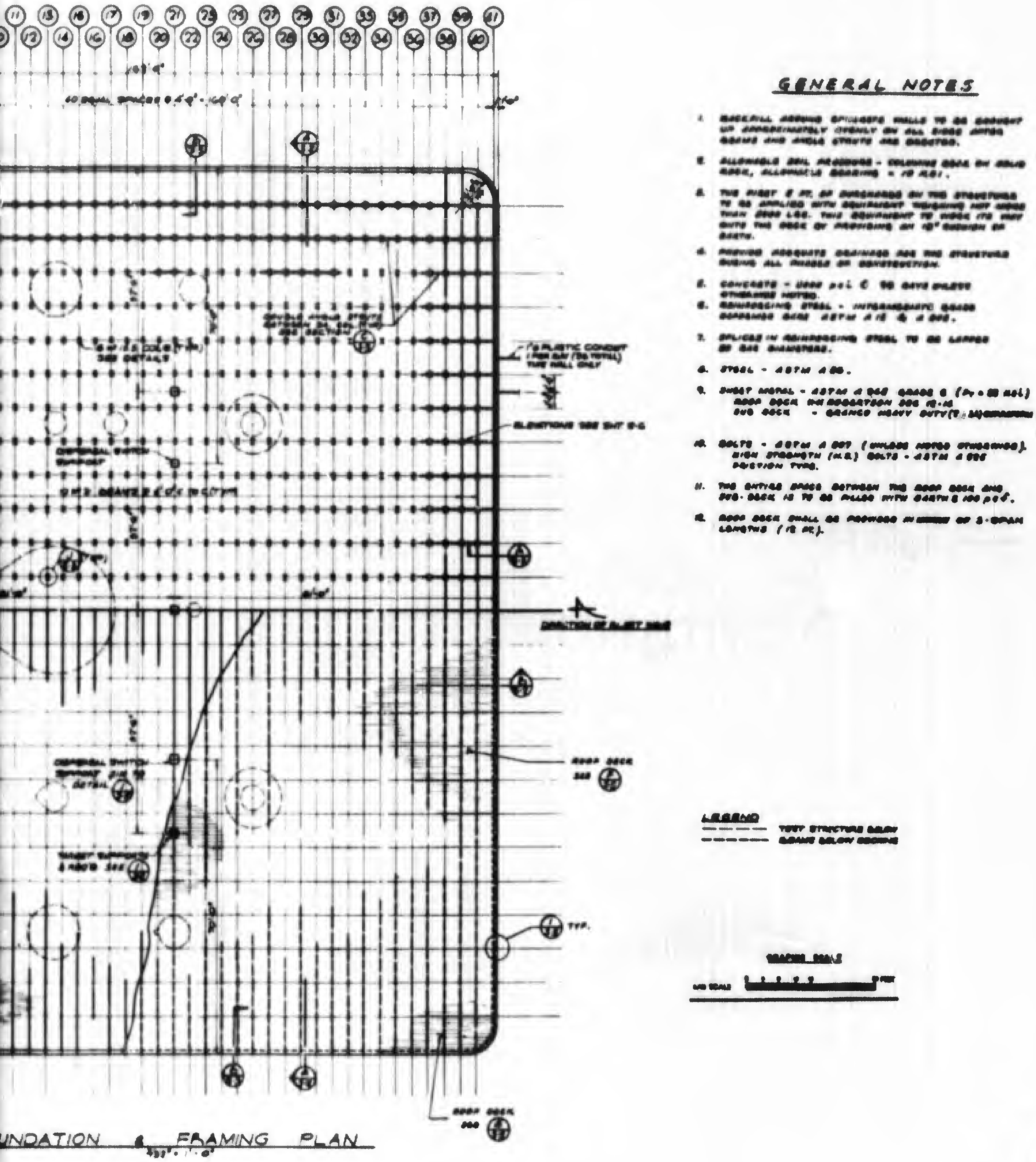
SURCHARGE
EARTH BERM
LONGITUDINAL SECTION
TRANSVERSE SECTION
ELEVATION
PLAN
POINTER DETAIL
BACKGROUND
TARGET DETAIL

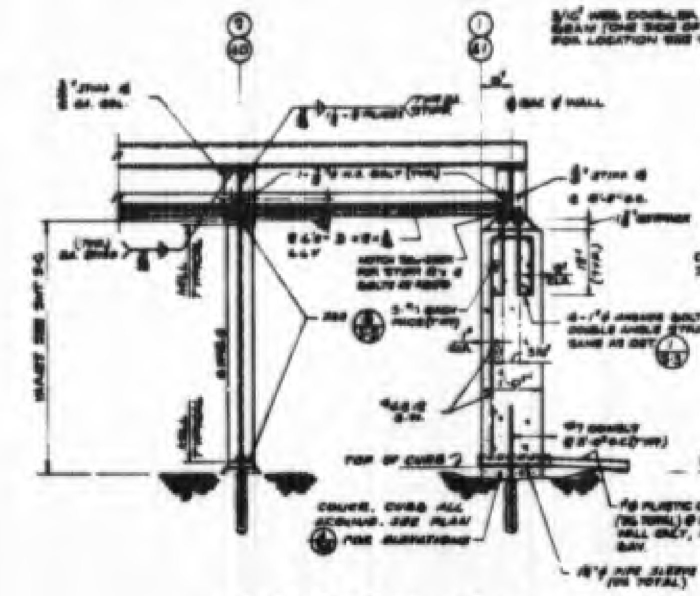

SURCHARGE
SPLICE
EARTH BERM
COMPACT EARTH BERM TO 95% OF MAXIMUM DENSITY
ENCLOSURE WALL
EXISTING GRADE
ELEVATION OF ROCK FLOOR VARIES
SECTION
COMPACT EARTH BERM TO 95% OF MAXIMUM DENSITY
EXISTING GRADE
NOTE:
1 FINAL DEPTH OF SURCHARGE WILL BE GOVERNED BY ACTUAL MEASURED DENSITY OF MATERIAL
2 MAXIMUM LOAD ON TEST FACILITY TO BE 2000 PSF
LEGEND
CONCRETE
STEEL
ROCK
SURCHARGE
COMPACTED EARTH BACKFILL
BACKGROUND
POINTER
TOP OF SURCHARGE
PLASTIC PIPE
WELD IN PLACE
TOP OF STEEL DECKING
GRAPHIC SCALE
TARGET DETAIL



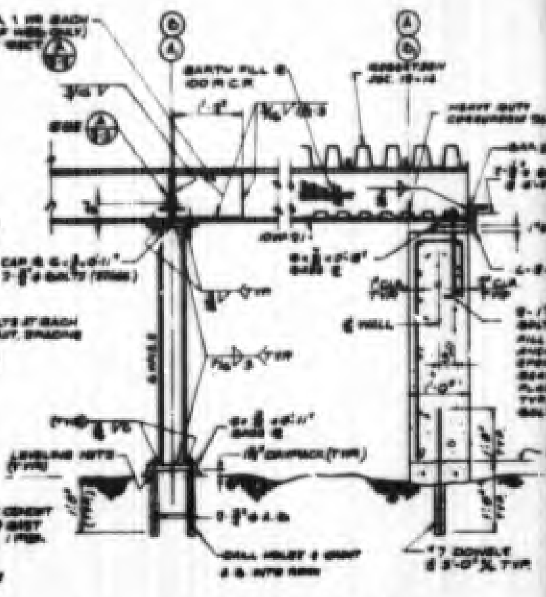
FOUNDATION & FRAMING PLAN

A

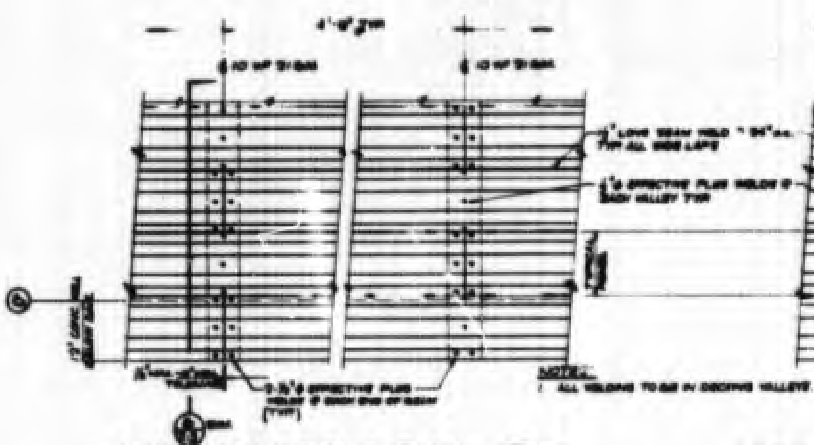

GENERAL NOTES
8. STEEL - ASTM A 36.
LEGEND
UNDATION & FRAMING PLAN



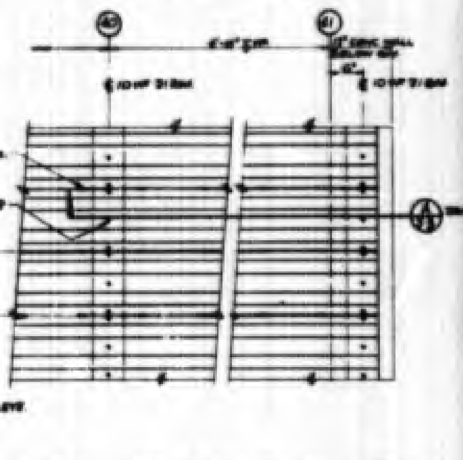
SECTION
1" = 1'-0"



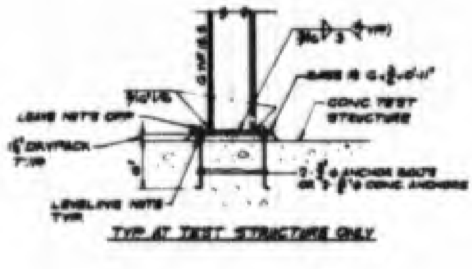
SECTION
1" = 1'-0"



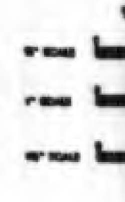
ROOF DECK WELDING PLAN
N.T.S.



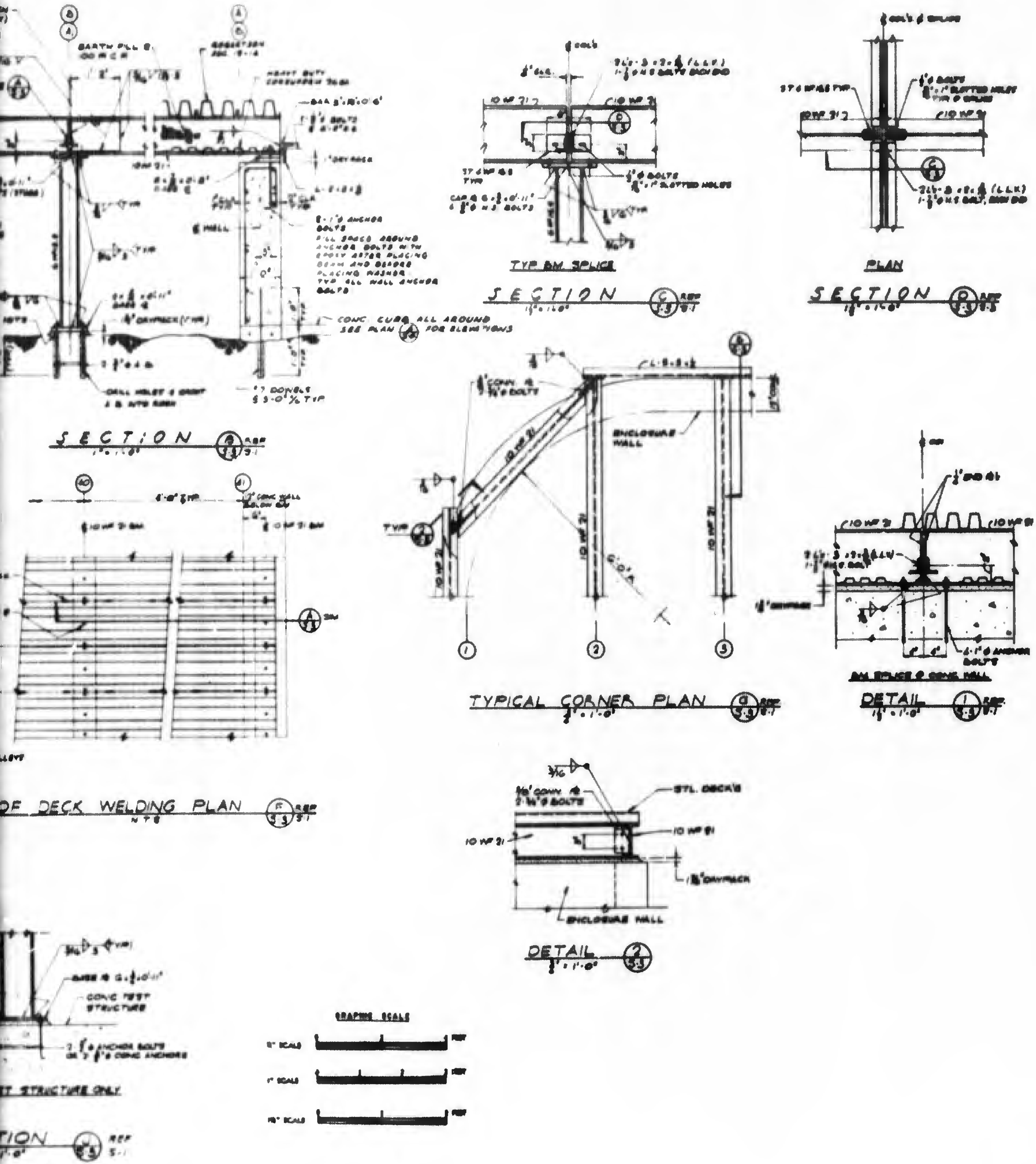
ROOF DECK WELDING PLAN
N.T.S.

