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TR67-25

TECHNICAL REPORT NO. 67-25

# OPERATION OF TFSO

Quarterly Report No.1, Project VT/7702

1 January through 31 March 1967

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GEOTECH

A TELEDYNE COMPANY

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TECHNICAL REPORT NO. 67-25

# OPERATION OF TFSO

Quarterly Report No. 1, Project VT/7702
1 January 1967 through 31 March 1967

Sponsored by

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

GEOTECH
A Teledyne Company
3401 Shiloh Road
Garland, Texas

1 May 1967

## IDENTIFICATION

| | |
|---|---|
| AFTAC Project No: | VELA T/7702 |
| Project Title: | Operation of TFSO |
| ARPA Order No: | 624 |
| ARPA Program Code No: | |
| Name of Contractor: | Teledyne Industries<br>Geotech Division<br>Garland, Texas |
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| Contract Expiration Date: | 31 December 1967 |
| Program Manager: | B. B. Leichliter, BR1-2561 |

CONTENTS


| | Page |
|---|---|
| ABSTRACT | |
| 1. INTRODUCTION | 1 |
| 1.1 Authority | 1 |
| 1.2 History | 1 |
| 2. OPERATION OF TFSO | 1 |
| 2.1 General | 1 |
| 2.2 Standard seismograph operating parameters | 3 |
| 2.3 Data channel assignments | 3 |
| 2.4 Completion and shipment of data | 3 |
| 2.5 Quality control | 6 |
| 2.5.1 Quality control of 16-millimeter film seismograms | 6 |
| 2.5.2 Quality control of magnetic-tape seismograms | 6 |
| 2.6 Security inspection | 7 |
| 2.7 Small business administration visit | 7 |
| 2.8 Emergency power generator | 7 |
| 3. MAINTENANCE OF TFSO EQUIPMENT | 7 |
| 3.1 Spiral-four cable replacement | 7 |
| 3.2 Routine tests | 8 |
| 3.2.1 Phase-shift checks | 8 |
| 3.2.2 Test equipment calibrations | 8 |
| 3.2.3 Semiannual seismometer motor-constant check | 8 |
| 3.3 Maintain TFSO facilities | 8 |
| 4. EVALUATE DATA AND DETERMINE OPTIMUM OPERATIONAL CHARACTERISTICS | 8 |
| 4.1 Modifications to TFSO instrumentation | 8 |
| 4.1.1 TFSO long-period response change | 8 |
| 4.1.2 Deletion of elements from the 31-element and crossed-linear arrays | 13 |
| 4.2 Testing of TFSO instrumentation | 13 |
| 4.2.1 Long-period surface vault | 13 |
| 4.2.2 Tests of Johnson-Matheson seismometers with high-impedance coils | 13 |
| 5. ANALYZE DATA | 17 |
| 5.1 Report events to Coast and Geodetic Survey | 17 |
| 5.2 Daily analysis for multistation earthquake bulletin | 17 |
| 5.3 Continue noise survey | 20 |

CONTENTS, Continued


| | Page |
|---|---|
| 6. PROVIDE OBSERVATORY FACILITIES AND ASSISTANCE TO OTHER ORGANIZATIONS | 20 |
| 6.1 Astrodata data acquisition system (ASDAS) | 20 |
| 6.2 Recordings for the California Institute of Technology | 20 |
| 6.3 Telemetry to Massachusetts Institute of Technology | 20 |
| 6.4 Astrogeological department of USGS | 20 |
| 6.5 Sonic boom study | 21 |
| 6.6 Copies of C&GS message to BMSO | 21 |
| 6.7 Visitors | 21 |
| 6.7.1 Sonic boom program | 21 |
| 6.7.2 Visits by school groups | 21 |
| 7. RESEARCH PROGRAMS | 22 |
| 7.1 Tests of long-period seismometers in an evacuated spherical chamber | 22 |
| 7.2 Technique for sealing spiral-four cable connectors | 22 |
| 7.3 Communications system | 23 |
| 7.4 Design and install a short-period array | 24 |
| 7.4.1 Land permitting | 24 |
| 7.4.2 Archeological control | 24 |
| 7.4.3 Arizona state highway permits | 24 |
| 7.4.4 Preliminary operation plan | 24 |
| 7.4.5 Site selection | 24 |
| 7.4.6 Cable trail selection | 24 |
| 7.4.7 Material received | 27 |
| 7.4.8 Cable installation | 27 |
| 7.4.9 Array survey | 27 |
| 7.4.10 Modification of array seismometers | 27 |
| 7.5 Design and install a long-period array | 27 |
| 7.5.1 Long-period noise study | 27 |
| APPENDIX - Statement of work | |

