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OPERATION OF THE TONTO FOREST SEISMOLOGICAL OBSERVATORY

Teledyne Geotech

Prepared for:

Advanced Research Projects Agency

September 1973

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

UNCLASSIFIED
Security Classification

AD-769353

DOCUMENT CONTROL DATA - R & D

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

1. ORIGINATING ACTIVITY (Corporate author)
Teledyne Geotech
3401 Shiloh Road
Garland, Texas 75041

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE
Operation of Tonto Forest Seismological Observatory
Final Report, Project VT/3704
1 July 1972 through 30 June 1973

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

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

6. REPORT DATE
20 September 1973

7a. TOTAL NO. OF PAGES
~~67~~ 68

7b. NO. OF REFS

8a. CONTRACT OR GRANT NO.
F33657-72-C-0800

b. PROJECT NO.
VELA T/3704

c. ARPA Order No. 1714

d. ARPA Program Code No. 1F10

9a. ORIGINATOR'S REPORT NUMBER(S)
TR 73-11

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT
Approved for public release. Distribution unlimited.

11. SUPPLEMENTARY NOTES
Details of illustrations in this document may be better studied on microfiche.

12. SPONSORING MILITARY ACTIVITY
Advanced Research Projects Agency
Nuclear Monitoring Research Office
Arlington, Virginia 22209

13. ABSTRACT

This is a report of the work accomplished on Project VT/3704 from 1 July 1972 through 30 June 1973. It describes the operation, evaluation, and improvement of the Tonto Forest Seismological Observatory (TFSO) located near Payson, Arizona, research and test functions carried out at the TFSO, and research and development tasks performed by the Garland, Texas, staff using TFSO data.

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Long-Period Array						
Short-Period Array						
Seismograph Operating Parameters						
Multichannel Filter						

UNCLASSIFIED

Security Classification

TECHNICAL REPORT NO. 73-11

OPERATION OF THE
TONTO FOREST SEISMOLOGICAL OBSERVATORY
Final Report, Project VT/3704
Contract F33657-72-C-0800
1 July 1972 through 30 June 1973

Sponsored by

Advanced Research Projects Agency
Nuclear Monitoring Research Office
ARPA Order No. 1714

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TELEDYNE GEOTECH
3401 Shiloh Road
Garland, Texas

20 September 1973

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IDENTIFICATION

AFTAC Project No.	VELA T/3704
Project Title:	Operation of TFSO
ARPA Order No.	1714
ARPA Program Code No.	1F10
Name of Contractor:	Teledyne Industries, Inc., Geotech Division Garland, Texas
Contract No.	F33657-72-C-0800
Effective Date of Contract:	1 July 1972
Amount of Contract:	$392,990
Contract Expiration Date:	31 December 1973
Program Manager:	B. B. Leichliter 271-2561, ext. 222

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ABSTRACT

This is a report of the work accomplished on Project VT/3704 from 1 July 1972 through 30 June 1973. Project VT/3704 includes the operation, evaluation, and improvement of the Tonto Forest Seismological Observatory (TFSO) located near Payson, Arizona. It also includes information about research and test activities carried out at the TFSO and at Garland, Texas, using TFSO data.

OPERATION OF THE
TONTO FOREST SEISMOLOGICAL OBSERVATORY
Final Report, Project VT/3704
Contract F33657-73-C-0800
1 July 1972 through 30 June 1973

1. INTRODUCTION

1.1 AUTHORITY

The research described in this report was supported by the Advanced Research Projects Agency, Nuclear Test Detection Office, and was monitored by the Air Force Technical Applications Center (AFTAC) under Contract F33657-72-C-0800, dated 1 July 1973. The Statement of Work for Project VT/3704 is included as appendix 1 to this report.

1.2 HISTORY

The Tonto Forest Seismological Observatory (TFSO), located near Payson, Arizona, as shown in figure 1 was constructed by the United States Corps of Engineers in 1963. TFSO was designed to record seismic events and to be used as a laboratory for testing, comparing, and evaluating advanced seismograph equipment and recording techniques. The instrumentation was assembled, installed, and operated until 30 April 1965 by United Electrodynamics (UED) - later Earth Sciences, A Teledyne Company - under Contract AF 33(657)-7747. In March 1964, the Long-Range Seismic Measurements (LRSM) Program provided eight mobile seismic recording vans to extend the existing instrument arrays at TFSO. On 1 May 1965, Geotech assumed the responsibility of operating TFSO. The LRSM vans were phased out of the TFSO operation on 3 October 1965. During the 20-month period from 1 May 1965 through 31 December 1966, the operation of TFSO under Project VT/5055 was closely allied with the work performed at the Blue Mountains, Uinta Basin, and Wichita Mountains Seismological Observatories under Projects VT/1124, VT/4054, and VT/5054. When reasonable, operating procedural changes, observatory instrumentation improvements, and special research investigations were accomplished simultaneously at all observatories. In other instances, improvements, modifications, and/or procedures that had been developed and proven at another observatory were incorporated into the TFSO operation. During 1967, under Contract AF 33(657)-67-C-0091, Project VT/7702, a 37-element, short-period array and a 7-element long-period array were designed and installed. Since 1967, TFSO has been operated routinely to record seismic data and to provide facilities for testing and evaluating a variety of new seismic instruments, including the triaxial seismometer and the KS force-balance seismometer system.

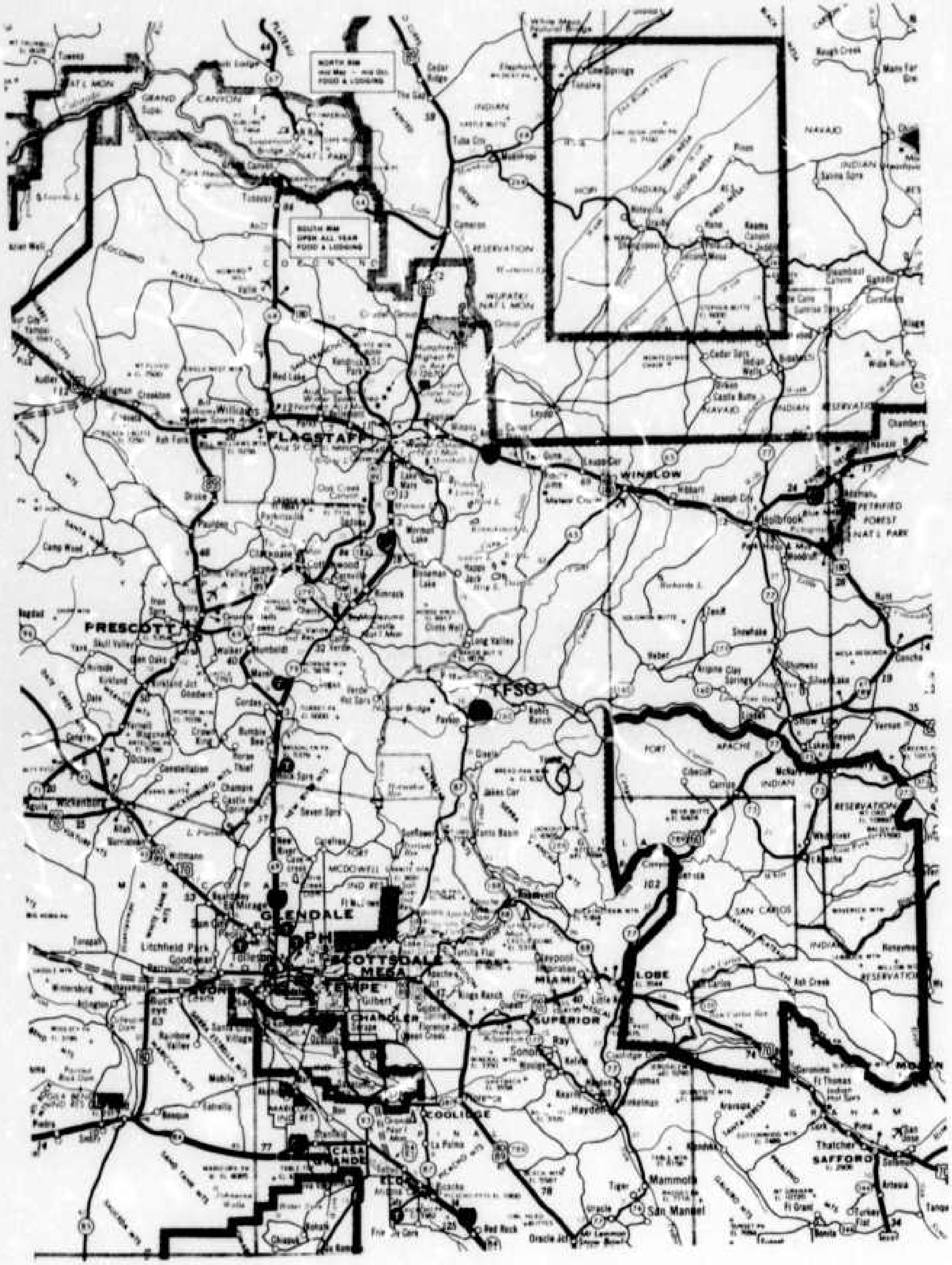

Figure 1. Location of the Tonto Forest Seismological Observatory

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1.3 WORK OF PROJECT VT/3704

The work of Project VT/3704 was a continuation of the work of earlier TFSO projects. The work of this project can be divided into the following general categories:

a. Continued operation of TFSO;

b. Evaluation and improvement of the standard instrumentation to provide a more efficient and effective observatory;

c. Field testing of newly developed and experimental instrumentation;

d. Analysis of resulting seismometric data;

e. Incorporation of new equipment into the systems operating at the TFSO.

2. SUMMARY

Three seismograph systems - the 37-element short-period array; the 7-element, 3-component long-period array; and the broad-band vertical seismograph - were operated continuously at the Tonto Forest Seismological Observatory from 1 July 1972 through 30 June 1973. Film and magnetic tape recordings of array data were shipped to the Seismic Data Laboratory, Alexandria, Virginia. Each week, some of these recordings were routed through the Geotech laboratories at Garland, Texas, where they were inspected for control of quality.

Modifications to the long-period array circuits, made between the 1969 and 1970 lightning storm seasons, greatly reduced lightning damage to amplifiers in these circuits. Similar modifications, made to circuits in the short-period array, greatly reduced lightning damage to amplifiers in that branch.

Operational tests were conducted with a multichannel filter, a quartz accelerometer and a force-balance seismometer.

Facilities and assistance were provided to personnel from two industrial organizations.

3. OPERATION OF THE TONTO FOREST SEISMOLOGICAL OBSERVATORY

3.1 GENERAL

Data normally were recorded continuously at the TFSO. Maintenance times, calibration times, and recording film or tape change times were staggered so that data recording was interrupted in only one system at a time.

The observatory was manned by an 8:00 a.m. to 5:00 p.m. shift and a 9:30 a.m. to 6:00 p.m. shift. The 8 to 5 shift was worked each Monday through Friday except holidays and was the regular work day for all personnel. The 9:30 to 6 shift was worked every day including Saturdays, Sundays, and holidays, and was staffed by one man on a rotational basis. The observatory operated unmanned from 6:00 to 8:00 a.m. MST every day. Technical work is handled by a full-time staff of four people. Secretarial work is handled by one half-time person.

3.2 SEISMOGRAPH SYSTEMS OPERATED DURING PROJECT VT/3704

3.2.1 Thirty-Seven Element Array

A 37-element array of short-period vertical seismograph (figure 2) was installed under Project VT/7702. Under Project VT/8702, this array was evaluated from the standpoint of reliability, beam-steering capability, and detection capability. Operation of this array continued under Projects VT/9702 and VT/2704. Recording of the outer-ring channels, Z21 through Z37, was discontinued on 15 October 1971, when only one of these channels was operational and when other duties at the observatory would not permit these channels to be repaired.

3.2.2 Seven-Element Array of Three-Component Long-Period Seismographs

A seven-element array of three-component long-period seismographs was installed during Project VT/7702. Under Project VT/8702, operational difficulties were experienced with seismographs in this array and the major efforts were directed toward solving these problems. Some modifications and changes were made to the seismographs and its operation was continued during Project VT/9702. The configuration of this array is also shown in figure 2.

3.2.3 Broad-Band Seismograph

The vertical broad-band seismograph uses a seismometer installed in the LP1 vault and a phototube amplifier installed in the CRB, and has the frequency response shown in figure 3.

3.3 STANDARD SEISMOGRAPH OPERATING PARAMETERS

The operating parameters and tolerances for the TFSO standard seismographs are shown in table 1. Frequency response tests are scheduled every 3 months, and the parameters of seismograph systems not conforming to the tolerances shown in tables 2, 3, and 4 are reset. Normalized response characteristics of TFSO standard seismographs are shown in figure 3.

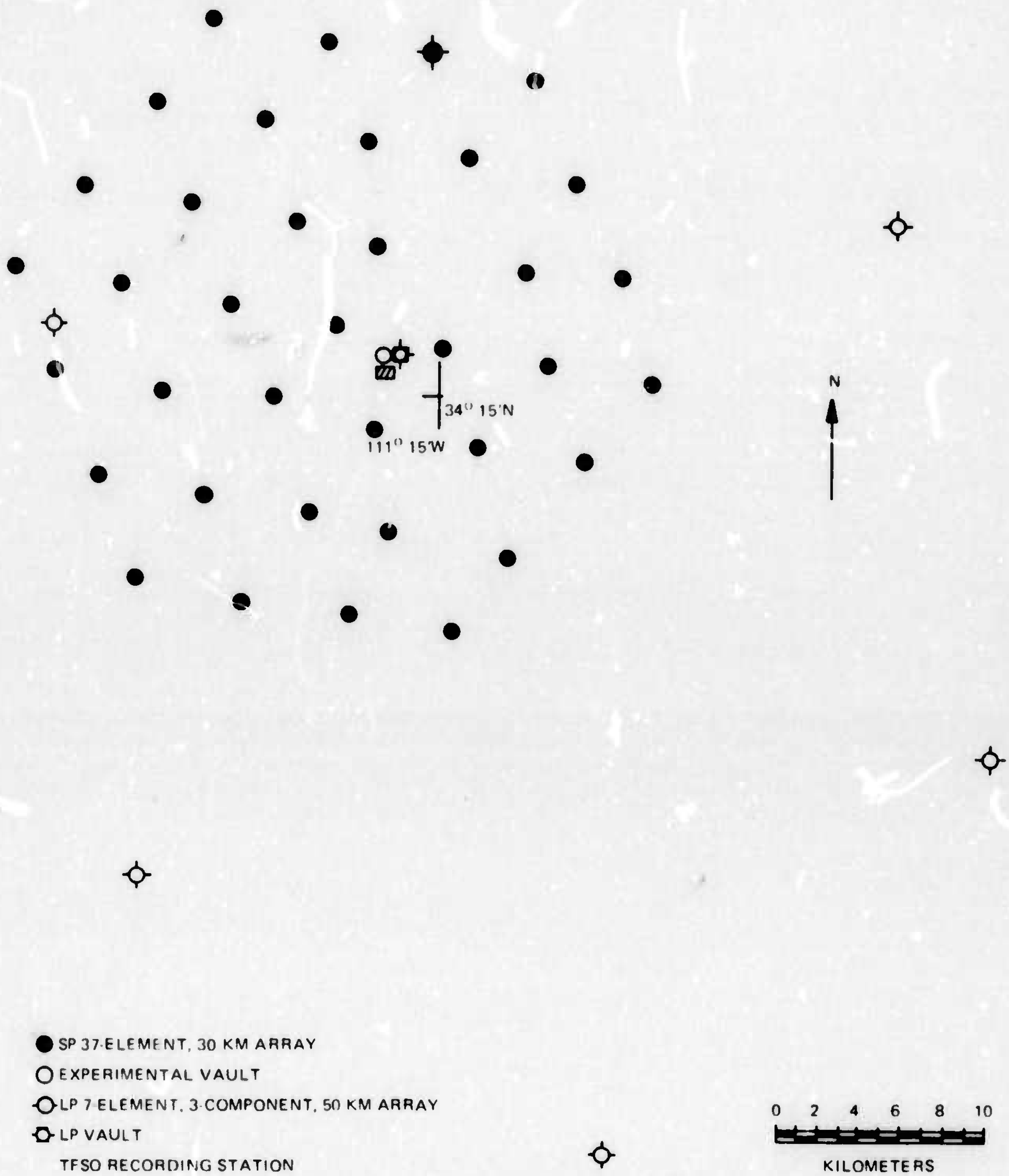

Figure 2. Vault locations in the 37-element short-period array, and the 7-element long-period array at TFSO