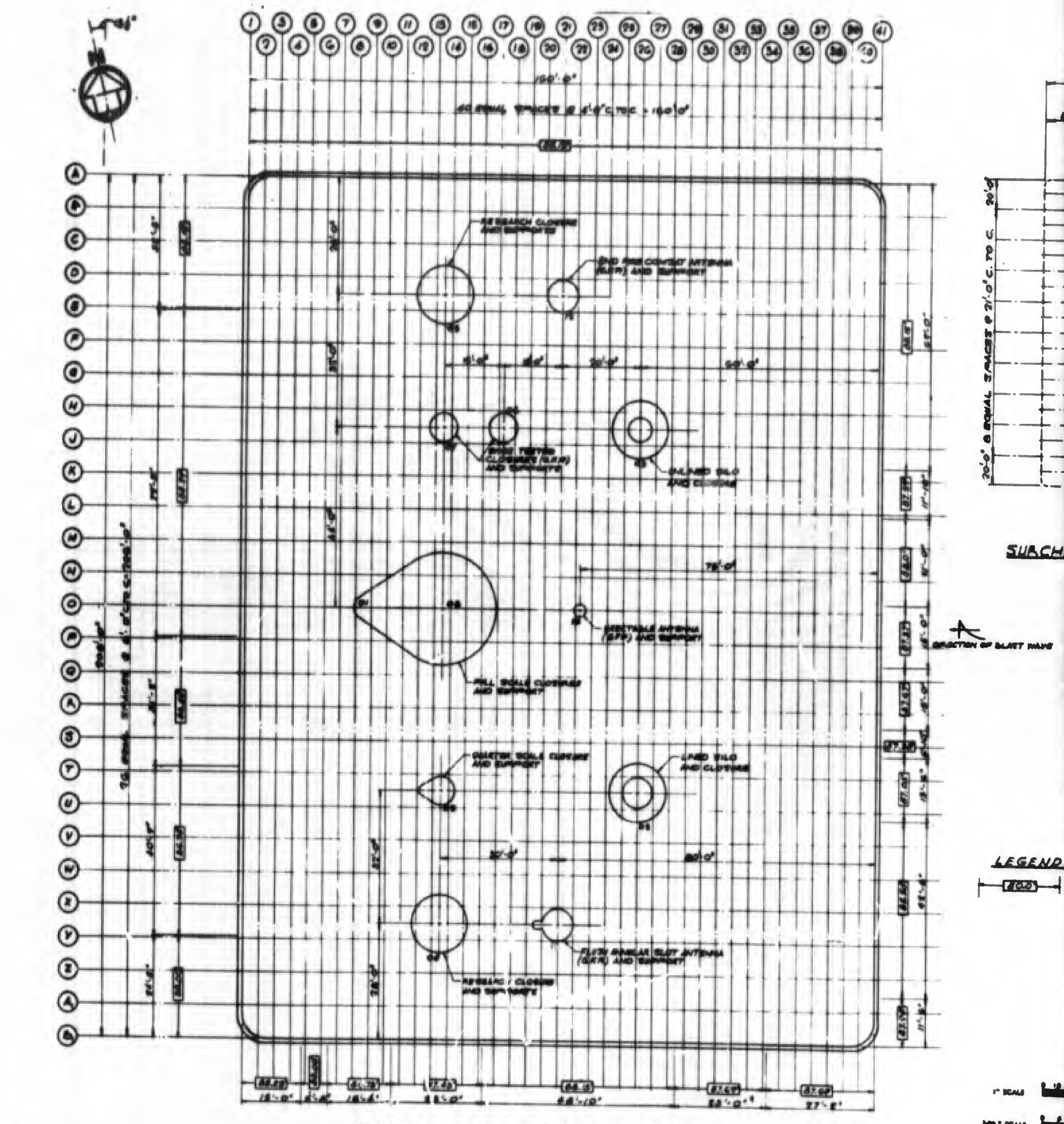


SECTION
REF. S-1

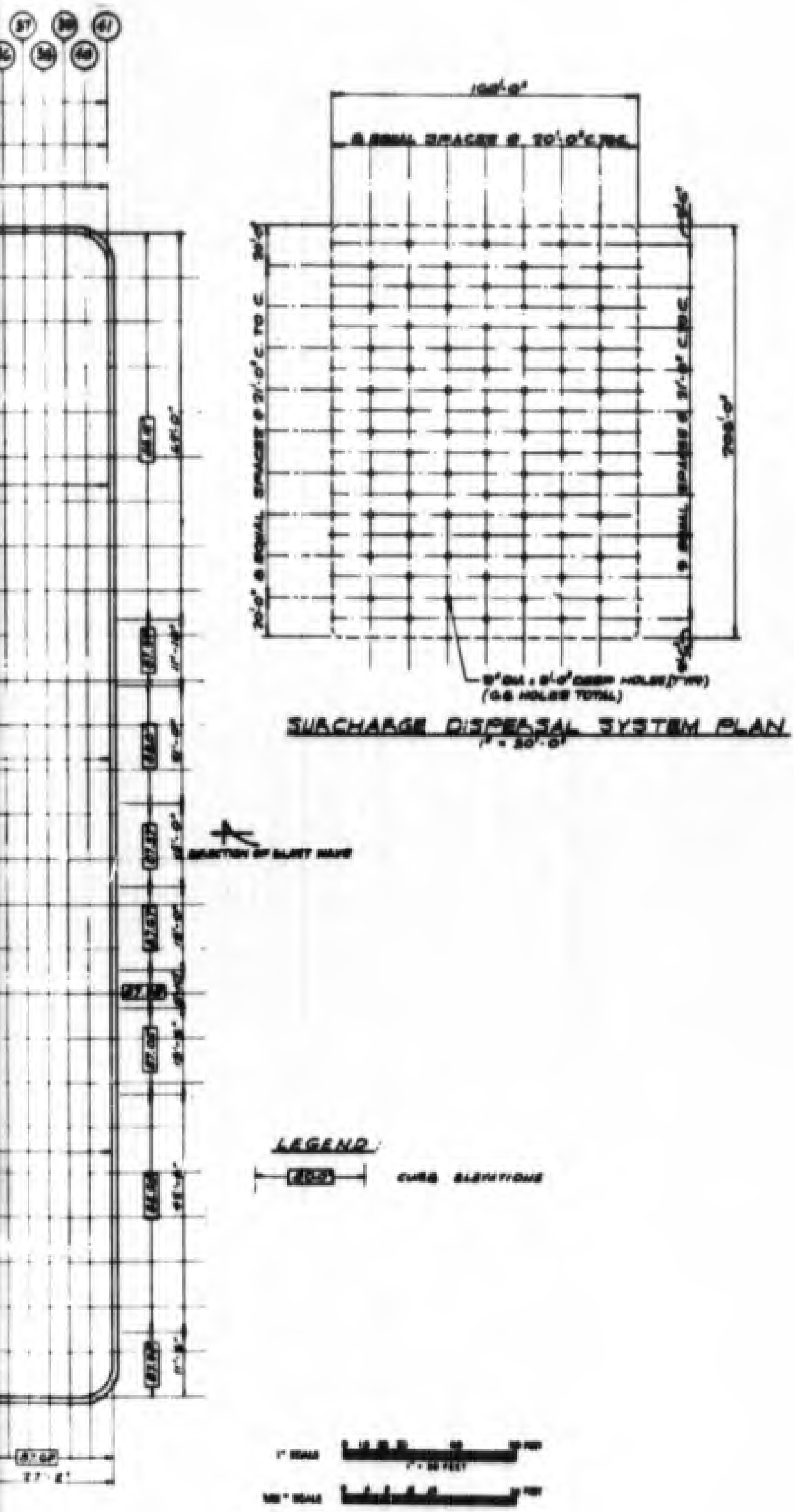


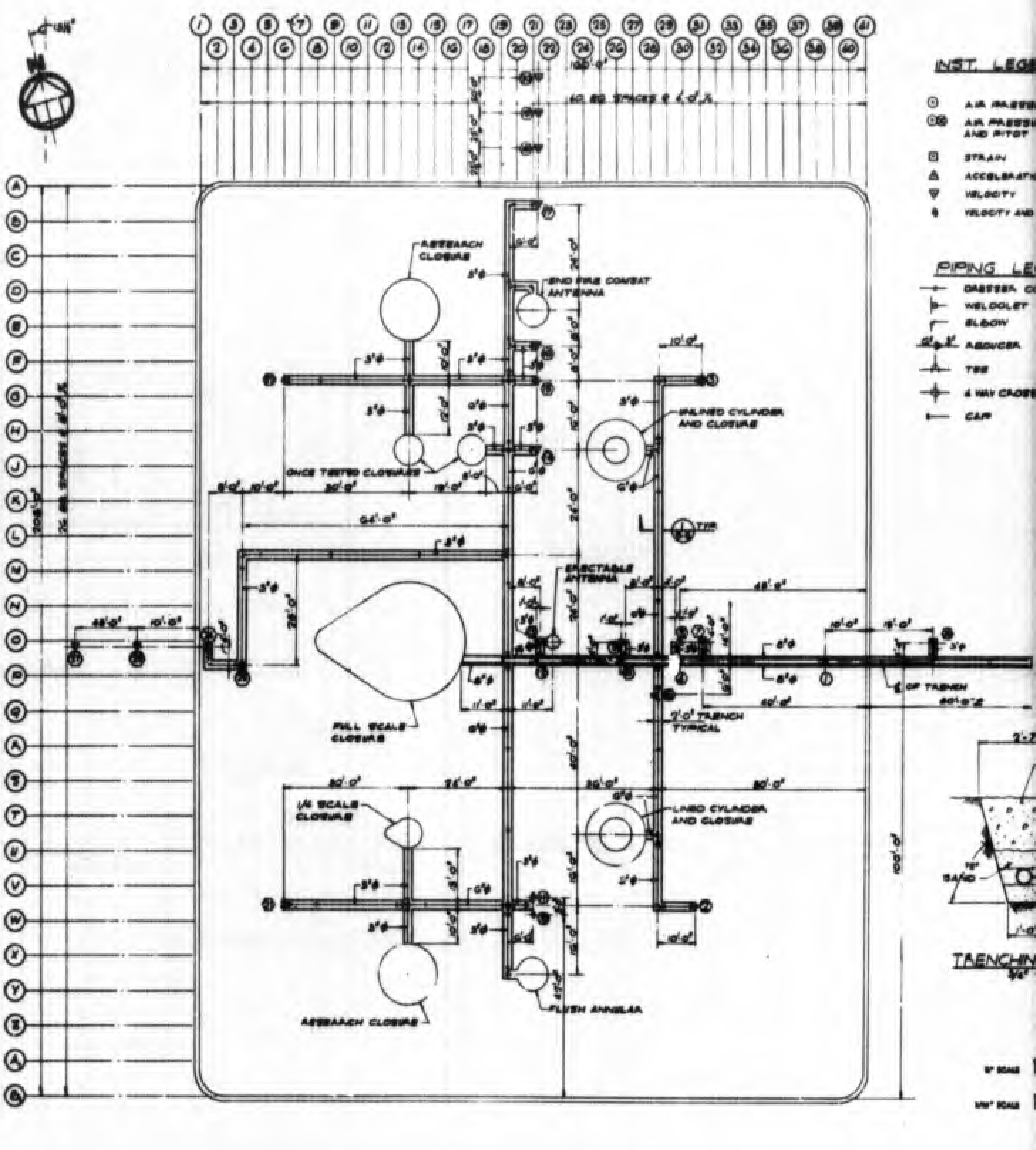
A


SECTION
SECTION
TYP BM SPLICE
PLAN
SECTION
TYPICAL CORNER PLAN
DETAIL
BM SPLICE @ CONC WALL
DETAIL
ENCLOSURE WALL
STL. DECK'G
GRAPHIC SCALE

