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TR 70-13

TECHNICAL REPORT NO. 70-13

OPERATION OF THE TONTO FOREST SEISMOLOGICAL OBSERVATORY

Quarterly Report No. 1, Project VT/9704

Contract F33657-70-C-0733

1 January through 31 March 1970

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TELEDYNE GEOTECH

TECHNICAL REPORT NO. 70-13

OPERATION OF THE TONTO FOREST SEISMOLOGICAL OBSERVATORY

Quarterly Report No. 1, Project VT/0704
Contract F33657-70-C-0733
1 January through 31 March 1970

Sponsored by

Advanced Research Projects Agency
Nuclear Test Detection Office
ARPA Order No. 624

TELEDYNE GEOTECH
3401 Shiloh Road
Garland, Texas

22 April 1970

IDENTIFICATION

AFTAC Project No:	VELA T/0704
Project Title:	Operation of TFSO
ARPA Order No:	624
ARPA Program Code No:	8F10
Name of Contractor:	Teledyne Industries, Geotech Division Garland, Texas
Contract No:	F33657-70-C-0735
Effective Date of Contract:	1 January 1970
Amount of Contract:	$554,696
Contract Expiration Date:	30 June 1971
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/0704 from 1 January through 31 March 1970. Project VT/0704 includes the operation, evaluation, and improvement of the Tonto Forest Seismological Observatory (TFSO) located near Payson, Arizona. It also includes special research and test functions carried out at TFSO and research and development tasks performed by the Garland, Texas, staff using TFSO data.

OPERATION OF THE TONTO FOREST SEISMOLOGICAL OBSERVATORY
Quarterly Report No. 1, Project VT/0704
Contract F33657-70-C-0733
1 January through 31 March 1970

1. INTRODUCTION

1.1 AUTHORITY

The work 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 F33657-70-C-0733. The effective date of the contract is 1 January 1970; the Statement of Work for Project VT/0704 is included in the appendix to this report.

1.2 HISTORY

The Tonto Forest Seismological Observatory (TFSO) 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 seismometric recording techniques. The instrumentation was assembled, installed, and operated until 30 April 1965 by the Earth Sciences Division of Teledyne Industries under Contract AF 33(657)-7747. On 1 May 1965, Geotech assumed the responsibility of operating TFSO. The location of TFSO is shown in figure 1.

2. OPERATION OF TFSO

2.1 GENERAL

Data are recorded at TFSO on a 24-hour per day basis. The observatory is manned continuously. A full complement of personnel is on duty 8 hours per day, 5 days per week: at other times, a reduced operating crew is on duty.

2.2 STANDARD SEISMOGRAPH OPERATING PARAMETERS

The operating parameters and tolerances for the TFSO standard seismographs are shown in table 1. Frequency response tests are made routinely, and parameters are checked and reset to maintain the specified tolerances.

Normalized response characteristics of TFSO standard seismographs are shown in figure 2. In addition to these standard seismographs, two filtered summation seismographs are operated. The ΣTF seismograph utilizes a (UED)

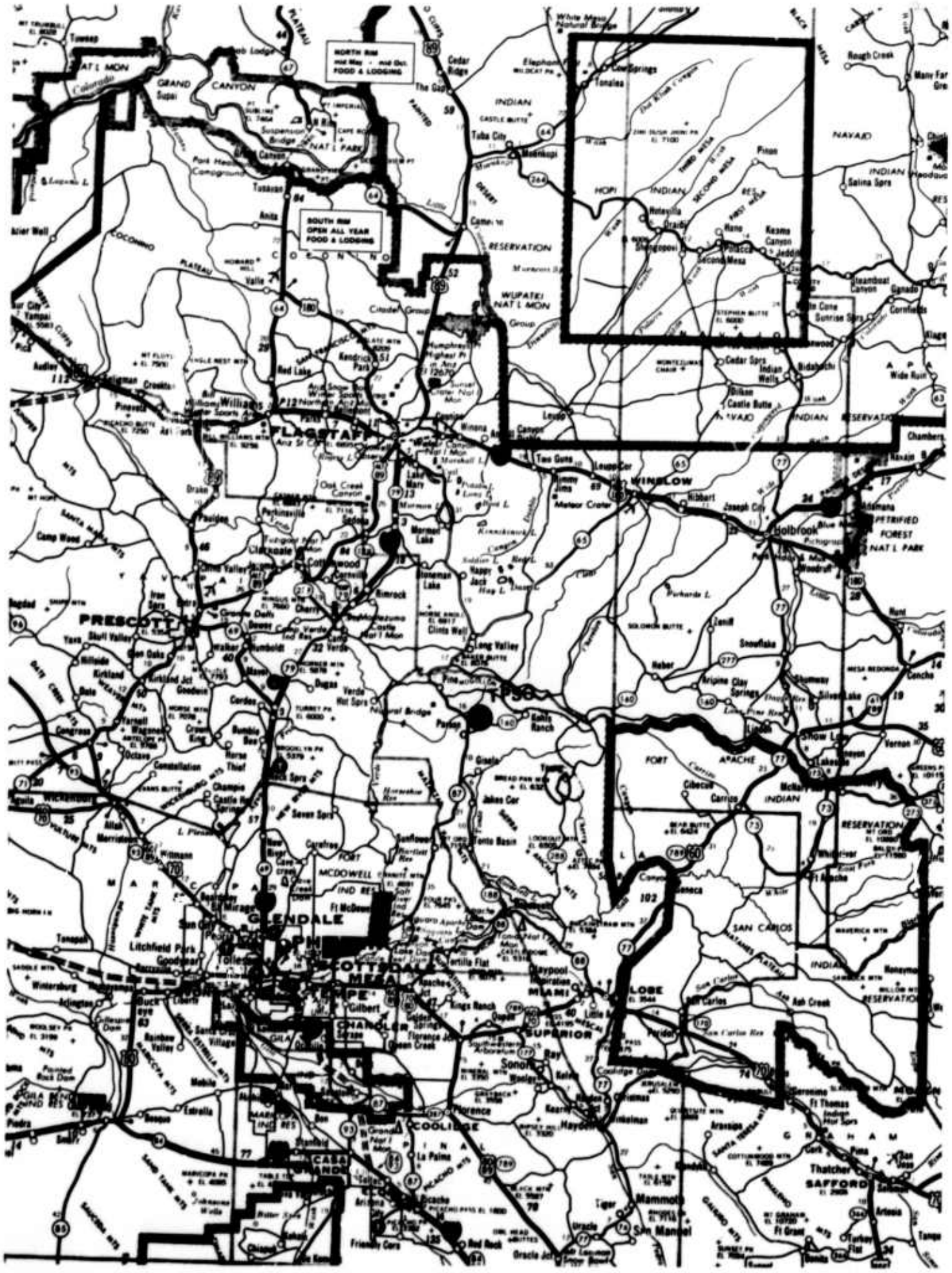


Figure 1. Location of TFSO

G 4970

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

Seismograph				Operating parameters and tolerances				Filter settings		
System	Comp	Type	Model	Ts	λs	Tg	λg	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
IB Intermediate band
LP Long period
UA Unamplified (i.e., earth powered)
BB Broad band

