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TECHNICAL REPORT NO. 67-17

FINAL REPORT, PROJECT VT/6701
LASA LP SYSTEM

GEOTECH
A TELEDYNE COMPANY

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FINAL REPORT, PROJECT VT/6701
LASA LP SYSTEM

by

M. G. Gudzin
and
F. M. Hennen

The work reviewed in this report was sponsored by the Advanced Research Projects Agency (ARPA), Nuclear Detection Office, ARPA Order No. 599. This research was supported by ARPA under Project VELA-Uniform and accomplished under the technical direction of the Air Force Technical Applications Center under Contract No. AF 33(657)-15190.

GEOTECH
A TELEDYNE COMPANY
3401 Shiloh Road
Garland, Texas

20 April 1967

IDENTIFICATION

AFTAC Project No. VELA T/6701
Project Title: LASA LP System
ARPA Order No. 599
ARPA Program Code No. 8100
Contractor: Geotech, A Teledyne Company
Garland, Texas
Contract No. AF 33(657)-15190
Date of Contract: 1 August 1965
Date of Supplemental Agreement No. 1: 27 July 1966
Date of Supplemental Agreement No. 2: 21 November 1966
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ABSTRACT

During the time period from August 1965 to October 1966, a set of three-component long-period instrumentation was added to each subarray of the Montana LASA. The instrumentation, which provides analog signals to the existing data handling and telemetry system of the LASA, consists of three LP seismometers housed in an underground concrete vault and a three-channel, solid-state parametric amplifier located in the Central Telemetry Housing at each subarray. Equipment for interconnection of the instrumentation, lightning protection, and remote adjustments to the seismometers was installed. During the installation, each set of instrumentation was calibrated. This report briefly describes the instrumentation, the installation and calibration procedures, and the problems encountered during the installation of the LASA LP system.

FINAL REPORT, PROJECT VT/6701
LASA LP SYSTEM

1. INTRODUCTION

1.1 GENERAL

This is a final report of the work done by Geotech, A Teledyne Company, to provide a long-period (LP) seismic signal acquisition capability to the Large Aperture Seismic Array (LASA) in Montana. The work was accomplished under Contract AF 33(657)-15190, Project VT/6701, with the technical supervision of the Air Force Technical Applications Center (AFTAC) under the overall direction of the Advanced Research Projects Agency (ARPA). All work was coordinated with representatives of the Massachusetts Institute of Technology (MIT) Lincoln Laboratory, who were responsible for the development and operation of the Montana LASA. This report includes a description of the equipment provided, a summary of the installation procedure, a preliminary evaluation of the equipment, a review of the problems encountered during installation of the system, and recommendations for improvements to the system. It is submitted in compliance with contractual requirements outlined in the Statement of Work for the subject contract. Reproductions of the Statement of Work and the supplemental agreements amending it are presented in appendix 1.

1.2 PREPARATORY WORK

Work directed toward the development of improved installation techniques for the LASA LP system was conducted at LASA Subarray F3 (Hysham, Montana) from April until September 1965. This work is described in appendix 2.

1.3 TIME SCHEDULE

Work under the LASA LP System contract was begun during the first week in August 1965. Detailed planning of the work to be accomplished in the program was initiated, and material procurement and instrument manufacture were begun. During September a field depot was established in Miles City, Montana, and selection and preparation of the LP sites were begun. The manufacture, procurement, and testing of the major components were completed by 30 April 1966 and they were shipped from Garland, Texas, by commercial padded van to the Miles City field depot, arriving on 8 May 1966. Installation and calibration of the entire LASA LP System were complete by 21 October 1966 and an acceptance inspection by the Project Officer was conducted immediately. The time schedule is summarized in table 1-1.

2. DESCRIPTION OF THE SYSTEM

2.1 GENERAL

The objective of the LASA is to provide improved capability for discrimination between nuclear explosions and earthquakes. The large number of sensors and the large apertures provided by the array design promise a significant reduction in seismic noise and a consequent significant increase in signal-to-noise ratios when array-processing techniques are applied. As originally constructed, the LASA signal acquisition system consisted of 525 short-period (SP) seismometers spread over an area of 30,000 square kilometers in southeastern Montana. Although the climate of this area is characterized by cold winters, hot dusty summers, and frequent lightning storms and turbulent winds in the spring and early summer, the area offers the advantages of being sparsely populated and of fairly uniform geological structure. The center of the array is about 25 miles northwest of Miles City. The 525 SP seismometers are grouped into clusters of 25, forming 21 subarrays located as shown in figure 2-1. At the center of each subarray telemetry equipment is housed in an underground concrete vault called a Central Telemetry Housing (CTH). This equipment receives the amplified data from the 25 SP seismometers, digitizes it, and transmits it to the LASA Data Center in Billings, Montana.

2.2 PURPOSE

The purpose of the LASA LP System, Model 26500-01, is to expand the detection capabilities of the LASA by providing an additional frequency spectrum of data. The short-period data acquisition system provides data in the frequency range of approximately 0.1 to 10 hertz. The LP system provides data in the range from 0.005 to 0.1 hertz. One set of LP instrumentation is installed at the central site of each of the 21 subarrays as illustrated in figure 2-2.

2.3 CAPABILITIES

The following information describes the capabilities of the LP system.

Input	The vertical, north-south, and east-west components of earth motion are sensed

Table 1-1. Time schedule - long-period LASA in Montana

1. Planning
2. Establish and operate a field depot
3. Operate a prototype system in Garland, Texas
4. Select and prepare sites
5. Manufacture and test major components
6. Install instrumentation
7. Inspection by the Project Officer
8. Prepare and submit reports

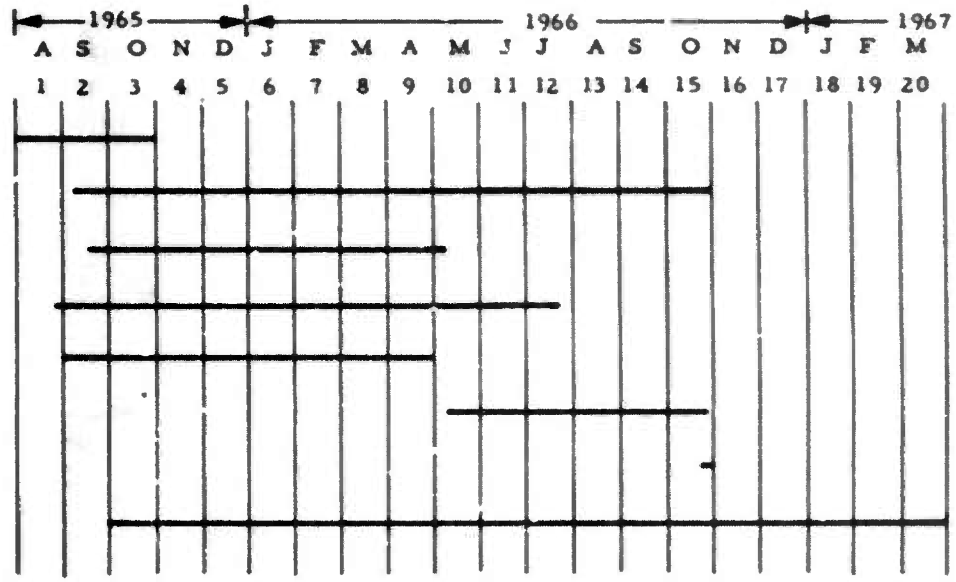
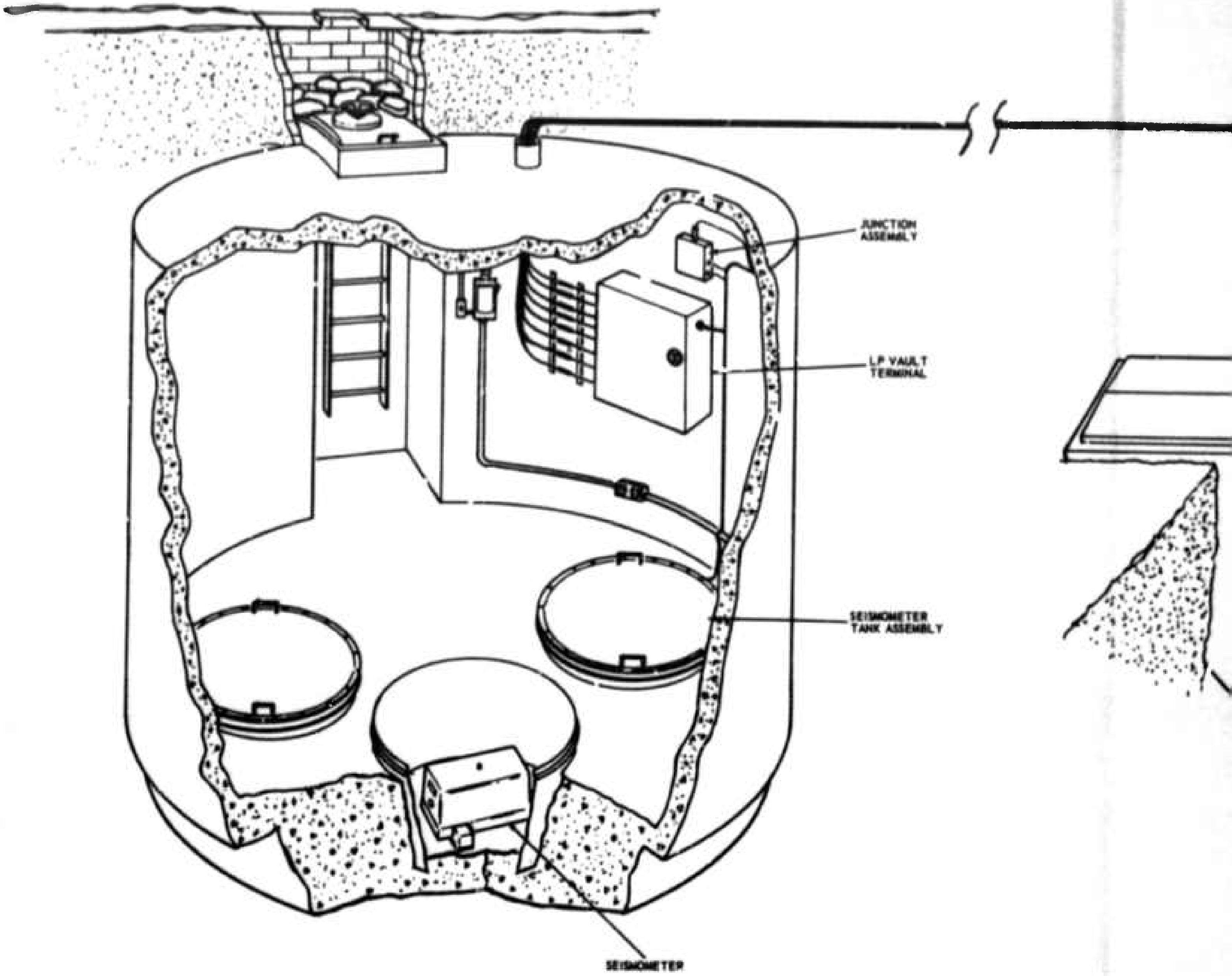


Figure 2-1. Map of the LASA subarray system G 1967


JUNCTION ASSEMBLY
LP VAULT TERMINAL
SEISMOMETER TANK ASSEMBLY
SEISMOMETER

LP VAULT

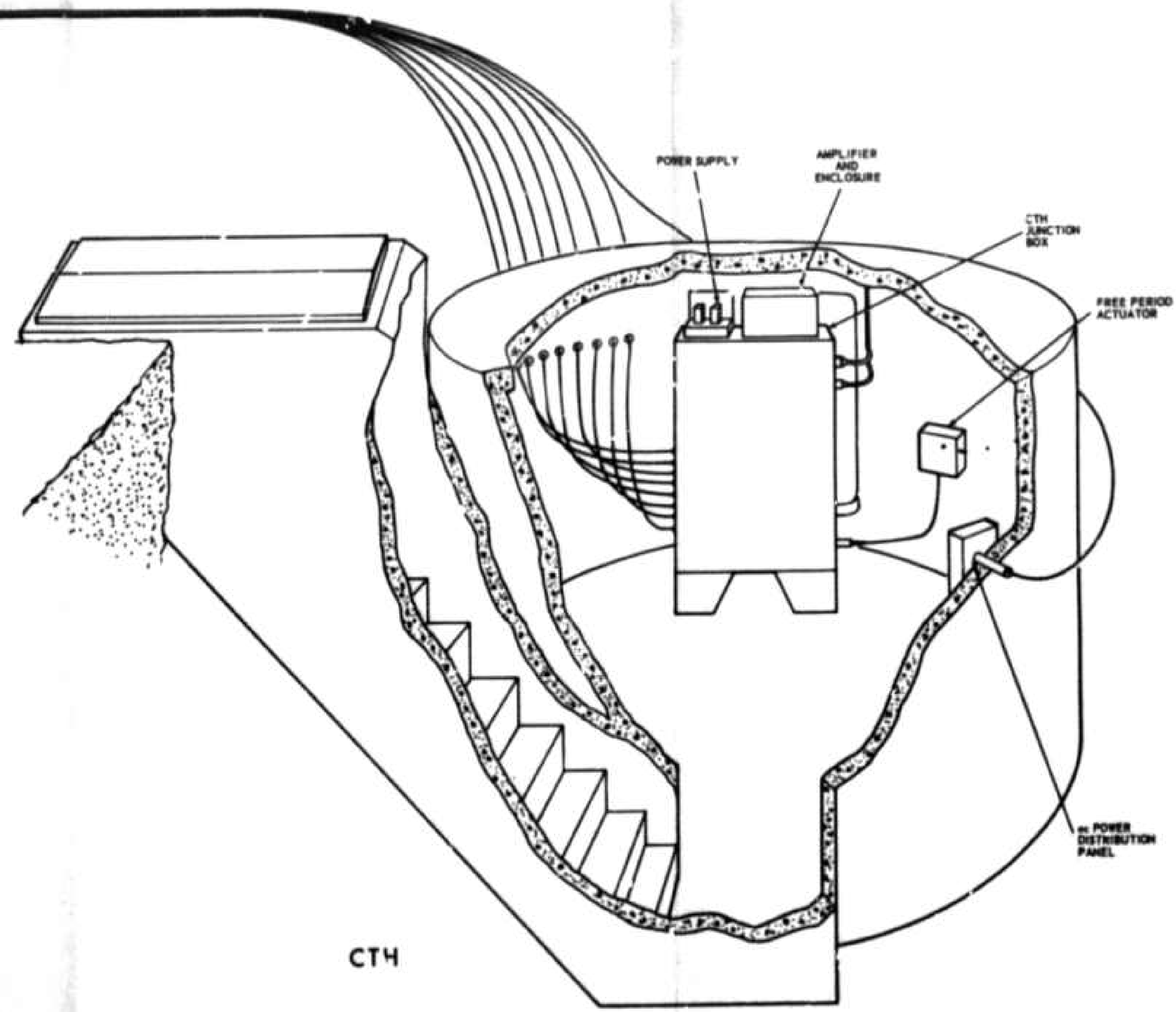


Figure 2-2. LP instrumentation at a typical subarray of the LASA

G 2183

2

Output	Each channel produces a voltage analog of the earth motion sensed. Maximum channel output is 56 V p-p
Sensitivity (overall system)	1500 mV/μ at 25 sec, "A" response 320 mV/μ at 45 sec, "B" response
System noise	Equivalent to less than 30 mμ of earth motion at a period of 25 sec
Environmental characteristics	As installed in underground vaults, the system will operate when outdoor temperatures range from below -40°C to above +45°C

2.4 POWER REQUIREMENTS

The power requirements for the LP instrumentation at each subarray are:

Ac power	100 mA, 115 V, 60 Hz (during normal operation)
	20 A, 115 V, 60 Hz (during calibration and maintenance)
Dc power	1 A, 30 V (during calibration)

2.5 EQUIPMENT SUPPLIED

Table 2-1 lists the major pieces of equipment in the LP system.

Table 2-1. Major equipment furnished

Quan	Name	Supplier or manufacturer	Model or part No.	Function
21	Vertical seismometer	Geotech	7505B	Vertical motion sensor
42	Horizontal seismometer	Geotech	8700D	Horizontal motion sensor
105	Remote centering and period adjusting device	Geotech	14495-M1	Mass position and free period control

Table 2-1, Continued

Quan	Name	Supplier or manufacturer	Model or part No.	Function
63	Junction assembly	Geotech	14415-02	Seismometer damping control
21	Power supply	Geotech	25982-01	Amplifier power
21	Amplifier	Texas Instruments	Type II	Signal conditioning
21	Free-period actuator	Geotech	25557-01	Remote seismometer damping control
21	Amplifier enclosure	Geotech	26792-01	Magnetic shield for amplifier
21	Bracket assembly	Geotech	25606-01	Mount, amplifier power supply
21	LP vault terminal	Geotech	26934-01	Interconnecting junction
21	Long-period protector	Geotech	25515-01	Lightning protection
21	Long-period vault	Stormaster Shelter Corp.	24791	Equipment housing
21	Vault cover	Texas Tank	24801	Vault entry, LPV
21	Enclosure cover	Novelty Designs	113-1	Protective cover, LPV
63	Seismometer Tank assembly	Texas Tank	23232A	Seismometer housing

2.6 OPERATION

The following is a brief description of the operation of the LP signal acquisition system. Detailed descriptions may be found in the LASA LP Construction Manual, the Operation and Maintenance Manual, LASA LP System, Model 26500-01, and the various operation and maintenance manuals pertaining to individual instruments within the system.

The block diagram, figure 2-3, shows all the major components of the LP instrumentation at a typical subarray of the LASA. In the figure, the components are divided into three sections: the LP vault group, shown on the left; the field cables, in the center; and the CTH group, on the right.

The LP vault group consists of the seismometers and the associated equipment necessary to adjust, calibrate, and house the seismometers. The seismometers, 1 Model 7505B long-period vertical seismometer and 2 Model 8700D long-period horizontal seismometers, are oriented to sense the vertical, north-south, and east-west components of earth motion. Each is equipped with three coils: a high-impedance data coil, a calibration coil, and a damping coil. The data coil impedance is high to optimize the seismic signal-to-source resistance thermal noise ratio. Each seismometer contains a mass position monitor which permits remote observation of the position of the inertial mass. If the mass drifts beyond a prescribed limit, it can be returned to proper position by a remotely controlled centering device. Another device attached to each seismometer permits adjustment of the free period from the CTH. The damping of each seismometer, which must be reduced for a free period check, is controlled by a junction assembly. Each seismometer is installed in a separate metal tank embedded in the floor of an underground concrete vault (LP vault). The metal tanks are sealed to prevent changes of atmospheric pressure from affecting the performance of the seismometers. Fiberglass insulation around each seismometer, together with the insulating blanket of earth over the LP vault, prevents rapid changes of temperature from reaching the seismometers. The LP vault terminal provides the connection between the vault wiring harnesses and the field cables.

Buried field cables interconnect the LP vault and CTH at each subarray. This group consists of six type PE-23 cables, two No. 4-TW stranded ground conductors, and one No. 10 AZUF power cable.

The LP equipment housed in the CTH at each subarray consists of the data amplifier, a power supply, an amplifier enclosure, remote controls for the seismometer adjustments, and lightning protection for the LP circuits entering the CTH. The amplifier used in the LASA LP system is the Multichannel Parametric Amplifier, Type 11, manufactured by Texas Instruments Inc. This amplifier is a three-channel, solid-state device utilizing plug-in filter cards to control frequency response. Each amplifier data channel is equipped with a 24 dB/octave high-cut filter to provide a system response peaked at 0.04 hertz and a 36 dB/octave high-cut filter for a system response peaked at 0.022 hertz. In addition, eleven broadband (12 dB/octave high-cut) filters were furnished under this contract for experimental purposes. A separate power supply provides ±18 Vdc to the amplifier. The amplifier, if unprotected, is affected by changes in the temperature or the magnetic field surrounding it. To reduce these effects, the amplifier is installed in an enclosure that provides both thermal and magnetic shielding. The LP protector provides lightning protection and termination for the LP field cables entering the CTH.

It also provides terminal points at which the amplified LP data are connected to the input to the SEM. The free period actuator is a device for operating the junction assemblies from the CTH.

The LASA LP system includes two sets of portable service and calibration equipment. Either set will perform at any LP site, and is used for determination and control of the system parameters. The two basic instruments of each set are a control-monitor unit and a service recorder. The control-monitor unit controls the mass position and free period adjusting devices attached to each seismometer, contains the mass position monitor indicator, and provides an adjustable amplitude and frequency source for electromagnetic calibration of each channel of the LP instrumentation. The service recorder is used to monitor the LP data during system adjustments. To facilitate the connection of the control-monitor unit and the recorder, service receptacles are installed in the CTH junction box at each subarray. The remainder of each set of portable service equipment consists of an oscilloscope, a dc microvolt-ammeter, a VOM, a VTVM, a megohmmeter, and a pair of field phones.

3. INSTALLATION

3.1 SITE SELECTION

The LP vault was located within the 150-foot square, fenced area containing the CTH at each subarray except F3. The vault at F3 was built prior to the beginning of Project VT/6701 and was placed near an existing surface LP installation as a part of the preliminary evaluation program. At the remaining 20 subarrays the vault location within the fenced area was governed by the following criteria:

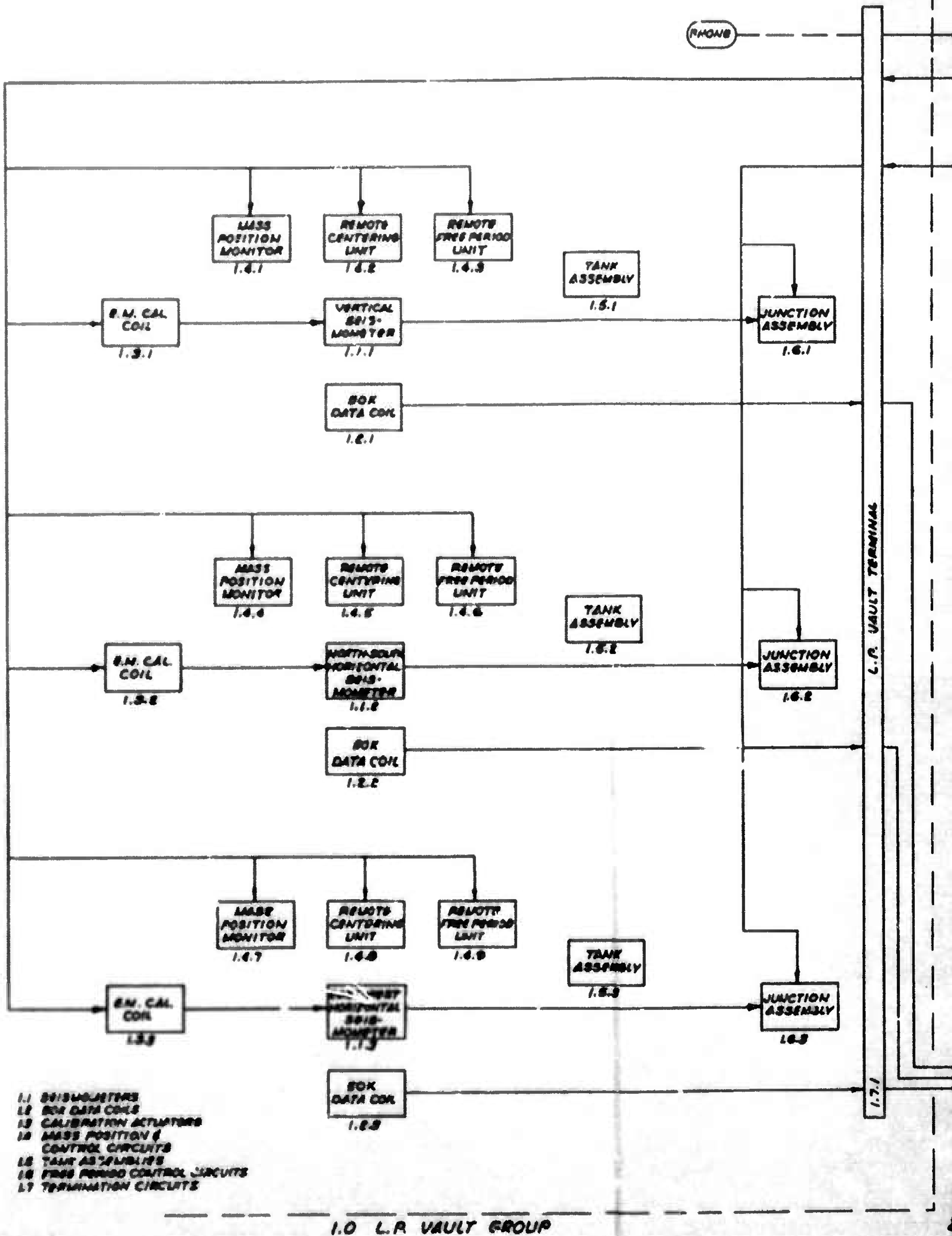
a. The minimum distance between the LP vault and the CTH was 75 feet.

b. The maximum practical separation was provided between the LP vault and probable noise sources, such as power poles, and fences.

c. Excavation in areas containing underground cables was avoided.

d. Where possible, locations were chosen to utilize existing surface drainage.

Application of these criteria permitted selection of 1 preferred location and 1 alternate location at each subarray. In every case, the LP vault was installed at the preferred location. Following site selection by the Geotech representative, locations were reviewed and approved by a representative of MIT. Appendix 3 contains plats showing the location of all major items within each central area.



PHONE
MASS POSITION MONITOR
1.4.1
REMOTE CENTERING UNIT
1.4.2
REMOTE FREE PERIOD UNIT
1.4.3
TANK ASSEMBLY
1.5.1
E.M. CAL COIL
1.3.1
VERTICAL SEIS-MOMETER
1.1.1
JUNCTION ASSEMBLY
1.6.1
BOX DATA COIL
1.2.1
MASS POSITION MONITOR
1.4.4
REMOTE CENTERING UNIT
1.4.5
REMOTE FREE PERIOD UNIT
1.4.6
TANK ASSEMBLY
1.5.2
E.M. CAL COIL
1.3.2
NORTH-SOUTH HORIZONTAL SEIS-MOMETER
1.1.2
JUNCTION ASSEMBLY
1.6.2
BOX DATA COIL
1.2.2
MASS POSITION MONITOR
1.4.7
REMOTE CENTERING UNIT
1.4.8
REMOTE FREE PERIOD UNIT
1.4.9
TANK ASSEMBLY
1.5.3
E.M. CAL COIL
1.3.3
HORIZONTAL SEIS-MOMETER
1.1.3
JUNCTION ASSEMBLY
1.6.3
BOX DATA COIL
1.2.3
L.P. VAULT TERMINAL
1.7.1
1.1 SEISMOMETERS
1.2 BOX DATA COILS
1.3 CALIBRATION ACTUATORS
1.4 MASS POSITION & CONTROL CIRCUITS
1.5 TANK ASSEMBLIES
1.6 FREE PERIOD CONTROL CIRCUITS
1.7 TERMINATION CIRCUITS
1.0 L.P. VAULT GROUP

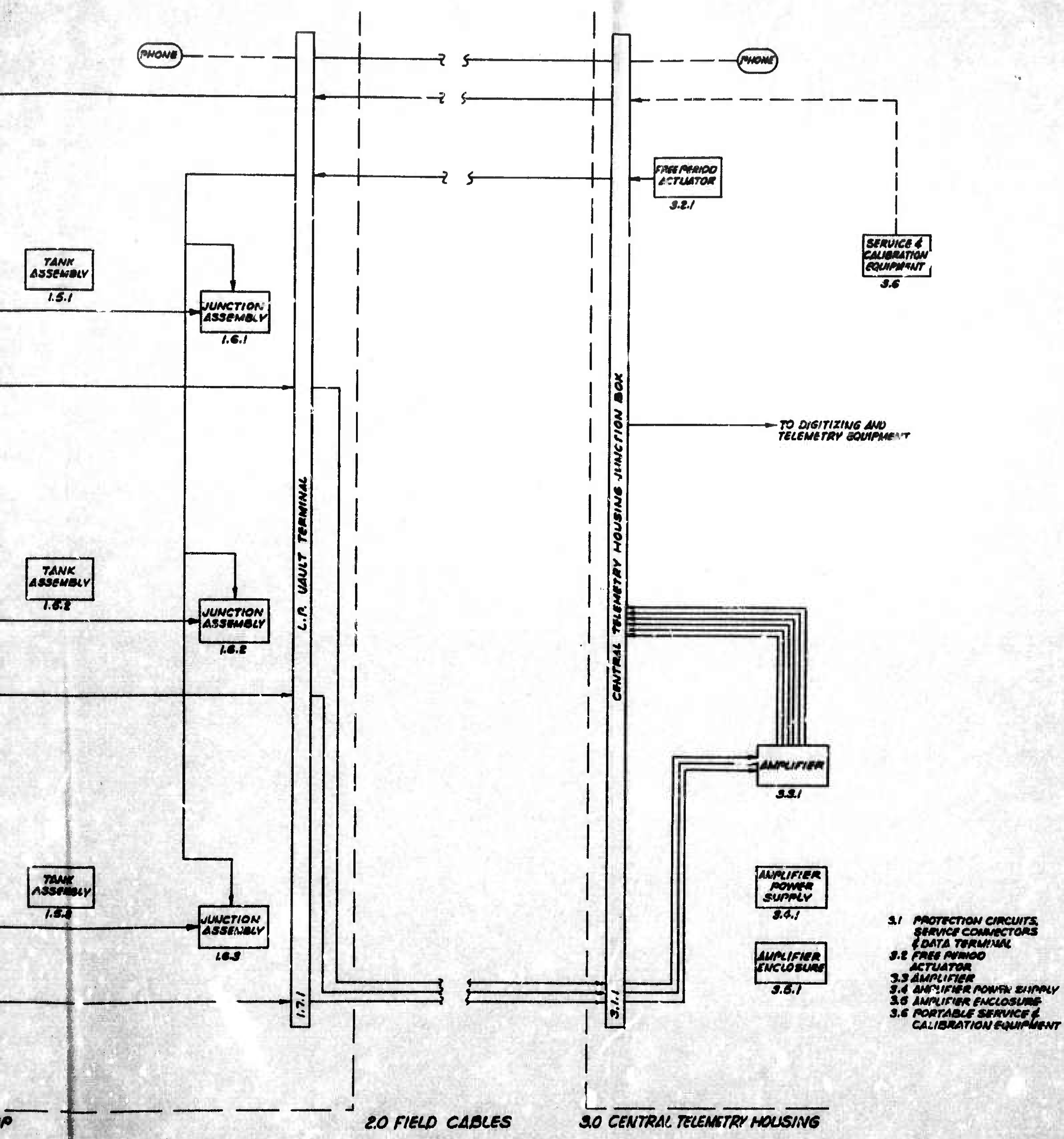


Figure 2-3. Block diagram, typical subarray LASA LP

G 1894

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3.2 CONSTRUCTION

Vault construction was accomplished by the Stormaster Tornado Shelter Corp. under the supervision of a Geotech representative. Vault construction details are given in figure 3-1. Excavation for the vaults, which were installed 4 feet below final grade level, was accomplished through the use of a small backhoe and hand tools. At several subarrays, excavation was impeded by hard materials. In these cases, pneumatic drills and dynamite were used to speed material removal. Figure 3-2 shows excavation in progress. The external surfaces of the vaults were formed by the excavation walls. The internal surfaces were shaped by steel forms, anchored in the excavation by steel foot-plates. Various form placement operations are shown in figure 3-3.

During the construction of the LP vaults, the vault design was evaluated by two independent consulting engineering firms. Both concluded that, according to accepted construction designs, the concrete vault lacked sufficient reinforcing. Both firms recommended alternate reinforcing designs. At the time of the evaluation, the vaults at 11 subarrays were already constructed. The recommended reinforcing design was incorporated into the final 10 vaults. Table 3-1 identifies the LP vaults with the reinforcing methods used during construction.

Table 3-1. Subarray grouping according to reinforcing method used

Group A			Group B		
B2	D3	F1	A0	C2	E2
B3	E1	F3	B1	D1	F2
C3	E3	F4	B4	D2	
C4	E4		C1	D4	

Vaults of Group A were reinforced in accordance with the normal practice of the Stormaster Shelter Corp. One thickness of paving mesh, 6 x 6 x 10/10 was used in vault walls and floor. Twenty 1/2-inch standard reinforcing rods were placed radially in the roof section and extended from the roof center to a point in the wall approximately 2-1/2 feet below the vault roof.

Vaults of Group B were reinforced in accordance with the design recommended by William L. Cobb Associates, Inc. (see appendix 4).

Except for the methods of reinforcing the concrete, 20 of the LP vaults are identical. The one vault that differs from the others is at subarray F3. This vault was constructed as a part of the preliminary evaluation program conducted under Contract AF 33(657)-12145. It differs from the other vaults as follows:

a. The vertical shaft serving as an entryway is larger and extends to within 2 inches of the surface of the surrounding terrain.

b. Two of the three seismometer tanks are isolated from the vault floor by a 2-inch annular gap.

c. The floor of the vault is only 8 inches thick. It does not have the 3-foot thick, kidney-shaped section that couples all three seismometer tanks in the other LP vaults.

d. It is located approximately 350 feet from the CTH.

At all subarrays except F3, three Tank Assemblies, Model 23232A, were embedded to a depth of 22 inches in a 3-foot thick section of the vault floor. Figure 3-1 gives dimensions and location of the tank assemblies. Figure 3-4 shows installation of the tank assemblies. For convenience and accurate location, the tank assemblies were supported during concrete placement by members attached to the internal concrete form.

All concrete was provided by the Miles City Ready Mix Co. Fine and coarse aggregates were washed and graded from natural gravel deposits in the Yellowstone River Basin. Portland cement, Type II, was provided by the South Dakota Portland Cement Co. Resistance of the concrete to damage due to freezing and thawing was increased through the addition of an air entraining agent. At low temperatures, calcium chloride was used to accelerate setting of the mixture. During the casting operation, the concrete was poured via chutes from the mixer trucks and was vibrated into place about the steel form (see figure 3-5).

All vaults were cast in cold weather, when temperatures ranged from -10°F to 55°F. The following protective measures were taken:

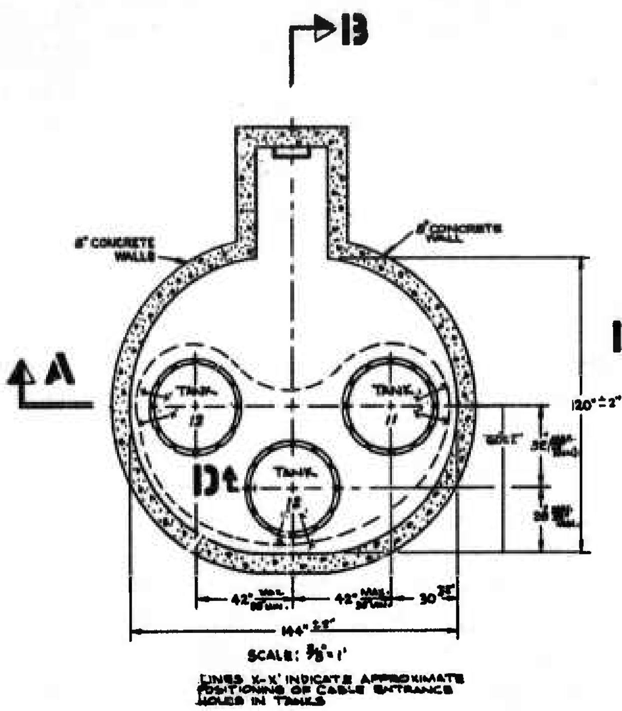
a. At temperatures lower than 45°F, warm water was used in the concrete mixture.

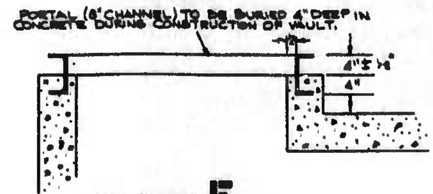
b. At temperatures lower than 35°F, calcium chloride was used to accelerate hydration.

c. At temperatures lower than 32°F, windbreakers were used during casting, and a protective covering of plastic and loose earth was placed over the finished surface.

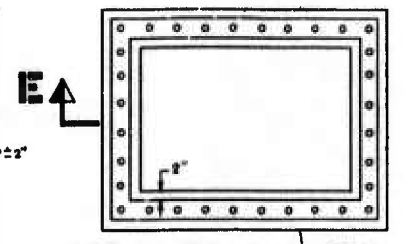
d. At temperatures lower than 15°F, a large tent was erected above the excavation prior to casting. The tent was heated by gasoline stoves until the heat of hydration increased the concrete temperature to 60°F. At that temperature, the heat of hydration was sufficient to sustain the setting process. Figure 3-6 shows the tent in place at subarray F2.

Two to three days after the concrete was placed, the internal form sections were stripped and removed through the vault entrance. After the vaults had dried, all grease and dirt were removed, imperfections repaired, and a coat of hydraulic cement paint applied to the interior surfaces.