## ILLUSTRATIONS


| Figure | | Page |
|---|---|---|
| 1 | Location of TFSO | 2 |
| 2 | Normalized response characteristics of standard seismographs at TFSO | 5 |
| 3 | Typical response of TFSO three-component long-period system as modified on 18 January 1967 | 10 |
| 4 | Long-period seismogram showing format of data group 7205 during long-period noise study project. Signal is from unknown epicenter. (X10 enlargement of 16-millimeter film) | 11 |
| 5 | Long-period seismogram showing response of instruments to surface waves from unknown epicenter. (X10 enlargement of 16-millimeter film) | 12 |
| 6 | TFSO long-period experimental seismogram illustrating the response of Z57LP and Z54LP (housed in a surface tank-type vault) and Z51LP and Z44LP (located in a large walk-in concrete vault) during a period of atmospheric pressure changes and winds of about 10 mph. (X10 enlargement of 16-millimeter film) | 14 |
| 7 | Long-period seismogram comparing response of horizontal component located in a surface tank vault (N 57 LPX and N 54 LPX) with the response of a standard horizontal component located in a walk-in concrete vault (N 46 LP) to low-level background noise. (X10 enlargement of 16-millimeter film) | 15 |
| 8 | Long-period experimental seismogram showing spiking of horizontal LPX in surface tank vault, (N 57LPX and N 54LPX) as compared with standard horizontal component located in a walk-in concrete vault (N 46LP). (X10 enlargement of 16-millimeter film) | 16 |
| 9 | Short-period seismogram comparing the response of Z102 and Z103X to a near regional event. (X10 enlargement of 16-millimeter film) | 18 |

ILLUSTRATIONS, Continued


| Figure | | Page |
|---|---|---|
| 10 | Short-period seismogram comparing the response of Z102X and Z103X with Z4 epicenter OAXACA, Mexico. $\Delta \cong 23.30$; AZ = SSE; h = 46 km, o = 19 39 14.2, m = 4.7 (C&GS). (X10 enlargement of 16-millimeter film) | 19 |
| 11 | TFSO communication systems antenna tower and equipment building installed at Diamond Point | 23 |
| 12 | Plan for the 37-element array at TFSO showing the fire main array segments | 25 |
| 13 | Plan of the 37-element array showing the locations of the sites and cable trails | 26 |
| 14 | Long-period noise study vaults during installation and area in the immediate vicinity of PY3AZ | 29 |
| 15 | Average phase response for portable LRSM long-period systems | 30 |
| 16 | Typical long-period response of the LRSM portable long-period system | 31 |

## TABLES


| Table | | Page |
|---|---|---|
| 1 | Operating parameters and tolerances of seismographs at TFSO | 4 |
| 2 | TFSO semiannual motor constant checks | 9 |

## ABSTRACT

This is a report of the work accomplished on Project VT/7702 from 1 January through 31 March 1967. Project VT/7702 includes the operation, evaluation, improvement, and expansion 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

## 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 AF 33(657-67-C-0091. The contract was effective 1 January 1967; the statement of work for Project VT/7702 is included as the appendix to this report.

### 1.2 HISTORY

The Tonto Forest Seismological Observatory (TFSO) was originally 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. 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 for operating TFSO. The LRSM mobile vans were phased out of the TFSO operation on 3 October 1965.

On 1 January 1967, a new contract was awarded to Geotech for the operation and expansion of the Tonto Forest Seismological Observatory. 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-a-day basis. The observatory is manned continuously. A full complement of personnel is on duty 8 hours a day, 5 days a week; at other times, a reduced operating crew is on duty.