Ts Seismometer free period (sec)
Tg Galvanometer free period (sec)
λs Seismometer damping constant
λg Galvanometer damping constant

[a]37-element hexagonal array

[b]Linear array and 3 comp

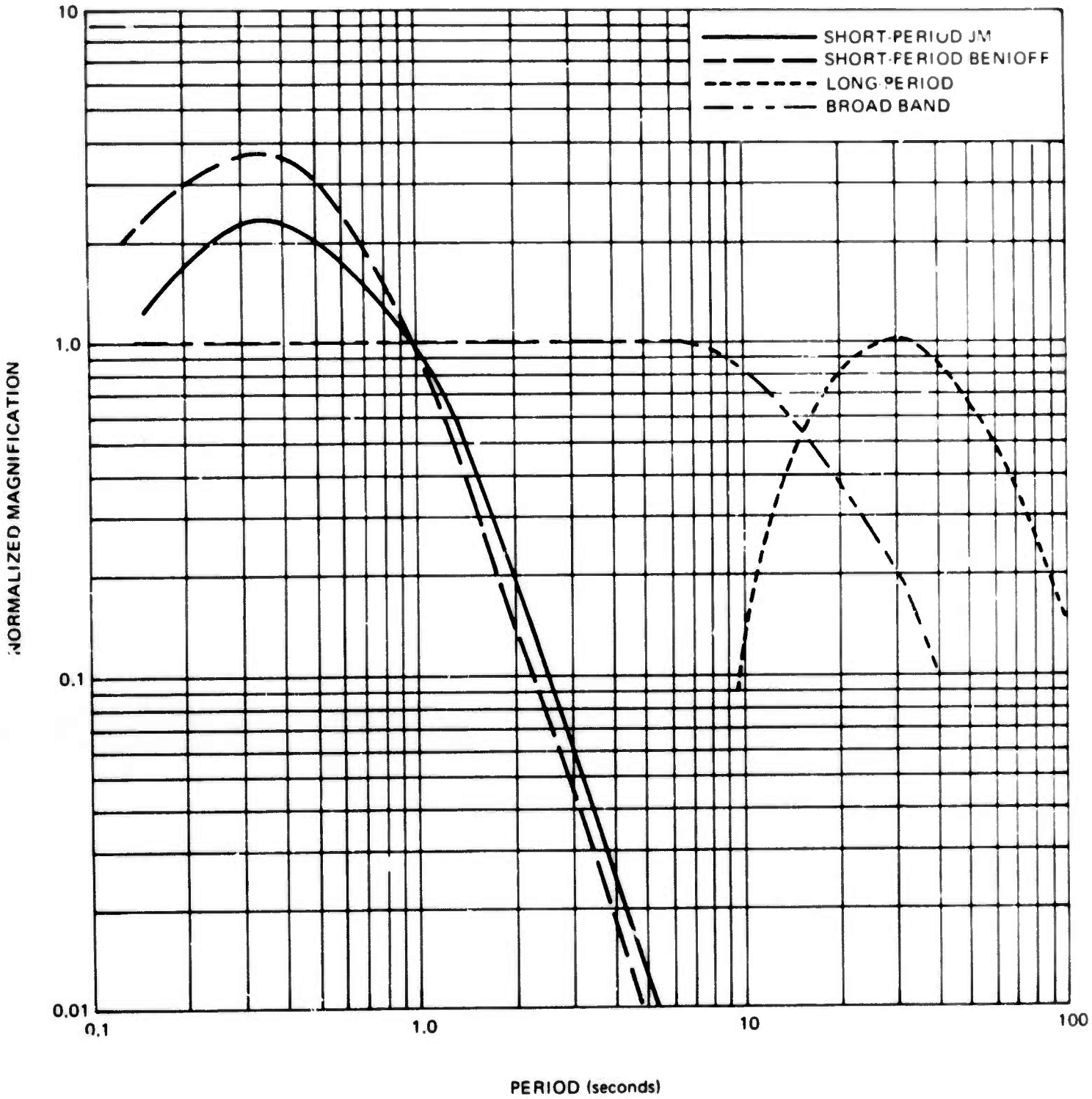


Figure 2. Normalized response characteristics of standard seismographs at TFSO

G 5048

filter with a high-cut frequency of 1.75 cps and a slope of 12 dB per octave, and a low-cut frequency of 0.7 cps and a slope of 24 dB per octave. The ETFK seismograph utilizes a Krohn-Hite filter; the high-cut frequency is set at 2.0 cps with a slope of 24 dB per octave, and the low-cut frequency is set at 1.0 cps with a slope of 24 dB per octave. Both filtered seismographs are recorded on 16-millimeter film on Data Trunk 1.

2.3 DATA CHANNEL ASSIGNMENTS

Each data format recorded at TFSO is assigned a Data Group number. When a data format is changed, a new Data Group number is assigned. Several Data Format Change Notices reporting changes in channel assignments were submitted to the Project Officer and to frequent users of the TFSO data during this reporting period.

2.4 COMPLETION AND SHIPMENT OF DATA

Six analog FM magnetic-tape units are used to record data for the AFTAC/VELA Seismological Center (VSC). Tapes from these units are sent weekly to our Garland, Texas, laboratory for quality control and are shipped from Garland to SDL about 15 days after the end of the month in which they were recorded.

Until 27 February 1970, Astrodata Seismic Data Acquisition System digital tapes were shipped daily from TFSO to SDL except two per week that were sent to the Garland laboratory for quality control. These tapes were sent to SDL by the Garland facility at a later date. Effective 27 February 1970, all digital tapes, except those sent to Garland for quality control, are held at the observatory for a period of about eight weeks and are then recycled if not requested.

All Develocorder (16-millimeter film) seismograms, except quality control copies, are routinely shipped to SDL. One seismogram from each of the 12 Develocorders is sent each week to the Garland, Texas, laboratory for quality control. These recordings are sent to SDL at a later date.

Since February, ASDAS recordings and corresponding films for Thursday recordings have been mailed on Friday to the Garland office for quality control. This will normally allow checks to be made in Garland on Monday and afford the most effective basis for the detection and correction of problems in the field operation.

Copies of calibration and operational logs accompany all data shipments.

2.5 QUALITY CONTROL

2.5.1 Quality Control of 16-Millimeter Film Seismograms

Twice per month, quality control checks of randomly selected 16-millimeter film seismograms from Data Trunks 1, 2, and 8 and the associated operating

logs are made in Garland. Items that are 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 are sent to the observatory for their review and comment.