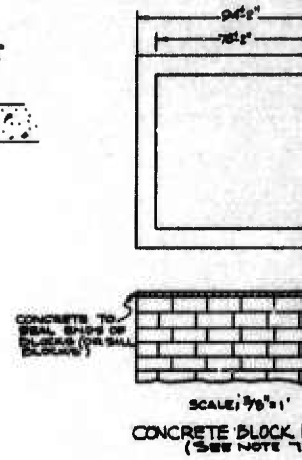




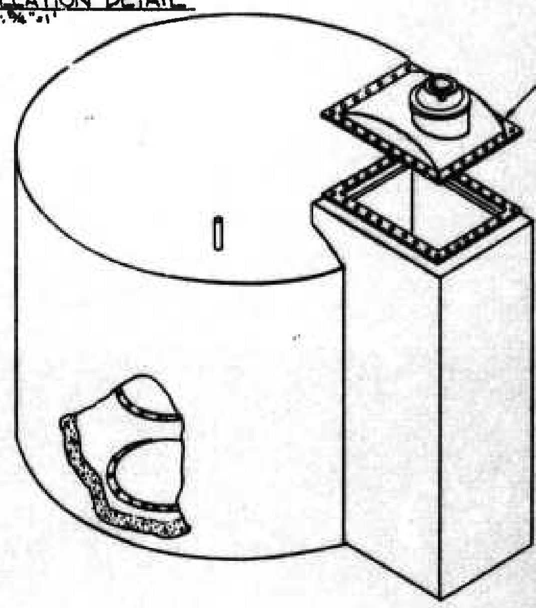
SECTION E

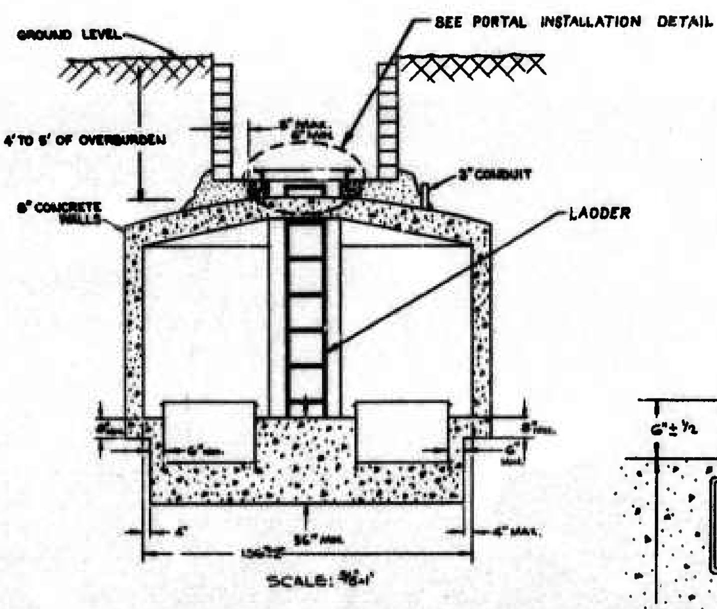


PORTAL INSTALLATION DETAIL

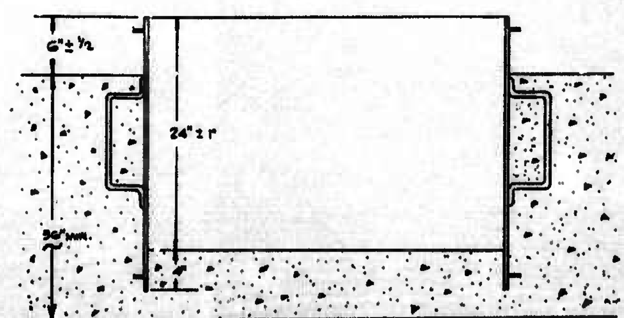


CONCRETE BLOCK





SECTION A



SECTION D

TANK BURIAL IN FLOOR OF VAULT

SCALE: $1\frac{1}{2}$" = 1'

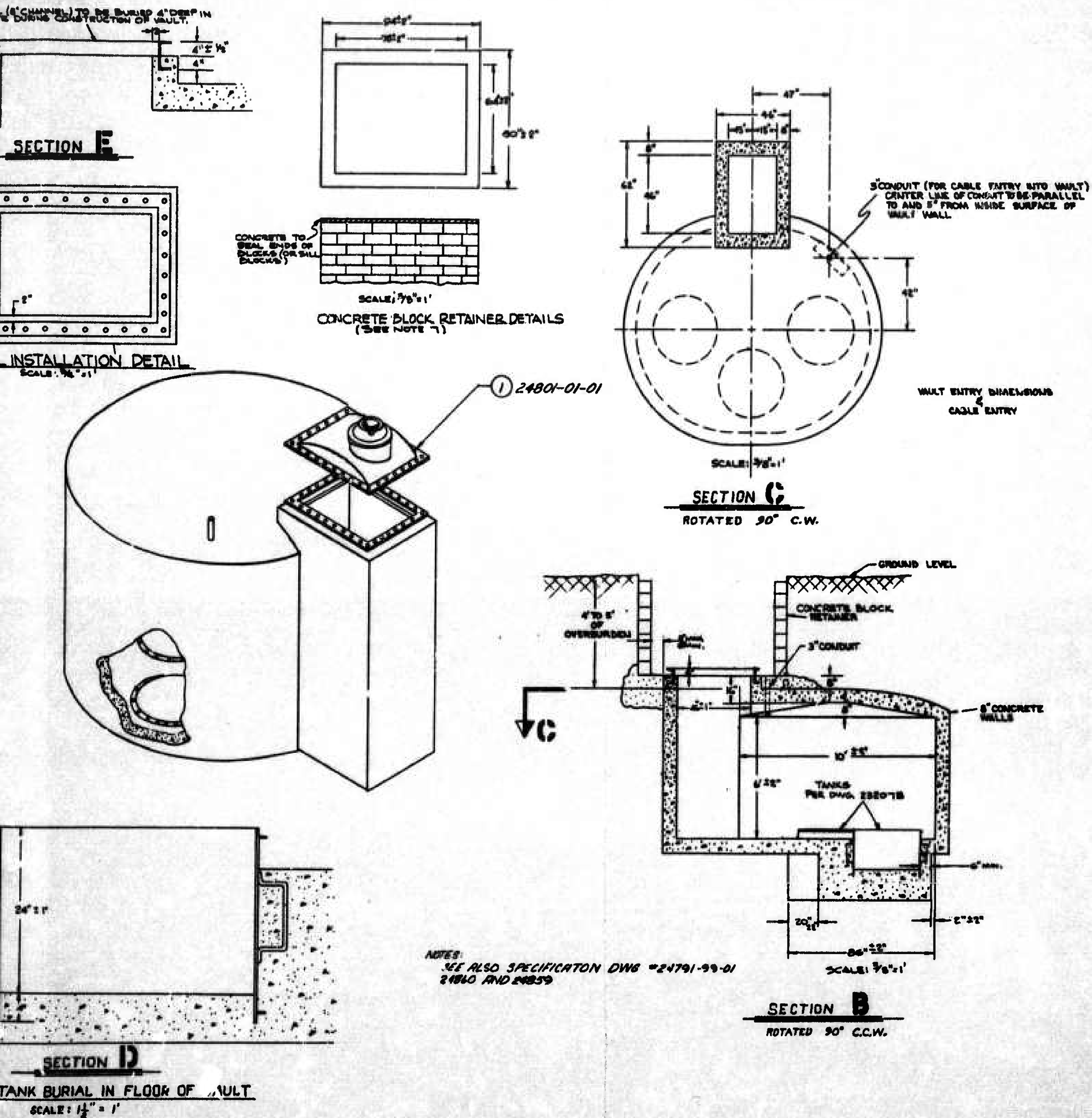


Figure 3-1. LP vault construction details

G 2512

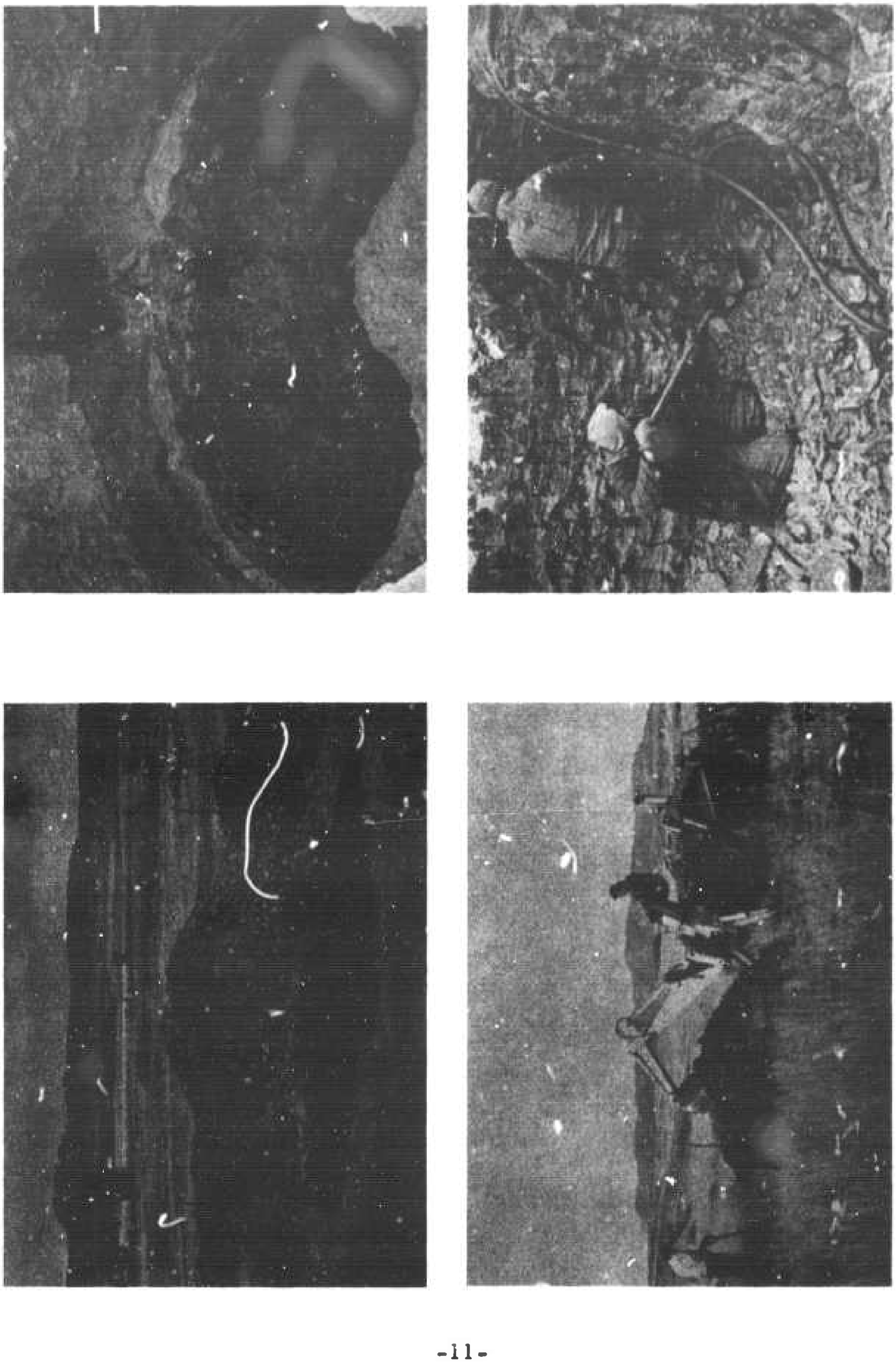


Figure 3-2. Vault excavation

G 2513

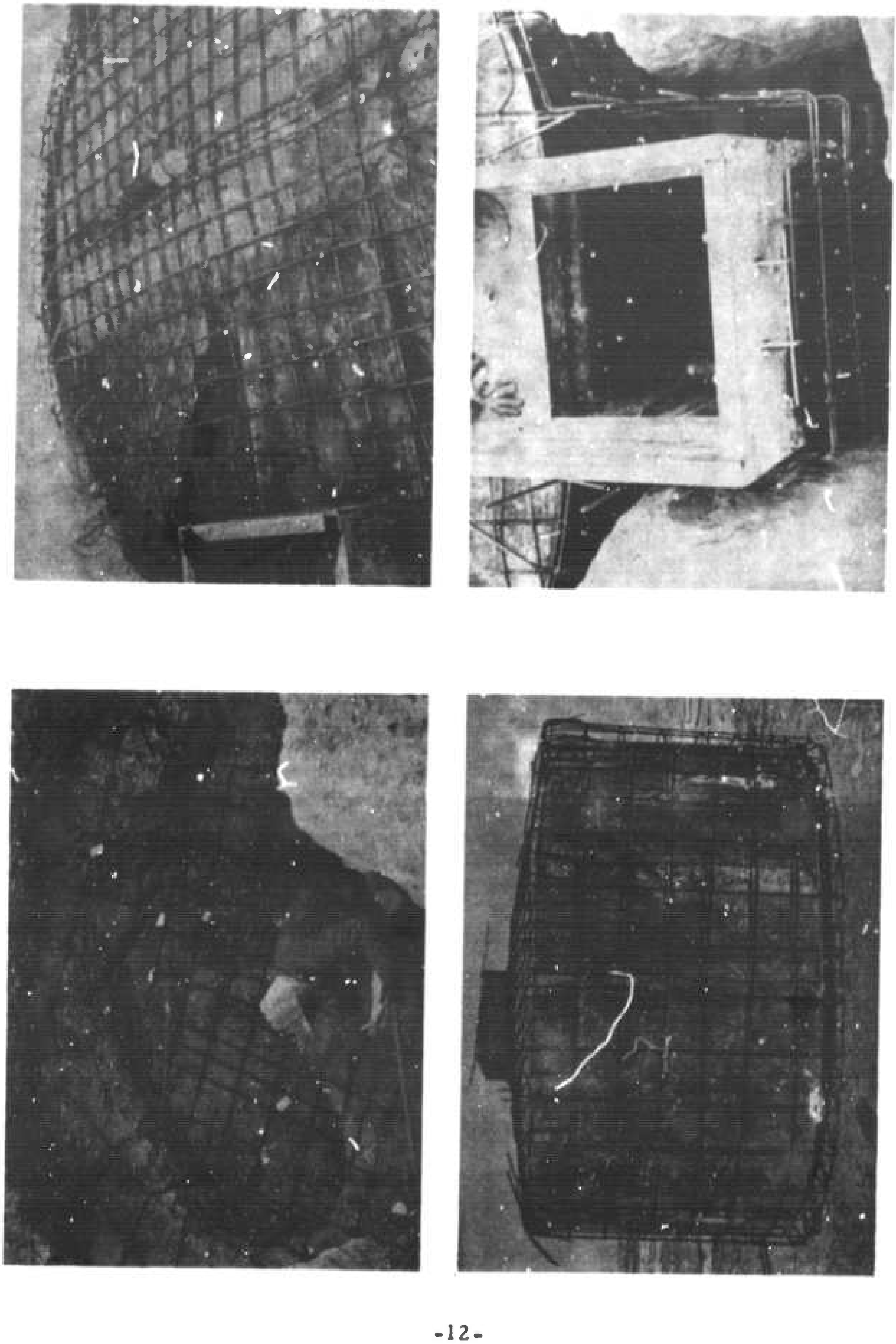


Figure 3-3. Vault casting forms

G 2514

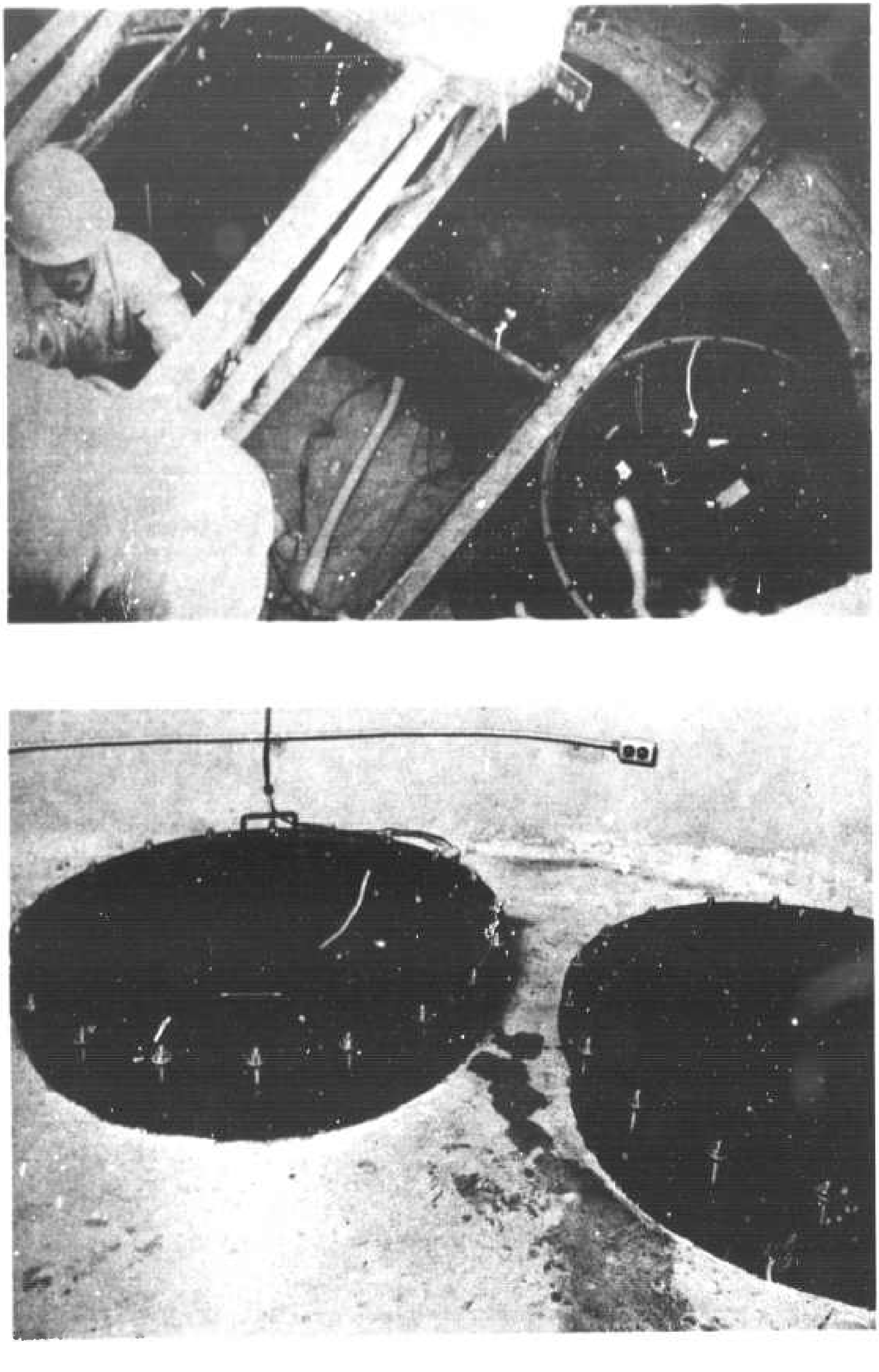


Figure 3-4. Installation of seismometer tanks

G 2515

Figure 3-5. Concrete placement operation

G 2516

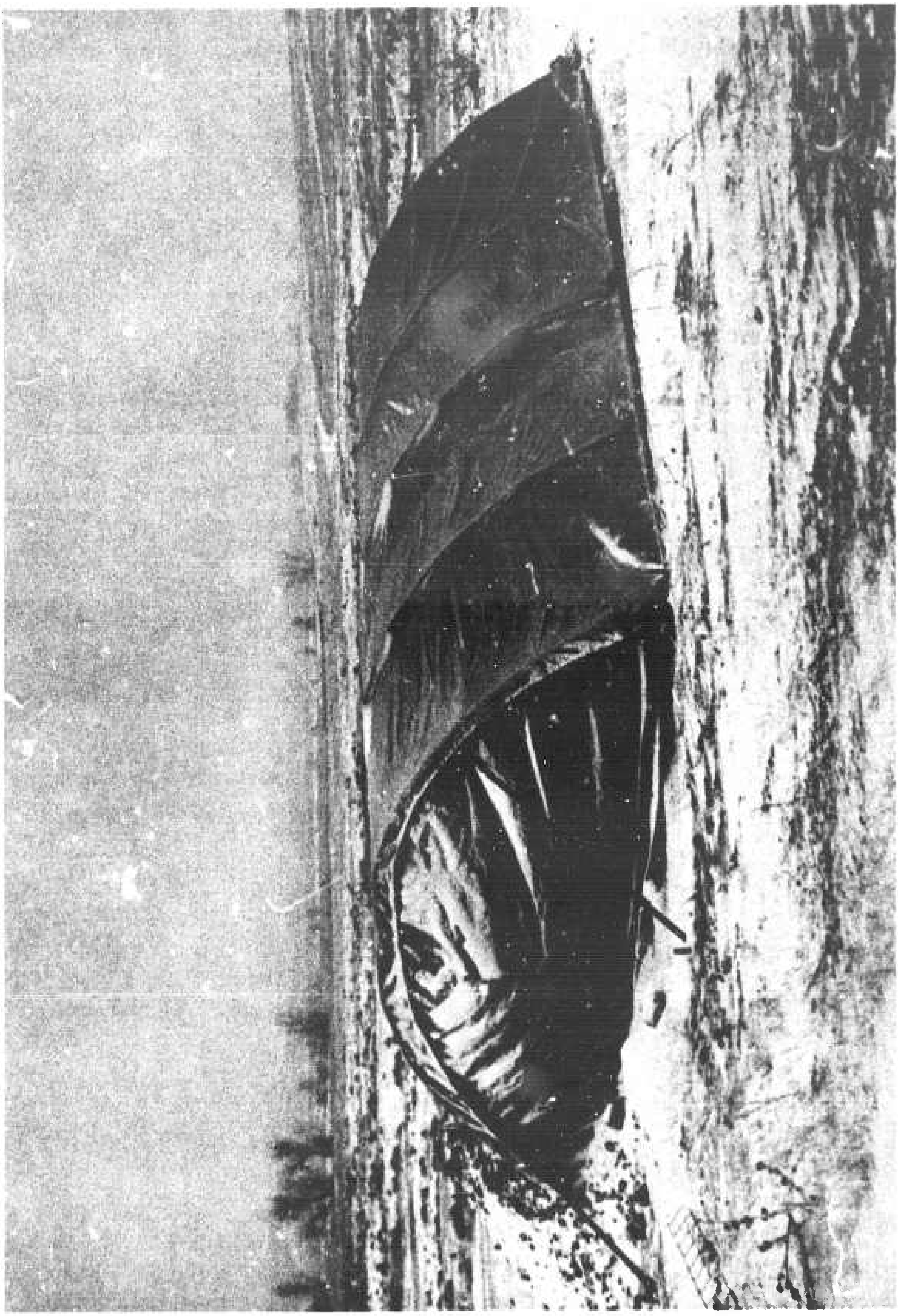


Figure 3-6. Protective tent in use at subarray F2

G 2517

The vault entry is protected by a 48-inch high retainer constructed of masonry blocks. A layer of washed sand placed beneath the retainer is used to minimize coupling between the retainer and the vault. Figure 3-7 shows the retainer construction in progress.

Following the retainer construction the vault cover, illustrated in figure 3-8, was bolted to a steel portal that was cast into the concrete, forming the vault entrance. The vault cover contains a 21-inch diameter marine scuttle to facilitate entry of personnel into the vault. The retainer cover was cemented with masonry mortar to the top course of blocks of the retainer. This cover, shown in figure 3-9, is made of wood and fiberglass.

The Construction Specifications, appendix 4, governed all construction for the LASA LP system. A Geotech representative performed inspections and tests to ensure conformance to these specifications. The concrete used in each vault was subjected to general inspection. Representative test cylinders were cast, shipped to Northern Testing Laboratories, Billings, Montana, and were broken in compression at ages 7 and 28 days. Results of these tests are given in appendix 5. Visual inspection ensured the use of proper mixtures and suitable materials. Six structural inspections were made during vault construction at each subarray. These were:

a. Inspection of excavation quality and dimensions;

b. Inspection of reinforcing steel, steel placement, form placement, and tank assembly location;

c. Inspection of interior surfaces and general workmanship following removal of forms;

d. Inspection of interior surfaces following repair of any existing blemishes;

e. General inspection following final finish;

f. Final inspection of structure, following installation of the retainer and retainer cover.

A field inspection certificate listing results of the inspections and comments about the construction was completed for each LP vault. This form is shown in appendix 6.

Field cable installation was accomplished by L. P. Anderson, Contractor, Inc., and was supervised by a Geotech representative. The field cables were entrenched from the LP vault to the CTH. The trench was 4 inches wide and 22 inches deep. A major portion of the trenching was done by a mechanical ditcher. In areas containing previously entrenched cables excavation was done by hand. Cable trenching operations are shown in figure 3-10.

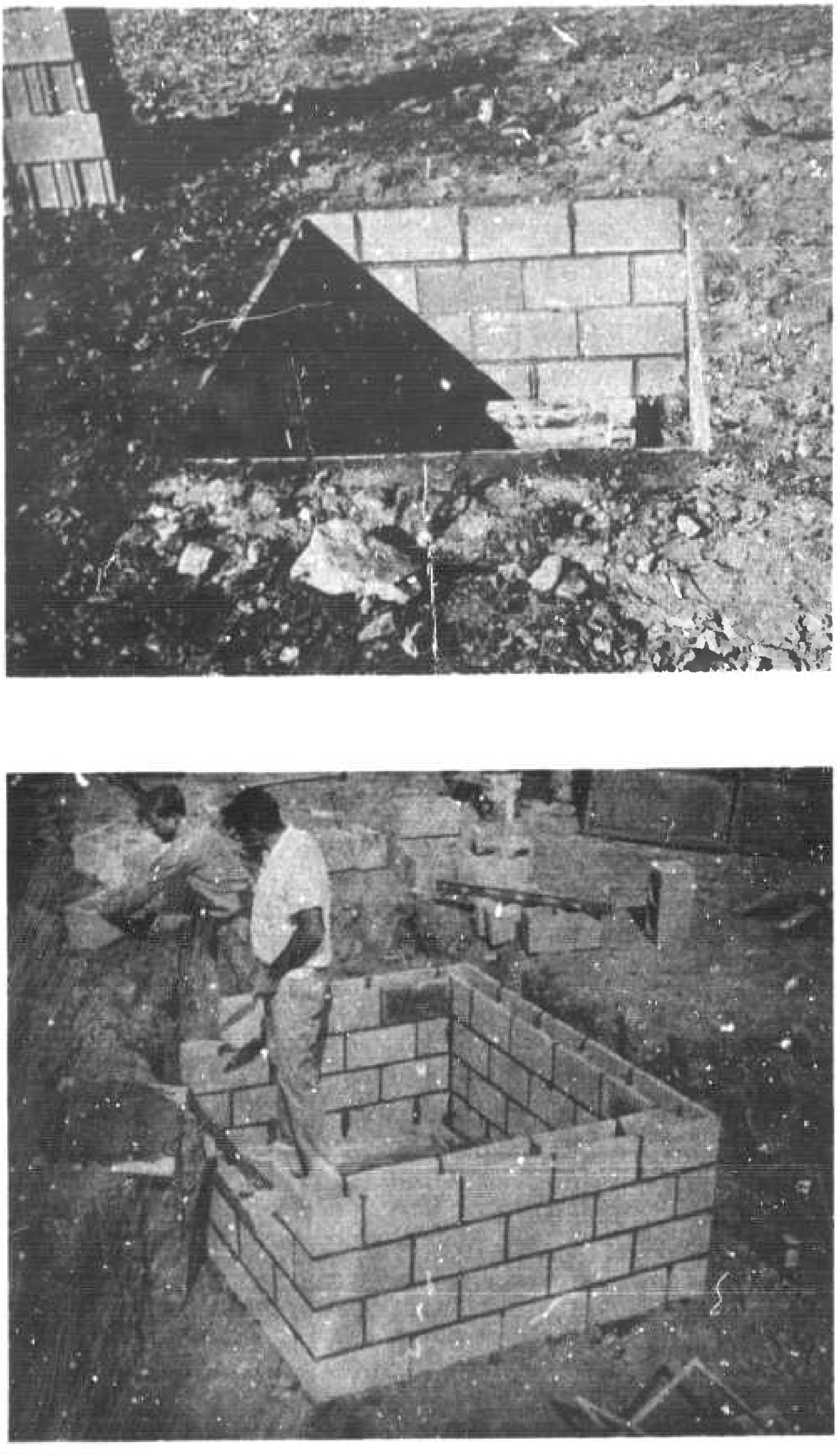


Figure 3-7. Retainer construction

G 2518

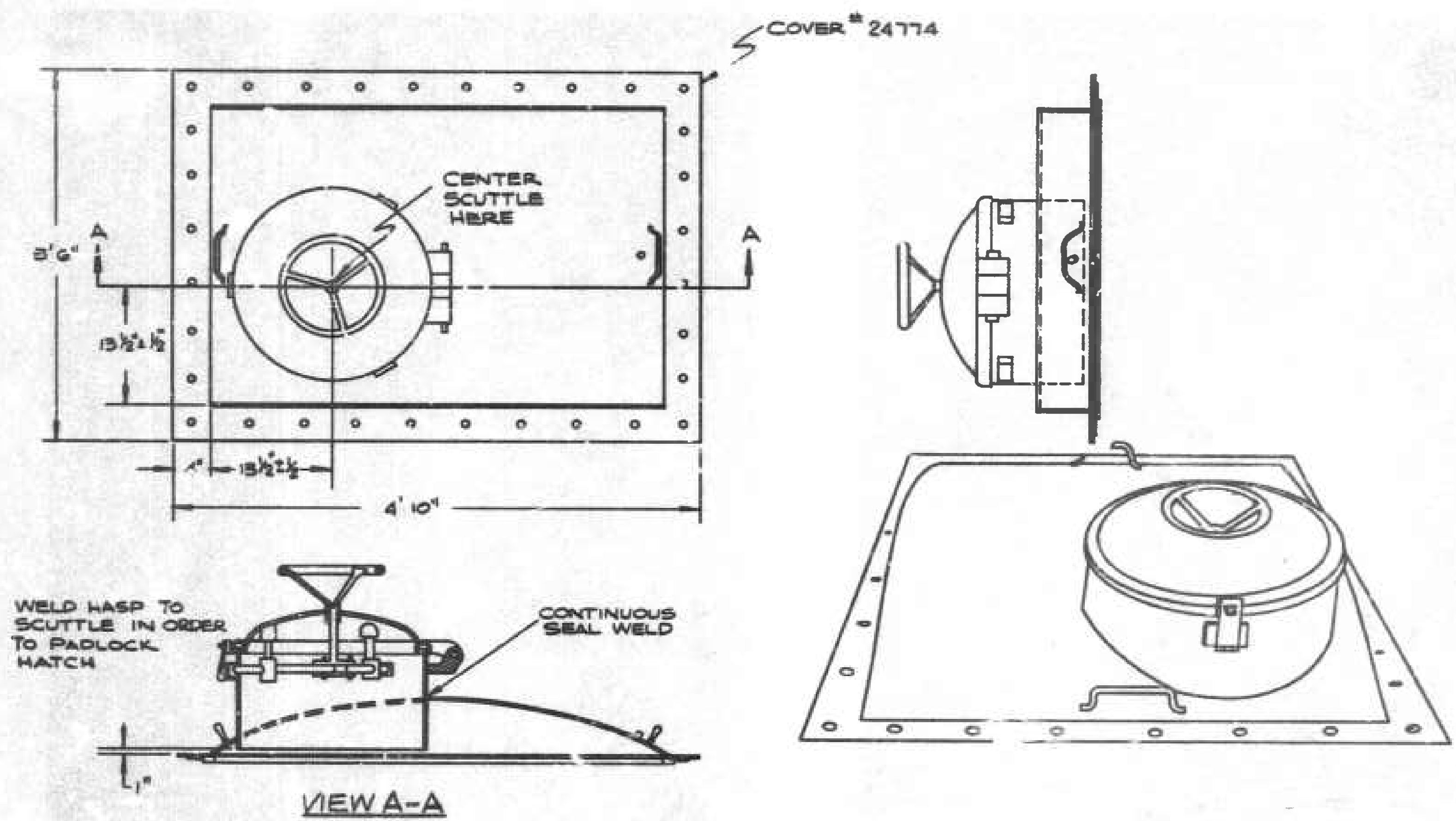


Figure 3-8. Vault hatch cover

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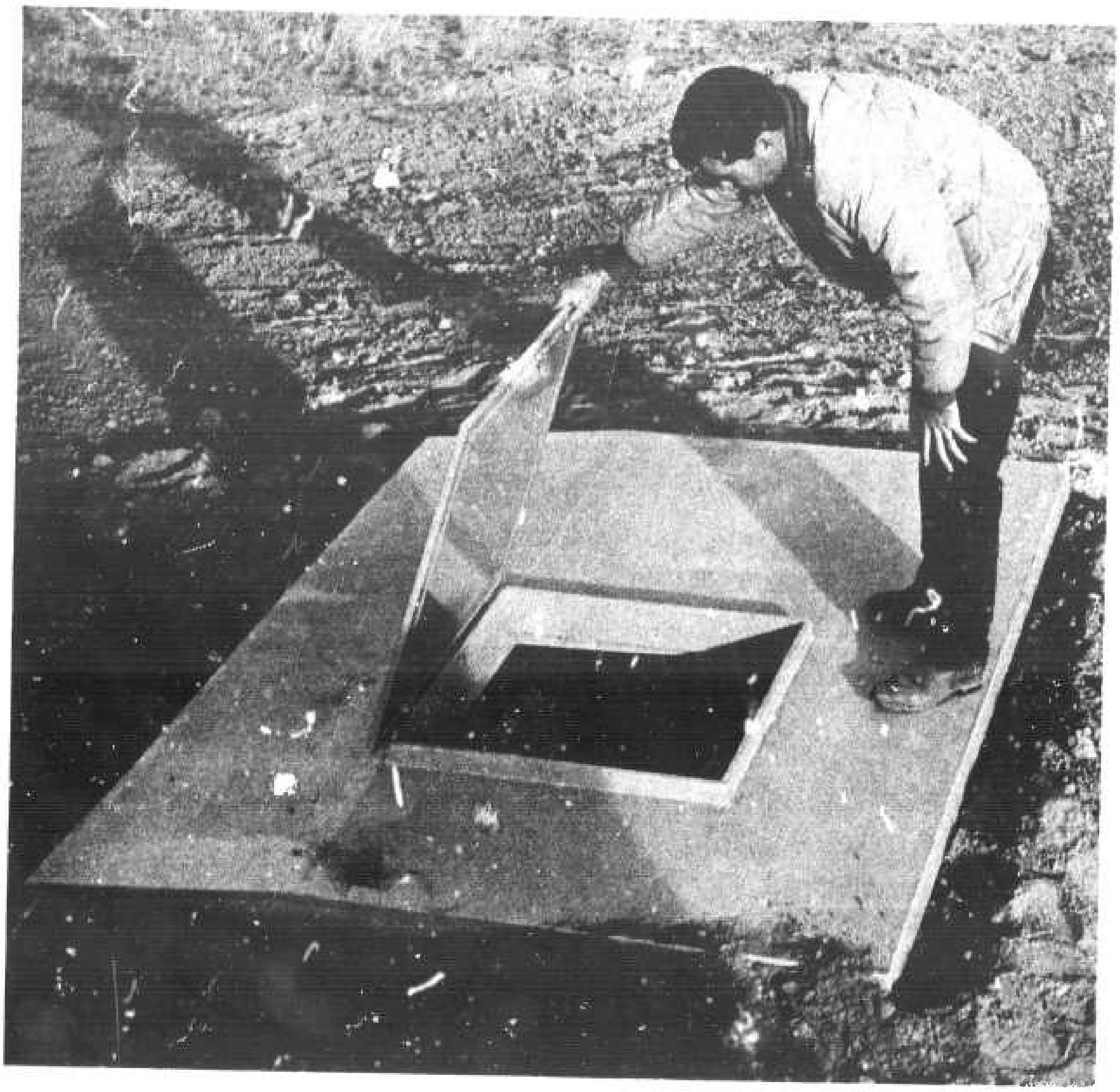

Figure 3-9. Retainer cover

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Figure 3-10. Cable trenching operation G 2520

All field cables were brought into the LP vault via one 3-inch diameter conduit, placed in the vault roof during construction. A condulet, attached to the conduit inside the vault, is used to seal the cable entry. Figure 3-11 shows two views of a completed installation. All field cables were brought into the CTH through existing 1-1/2 inch conduits. Figure 3-12 shows a completed installation.

As the final stage of the construction operation, each subarray area was restored to normal condition. All excavations were backfilled and consolidated. The excess materials were graded within the area to provide good drainage. Typical landscaping operations are shown in figure 3-13. Area restoration was done by L. P. Anderson, Contractor, Inc., under the supervision of a Geotech representative.

3.3 SITE PREPARATION

In each CTH, an additional circuit breaker and a quadruple service outlet were installed to accommodate the LP instrumentation. One ac power circuit was installed in each LP vault. This circuit contained a fused master switch box, 1 overhead light fixture with wall switch, and 3 duplex service outlets located near the tank assemblies.

All tank assemblies were sealed and tested prior to the installation of the seismometers. Their time constants were made to exceed 8 hours. Tables in appendix 7 give the actual time constants at time of installation.

Prior to instrument installation, orientation lines were painted on the floor of each tank assembly assigned to horizontal seismometers. For the N-S seismometer, a line was drawn along an azimuth of 90°. For the E-W seismometer, an azimuth of 0° was established. Azimuths were established by survey and measurement. The surveying procedure was reversed to check the results. The technique used produced azimuth precision of $\pm 0.5^{\circ}$.

All field cables entering the LP vault were internally sealed, using splice kits, to prevent their insulation from acting as pipes to pass pressure changes into the vault. Upon completion of the sealing procedures, all circuits were checked to assure proper connection, continuity, and freedom from leakage. The minimum cable leakage resistance accepted was 50 megohms.