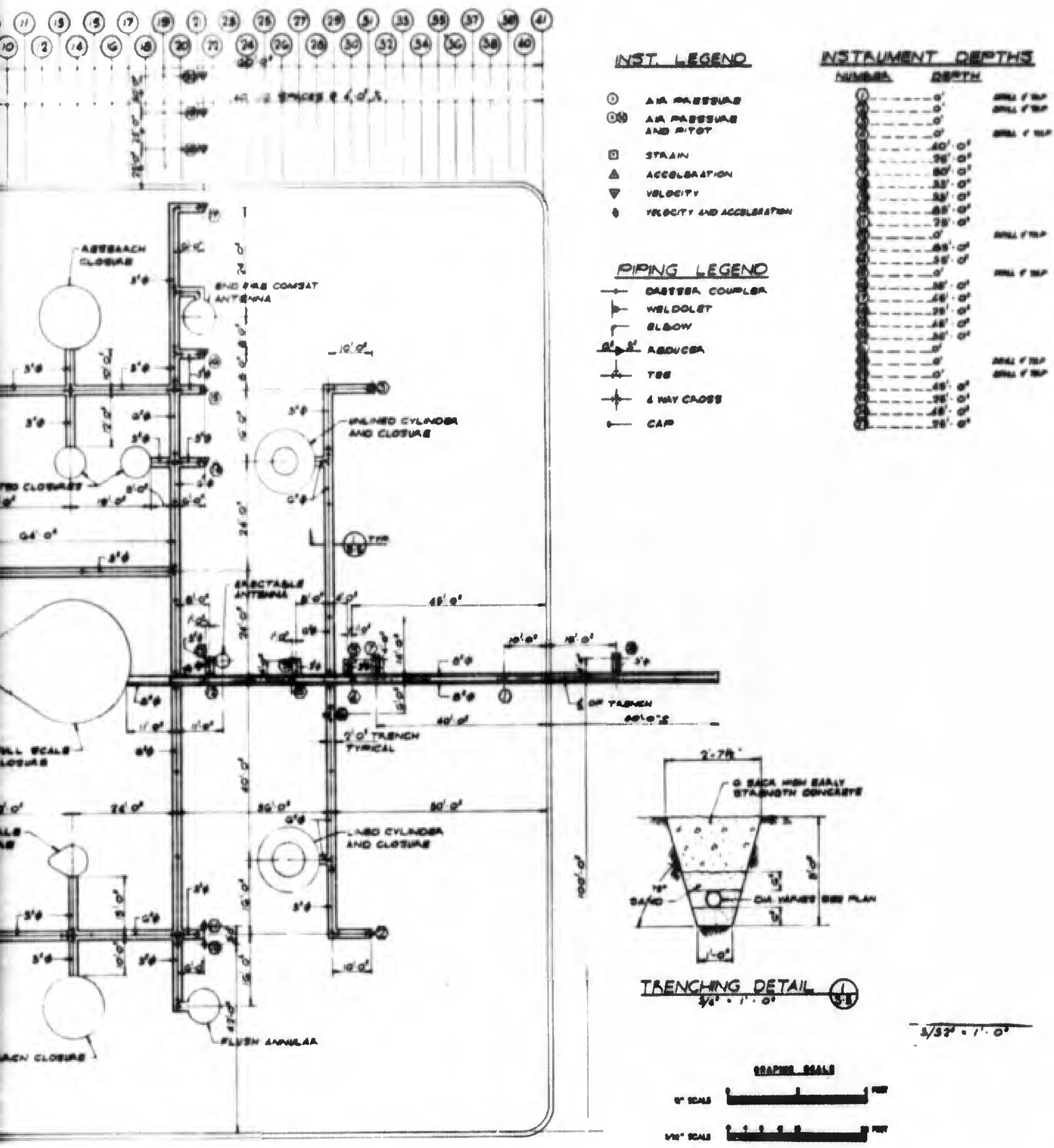


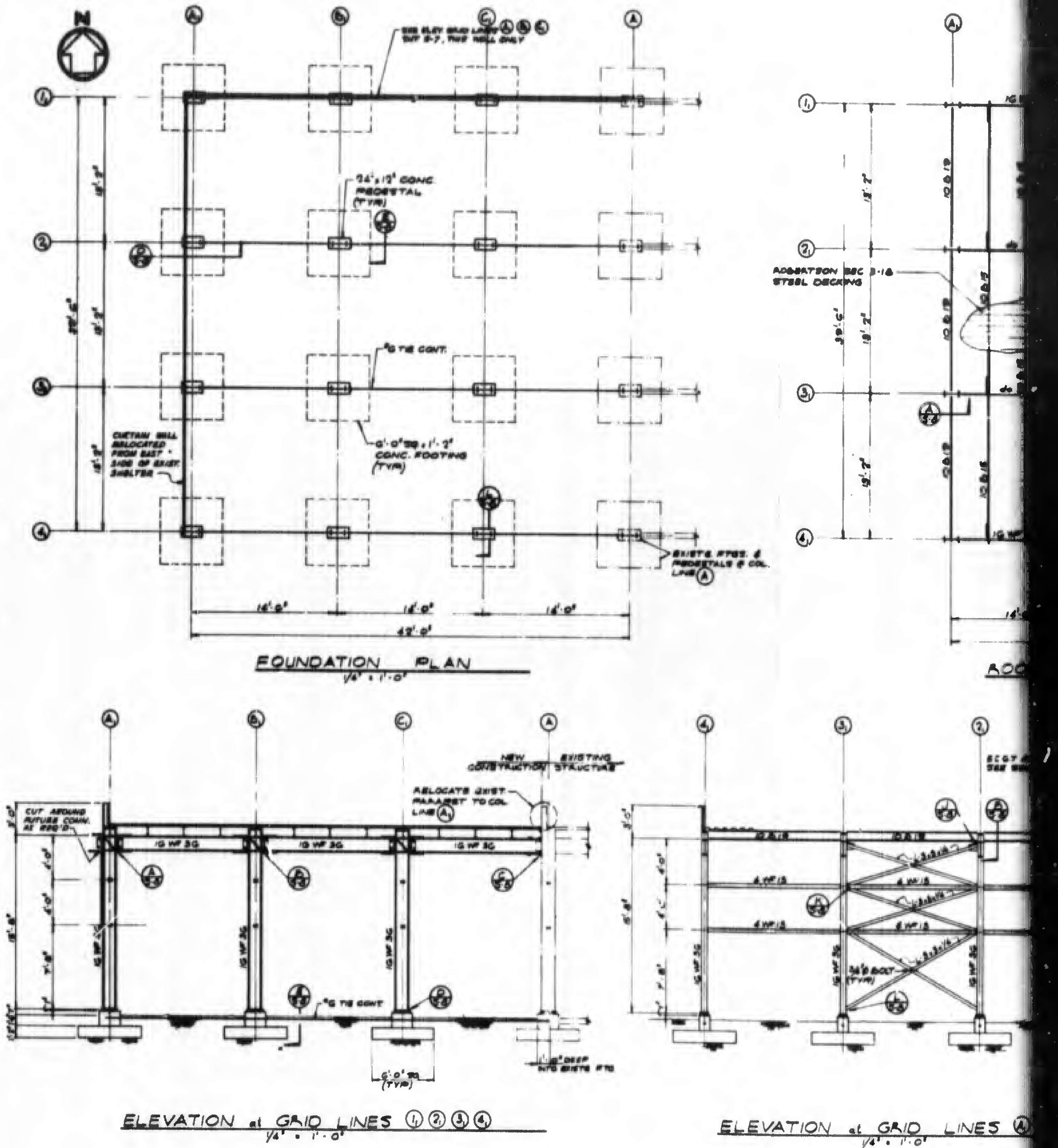
TEST STRUCTURE PLAN


100'-0"
SURCHARGE DISPERSAL SYSTEM PLAN
LEGEND
CURB ELEVATIONS

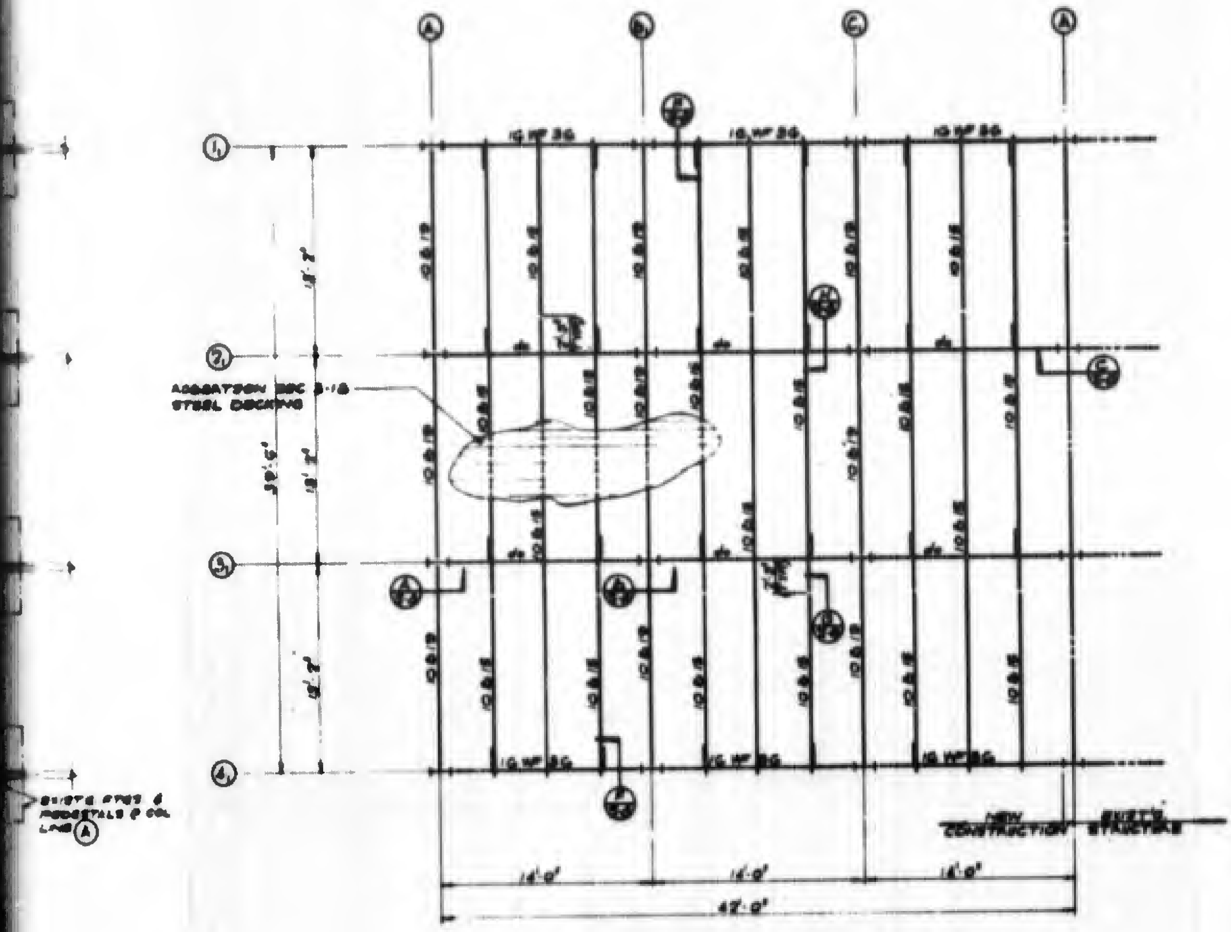

INST. LEG
STRAIN
VELOCITY
PIPING LE
WELDOLET
ELBOW
REDUCER
TEE
4 WAY CROSS
CAP
RESEARCH CLOSURE
END FIRE COMBAT ANTENNA
UNLINED CYLINDER AND CLOSURE
ONCE TESTED CLOSURES
SPECTACLE ANTENNA
FULL SCALE CLOSURE
7'-0" TRENCH TYPICAL
LINED CYLINDER AND CLOSURE
1/4 SCALE CLOSURE
FLUSH ANNULAR
RESEARCH CLOSURE
TRENCHIN
SAND

A

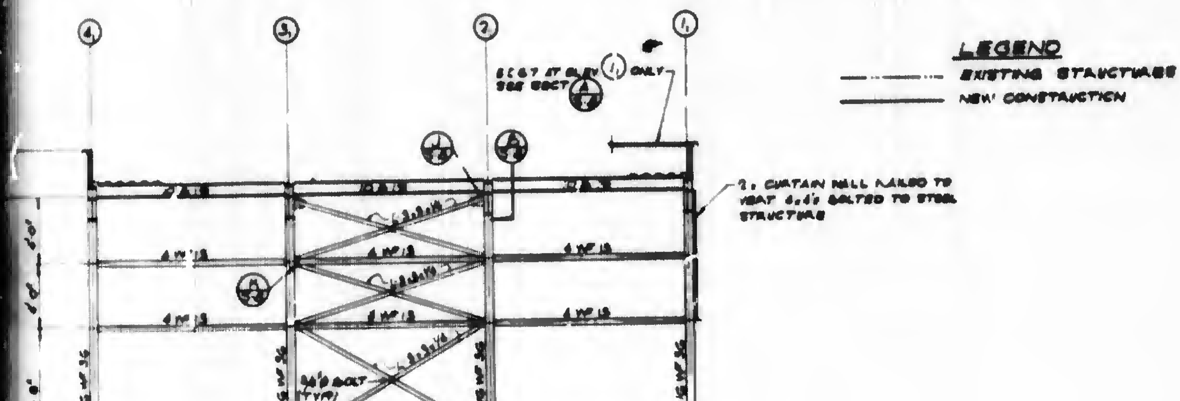

INST. LEGEND
AIR PRESSURE
AIR PRESSURE AND PITOT
STRAIN
ACCELERATION
VELOCITY
VELOCITY AND ACCELERATION
PIPING LEGEND
DRESSER COUPLER
WELDOLET
ELBOW
REDUCER
TEE
4 WAY CROSS
CAP
INSTRUMENT DEPTHS
NUMBER
DEPTH
RESEARCH CLOSURE
END FIRE COMSAT ANTENNA
UNLINED CYLINDER AND CLOSURE
ERECTABLE ANTENNA
LINED CYLINDER AND CLOSURE
FLUSH ANNULAR
TRENCHING DETAIL
GRAPHIC SCALE