2.5.2 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;

g. Relative phase shift between array seismographs;

h. Level of the system noise;

i. Oscillator alignment;

j. Quality of recorded WWV signal where applicable;

k. Time-pulse carrier;

l. Binary-coded digital time marks.

2.5.3 Quality Control of Digital Magnetic-Tape Seismograms

Quality control checks of digital 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. Parity errors;

c. Recording level of each channel;

d. Fidelity of reproduction;

e. Presence of header record and correct record length.

2.6 SECURITY INSPECTION

Mr. Ken Ozbolt, Industrial Security Inspector from Phoenix, Arizona, made a routine security inspection of the observatory on 29 January 1970. All items checked were found to be in order and the revised SPP for TFSO was approved.

2.7 DEFENSE CONTRACT ADMINISTRATION

The quarterly small business report was submitted on 28 January 1970 to Mr. C. P. Fink, Special Assistant for Small Business of the Defense Contract Administration Service District (DCASD) in Phoenix.

2.8 INVENTORY OF GOVERNMENT PROPERTY

A physical inventory of all property at TFSO was completed during February 1970.

2.9 GOVERNMENT PROPERTY INSPECTION

Mr. L. R. Madden, Property Administrator, and Mr. P. B. Johnson, Quality Control, both of the Phoenix DCASD visited the observatory on 25 February 1970 to discuss residual contract materials and to check maintenance procedures of DIPEC equipment and test equipment.

2.10 EMERGENCY POWER GENERATOR

The emergency power generator was modified for automatic start by the Empire Machine Company of Phoenix, Arizona, during the period 16 through 20 February. There were less than 4 hours of total downtime during the modification. With this change, all observatory facilities will automatically be switched to emergency power when commercial power fails for more than 3 seconds. The

generator will start 6 seconds later and will continue to run for 10 minutes after commercial power returns to normal. The automatic return to commercial power may be manually overridden so that we may operate the generator continuously during periods of lightning and momentary power spikes. Empire Machine provided several well-documented copies of a manual which documents the changes that were made.

One of the switches used in the automatic-start equipment failed on 21 March, disconnecting the observatory from commercial power circuits and switching it to emergency generator power. Repairs were undertaken by a representative of the Empire Machine Company, and the observatory resumed normal operation on 31 March. From 21 to 31 March, the emergency power generator was operated 228 hours continuously, except for a brief period each day during which inspection and maintenance was performed. The switch failure was traced to loose terminal bolts to which commercial power had been connected. A second switch used in automatic-start equipment was inspected, found incorrectly assembled, and was repaired.

The 100 kW standby generator, diesel power unit, Caterpillar Model 59825, was operated a total of 240 hours during this report period: 233.2 hours were due to commercial power loss and 6.8 hours for maintenance and for tests under full load.

2.11 RESTORATION OF FOREST LAND

A program of restoration for discontinued short-period vault sites was initiated on an "as time permits" basis. This type of work is required under our agreement with the Forest Service and the sites are those in the abandoned 31-element array plus those of the linear array not in operation. Vault lids, covers, bolts, J-boxes, and fence posts are being salvaged. Vault holes are being filled and the area is being seeded. Old spiral-4 cable is being picked up to the main cable trails and access roads are being conditioned to meet U. S. Forest Service approval. To date, work has been completed at 20 sites within the 31-element array and at 6 sites within the linear array.

Substantial fences complying with Forest Service regulations were reconstructed at 18 sites within the 37-element array during this report period. The original fences at these sites had deteriorated and were permitting cattle within the vault area.

2.12 FACILITY MAINTENANCE

The TFSO facilities were maintained in accordance with sound industrial procedures throughout the reporting period. This work included pest extermination, fire extinguisher inspection, work area cleaning, and repairs to office, air conditioning, and heating equipment.

2.13 DEVELOCORDER OPERATION AND MAINTENANCE

The Develocorder retrofit program was continued throughout the report period, and six Develocorders were renovated.

A procedure was initiated in January 1970 to keep Develocorder channels aligned by adjusting dc offsets. Develocorder galvanometers were mechanically locked into a zero position and personnel were instructed not to align the traces by turning the galvanometer unless electrical centering controls failed to operate. This procedure has improved the record quality of the solid-state short-period and long-period seismographs. Those with PTA's require more effort to keep circuits balanced and, consequently, have not shown the same improvement in record quality. Nevertheless, this procedure improves overall observatory performance as it assures correct balance on the tape recorders.

3. EVALUATE DATA AND DETERMINE OPTIMUM OPERATIONAL CHARACTERISTICS

3.1 SHORT-PERIOD ARRAY

3.1.1 Lightning Protection

The one lightning storm that occurred during this reporting period is believed to have damaged a line driver card in Z34 short-period seismograph.

The annual check of lightning protection circuits used at the observatory was started in February. All AEI protectors presently in service are being removed and sent to Garland to be tested for acceptable performance. They are being replaced with proven units. In addition, the resistance of grounding circuits is being measured at each site. To date, this work has been accomplished at 15 sites of the 37-element array.

3.1.2 Solid-State Amplifiers

Amplifier modification work was continued throughout the report period. Whenever an amplifier was brought in from the field for maintenance, its output circuit was modified to increase its output carrier level. One amplifier was modified during this report period. To date, 33 of the 43 amplifiers have been modified.

3.1.3 Spiral-4 Cable Replacement

During the report period, 41 quarter-mile sections of spiral-4 cable were replaced in the 37-element array. Of these, 39 sections had low leakage resistance or open lines, and 2 had cuts made by varmints or vandals.

Cables that were cleanly cut were spliced and sealed. Of the seven cables spliced during this report period, three were cut by Mountain States Telephone maintenance men, two by country maintenance men, one by an unknown vehicle, and one by a vandal.

3.2 LONG-PERIOD SEISMOGRAPH ARRAY

3.2.1 Lightning Protection

There was one known electrical storm during this reporting period, and it caused no damage to the long-period array seismographs.

AEI lightning protectors have been replaced at three sites within the long-period array.

3.3 ASTRODATA SEISMIC DATA ACQUISITION SYSTEM

3.3.1 Recording Format

There were no changes in the ASDAS recording format: format 18 was recorded throughout the report period.

3.3.2 Defective Tapes

The visual check of tapes for wrinkles and oxide scratches detected 25 (about 3% of those checked) defective tapes during this report period.

3.3.3 Miscellaneous Repairs

Several malfunctions occurred during February and March. All of these were repaired with equipment on hand, and included the replacement of indicator lamps, transistors, diodes, motor brushes, and motors.

Head alignment was checked each month, and the photo-sense circuits on both tape decks were adjusted once.

4. ANALYZE DATA

The arrival time, period, and peak amplitudes of events recorded at TFSO are reported daily to the Director of the Environmental Science Services Administration Coast and Geodetic Survey in Washington, D. C. The number of events reported by TFSO during each month of the reporting period is shown in table 2.