3.4 ASSEMBLY AND TEST

During the site selection, construction and preparation phases described in the previous paragraphs, all LP system instrumentation except the amplifiers was being manufactured in the Geotech plant at Garland, Texas. In addition, a laboratory was established in Garland. There, all system components were inspected, tested, and, if necessary, adjusted for proper operation. A

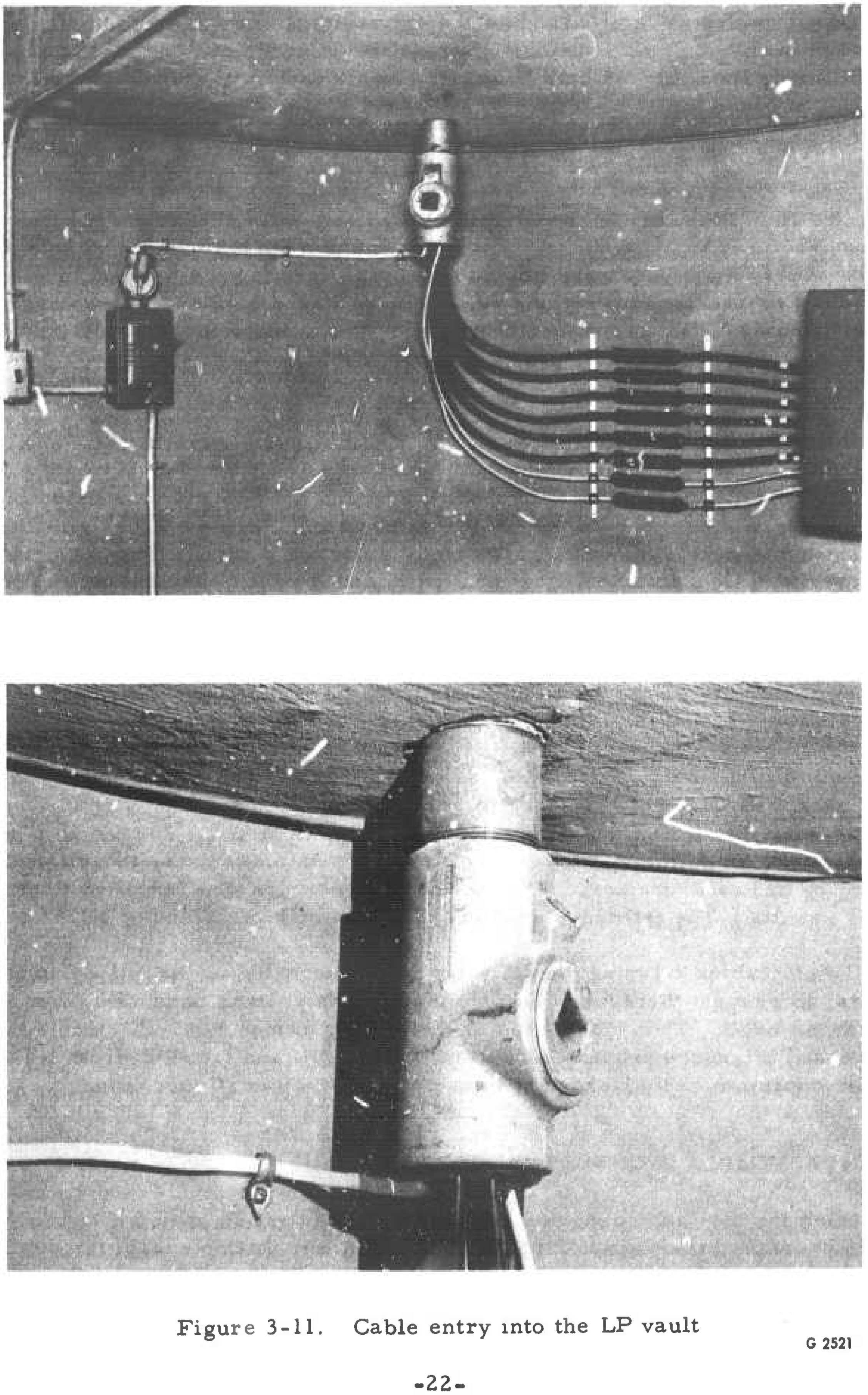


Figure 3-11. Cable entry into the LP vault

G 2521

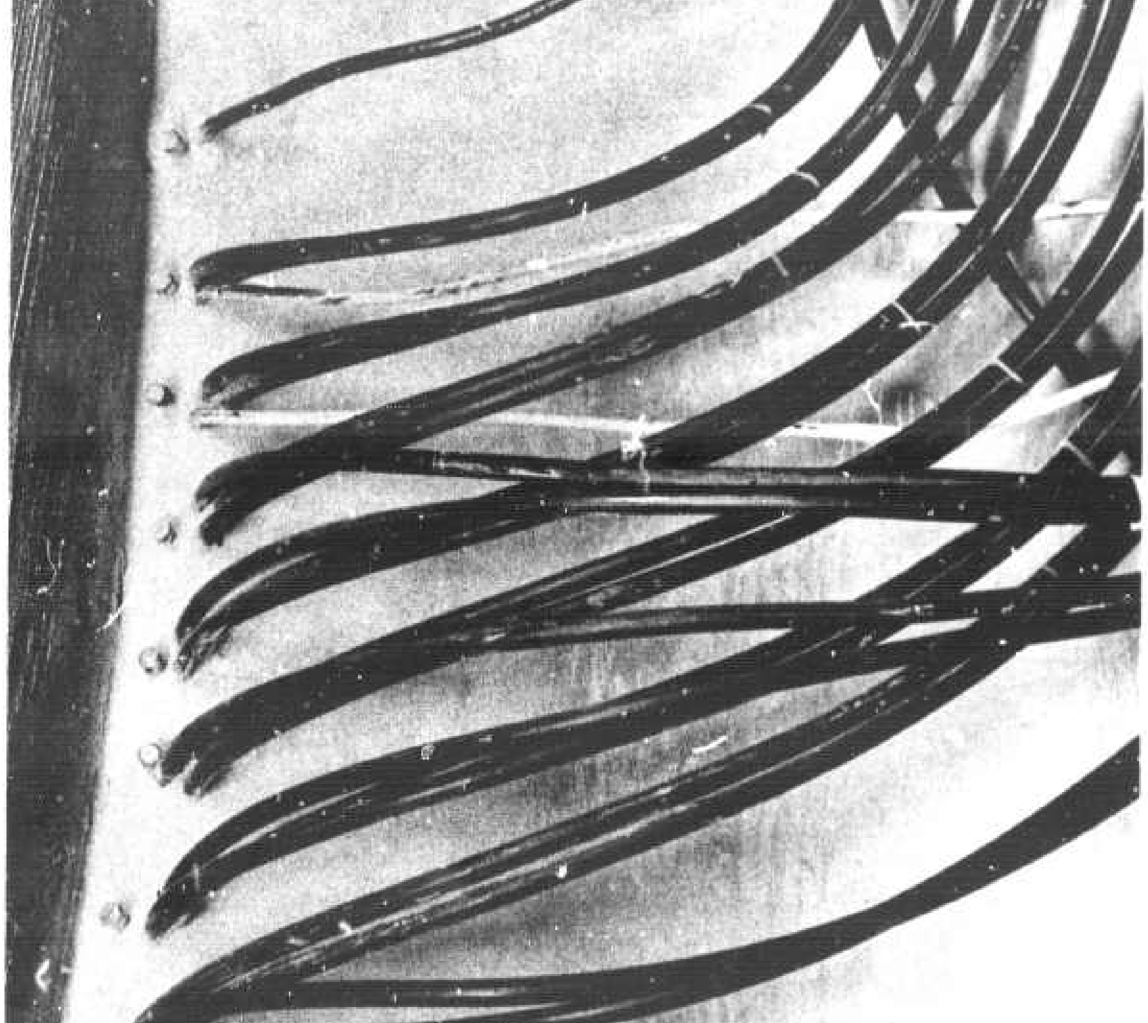
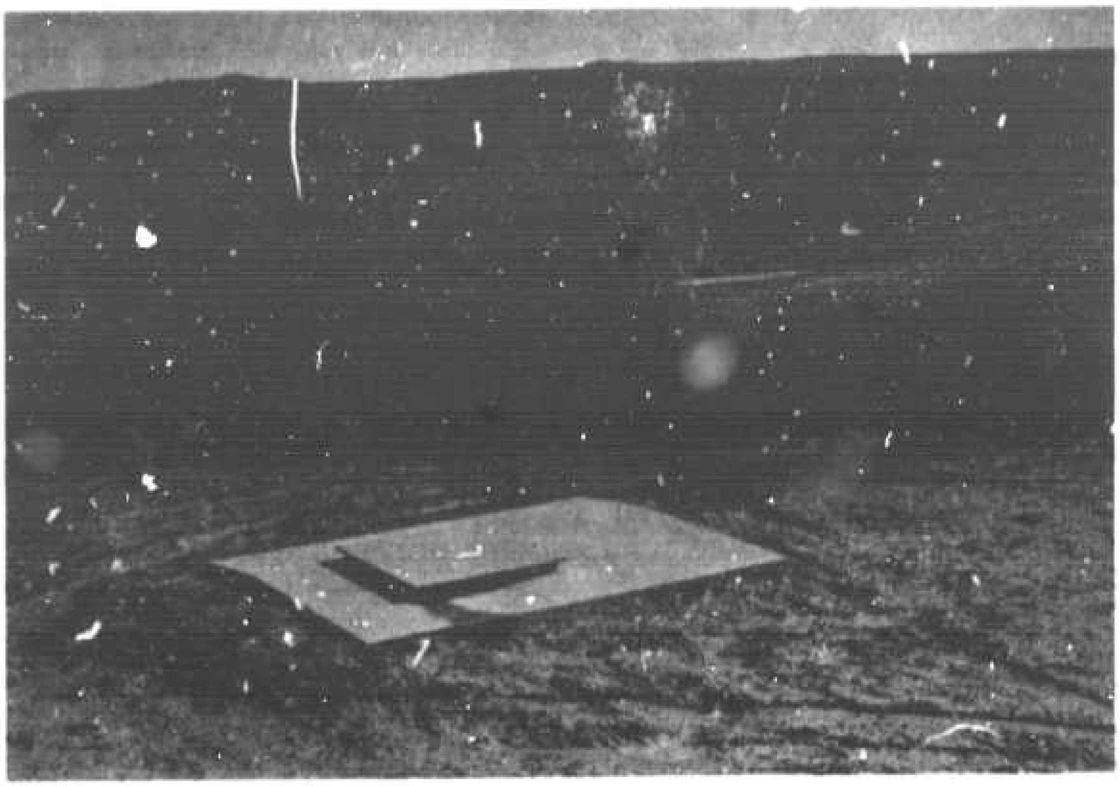


Figure 3-12. Cable entry into the CTH

G 2522



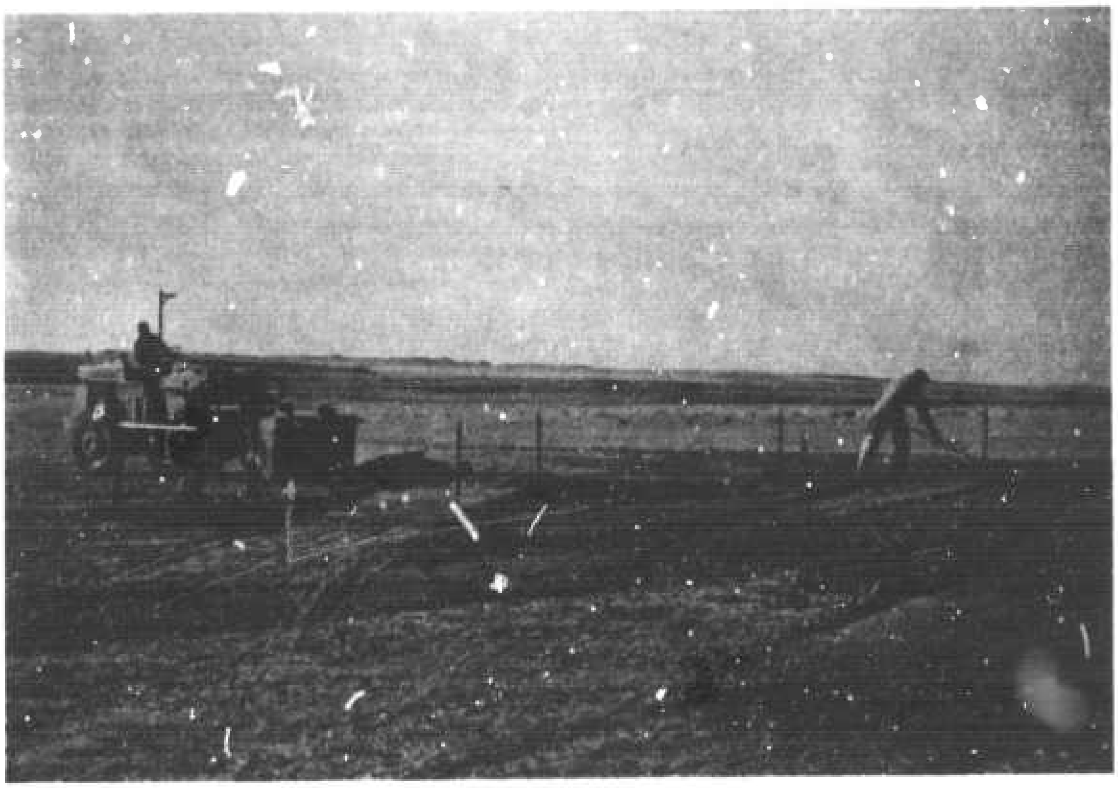


Figure 3-13. Landscaping operation G 2523

prototype model of the LASA LP system was assembled in the laboratory and used to prove the system design, component compatibility, and system capabilities. Upon completion of the assembly and test phase in Garland, the majority of the instrumentation was shipped to Montana in a soft-suspension moving van. The prototype system was maintained and used to solve problems that could not be solved in the field.

3.5 EQUIPMENT INSTALLATION

As the equipment was received at the field depot in Miles City, it was uncrated and inspected for damage due to shipping. It was then put back in the shipping crates and stored until needed at the sites. A complete set of the LP instrumentation was installed at subarray B2 to prove installation techniques and to serve as a field prototype. After the procedures were refined at the prototype, installation was undertaken at the remaining 20 subarrays. Three field teams of two men each accomplished the installation of all equipment. One team distributed the equipment to the sites and mounted all components to be attached to the walls of each LP vault and each CTH. This team also left a dehumidifier operating in the LP vault upon their departure. The other two teams completed the installation of the equipment.

Figures 3-14 through 3-16 show equipment mounted in position at a typical site.

3.6 SYSTEM TEST AND CALIBRATION

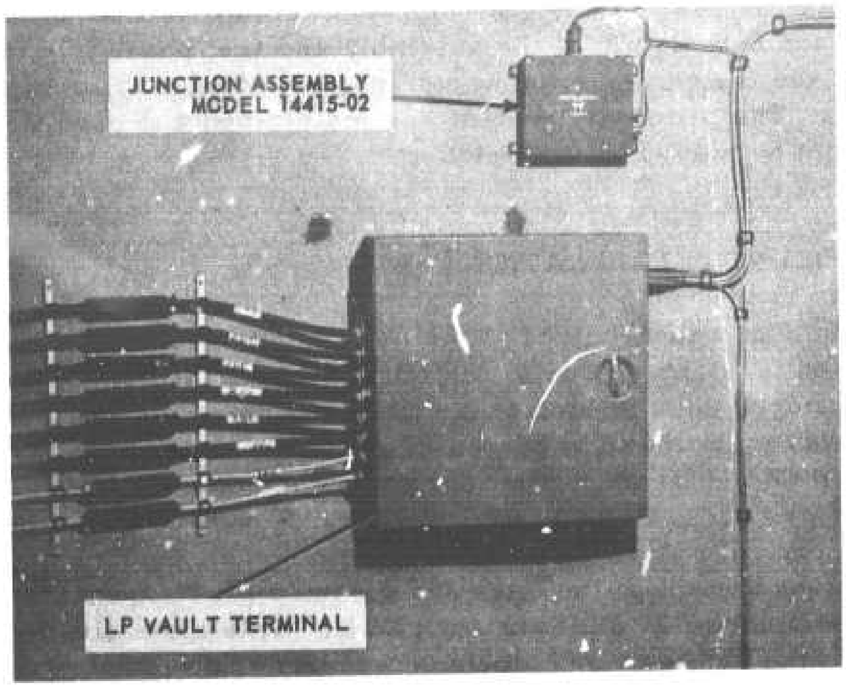
Each system channel was calibrated and tested to assure proper operation of all components. The following is a summary of the tests and calibrations performed. These are described in detail in the LASA LP Construction Manual.

Following the installation of each seismometer, a thorough check of its suspension alignment, basic parameters, and electrical circuits was performed. Where required, adjustments were made. The basic parameters are the generator constant of the data transducer, the motor constant of the electromagnetic calibrator, and the seismometer damping. The values obtained for these parameters and the value of the external resistor used to properly damp each seismometer are tabulated in appendix 7.

Each mass position monitor was adjusted such that full scale deflection was produced when the inertial mass position was 5 millimeters from zero.

All remote centering circuits were tested. Final mass position adjustment for each seismometer was performed remotely.

With the seismometers operating within the range of setup tolerances, the gain of each amplifier was adjusted to produce the prescribed system sensitivity for system channels containing 24 dB/octave filters. Originally, the



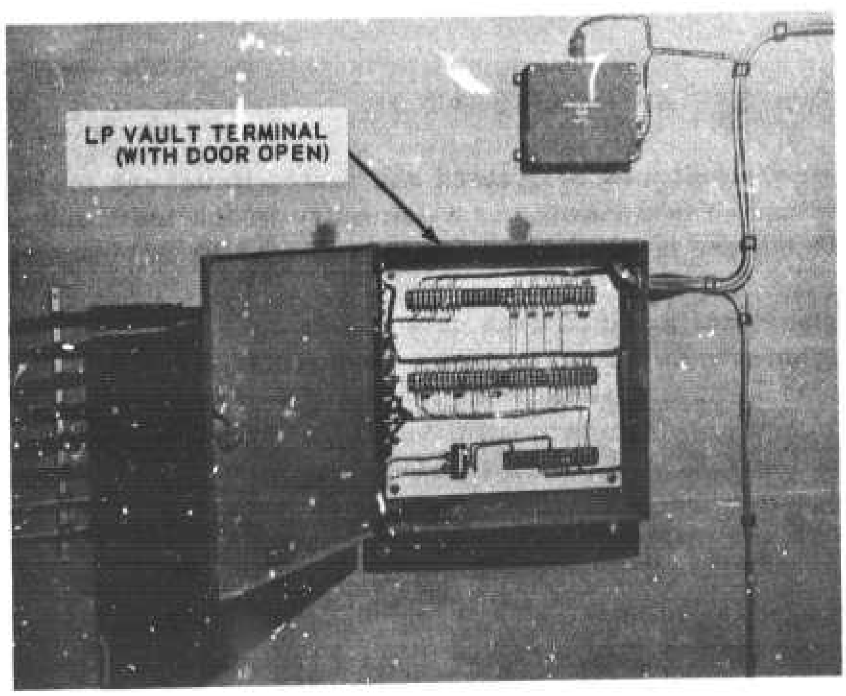


Figure 3-14. LP vault terminal

G 1974

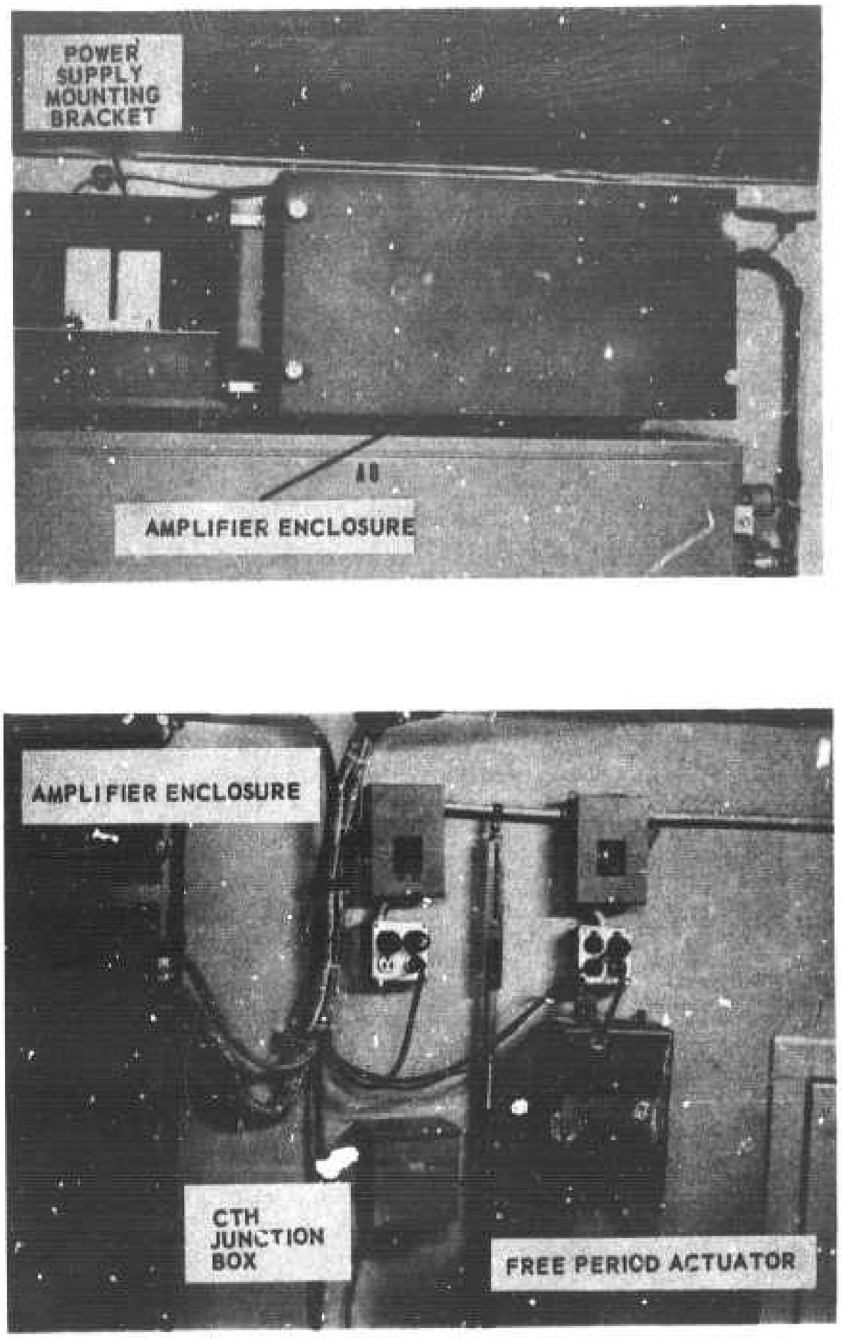


Figure 3-15. Equipment mounting configuration in the CTH

G 1978

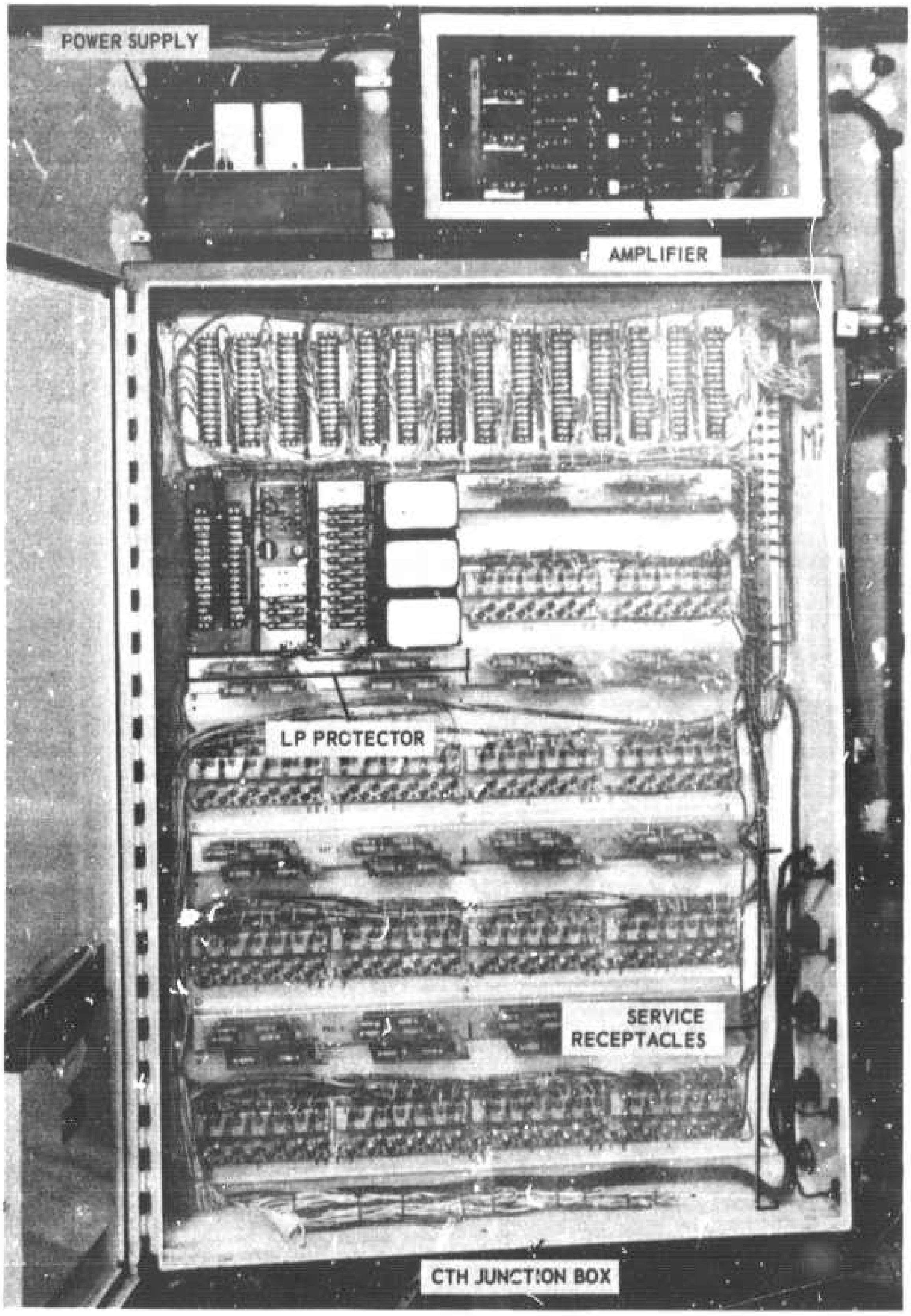


Figure 3-16. Location of the LP protector and service receptacles in the CTH junction box

G 2182

amplifiers were adjusted for a system sensitivity of 110 $\frac{mV}{\mu}$ at 0.04 hertz. Later the amplifiers were modified for high-gain operation and the gains were adjusted for a system sensitivity of 1500 $\frac{mV}{\mu}$ at 0.04 hertz.

The amplifier line drivers were adjusted for a maximum of 200 mV dc offset at the output.

The frequency response of each operating channel was measured. The data were normalized, tabulated, and plotted to show maximum deviation from a typical curve. Figure 3-17 shows the theoretical response, the worse case tolerances and the average response and worse case deviations of the 63 channels containing 24 dB/octave high-cut filters. Figure 3-18 shows like data for the channels containing 36 dB/octave high-cut filters.

System noise levels were determined for each channel containing a 24 dB/octave filter. After gain adjustment and parameter determination, each seismometer inertial mass was locked and the resultant output recorded for a period of 2 hours. The maximum noise level for each channel was less than 30 mμ equivalent earth motion referred to 0.04 hertz.

3.7 INSULATION

Following system test and calibration, the volume surrounding the seismometer in each tank assembly was completely filled with spun fiberglass insulation. Figure 3-19 shows the tank assembly while insulation was in progress. The retainer enclosing the LP vault entry was filled with plastic bags containing shredded styrofoam insulation.

3.8 MISCELLANEOUS

Under this contract three short-period Develocorders, transferred from another contract, were modified for long-period operation. These were installed in the LASA Data Center at Billings, Montana, to record the LP data. At installation, the LP Develocorders were connected to record as follows:

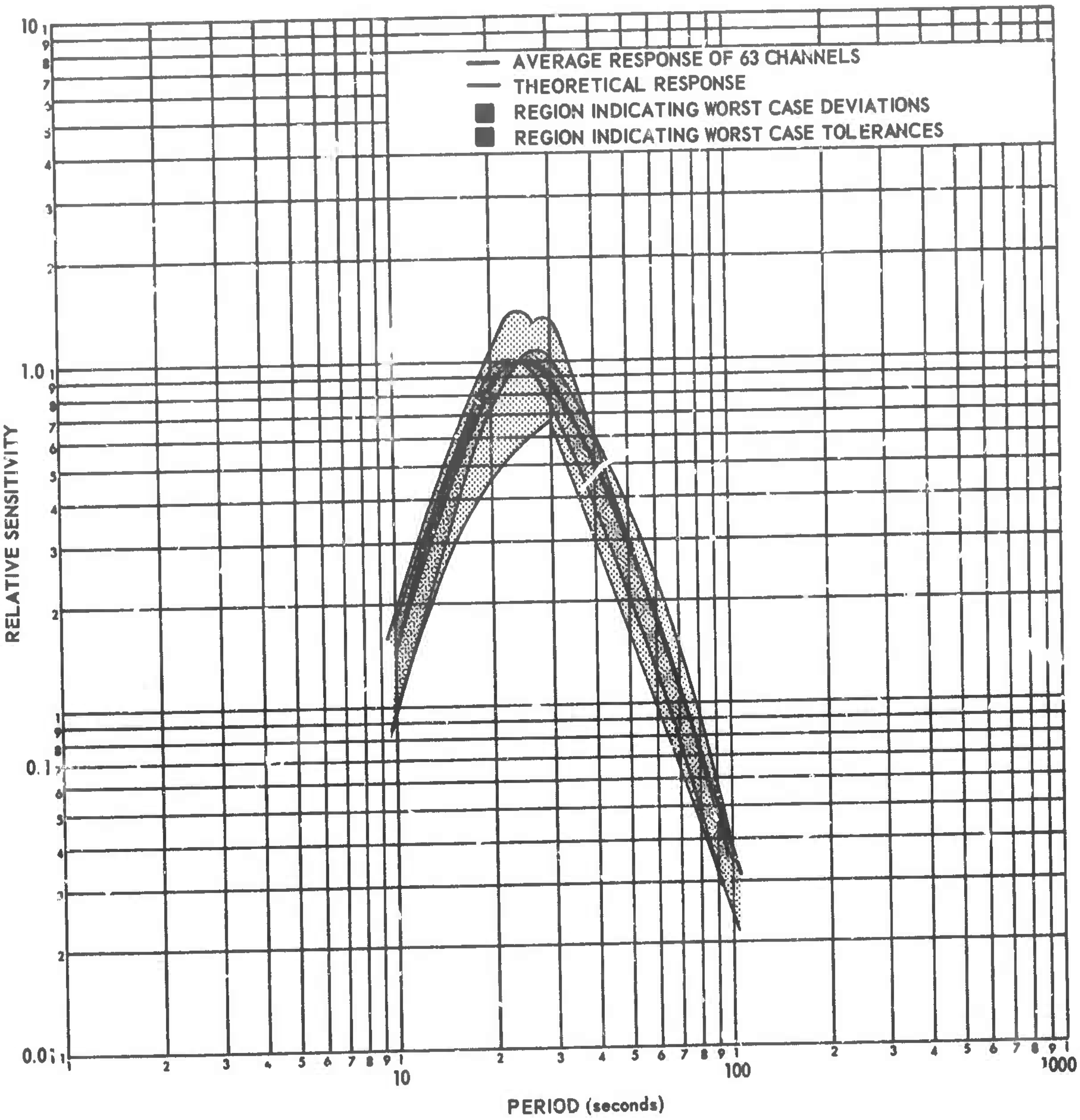


Figure 3-17. Frequency response for LASA LP system channels containing a 24 dB/octave high cut filter. This illustrates the theoretical response, the worst case tolerances, and the average response and worst case deviations of 63 channels

G 2524

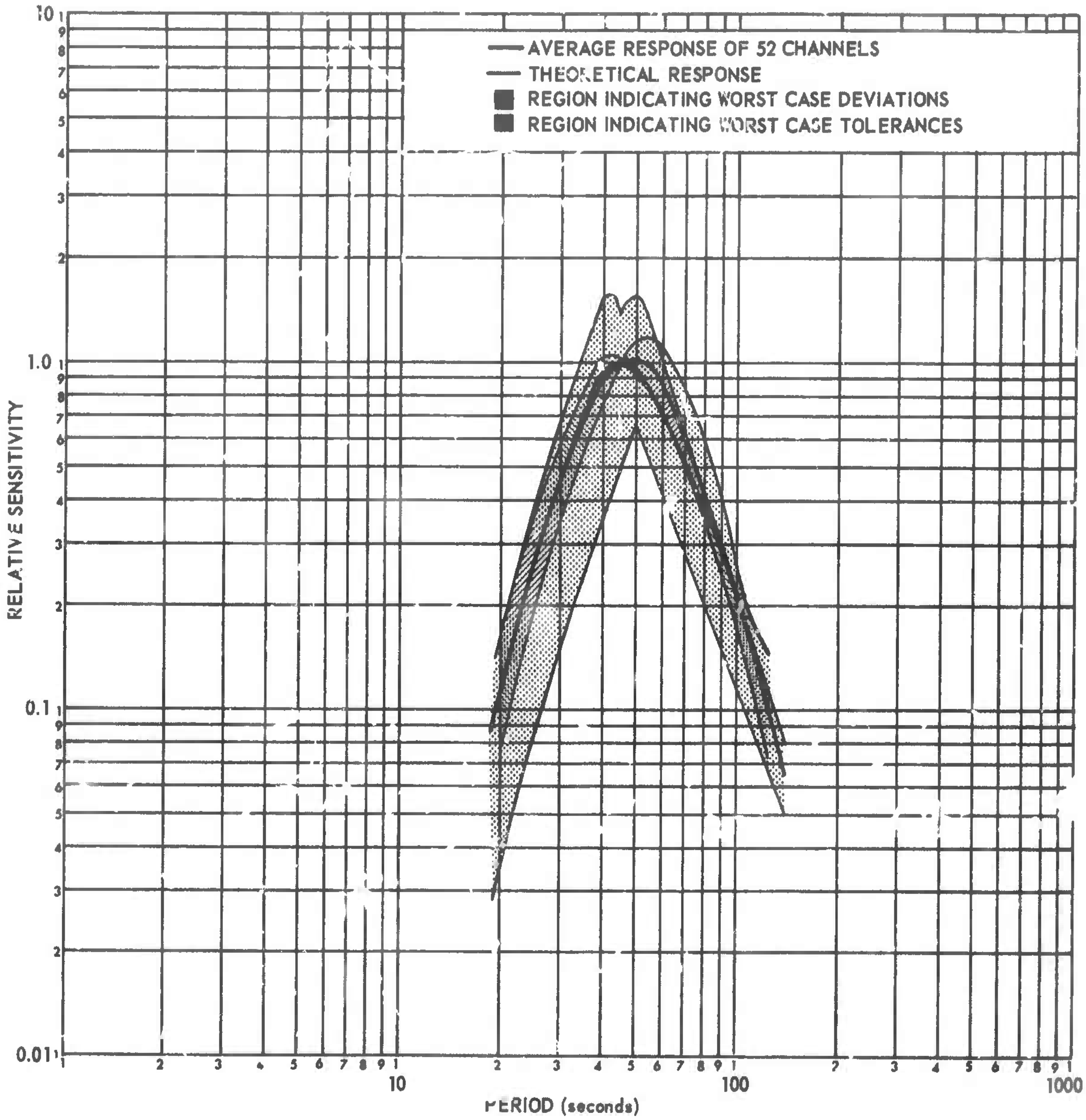


Figure 3-18. Frequency response for LASA LP system channels containing a 36 dB/octave high cut filter. This illustrates the theoretical response, the worst case tolerances, and the average response and worst case deviations of 52 channels

G 2525

G 2526

Figure 3-19. A tank assembly partially insulated

Trace No.	Develocorder No. 5		Develocorder No. 6		Develocorder No. 7	
1	F1	11AL	F3	11AL	A0	12AH
2	F1	11AH	F3	11AH	A0	13AH
3	F1	12AH	F3	12AH	A0	11AL
4	F1	13AH	F3	13AH	E1	11AH
5	F2	11AL	F4	11AH	E2	11AH
6	F2	11AH	F4	12AH	E3	11AH
7	F2	12AH	F4	13AH	E4	11AH
8	F2	13AH			F4	11AL
9					WWV	

Key:
- 11 Vertical
- 12 North-South
- 13 East-West
- L Low gain, 2.9K
- H High gain, 50K on vertical, 25K on horizontal

Later in the program the channel assignments were revised. Since 13 September 1966, the channel arrangement has been:

Trace No.	Develocorder No. 5		Develocorder No. 6		Develocorder No. 7	
1	F1	11AL	F3	11AH	F4	11AL
2	F1	11AH	F3	12AH	F4	11AH
3	F1	12AH	F3	13AH	F4	12AH
4	F1	13AH	E1	11AH	F4	13AH
5	F2	11AL	E2	11AH	F3	11AL
6	F2	11AH	E3	11AH	A0	11AL
7	F2	12AH	E4	11AH	A0	11AH
8	F2	13AH			A0	12AH
9					A0	13AH
10					WWV	

The digital-to-analog (D/A) converter in the data center could handle only 10 of the 14 data bits available from the transmission system; hence, for the low-magnification channels the 4 least significant bits (LSB) were dropped from the data input to the converter. Conversely, the 10 least significant bits were retained and the 4 most significant bits (MSB) were dropped for the high-magnification channels. During the installation of the LP system, a modification to the Type II data amplifier increased the sensitivity of each LP channel from approximately 110 $\frac{mV}{\mu}$ to 1500 $\frac{mV}{\mu}$. In order to obtain a magnification of 50,000 at the Develocorder view screen prior to the amplifier modification, it was necessary to operate the Develocorder galvanometers at such high sensitivity that the data appeared as a series of discrete steps; that is, the digital data bits were recognizable. The trace identified as D3-11AH in figure 3-20 illustrates this. The amplifier modification permitted the reduction of the Develocorder galvanometers sensitivity resulting in improved trace quality (see trace identified as F2-11AH in figure 3-20).

4. SYSTEM PERFORMANCE

An indication of the overall system performance is given by the sample records shown in figures 4-1 through 4-10. Figure 4-1 shows the typical LP background at subarrays F1 and F2 during the daylight hours. The background for these sites during the nighttime hours is shown in figure 4-2. The background for these same sites during a period of increased microseism activity is shown in figure 4-3. Figure 4-4 shows a typical recording of an event by the three LP Develocorders at the LASA Data Center.

The disturbance shown on the lower four traces of figure 4-5 resulted when a large truck was stopped within 6 feet of the LP vault entrance of subarray A0. The truck weighed approximately 12,000 pounds. The technician driving the truck spent about 30 minutes in the CTH and around the truck before entering the LP vault. There was no significant change in the background after his arrival except when he actually entered the LP vault.

The calibration shown on the lower four traces of figure 4-6 was performed to determine the operating magnifications of the subarray F2 channels as viewed on the Develocorder at the LASA Data Center. In order to obtain an adequate signal-to-noise ratio during the calibration, a X0.02 attenuator was installed between the Type II data amplifier and the SEM input, and a calibration current of 600 μA p-p at 0.04 hertz was used. Immediately following the calibration, the attenuator was removed. Thus, the "operate" magnifications of the four channels would be 50 times the calibration magnifications. Note that at the time of this calibration, the vertical high-gain channel was operating at the same magnification as the horizontal channels. At a later date, the operate magnification of the vertical channel was increased from 25,000 to 50,000.