FOUNDATION PLAN
1/4" = 1'-0"
24" x 12" CONC. PEDESTAL (TYP)
G'-0" SQ. x 1'-2" CONC. FOOTING (TYP)
CURTAIN WALL RELOCATED FROM EAST SIDE OF EXIST. SHELTER
14'-0"
42'-0"
ROBERTSON SEC 3-18 STEEL DECKING
ELEVATION at GRID LINES ① ② ③ ④
1/4" = 1'-0"
NEW CONSTRUCTION
EXISTING STRUCTURE
RELOCATE EXIST. PARAPET TO COL LINE Ⓐ
CUT AROUND FUTURE CONN. AS REQ'D.
16 WF 36
6'-0" SQ (TYP)
ELEVATION at GRID LINES Ⓐ
1/4" = 1'-0"

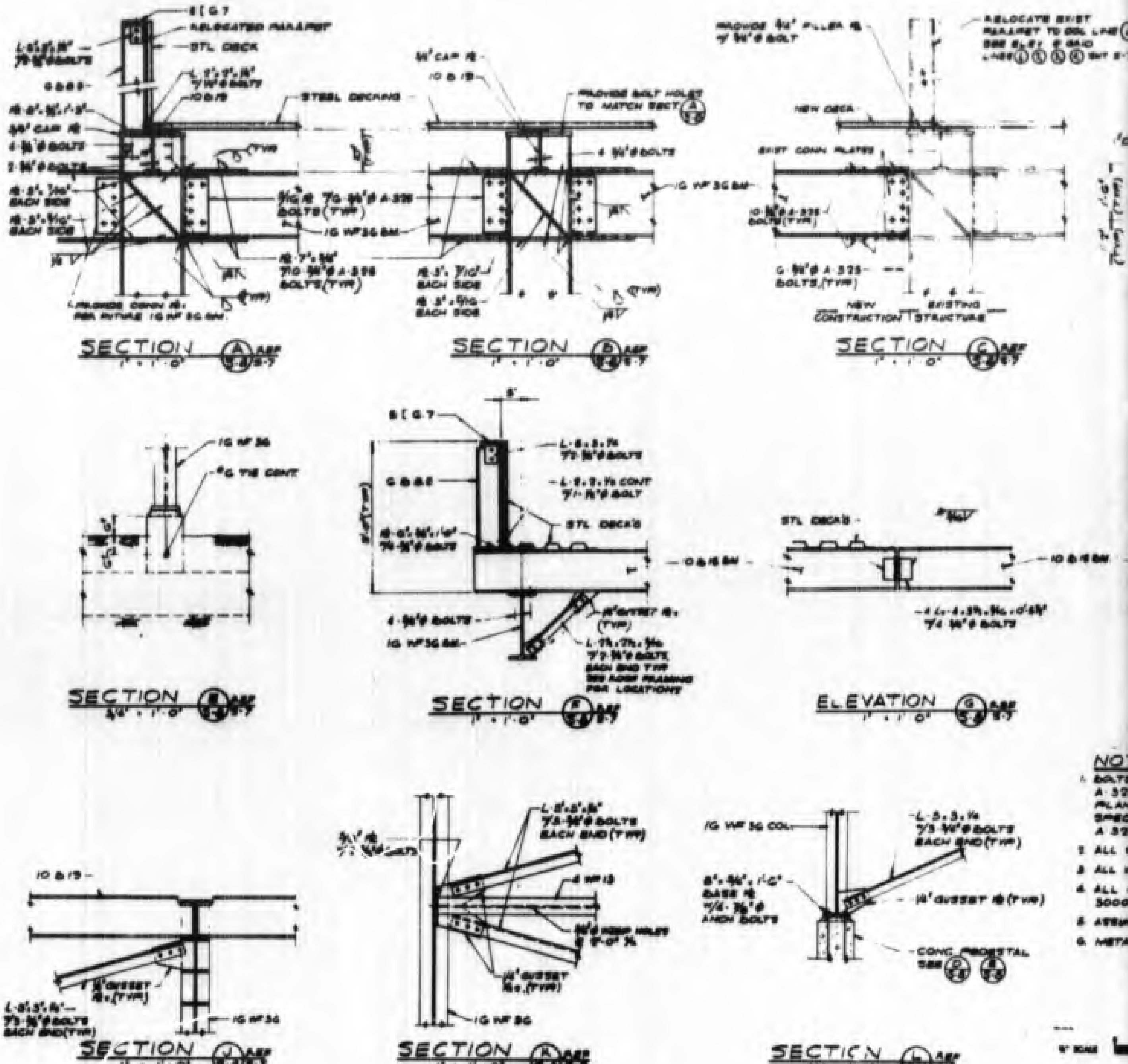
A



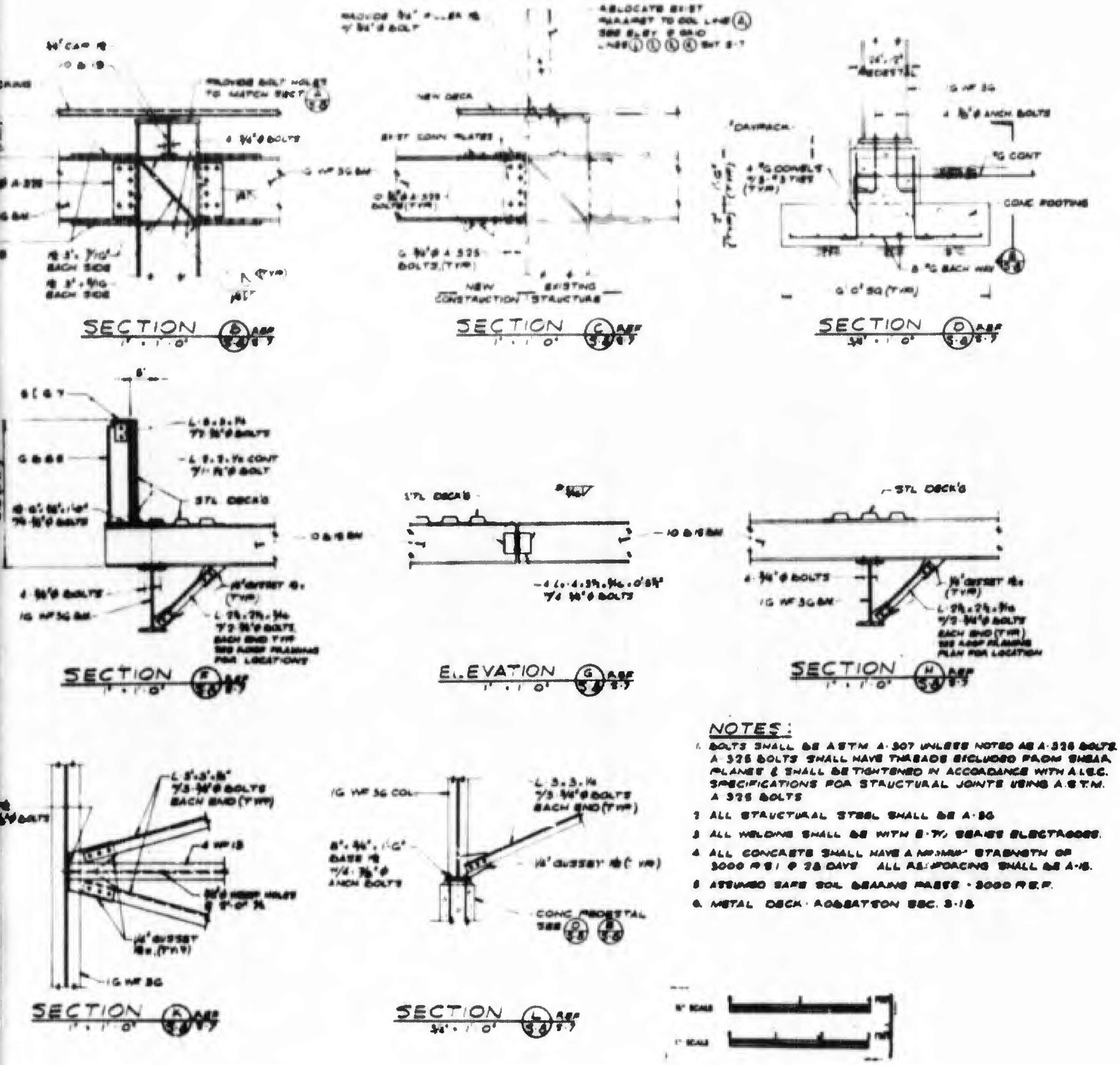
ROOF FRAMING PLAN
1/8" = 1'-0"



ELEVATION at GRID LINES (A) (B) (C)
1/8" = 1'-0"

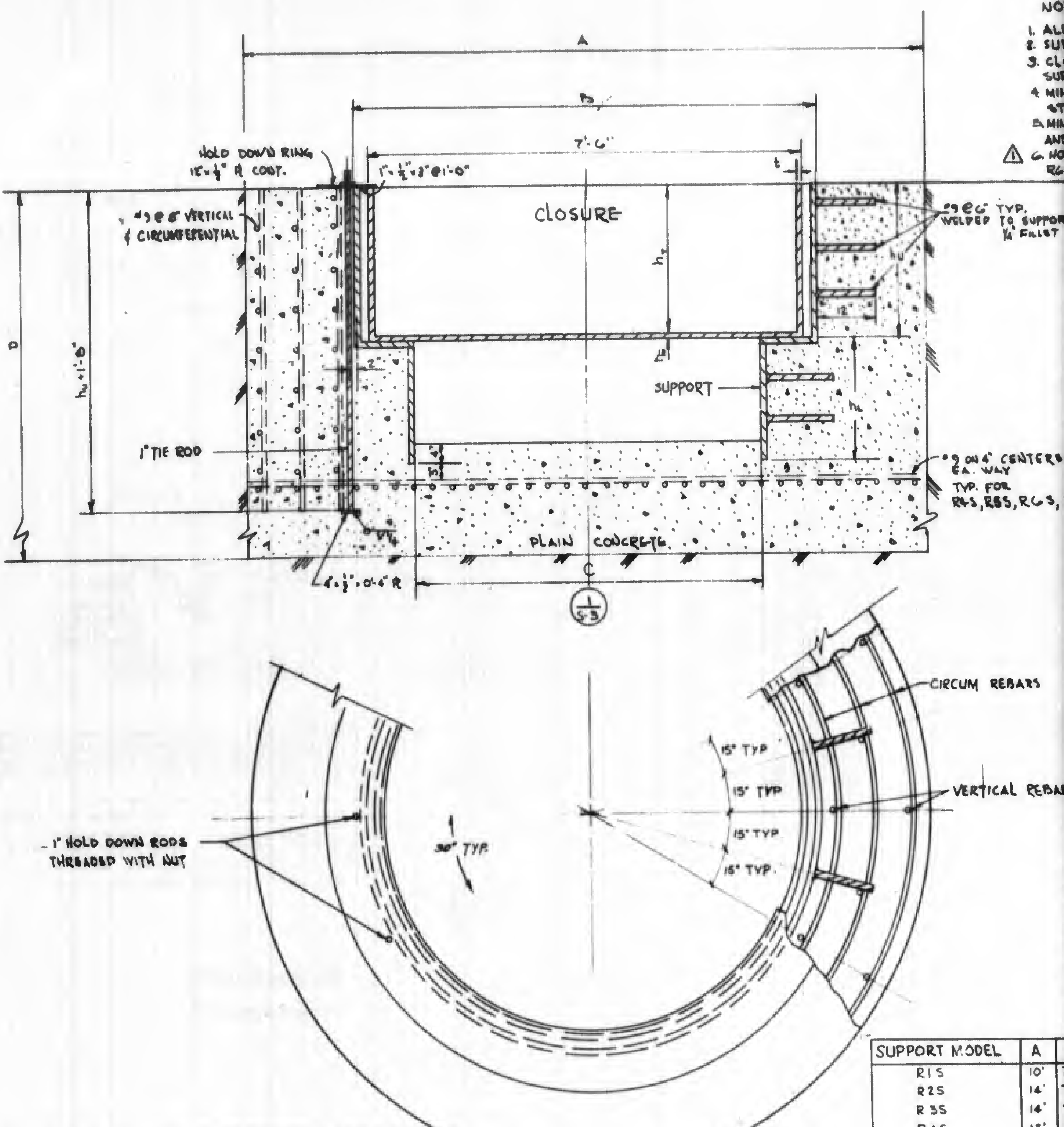


STEEL DECKING
NEW DECK
NEW CONSTRUCTION
EXISTING STRUCTURE
SECTION A
1" = 1'-0"
SECTION B
1" = 1'-0"
SECTION C
1" = 1'-0"
SECTION
STL DECK'G
SECTION
1" = 1'-0"
ELEVATION G
1" = 1'-0"
SECTION
1" = 1'-0"
SECTION K
1" = 1'-0"
SECTION


SECTION B
SECTION C
SECTION D
SECTION F
ELEVATION G
SECTION H
SECTION K
SECTION L
NOTES:
1. BOLTS SHALL BE ASTM A-307 UNLESS NOTED AS A-325 BOLTS. A-325 BOLTS SHALL HAVE THREADS EXCLUDED FROM SHEAR PLANES & SHALL BE TIGHTENED IN ACCORDANCE WITH A.I.S.C. SPECIFICATIONS FOR STRUCTURAL JOINTS USING A.S.T.M. A 325 BOLTS
2. ALL STRUCTURAL STEEL SHALL BE A-36
3. ALL WELDING SHALL BE WITH E-70 SERIES ELECTRODES.
4. ALL CONCRETE SHALL HAVE A MINIMUM STRENGTH OF 3000 P.S.I. @ 28 DAYS. ALL REINFORCING SHALL BE A-15.
5. ASSUMED SAFE SOIL BEARING PRESS. - 3000 P.S.F.
6. METAL DECK - ROBERTSON SEC. 3-18