Table 2. Events reported to the C&GS by TFSO for January, February, and March 1970

Month	Local	Near regional	Regional	Teleseisms	Total
January	2	76	6	1141	1225
February	0	50	6	937	993
March	1	57	9	900	967

5. PROVIDE OBSERVATORY FACILITIES AND ASSISTANCE TO OTHER ORGANIZATIONS

5.1 TELEMETRY TO MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Telemetry of seven seismograph channels to Lincoln Laboratories, Massachusetts Institute of Technology, was contained throughout this reporting period.

5.2 UNIVERSITY OF UTAH

TFSO has continued to send copies of the daily station message to Dr. Kenneth Cook, University of Utah.

5.3 BLUE MOUNTAIN SEISMOLOGICAL OBSERVATORY

Effective 1 January 1970, copies of the daily station message have been sent to BMSO. The copies are sent on Mondays and Fridays.

5.4 UNIVERSITY OF CALIFORNIA, SAN DIEGO

University of California, San Diego representatives, Mr. Bill Farrell, Mr. Charles W. VanSice, and Mr. C. B. Hollinshead, visited TFSO several times during this report period to collect data and to maintain their instruments. Most of their instruments are in the west vault.

5.5 VISITORS

Mr. Jack Furry, Senior Project Safety Engineer, Argonaut Insurance, visited on 24 February 1970. He was given a tour of the facility and commented favorably on the condition of the observatory and the safety programs we have initiated.

Mr. Willard Groene, Director, Mummy Mountain Observatory, Scottsdale, Arizona, was given a tour of the observatory on 26 February 1970.

6. RESEARCH PROGRAMS

6.1 MULTICHANNEL FILTER SYSTEM (MCF)

The MCF was inoperative during most of the month of January while work was in progress to configure the MCF to operate as a Fisher processor. This was accomplished with the help of Texas Instruments, manufacturer of the MCF, on 29 January 1970. An MCF program for producing beam-steered outputs was generated at the observatory, and routine recording of MCF data was started on 6 February using Data Format No. 7291, which follows:

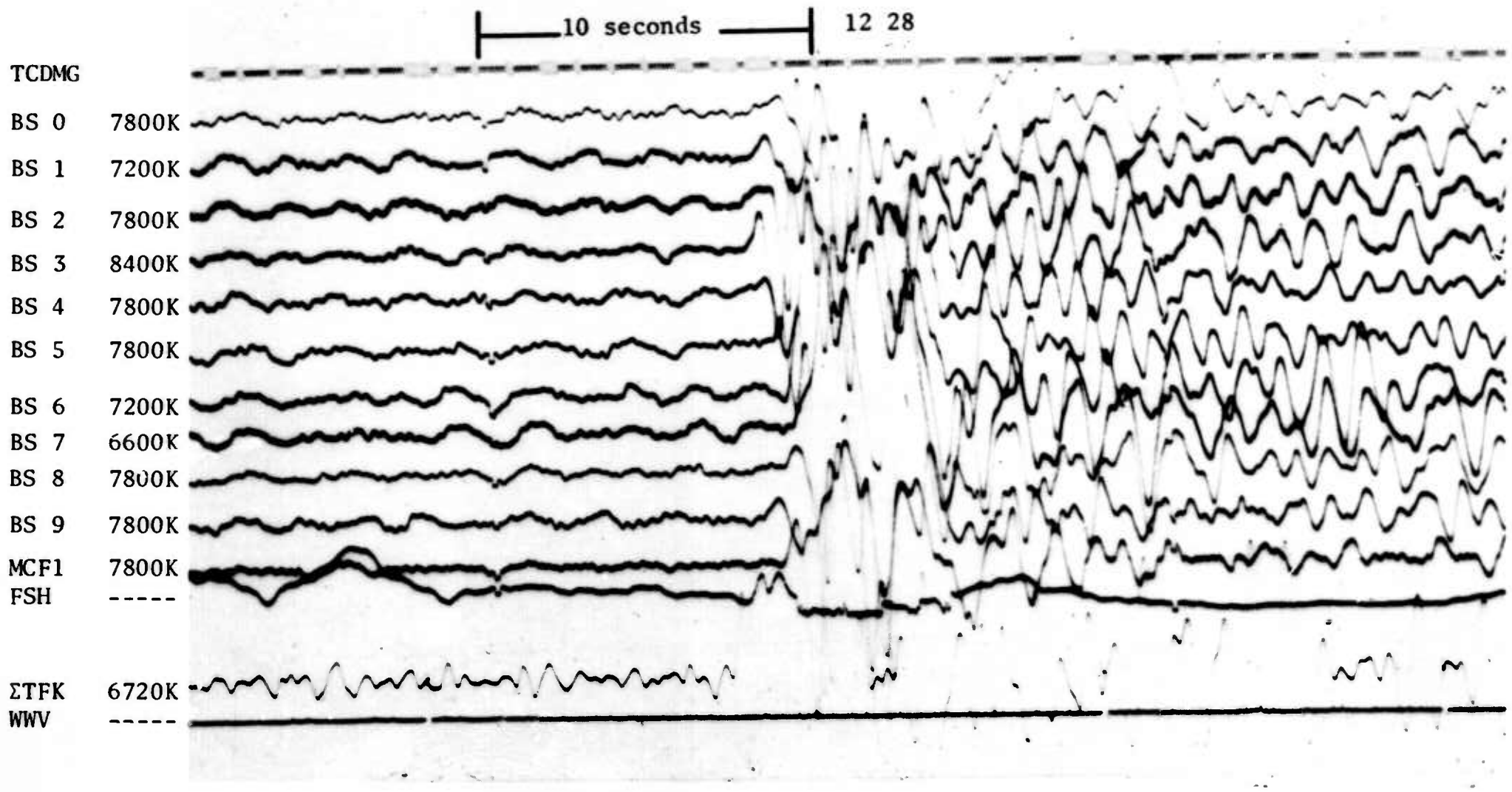
MCF Data Format 7291
6 February 1970

Channel identification	Azimuth from TFSO	Distance from TFSO	Approximate location	Apparent velocity (km/sec)
TCDMG	-	-	-	-
BS 0	0	70	Novaya Zemlya	18
BS 1	45	70	Off coast of Spain	18
BS 2	90	70	S. North Atlantic	18
BS 3	135	70	S. Bolivia	18
BS 4	180	70	S. Central Pacific	18
BS 5	225	70	Cook Islands	18
BS 6	220	70	NE Marshall Islands	18
BS 7	315	70	Kurile Islands	18
BS 8	346	104	Lop Nor, China	25
BS 9	29	61	Reykianes, Ridge, North Atlantic	16
MCF	-	-	-	Infinite
FSH	-	-	-	Infinite
ΣTFK	-	-	-	-
WWV	-	-	-	-

Figures 3, 4, and 5 show Develocorder recordings made using this format.