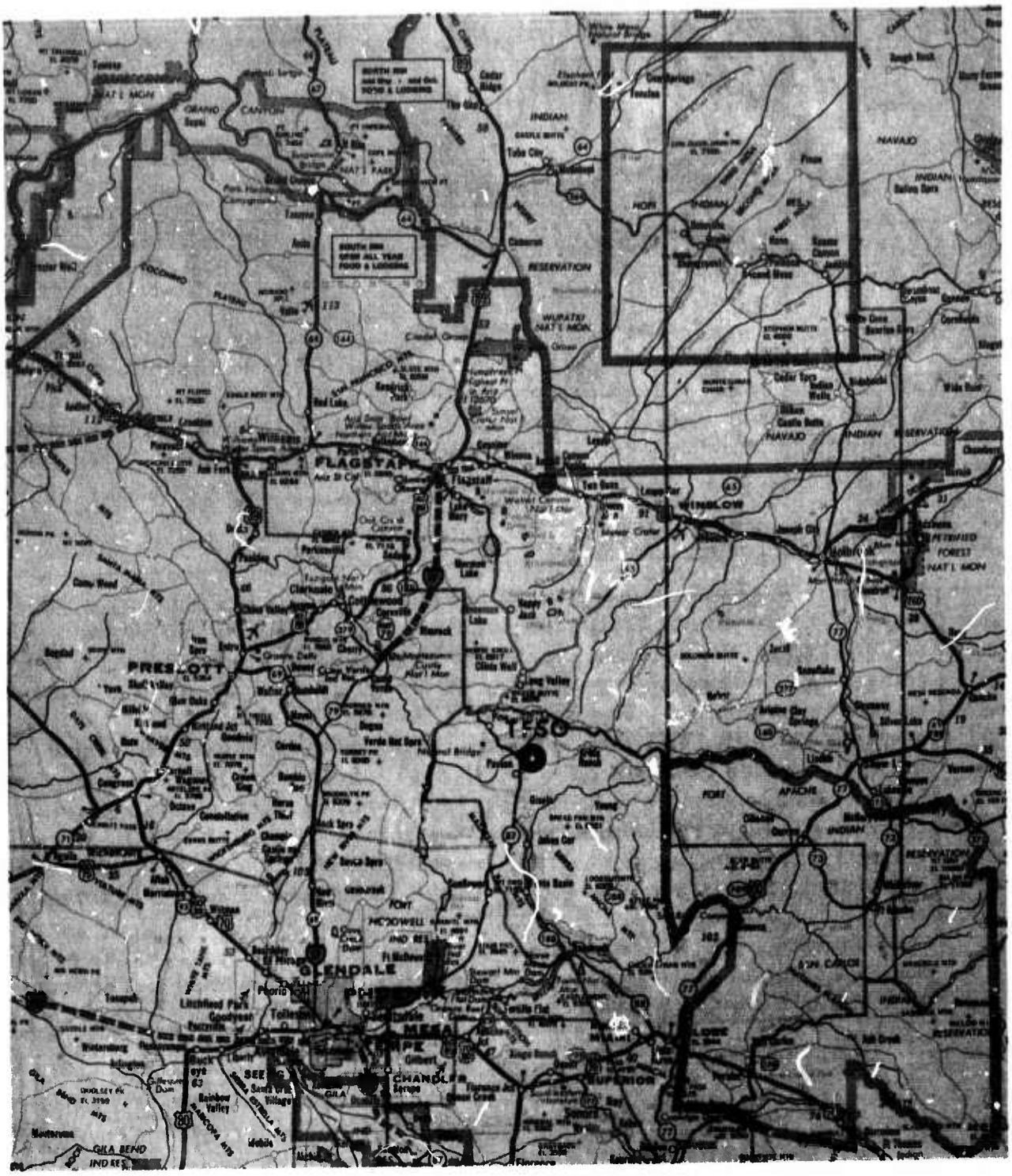



Figure 1. Location of TFSO

G 650

## 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. During portions of this reporting period, the response of the TFSO long-period system was changed to conform to the response of the portable systems used for the long-period noise survey which is discussed in section 4.1.1.

In addition to these standard seismographs, two filtered summations are recorded. A UED filter with a high-cut frequency at 1.75 cps with a slope of 24 dB per octave and a low-cut frequency at 0.7 cps with a slope of 24 dB per octave is used to record the ΣTF seismograms on 16-millimeter film (Data Trunks 1 and 7) and on magnetic tape (Data Trunks 2 and 5).