III-10

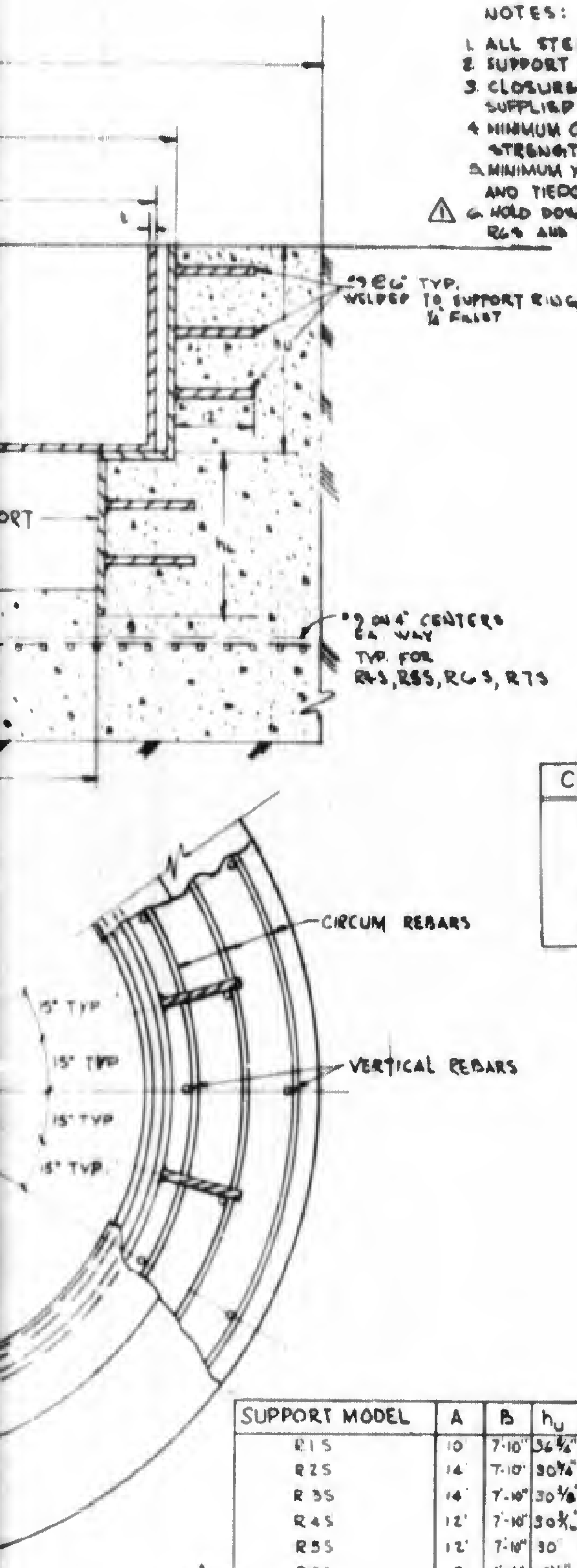
B



REVISIONS					
SYM	ZONE	LTR	DESCRIPTION	DATE	APPROVED
1	2	B	NOTE ADDED	6MAY64	
2	1	C	CHANGE & DIM. ON R6C & R7C	31MAY64	

SUPPORT MODEL	A
R1S	10'
R2S	14'
R3S	14'
R4S	12'
R5S	12'
R6S	7'
R7S	7'

A



NOTES: THIS SHEET

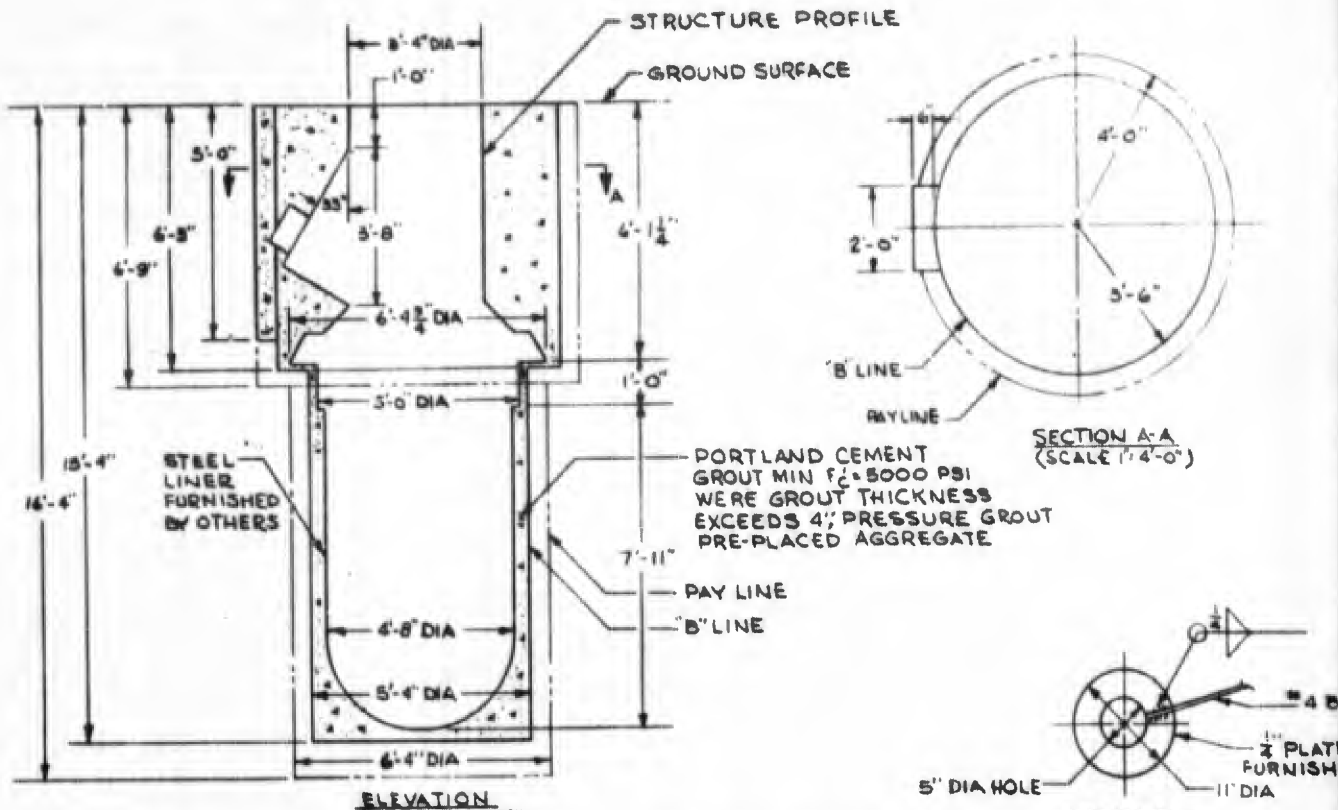
1. ALL STEEL PLATE - A36
2. SUPPORT RING THICKNESS - 1/2"
3. CLOSURES FOR SUPPORTS R6S & R7S SUPPLIED BY OTHERS
4. MINIMUM CONCRETE COMPRESSIVE STRENGTH = 4000 PSI
5. MINIMUM YIELD STRENGTH OF REINFORCEMENT AND TIEDOWN RODS = 40,000 PSI
6. (△1) HOLD DOWN RING AND TIE RODS FOR SUPPORTS R6S AND R7S FURNISHED BY CONTRACTOR

CLOSURE MODEL	h_B	h_T	t
R1C	3/16"	36"	3/16"
R2C	3/16"	30"	3/16"
R3C	3/16"	30"	3/16"
R4C	3/16"	30"	3/16"
R5C	0	30"	0

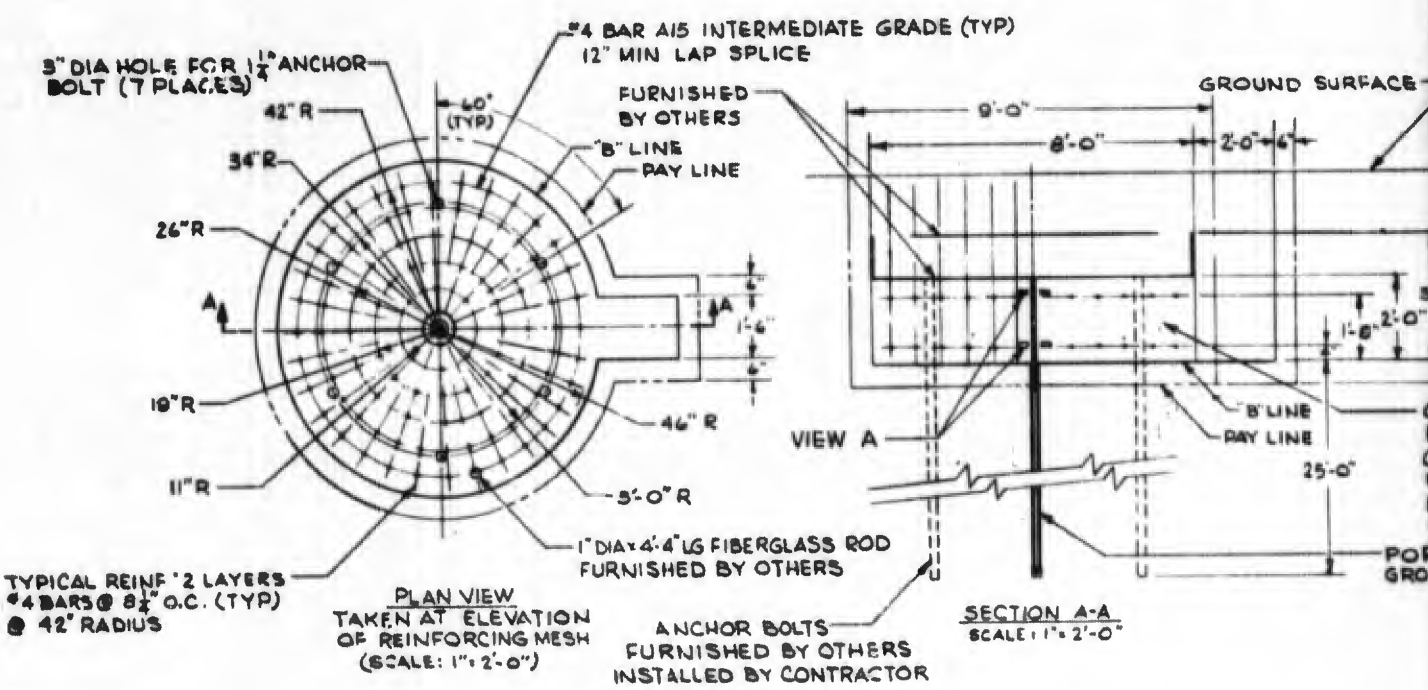
SUPPORT MODEL	A	B	h_U	h_L	C	D	NOTES
R1S	10'	7'-10"	36 3/4"	24"	6'	30'	IN FULL SCALE
R2S	14'	7'-10"	30 3/4"	30"	6'	5'	LINED SILO
R3S	14'	7'-10"	30 3/8"	30"	6'	5'	UNLINED SILO
R4S	12'	7'-10"	30 3/16"	30"	6'	15'	RES. CLOSURE
R5S	12'	7'-10"	30"	30"	6'	15'	RES. CLOSURE
R6S	7	4'-4"	10 1/4"	13"	3'	4'	ONCE TESTED CLOSURE
R7S	7	4'-4"	15 1/4"	15"	3'	4'	ONCE TESTED CLOSURE