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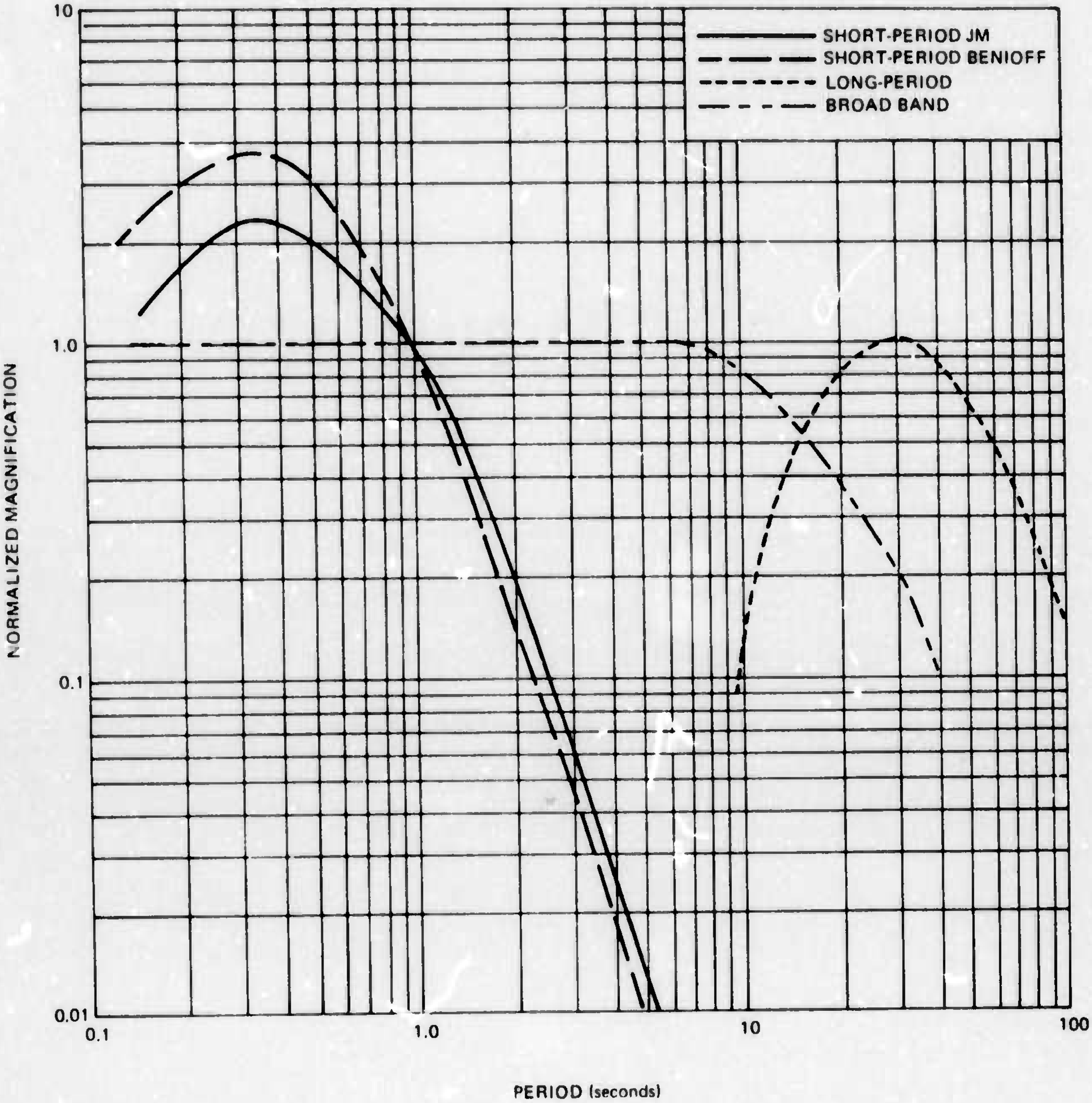


Figure 3. Normalized response characteristics of standard seismographs at TFSO

G 5048

Table 1. Operating parameters and tolerances of standard seismographs at TFSO

Seismograph				Operating parameters and tolerances				Filter and settings		
System	Comp	Type	Model	T_s	λ_s	T_g	λ_g	Model	Bandpass at 3 dB cutoff (sec)	Cutoff rate at SP side (dB/oct)
SP[a]	Z	Johnson-Matheson	6480	1.25 ±2%	0.54 ±5%	---	---	2888-1	0.2 - 1.0	6
SP[b]	Z	Johnson-Matheson	6480	1.25 ±2%	0.54 ±5%	0.33 ±5%	0.65 ±5%	6824-1	0.1 - 100	12
SP[b]	H	Johnson-Matheson	7515	1.25 ±2%	0.54 ±5%	0.33 ±5%	0.65 ±5%	6824-1	0.1 - 100	12
SP	Z	Benioff	1051	1.0 ±2%	1.0 ±5%	0.2 ±5%	1.0 ±5%	6824-1	0.1 - 100	12
SP	H	Benioff	1101	1.0 ±2%	1.0 ±5%	0.2 ±5%	1.0 ±5%	6824-1	0.1 - 100	12
SP	Z	UA Benioff	1051	1.0 ±2%	1.0 ±5%	0.75 ±5%	1.0 ±5%	---	---	--
BB	Z	Press-Ewing	SV-282	12.5 ±5%	0.45 ±5%	0.64 ±5%	9.0 ±5%	6824-7	0.05- 100	12
LP	Z	Geotech	7505A	20.0 ±5%	0.77	---	---	30024	80 - 300	6
LP	H	Geotech	8700C	20.0 ±5%	0.77	---	---	30024	80 - 300	6

KEY

SP Short period
LP Long period
UA Unamplified (i.e., earth powered)
BB Broad band

T_s Seismometer free period (sec)
T_g Galvanometer free period (sec)
λ_s Seismometer damping constant
λ_g Galvanometer damping constant

[a] 37-element hexagonal array
[b] 3 -component

Table 2. Frequency response norms and tolerances for TFSO short-period seismographs

T (sec)	f (Hz)	Tolerance (percent)	Relative amplitude Norm	Max	Min
5.0	0.2	10	0.0118	0.013	0.0106
2.5	0.4	7.8	0.0988	0.106	0.0916
1.25	0.8	5.0	0.68	0.714	0.646
1.00	1.0	0	1.00	1.00	1.00
0.67	1.5	5.2	1.55	1.63	1.47
0.50	2.0	5.1	1.97	2.07	1.87
0.33	3.0	7.3	2.30	2.47	2.13
0.25	4.0	12.2	2.05	2.30	1.80
0.167	6.0	20.3	1.38	1.66	1.10

Table 3. Frequency response norms and tolerances for TFSO long-period seismographs

T (sec)	f (Hz)	Tolerance (percent)	Relative amplitude Norm	Max	Min
100	0.01	20	0.135	0.162	0.108
80	0.0125	20	0.278	0.333	0.222
60	0.0167	15	0.485	0.558	0.412
50	0.02	15	0.644	0.741	0.548
40	0.025	10	0.874	0.961	0.787
30	0.033	5	1.03	1.082	0.978
25	0.04	0	1.00	1.00	1.000
20	0.05	5	0.825	0.866	0.784
15	0.0667	10	0.470	0.517	0.423
10	0.1	20	0.110	0.132	0.0879

Table 4. Frequency response norms and tolerances for TFSO broad-band seismographs

T (sec)	f (Hz)	Tolerance (percent)	Relative amplitude Norm	Max	Min
25.0	0.04	20	0.104	0.125	0.0832
16.7	0.06	20	0.350	0.420	0.280
12.5	0.08	15	0.775	0.891	0.659
10.0	0.1	10	0.950	1.04	0.855
5.0	0.2	5	1.00	1.05	0.950
2.5	0.4	5	1.00	1.05	0.950
1.25	0.8	0	1.00	1.00	1.00
0.625	1.6	5	1.00	1.05	0.950
0.312	3.2	10	1.00	1.10	0.900
0.156	6.4	15	0.98	1.13	0.833

3.4 DATA CHANNEL ASSIGNMENTS

Each data format recorded at TFSO was assigned a number (format number in the case of digital seismograms), and each time a new data format was established a new number was assigned. Data format change notices showing both the new data channel assignments and the previous data channel assignments were submitted to the Project Officer and were distributed to frequent users of TFSO data. The data formats recorded during Project VT/2704 are summarized in tables 5 and 6, and a key to the seismograph designators is given in table 7.

3.5 QUALITY CONTROL

3.5.1 Quality Control of 16-Millimeter Film Seismograms

Quality control checks of randomly-selected 16-millimeter film seismograms from Data Trunks 2, 4, and 8 and the associated logs were made in Garland. Items that were routinely checked by the quality control analyst include:

a. Film boxes - neatness and completeness of box markings;

b. Develocorder logs - completeness, accuracy, and legibility of logs;

c. Film -

(1) Quality of the overall appearance of the record (for example, trace spacing and trace intensity);

(2) Quality of film processing;

d. Analysis - completeness, legibility, and accuracy of analysis sheets. Results of these evaluations were sent to the observatory for their review and comment.

3.5.2 Quality Control of Analog FM Magnetic-Tape Seismograms

Each week, quality control checks of three randomly-selected magnetic tape seismograms are made in Garland and at TFSO to assure the recordings meet specified standards. The following items are checked:

a. Tape and box labeling;

b. Accuracy, completeness, and neatness of logs;

c. Adequate documentation of logs by voice comments on tape where applicable;

d. Seismograph polarity;

e. Level of the microseismic background noise;

f. Level of calibration signals;

Table 5. Data channel assignments for TFSO 16-millimeter film seismograms made during Project VT/3704. Dates without asterisks are start dates; dates with asterisks are stop dates.

DEVELOCORDERS
Fast speed, 30 mm/minute

Channel	Data group 7240 14 Nov 67	Data group 7299 21 Oct 70 26 Feb 71* 4 Mar 71	Data group 7301 30 Mar 71	Data group 7304 15 Oct 71
1	TCDMG	TCDMG	TCDMG	TCDMG
2	Z 1	BX 0	MS	Z 15
3	Z 2	BS 1	BFV	Z 16
4	Z 3	BS 2	Z60SP	Z 17
5	Z 4	BS 3	N60SP	Z 18
6	Z 5	BS 4	E60SP	Z 19
7	Z 6	BS 5	Z60LL	Z 20
8	Z 7	BS 6	N60LL	ZSH
9	Z 8	BS 7	E60LL	MS
10	Z 9	BS 8	Z60SL	Wi
11	Z 10	BS 9	N60SL	Z47BF
12	Z 11	FSH	E60SL	N47BF
13	Z 12	FTH	Wi	E47BF
14	Z 13	WWV	WWV	WWV
15	Z 14	-	-	-
16	WWV	-	-	-

DEVELOCORDERS
Slow speed, 3 mm/minute

Channel	Data group 7276 23 Jan 69	Data group 7285 21 May 69	Data group 7286 26 Jul 69	Data group 7303 19 Aug 71
1	Z4LP	Z6LP	Z2LP	TCDMG
2	N4LP	N6LP	N2LP	ML
3	E4LP	E6LP	E2LP	E1LP
4	Z5LP	Z7LP	Z3LP	N1LP
5	N5LP	N7LP	N3LP	Z1LP
6	E5LP	E7LP	E3LP	ZXLP
7	ML	Z39BB	ZZLP	MS
8	Wi	ML	ML	ZXLL
9	WWV	Wi	Wi	Z1LL
10		WWV	WWV	N1LL
11				E1LL
12				Wi
13				WWV
14				
15				
16				

Table 6. Data channel assignment for TFSO FM magnetic-tape seismograms made during Project VT/3704. Dates without asterisks are start dates; dates with asterisks are stop dates.

	FM Tape Recorders			
Channel	Data group 7239 16 Nov 67	Data group 7241 15 Nov 67	Data group 7265 25 May 68	Data group 7302 30 Mar 71
1	TCDMG	TCDMG	TCDMG	TCDMG
2	Z 1	Z 13	Z1LP	Z5LP
3	Z 2	Z 14	N1LP	N5LP
4	Z 3	Z 15	E1LP	E5LP
5	Z 4	Z 16	Z2LP	Z6LP
6	Z 5	Z 17	N2LP	N6LP
7	Comp	Comp	Comp	Comp
8	Z 6	Z 18	E2LP	E6LP
9	Z 7	Z 19	Z3LP	Z7LP
10	Z 8	Z 20	N3LP	N7LP
11	Z 9	Z 21	E3LP	E7LP
12	Z 10	Z 22	Z4LP	ΣZLP
13	Z 11	Z 23	N4LP	
14	Z 12	Z 24	E4LP	Z 37

Table 7. Key to the designations used in the data channel assignments at TFSO

TCDMG	Time Code Data Management Generator
Z	Amplified vertical seismograph from site identified by number
N	North-south horizontal seismograph
E	East-west horizontal seismograph
SP	Short-period seismograph
WWV	Radio time from National Bureau of Standards Radio Station WWV (WWV, STS, and Voice on tape)
BF	Seismograph using Benioff seismometer
LL	Low, Low magnification (short-period) or low magnification long-period seismograph
MS	Short-period microbarograph
V	Unamplified (earth-powered) vertical seismograph
SL	Low magnification short-period seismograph
Wi	Wind indicator
LP	Long-period seismograph
BB	Broad-band seismograph
Comp	Tape recorder wow and flutter compensation channel
BS	Beam steer
MCF	Multi-channel filter
FSH	Fisher process

g. Relative phase shift between array seismographs;

h. Level of system noise;

i. Oscillator alignment;

j. Quality of recorded WWV signal where applicable;

k. Time-pulse carrier;

l. Binary-coded digital time marks.

3.5.3 Quality Control of ASDAS Magnetic-Tape Seismograms

Quality control checks of ASDAS tapes are made routinely. At present, one tape from each of the two transports is checked weekly for the following items:

a. Neatness and accuracy of the associated logs;

b. Polarity errors;

c. Recording level of each channel;

d. Fidelity of reproduction;

e. Presence of header record and correct record length;

f. Tape parity errors;

g. Timing information.

3.5.4 Quality Control of DGRDAS Magnetic-Tape Seismograms

Quality control checks of DGRDAS tapes are made routinely. At present, one tape is checked each week for items listed under section 3.5.3 and, in addition, for the following items:

a. Field transmission parity errors;

b. Central digital system parity errors;

c. Gain code errors.

3.6 COMPLETION AND SHIPMENT OF DATA

Two ASDAS digital tapes were shipped each week from TFSO to the Garland laboratory for quality control. All other digital tapes were held at the observatory for a period of about 8 weeks and then were recycled if not requested by the SDL.

Four analog FM magnetic-tape units were used to record data for the AFTAC VELA Seismological Center (NYV). FM tapes for six days of each week were sent directly to SDL. The tapes for the seventh day were sent to our Garland laboratory for quality control inspection, then forwarded to SDL.

All Develocorder (16-millimeter film) seismograms, except quality control copies, were routinely shipped to SDL. One seismogram for each Develocorder was sent each week to our Garland, Texas, laboratory for quality control, then forwarded to SDL.

Copies of calibration and operational logs accompanied all data shipments.

3.7 CALIBRATION OF TEST EQUIPMENT

Test instruments were routinely calibrated at TFSO during the contract period and calibration logs were maintained for all such instruments. All calibrations were referred to Eppley standard cells which, in turn, were periodically certified to deviate less than 0.001 percent from standards maintained by the National Bureau of Standards.