Two differently filtered outputs are available from each channel of the LP data amplifier; one peaked at 0.04 hertz and called the "A" response and another peaked at 0.022 hertz and called the "B" response. Figure 4-7 illustrates the effect of the two responses in emphasizing different frequency bands of the data. The record was made at subarray B1 during a test to determine the effects of thermally shaking the LP horizontal seismometers. For the test, the east-west horizontal seismometer had been reoriented to become a

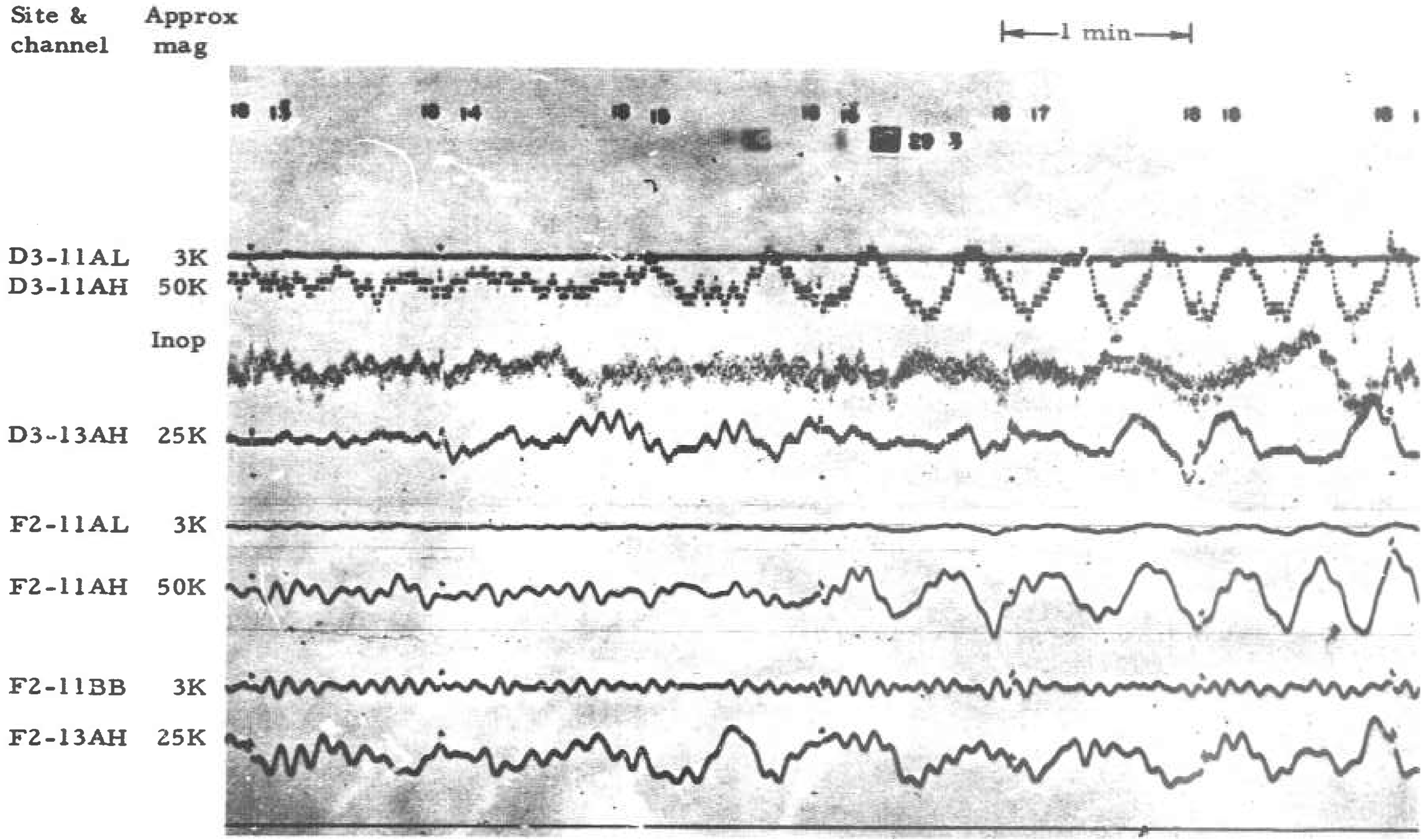


Figure 3-20. Record showing difference between high-gain and low-gain operation of the Type II data amplifier (X10 enlargement of 16mm film)

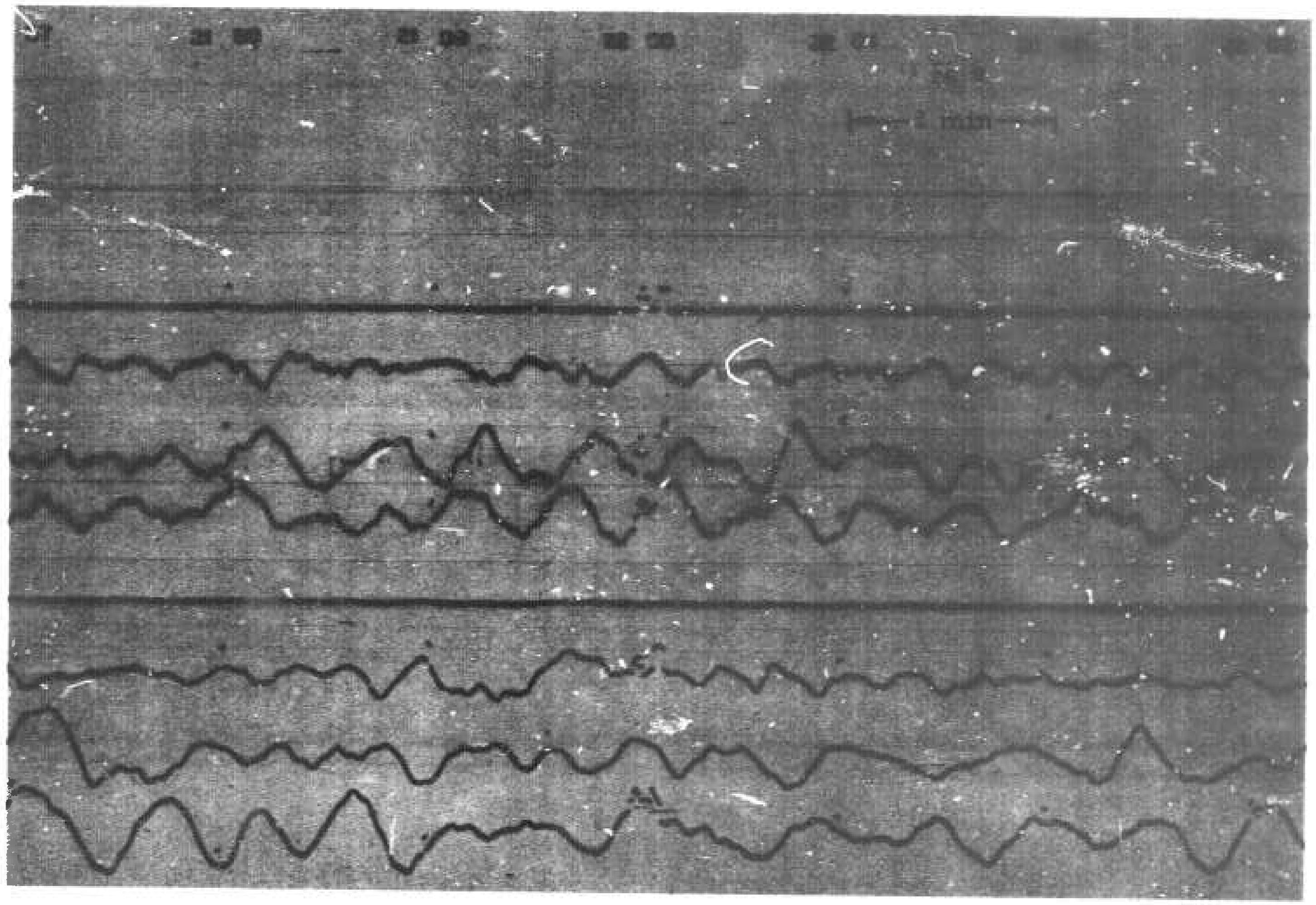


Figure 4-1. Typical background during daylight hours
(X10 enlargement of 16 mm film)

Site & channel	Approx mag
F1-11AL	3K
F1-11AH	50K
F1-12AH	25K
F1-13AH	25K
F2-11AL	3K
F2-11AH	50K
F2-12AH	25K
F2-13AH	25K

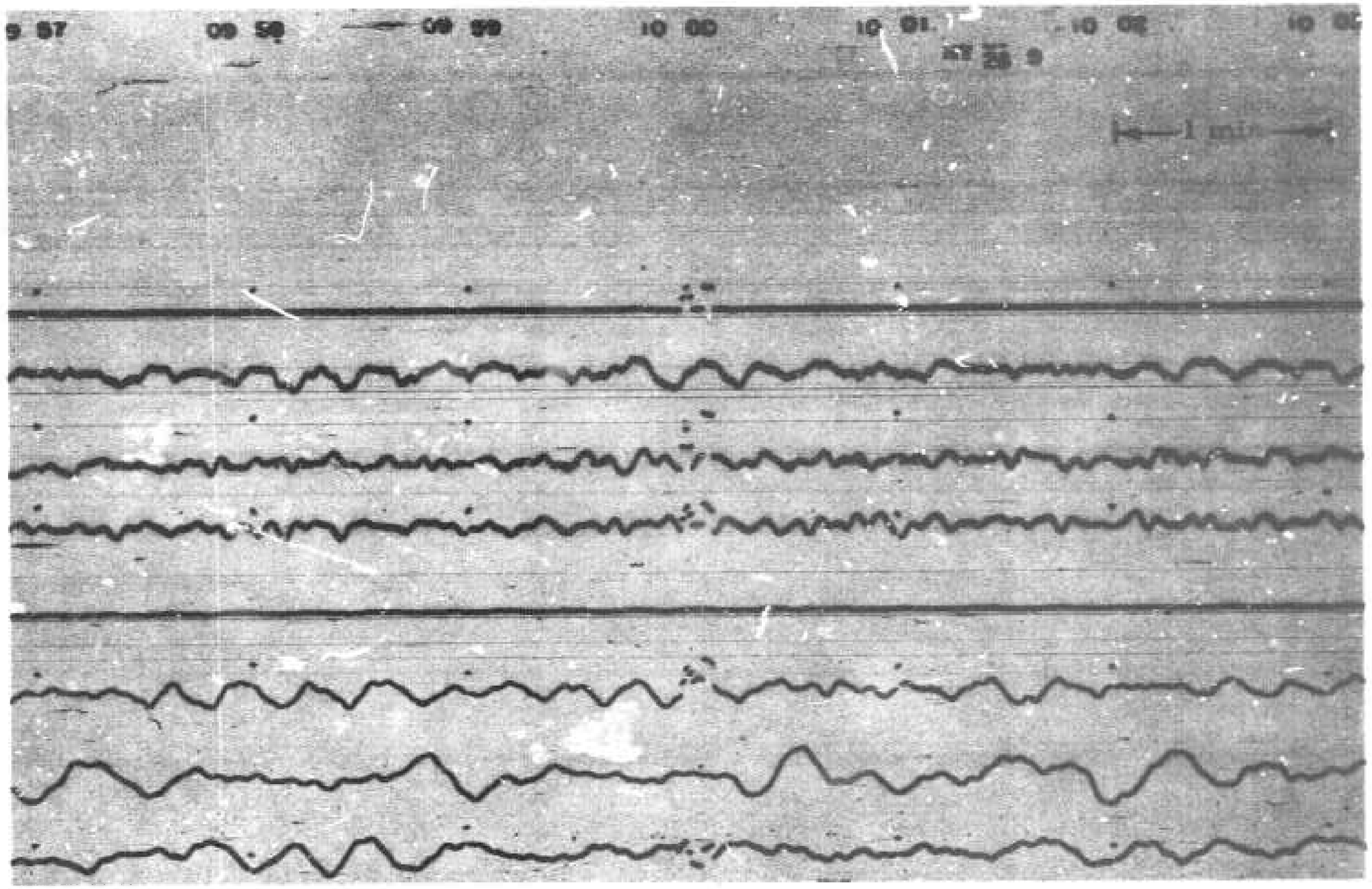


Figure 4-2. Typical background during nighttime hours (X10 enlargement of 16 mm film)

Site & channel	Approx mag
F1-11AL	3K
F1-11AH	50K
F1-12AH	25K
F1-13AH	25K
F2-11AL	3K
F2-11AH	50K
F2-12AH	25K
F2-13AH	25K

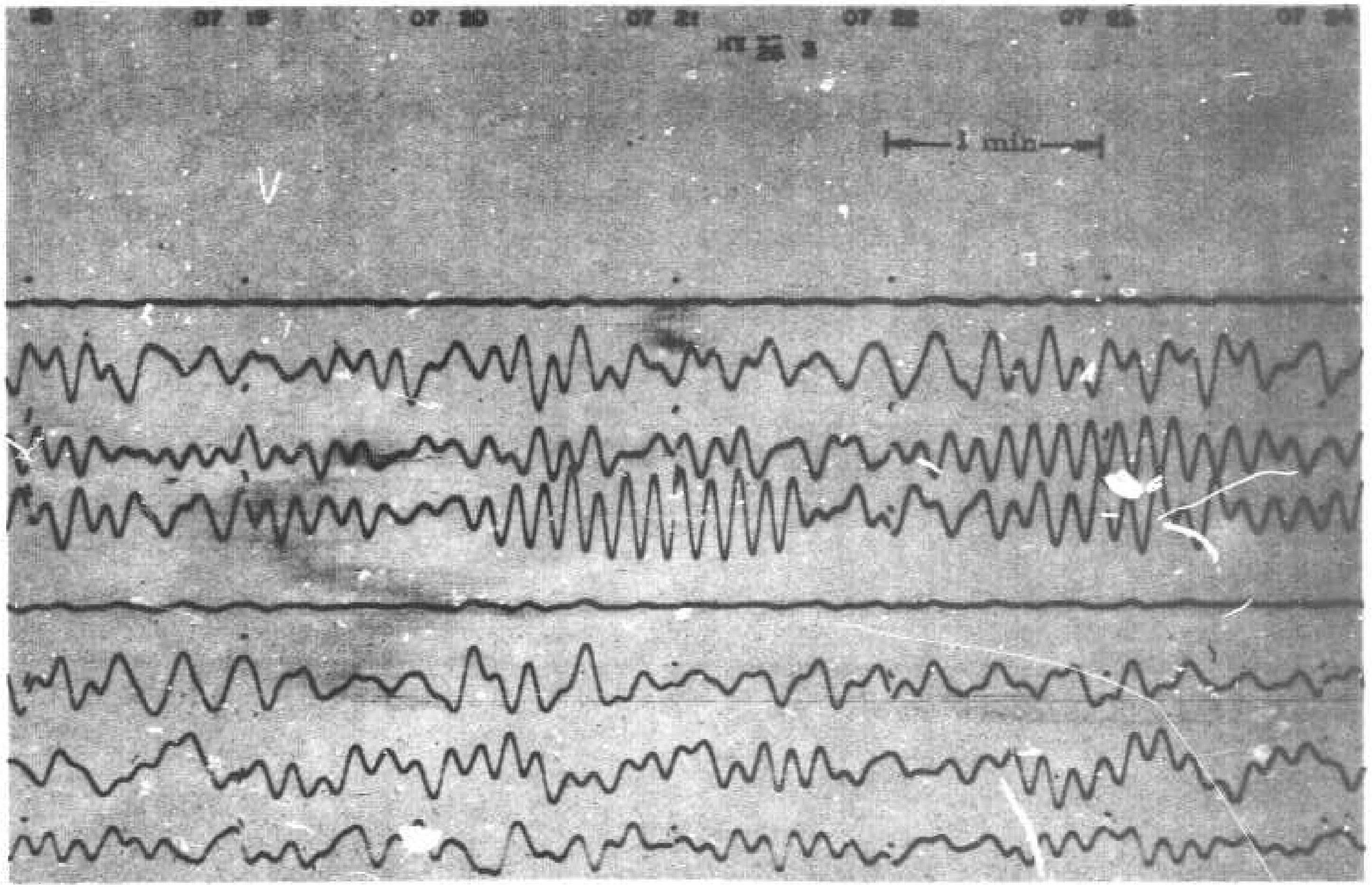


Figure 4-3. Example of high-level microseism activity
(X10 enlargement of 16 mm film)

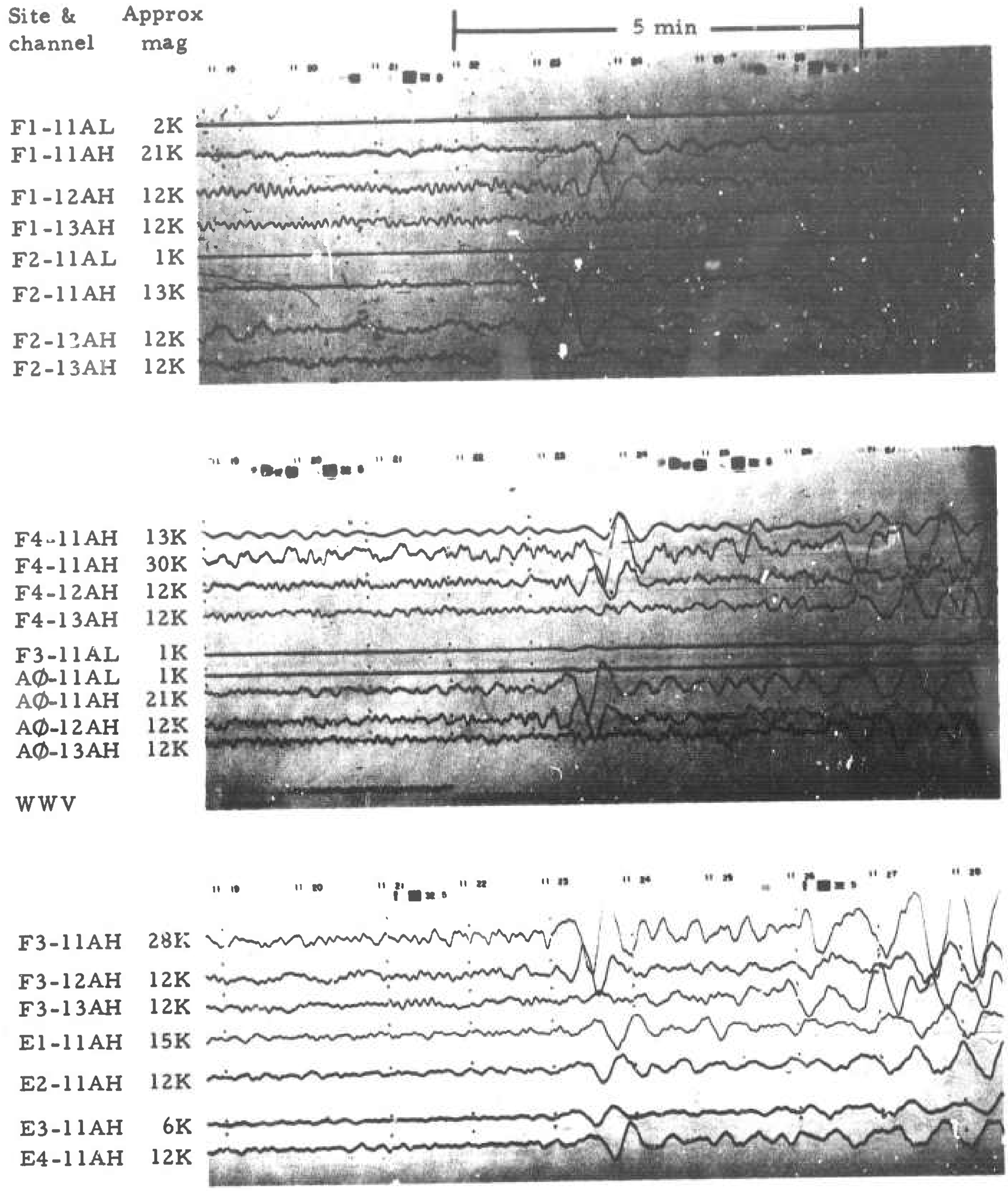


Figure 4-4. Typical recording of an event by the three LP Develocorders at the LASA Data Center. The event was from Michoacan, Mexico. Epicenter 18.8°N, 102.3°W; distance and azimuth from subarray AØ was 3119 km at 172°; depth 87 km; magnitude 4.7 (X5 enlargement of 16 mm film)

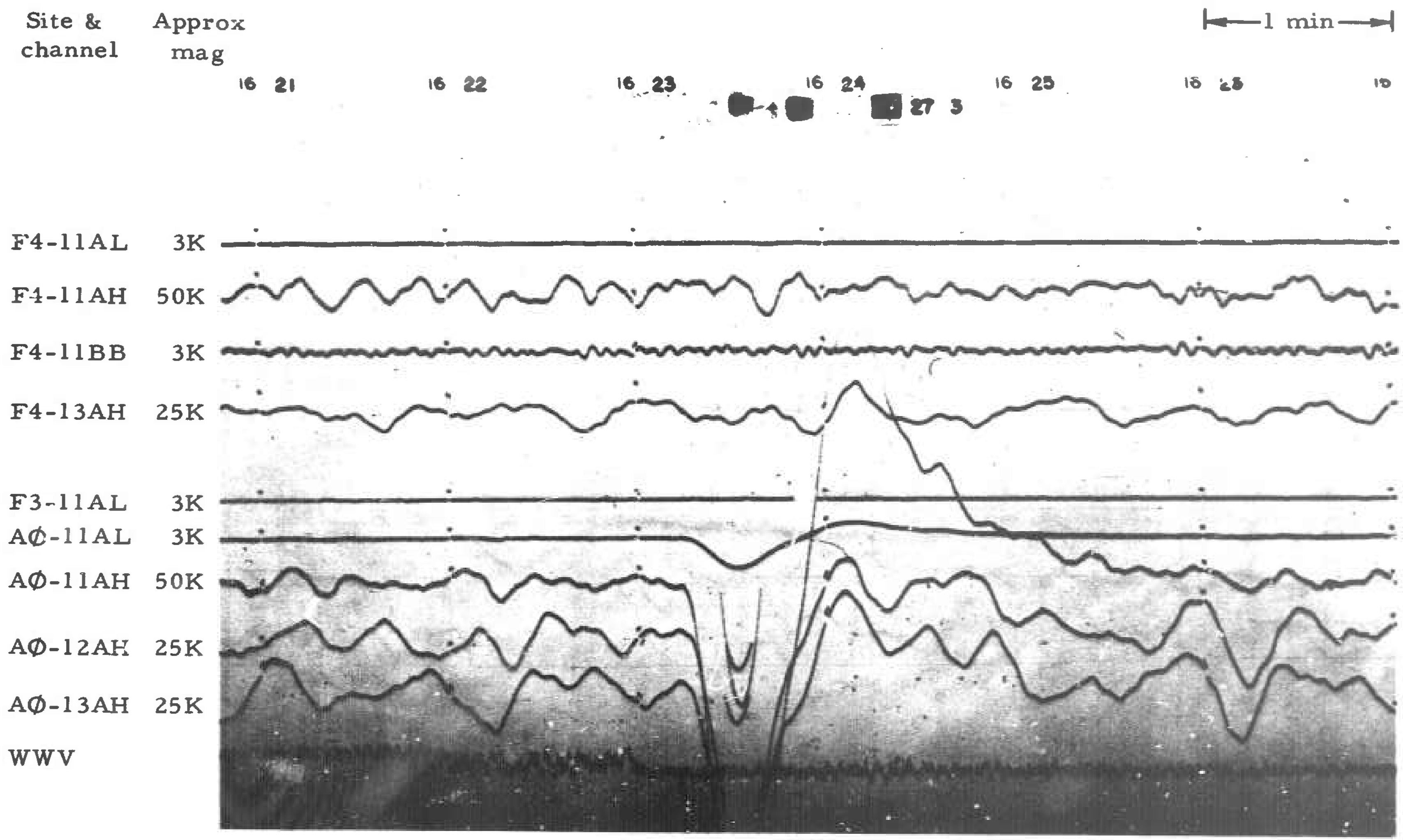


Figure 4-5. Disturbance due to stopping a vehicle near the LP vault
(X10 enlargement of 16 mm film)

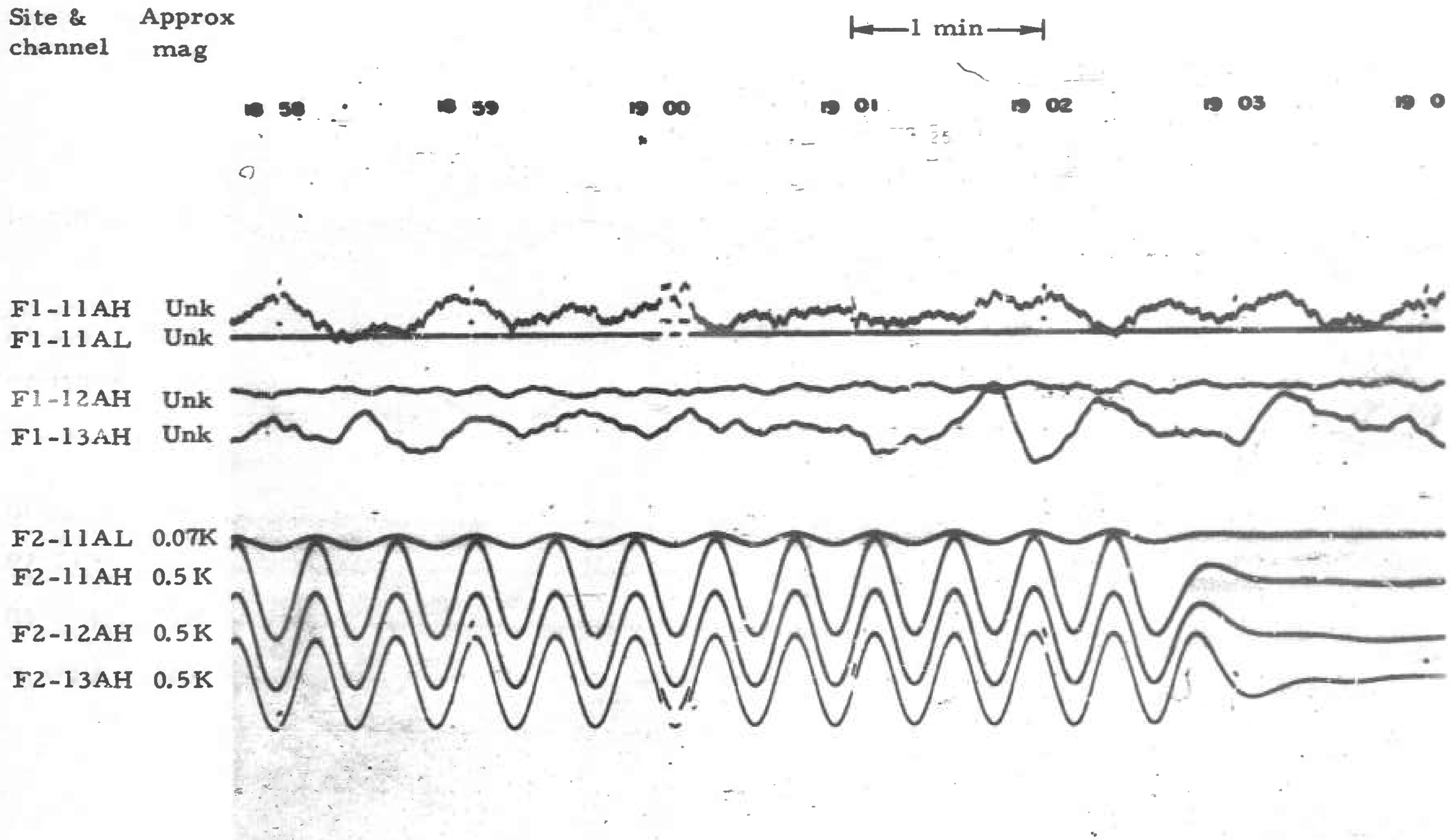


Figure 4-6. Example of a 0. 04 hertz calibration to check magnifications as viewed on the Develocorder (X10 enlargement of 16 mm film)

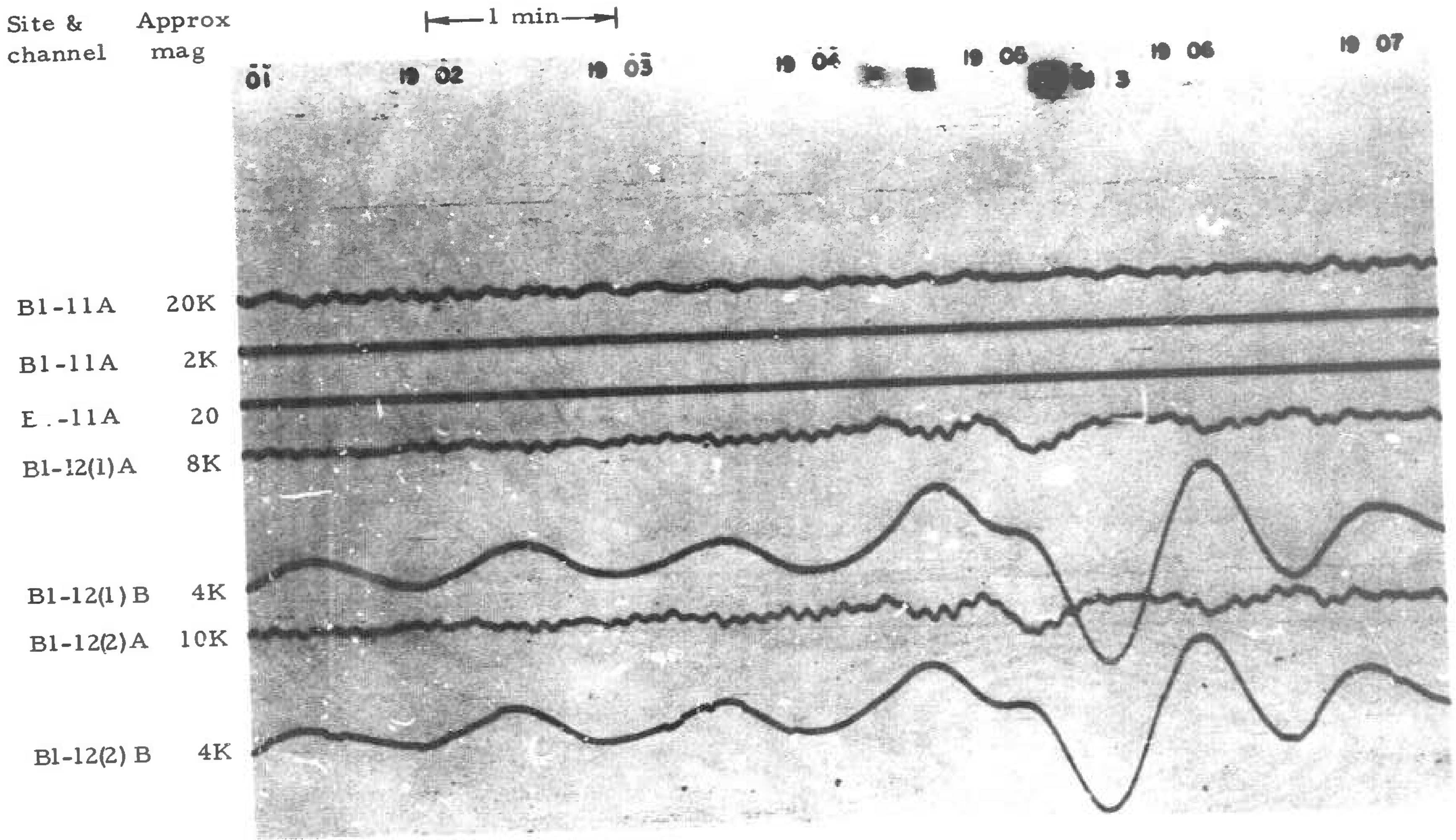


Figure 4-7. Comparison of A Response and B Response outputs (X10 enlargement of 16 mm film)

Site & channel	Approx mag
F3-11AH	50K
F3-11BB	3K
F3-13AH	25K
E1-11AH	25K
	Inop
E3-11BB	3K
E4-11AH	25K

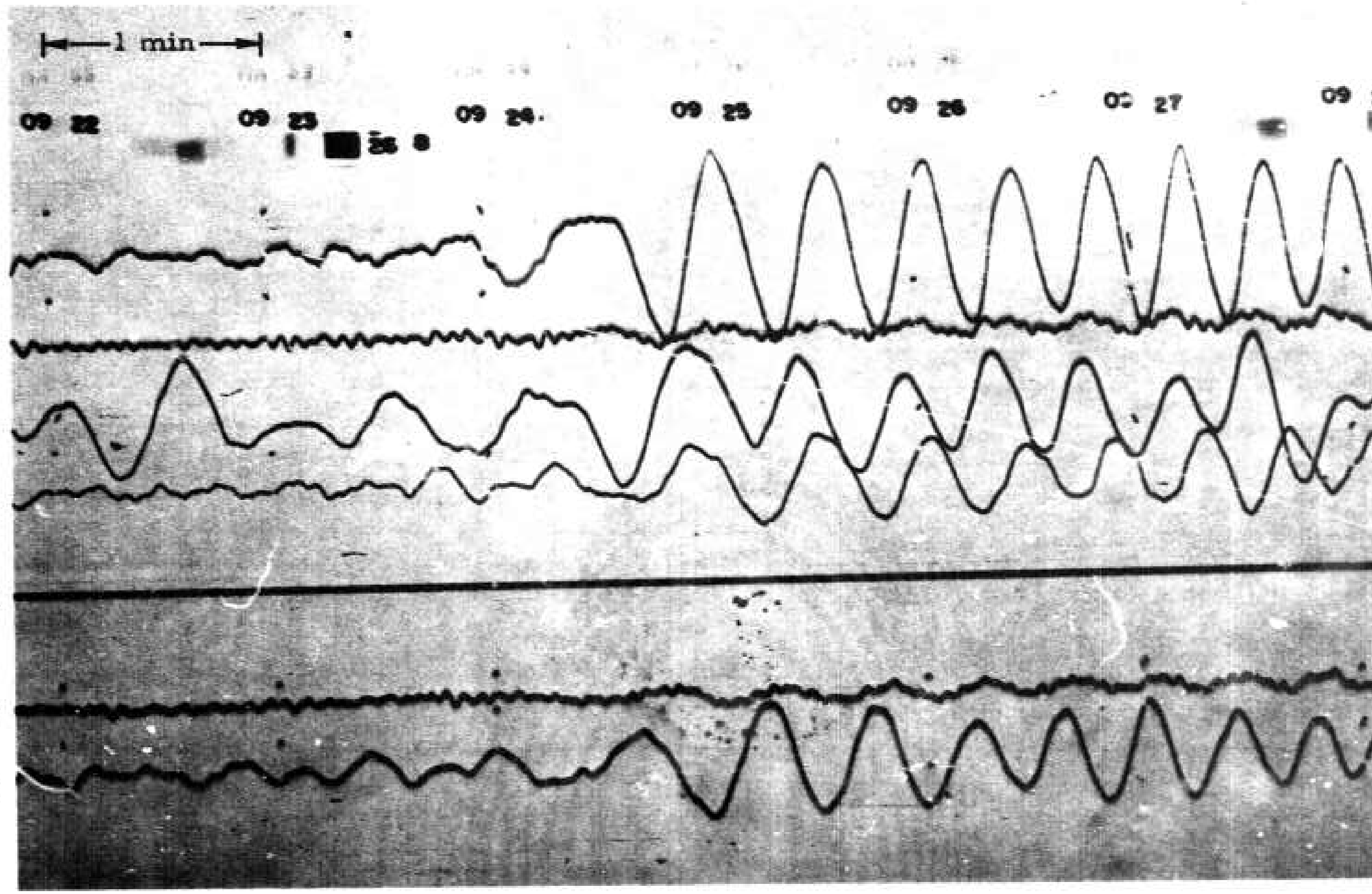


Figure 4-8. Comparison of A Response and C Response outputs (X10 enlargement of 16 mm film)

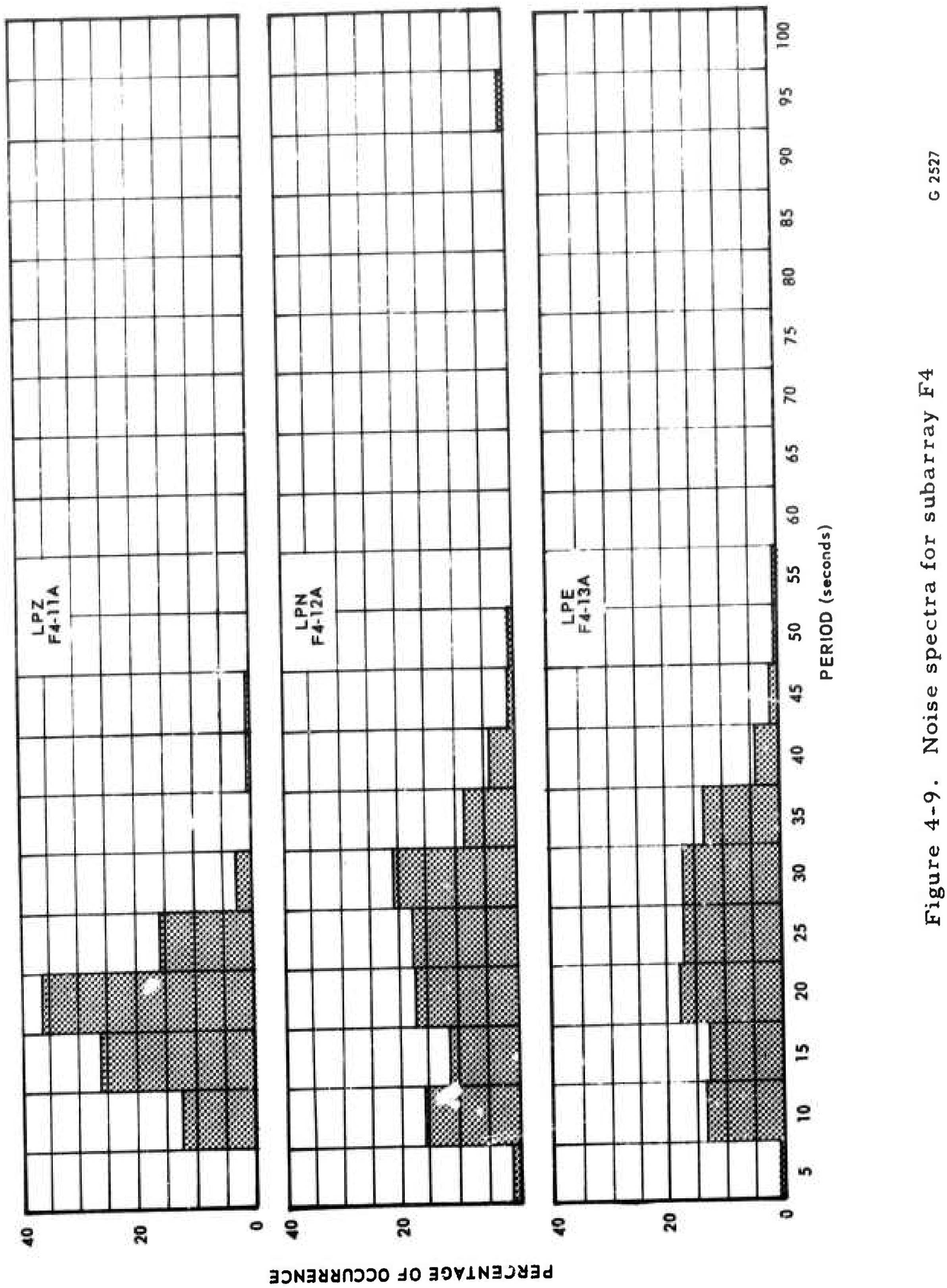


Figure 4-9. Noise spectra for subarray F4

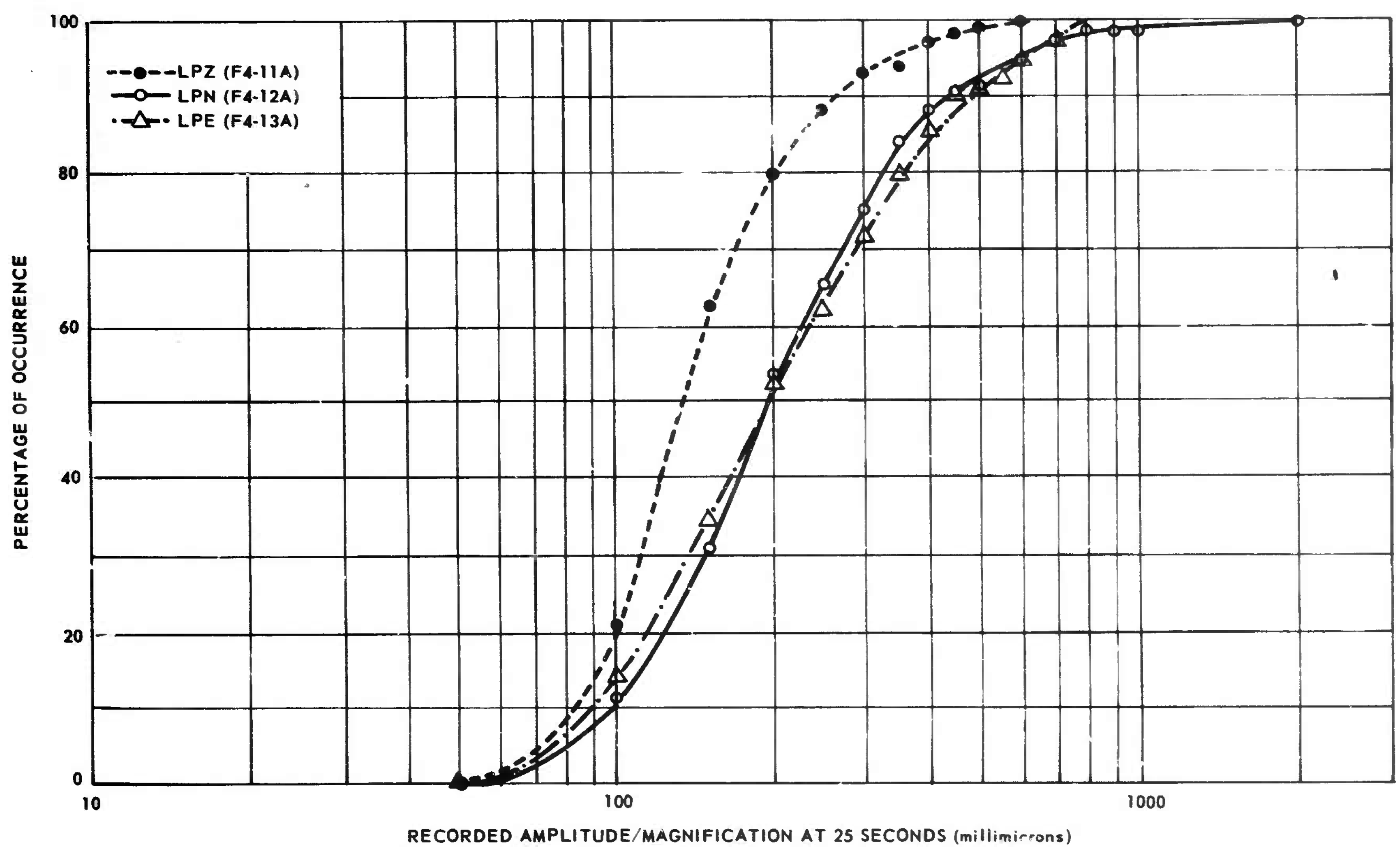


Figure 4-10. Percentage of occurrence, long-period background, subarray F4

G 2528

north-south seismometer identified as B1-12(2). The original north-south seismometer remained in position and was identified as B1-12(1). The letter A following the channel designator indicates an "A" response output from the data amplifier and a B following the designator indicates a "B" response output. The approximate magnifications given in the figure are at 0.04 hertz.