-14

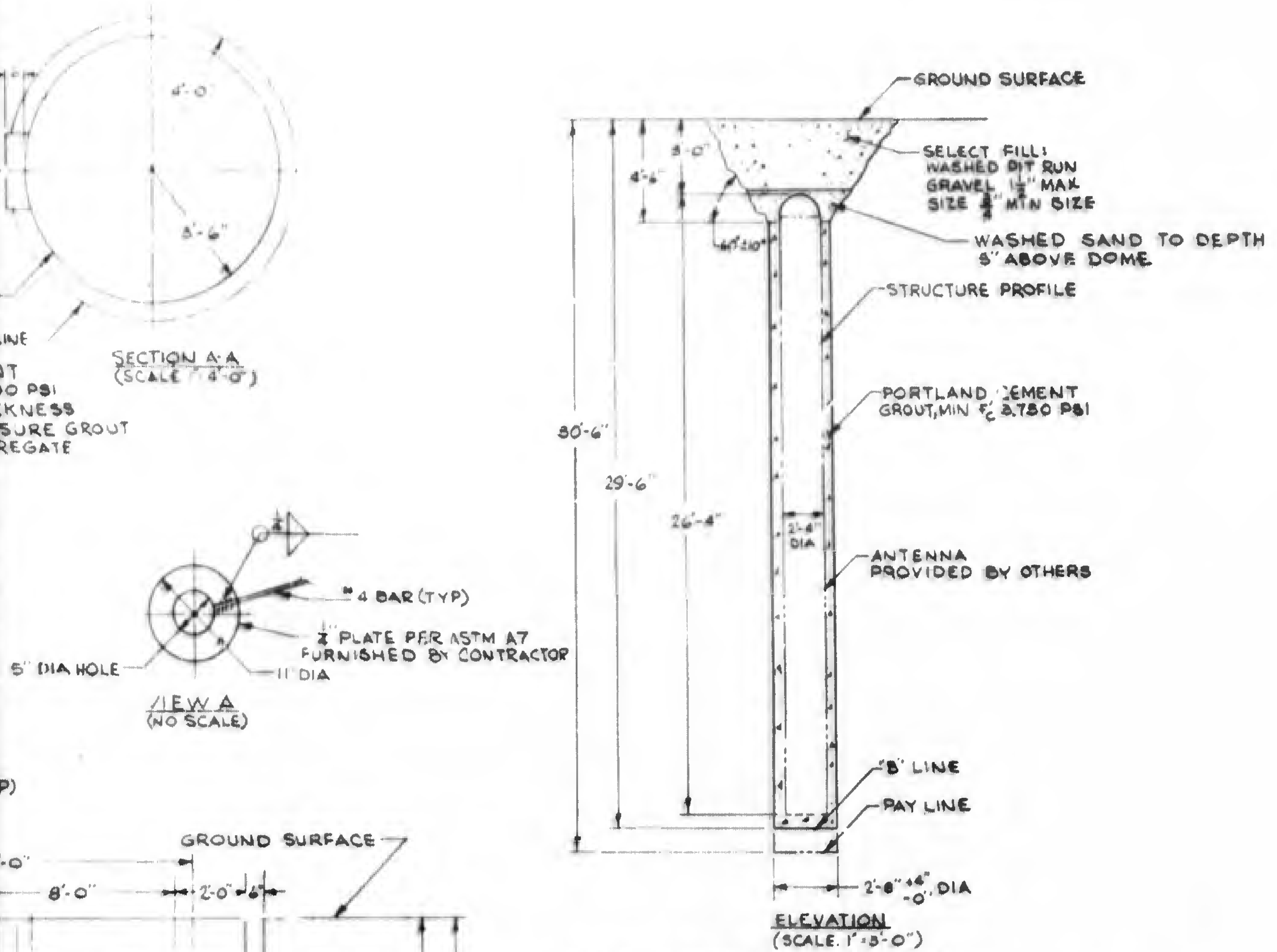
B

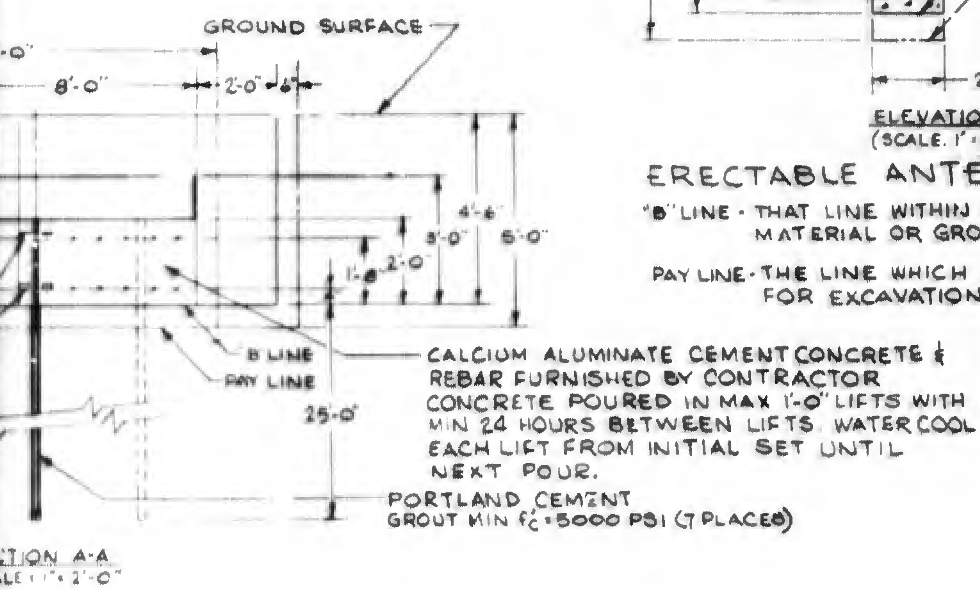


BELOW SURFACE SATELLITE ANTENNA



FLUSH ANNULAR SLOT ANTENNA

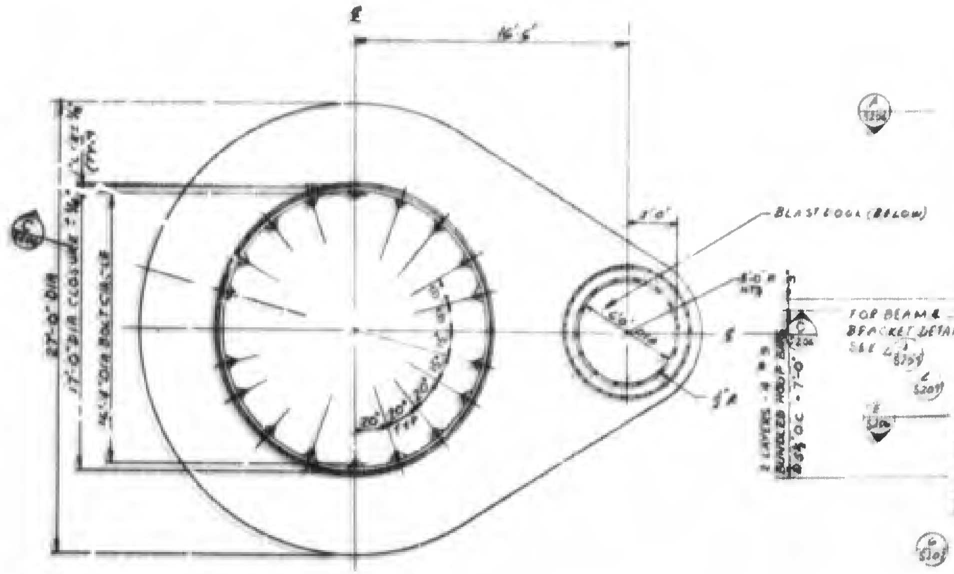




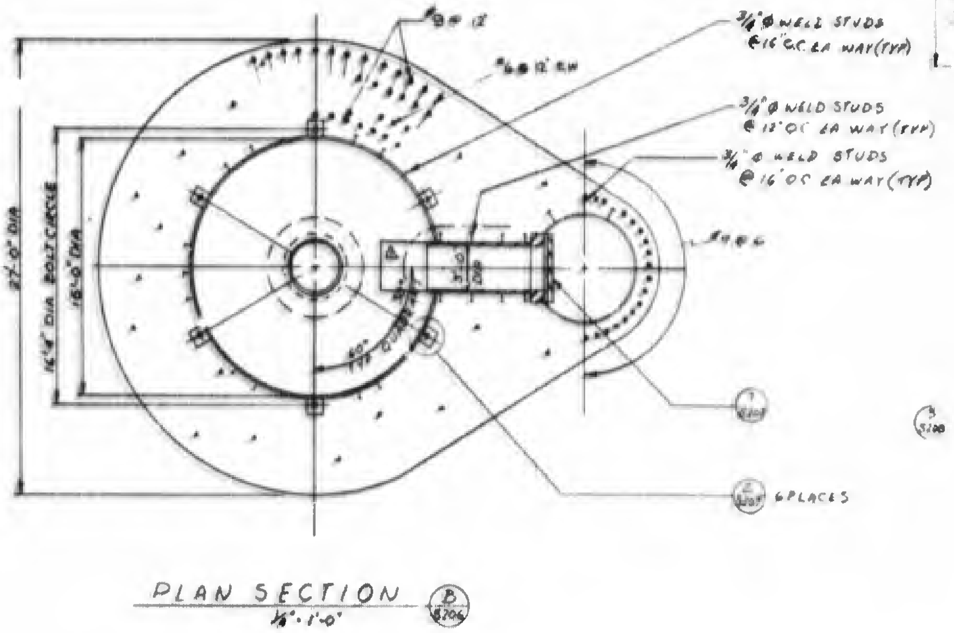
ERECTABLE ANTENNA

"B" LINE - THAT LINE WITHIN WHICH NO UNEXCAVATED MATERIAL OR GROUTED FILL WILL BE PERMITTED

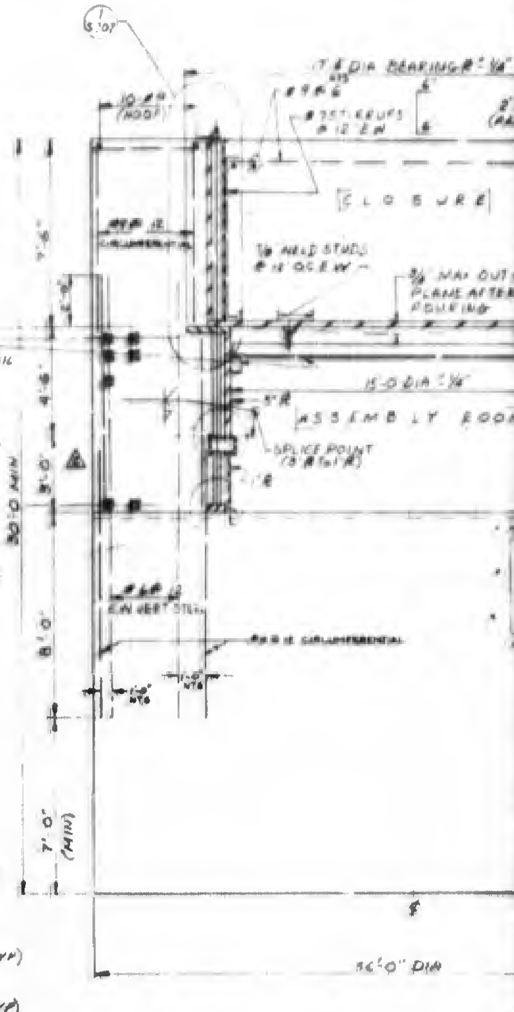
PAY LINE - THE LINE WHICH CONSTITUTES LIMITS OF PAYMENT FOR EXCAVATION AND CONCRETE LINING



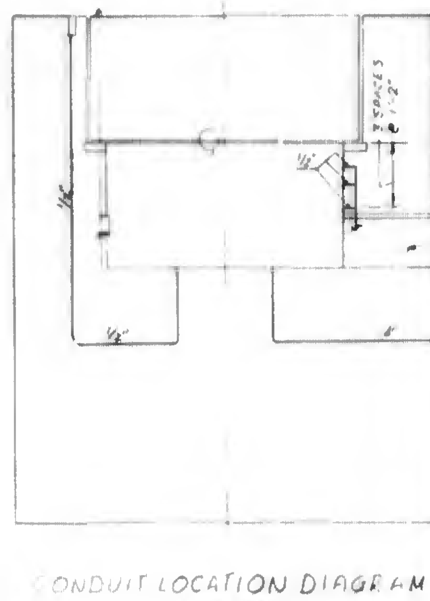
PLAN AT TOP (A/5206)
1/4" = 1'-0"



PLAN SECTION (B/5206)
1/8" = 1'-0"



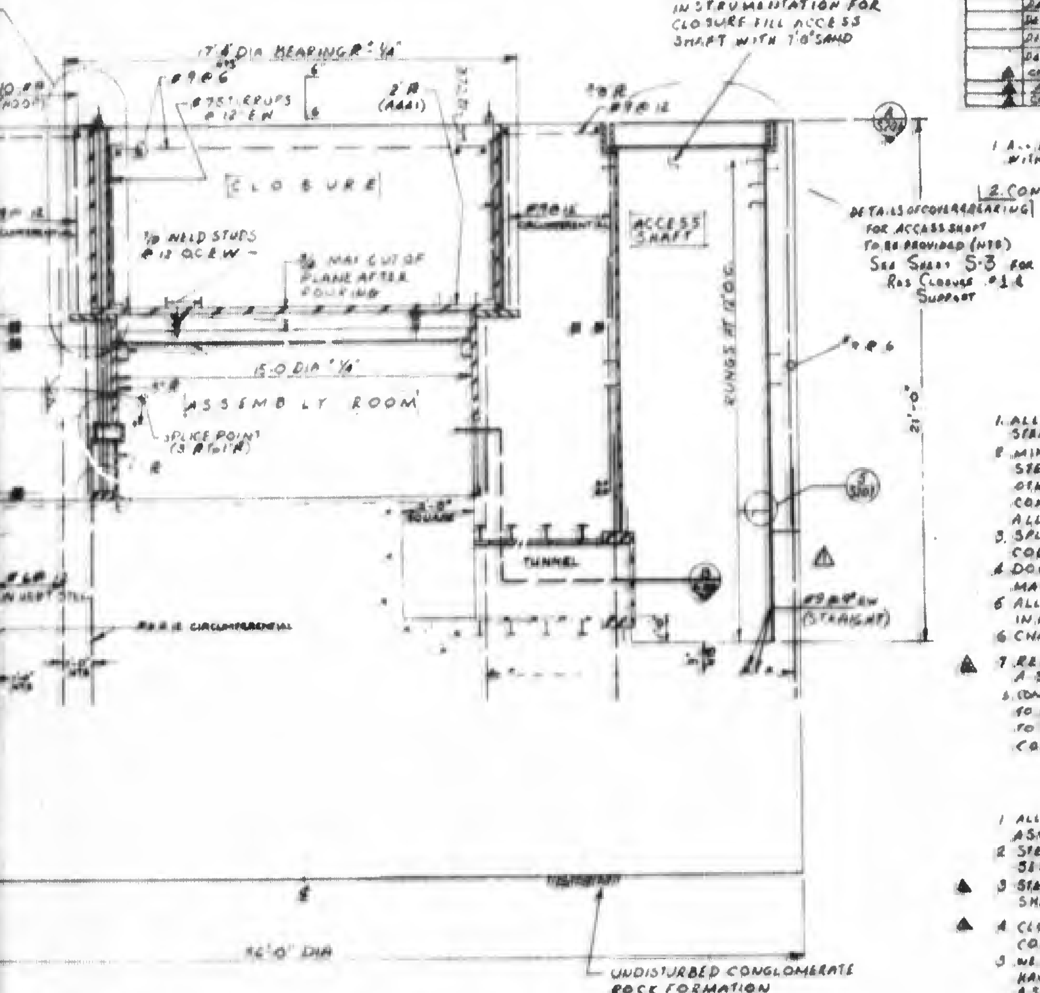
S E C T I O



CONDUIT LOCATION DIAGRAM
NOT TO SCALE

A

Zone	Ltr	Description	Date	Approved
			[illegible]	NK
		OUTSIDE DIMEN NEAR BLAST DOOR	[illegible]	[illegible]
		DETAIL OF RESEARCH CLOSURE	[illegible]	[illegible]
		DEPTH OF CONDUIT AS IT EXIT FROM STRUCTURE	[illegible]	[illegible]
		DELETED INSTRUMENTATION CHAMBER	[illegible]	[illegible]
		DELETED GAGE MOUNTS	[illegible]	[illegible]
	▲	CHANGED LOCATION OF TUNNEL	[illegible]	[illegible]
	▲	ADDED STEEL	[illegible]	[illegible]
	▲	CHANGED STEEL TYPE	[illegible]	[illegible]