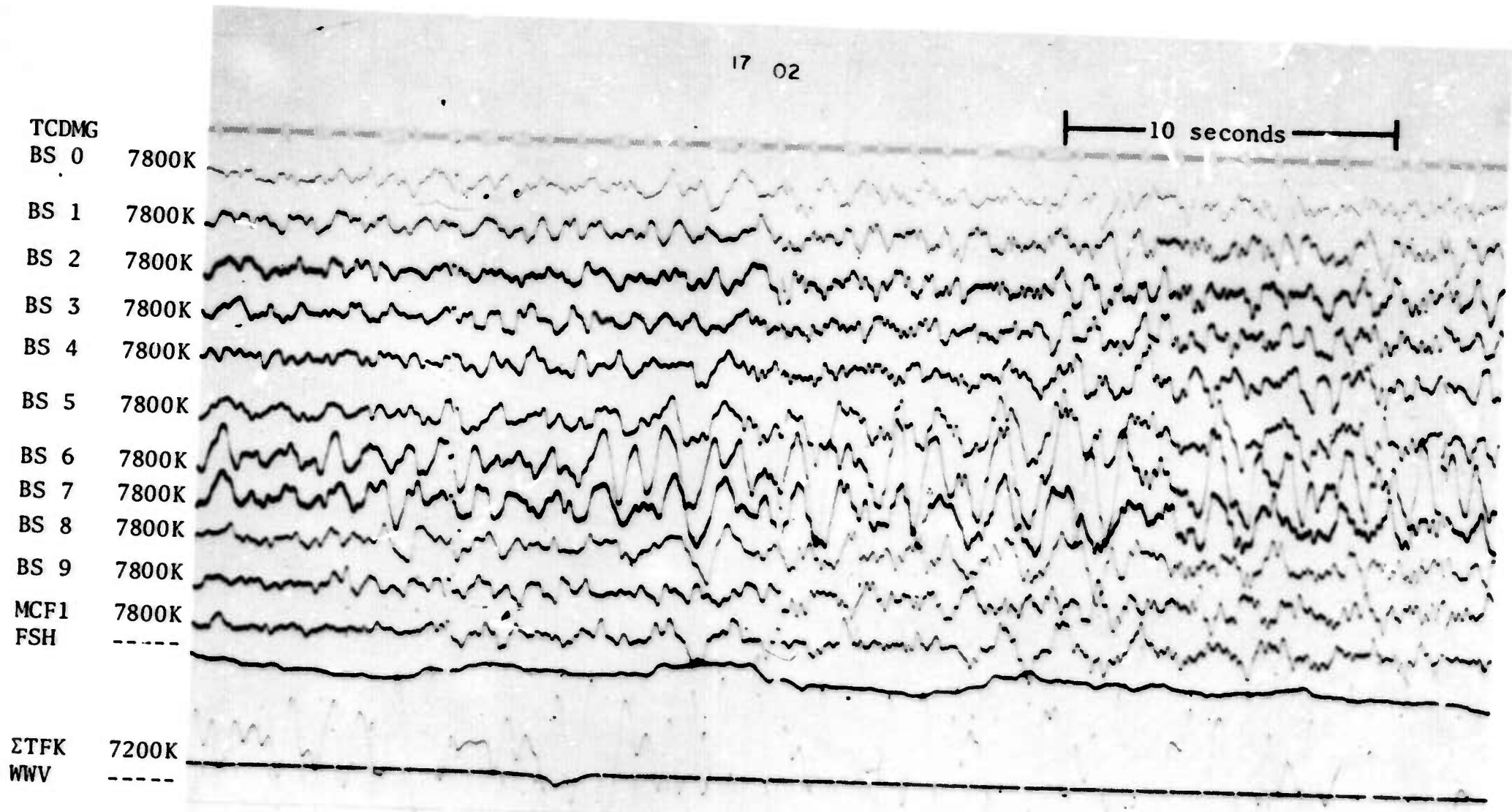
6.2 EXTENDED LONG-PERIOD SEISMOGRAPHS

Experimental long-period seismographs ZXLP and ZYLP have operated satisfactorily throughout the report period. A low-gain trace for ZXLP was designated ZXLL and was recorded on Data Trunk 2 since 27 January 1970. Seismograph circuit gains were adjusted so that seismogram traces were recorded with magnifications of 10K for ZXLL; 125K for ZXLP, and 200K for ZYLP at 0.025 Hz. The ZXLP



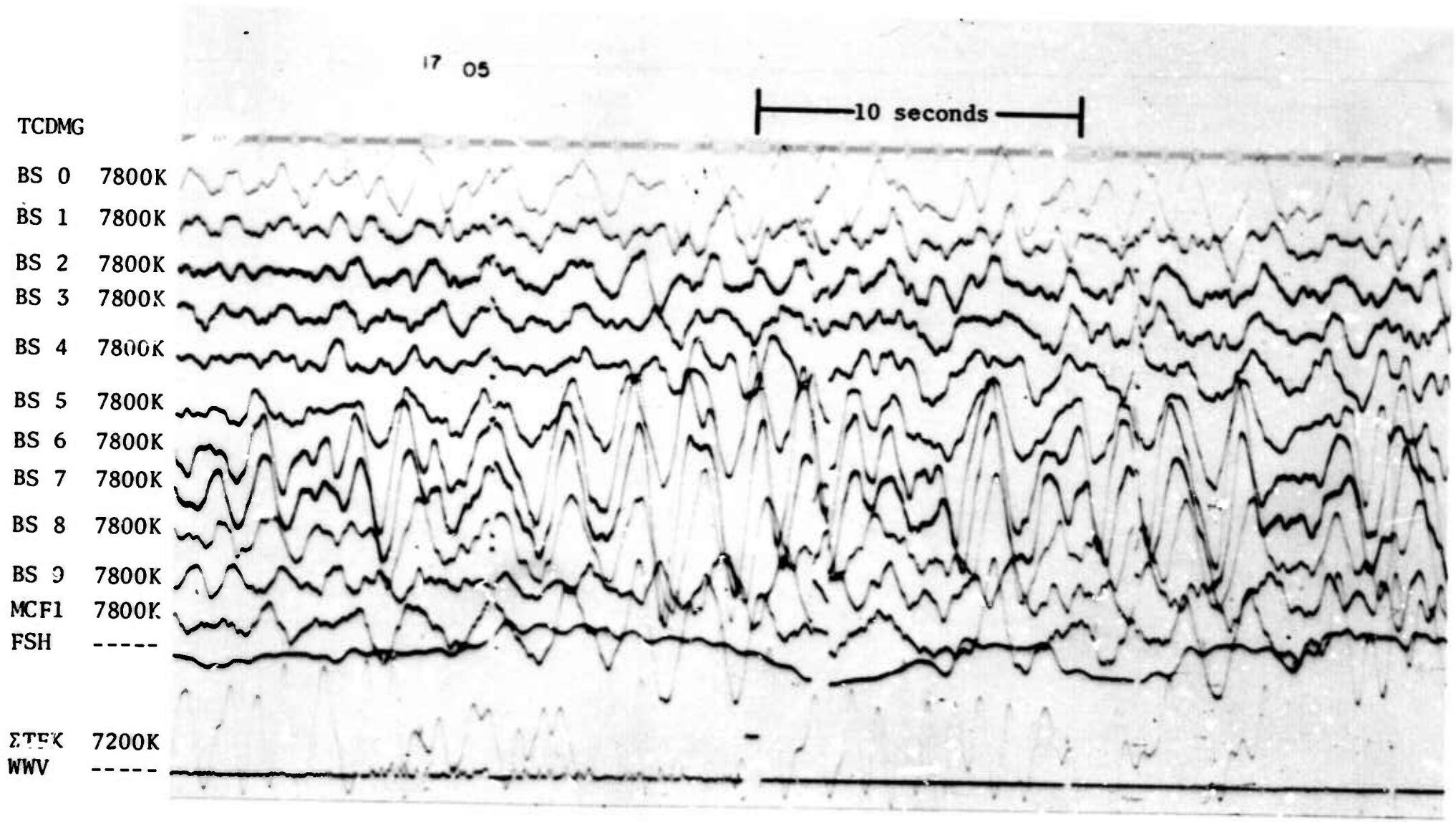
TFSO
Run 082
23 March 1970
DEV 7
Data Trunk 6
Data Group 7291