3.8 EMERGENCY POWER GENERATOR

During this report period, the emergency power generator was operated a total of 56.2 hours. It was operated 44.5 hours during loss of commercial power, and 11.7 hours during tests under full load.

3.9 SECURITY INSPECTION

Security inspections were conducted on 6 July 1972, 2 November 1972, and 13 April 1973 by Mr. Ken Ozbolt, Chief, Industrial Security, Phoenix, Arizona. Mr. J. H. Carichall, of the same office, assisted Mr. Ozbolt during the November inspection.

3.10 GOVERNMENT PROPERTY INSPECTIONS

An industrial plant equipment inspection was conducted on 1 August 1972 by Mr. George Riley of the DCASD, Phoenix, Arizona, and on 20 June 1973 by Messrs. George Riley and Ben Lucart, of the DCASD, Phoenix, Arizona.

Real Property inspections were conducted on 16 September 1972 by Mr. Thomas Muir, and on 18 May 1973 by Messrs. T. L. Onyshczak and E. E. Dale of the Williams Air Force Base.

3.11 FACILITY MAINTENANCE

The TFSO facilities were maintained in accordance with sound industrial practices throughout the report period. This work included pest extermination, fire extinguisher inspection, work area cleaning, and lubrication and cleaning of

the heating and air conditioning equipment. In addition, the following tasks were undertaken to fulfill the requirements of Supplemental Agreement P00005 to the subject contract.

Cable trails and access roads in the array areas were graded, and arrangements were made for work in August to patch and seal the asphalt roads and the parking lot near the central recording building (CRB). Interior walls and exterior doors of the shop and the CRB were painted. A variety of repairs were performed on the air-conditioning and heating system. These included the recharging of the engineering laboratory air conditioner, the replacement of corroded pipe components in the air-handling units, the descaling of the chillers in an acid bath, and the replacement of the cooling tower motors, the furnace smoke stack, and the furnace control unit. Insulation was installed on pipes in the chiller, generator, and air-handling rooms. The water well jet pump was pulled and serviced. Worn sewage system motors were replaced, and evaporation tanks were cleaned. The cranking battery for the emergency power motor generator was replaced.

3.12 SPIRAL-FOUR TRANSMISSION CIRCUITS

A total of 213 spiral-four cable failures were detected and repaired between 1 July 1972 and 30 June 1973. The cables were shot or chopped by vandals, cut by road construction machinery, burned by forest fires, deteriorated by exposure to the elements, chewed by animals, and damaged by lightning. Repairs were accomplished by splicing or by replacing one-fourth mile cable sections. Table 8 shows a breakdown of the failures and repairs during each quarter of the report period.

Table 8. Spiral-four transmission circuit failures

	Number of failures in each quarter				
Cause of failure	Jul-Sep 72	Oct-Dec 72	Jan-Mar 73	Apr-Jun 73	Totals
Vandalism	4	4	1	3	12
Accidental cuts	5	1	5	5	16
Fire	5	0	0	0	5
Deterioration	9	60	43	44	156
Chewed by animal	0	1	0	0	1
Lightning	0	2	0	21	23
Totals	23	68	49	73	213
Repair technique	Number of repairs in each quarter				
Replace cable section	8	63	46	62	179
Splice cable	15	5	3	11	34
Totals	23	68	49	73	213

4. MAINTENANCE AND MODIFICATION OF TFSO INSTRUMENTATION

4.1 LIGHTNING PROTECTION

The total lightning activity in the TFSO array area was the same in calendar year 1972 as it was in calendar year 1971. Lightning was observed during 78 days in both years, but its distribution in 1972 was different from that in previous years. Data for the years 1968 through 1972 and for the first half of 1973 are presented graphically in figure 4. Note that the sharp peak of activity that occurred during July or August in the years 1968 through 1971 was not so prominent during 1972. Instead, the higher activity started earlier (in June), did not peak as sharply in July or August, and decreased slowly. Lightning was observed during every month from May 1972 until June 1973. The lightning was accompanied by unusually frequent precipitation.

Historical information about lightning damage to solid-state amplifiers used at the field sites of the long-period and short-period arrays is presented in table 9. In addition, a monthly analysis of short-period array amplifier failures is presented in figure 5. The dramatic decrease in the long-period amplifier failure rate is most welcome, but cannot be explained. No changes were made to the lightning protection in these amplifier circuits during 1971 or 1972. The decrease in short-period amplifier failures can be related to modifications made to its lightning protection circuits. Note that there were no failures in 1973 after correctly installed modifications were made to power, data, and calibration circuits.

Table 9. Solid-state amplifiers damaged by lightning

Amplifier	1968	1969	1970	1971	1972
	Number of failures				
SP, Model 25220	44	25	43	17	10
LP, Model 28470	25	36	10	12	1
	Number of lightning days				
SP amplifiers	1.16	0.43	0.68	0.22*	0.13*
LP amplifeirs	0.66	0.62	0.16	0.15	0.013

*Maintenance in 17 of the 37 SP channels was performed less than 6 months in 1971 and not at all in 1972.

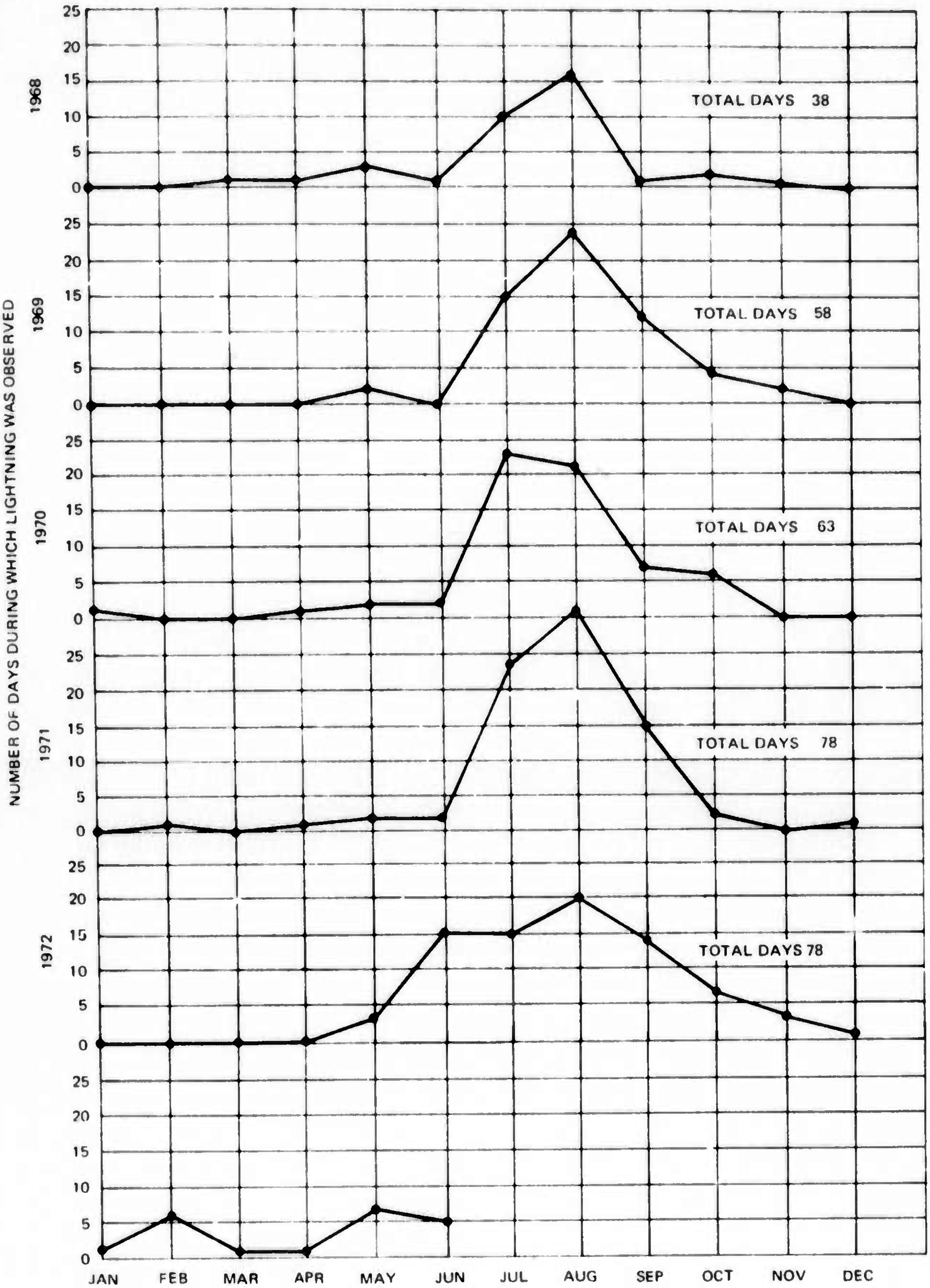


Figure 4. Monthly distribution of lightning storms in TFSO area

G 7205

CHANNEL	1972						1973					
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
Z1		●							DP		(SEE NOTE)	
Z2			●								DP●	
Z3			●						DP			
Z4		●	●							DP		
Z5									DP			
Z6										DP		
Z7										DP		
Z8											DP	
Z9										● DP		
Z10	•										● DP	
Z11	•									D		
Z12	•			●								
Z13	•										D	
Z14	•									D		
Z15	•										●	D
Z16	•											D
Z17	•											D
Z18	•										D	
Z19	•										D	
Z20	•											

KEY

● – ONE AMPLIFIER FAILURE
P – POWER CIRCUIT MODIFIED
• – POWER CIRCUIT MODIFIED BEFORE JULY 1972
D – DATA AND CALIBRATION CIRCUIT MODIFIED

NOTE – Z2 DATA AND POWER CIRCUITS WERE INCORRECTLY MODIFIED IN EARLY MAY, THEY WERE CORRECTED AFTER THE AMPLIFIER FAILURE ON 21 MAY

Figure 5. Short-period array amplifier failures

4.2 SHORT-PERIOD SEISMOGRAPH ARRAY

4.2.1 General

Data from short-period array channels Z1 through Z20 were recorded when they were available, but frequent precipitation from October 1972 until mid-April 1973 keep many array roads and cable trails impassable and prevented field maintenance work from being accomplished. The operational status of these channels is shown chronologically in figure 6. Major component failures that interrupted array channel operation included the following:

Component	Number of failures
Spiral-four cable	111
Power resistor (CRB)	2
Isolation filter	8
Amplifier	14
Unknown	4
Water in vault	4

The most frequent cause of channel outage was cable failure. In addition, most of the cable failures were compound. That is, 179 cable sections were replaced and 34 splices were made to restore 111 channel outages.

4.2.2 Lightning Protection

The lightning protection circuit that was tested on the power circuits of Z12 and Z20 early in 1971, and was installed on the power circuits of Z11 and Z13 through Z19 later in 1971, was installed on the power circuits of Z1 through Z10 during 1973. Lightning protection circuits using Zener diodes were also added to the data and calibration circuits of all short-period array channels except Z12, Z20, and Z21 through Z37. Z12 and Z20 circuits will be modified soon; Z21 through Z37 are not active and will not be modified at this time. Figure 7 shows the modifications made to the short-period data and calibration circuits. The protective devices included in the modified circuits are expected to greatly reduce lightning damage to both the solid state amplifiers and the isolation filters in the short-period array.

4.2.3 Cover Boards

New cover boards were installed over tank vaults at sites Z1 through Z20 and were covered with sawdust. The old cover boards had deteriorated from exposure to moisture and temperature cycling, and could no longer support the sawdust cover required.