SECTION C/S206
3/8" = 1'-0"

GENERAL NOTES

1. ALL MATERIALS & WORKMANSHIP SHALL COMPLY WITH CONTRACT SPECIFICATIONS
2. CONTRACTOR MUST VERIFY ALL DIMENSIONS IN FIELD

REINFORCED CONCRETE

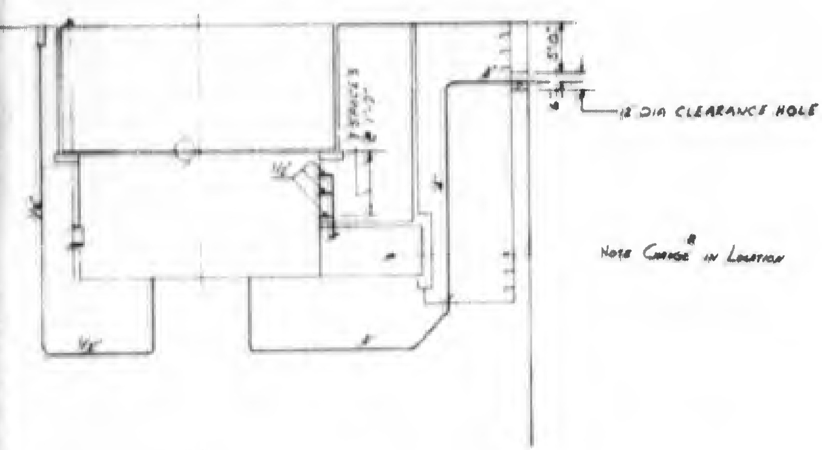
1. ALL CONCRETE SHALL ATTAIN A COMPRESSIVE STRENGTH OF 6000 PSI AT 28 DAYS
2. MINIMUM CLEAR COVER FOR REINFORCING STEEL SHALL BE AS FOLLOWS UNLESS OTHERWISE SHOWN ON THE DRAWINGS:
   CONCRETE POURED AGAINST EARTH OR ROCK — 3"
   ALL OTHERS — 2"
3. SPLICES SHALL BE IN ACCORDANCE WITH A.C.I CODE CODE 318-63 (SPLICES SHALL BE A MIN OF 30 DIA
4. DOWELS SHALL BE THE SIZE & SPACING AS THE MATCHING REBAR
5. ALL REBAR & ANCHOR BOLTS SHALL BE SECURED IN POSITION BEFORE CONCRETE IS POURED
6. CHAMFER ALL EXPOSED CORNERS 3/4"
7. ▲ REINFORCEMENT SHALL CONFORM TO A.S.T.M. A 305 INTERMEDIATE GRADE OR GREATER
8. CONTRACTOR TO PROVIDE SHORING AS NECESSARY TO LIMIT DEFLECTION AT CENTER OF CLOSURE TO ¼" MAX. AFTER PLACEMENT & CURING OF CONCRETE.

STRUCTURAL STEEL

1. ALL STRUCTURAL STEEL SHALL CONFORM TO ASTM A 36 UNLESS OTHERWISE NOTED
2. STEEL FABRICATOR SHALL PROVIDE ANCHOR BOLT SETTING PLAN.
3. ▲ STEEL SPECIFIED AS HIGH STRENGTH STEEL (H.S.S) SHALL CONFORM TO 4130 HEAT TREATED.
4. ▲ CLOSURE SIDE SHELL & BOTTOM PLATE SHALL CONFORM TO CORTEN GRADE STEEL
5. WELD STUDS SHALL BE LOW CARBON STEEL HAVING MINIMUM YIELD STRENGTH OF 60,000 PSI & SHALL CONFORM TO ASTM A-108
6. ALL FIELD SPLICES SHALL BE FULL PENETRATION BUTT WELDS UNLESS OTHERWISE NOTED.
7. WELDING SHALL CONFORM TO CONTRACT SPECIFICATIONS
8. DESIGN FABRICATION & ERECTION SHALL BE IN ACCORDANCE WITH THE LATEST A.I.S.C. SPECIFICATIONS

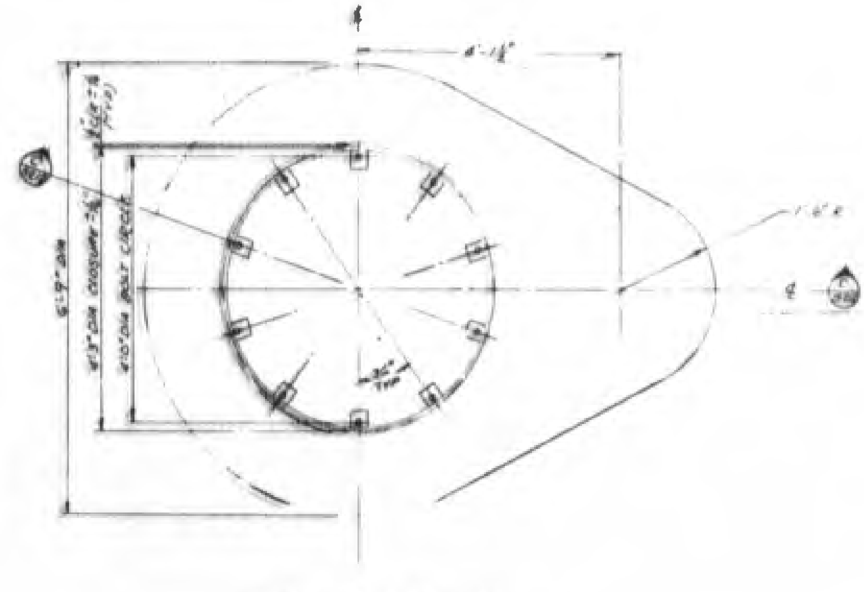
MISCELLANEOUS

1. ALL CONDUITS & FITTINGS SHALL BE HEAVY WALL & CONFORM TO FEDERAL SPECIFICATION WW-C-581-C UNLESS OTHERWISE INDICATED
2. GASKETS WHERE INDICATED SHALL BE SOFT COPPER 1/8" THICK x 3/8" WIDE & SHALL BE PROVIDED INSIDE BOLT CIRCLE



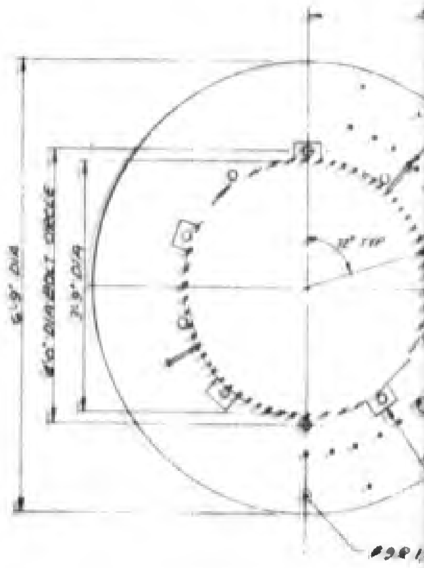
CONDUIT LOCATION DIAGRAM
NOT TO SCALE

B



PLAN AT TOP (A/5212)

1"=1'-0"

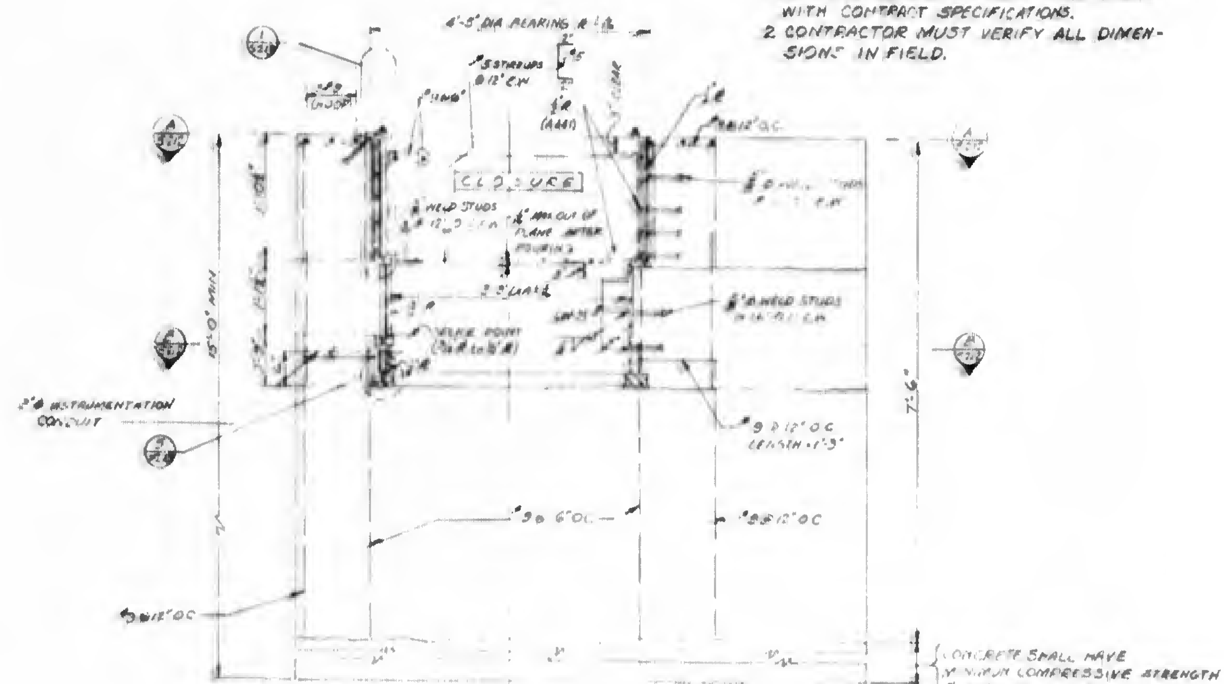


PLAN SECTION

1"=1'-0"

GENERAL NOTES

1. ALL MATERIALS & WORKMANSHIP SHALL COMPLY WITH CONTRACT SPECIFICATIONS.
2. CONTRACTOR MUST VERIFY ALL DIMENSIONS IN FIELD.