The two top traces of figure 4-8 are recordings of the vertical channel of subarray F3. The first trace, identified as F3-11AH, is an "A" response output for that channel. The second trace, identified as F3-11BB is a broad-band or "C" response for that channel. The approximate magnifications given in the figure are at 0.04 hertz. The event shown was from south of the Fiji Islands: Epicenter 26.6°S, 179.3°E; depth, 481 km; magnitude 4.0.

The histograms shown in figure 4-9 indicate the relative distribution of noise periods expressed in terms of percentage of occurrence from the three long-period channels at subarray F4. The random sampling technique used to obtain the data included all periods of operation (that is, windy and quiet periods, daytime and nighttime hours, etc.). The samples were read from 16 mm film at a viewer magnification of X20. The maximum trace amplitude present within the period range of 6 to 100 seconds during the first 5 minutes of each hour was measured peak-to-peak to the nearest 0.5 millimeter; periods were measured to the nearest second. Earthquake signals were excluded. The sampling period was from 20 September through 28 September 1966.

The percentage of occurrence curves shown in figure 4-10 are for the three long-period channels at subarray F4 during the period between 20 September and 28 September 1966. They indicate the probability of microseisms in the 6- to 100-second period range occurring at or less than a given trace amplitude for that subarray during the 9-day period sampled. The sampling technique is described in the previous paragraph.

5. EQUIPMENT PERFORMANCE

The following describes the performance of each principal piece of equipment in the LP system and discusses the problems encountered during their installation.

5.1 SEISMOMETER

In general, the performance of the seismometers has been satisfactory. The only significant problem that occurred during installation was the appearance of "spikes" in the output of the horizontal seismometers. These spikes were large deflections, frequently full scale (at operating magnifications of 25K), and all of the same polarity, that appeared at random time intervals. The large pulse appearing in the fourth trace (F1-13AH) of figure 5-1 is typical of the spikes. They are believed to be caused by the relaxation of mechanical stresses introduced in the instruments during installation. The stress relief was accelerated by thermally cycling all horizontal instruments. That is, they were alternately heated and cooled for a period of several days. This technique was successful in stopping the spiking.

As expected, the free period and mass position drift of the seismometers was large during the first few days after installation but diminished with time.

5.2 AMPLIFIER

Several problems had to be solved before the amplifier used in the Montana LASA LP system performed satisfactorily.

The amplifier is sensitive to magnetic field changes. The effects of these changes were reduced to an acceptable level by housing the amplifier in an enclosure made of 1/4-inch thick plate steel.

During installation, a field modification was made to the reactance section of each amplifier to install a ground connection that was omitted during manufacture.

When first received, each of the broadband filters failed to meet specifications. They were nonlinear in amplitude and did not display the desired filter response at frequencies higher than 0.167 hertz. Each of the broadband filters was returned to the manufacturer for correction.

During installation and calibration of the LP system, a total of 28 Type II amplifier channels became inoperative due to failures of line driver cards. Three of these failures were due to lightning hitting the power line at subarray F1. The rest of the failures were due to defective components or operational amplifiers in the line drivers.

5.3 AMPLIFIER POWER SUPPLY

This unit performs satisfactorily. During the installation, 2 failures occurred: 1 was due to lightning and 1 to a defective component.

5.4 LP VAULT TERMINAL

The performance of this unit is satisfactory. No failures or difficulties were encountered during its installation.

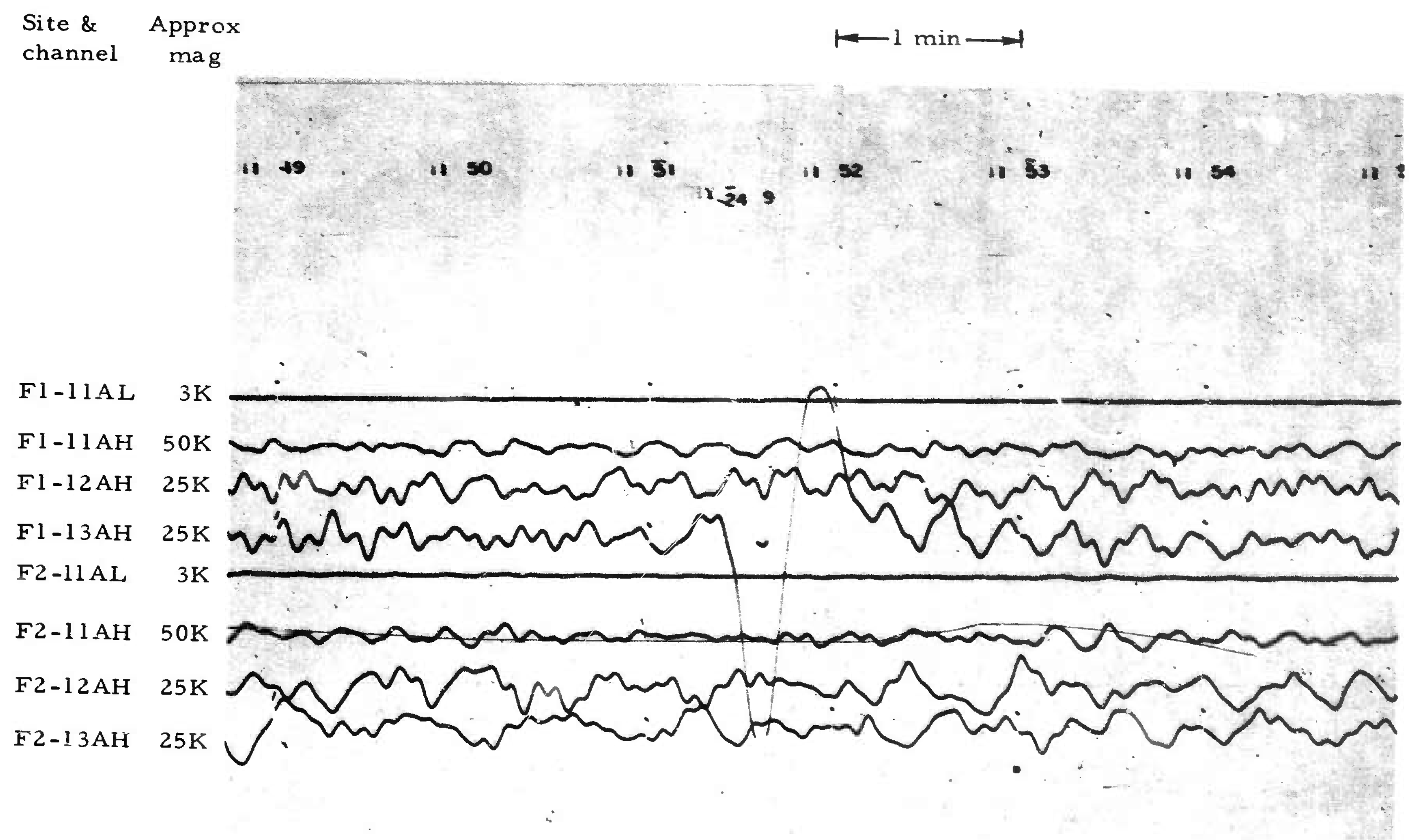


Figure 5-1. Example of an "instrumentation spike"

5.5 LP PROTECTOR

The performance of this unit is satisfactory. Routing the LP harness and field cables through the existing SP system wiring in the CTH junction box was difficult and time consuming. In future installations, this problem can be avoided if the SP and LP systems are installed at the same time.

5.6 SERVICE RECEPTACLES

The performance of the service receptacles is satisfactory. However, switching from channel to channel could be greatly speeded if quick-disconnect type receptacles were used.

5.7 JUNCTION ASSEMBLY

The junction assembly, used as a damping control for each seismometer, performs satisfactorily. No failures involving this unit were encountered.

5.8 FREE-PERIOD ACTUATOR

The performance of the free-period actuator is satisfactory. No problems were encountered during its installation or operation.

5.9 LP VAULT

Insufficient data are available at this time for a meaningful comparison of the two vaults designs that were used. No vaults have failed catastrophically, but several of the central telemetry housings (which are similar in design to the lesser reinforced LP vaults) exhibit hairline cracks in the floor and walls.

After construction, each LP (concrete) vault was tested for its pressure seal time constant. The time constants ranged from less than 2 minutes to 9 hours. Tests were performed at subarray C4 to determine the reason for the low time constants and what procedures were necessary to improve them. The high leakage was traced to the porosity of the concrete. Various methods and materials were tried to seal the concrete; however, the time constant was improved only from approximately 4 minutes to 30 minutes. It was concluded that the slight improvement in the vault time constant did not justify the expense or delay required to increase the time constants of the other vaults.

Equipment in the LP vaults was mounted to lead anchors driven into holes drilled into the vault walls. Due to the presence of agate in the aggregate of the concrete, the drilling process was slow and tedious and frequently the agates had to be broken with a star drill and hammer before drilling could be continued. Less time would have been consumed if anchors had been bolted to the interior forms and cast into the vault walls as they were constructed. The increased time for removal of the forms would have been more than offset by the saving of time during the equipment mounting phase of the program.

5.10 SEISMOMETER TANKS

The performance of the tanks housing the seismometers is satisfactory. A minimum leak rate time constant of 8 hours was obtained for each.

5.11 AMPLIFIER ENCLOSURE

At the beginning of this program, an amplifier enclosure was designed and built to provide thermal and electrostatic shielding in accordance with the recommendation of the manufacturer of the amplifier. These enclosures had been built and shipped to Montana when it was discovered that the amplifier also needed protection from changes in magnetic field. It was decided to proceed with the field installation using the amplifier enclosures on hand and to replace these later with a new enclosure that also provided magnetic shielding. The replacement was accomplished during the first two weeks in October 1966. Since the installation of the new enclosure, it is possible for maintenance personnel to work in the CTH using conventional steel hand tools and meters without introducing spurious signals into the LP channels.

5.12 REMOTE ADJUSTMENT DEVICES

Due to the humid atmosphere within the LP vault, the motors in the remote centering and period adjusting devices frequently would not start upon application of the normal operating voltage. The probability of failure increased as a function of inactive time. In one attempt to correct the problem all motors were cleaned, sprayed with water-repellent material, and reinstalled. In another attempt, bags of desiccant were placed within the housing covering the motor and the housing was sealed on 10 units. Neither of these methods proved satisfactory. It is suspected that over prolonged periods, corrosion builds up between the motor commutator and brushes and acts as an insulator. It was found that the motors would start and operate at normal voltage if 60 Vac were momentarily applied to them. This method was adopted as a temporary solution to the problem.

5.13 TEST EQUIPMENT

Two control monitor units were provided under the contract. During their use in the installation and calibration of the LP system, only one failure occurred. This was corrected by the replacement of several transistors and a Zener diode in the function generator of the faulty unit.

All other test equipment used in the installation and calibration of the LP system was satisfactory.

6. CONCLUSIONS

It is concluded that the services and materials called for in Contract AF 33(657)-15190 and the supplemental agreements have been furnished as required, and that, with the submission of this report, all work on this contract is complete.

All equipment s performing satisfactorily except the seismometer remote adjust devices and output line drivers of the data amplifiers. The seismometer remote adjust devices frequently fail to respond to the normal command signal and must be jarred into operation by the application of a high-level voltage impulse. The failure rate of the output line drivers of the data amplifier is excessive; however, no corrective action has been taken other than replacement of the defective units as they fail.

7. RECOMMENDATIONS

As the work of installing and testing the LASA LP system progressed, it was noted that several changes could be made to improve both the installation task and the equipment. These are presented below as specific recommendations.

7.1 A troublesome component of the seismometer remote adjust devices is the dc motor used to power each one. It is recommended that these dc motors be replaced by a sealed, brushless ac motor for more dependable operation. A project recommendation concerning this change has been submitted to the Project Officer.

7.2 The excessive failure rate of the output line drivers of the data amplifier indicates that either circuit redesign or component improvement is needed in that stage.

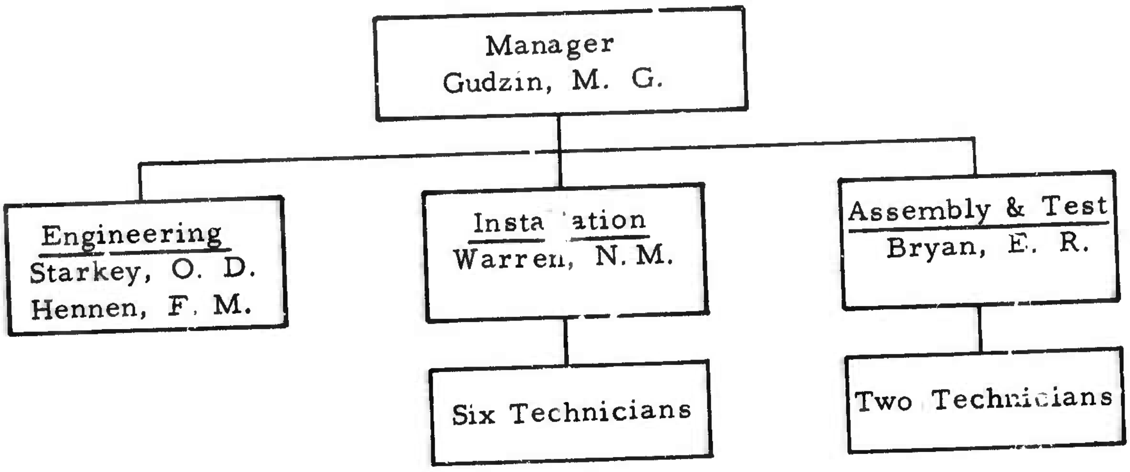
7.3 It is recommended that in future installations the LP system be installed at the same time as the SP system. This would decrease the overall installation time and reduce the cost that results from the duplication of effort in such things as cable entry sealing, ditching, landscaping, etc.

7.4 Considerable time and effort were invested in the drilling of equipment mounting holes in both the LP vault and the CTH at each subarray. It is recommended that in future installations, screw anchors for supporting the equipment be cast into the concrete walls during construction of the vaults.

7.5 It is recommended that quick-disconnect type connectors be used for the service receptacles in future installations.

8. ADMINISTRATION

The work described in this report was performed by 3 engineers and 7 technicians under the overall supervision of the program manager, Mr. M. G. Gudzin.



9. ACKNOWLEDGEMENTS

We wish to thank the personnel of the following companies for their cooperation and assistance during this program:

The Stormaster Tornado Shelter Co.
L. P. Anderson, Contractor, Inc.
The Earth Sciences Division of Teledyne Industries
The TechRep Division of the Philco-Ford Corporation
Massachusetts Institute of Technology, Lincoln Laboratory
The Science Services Division of Texas Instruments Inc.

APPENDIX 1 to TECHNICAL REPORT NO. 67-17

WORK STATEMENT
and
SUPPLEMENTAL AGREEMENTS

EXHIBIT "A" 4 MAY 1965

STATEMENT OF WORK TO BE DONE
AFTAC Project Authorization No. VELA T/6701

1. **Tasks**. Using approved long-period (LP) seismograph installation guidelines and specifications resulting from tests conducted at LASA subarray F3 (Hysham, Montana), provide the following:

a. Install in close proximity to the underground central telemetry vault a suitable underground LP vault at each LASA subarray. A total of 20 vaults will be required. Care will be given to obtaining moisture, temperature, and pressure control within the interior of the vault. Each vault will contain 3 sealed instrument tanks embedded in concrete in the floor. Power and data lines will be terminated at the subarray central telemetry vault.

b. Assemble and check out at the contractor's plant the LP 3-component seismograph instrumentation. LP seismometers, Model 7505A and Model 8700C, will provide the basic system sensors. Station protectors, data line termination, amplifiers, and a remote control and monitoring capability are required. Relatively unattended operation is required, comparable with that attained in the LASA short-period seismograph instrumentation design. Complete equipment specifications and bill of materials will be reviewed by the AFTAC project officer for final approval prior to delivery for installation.

c. Install and test the LP system. The LP system analog outputs shall be compatible with Lincoln Laboratory telemetry electronics used in digital transmission of subarray data to the Billings, Montana, Data Center. Tests will be conducted to establish optimum system magnifications using portable recording apparatus connected at convenience outlets from line terminals in the central telemetry vault. While subcommutation will not be specified at this time, dual level outputs from each instrument to obtain wide dynamic range and desired filtering shall be provided.

NOTE: Up to 3-data channels are available at each subarray from Lincoln Laboratory telemetry equipment.

d. Provide to the government complete installation records, graphs, wiring diagrams, and system component operation and maintenance instructions for the LASA LP system. Installations should be standardized to the maximum extent possible, in accordance with best engineering practices as specified in DD Form 1423.

ATTACHMENT 1 to DD FORM 1423

REPORTS

AFTAC Project Authorization No. VELA T/6701

1. Monthly Progress Reports. Monthly progress reports will be submitted in 15 copies, commencing the 5th day of the second month after the effective date of the contract. The report will include identification information as outlined in paragraph 2b. These reports will include but not be limited to the following subject areas:

a. Technical Status.

(1) Major accomplishments.

(2) Problems encountered.

(3) Future plans.

(4) Action required by the government.

(5) Illustrations and photographs, as applicable.

b. Financial Status.

(2) Man-months expended to date.

(3) Statement concerning overrun possibilities.

2. Final Report. The final report will be submitted in 50 copies not later than 2 months after the contract period. Format for this report will be in accordance with the final report format established under Contract No. AF 33(600)-43369. DD Form 1473, Document Control Data - R&D, will be attached to each report (reference AFR 80-29). This report will include the following:

a. Notices on the cover, first page, or title page as follows:

(1) Sponsored by: Advanced Research Projects Agency, Nuclear Test Detection Office, ARPA Order No. 599.

(2) Availability: Qualified users may request copies of this document from:

Defense Documentation Center
Cameron Station
Alexandria, Virginia 22341

(3) Acknowledgment: This research was supported by the Advanced Research Projects Agency, Nuclear Test Detection Office, and was monitored by the Air Force Technical Applications Center under Contract No. AF ____________________

b. Identification Information:

AFTAC Project No. VELA T/6701

Project Title

ARPA Order No. 599

ARPA Program Code No. 8100

Name of Contractor

Contract Number

Effective Date of Contract

Amount of Contract

Contract Expiration Date

Project Manager's, Scientist's, or Engineer's Name and Telephone Number

c. All seismograms and operating logs to include pertinent information concerning time, date, type of instruments, magnification, etc., will be provided when requested by the project officer.

3. Special Reports.

a. Special reports of major events will be forwarded by telephone, telegraph, or separate letter as they occur and should be included in the following monthly report. Specific items are to include, but are not restricted to, program delays, program breakthroughs, and changes in funding requirements.

b. Special technical reports will be required for instrument evaluations, project recommendation, and special studies when it is more desirable to have these items reported separately from the monthly or final reports. Specific format, content, number of copies, and due dates will be furnished by this headquarters.

CONTRACT CHANGE NOTIFICATION	AUG 1 1966 49433	1. MASTER SERIAL NO. 7N-67
		2. CCN NO. 1
		3. PAGE 1 OF 1 PAGES

4. TO	5. FROM:
Teledyne Industries, Inc. (Geotech Division) 3401 Shiloh Road Garland, Texas 75228	HQ ASD (ASWKS) Wright-Patterson Air Force Base, Ohio 45433

6. PURCHASE REQUEST NO.	7. CONTRACT NO. AND/OR PURCHASE ORDER NO.	8. PROPERTY CLASS
WK-7-RD-651	AF 33(657)-15190	N/A

9. Pursuant to the clauses of the contract relating to changes, the above named Contractor is hereby authorized and directed to accomplish the changes listed below in respect to the articles called for under said contract as the same has heretofore and may hereafter be amended; subject, however, to the terms and provisions set forth on the reverse side hereof. Whenever both a purchase order number and a contract number are shown above, both numbers will be used in any shipping paper, packing sheet, invoice, correspondence, or related document, the purchase order number preceding the contract number.

I THE STATEMENT OF WORK TO BE DONE, referred to in Part I is amended to include Project Authorization No. VELA T/6701 Amendment No. 3 dated 30 June 1966, to the basic authorization as follows:

"Change Task 1c in the Statement of Work to be Done contained in Project Authorization No. VELA T/6701 is amended to include installation of Broadband Filters on LP components at 8 sub-arrays; increasing by 30 DB the gain on LP seismograph amplifiers at all sub-arrays, and installation of magnetic shields on LP seismograph amplifiers at all sub-arrays."

"The work specified in this amendment should begin 8 July 1966 and be completed by 30 November 1966."

II It is anticipated that incorporation of the changes cited above will increase the contract price by an estimated amount of Thirty Six Thousand Four Hundred Dollars ($36,400.00) are hereby obligated to cover the estimated increase in price resulting from this CCN. This obligation is for administrative purposes only and will not effect the right of either party to negotiate an equitable adjustment according to the provisions of the clause pursuant to which this CCN is made.

Fund Allotment: 79X0400.1302 786 6199 6F10 VT/6701 S595600/591600
77

MAILING DATE JUL 27 1966

10. DATE	11. TYPED NAME, GRADE, AND SIGNATURE OF CONTRACTING OFFICER
12 July 1966	Robert A. Gessaman ROBERT A. GESSAMAN/CONTRACTING OFFICER

12. DISTRIBUTION Same as basic contract, as amended.

CONTRACT DATA REQUIREMENTS LIST

ATCH NR ____ TO EXHIBIT ____

TO CONTRACT/PR SA #2 to AF33(657)-15190 CATEGORY ____

SYSTEM/ITEM VT/6701

CONTRACTOR ____

1. SEQUENCE NUMBER	2. TITLE OR DESCRIPTION OF DATA / 3. SUBTITLE	4. AUTHORITY (Data Item Number)	5. CONTRACT REFERENCE	6. TECHNICAL OFFICE	7. DD250 REQ	8. APP CODE (A)	9. INPUT TO IAC (X)	10. FREQUENCY	11. AS OF DATE	12. DATE OF 1ST SUBMISSION	13. DATE OF SUBSEQUENT SUBM/EVENT ID	14. DISTRIBUTION AND ADDRESSEES (Addressee—Regular Copies/Repro Copies)	15. TOTAL
9	a. LASA LP Component Construction Manual	H-11-46.0-1	Task 1d	HQ USAF AFTAC/VSC		A		O Time	Comp Task 1e	31 Dec 1966		HQ USAF AFTAC/VSC 100/0	100/0

16. REMARKS

Format shall be like that of the SP Component construction manuals furnished under Project VT/5071

16. REMARKS

16. REMARKS

16. REMARKS

PREPARED BY E. E. Dismeier/DMO/ASWKS | DATE 11 Jul 66 | APPROVED BY A. J. Feliciangeli, Data Management Monitor, Directorate of Specialized Subsystems & Equipment | DATE 11 July 66

DD FORM 1 SEP 63 1423 REPLACES EDITION 1 MAR 63 WHICH MAY BE USED UNTIL 31 DEC 1963.

DCASR, Dallas

CONTRACTOR'S COPY APR 6 1967
51455

CPFF SUPPLEMENTAL AGREEMENT AJ	EFFECTIVE DATE 10 March 1967	PAGE NO. 1	NO. OF PAGES
REQUISITION NO./PURCHASE AUTHORITY Not Applicable	CONTRACT (Order) NO. AF 33(657)-15190 Class: None	MODIFICATION NO. 4	

TO: (Contractor's name and address)	ISSUED BY
TELEDYNE INDUSTRIES, INC. (Geotech Division) 3401 Shiloh Road Garland, Texas 75041	UNITED STATES AIR FORCE AFSC AERONAUTICAL SYSTEMS DIVISION WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433 Buyer: G. J. Pearson (ASWKS)

ACCOUNTING AND APPROPRIATION DATA

Not Applicable

MAILING DATE APR 3 1967

The above-numbered contract is modified as follows:

1. By changing "100/0" appearing in Blocks 14 and 15 of Sequence Item 9 on DD Form 1423, attached to Supplemental Agreement No. 2 to said contract, to read "130 copies/1 set reproducible" at no change in estimated cost or fixed fee.

ADMINISTRATIVE INFORMATION

Subject: Change in Quantity of Distribution Copies of Component Construction Manual

Change in Estimated Cost: None

Change in Fixed Fee: None

Administrative Office: DCASR, Dallas
MerchandiseMart Bldg.
500 South Ervay Street
Dallas, Texas 75201

Finance Office: DCASR, Dallas
Attn: Office of Data and Financial Management
500 South Ervay Street
Dallas, Texas 75201

REPRODUCTION

Except as hereby modified, all terms and conditions of said contract as heretofore modified remain unchanged and in full force and effect. This Supplemental Agreement is entered into pursuant to the XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX "Changes" clause of the General Provisions of said contract.

	UNITED STATES OF AMERICA
TELEDYNE INDUSTRIES, INC. NAME OF CONTRACTOR	
BY [signature] SIGNATURE — 31 Mar 67 DATE	BY Thomas B. Kain SIGNATURE OF CONTRACTING OFFICER — 67 DATE
J. L. Wood TYPED NAME	THOMAS B. KAIN TYPED NAME OF CONTRACTING OFFICER
Vice President TITLE	

DD FORM MAY 64 1320

APPENDIX 2 to TECHNICAL REPORT NO. 67-17

PRELIMINARY TESTS CONDUCTED AT SUBARRAY F3

PRELIMINARY TESTS CONDUCTED AT SUBARRAY F3

From April until September 1965 an experimental program was conducted at LASA subarray F3 (Hysham, Montana) to develop improved installation techniques for the LASA LP system. The work performed in this program was authorized under paragraphs 1c (2) and 1d of AFTAC Project Authorization No. VELA T/4051, Amendments 2 and 3. For the program a prototype LP vault was constructed adjacent to a surface installation of three LP seismometers which were part of an LRSM Program mobile laboratory being operated by Geotech at subarray F3 at that time. Three seismometer tank assemblies were installed in the LP vault; 1 cast directly into the concrete floor of the vault and 2 more installed through the floor but isolated from it by a 2-inch annular gap. One Vertical Seismometer, Model 7505A, and two Horizontal Seismometers, Model 8700C, were installed in the tank assemblies. Both the horizontal seismometers were oriented to the same azimuth, 131 degrees from true north. The data amplifier used in the test systems was the Phototube Amplifier, Model 5240. Recording was on the Benioff Film Recorder, Geotech Model 1301A. The test system parameters were adjusted to LRSM standards to permit direct comparison of the test system to the LRSM surface installation.

During the testing program a third horizontal seismograph, consisting of the same instrumentation and oriented in the same direction as the existing test seismographs, was added. The seismometer of this channel was placed on the floor of the test vault.

Three technical reports concerning the experimental program were published. They are TR 65-47, dated 28 May 1965; TR 65-61, dated 24 June 1965; and TR 65-106, dated 20 August 1965. These reports cover the tests performed prior to 17 July 1965. The test program was extended to the end of August in order to continue the investigation of two major problems; a wind-generated noise that affected each of the horizontal seismographs and a lack of phase coherence exhibited by one of the seismographs during that noise.

The following is a summary of the major tests performed after 17 July 1965.

a. An earthen mound which had been constructed over the vault entrance was lowered and smoothed in an effort to reduce its wind resistance.

b. The vertical seismometer was moved into the coupled tank and the horizontal seismometer was moved from the coupled tank into the decoupled tank that had held the vertical seismometer. The seismometer on the vault floor and the seismometer displaying poor phase coincidence were left undisturbed during this change.

c. The test vault was unsealed for several hours then resealed. Microbarograms made before and after the vault was sealed were compared to each other and to the seismograms produced during this period.

d. The locations of the horizontal seismometer on the vault floor and the horizontal seismometer displaying poor phase coincidence were interchanged. The vertical and horizontal seismometers that had been previously interchanged (paragraph b, above) were left undisturbed during this change.

e. At the conclusion of the preceding test (paragraph d) a tilt test similar to that described in TR 65-61 was performed. A 100-foot length of rope was attached to the vault. The other end of the rope was attached to a vehicle through a spring scale. The vehicle was backed slowly along a line 131 degrees from true north until the desired force was indicated on the scales. The force was held for 1 minute, then released. The procedure was repeated several times to ensure repeatability of the results.

Results of the tests:

a. No decrease in the noise level was obtained by lowering and smoothing the earthen mound over the vault entrance.

b. No change was noted in the performance of the horizontal seismometer that was moved from the coupled tank into an uncoupled tank; it continued to respond "in phase" with the horizontal seismometer on the vault floor and the amplitude of its response to noise remained very nearly the same as when it was in the coupled tank.

c. With the test vault vented to atmosphere the microbarograms showed close agreement with the seismograms (that is, the amplitude of the seismic noise increased as the amplitude of the pressure fluctuations increased over prolonged periods). When the test vault was sealed the noise level on the microbarogram decreased approximately 18 dB but the noise level on the seismograms stayed about the same and the correlation between the microbarograms and the seismograms disappeared.

d. When placed on the floor of the vault the horizontal seismometer that had previously displayed poor phase coincidence showed good phase coincidence with the undisturbed horizontal seismometer. The seismometer that was originally on the floor of the vault displayed poor phase coincidence when placed in the decoupled vault.

e. The results of the tilt tests were similar to the results reported in TR 65-61 in that all horizontal seismometers responded in phase and the output of the horizontal seismometer located on the vault floor was approximately 4 dB larger than those of the horizontal seismometers located in tanks.

Conclusions:

a. The earthen mound constructed over the vault entry did not reduce the amplitude of the wind-generated noise. An alternate method of eliminating the portion of vault exposed above ground would have been to modify the vault by breaking up the concrete forming the entrance and casting a new, shorter entrance onto the vault. This approach was not attempted due to the delay that would have resulted in the testing program. It is still not certain how the wind generated noise is transmitted to the seismometers although the microbarograms made before and after the vault was sealed indicate that the noise is not dependent upon pressure changes occurring inside the vault. It appears as though the noise is coupled directly through the ground.

b. There appears to be no advantage in decoupling the tanks. No appreciable change was noted in the performance of a horizontal seismometer after it was transferred from a coupled tank to a decoupled tank. Decoupling of the tank was verified by the results of the tilt test.

c. Interchanging the locations of the horizontal seismometers eliminated the instrumentation as the source of the poor phase coincidence problem. It was established that the problem was always associated with the instrument in the decoupled tank to the left as viewed from the vault entrance. There are several possible actions that could cause the problem (that is, a "piston effect" by the tank, deformation of the vault floor, etc.). Each of these actions could be eliminated by coupling the tanks to the vault floor and increasing the thickness of the vault floor.

Recommendations:

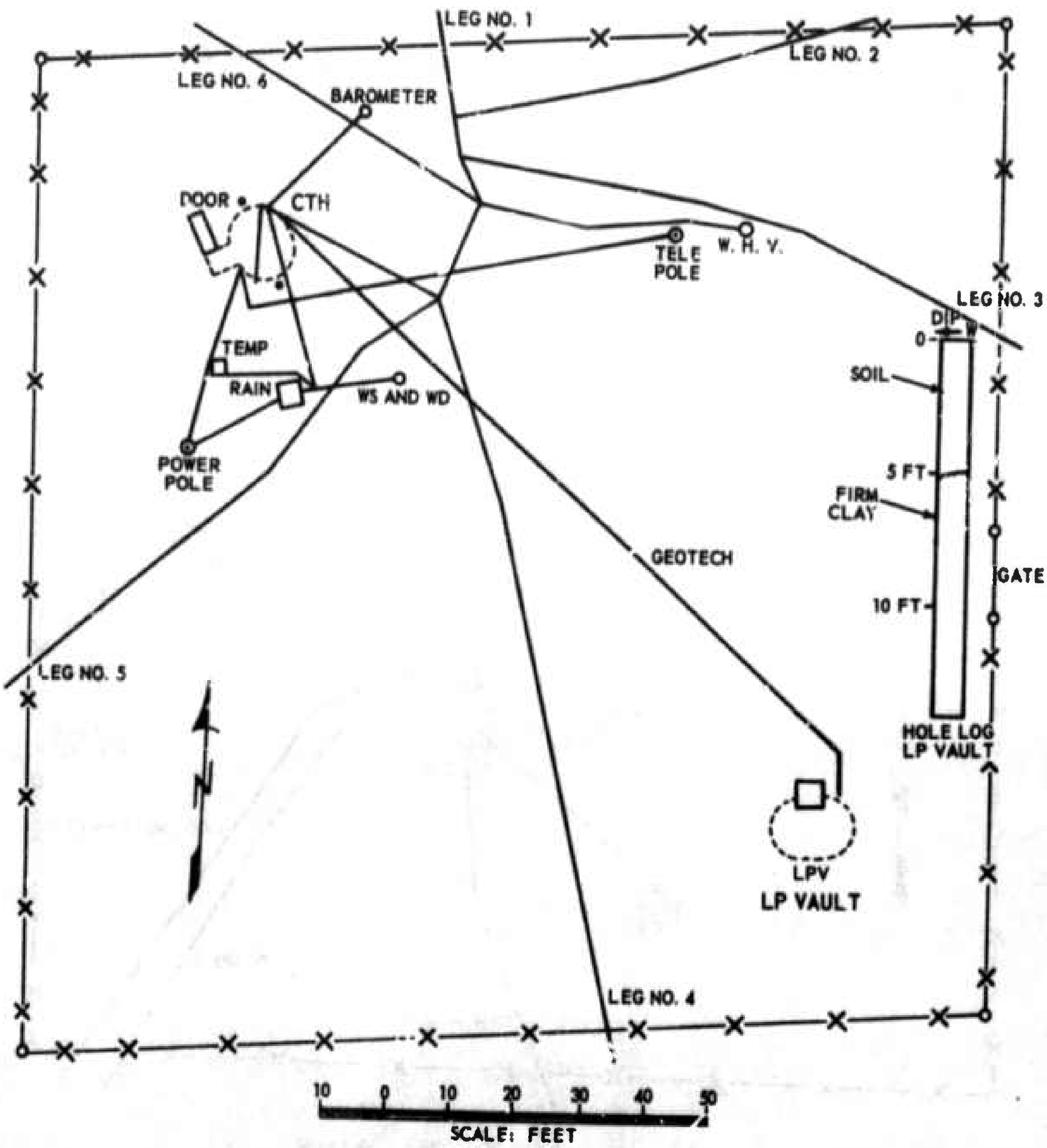
a. It is recommended that all seismometer tanks of the LASA LP system be coupled to the vault by casting them directly into the concrete floor.

b. The floor area containing the tanks should be made at least 36-inches thick in the LASA LP vaults.

c. The vaults should be constructed so that no portion of the vault protrudes above the ground. Following the installation of a vault the area should be landscaped into a smooth, even surface. Although drainage is necessary, no appreciable mound of earth should be permitted over or near-by the vault.