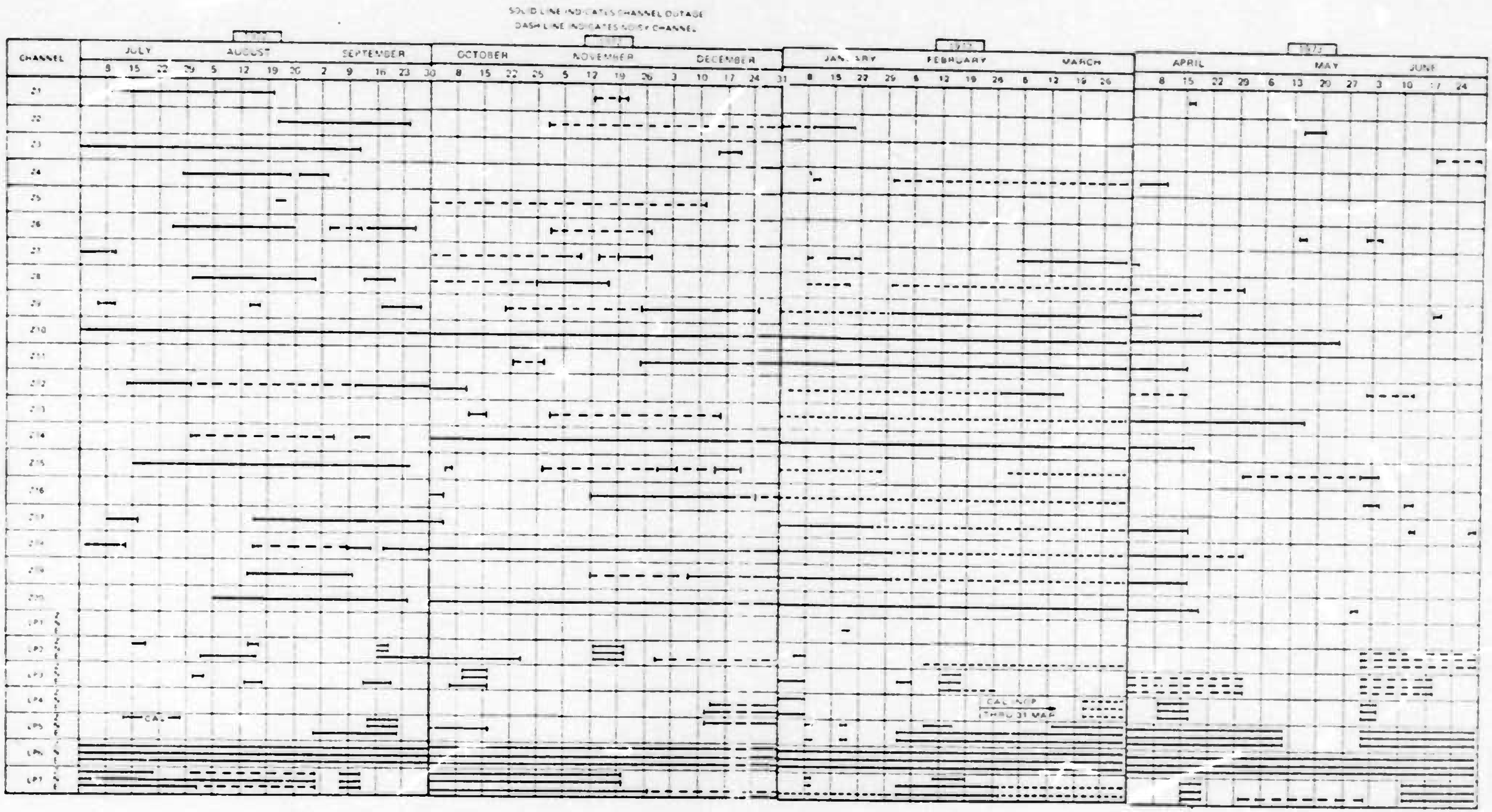


Figure 6. TFSO channel outage

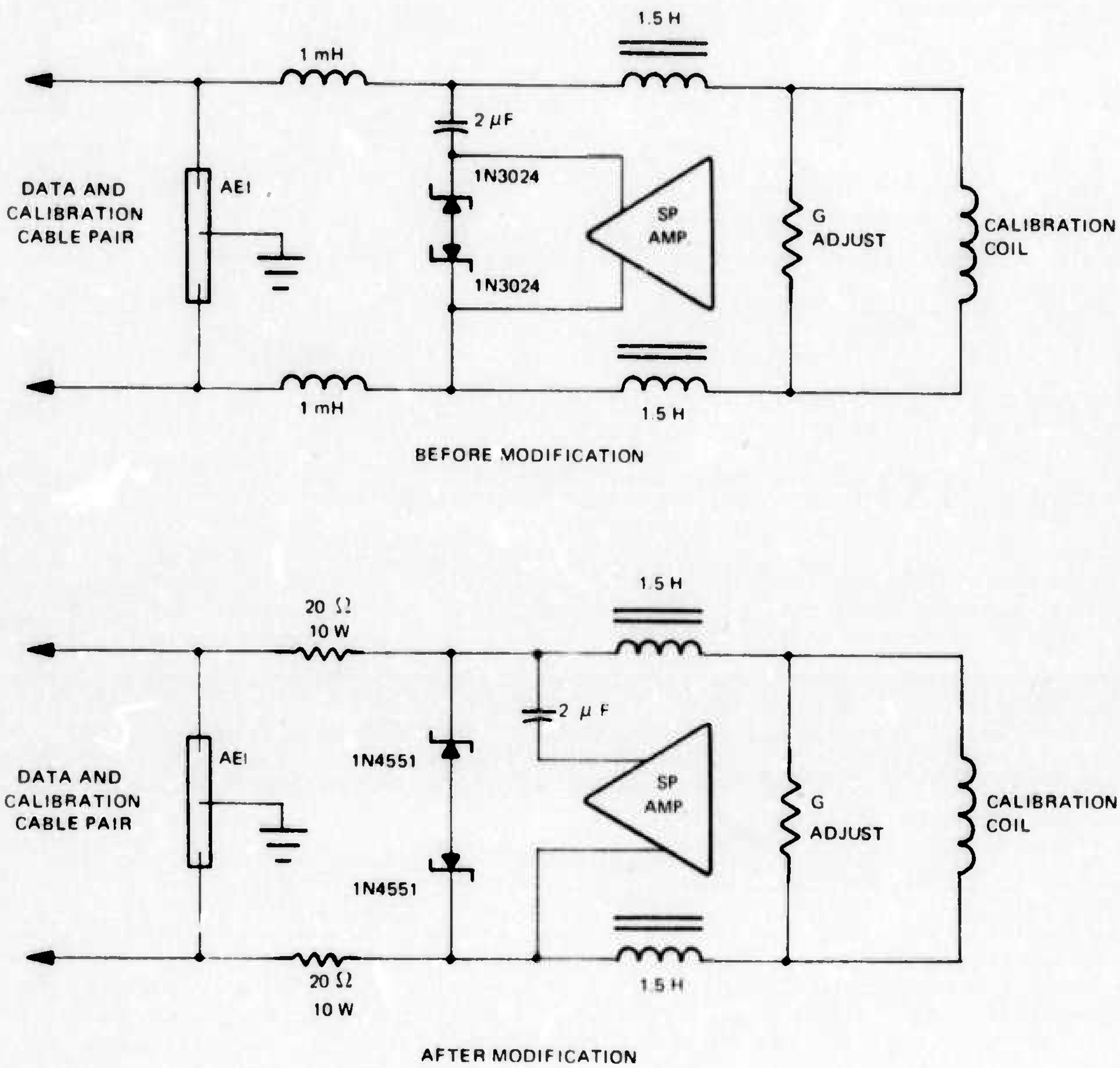


Figure 7. Modifications to short-period array data and calibration lightning protection circuits

G 7206

4.3 LONG-PERIOD SEISMOGRAPH ARRAY

4.3.1 General

Long-period seismograph array data were recorded throughout the report period. The operational status of long-period array channels is shown chronologically in figure 6. Major component failures that interrupted array channel operation included the following:

Component	Number of failures
Microwave system	7
Seismometer (mass against stop)	33
Free period relay	1
Power fuse (remote site)	3
Spiral-four cable	10
Water in vault	1
Telephone circuit	2
Lack of fuel	2
Solid state amplifier	1

The frequent precipitation during this report period had a far more detrimental effect upon the performance of the long-period array than it did upon the performance of the short-period array. It caused long-period piers to tilt, moving seismometer masses to their stops 33 times, and it prevented the access to several remote sites. LP5 and LP7 became inoperative when fuel for their electric power generators was depleted and could not be replenished because floodwaters closed access roads to these sites. LP6 was inoperative first because of site relocation, then because of delays in the provision of service by the telephone company.

4.3.2 Lightning Protection

Three of the interruptions in long-period channel operation were caused by lightning-induced voltage surges large enough to fire the AEI gas triode protector in the power circuits. Under these conditions, the AEI drew enough current to blow the line fuse. This caused channel operation to stop until the remote site was visited, and the fuse replaced. To prevent such outages from occuring while retaining the same degree of lightning protection, the fuse was replaced with a thermal, automatic-reset, circuit breaker as shown in figure 8. This will allow the gas triode to fire, but will extinguish any sustained art it tries to maintain with line power.

In previous years, lightning frequently had damaged the inductors and diodes used in the lightning protection circuits of the data and calibration circuits at the remote sites. These were replaced with heavier-duty components as shown in figure 9.

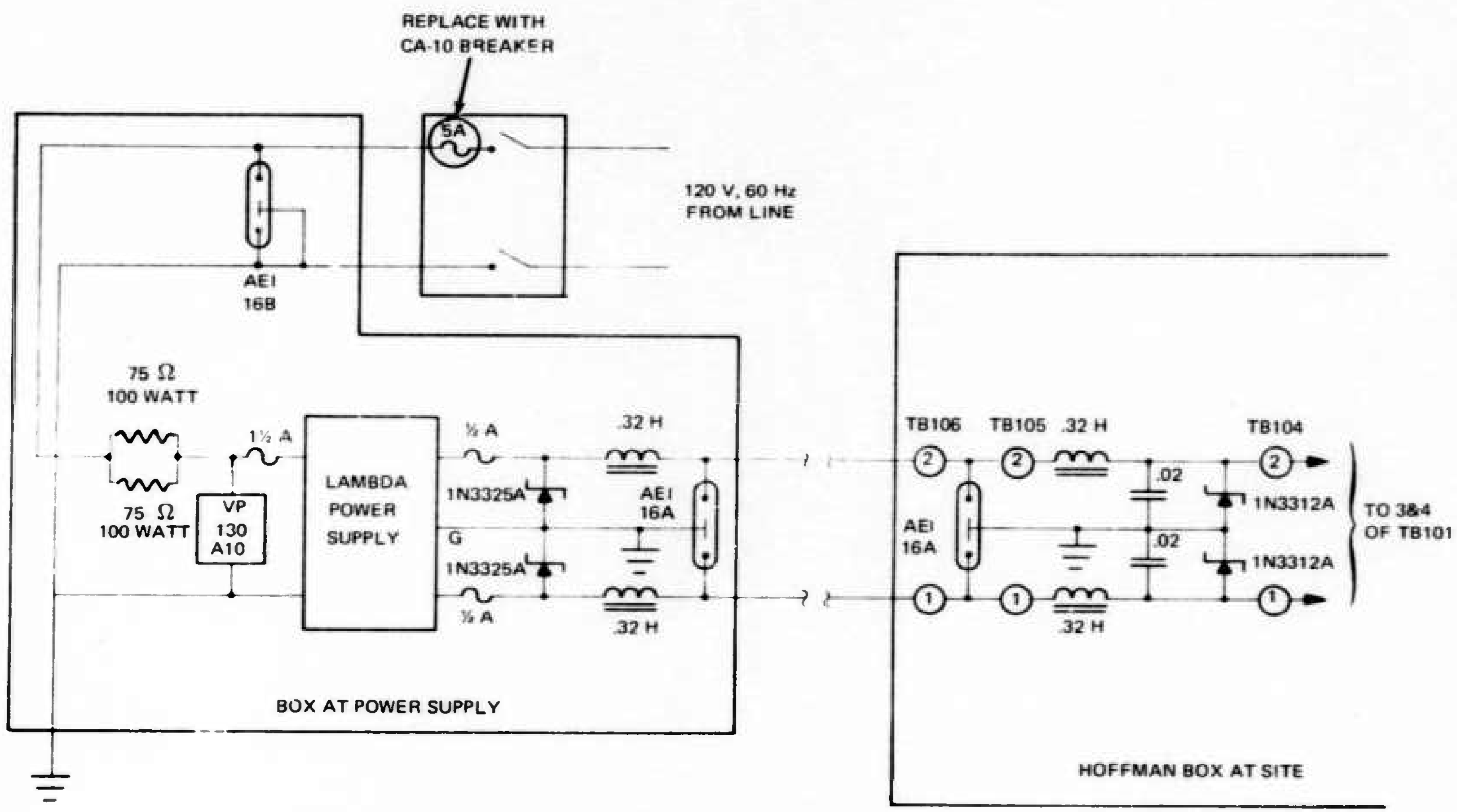


Figure 8. Modification of long-period array remote site power circuits.

G 7207

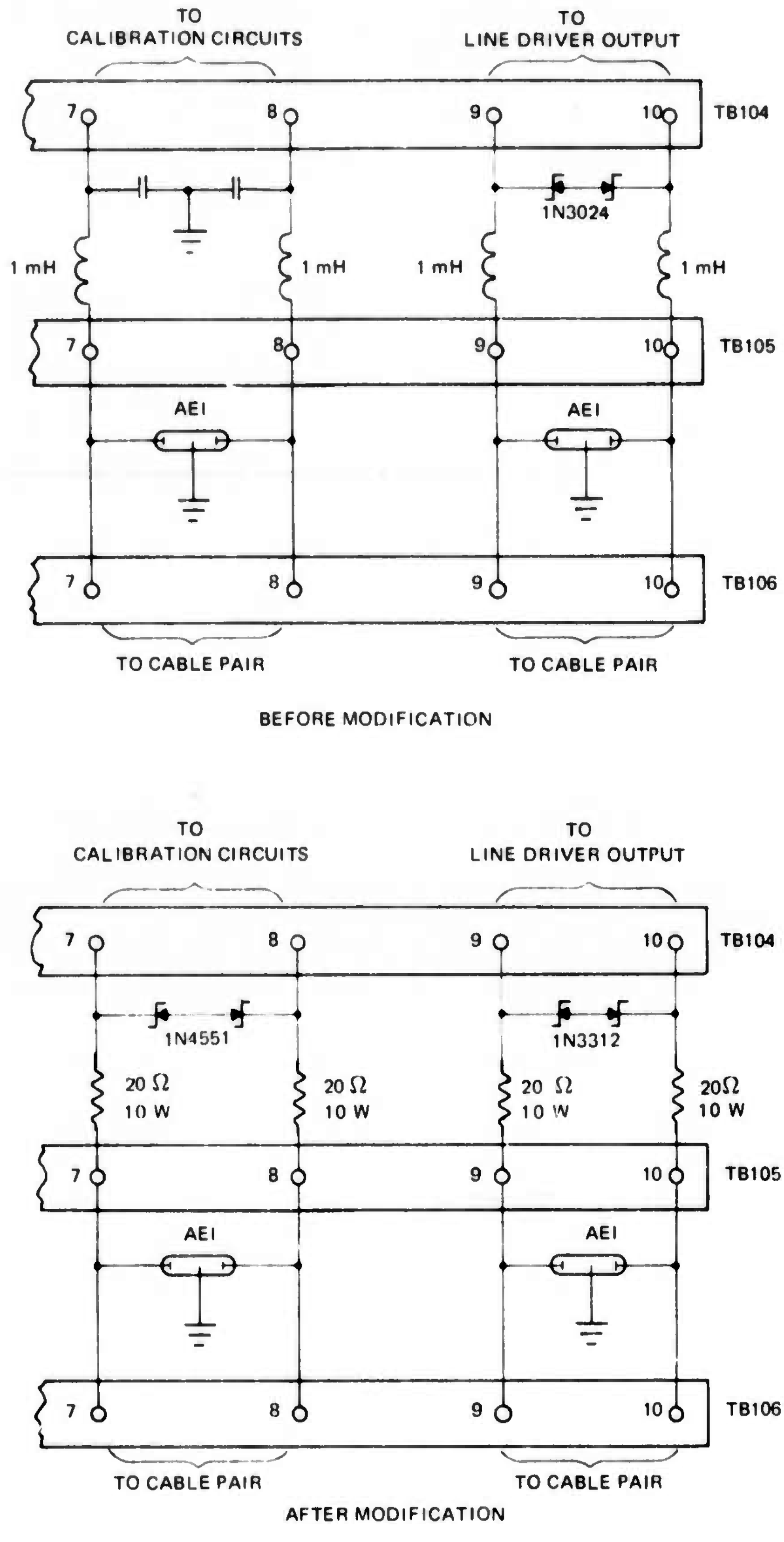


Figure 9. Wiring diagram for modified data and calibration lightning protection circuits in long-period array field sites

G 7208

4.3.3 LP5 Power Generator

Routine maintenance, including changes of oil, oil filter, and air cleaner, and filling of water, oil and fuel tanks are scheduled to be performed every three months. This schedule was interrupted by the frequent precipitation which made roads to the generator site at Chalk Mountain impassable from the latter weeks in 1972 until 26 April 73. Consequently, when the generator fuel ran out on 2 January, there was no power for the LP5 equipment until 26 April.

4.3.4 Relocation of LP6

Amendments 7 and 8, authorizing the relocation of the LP6 site and releasing the S 1/2 of the S 1/2 of Sec. 26, T11N, R10E from the withdrawn area, were received from the Real Estate Division, U.S. Army Engineers, Los Angeles District in August. Construction of the new LP6 began shortly thereafter. In order to permit comparative evaluations of three different types of vaults under identical installation conditions, three piers were installed within a few feet of each other, at the same depth below the earth's surface, and housed within a common wooden structure.

A Lamont tank vault was installed on one pier, a bottomless tank on another, and a 14414 tank (with a metal bottom) was installed on the third. Instruments in the vaults are approximately 8 feet below the earth's surface. To implement tank evaluation, three horizontal seismometers were installed in the tanks, and were all oriented in an east-west azimuth.

Construction of the access road, closing the old site, closing the old road by constructing water bars as flagged by the Forest Service, and patching of rough placed in the existing road were completed during the month of September. The closing of the old road was monitored by a representative of the Forest Service. All construction work at the LP6 remote site is complete and commercial power is available. Data transmission from the site to the CRB will be started when telephone service is made available by the telephone company. Figures 10 through 12 show photographs of the installation.

4.3.5 Install Microwave Telemetry Circuits

Work was undertaken to upgrade the microwave telemetry system to LP5 and to provide a completely new one for LP7. The old LP5 microwave system, which transmitted data between LP5 and the CRB via a repeater at Diamond Point, will be replaced with a system that will transmit data directly between these points without a repeater. The new system which will transmit data between LP7 and the CRB will also operate without a repeater. Figure 13 shows a block diagram of the equipment configuration of these systems. To take advantage of terrain and provide the best transmission paths, the CRB telemetry equipment and antennas will be located at LP1, and data between the CRB and LP1 will be carried by spiral-four cable.

Assignments have been received to operate the equipment on military frequencies, and the equipment has been ordered. By the end of June 1973, only antenna towers needed for this task had been received. Deliveries of the remaining equipment were delayed by the lack of operating frequency assignments. In view of this, the Contracting Office has extended the performance period of this task to 31 December 1973.

Figure 10. LP6 tank vaults installed on piers in excavation. Lamont tank is at rear in wooden shelter. Bottomless tank is embedded in center concrete pier. Model 14414 tank, which has domed steel bottom is in foreground.