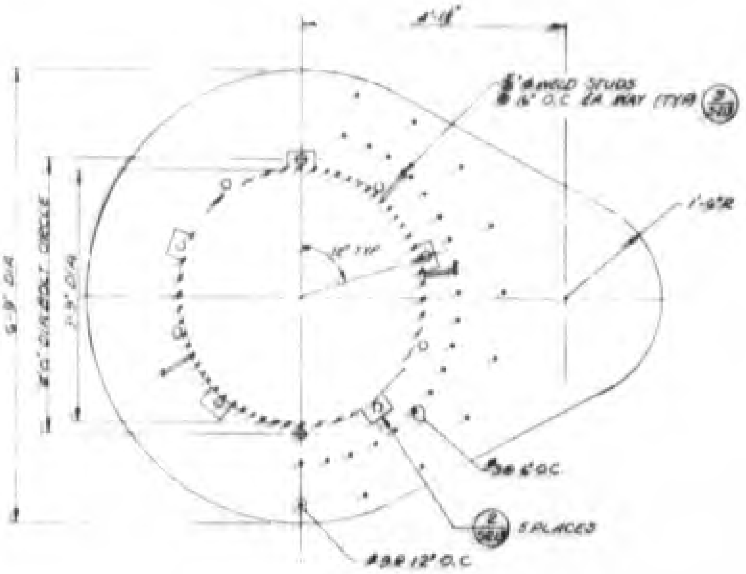
SECTION (C/5212)

1"=1'-0"

REVISIONS

STEEL NOTE

A



PLAN SECTION (B/S212)
1" = 1'-0"

GENERAL NOTES
1. ALL MATERIALS & WORKMANSHIP SHALL COMPLY WITH CONTRACT SPECIFICATIONS.
2. CONTRACTOR MUST VERIFY ALL DIMENSIONS IN FIELD

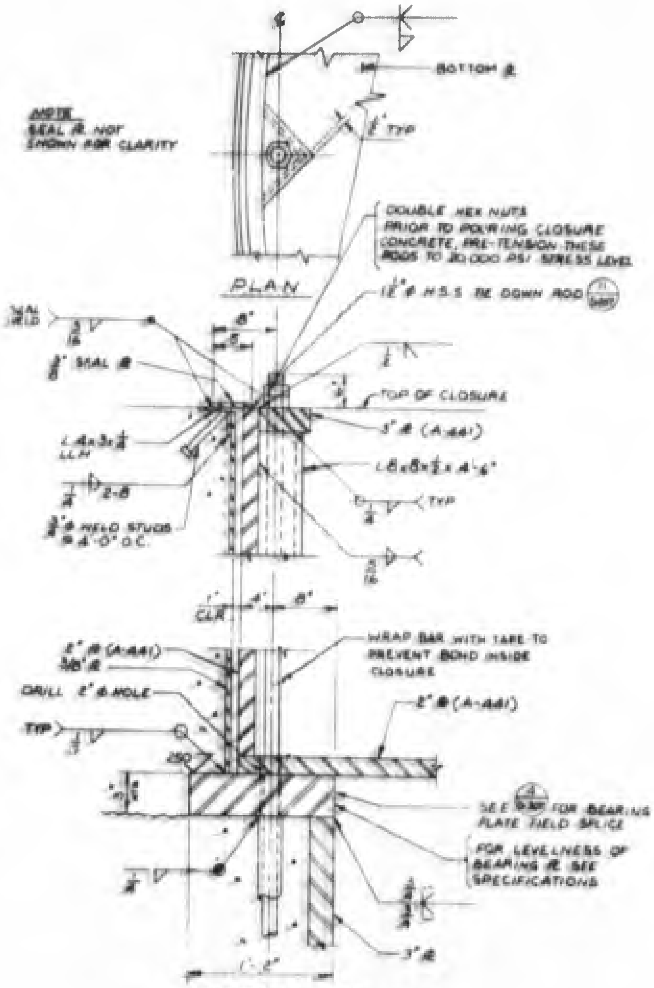
REINFORCED CONCRETE
1. ALL CONCRETE SHALL ATTAIN A COMPRESSIVE STRENGTH OF 6,000 PSI AT 28 DAYS UNLESS OTHERWISE SHOW ON DRAWINGS.
2. MINIMUM CLEAR COVER FOR REINFORCING STEEL SHALL BE AS FOLLOWS UNLESS OTHERWISE SHOWN ON THE DRAWINGS:
CONCRETE POURED AGAINST EARTH OR ROCK ——— 3"
ALL OTHERS ——— 2"
3. SPLICES SHALL BE IN ACCORDANCE WITH A.C.I. CODE, CODE 318-63 (SPLICES SHALL BE A MINIMUM OF 30 DIA)
4. DOWELS SHALL BE THE SIZE & SPACING AS THE MATCHING REBAR
5. ALL REBAR & ANCHOR BOLTS SHALL BE SECURED IN POSITION BEFORE CONCRETE IS POURED.
6. CHAMFER ALL EXPOSED CORNERS 3/4"
7. REINFORCEMENT SHALL CONFORM TO A.S.T.M A305 INTERMEDIATE GRADE.

STRUCTURAL STEEL
1. ALL STRUCTURAL STEEL SHALL CONFORM TO A.S.T.M A-36 UNLESS OTHERWISE NOTED.
2. STEEL FABRICATOR SHALL PROVIDE ANCHOR BOLT SETTING PLAN.
3. CLOSURE SIDE SHELL & BOTTOM PLATE SHALL CONFORM TO ASTM A-441 OR COR-TEN GRADE
4. WELD STUDS SHALL BE LOW CARBON STEEL HAVING MINIMUM YIELD STRENGTH OF 60,000 PSI & SHALL CONFORM TO ASTM A-108 OR GREATER
5. ALL FIELD SPLICES SHALL BE FULL PENETRATION BUTT WELDS UNLESS OTHERWISE NOTED.
6. WELDING SHALL CONFORM TO CONTRACT SPECIFICATIONS.
7. DESIGN, FABRICATION & ERECTION SHALL BE IN ACCORDANCE WITH THE LATEST AISC SPECIFICATIONS.

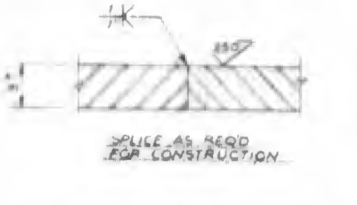
REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	[illegible]	STEEL [illegible]	[illegible]	[illegible]

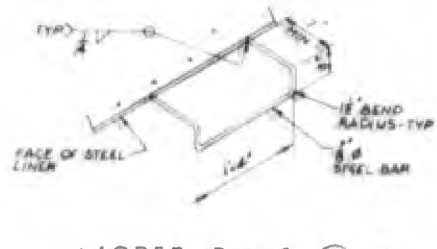
B



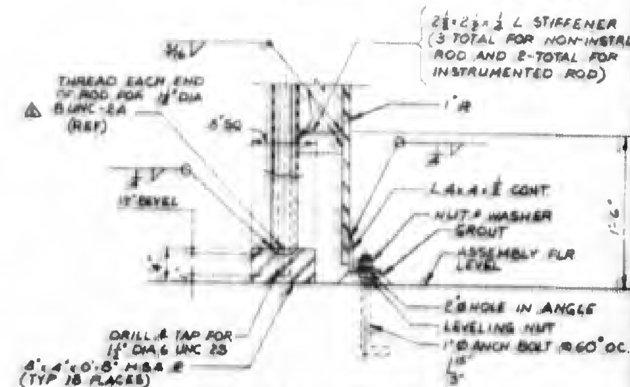
DETAIL 1 REF S-207 S-206
1½" = 1'-0"



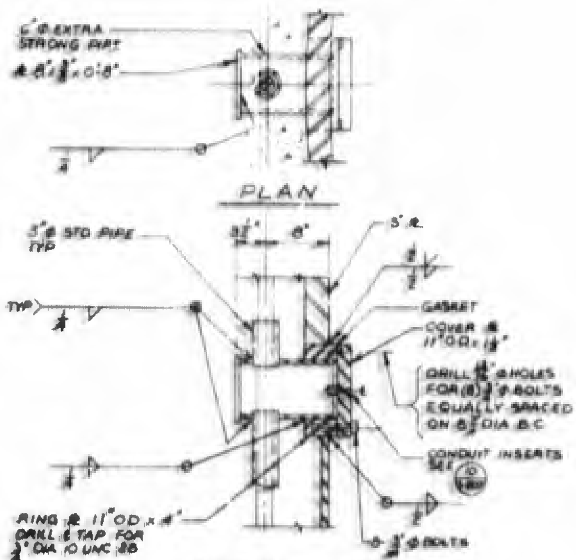
SPLICE DETAIL 4 S-207



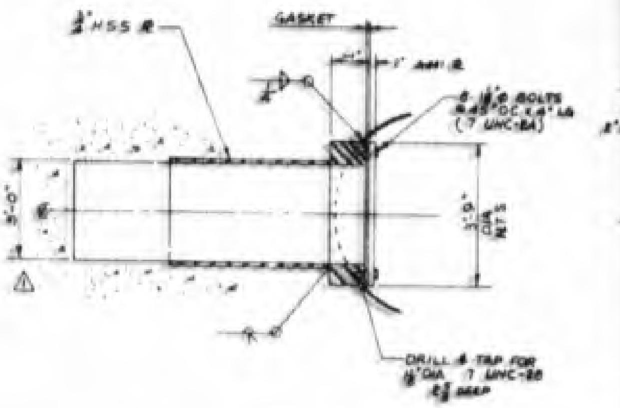
LADDER RUNG 5 S-207 REF S-206
N.T.S



DETAIL 6 S-207 REF S-206
1½" = 1'-0"

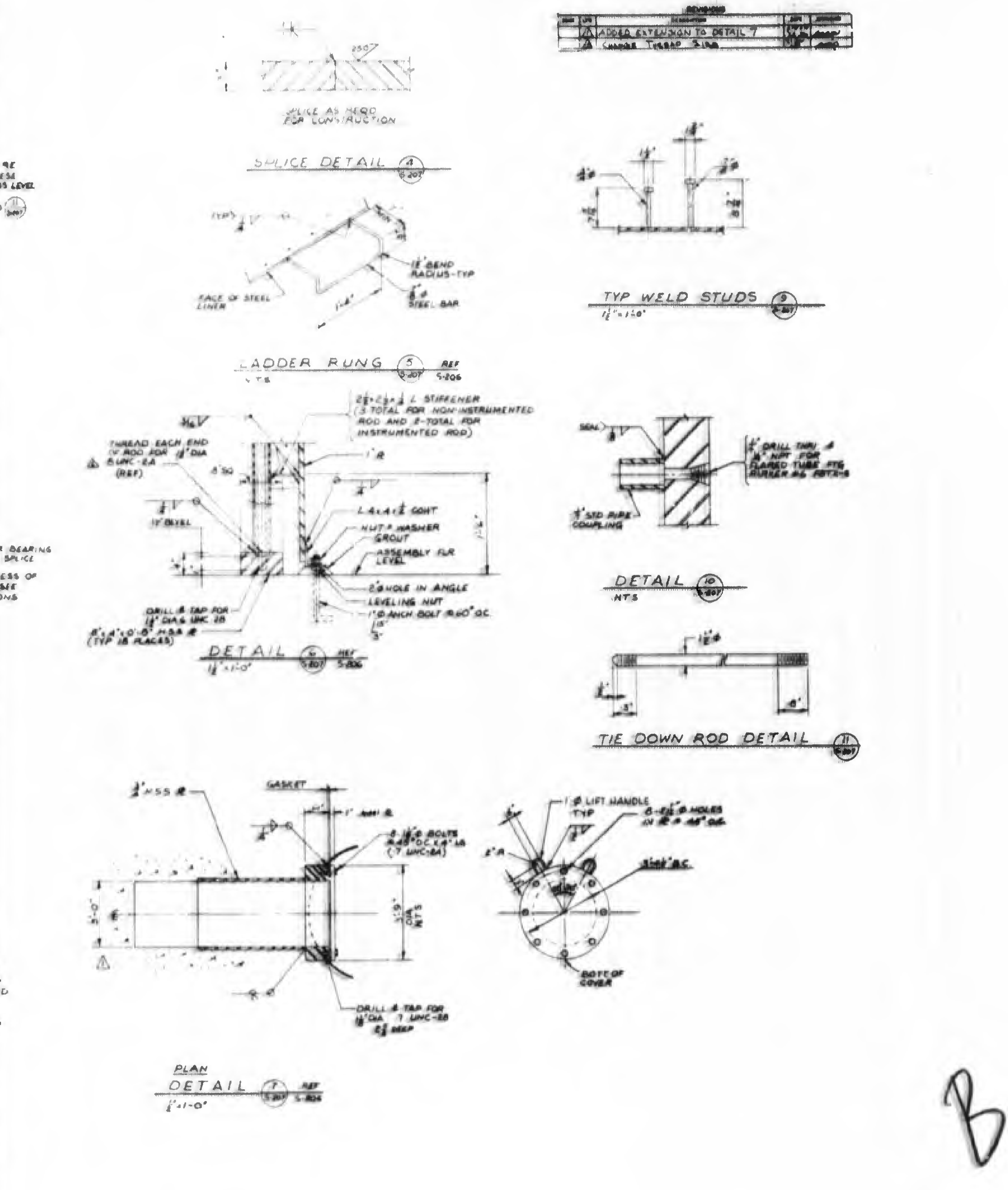


DETAIL 2 S-207 REF S-206
1½" = 1'-0"



PLAN
DETAIL 7 S-207 REF S-206
1" = 1'-0"

A



ADDED EXTENSION TO DETAIL 7
SPLICE DETAIL
LADDER RUNG
TYP WELD STUDS
DETAIL
TIE DOWN ROD DETAIL
PLAN
DETAIL

III-17

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) The Ralph M. Parsons Company 617 W. 7th Street Los Angeles, CA 90017	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

DESIGN AND CONSTRUCTION OF A TEST FACILITY TO SIMULATE THE EFFECTS OF A NUCLEAR DETONATION (ROCKTEST I)

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

June 1968 through January 1969

5. AUTHOR(S) (First name, middle initial, last name)

Howard L. Taylor

Donald C. Phillips

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
May 1970	122	19

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10. DISTRIBUTION STATEMENT This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of AFWL (WLCD), Kirtland AFB NM 87117. Distribution is limited because of the technology discussed in the report.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY AFWL (WLCD) Kirtland AFB, NM 87117

13. ABSTRACT

(Distribution Limitation Statement No. 2)

A method of simulating the effects of the static pressure of the airblast and airblast-induced ground motions was developed by Air Force Weapons Laboratory, and was designated High Explosive Simulation Technique (HEST). Proposed construction of new, more hardened weapon systems in rock sites made it desirable to apply the HEST method to full size and 1/4 scale models of missile facilities located in rock. This report describes the design and construction of this first ROCKTEST facility which covered a plan area of 160 by 208 feet. Design criteria are presented, some unique construction methods used are described, recommendations are made for application to future similar projects, and a complete set of design drawings and construction photographs is included.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Hardrock Silo Program HEST Silo closures Explosive instrumentation						