Figure 3. Short-period seismogram showing MCF record for an event with its epicenter approximately 57 degrees NW of TFSO



TFSO
Run 089
30 March 1970
DEV 7
Data Trunk 6
Data Group 7291

Figure 4. Short-period seismogram showing the MCF record for the P-diffracted phase event having its epicenter located approximately 112 degrees WNW of TFSO



TFSO
Run 089
30 March 1970
DEV 7
Data Trunk 6
Data Group 7291

Figure 5. Short-period seismogram showing the MCF record for a PKP phase of an event with its epicenter located approximately 112 degrees WNW of TFSO

magnification was set to equal the Z1LP magnification at .040 Hz. Figures 6, 7, and 8 are typical records produced by these seismographs.

6.3 HIGH-FREQUENCY SEISMOGRAPH

The high-frequency seismograph, ZHF8, was operated routinely from 1 January to 3 February when motor constant measurements were made. On 10 February, following the completion of motor constant measurements, the seismograph magnification was set to about 20,000K at 8 Hz.

6.4 NITROGEN-FILLED LONG-PERIOD TANK VAULTS

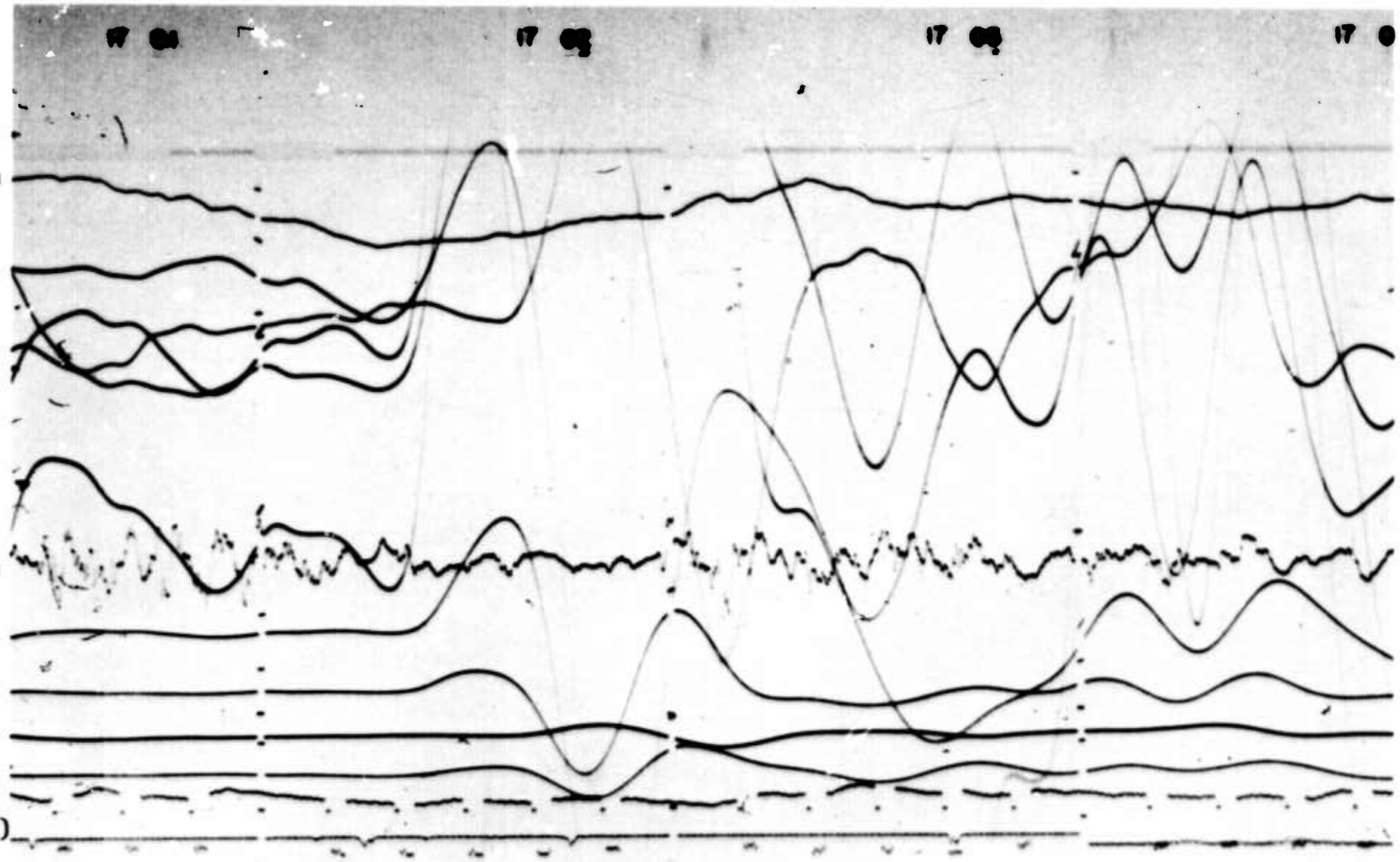
The nitrogen-filled tank tests that were stopped on 18 December 1969 were resumed 13 January 1970 after leaks in the N7LP and E7LP vaults were sealed. The vaults were pressurized to 1 psi with dry nitrogen from a new supply tank that contained 220 cubic feet. Periodic checks showed that the initial gas usage rate was 2.4 cubic feet per day, but that during later February and early March the usage rate had dropped to 1.85 cubic feet per day.