G 7209

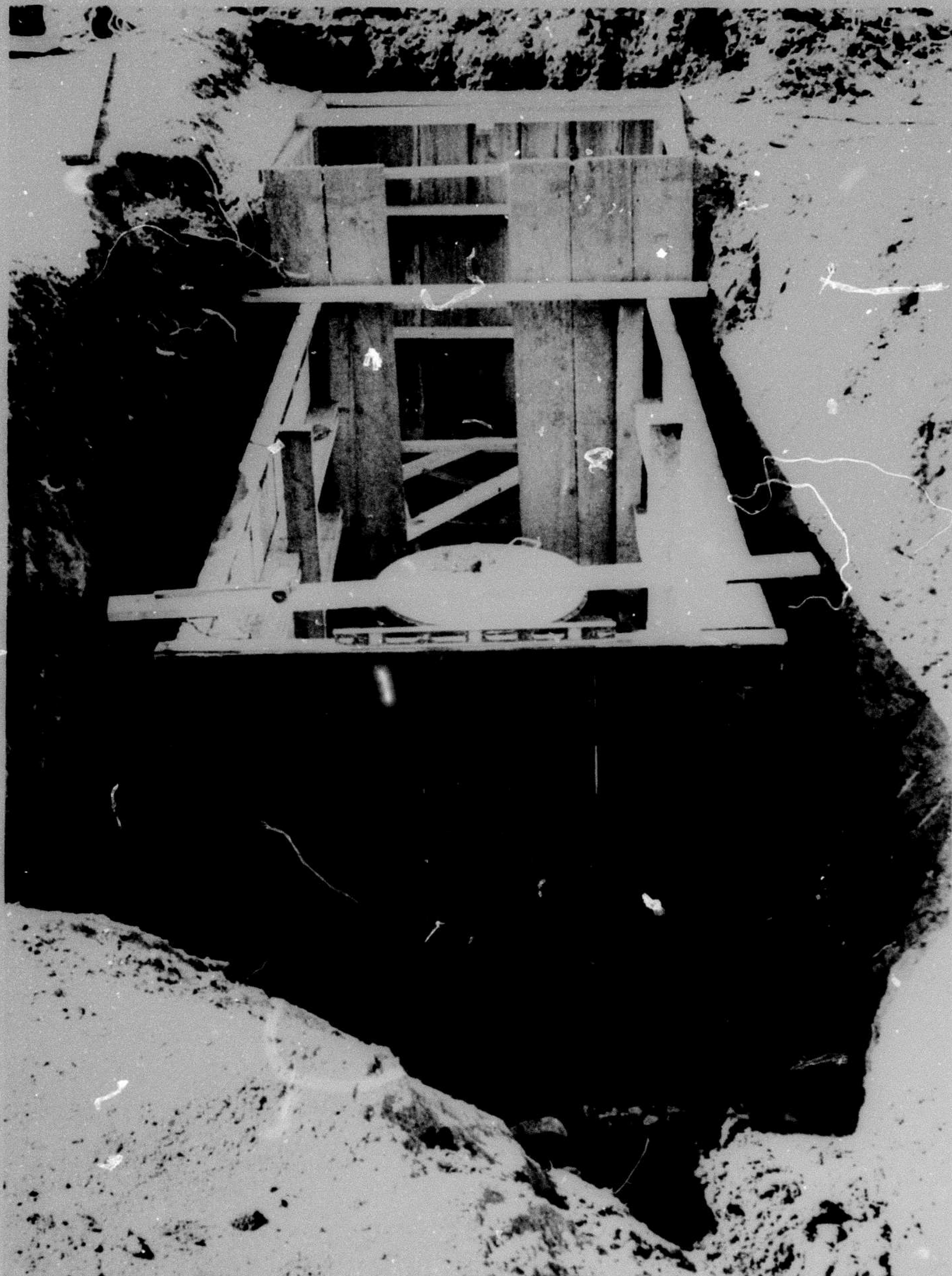


Figure 11. LP6 vault site with wooden retainer walls in place, before roof was installed.

7210

Figure 12. Wooden structure over tank vaults at LP6 remote site. Plastic sheet is being nailed in place before backfilling around and covering over structure. Entry to tanks will be through door in top of taller section of wooden structure.

G 7211

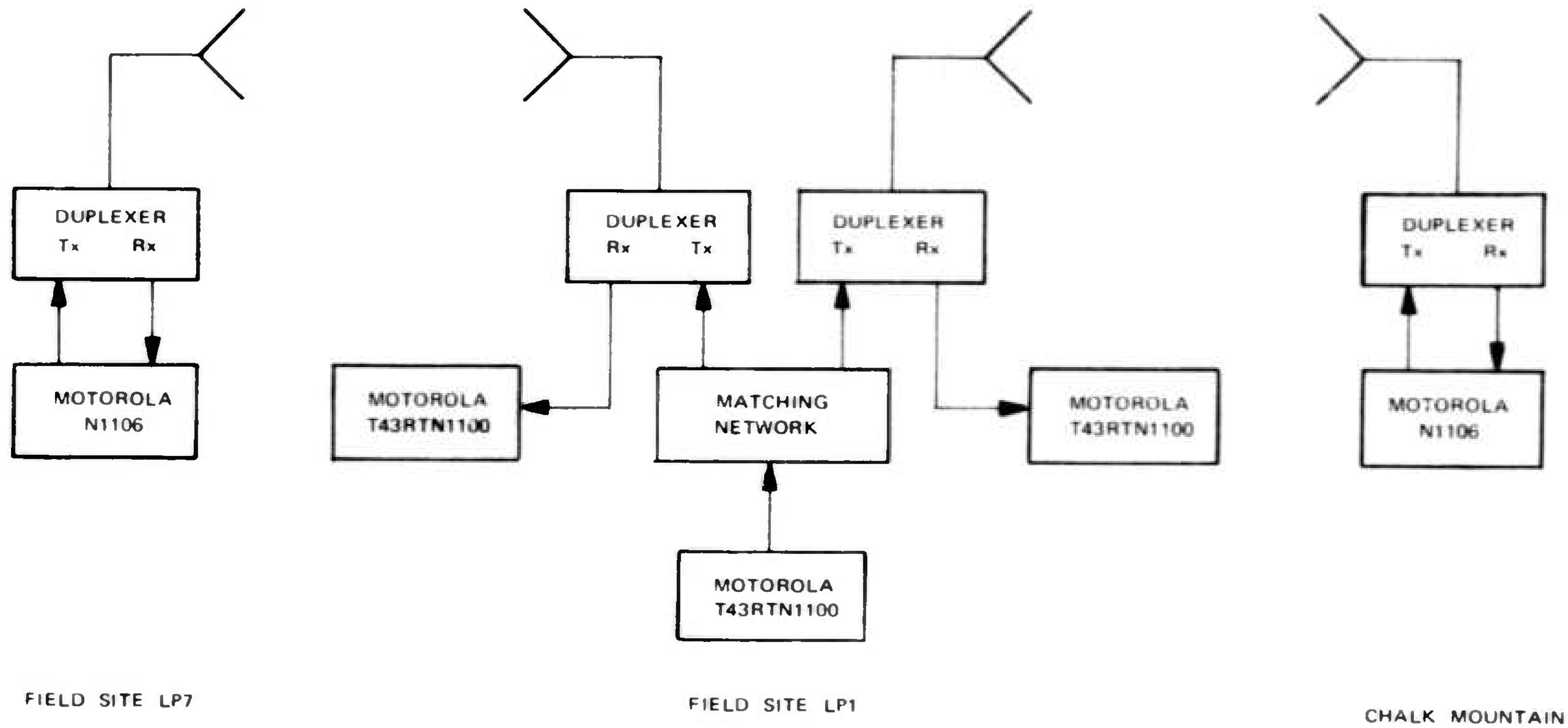


Figure 13. Microwave telemetry circuits for LP5 and LP7

4.4 ASTRODATA SEISMIC DIGITAL ACQUISITION SYSTEM

4.4.1 Recording Time Schedule

The Astrodata Seismic Digital Acquisition System (ASDAS) was operated from 0000Z through 0430Z and 1425Z through 2330Z on Monday through Friday except on holidays, and was operated from 0000Z through 0430Z and 1630Z through 2330Z on Saturdays, Sundays, and holidays.

4.4.2 Recording Formats

Data were recorded on magnetic tape by the ASDAS using the format shown in table 10.

4.4.3 Operation and Maintenance

The ASDAS was operated routinely with interruptions only for tape change, scheduled maintenance, and repairs. Adjustments were made to vacuum controls, the capstan rollers, and the head alignment. Components requiring replacement included vacuum motor brushes, capstan drive belts, switches, one recording head assembly, and several electronic components.

4.5 DIGITAL GAIN RANGING DATA ACQUISITION SYSTEM

The digital gain ranging data acquisition system (DGRDAS) was inoperative from 1 through 7 July and from 25 through 28 November for repairs and adjustments of the Kennedy incremental magnetic-tape recorder, whose malfunctions were causing tape parity errors (TPE) to occur at a gradually increasing rate. By 27 March, just before the Kennedy recorder was replaced with a new PEC recorder, the TPE rate had become marginally acceptable. After the PEC recorder was installed the TPE became insignificant. The Kennedy recorder is scheduled to be returned to the factory for service, after which it will be kept as a standby to be used when the PEC fails.

Table 10. Astrodata seismic digital acquisition system recording format used at the TFSO from 1 July 1972 through 30 June 1973

Format No. 19

Channel	Data	Channel	Data
1	Z 1	25	
2	Z 2	26	
3	Z 3	27	
4	Z 4	28	
5	Z 5	29	
6	Z 6		
7	Z 7	31	
8	Z 8	32	
9	Z 9	33	
10	Z 10	34	
11	Z 11	35	
12	Z 12	36	
13	Z 13	37	
14	Z 14	38	Z1LP
15	Z 15	39	Z2LP
16	Z 16	40	Z3LP
17	Z 17	41	Z4LP
18	Z 18	42	Z5LP
19	Z 19	43	Z6LP
20	Z 20	44	Z7LP
21		45	ZXLP
22		46	BS 9
23		47	FSH
24		48	STS

5. INSTRUMENT EVALUATION

5.1 MULTICHANNEL FILTER

The multichannel filter (MCF) was operated from 1 July until 12 August, when it was shut down because there were not enough short-period channels operational to justify its continued operation. During this operational period, the MCF failed once and was repaired by the replacement of a fuse.

The MCF was returned to routine operation on 29 May. It was programmed to provide the following beam-steered outputs, which were recorded on Develocorder #7, Data Trunk #6.

Channel identification	Azimuth from TFO (degrees)	Distance from TFO (degrees)	Approximate location	Apparent velocity (km/sec)
BS0	0	70	Novaya Zemlya	18
BS1	315	70	Kurile Island	18
BS2	270	70	Marshall Islands	18
BS3	225	70	Cook Island	18
BS4	180	70	Easter Islands	18
BS5	135	70	Africa Chile	18
BS6	90	70	Cape Verde Basin	18
BS7	45	70	Portugal	18
BS8	Any	180	East Crozet Basin	∞
BS9	313	70	Kurile Islands	18

FISHER - Beamed for 313° Azimuth, 70° Distance

FISHER THRESHOLD - Set to 240_8 - 206_{10}

5.2 EXTENDED LONG-PERIOD SEISMOGRAPH

Testing of the extended long-period seismograph was terminated on 5 August 1972 with the approval of the Project Officer.

5.3 GRAVITY FEED CHEMICAL SUPPLY SYSTEM

From July through September, the gravity feed chemical supply systems on the short-period Develocorders continued to operate without failures. Occasionally, adjustments were made to the drip rates. In some cases, simply pinching the hoses flushed out chemical buildups and corrected the flow rates.

Overdeveloping of the film on the long-period recordings continued on the long-period Develocorders until 25 August when the developer dilution was increased from 20:1 to 40:1 (40 parts water, 1 part developer).

From October through December, there were seven failures in the gravity feed chemical supply systems used to furnish fixer to LP Develocorders and one failure in the system that supplies fixer to a SP Develocorder. All systems were restored to service by cleaning or adjusting the flow control valves. There were no failures in the develop r supply lines.

During December, three chemical supply systems were removed from service, completely cleaned, and returned to service. Later in the month, during a visit by the Project Officer and the Program Engineer, it was noted that dust collects in substantial quantities on the surface of the liquid in each chemical supply tank, and that it probably contributes strongly to the system clogging. Plans were formulated to modify the system so that the chemicals could be kept clean and could be furnished to each control valve at a greater pressure (head) than is now used.

The gravity-feed chemical supply system for the TFSO Develocorders continued to provide an unsatisfactory performance, failing four times during January. To obtain a better performance, the system was modified as described in the Test Plan presented in appendix 2 of this report. The newer system features common chemical supply reservoirs for all Develocorders, and a larger chemical supply pressure. Figures 14 and 15 show photographs of the modified system.

An early review of the newer system performance indicates that Develocorder film record quality has significantly improved, but that for best performance, flow rates must be monitored and adjusted. The flow of fixer to one Develocorder failed once during February and once during March. No failures have occurred since that time. The simplified chemical handling procedures, which involve replenishment of one type of chemical to each of three large centralized containers, has reduced the spilling of chemicals onto the Develocorders and the surrounding furniture.

Chemical flow rates were adjusted to the minimum that would produce good quality recordings. The total volume of chemicals used from 5 February to 29 March, and their usage rates are as follows:

Dilute chemical	Volume used in 52 days gallons	Approx. no. gal. per day	Develocorders
Fixer	24.7	0.5	7
LP developer	10.7	0.2	4
SP developer	3.0	0.06	3

At present, each central chemical container is filled when its fluid level has dropped approximately one gallon.

Figure 14. Gravity feed chemical supply system with centralized supply tanks

G 7030

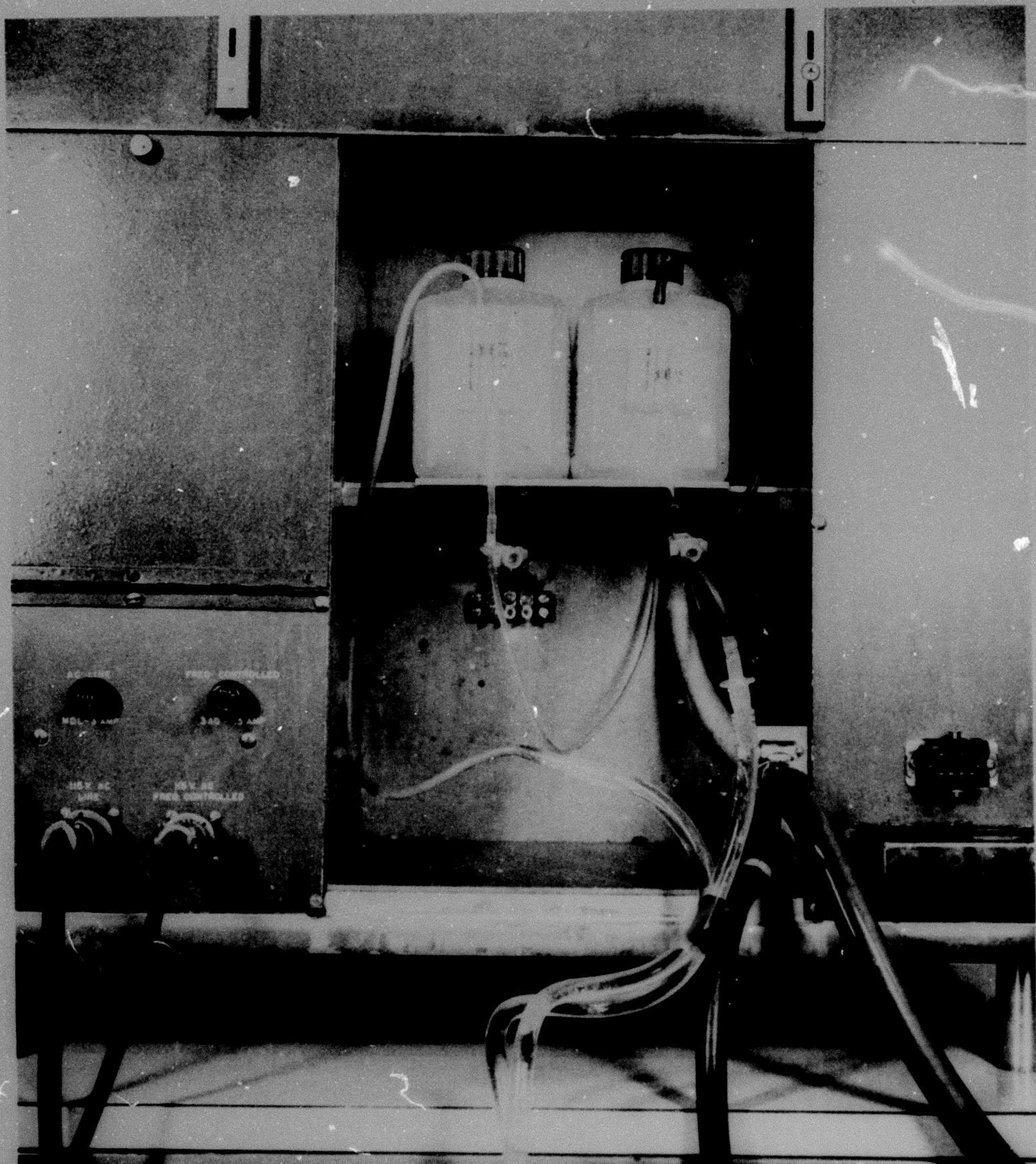


Figure 15. Gravity feed chemical supply system connections to Develocorder

G 7031

5.4 QUARTZ ACCELEROMETER

Work continued on the Block and Moore quartz accelerometer tests. A quartz spacer block for the horizontal unit and ten quartz suspension fibers were received from Worden Quartz Products, Inc., of Houston, Texas, early in July, and six quartz blanks, ready for fiber drawing operations, were received from the Frankford Arsenal in Philadelphia, Pennsylvania. The block and one fiber were installed in the horizontal accelerometer after 3 of the 10 fibers were broken while learning the proper handling technique. The fiber for the vertical unit was installed with no difficulty. All work with the inner components of these units was done in the "clean room" facility at the Garland plant. Parts were thoroughly cleaned and handled with white gloves to prevent introduction of contaminants which could cause problems in evacuation of the hard vacuum cans.