APPENDIX 3 to TECHNICAL REPORT NO. 67-17

SITE PLATS



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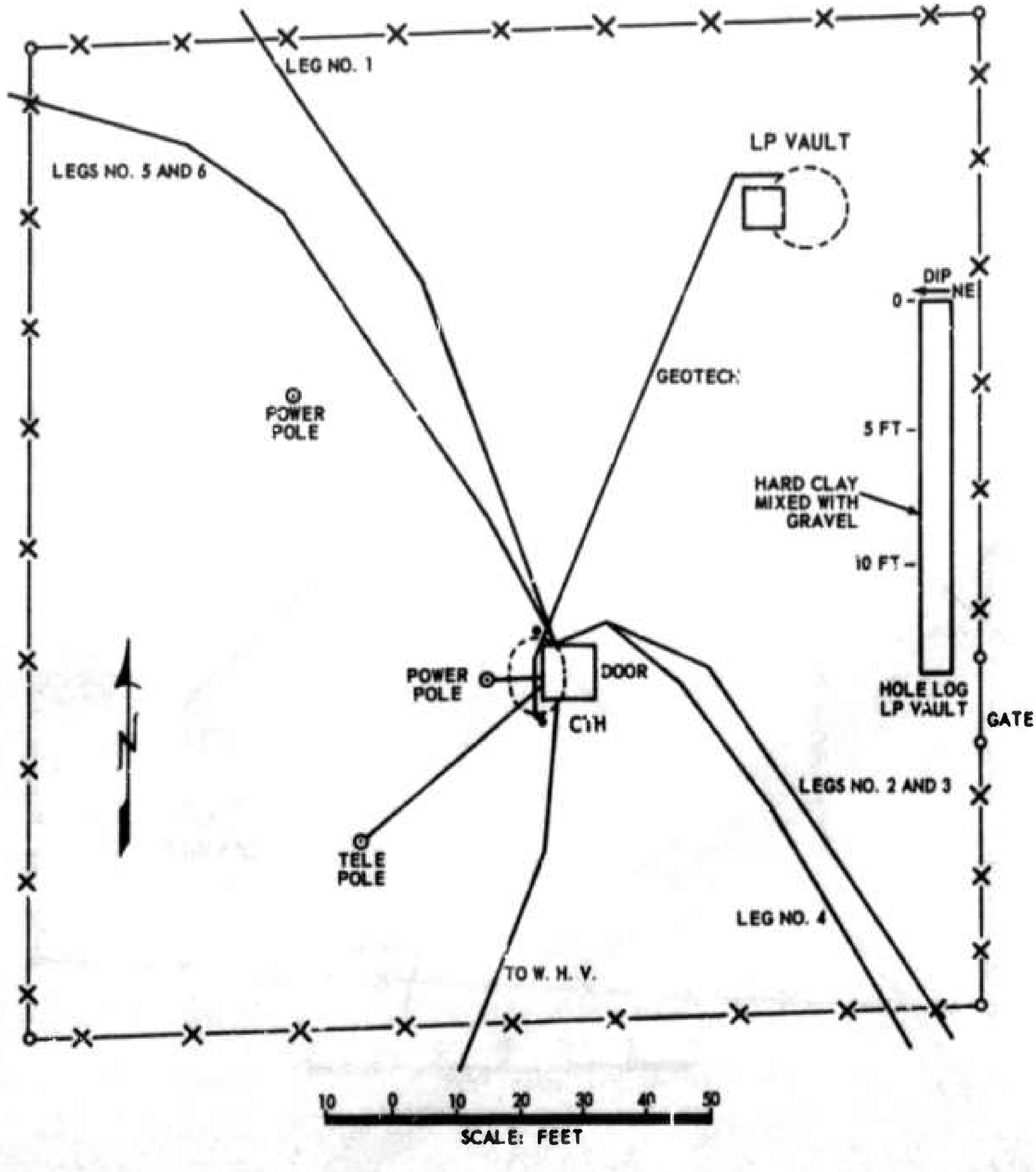

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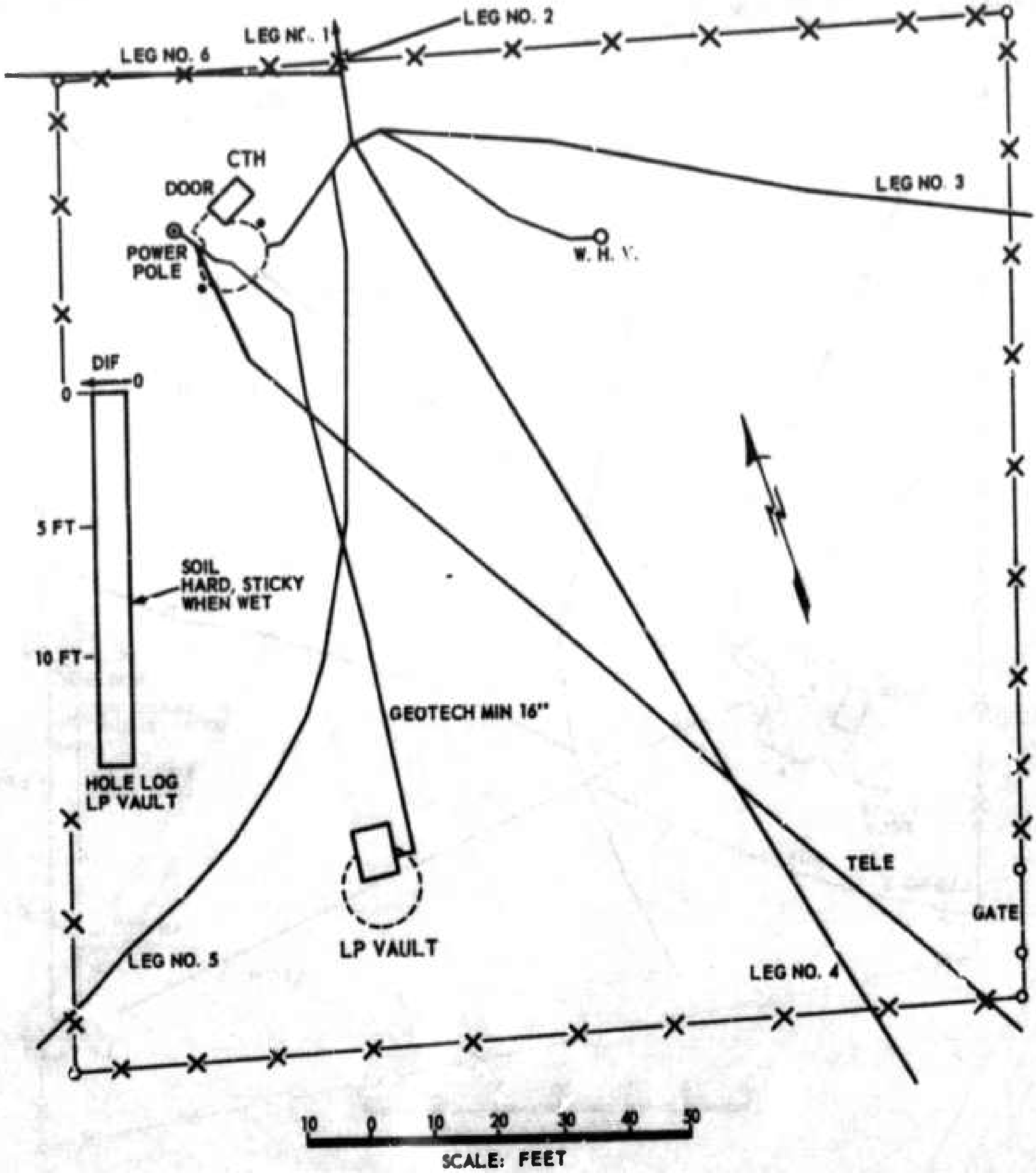

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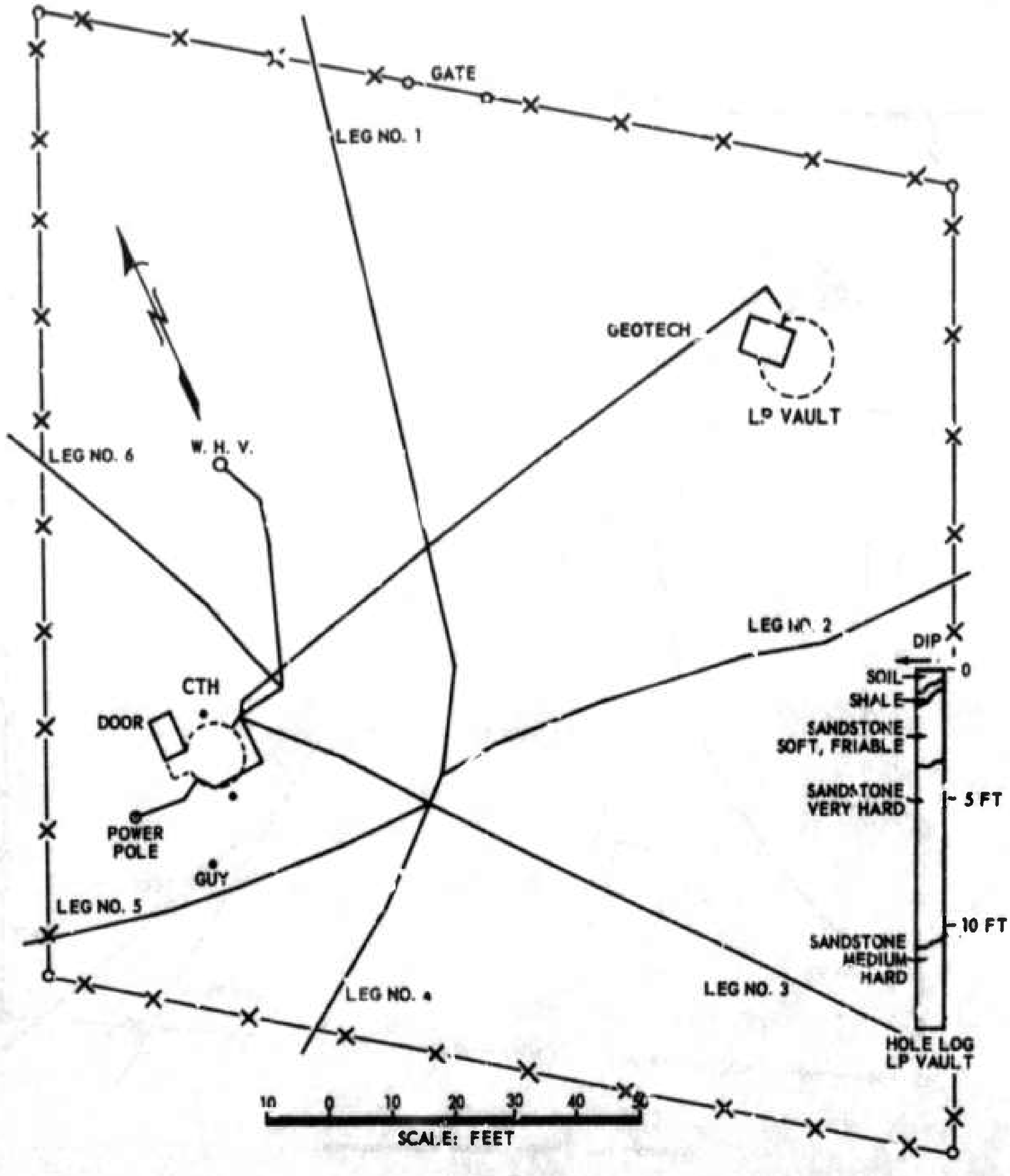

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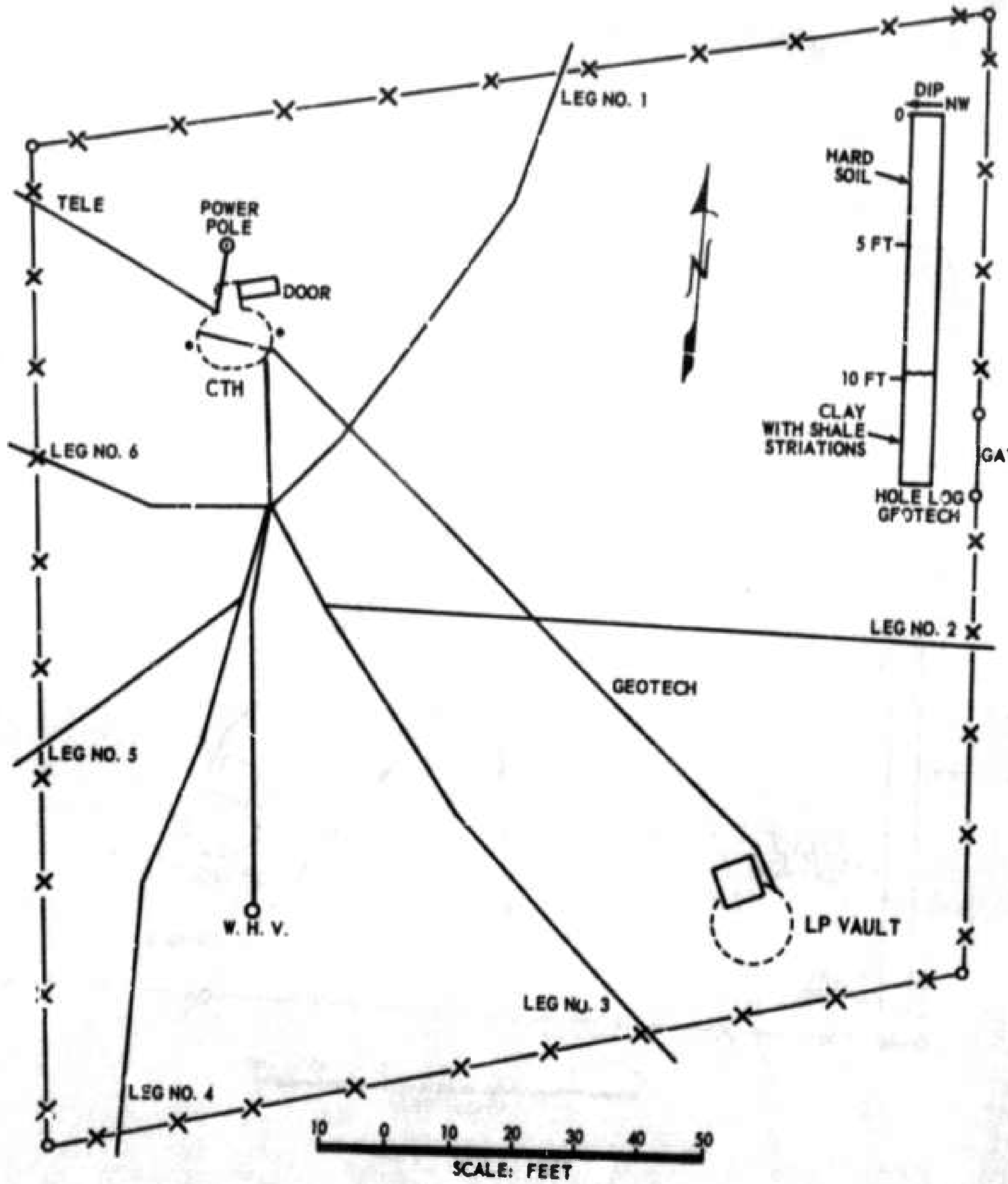

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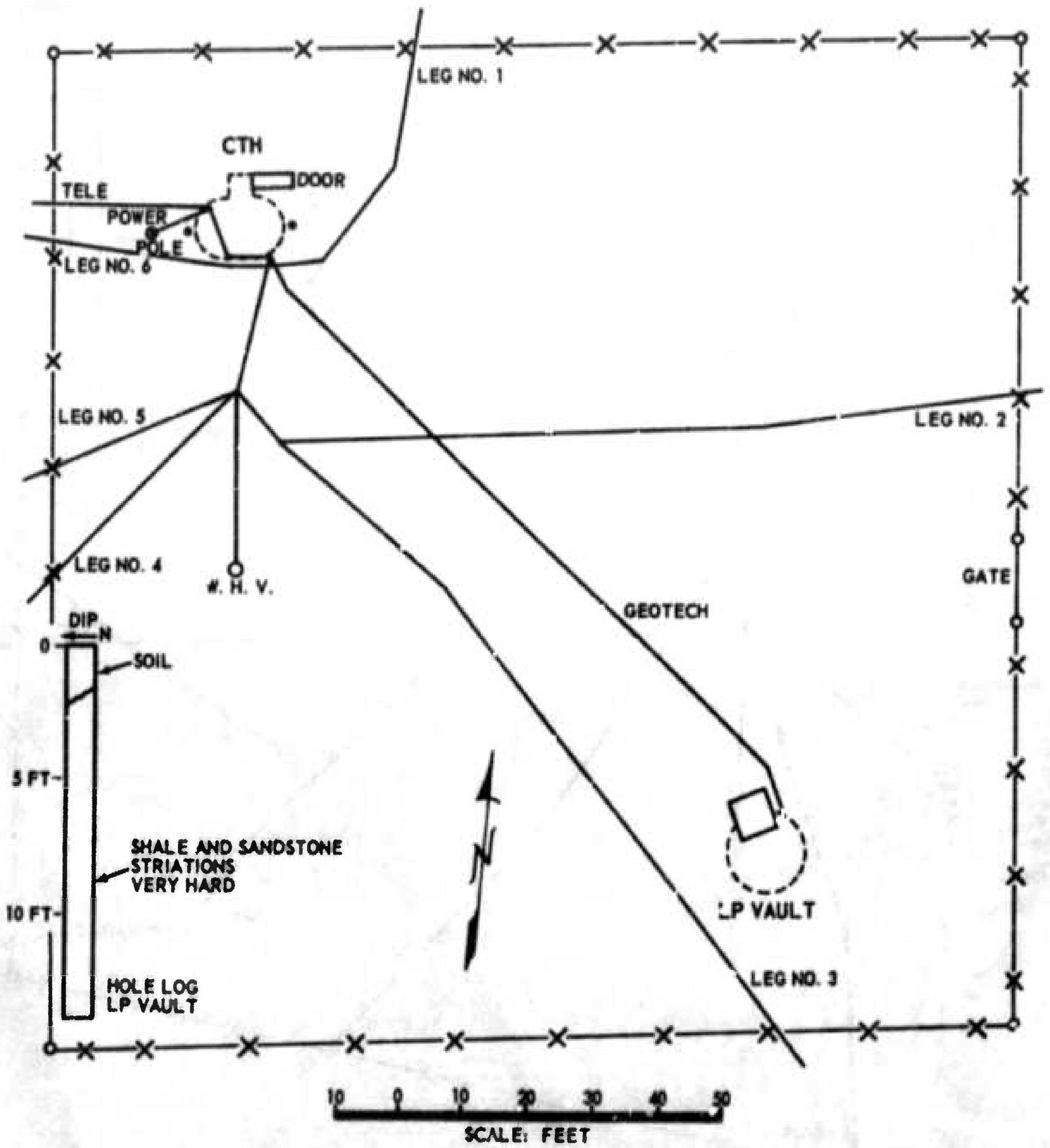

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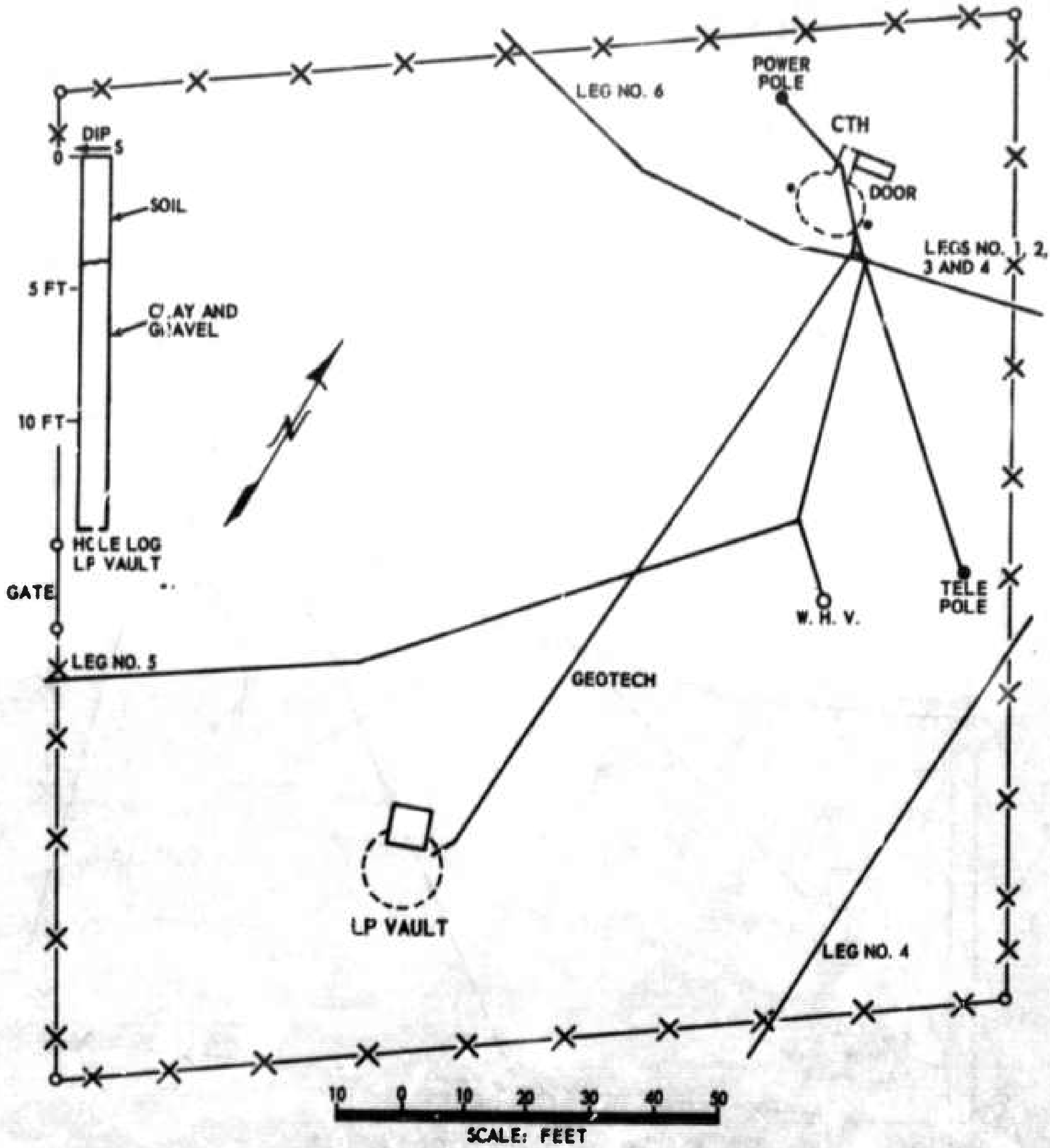

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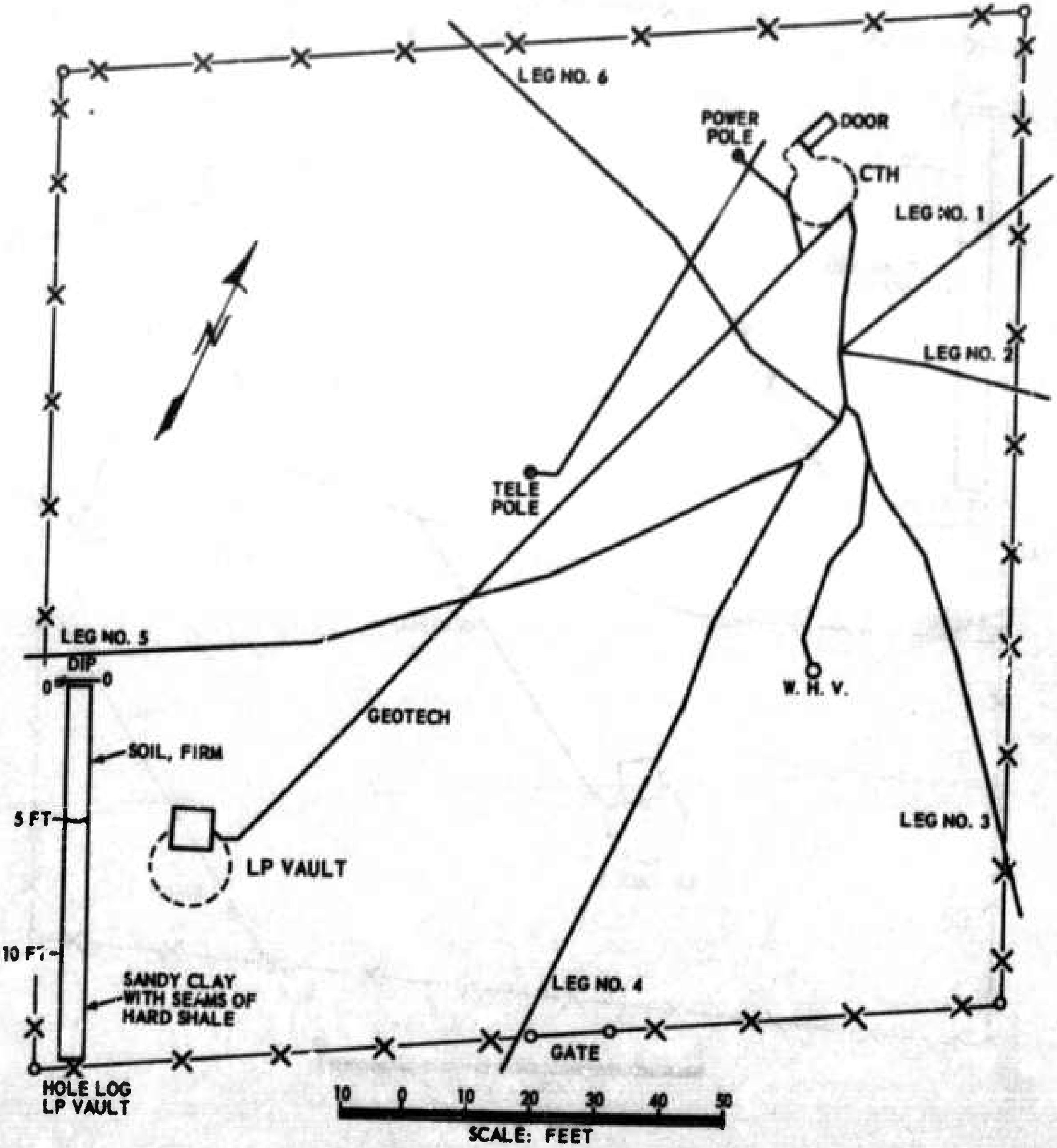

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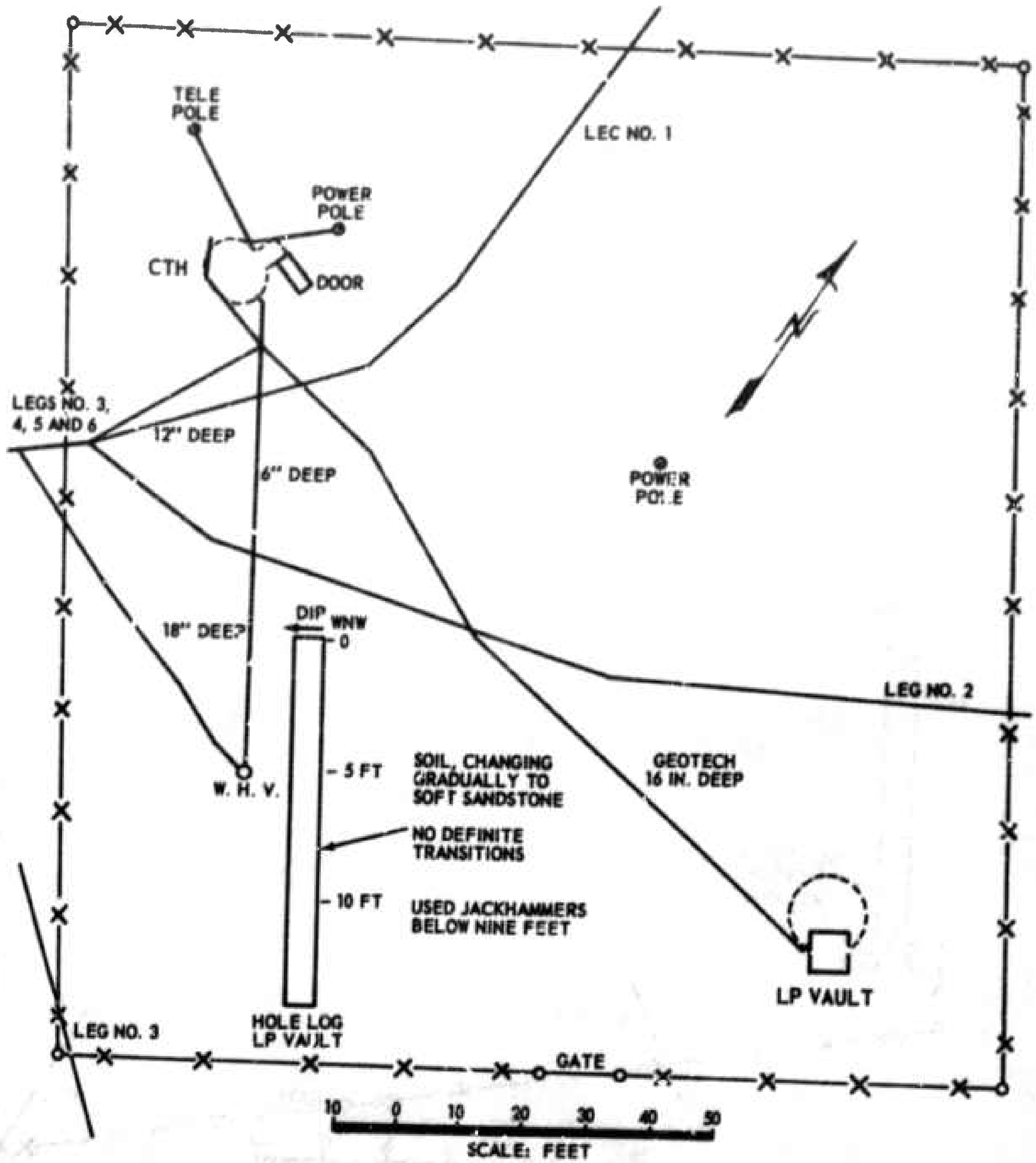

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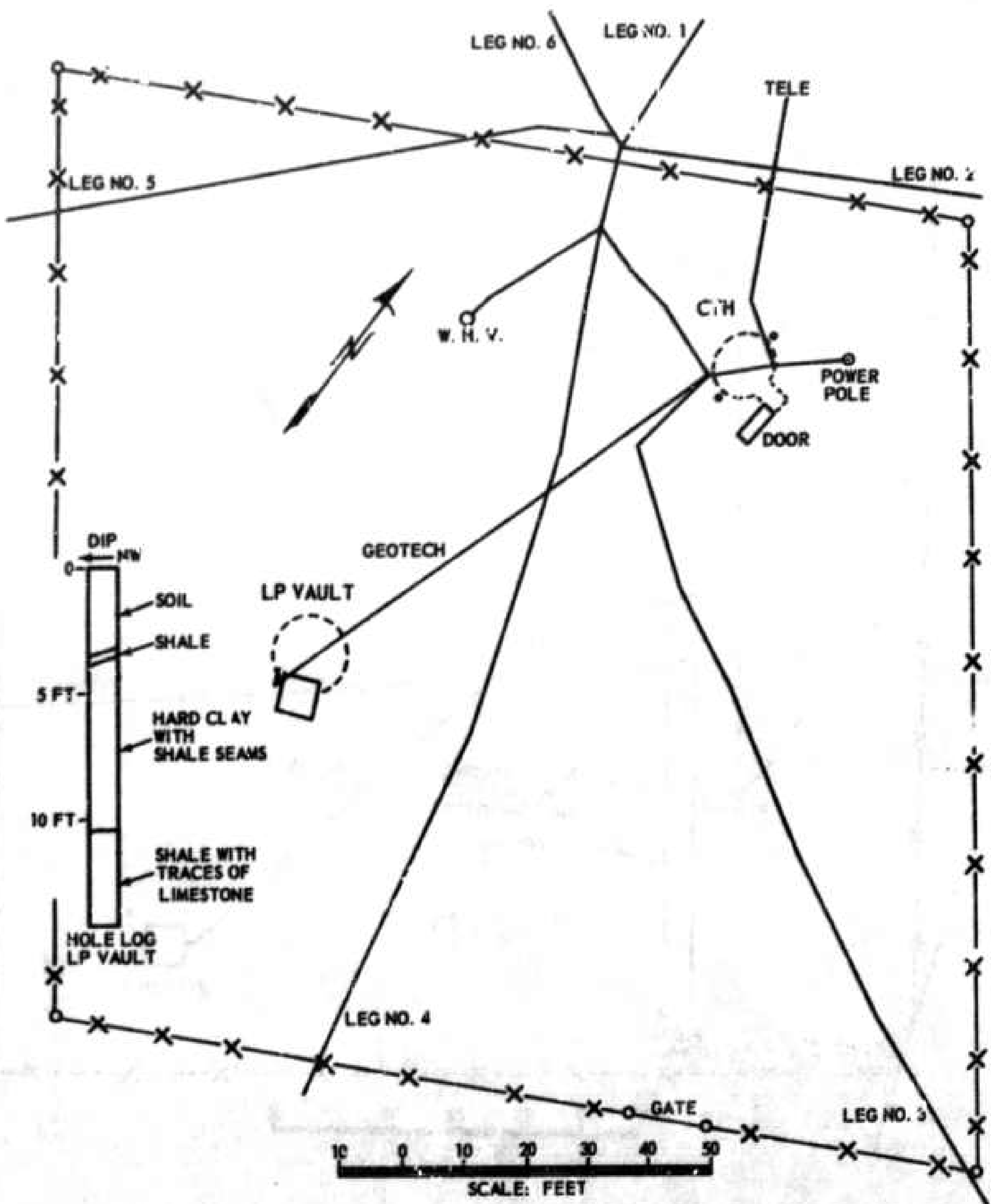

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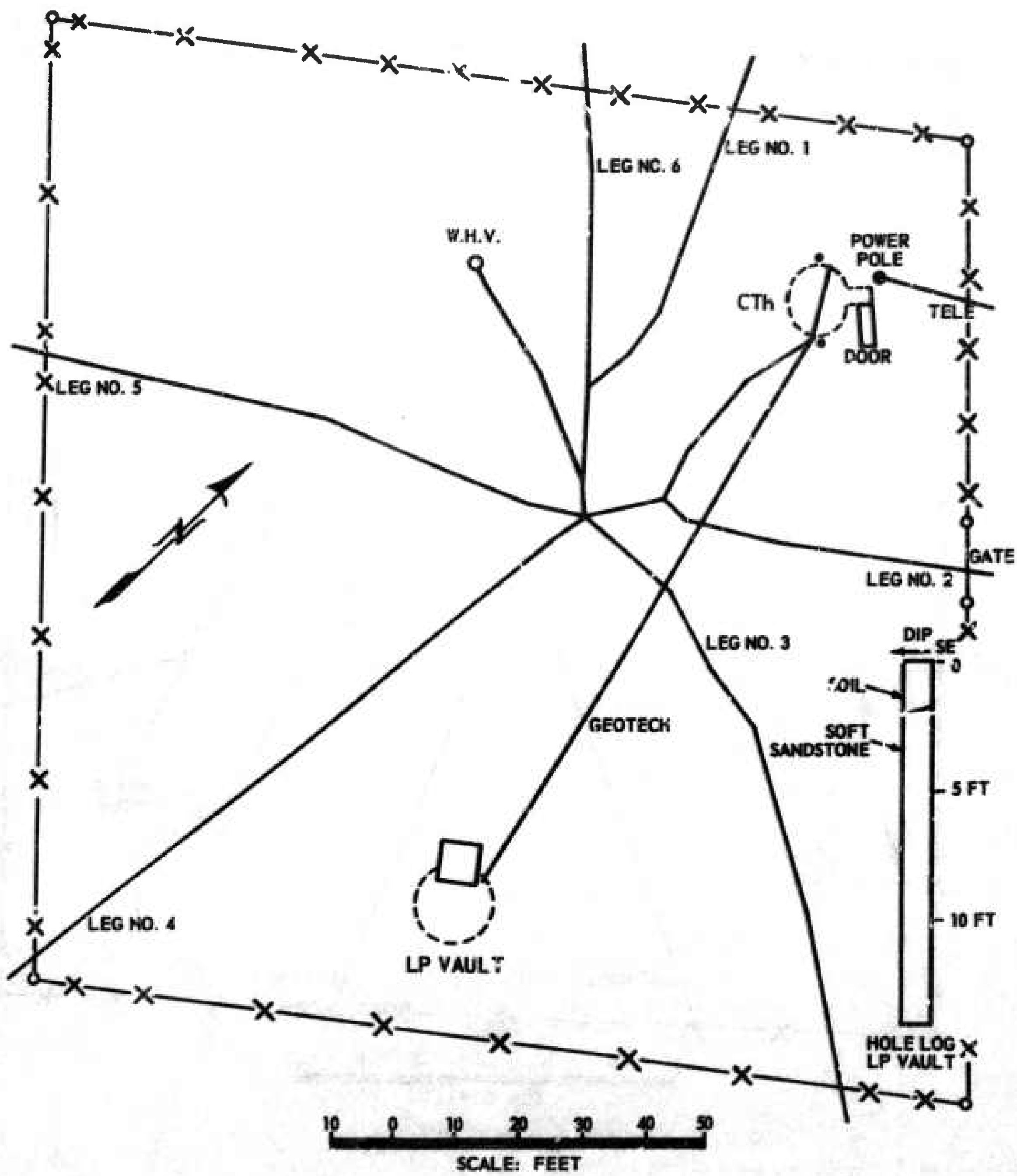

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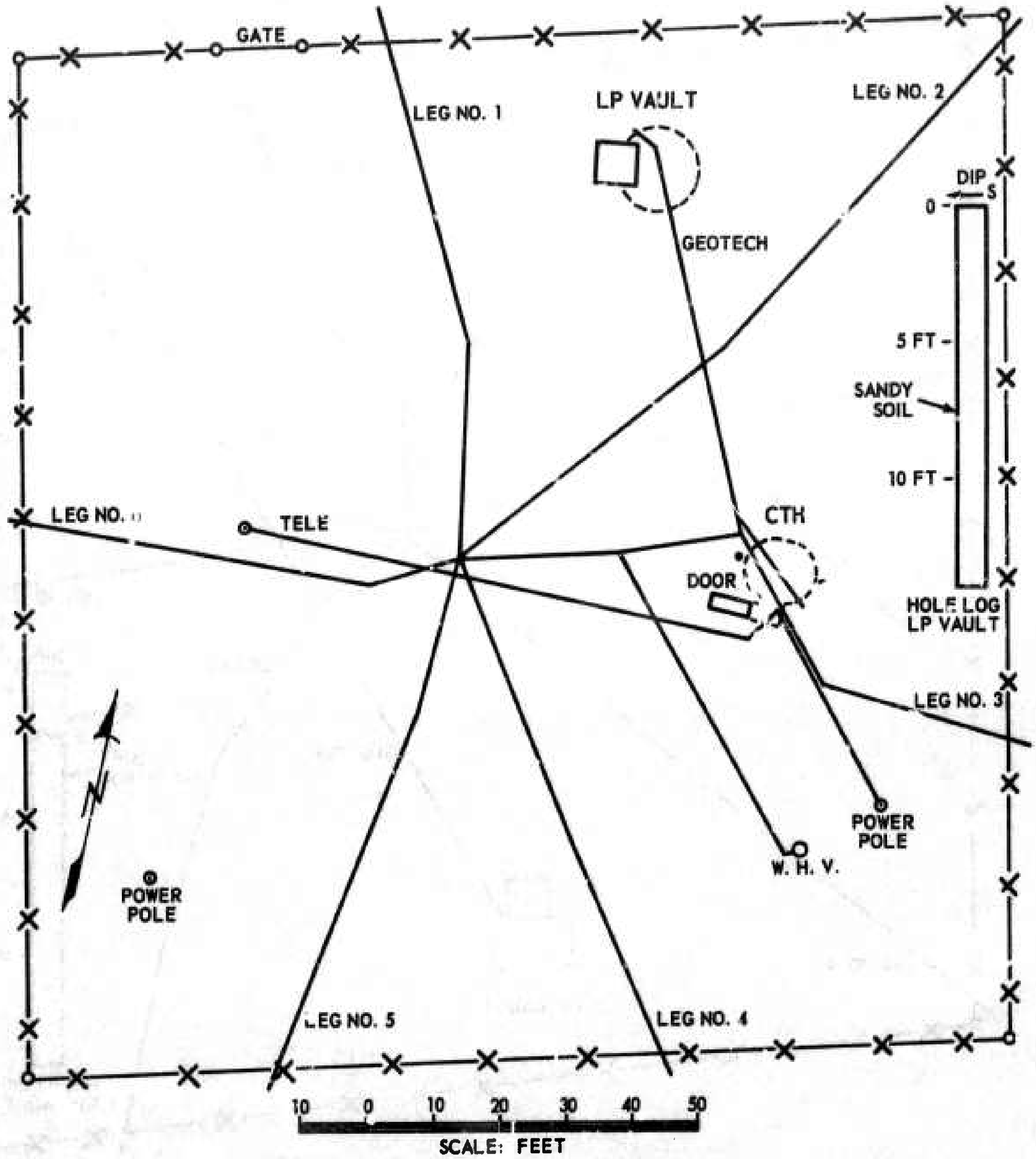