6.5 THIRTEEN-ELEMENT SHALLOW-WELL ARRAY

Suggestions for the location of sites in the 13-element shallow-well array were forwarded to the Project Officer. Consideration was given to the background noise and accessibility, as well as other criteria in the formulation of these suggestions.

6.6 EXPERIMENTAL DEVELOCORDER PUMP, MODEL 30082

The experimental Develocorder pump operated throughout the report period without failure.



TFSO
Run 089
30 March 1970
DEV 4
Data Trunk 2
Data Group 7290

Figure 6. Long-period seismogram showing P-diffracted phase of an event with epicenter located approximately 112 degrees WNW of TFSO

TFSO
28 January 1970
70-028

TCDMG

ML	Sens=4.8 μb/mm
E1LP	58K
N1LP	50
Z1LP	102
ZXLP	124
ZYLP	196
MS	Sens=1.8 μb/mm
ZXLL	10K
Z1LL	5
N1LL	3
E1LL	3
Wi	3mph=1m
WWV	S=0/8mm

Dev. #4
Data Trunk 2
Data Group 7290

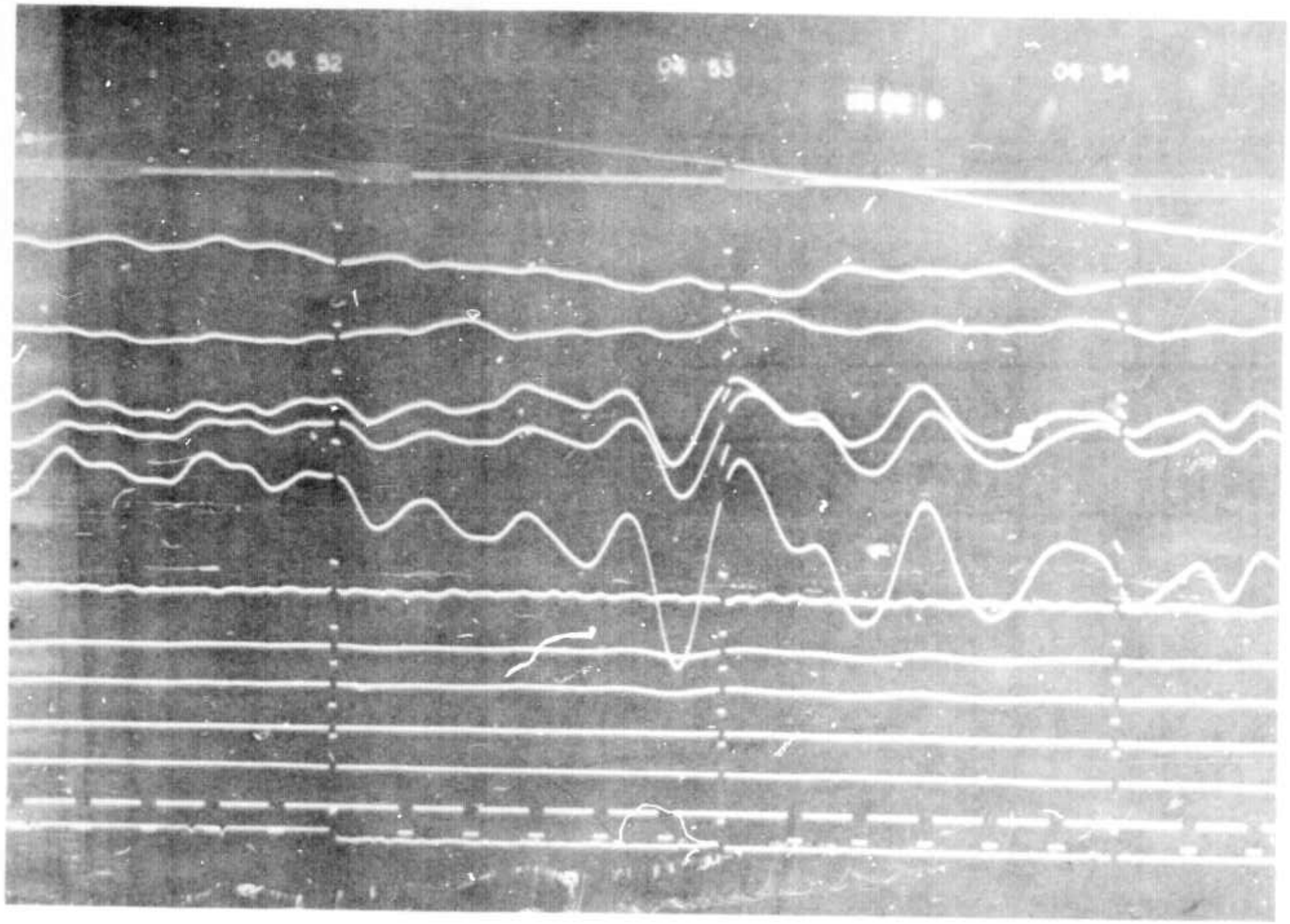


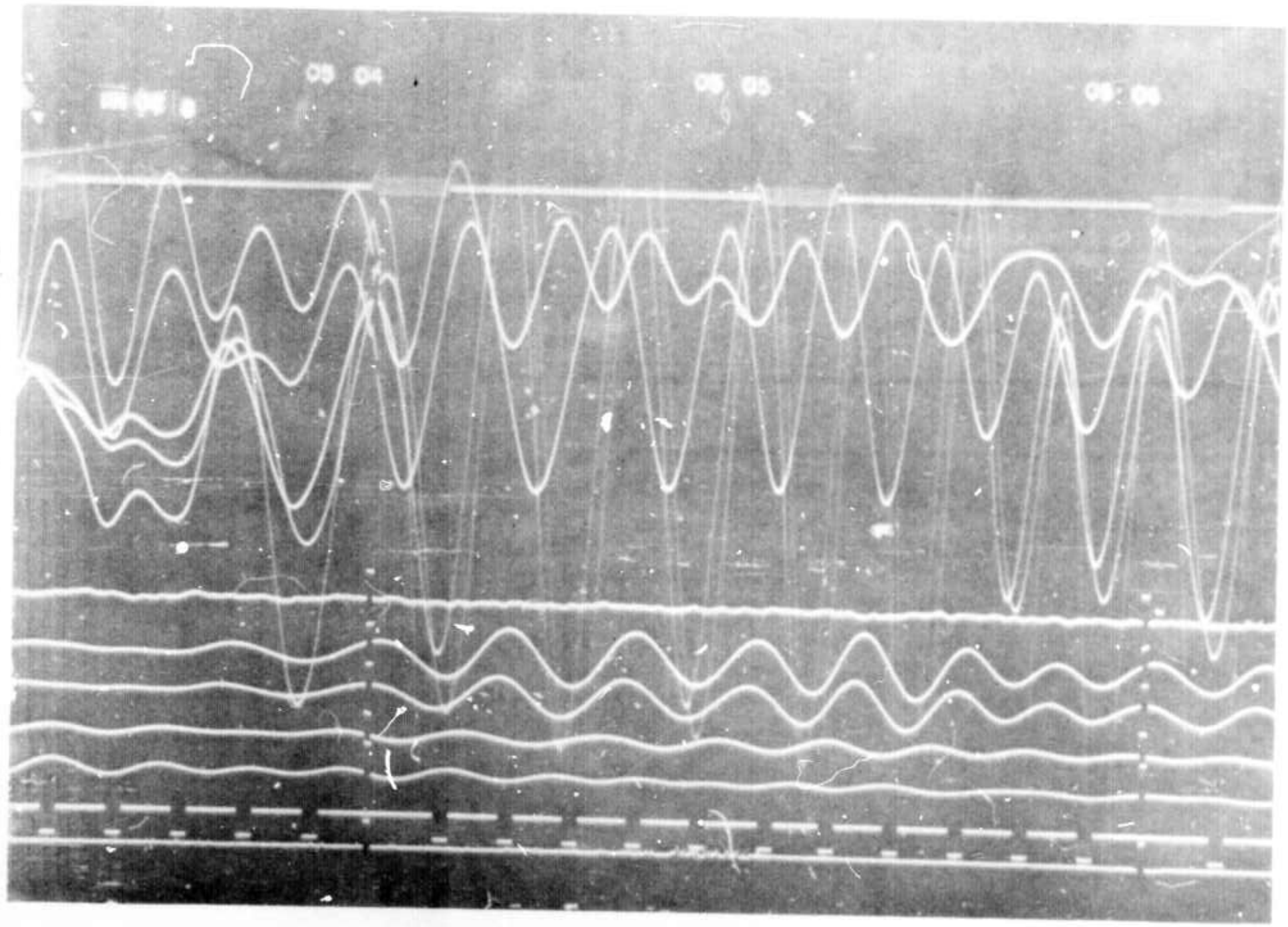
Figure 7. Long-period seismogram showing ZXLL record of P wave from an event with unknown epicenter

TFSO
28 January 1970
70-028

TCDMG

ML	Sens=4.8 μb/mm
E1LP	58K
N1LP	50
Z1LP	102
ZXLP	124
ZYLP	196

MS	Sens=1.8 μb/mm
ZXLL	10K
Z1LL	5
N1LL	3
E1LL	3
Wi	3mph=1mm
WWV	S=0/8mm



Dev. 4
Data Trunk 2
Data Group 7290

Figure 8. Long-period seismogram showing ZXLL record of Rayleigh wave from an event with unknown epicenter

APPENDIX to TECHNICAL REPORT NO. 70-13

STATEMENT OF WORK TO BE DONE

STATEMENT OF WORK TO BE DONE
(AFTAC Project Authorization No. VELA T/0704/S/ASD) (32)

Tasks:

a. Operation.

(1) Continue operation of the Tonto Forest Seismological Observatory (TFSO), normally recording data continuously.

(2) At the beginning of the project, the required level of effort at the station will be approximately the same as the final level on Project VT/9702. By the end of calendar year 1970, routine operational requirements and support of developmental tasks will have been reduced to 50 percent, and by 1 Jul 1971, these requirements will have been further reduced to 20 to 25 percent of initial level.

(3) For the 12-month period from 1 Jan through 31 Dec 1970, conduct routine daily analysis of seismic data at the observatory and transmit daily seismic teletype reports to the US Coast and Geodetic Survey, Environmental Science Services Administration, Washington Science Center, Rockville, Maryland, using the established report format and detailed instructions.

(4) The contractor shall provide for the transmission to and recording at TFSO of strain data from the VELA Long-period strain project. This will entail a leased telephone line and installation of a GFP Zipagram system.

(5) Quality control and evaluate the seismic data to determine optimum operational characteristics and make changes in the operating parameters as may be required to provide the most effective observatory practicable. Addition and modification of instruments are within the scope of work; however, such instrument modifications and additions, data evaluation, and major parameter changes are subject to the prior approval of the Government. Included in this task will be evaluation of data processing procedures using the multichannel filter processor; signal processing, recording, and transmission system; and any other designated systems as directed by the Government.