Dr. Robert D. Moore has been retained on a part-time basis as a consultant for the duration of this project. He visited the Garland plant on 19 and 20 July. In general, he was pleased both with our approach to the overall tests planned and with our methods of working on the accelerometers. He made several suggestions for further tests which will be included in the test plan. Also, he gave detailed instructions for the assembly, adjustment, and evacuation of the accelerometer.

By the end of July, the two instruments were ready for final assembly and vendors were being located for purchase or lease of the required evacuation and bake-out equipment. At that time, a second shipment of equipment from the University of California at San Diego was received at TFSO and was reshipped to Garland. This shipment contained the soft vacuum cans and the thermal heater/isolators for the accelerometers.

In August, difficulty was experienced in tensioning the quartz fibers. All installed fibers broke when tensioned. Most held together initially when strung, but broke as long as several hours later. Following a detailed review of installation techniques and theoretical fiber strengths with Dr. Robert Moore and Ray Worden, it was concluded that all fibers had been weakened by exposure to moist air, and plans were made to prevent this from happening again. It was decided that, immediately after fabrication, each new quartz fiber would be placed into a glass tube which would be evacuated by a mechanical pump and sealed. The glass tube would be broken open just before the fiber was to be installed in the seismometer. If the installation and adjustments were not completed during one day, the partially assembled instrument would be protected from moisture by storing it in an evacuated bell jar overnight or until assembly work was to be continued.

Twenty-two quartz fibers were ordered from Worden Quartz Products, Inc., and a partial shipment of ten quartz fibers was received late in August. The fibers were hand-carried because they were packaged in evacuated glass tubes and could not be secured within the tubes. During an attempted installation of the first fiber, it was discovered that all ten had been improperly drawn and could not be used. The vendor agreed to repair or replace the defective units and to expedite the manufacture of the remaining part of the order. On 6 September, the defective units were returned to Worden and twelve more were picked up.

Dr. Robert Moore visited the Garland plant from 11 through 14 September. During that time the first of the new fibers was installed in the vertical accelerometer, the complete unit was assembled, and placed in the bell jar for preliminary tests under vacuum. The auxiliary damping paddles were found to interfere with full scale motion of the detector paddle. Also, the paddle damping, which had been noted during preliminary tests, was still evident even at pressures of about 5 torr (1 torr ≅ 1 mm of mercury). The accelerometer was then disassembled to adjust the auxiliary paddles and to check closely for foreign material which might cause the damping. During subsequent reassembly, the fiber was broken. After installing a new fiber, the completed unit was again placed in the bell jar and evacuated to about 5 torr. The detector plate was still overdamped. At Dr. Moore's suggestion, the bell jar was connected to the vacuum system of the Veeco Model MS90AB leak detector, which was leased for use on this program. When the pressure reached about 0.1 torr, the damping disappeared. From this, it was deducted that the damping originally noted in the vertical accelerometer was caused by a very small leak in its hard vacuum can. During future tests, damping as a function of pressure will be determined. This discovery has pointed out that the seal must be completely leak-free. Efforts will be made to assure this during final assembly.

While Dr. Moore was at Geotech, a thorough inventory was made of all parts and equipment received from Diax, Inc. It was found that some of the electronic items required repair and that some of the mechanical components required for operation were missing. With Dr. Moore's help, a complete list was made of these and all other items which will be necessary to put the two accelerometers in operation.

During the remainder of September, efforts were directed primarily toward the accumulation of the many detail parts. Sketches for missing components were made and fabrication of the parts was initiated. Vendors for the commercial parts were located and these items were ordered.

Assembly and test of the quartz accelerometer were completed during the remainder of 1972, and the results of the work were published in a separate report, Geotech Technical Report No. 73-2, Evaluation of Block and Moore Quartz Fiber Accelerometer, dated 31 December 1972.

5.5 LAMONT-DOHERTY SEISMOMETER ENCLOSURE

Operational testing of the Lamont vault continued during the report period. Recordings from the control channel were interrupted twice when the discriminator in that channel was damaged by lightning. Before August, there was no consistent difference in the noise levels of the Lamont vault and the control vault channels. During August and September, however, the Lamont channel was rarely noisier than the control channel, and the control channel was frequently noisier than the Lamont channel. Both channels were equally quiet when atmospheric pressure was stable; that is, when winds did not blow and when no storms or pressure fronts were passing through the TFSO area.

Data recorded early in October indicated that the Lamont tank instruments performed more quietly than did the control tank instruments, but maintenance work revealed that the control channel noise was caused by a defective

solid-state amplifier and by moisture in the tank and the circuit cable connector. After the amplifier was replaced and the tank and cable connector were dried, there was a period of intermittent operation which ended when one section of spiral-4 was replaced. From mid-November until 25 January, the control channel was quieter than the Lamont channel.

On 25 January, the earth and the wooden lid over the Lamont tank were removed, and it was found that the Lamont tank was submerged in 5 feet of water. The water was pumped out and all connectors on the outside of the tank were found to be dry. Because previous tests had indicated the tank to be well sealed, it was not opened for inspection. The wooden lid was replaced and covered with plastic to shed water. Sawdust was placed over the plastic as an insulating material, and operational tests were continued. Since the water was removed, the Lamont tank channel noise level appears to be approximately one-half the control tank channel noise level at periods above 20 seconds.

Operational tests of the Lamont vault were stopped on 13 March and the seismometers were removed so that they could be refurbished prior to their installation at the LP6 site. The interiors of both the Lamont and control vaults were found to be dry despite their submersion in water.

It is concluded that the Lamont tank may be as much as 6 dB quieter than the control tank at periods longer than 20 seconds but that this may be related to the local conditions at the two tank sites. It is recommended that results of operational tests at the new LP6 site be evaluated before reaching a final conclusion concerning the performance of the Lamont tank. The Lamont tank and the other two tanks at LP6 are installed close together at the same elevation and in a common shelter.

5.6 PACKAGE BOREHOLE SEISMOMETER

Engineering Change Proposal No. 1, Package Geotech-Designed Borehole Seismometer, was negotiated on 27 October 1972, and work on this task was begun immediately.

By the end of December 1972, the majority of the parts for the holelock, stabilizer, strain relief and the cable head assembly were designed and built, and partial assemblies were made. A developmental model of the pneumatic seismometer locking and leveling mechanism and a solenoid-actuated pump were built and tested to prove the soundness of the design approach. The locking and leveling mechanism performed satisfactorily, but the solenoid-actuated pump was under-powered. It was replaced by a motor-driven, spring-actuated pump, a model of which was built and tested.

The seismometer housing design was complete except for one dimension that depended on the size of the electronics printed circuit boards. Twenty-five percent of the parts for this unit were fabricated.

The holelock installation tool design was complete and all parts were being fabricated. A partial model of the unit was built and tested to aid in the selection of the holelock setting motor. A 10-foot section of standard 7-inch well casing was used for the tests.

The design of all electronic and electrical circuits was complete and all component parts were ordered. Laboratory models of all designs were bench tested.

Detailed designs for all components of the Model 36000 borehole seismometer package were completed during February 1973. Sketches for all components were drawn, parts were procured or fabricated, and assembly and checkout of subassemblies were completed. Figure 16 shows, from top to bottom, the cable strain relief connected by a chain to the stabilizer assembly, which is connected to the top of the main transducer package. The outer case was not on the transducer package in this photograph. Figure 17 shows the holelock which will support the transducer package in the borehole. Figure 18 shows the installation tool that will be used to install the holelock in the borehole. The impact tool is shown removed from the remainder of the assembly. Figure 19 shows the installation tool mated with the holelock.

The testing and evaluation of this instrument is being accomplished under another contract.

5.7 DEVELOCORDER PROJECTION LAMPS

A life test of Develocorder projection lamps was begun in September to determine the relationship among operating time, lamp life, and duty cycle. More specifically, the test was begun to determine if the lamp life could be extended by operating it only during the observatory manned periods (approximately 9 hours per day) rather than by operating it continuously. It was not known which would affect lamp life more: (1) the thermal shock of turning the lamp power on and off each day; or (2) the longer operating time of continuous operation.

The first data indicate that thermal shock has little effect on lamp life, and that it is advantageous to operate the lamps only during 9 hours each day. These data are:

Mode of operation	Lamp life	Lamp operation
Continuous	35 days	840 hours
9 hours per day	126 days	1234 hours

These tests will be continued to collect more representative data.

5.8 INVESTIGATE SIGNAL ACQUISITION AND TRANSMISSION

On 21 February 1973, a Task Change Proposal, P-2164, was submitted. This recommended that a program be undertaken to investigate the signal range and technique needed to acquire and transmit low frequency data from remote instrument locations. In response to the task change proposal, work was added to Contract F33657-72-C-0800 by Supplemental Agreement No. P00006, effective on 16 April 1973. The supplemental agreement extends the contract to 31 December 1973, and adds tasks that call for an investigation of signal range requirements and techniques to be used in acquiring and transmitting low frequency data from