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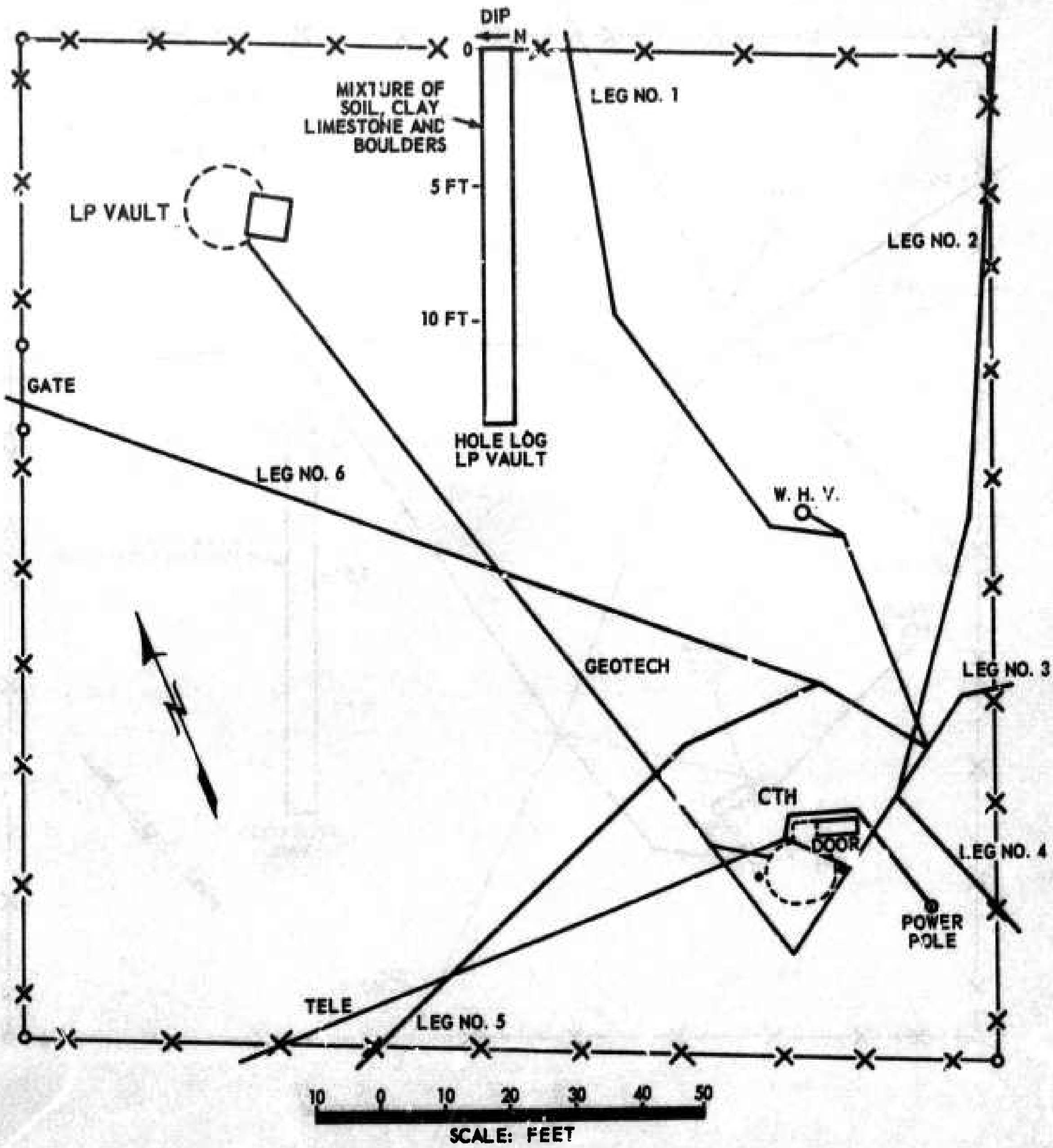

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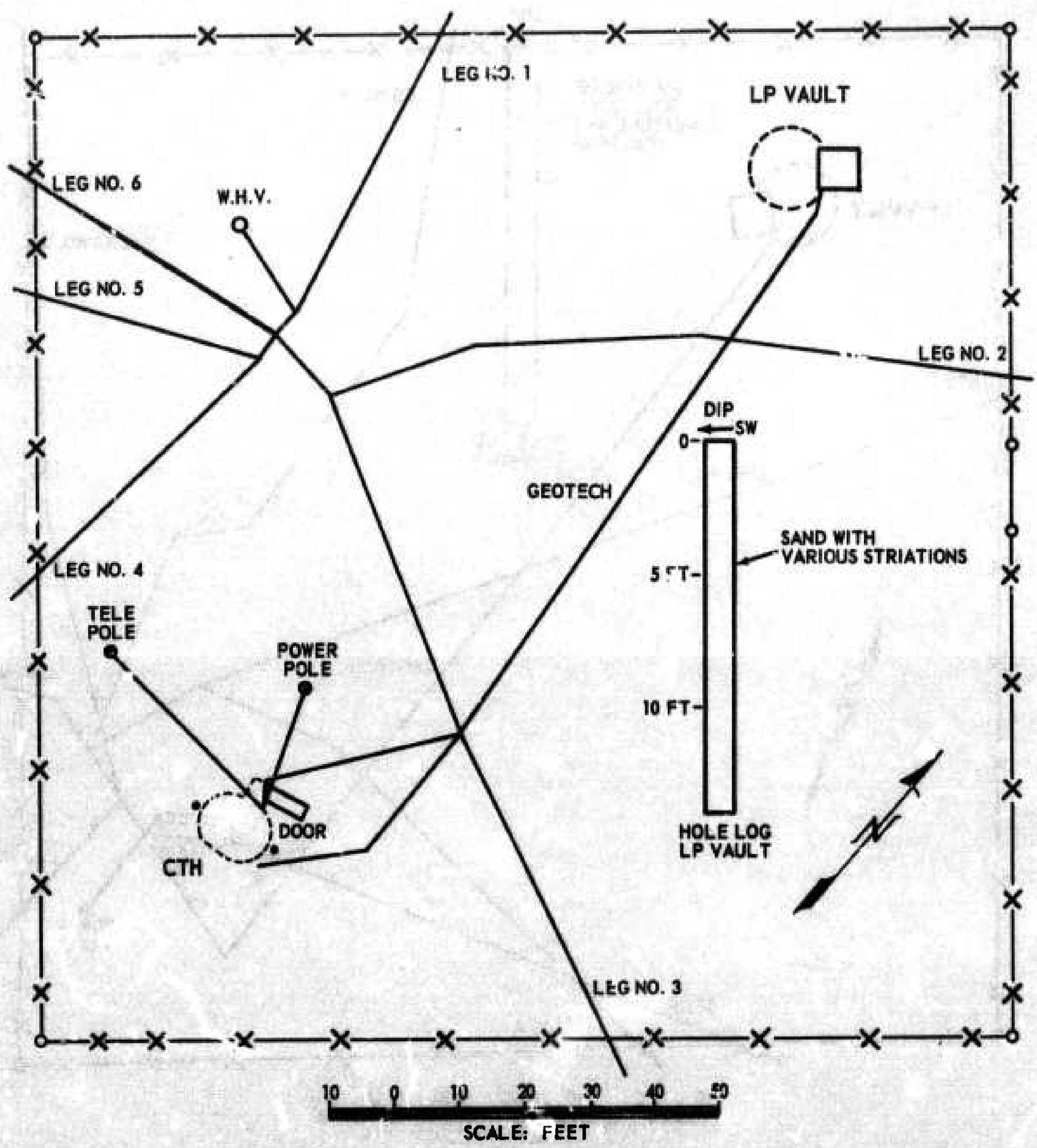

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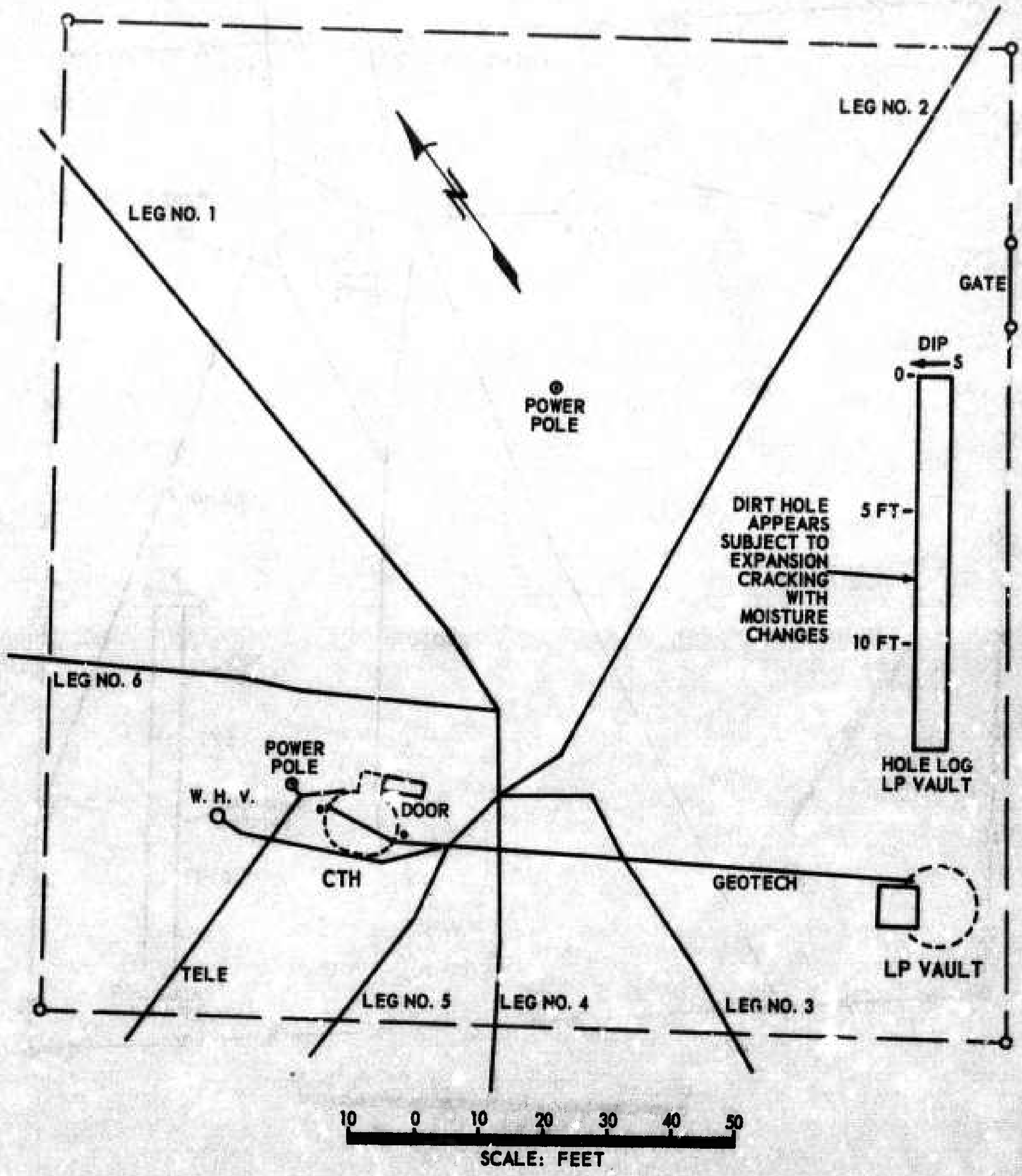
TR 67-17, app ?



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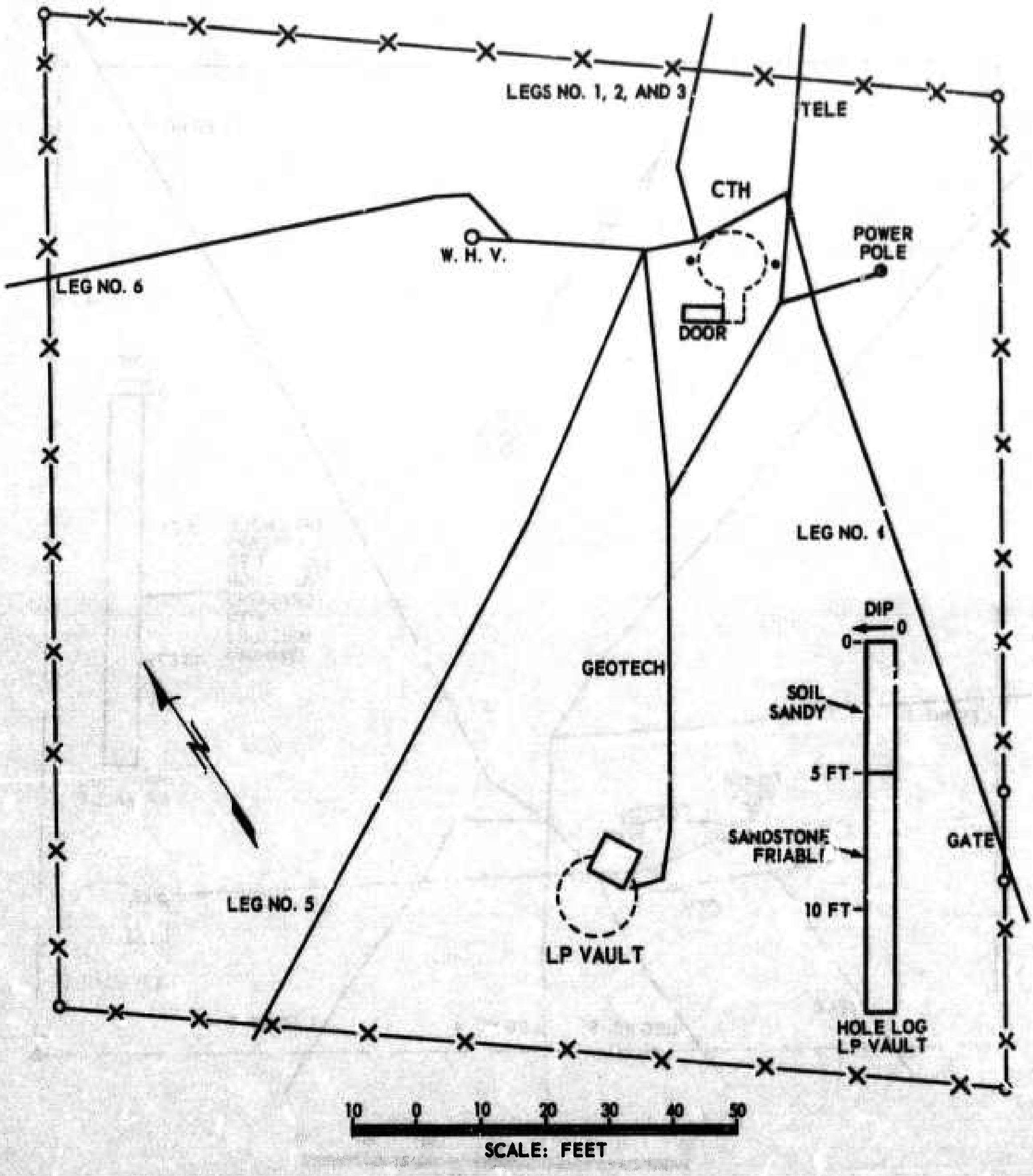

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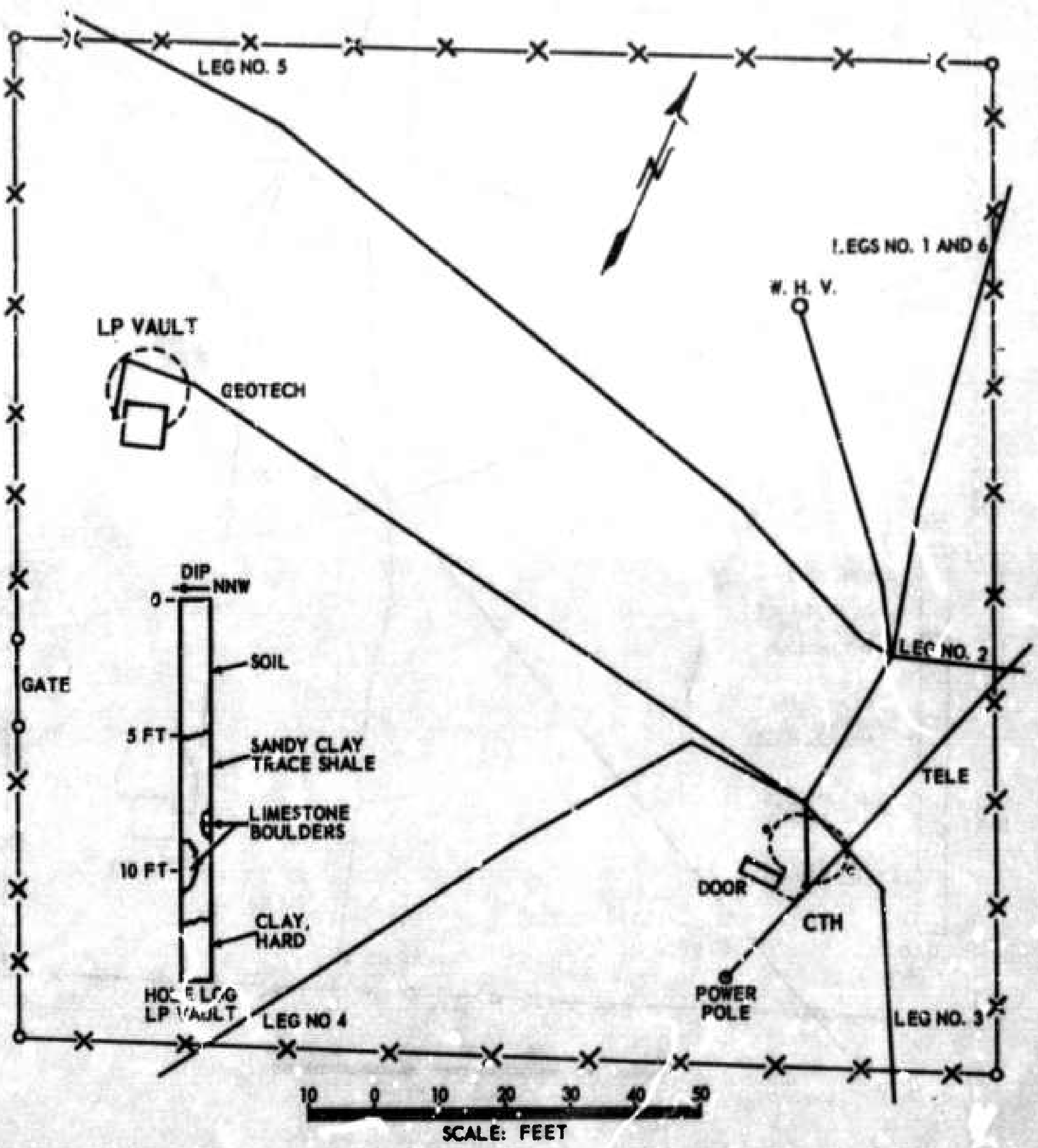

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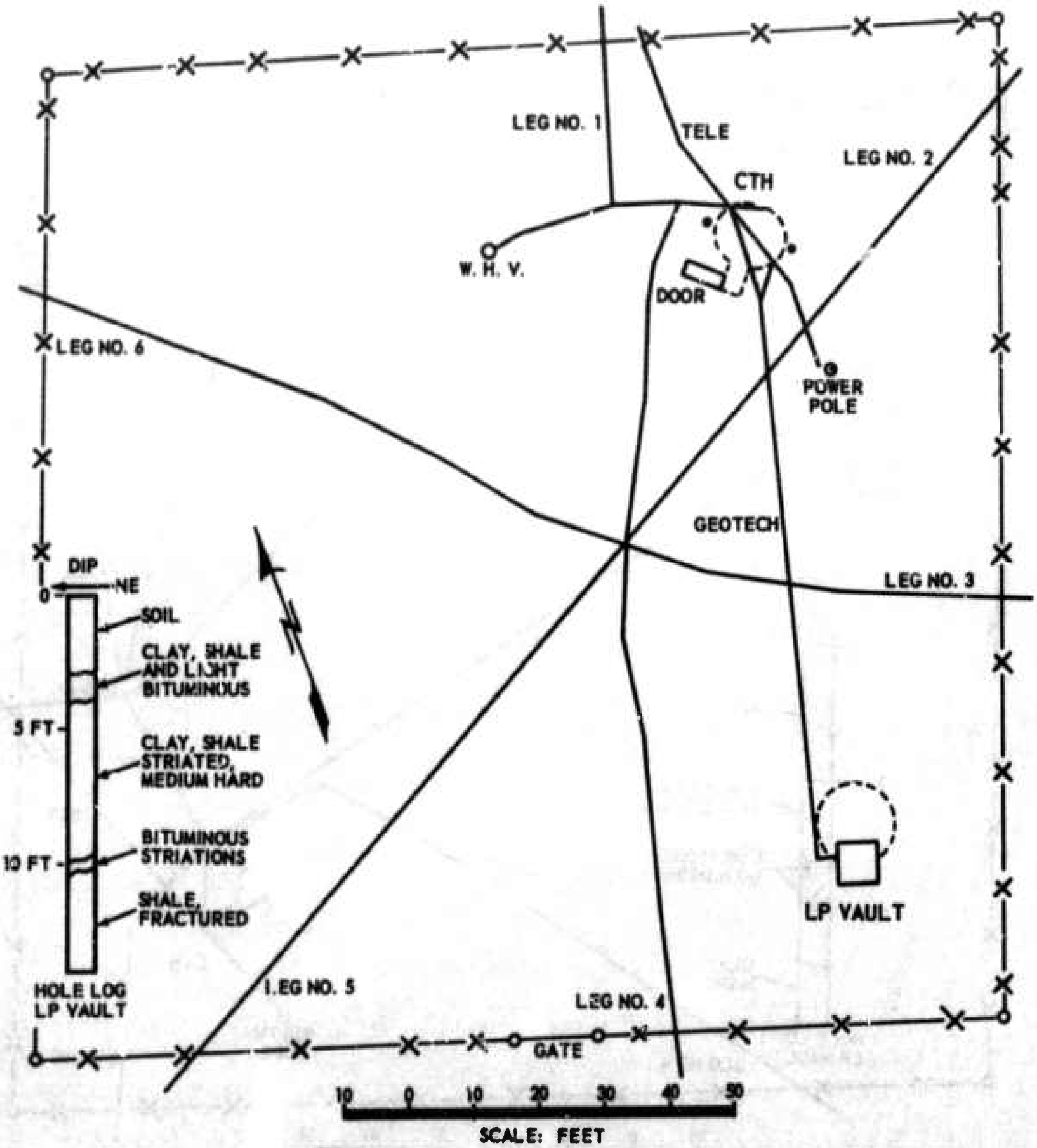

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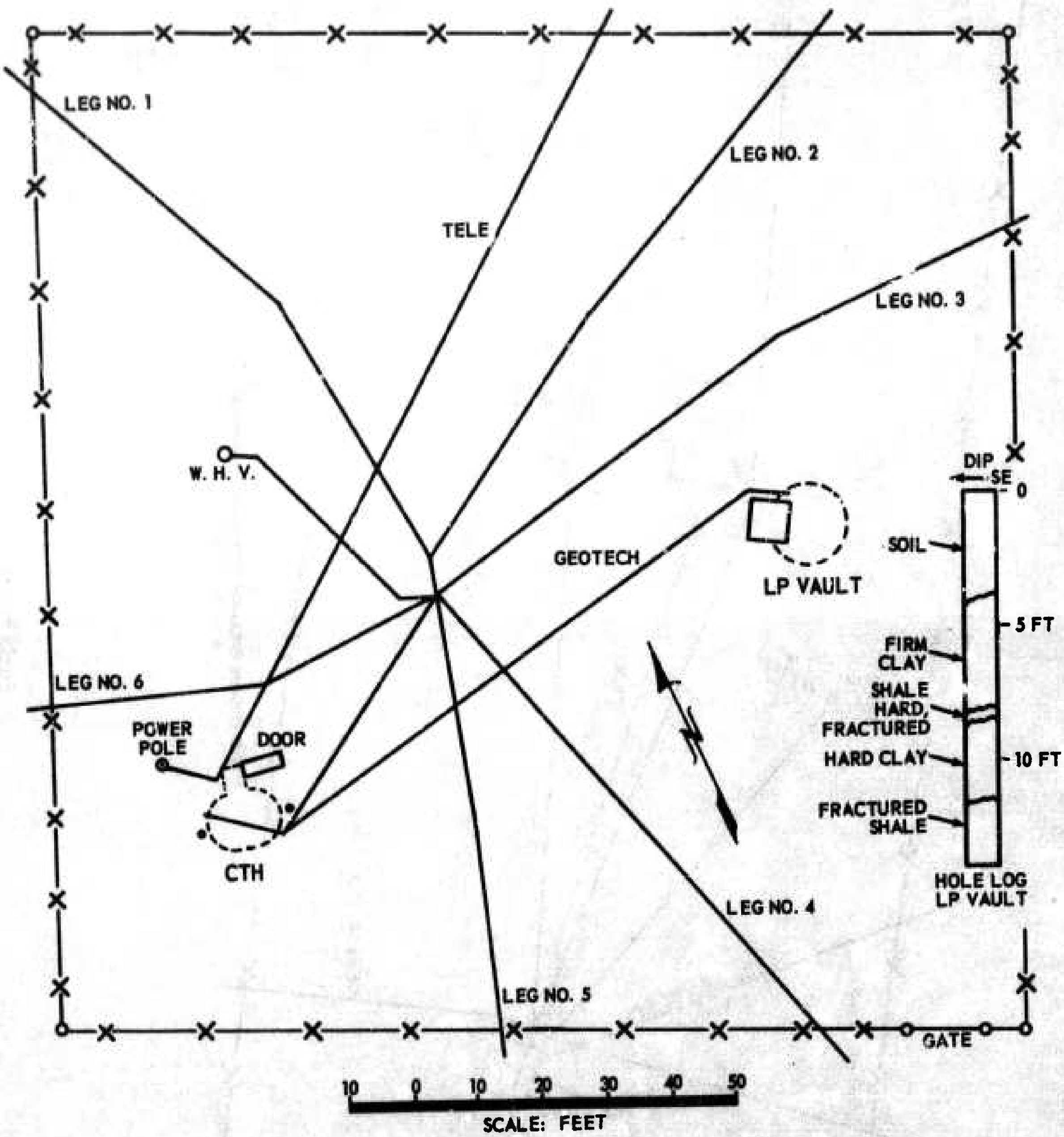

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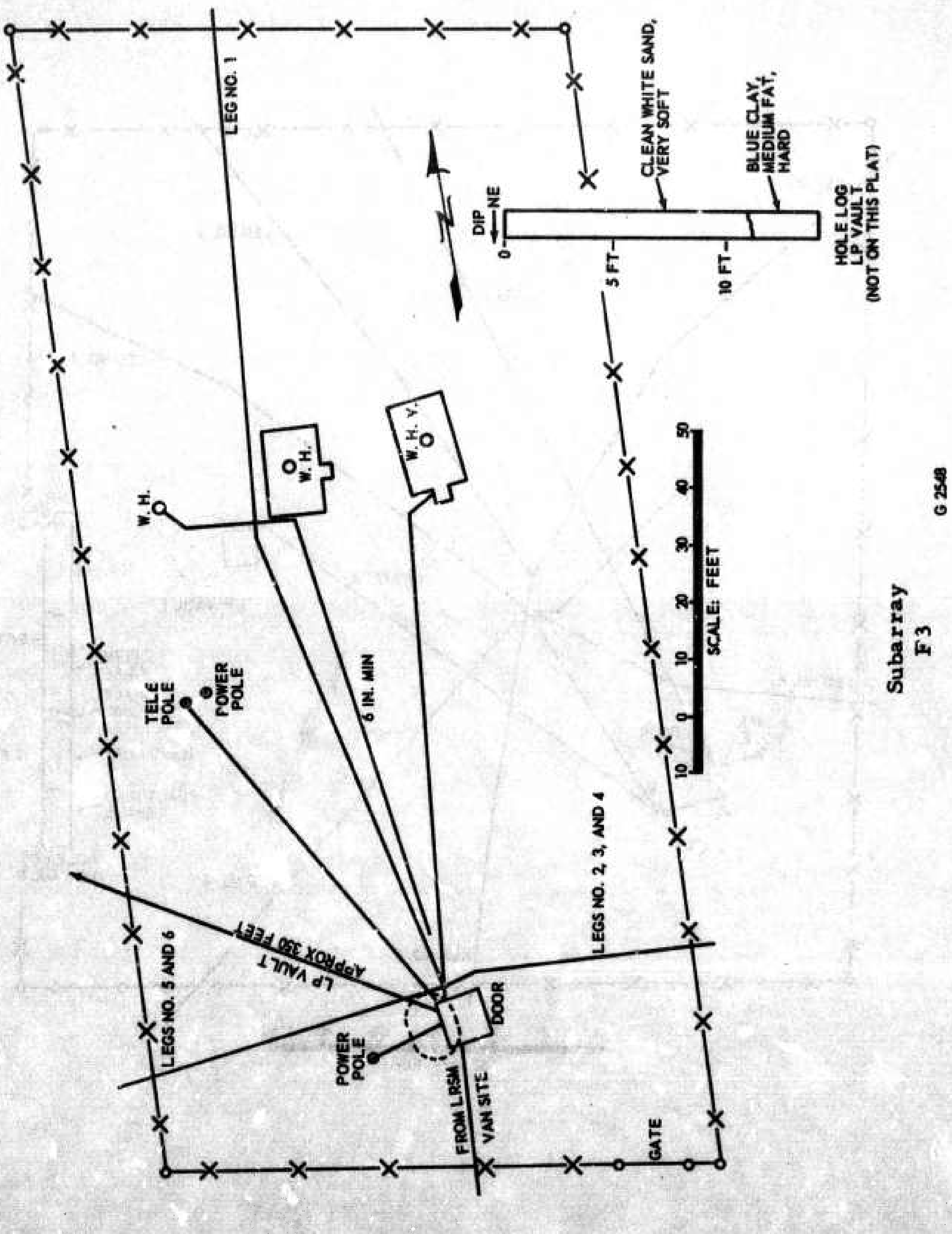
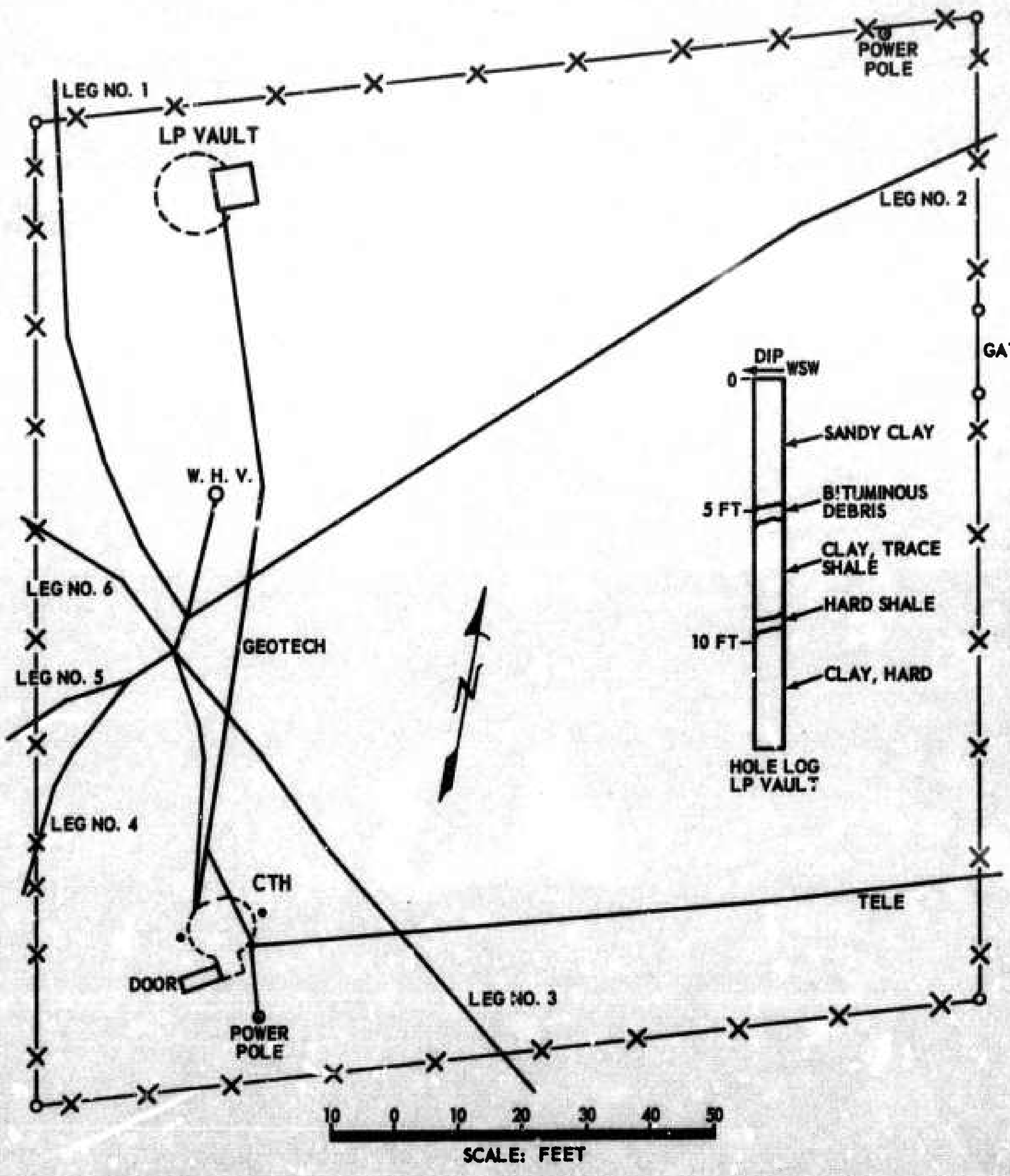


LEG NO. 1
CLEAN WHITE SAND, VERY SOFT
BLUE CLAY, MEDIUM FAT, HARD
DIP
NE
0
5 FT
10 FT
HOLE LOG LP VAULT (NOT ON THIS PLAT)
N
W. H.
W. H.
W. H. Y.
SCALE: FEET
50
40
30
20
10
0
10
TELE POLE
POWER POLE
6 IN. MIN
LEGS NO. 2, 3, AND 4
LP VAULT APPROX 350 FEET
LEGS NO. 5 AND 6
POWER POLE
DOOR
FROM LRSM
VAN SITE
GATE
G 2548

Subarray F3



Subarray
F4

G 2549

APPENDIX 4 to TECHNICAL REPORT NO. 67-17

LP VAULT CONSTRUCTION SPECIFICATIONS

LP VAULT CONSTRUCTION SPECIFICATIONS

1. SCOPE

This specification describes the construction requirements for a concrete vault designed to house long-period seismometers used in the Large Aperture Seismic Array. The vault is monolithic structure and is reinforced with steel bars. Three bottomless steel tanks are embedded in the vault floor. A portal is embedded in the concrete of the vault entry way. A cover containing an access hatch will be fastened to this portal.

2. CONSTRUCTION REQUIREMENTS

Geotech drawing No. 90-24791-01-01, (figure 3-1), and the four attached drawings prepared by William L. Cobb Associates are a part of this specification. These drawings set forth the dimensions and tolerances of the vault, and of its steel reinforcement bars. Other requirements are as follows:

a. All walls, the roof, and the floor of the vault will be a minimum of 8 inches thick with the exception of the kidney-shaped area of the floor containing the three metal tanks. This portion of the floor will be 36 inches in depth and must provide at least a 6-inch concrete jacket for the metal tanks.

b. The entire vault will be a monolithic pour of a six sack per cubic yard mix with a 3600 psi minimum pressure test to be performed and successfully passed in 28 days. The concrete will be vibrated during the pouring of the vault.

c. The walls of the entry will be reinforced vertically with #4 steel bars at intervals of 12 inches, center-to-center; and reinforced horizontally with #3 steel bars at intervals of 12 inches, center-to-center.

d. The roof of the vault will be reinforced each way with #4 steel bars at intervals of 6 inches, center-to-center. Bars in the roof will be 2 inches or less from the lower surface of the roof.

e. The wall of the vault will be reinforced horizontally with #3 steel bars at intervals of 12 inches, center-to-center. Vertical reinforcement will be of #4 steel bars bent horizontally for a distance of 12 inches at the top and bottom. These vertical bars will be spaced at intervals of 12 inches, center-to-center. All bars will be located 3 to 5 inches from the interior surface of the wall.

f. The floor of the vault will be reinforced with #3 steel bars at intervals of 12 inches, center-to-center each way (see the attached drawings; sections A-A and B-B). Bars in the 8-inch section of the floor will be located 4 to 7 inches from the lower surface of the floor. Bars in the 36-inch section of the floor will be located at least 2 inches below the bottom of the embedded metal tanks.

g. All bars and the seismometer tanks will be held by appropriate fixtures so that there is a reasonable assurance that they will remain in their designated positions while concrete is being poured. In the completed structure, no reinforcing bar will protrude through or be exposed at any surface in the concrete.

h. The aggregate used for the concrete will consist of crushed stone (free from rock dust) and gravel (less than 1/4 of 1 percent by weight to consist of clay particles). The aggregate shall in no case exceed 3 inches in diameter.

i. The aggregate and the concrete shall be open to sampling by a Geotech representative.

j. Following the removal of the construction forms and prior to the application of any patching material or internal sealing coat, the vault will be inspected for flaws and blemishes by a Geotech representative. Flaws and blemishes include, but are not restricted to:

(1) Deviations from dimension tolerances.

(2) Holes deeper than 1/2 inch (after cleaning out loose material such as sand, clay, loose rock, etc).

(3) Form scars greater than 1/2 inch from wall proper.

k. It will be the responsibility of the contractor to correct all flaws and blemishes to the satisfaction of the Geotech representative; however, acceptance of the vault by the representative at this stage of construction does not free the contractor of repairing or correcting subsequent damage to the vault due to hidden or subsurface flaws, inferior materials, or workmanship.

l. Upon acceptance of the repairs by the Geotech representative, the contractor will then finish the interior surfaces of the vault with U. S. Gypsum Co. "Dura-Dry" or equivalent.

m. The portal (P/N 24776) and the metal tanks (Model 23232A) will be furnished by Geotech. All other materials necessary to construct the vault will be furnished by the contractor.

n. No trash resulting from this operation will be scattered or left on location. Damages, resulting from the contractor's (or his personnel's) failure to maintain fence gate conditions (gates that are open will be left open, gates that are closed will be left closed) will be borne by the contractor.

o. A concrete block retainer will isolate the vault entrance from the surrounding earth. The height of this retainer will depend upon depth of vault below ground level (bottom of retainer will be 8 inches above top of vault, top of retainer will be 8 inches below surface of ground).

p. Walls of retainer will be water-proofed.

q. Top and bottom rows of blocks will be sealed with concrete to prevent moisture from entering cavities in blocks (sill blocks may be used).

r. Retainer will be reinforced at every other layer of blocks with steel mesh wired together at each corner. Block cavities will be closed off with mortar at these layers.

3. REMOVAL OF EXCESS MATERIALS

Specifications for the removal and/or disposal of excess materials accumulated during the excavation for and installation of the LASA LP seismometer vaults are:

a. If possible, all excess materials will be dispersed within the 150-ft side fenced area designated as the vault area. This material will be placed in such a manner as to avoid all access roads and access walkways. The vault area, access roads, and access walkways are to be identified by the Geotech representative present.

b. If material cannot be placed within the fenced vault area, the Geotech representative present will specify an area outside of the fenced area. The contractor will not place materials outside the fenced vault area without specific instructions from the Geotech representative present.

c. The total area involved in the operation of materials removal and dispersion will be dressed to offer a minimum of wind resistance. All mounds will be smoothed to conform to the existing contours. The Geotech representative present will be the final authority on any questions that might arise as to finished condition of each site.

d. It is emphasized that no trash resulting from this operation will be scattered or left on location and that fence gate conditions (open or closed) are to be maintained at all times. Expenses resulting from neglect in maintaining fence conditions during this operation will be borne by the contractor.