(6) Provide observatory facilities and seismological data to requesting organizations and individuals after approval by the Government.

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

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b. Instrument Installation and Evaluation. On approval by the Government, install and evaluate the performance characteristics of experimental or off-the-shelf equipment offering potential improvement in the performance of observatory seismograph systems. Operation and test of such instrumentation under field conditions should normally be preceded by laboratory test and evaluation.

c. Station Modification. As directed by the Government, incorporate new equipment into the system at TFSO. Removal of equipment should also be included in this task. Specific jobs under this task which shall be undertaken are:

(1) Install within the TFSO array the Model 30000 Observatory equipment consisting of seven long-period instruments and 13 short-period instruments with their accompanying electronics presently at Wichita Mountains Seismological Observatory (WMSO).

(2) Install radio links between six of the 30000 Observatory long-period sites (which should closely coincide with the present ring of long-period sites at TFSO) and the central recording station for transmission of data.

(3) Drill and case with 5-inch J55 casing 13 holes for installation at TFSO of Model 23900 instruments from the WMSO 30000 Observatory to a minimum depth of 10 feet below weathering or 10 feet into competent rock, whichever comes first. Install the instruments in the holes.

(4) Install a Government-furnished Zipagram system (12 channels) for multiplexing TFSO data to a central recording and processing facility.

REPRODUCTION

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

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

1. ORIGINATING ACTIVITY *(Corporate author)*
Teledyne Geotech
3401 Shiloh Road
Garland, Texas 75040

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE
Operation of the Tonto Forest Seismological Observatory, Quarterly Report No. 1, Project VT/0704, Contract F33657-70-C-0733, 1 January through 31 March 1970

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

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

6. REPORT DATE
22 April 1970

7a. TOTAL NO. OF PAGES
13

7b. NO. OF REFS

8a. CONTRACT OR GRANT NO.
F33657-70-C-0733

b. PROJECT NO
VELA T/0704

c. ARPA Order No. 624

d. ARPA Code No. 8F10

9a. ORIGINATOR'S REPORT NUMBER(S)
70-13

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

10. DISTRIBUTION STATEMENT
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11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
Advanced Research Projects Agency
Nuclear Test Detection Office
Washington, D. C.

13. ABSTRACT

This is a report of the work accomplished on Project VT/0704 from 1 January through 31 March 1970. Project VT/0704 includes the operation, evaluation, and improvement of the Tonto Forest Seismological Observatory (TFSO) located near Payson, Arizona. It also includes special research and test functions carried out at TFSO and research and development tasks performed by the Garland, Texas, staff using TFSO data.

DD FORM 1 NOV 65 1473

Unclassified
Security Classification

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