Figure 16. Upper subassemblies of the Borehole Seismometer, Model 36000

G 7032

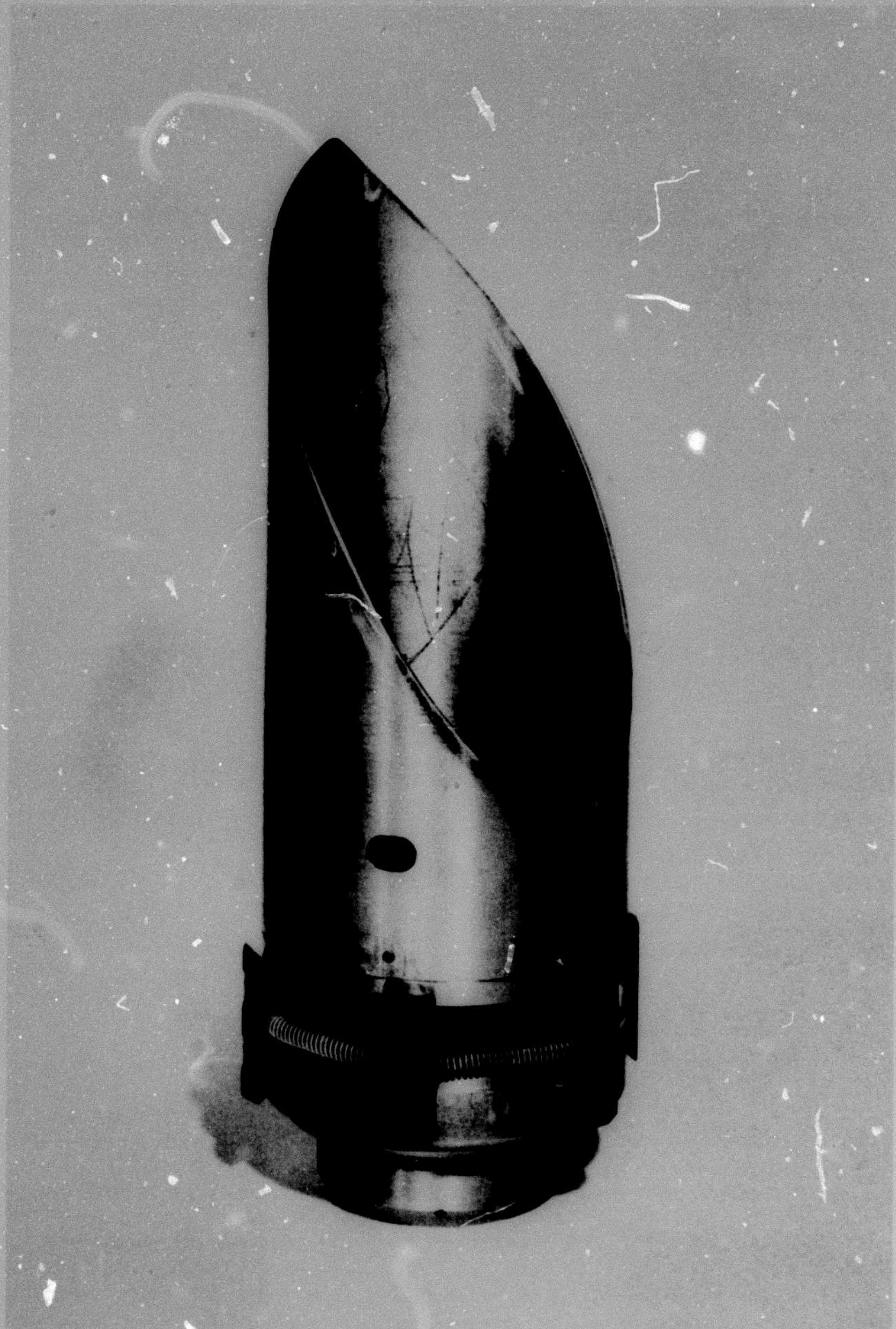


Figure 17. Holelock for Borehole Seismometer, Model 36000

G 7191

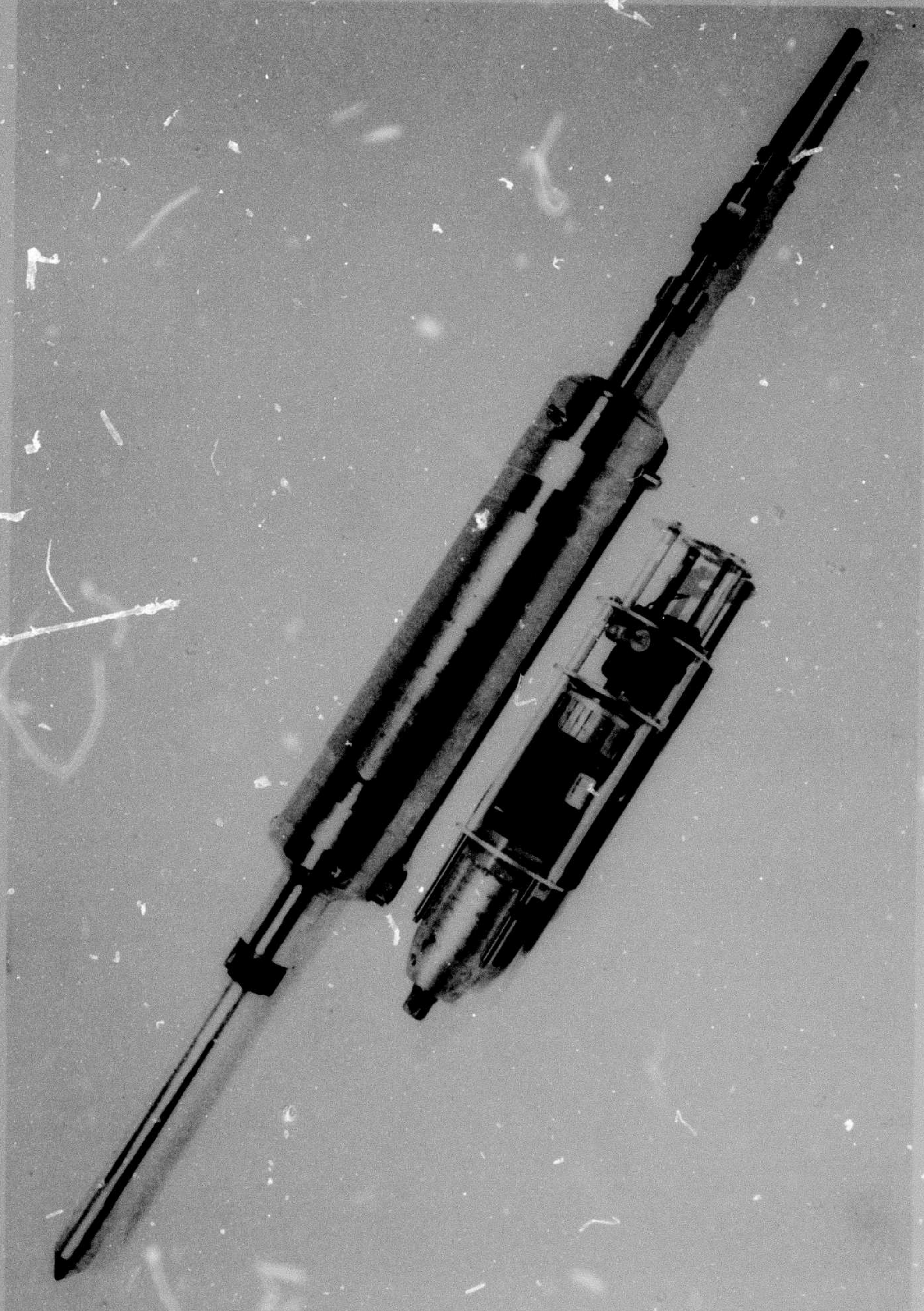
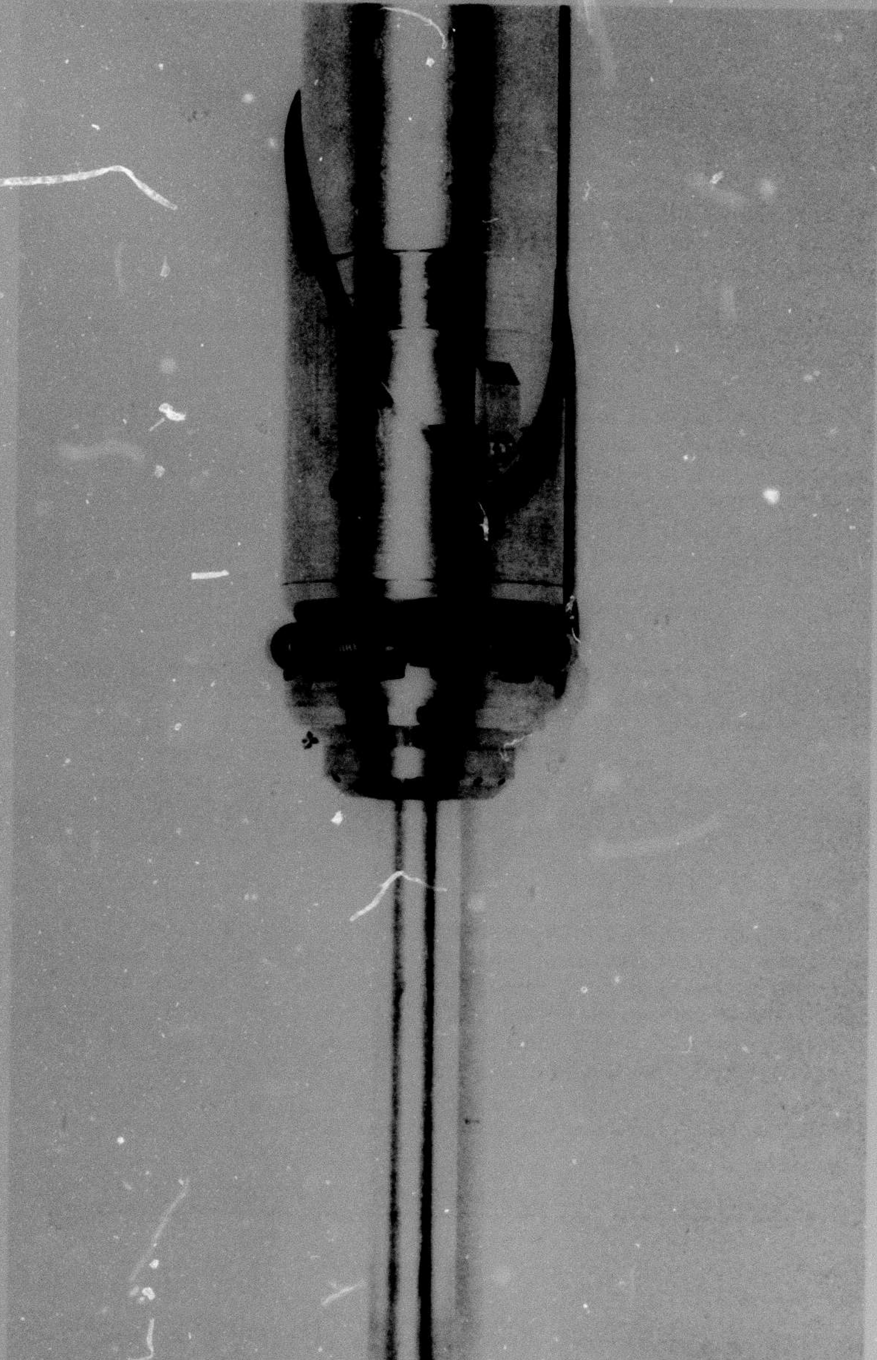


Figure 18. Installation tool for Borehole Seismometer, Model 36000

G 7034



G 7035

Figure 19. Installation tool mated with holelock. These are used with the Borehole Seismometer, Model 36000

remote instrument locations. The first work performed on this task was devoted to the preliminary definition of system concepts for both a "synchronized" and a "synchronous" system to acquire and transmit digital gain-ranged LP data from up to 10 remote field sites. This system was designated the Remote Data System (RDS), Model 37700. It will consist of a central Data Transfer Unit (DTU) and up to 10 Data Transfer Remotes (DTR's). A Texas Instruments Model 980A processor will be used for the central data transfer controller. This unit will receive the data from the remote field sites, evaluate performance parameters and present the data and parameter results to the Texas Instruments Station Processor. In addition, sensor calibration and control signals will be originated and transmitted on command from the Station Processor by the Data Transfer Unit.

A meeting was held at the Geotech plant on 11 May to discuss the alternatives with Project Office personnel. As a result of this meeting it was decided that the system approach selected would be designed for a synchronized mode of operation. Further study was requested by the Project Office to define the operational and cost differences between a design using a dedicated processor for the LP data system and a more limited design which could be incorporated into the existing Station Processor system. The study was completed by the end of May.

Detailed design of the Data Transfer Remote electronics was begun in June and preliminary designs for the electronics basket and Binary Gain Amplifier (BGA) have been completed. The Data Transfer Remote electronics will utilize RCA C/MOS logic and large scale integrated (LSI) components to the maximum extent possible to minimize power consumption. In addition, preliminary specifications are being written for the radio communications systems, and for the data and command links. Configurations are being defined for the remote power and supervisory systems.

In discussions with the Project Office, it was decided that the data and command link interfaces at the central station Data Transfer Unit would be defined up through the modem and that specifications for the modem interfaces would be generated. These specifications will include the functional requirements and timing constraints for the central processor and its interface to assure compatibility with the modem and system requirements.

6. FACILITIES AND ASSISTANCE PROVIDED TO OTHER GROUPS

6.1 TEXAS INSTRUMENTS

Texas Instruments (TI) personnel continued operational testing of the TI signal processor until 28 July. The processor was picked up from the TFSO on 5 August. Other equipment that was brought in by TI and was used to test the processor was stored at the TFSO. This material was picked up on 19 September by Mike Cowart.

6.2 TELEDYNE GEOTECH

Mr. O. D. Starkey, Teledyne Geotech, visited the TFSO from 4 August to 1 September and 11 through 19 September to test engineering models of his new force-balance long-period seismometers. Mr. T. D. Trosper continued this work from 19 September through 13 October and Mr. Starkey continued the work from 17 through 24 December.

Mr. John Sherwin, from Teledyne Geotech, Garland, Texas, was at the TFSO from 3 through 13 April to install one vertical and one horizontal Block and Moore quartz accelerometer in the SW pier room of the LP underground vault.

6.3 VISITORS

Mr. Robert Armstrong, Assistant Ranger, USFS, Payson, District, visited TFSO on 24 July to confirm locations of TFSO cable trails for a comprehensive study the Forest Service was preparing on the Tonto National Forest.

Mr. Robert Andrews of Honeywell, Inc., visited TFSO on 24 August to inspect the condition of the six FM magnetic recorders in use there.

Capt. J. H. Fergus, Project Officer, and Mr. M. G. Gudzin, Program Engineer, visited the TFSO from 7 through 9 December to review work progress and to discuss plans for accomplishment of contract tasks.

As part of an effort to acquaint staff members of the U. S. Forest Service with the occupants of the Tonto National Forest and their use of the land, Ranger Phil Smith brought Mr. Hal Watson and Mr. C. H. Thiede of Albuquerque, New Mexico, and Mr. John Blackwood of Phoenix, Arizona, to the TFSO on 24 January. They were given a tour, and the functions of the observatory were described.

Captain John H. Fergus, Jr. Project Officer, USAF, and Mr. B. B. Leichliter, Program Manger, Teledyne Geotech, visited the TFSO from 21 through 23 February to review and discuss work progress and plans.

Mr. M. J. Benham, Phoenix Jr. College, and 16 geology students visited the TFSO on 23 March.

Mr. John Stravens, of the U.S. Geological Survey, visited TFSO on 2 April to coordinate his activities in the Tonto National Forest with observatory personnel. He is engaged in conducting surveys and collecting information needed to upgrade maps of the area. It was decided that TFSO cable trails and access roads should not be shown on the U.S. Geological Survey maps.

Mr. Bob Lake of the Permutit Co., Phoenix, Arizona, visited TFSO on 18 May to check the performance of the TFSO water softener and to adjust it for proper operation. Operating routines were discussed and a test schedule was established.

Nine graduate students from the Geophysics Department of the University of Arizona visited TFSO on 30 May.

Rangers Phil Smith and Robert Tippeconnic, U.S. Forest Service, visited TFSO on 19 June. The purpose of their visit was to introduce Ranger Tippeconnic, who is replacing Ranger Smith in the Payson District. Ranger Smith is being transferred to California.

APPENDIX 1 to TECHNICAL REPORT NO. 73-11

STATEMENT OF WORK TO BE DONE

PART II - THE SCHEDULE
SECTION F - DESCRIPTION/SPECIFICATIONS

STATEMENT OF WORK TO BE DONE
(AFTAC Project Authorization No. VELA T/3704/B/ASD)

1. Objectives: The Tonto Forest Seismological Observatory (TFSO) is unique in its low level of background seismic noise and in its capability as a research center, being equipped with various film, paper, and analog and digital recorders, a shake table, a large walk-in vault for instrument evaluation, and assorted test and measurement equipment. The purpose of this project is to operate this observatory as a source of high-quality seismological data for use in Government-sponsored research projects, to use the TFSO as a field test site for evaluation of new seismological instrumentation and procedures, and to support other research projects as directed by the project officer. This project should require a technical manning level of approximately four man-years.

2. Tasks:

a. Operation.

(1) Continue operating the TFSO according to established procedures (Standard Operating Procedures for TFSO, 1 Nov 1970), providing recorded data to the Government. Special data requirements anticipated will include, but not be limited to, recording signals from special events at the Nevada Test Site and supplying beam-formed, or multichannel filtered data, for use in evaluation of the effectiveness of the ARPA long-period arrays: Montana Large Aperture Seismic Array, Alaskan Long Period Array, and Norwegian Seismic Array.

(2) Quality control the data acquisition systems and evaluate the seismic data recorded to determine optimum operating characteristics and perform research to improve operating parameters to provide the most effective observatory practicable. Major reconfigurations in equipment, those requiring more than 48 hours to remove, are subject to prior approval by the project officer.

(3) Provide use of observatory facilities and seismological data to requesting organizations and individuals as identified by the project officer.

(4) Maintain, repair, protect, and preserve the facilities of TFSO in good physical condition in accordance with sound industrial practice.

b. Instrument Evaluation. Evaluate the performance characteristics of experimental equipment identified by the project officer. This work includes investigation of the operational capability of dry film recorders, evaluation of the use of a single seismometer for obtaining both long- and short-period data, and study of altered modes of operation of cable

links and radio transmission of data. Additional investigations will be initiated as problems requiring investigation are identified. The total level of effort on this task will not exceed one man-year.

c. Upon identification and prior to the disposition of any equipment determined to be excess to the needs of the project, the contractor shall notify the project officer.

APPENDIX 2 to TECHNICAL REPORT NO. 73-11

TEST PLAN

MODIFY DEVELOCORDER GRAVITY FEED SYSTEM

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MODIFY DEVELOCORDER GRAVITY FEED SYSTEM

1. PURPOSE

This test plan describes a new Develocorder gravity feed chemical supply system that will be installed at the TFSO. Its principle features are the use of increased chemical supply pressures, and the use of three dual reservoirs to furnish chemicals to all TFSO Develocorders.

2. SYSTEM DESCRIPTION

Reference is made to figures 1 through 4 in the following description. Photographic film processing chemicals will be furnished to eleven Develocorders from six 5-gallon supply tanks (carboys) sitting on a platform approximately 8 feet above the floor. Two supply tanks will be used for LP developer, two for SP developer, and two for fixer. Only three tanks will be in service at any time. The other three will be clean and empty, ready to be filled and used when those in service require cleaning or other maintenance. Each tank will be connected to the distribution system through a quick disconnect fixture. Chemicals will be distributed through 1/4" Tygon tubing. Compression clamps will be used to squeeze the Tygon tubing at various points in the system and stop the flow of chemicals as required.

There are two groups of Develocorders at TFSO. The group of three near the supply tanks will be served by one leg of the distribution system. The group of eight in the center of the room will be served by another leg. The two supply lines in the first leg will be short and will connect directly to the Develocorders. The three supply lines in the second leg will be long and will run under the computer floor, through T-connectors near the lowest point in the line, and then to the Develocorders. The underfloor T-connectors will provide easy means for draining any sediments that may collect in that line.

Settling tanks will not be used in the new system. The bottles now used for this purpose will be cleaned, refilled with plain water, capped, and will be used to physically support the system flow meters.

3. INSTALLATION

Build a wooden rack approximately 8 feet tall to support the supply tanks. The top, which will serve as a shelf, should be 66 inches long by 12 inches deep. Use 2 x 2's or 2 x 4's as structural members and 3/4" thick plywood as the shelf material. Fasten a 1 x 10 or a piece of plywood across the front of the rack, approximately 12" below the shelf, to support the hoses and fittings connecting to the supply tanks. After painting the structure to match the CRB walls, secure it to the wall in the location shown in figure 2, and cover the top shelf with a rubber mat that can be easily cleaned.

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Cut a hole in the calibrated end of each supply tank near its bottom and install the bulkhead fitting and polyethylene elbow as shown in figure 4. Mark each tank with Marks-A-Lot just above the bulkhead fitting to identify its contents as SP DEVEL, LP DEVEL, or FIXER.

4. OPERATION

Each 5-gallon supply tank will weigh approximately 40 lbs. when filled and probably is too heavy to be lifted into place. It is suggested that each tank be placed on the shelf empty, and that it be filled using a plastic 1-gallon pitcher or similar container, and that it be removed only for cleaning.

The supply tank caps should be screwed loosely in place at all times to keep the contents clean. They must not be tight, as air must be able to bleed into the tank to replace the fluid dispensed to the Develocorders.