Sufficient slope should be maintained to provide drainage but should not be graded in such a manner as to encourage erosion of the area involved.

A REPORT ON THE INVESTIGATION OF THE STRUCTURAL DESIGN OF THE LASA LP VAULT

BY

WILLIAM L. COBB ASSOCIATES, INC.
Consulting Engineers
830 Interurban Building
Dallas, Texas 75201
RIverside 7-7561

A REPORT ON THE INVESTIGATION OF THE STRUCTURAL DESIGN OF THE LASA LP VAULT

An investigation of the structural design of the LASA LP Vault was undertaken at the request of Mr. Martin G. Gudzin of the Geotechnical Division of Teledyne Industries, Inc. The investigation was made to determine if the design, shown on the Geotechnical Corporation drawing numbered 24791 and dated August 27, 1965, was adequate with the reinforcing specified, and to make our recommendations for any changes which we believed necessary.

The design was first reviewed without consideration of the arch-action due to the shape of the structure. Under these conditions, the reinforcing specified was found to be inadequate. The structure was then analyzed assuming arch-action of the roof and side walls. This analysis was based on approximate methods since the size and complexity of the structure did not warrant a full and complicated analysis. This analysis indicated that the supporting earth would require a bearing value of around seven-thousand pounds per square foot (7,000#/□') to resist the thrust of the roof. Under all moisture conditions, this value was considered to be excessive; therefore, the structure, as designed, would be inadequate.

The fact that our analysis indicated the structure to be inadequate does not mean that a structure built under this design would fail. The oval shape and the arched roof, when poured directly against the excavation, would probably support the loads without reinforcing if the surrounding soil could be considered non-yielding under all conditions. Since the soil is fine, sandy soil, it is considered a yielding soil and, therefore, unreliable under all conditions of moisture.

Since we considered the design submitted inadequate, an alternate reinforcing design was made to give our recommendations for minimum reinforcing. This design was based on the fact that the vault houses delicate instruments and cannot tolerate cracking or shifting of the structure. We have based our analysis on generally accepted methods and approximations which are usually acceptable for structures of this size. Our reinforcing details are based on the use of bars exclusively since it is believed that they can be more accurately placed and will give a more reliable structure. The bars are of the size which can be cut and fabricated in the field from standard bar lengths.

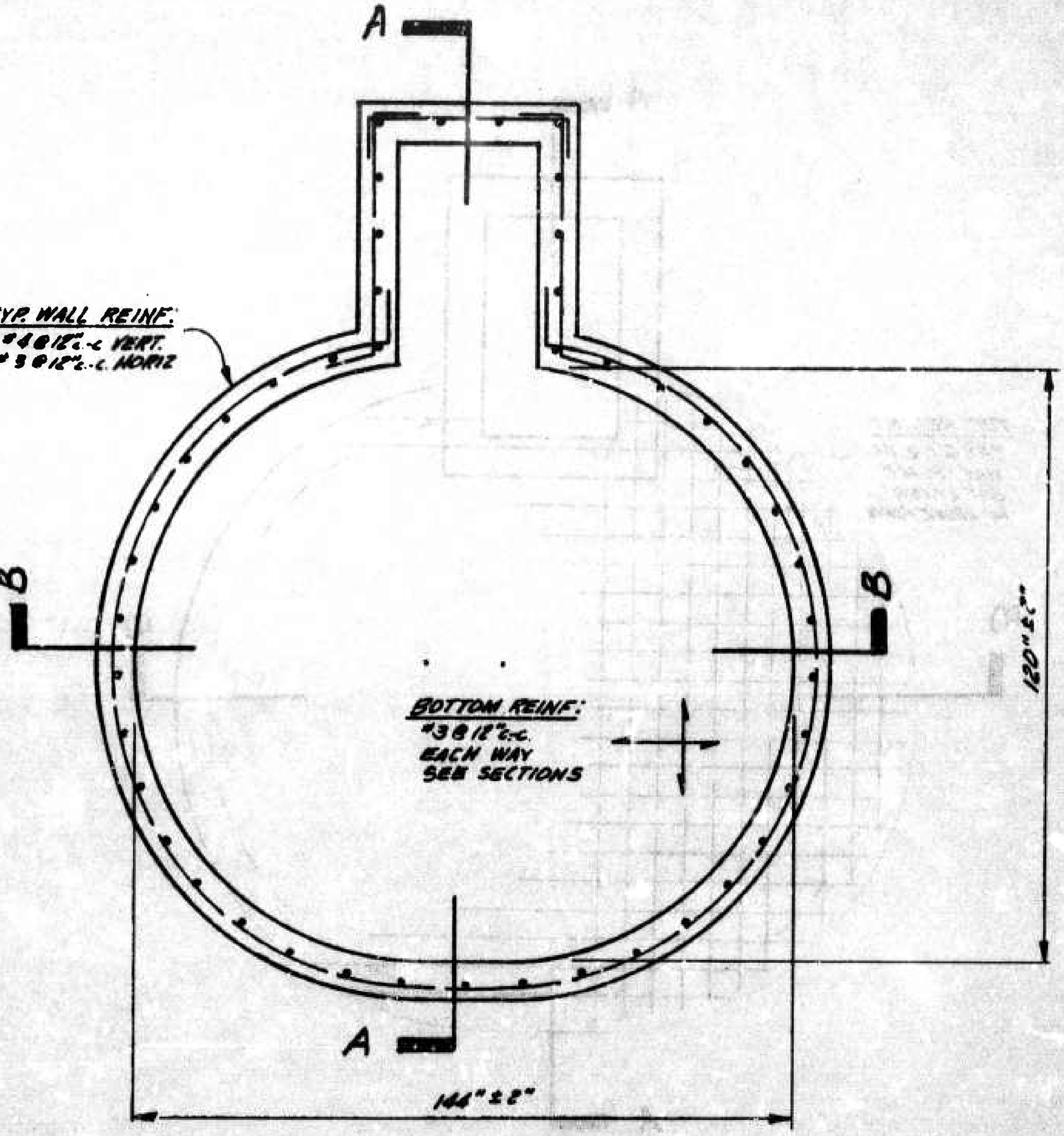
The details of our recommended reinforcing are shown on the attached prints.

William L. Cobb

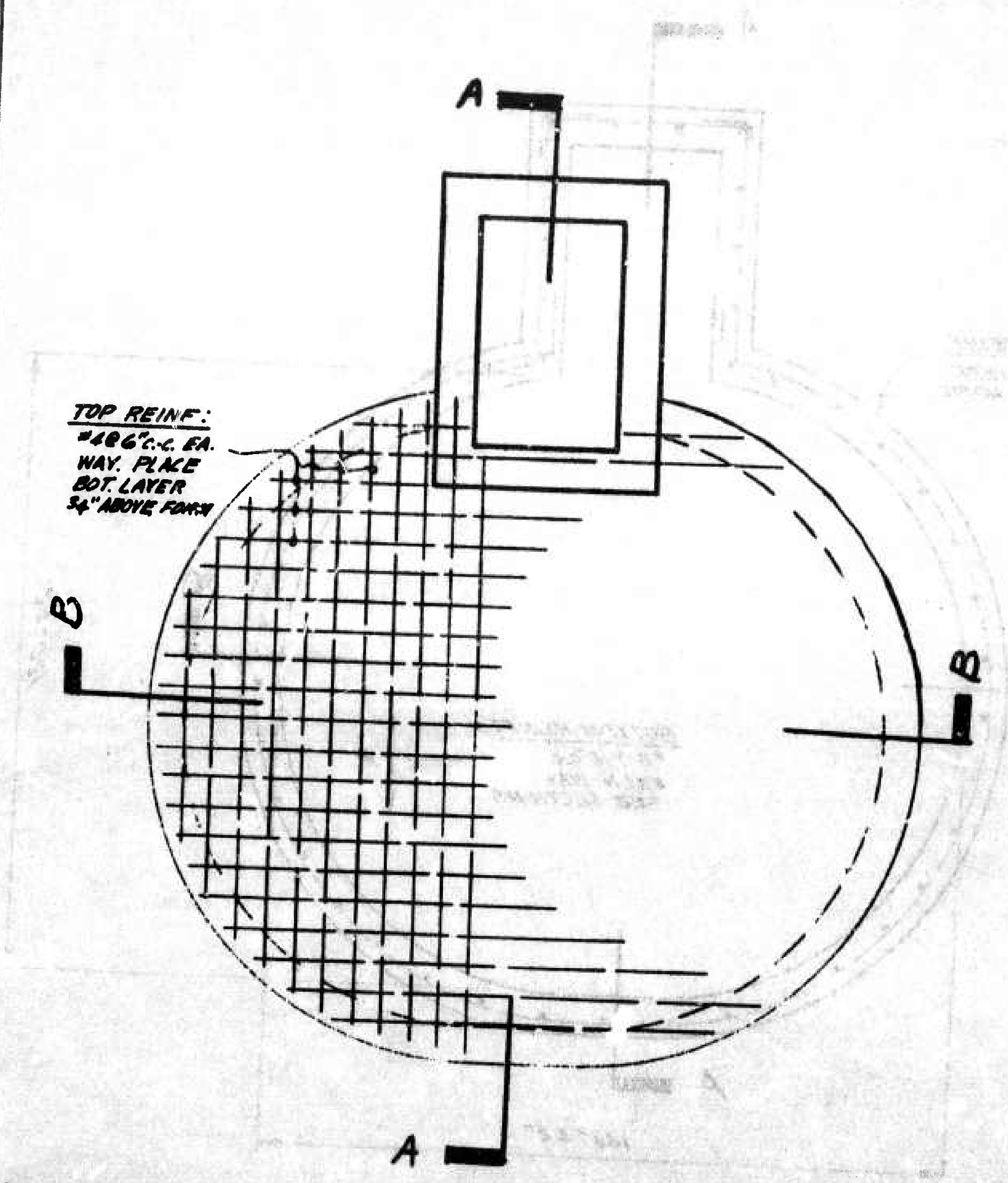
William L. Cobb, P.E.

mr

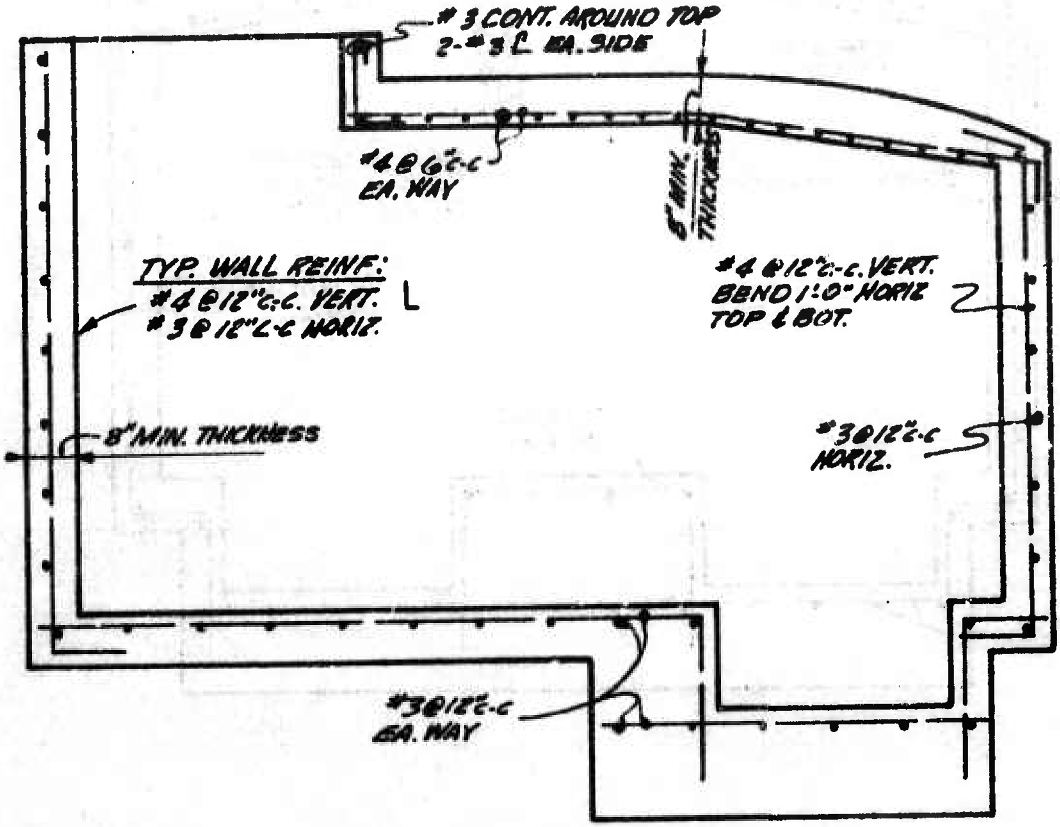
* * *



FOUNDATION & WALL PLAN
LASA LP VAULT
For
The Geotechnical Corporation
By
WILLIAM L. COBB ASSOCIATES, INC.
Consulting Engineers



ROOF FRAMING PLAN
LASA LP VAULT
For
The Geotechnical Corporation
By
WILLIAM L. COBB ASSOCIATES INC.
830 INTERURBAN BUILDING
DALLAS, TEXAS 75201
Consulting Engineers



SECTION A - A

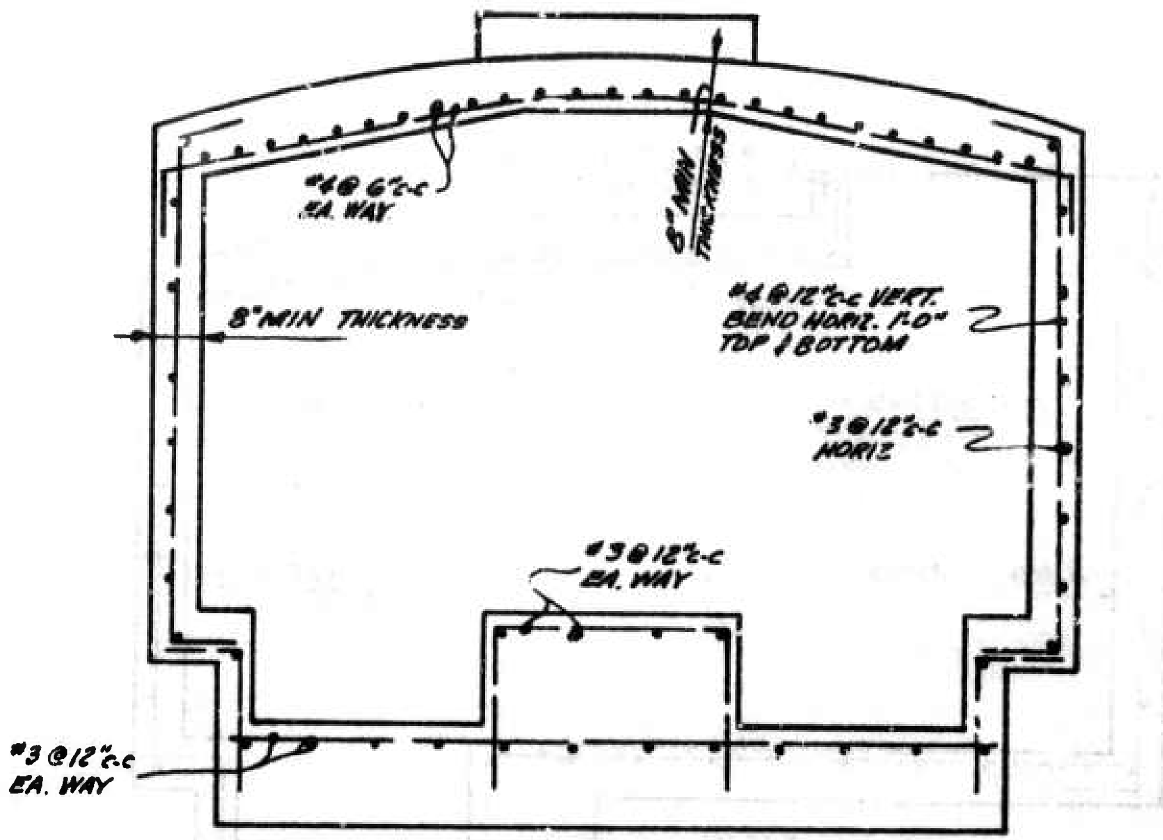
LASA LP VAULT

For

The Geotechnical Corporation

By

WILLIAM L. COBB ASSOCIATES INC.
Consulting Engineers
830 INTERURBAN BUILDING
DALLAS, TEXAS 75201



SECTION B - B

LASA LP VAULT

For

The Geotechnical Corporation

By

WILLIAM L. COBB ASSOCIATES, INC.
Consulting Engineers
6X INTERURBAN BUILDING
DALLAS, TEXAS 75201

APPENDIX 5 to TECHNICAL REPORT NO. 67-17

RESULTS OF COMPRESSION TESTS PERFORMED UPON SAMPLE CYLINDERS OF THE CONCRETE USED IN THE LP VAULTS

APPENDIX 5 to TECHNICAL REPORT NO. 67-17

RESULTS OF COMPRESSION TESTS PERFORMED UPON SAMPLE CYLINDERS OF THE CONCRETE USED IN THE LP VAULTS

Concrete test cylinder data

Site	Compressive strength (psi)	Age at test (days)	Compressive strength (psi)	Age at test (days)	Compressive strength (psi)	Age at test (days)	Comments
AØ	4280	28	4050	14	4720	28	
B1	2510	14	3800	28	3700	28	
B2	1720	7	2710	14	3610	28	
B3	2530	7	4170	28	4010	28	
B4	2650	14	3330	28	3640	28	
C1	2510	14	3930	28	3820	28	
C2	2090	14	2670	28	2710	28	
C3	2190	7	4210	28	4230	28	
C4	2850	7	4260	28	4300	28	
D1	2810	14	3500	28	3310	28	
D2	2600	7	3930	28	3870	28	
D3	1410	7	3020	28	3290	28	
D4	2760	14	3930	28	3870	28	
E1	1720	11	3220	28	3180	28	
E2	4920	7	6330	28	6300	28	
E3	2710	7	4160	28	4090	28	
E4	2940	7	5820	28	5430	28	
F1	2050	11	4700	28	4670	28	
F2	2940	7	4850	28	5090	28	
F3	-		-		-		Prototype
F4	1750	7	2830	28	2710	28	

APPENDIX 6 to TECHNICAL REPORT NO. 67-17

SAMPLE FORMS USED DURING INSTALLATION AND CALIBRATION OF THE LASA LP SYSTEM

No.	Title	Use
1	Record Information Label	Attached to records made during tests and calibrations
2	Calibration Data Card	Record of unit serial numbers and calibration results
3	Quality Control Check List	Used as a check list and progress report during the installation and calibration phases of each site
4	Mass Position vs Monitor Current	Calibration curves for mass position indicator
5	Field Inspection Certificate	A report of the results of inspections performed during the construction of each LP vault

LASA LP 1 **OPERATOR**..

Subarray.................... **Channel**.................. **Time**..................

Paper speed.............................. **Sensitivity**..............................

This record contains..

....

Reference.............................. **Date**..

S	**Remarks**..
Gc	....
I	....
To	
λ	

Record Information Label, Form LASA LP 1

CHANNEL	SEISMOMETER	AMPLIFIER	POWER SUPPLY	JUNCTION ASS'Y	CTR DEV	CTR DEV

DATE	FACTORY	SETUP	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL
Rm, dota coil (k ohms)										
Rd, damping coil (ohms)										
Rc, colibrator coil (ohms)										
Xi, dato coil										
I, doto coil (uo)										
Xw, weight off										
W, octuol (mg)										
W, effective (mg)										
Xi, col coil										
i, col coil (mo)										
G, dota coil (vs/m)										
G, cal coil (newtons/omp)										
Moss Position, G test										
Free Period										
X1, domp test										
X2, damp test										
X2/X1 (%)										
λ, damp test										
DRX (ohms)										

DATE		FACTORY	SETUP	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL
i, EM cal.	(uo P-P)										
SENSITIVITY											
Amplifier offset (mv)											
Tonk time constont											
Moss position, finol											
System Peok Sensitivity											

Calibration Data Card, Form LASA LP 2

FORM LASA LP 3

SUBARRAY________
DATE________

QUALITY CONTROL CHECK LIST

The LP Construction Manual describes the procedures for installation of a LASA LP site. This form is used as a check list and daily progress report during the installation.

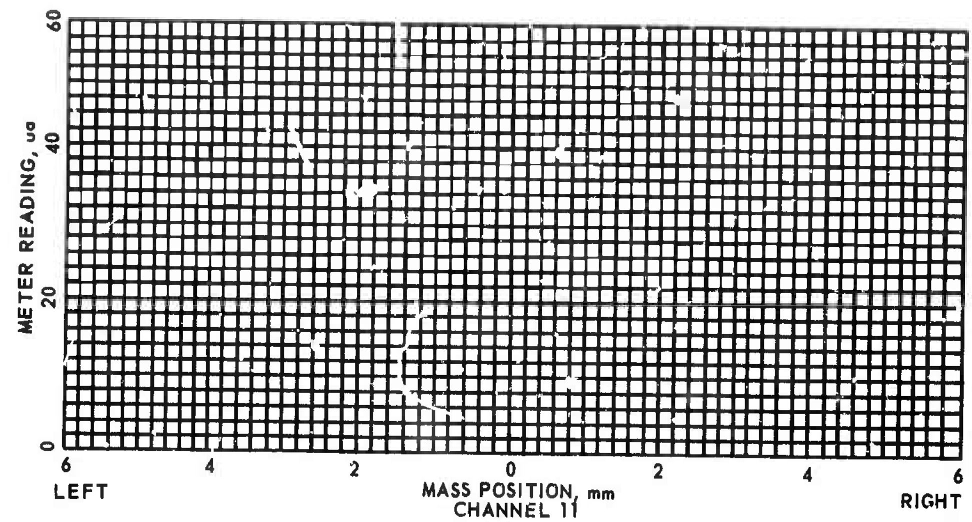
TASK		INITIAL	DATE
1	Serial numbers of components recorded on Calibration Data Card.		
2	Retainer cover cemented in place, rodent tight.		
3	All cable entries (PE-25 and power) properly sealed and finished.		
4	Main condulet sealed with black plastic cement. No sharp bends in cables at exit in ditch.		
5	Power cable sealed at fuse box.		
6	a. Remote adjust devices set at center of travel.		
	b. Front (stationary) feet of remote adjust devices set such that entire tapered end of screw, plus one thread, is visible from bottom of base.		
	c. Front feet of remote adjust devices locked with hex nuts.		
	d. 50,000 Ω data coil connected through J-101, red to pin B, black to pin C. Read resistance, enter on Calibration Data Card.		
	e. Damping coil (580 Ω) connected through copper terminal posts, white on right, black on left. Read resistance, enter on Calibration Data Card.		
	f. Data, damping, and calibration coil circuits separated from one another by leakage resistance exceeding 1 megohm.		
	g. Resistance from pin G, J-102, to all other circuits exceeds 1 megohm.		
	h. Resistance from pin G, J-102, to seismometer case 1 ohm or less.		
7	All cables from LP vault to CTH measure 50 megohms or greater.		
8	a. Ceramic buttons rest firmly on tank floor, glazed surface up.		
	b. Pointed feet of remote adjust bases rest in holes in ceramic buttons.		
	c. Devices connected to tank harness.		

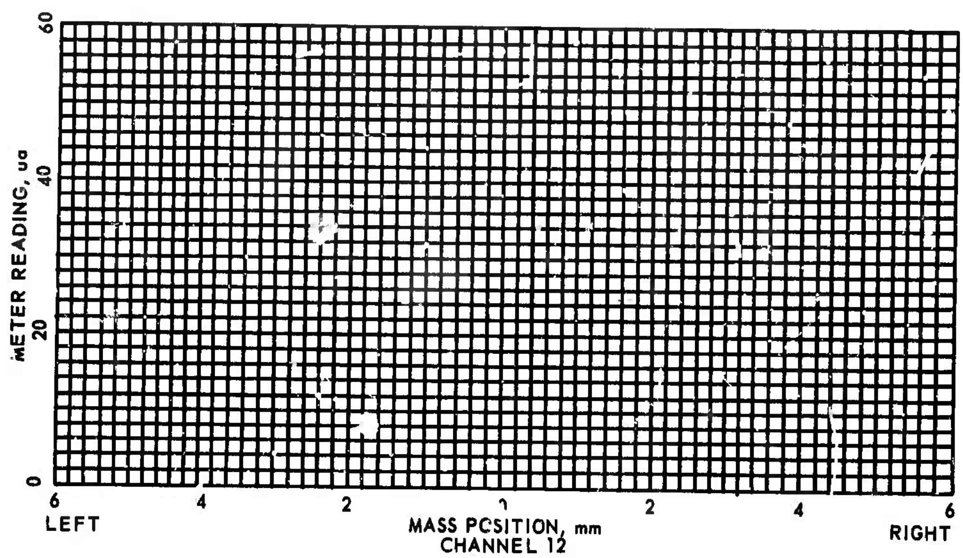
TASK		INITIAL	DATE
9	a. All remote adjust devices have proper seismometer foot resting in the depression NEAREST THE MOTOR.		
	b. Seismometer cover clip removed from end of base nearest period adjusting device.		
	c. Left front leg of each horizontal seismometer on one glass insulator, with flat metal top.		
	d. Left front leg of vertical seismometer on one glass insulator, with flat top.		
	e. Right front leg of vertical seismometer on one glass insulator, with circular indentation in metal top.		
	f. Starret level on machined portion of horizontal seismometer base indicates level when mass floats.		
	g. Transverse level bubble on vertical indicates level.		
	h. All seismometers adjusted to 20-second period +/- 0.5 sec.		
	i. All jam nuts on seismometer feet tight against base of seismometer.		
10	LP protector mounted in junction box, using holes tapped into backing plate.		
11	Cable entry to junction box corresponds with entry through vault walls, in proper order with leftmost cables at wall entering box through top strain relief connectors, rightmost cables enter box through bottom connectors.		
12	a. PE-23 shields terminated to ground at junction box entry.		
	b. Number four ground wire routed from Buchanan terminal block to ground plate. Connected at ground plate.		
	c. Data lines, unamplified, from incoming PE-23 removed from bundle, shielded, insulated, and connected. Shield continuous and grounded at data protector.		
	d. Spare pair (gray and white) from each PE-23 data cable routed same as above, with shield and insulation, but not connected.		
13	a. Junction box service receptacles and harness installed.		
	b. Cradleclips on wall for mounting data harness outside junction box.		

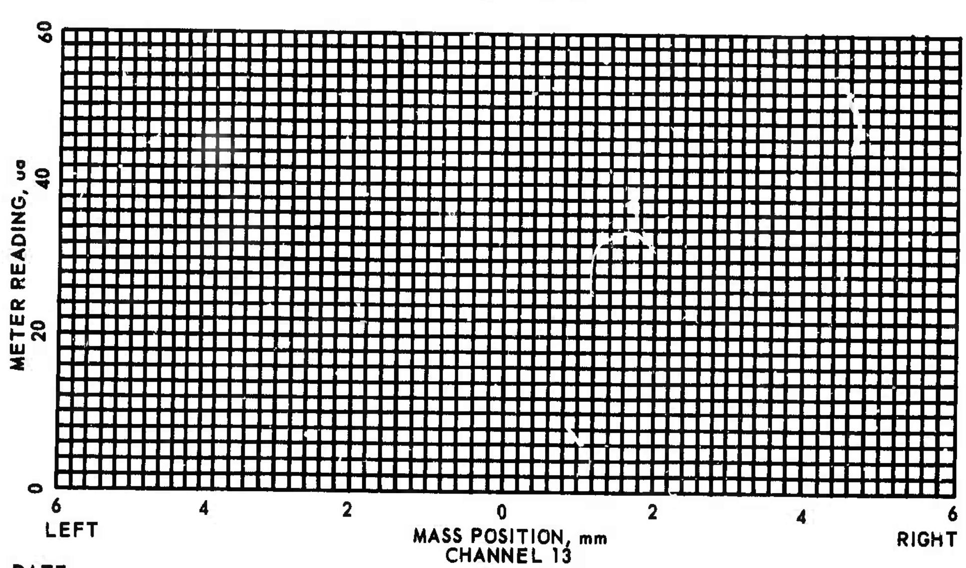
TASK		INITIAL	DATE
14	a. LP protector wiring completed.		
	b. Data harness, Belden 8451, laid up, laced, strain relief fittings potted in place, amplifier input and output plugs installed, connected.		
15	Free period actuator mounted on walls.		
16	Enclosure and power supply bracket mounted on channels.		
17	Cradleclips installed for amplifier power cable.		
18	Dc power cable properly routed from power supply to amplifier.		
19	a. Polarities correct: (1) Data; (2) Mass Position Monitor; (3) Remote Centering Device; (4) Period Adjusting Device; (5) Dc Pulses; (6) Recorders.		
	b. All circuits checked from CTH to LP vault for proper function and correct polarity.		
20	Connection to SEM completed. Verification of data received at LASA Data Center.		
21	Command response verified. (Applicable only if command devices are installed and functioning.)		
22	a. Mass position meter indicates zero, +/-3 μA, with mass centered.		
	b. Mass position meter indicates 50, +2/-5 μA, when mass is deflected either right or left to 5 mm.		
	c. Curve submitted for mass position verses monitor meter readings for each 1 mm interval from 5 mm left to 5 mm right.		
23	Seismometer free period verified and recorded. In range from 19.5 to 20.5 seconds.		
24	Weight "ON" produces positive voltage at monitor point.		
25	G_c, motor constant of cal coil, verified to be in the range from 0.0295 to 0.0345 Newtons/Ampere. Data recorded. <u>Calibration Data Card</u> completed.		

TASK		INITIAL	DATE
26	G_m, the generator constant for the data coil, is adjusted to the range 755 to 765 volt seconds per meter. Data recorded. Calibration Data Card completed.		
27	a. Seismometer damping set, overshoot X1/X2 in the range from 13.2 to 14.2. Data recorded. Calibration Data Card completed.		
	b. All Junction Assemblies, Geotech Model 14415, installed with four anchors, cables connected at LP terminal, fresh desiccant installed at final closure of assemblies.		
28	System sensitivity and amplifier balance set. Recorded on Calibration Data Card.		
29	Frequency response checked. Recorded from CTH. Calibration Data Card completed.		
30	a. Mass free to travel +/-10 mm from zero.		
	b. Blocked mass test completed. Data recorded. Calibration Data Card completed.		
	c. Horizontal seismometers have clips folded back, not clamped.		
	d. Vertical seismometer cover clipped down, using all clips except the one removed in Section 3.5.3.1, step d.		
31	a. Desiccant jars mounted and charged in horizontal tanks, with vault humidity 60% or less.		
	b. Package of desiccant placed in vertical tank, with vault humidity 60% or less.		
	c. All hardware for seismometer, including adjusting wrenches, extra clips, and unused portions of desiccator assembly, left on floor of tank.		
	d. Extra hardware, including glass insulators and weight lift apparatus, not used on seismometer, turned in for storage.		
	e. Seismometer shipping crates returned to depot.		
	f. Fiberglas insulation installed in tanks.		
32	All tank lids bolted metal-to-metal using all bolts, time constants entered on Calibration Data Card, plug in tank lid.		

TASK		INITIAL	DATE
33	a. All cables cut to correct length, properly dressed.		
	b. All cradleclips have rubber keepers.		
	c. All terminal connections made with crimped lugs.		
	d. Vault wall finish complete.		
	e. LP terminal thoroughly cleaned and correctly laced.		
	f. Caps on all condulets installed and threads sealed with plumber's putty.		
	g. Vault clean, trash can in place.		
	h. Latch installed on retainer cover, good condition.		
	i. Retainer cover hinges in good condition.		
34	Insulation installed in entryway.		
35	a. Site fully operational, including short-period system. Verified with LASA Data Center by telephone.		
	b. Final free period in range between 19.5 seconds and 20.5 seconds. Recorded at CTH. <u>Calibration Data Card</u> completed.		
	c. Final mass positions read from CTH. <u>Calibration Data Card</u> completed.		







DATE

OPERATOR

SUBARRAY

Mass Position vs Monitor Current LASA LP 4

FIELD INSPECTION CERTIFICATE
GEOTECH
A TELEDYNE COMPANY

SITE DESIGNATION: DATE OF FINAL INSPECTION:

The long-period bunker at site _____ has been inspected according to specifications, and reference is made specifically to the following points:

	PASSES	FAILS
HOLE DEPTH		
MATERIAL QUALITY		
REINFORCEMENT		
WALL THICKNESS		
INTERIOR DIMENSIONS		
FLOOR FINISH		
WALL FINISH (before painting)		
FINAL FINISH		
RETAINING WALL		
OTHER		

REMARKS:

This structure has been inspected by a representative of GEOTECH, and has been certified as ACCEPTABLE for our use in the LASA LP program. Any departure from specification, noted in remarks, above, has been made with permission of the GEOTECH representative.

DATE CERTIFIED________________ BY________________________
GEOTECH
A TELEDYNE COMPANY

FIELD INSPECTION CERTIFICATE
GEOTECH
A TELEDYNE COMPANY

SITE DESIGNATION: DATE OF FINAL INSPECTION:

The long-period bunker at site _____ has been inspected according to specifications, and reference is made specifically to the following points:

	PASSES	FAILS
HOLE DEPTH		
MATERIAL QUALITY		
REINFORCEMENT		
WALL THICKNESS		
INTERIOR DIMENSIONS		
FLOOR FINISH		
WALL FINISH (before painting)		
FINAL FINISH		
RETAINING WALL		
OTHER		

REMARKS:

This structure has been inspected by a representative of GEOTECH, and has been certified as ACCEPTABLE for our use in the LASA LP program. Any departure from specification, noted in remarks, above, has been made with permission of the GEOTECH representative.

DATE CERTIFIED_________________ BY_________________________
GEOTECH
A TELEDYNE COMPANY

APPENDIX 7 to TECHNICAL REPORT NO. 67-17

SYSTEM PARAMETERS AT INSTALLATION

SYSTEM PARAMETERS AT INSTALLATION

SUBARRAY	CHANNEL	G_m	G_c	h	DRX	C_v	C_t
A0	11	737	.03125	.640	2300	48	34.5
	12	758	.0314	.642	2283	48	34.5
	13	762	.0325	.636	2480	48	15.8
B1	11	746	.0312	.640	2410	3.0	100
	12	744	.0310	.640	2510	3.0	100
	13	760	.0316	.643	2661	3.0	100
B2	11	761	.0328	.634	2300	7.2	83.5
	12	742	.0306	.642	2400	7.2	100
	13	750	.0303	.641	2514	7.2	38.2
B3	11	737	.0326	.639	2460	1.7	100
	12	755	.0319	.642	2609	1.7	25.5
	13	740	.0301	.644	2645	1.7	100
B4	11	743	.0310	.645	2050	27	100
	12	746	.0302	.645	2270	27	100
	13	751	.0334	.635	2560	27	100
C1	11	735	.0301	.637	2250	9.1	100
	12	758	.0323	.635	2900	9.1	100
	13	753	.0313	.642	2500	9.1	100
C2	11	749	.0314	.638	2430	3.6	23.2
	12	754	.0323	.639	2740	3.6	11.5
	13	743	.0308	.638	2970	3.6	15.3
C3	11	741	.0307	.636	2660	8.0	12.4
	12	741	.03055	.638	2660	8.0	8.1
	13	766	.0307	.640	2810	8.0	23.2
C4	11	765	.0303	.639	2180	30	33.4
	12	743	.0326	.637	2600	30	32.5
	13	744	.0310	.638	2500	30	64.9
D1	11	756	.0322	.642	2550	60.3	50
	12	747	.0312	.640	2730	60.3	50
	13	739	.0310	.639	2350	60.3	19.1

SUBARRAY	CHANNEL	G_m	G_c	I_t	DRX	C_v	C_t
D2	11	741	.0305	.638	2690	6.7	24.7
	12	755	.0301	.642	2270	6.7	100
	13	760	.0323	.640	2710	6.7	23.1
D3	11	749	.0312	.642	2150	9.9	11.5
	12	741	.0308	.636	2500	9.9	15.3
	13	754	.0316	.639	2520	9.9	50
D4	11	739	.0331	.640	2260	67	51
	12	753	.0306	.640	2480	67	9.0
	13	765	.0316	.640	2730	67	23.2
E1	11	738	.03165	.641	2330	9.8	23.8
	12	746	.0304	.641	2360	9.8	100
	13	752	.03085	.642	2330	9.8	100
E2	11	763	.0296	.641	1780	7.8	50
	12	750	.0324	.640	2800	7.8	8.1
	13	739	.0298	.636	2355	7.8	50
E3	11	755	.0300	.644	2480	540	23.7
	12	745	.03195	.640	2460	540	15.6
	13	745	.0320	.640	2550	540	50
E4	11	743	.0316	.636	2367	13.7	50
	12	746	.03195	.636	2400	13.7	11.4
	13	758	.0300	.636	2300	13.7	9.0
F1	11	759	.0323	.637	2460	14.5	8.1
	12	758	.0323	.634	2520	14.5	15.6
	13	754	.0336	.636	2700	14.5	100
F2	11	742	.0312	.641	2370	17.5	100
	12	763	.0312	.639	2429	17.5	16.4
	13	746	.0307	.639	2920	17.5	9.0
F3	11	755	.0300	.634	2200	270	24.4
	12	761	.0310	.636	2200	270	50
	13	750	.0324	.637	2475	270	100

SUBARRAY	CHANNEL	G_m	G_c	h	DRX	C_v	C_t
F4	11	745	.0316	.636	2100	4.5	11.4
	12	757	.0313	.638	2860	4.5	9.0
	13	754	.0306	.637	2230	4.5	8.3

G_m = SEISMOMETER GENERATOR CONSTANT, VOLT SECONDS/METER
G_c = SEISMOMETER CALIBRATOR MOTOR CONSTANT, NEWTONS/AMPERE
h = SEISMOMETER DAMPING, FRACTION OF CRITICAL
DRX = EXTERNAL DAMPING RESISTANCE, (OHMS)
C_v = TIME CONSTANT OF LONG PERIOD VAULT (MINUTES)
C_t = TIME CONSTANT OF TANK ASSEMBLY (HOURS)

Unclassified
Security Classification

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13. ABSTRACT

During the time period from August 1965 to October 1966, a set of three-component long-period instrumentation was added to each subarray of the Montana LASA. The instrumentation, which provides analog signals to the existing data handling and telemetry system of the LASA, consists of three LP seismometers housed in an underground concrete vault and a three-channel, solid-state parametric amplifier located in the Central Telemetry Housing at each subarray. Equipment for interconnection of the instrumentation, lightning protection, and remote adjustments to the seismometers was installed. During the installation, each set of instrumentation was calibrated. This report briefly describes the instrumentation, the installation, and calibration procedures, and the problems encountered during the installation of the LASA LP system.

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