The following operating schedule is recommended:

1. Initially fill one supply tank with fixer, one with SP developer, one with LP developer.
2. Operate routinely for several days to determine chemical usage rate.
3. Refill tanks on a regular (weekly, biweekly, or monthly) sehceule as determined by usage rate. Refill before the fluid level falls below one gallon.
4. Every two months, drain about one pint of fluid from underfloor lines.
5. Every six months, drain and flush all lines with clean water, change supply tanks, and clean tanks that had been in service.

5. REPORTS AND DATA

Take photographs of all parts of the installation. Report work progress and system performance in the monthly station reports.

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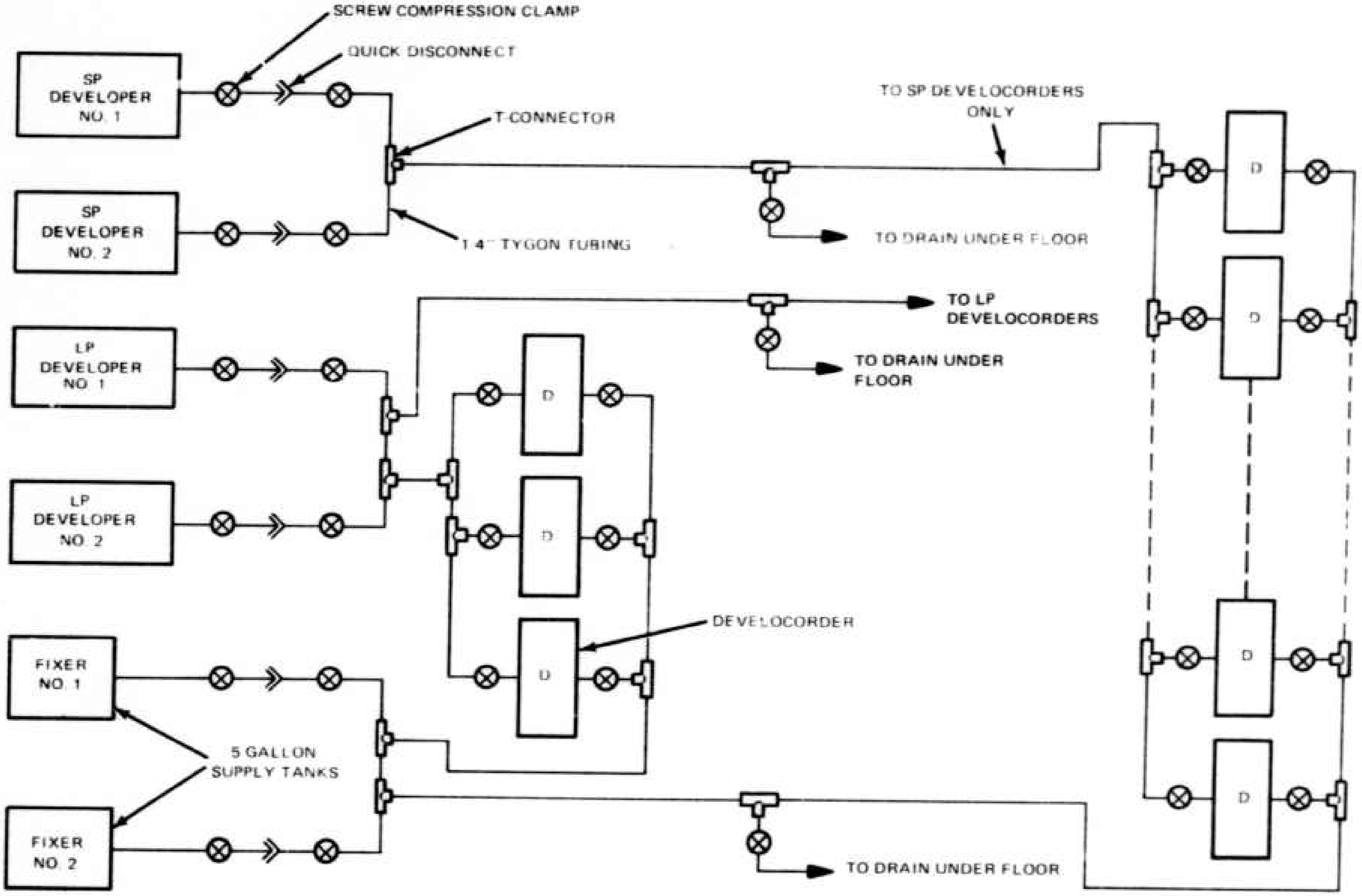

Figure 1. Schematic of modified Develocorder gravity feed chemical supply system

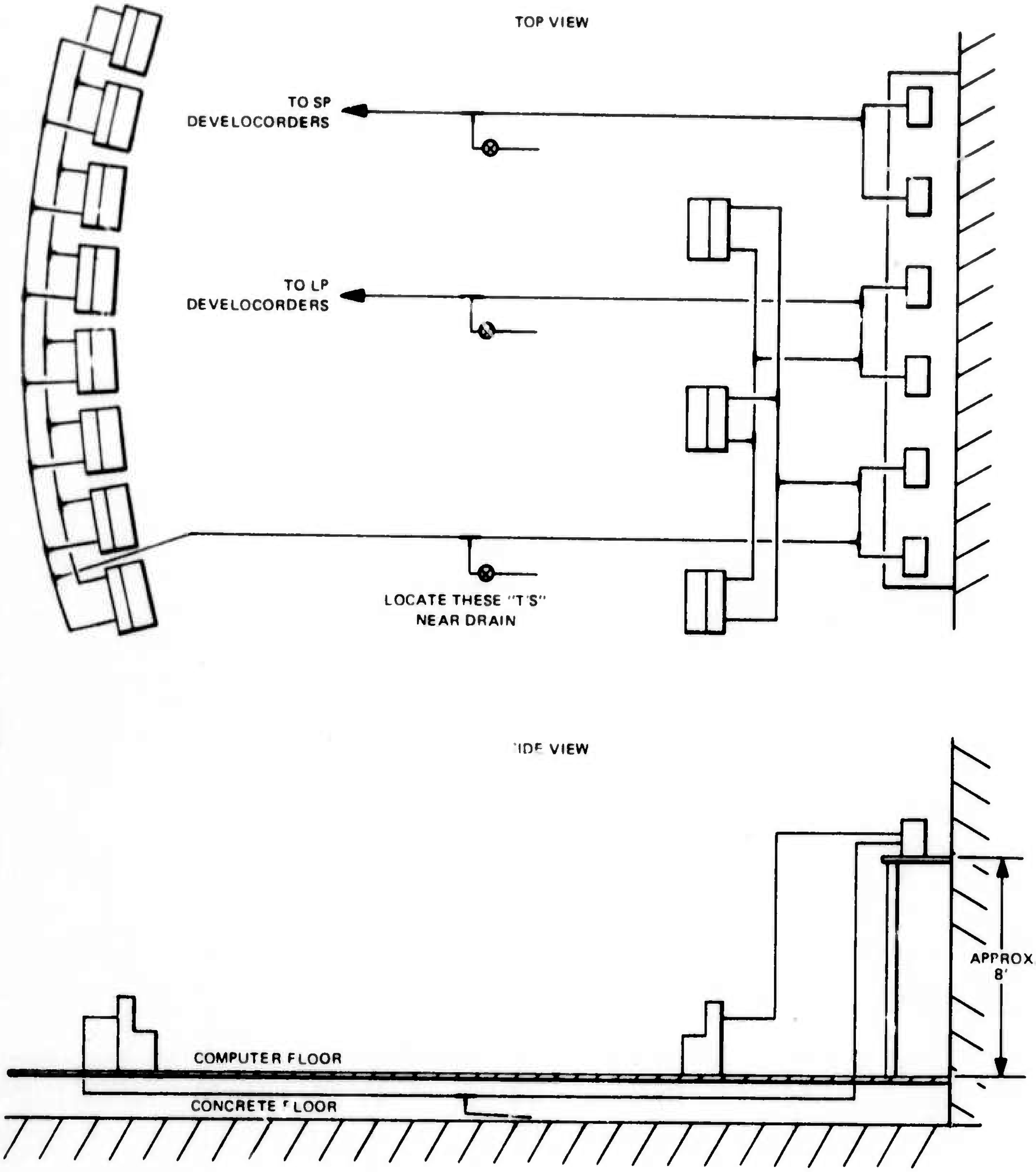

Figure 2. Sketch showing general arrangement of gravity feed system components

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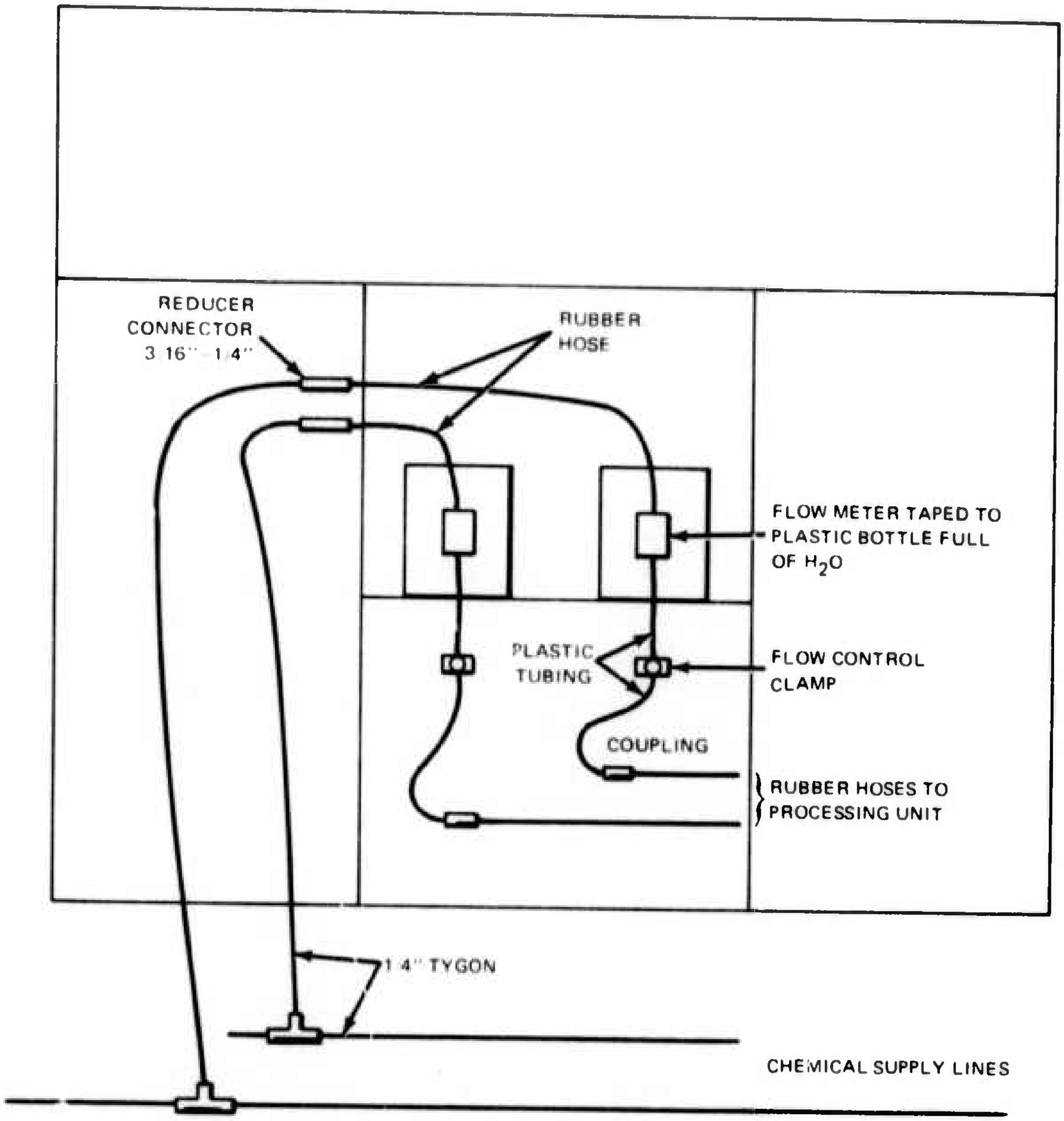

Figure 3. Detail of supply line connections to Develocorder

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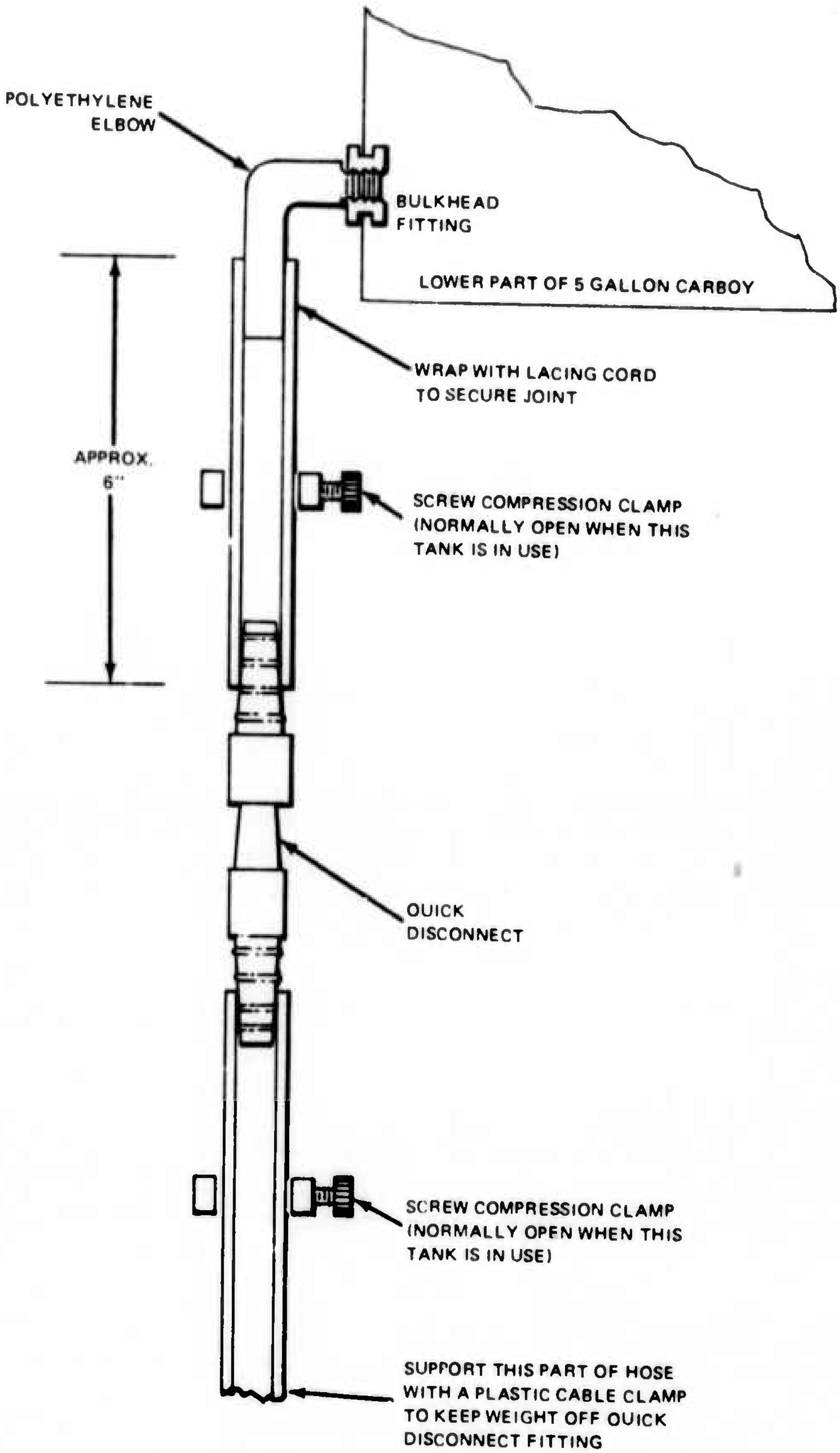

Figure 4. Detail of connections to supply tank

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