A Krohn-Hite filter with a high-cut frequency at 3.0 cps with a slope of 24 dB per octave and a low-cut frequency at 1.0 cps with a slope of 24 dB per octave is used to record the ΣTFK seismograms on 16-millimeter film (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 to the format. Data format change notices with the changes in channel assignments and data group numbers made during this reporting period were submitted to the Project Office and to frequent users of TFSO data.

## 2.4 COMPLETION AND SHIPMENT OF DATA

The magnetic-tape seismograms are shipped from TFSO each week. Three of the magnetic-tape units record data for the AFTAC VELA Seismological Center (VSC) and three are for use by universities. When data from all three magnetic-tape units are not required by the universities, the observatory notifies VSC.

Film records from ten Develocorders are routinely shipped to data users. The film and magnetic-tape operation logs and calibration logs are copied and shipped with the seismograms to each user. Sets of selected Develocorder prints are sent to Geotech regularly and to other data users on special request. The shipments of 16-millimeter film seismograms routinely sent to the Seismic Data Laboratory (SDL) repository are complete through 31 January 1967.

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

| Seismograph | | | | Operating parameters and tolerances | | | | Filter settings | | |
|---|---|---|---|---|---|---|---|---|---|---|
| System | Comp | Type | Model | Ts | $\lambda s$ | Tg | $\lambda g$ | $\delta^2$ | Bandpass at 3dB cutoff (sec) | Cutoff rate at SP side (dB/oct) |
| SP | Z | Johnson-Matheson | 6480 | 1.25±2% | 0.54 ±5% | 0.33 ±5% | 0.65 ±5% | 0.0117 | 0.1 - 100 | 12 |
| SP | H | Johnson-Matheson | 7515 | 1.25±2% | 0.54 ±5% | 0.33 ±5% | 0.65 ±5% | 0.0117 | 0.1 - 100 | 12 |
| SP | Z | Benioff | 1051 | 1.0 ±2% | 1.0 ±5% | 0.2 ±5% | 1.0 ±5% | 0.0104 | 0.1 - 100 | 12 |
| SP | H | Benioff | 1101 | 1.0 ±2% | 1.0 ±5% | 0.2 ±5% | 1.0 ±5% | 0.0104 | 0.1 - 100 | 12 |
| SP | Z | UA Benioff | 1051 | 1.0 ±2% | 1.0 ±5% | 0.75 | 1.0 ±5% | 0.0245 | | |
| SP | H | UA Benioff | 1101 | 1.0 ±2% | 1.0 ±5% | 0.75 | 1.0 ±5% | 0.0245 | | |
| IB | Z | Melton | 10012 | 2.25±5% | 0.65 ±5% | 0.64 ±5% | 1.2 ±5% | 0.0006 | 0.05 - 100 | 18 |
| IB | H | Lehner-Griffin | SH-216 | 2.25±5% | 0.65 ±5% | 0.64 ±5% | 1.2 ±5% | 0.0004 | 0.05 - 100 | 18 |
| BB | Z | Press-Ewing | SV-232 | 12.0 ±5% | 0.425 ±10% | 0.64 ±5% | 9.0 ±10% | 0.00027 | 0.05 - 100 | 18 |
| BB | H | Press-Ewing | SH-242 | 12.0 ±5% | 0.425 ±10% | 0.64 ±5% | 9.0 ±10% | 0.00027 | 0.05 - 100 | 18 |
| LP[a] | Z | Geotech | 7505A | 20.0 ±5% | 0.74 ±10% | 110.0 ±10% | 0.83 ±10% | 0.66 | 25 - 1000 | 12 |
| | | | | | | | | | 20 - 200[aa] | 12 |
| LP[a] | H | Geotech | 8700C | 20.0 ±5% | 0.74 ±10% | 110.0 ±10% | 0.83 ±10% | 0.66 | 25 - 1000 | 12 |
| | | | | | | | | | 20 - 200[aa] | 12 |

**KEY**

Z Vertical component
H Horizontal component
SP Short period
IB Intermediate band
BB Broad band
LP Long period

UA Unamplified (i.e., earth powered)
Ts Seismometer free period (sec)
Tg Galvanometer free period (sec)
$\lambda s$ Seismometer damping constant
$\lambda g$ Galvanometer damping constant
$\delta^2$ Coupling coefficient

[a]Temporarily deactivated on 18 January

[aa]With a 6-second notch filter

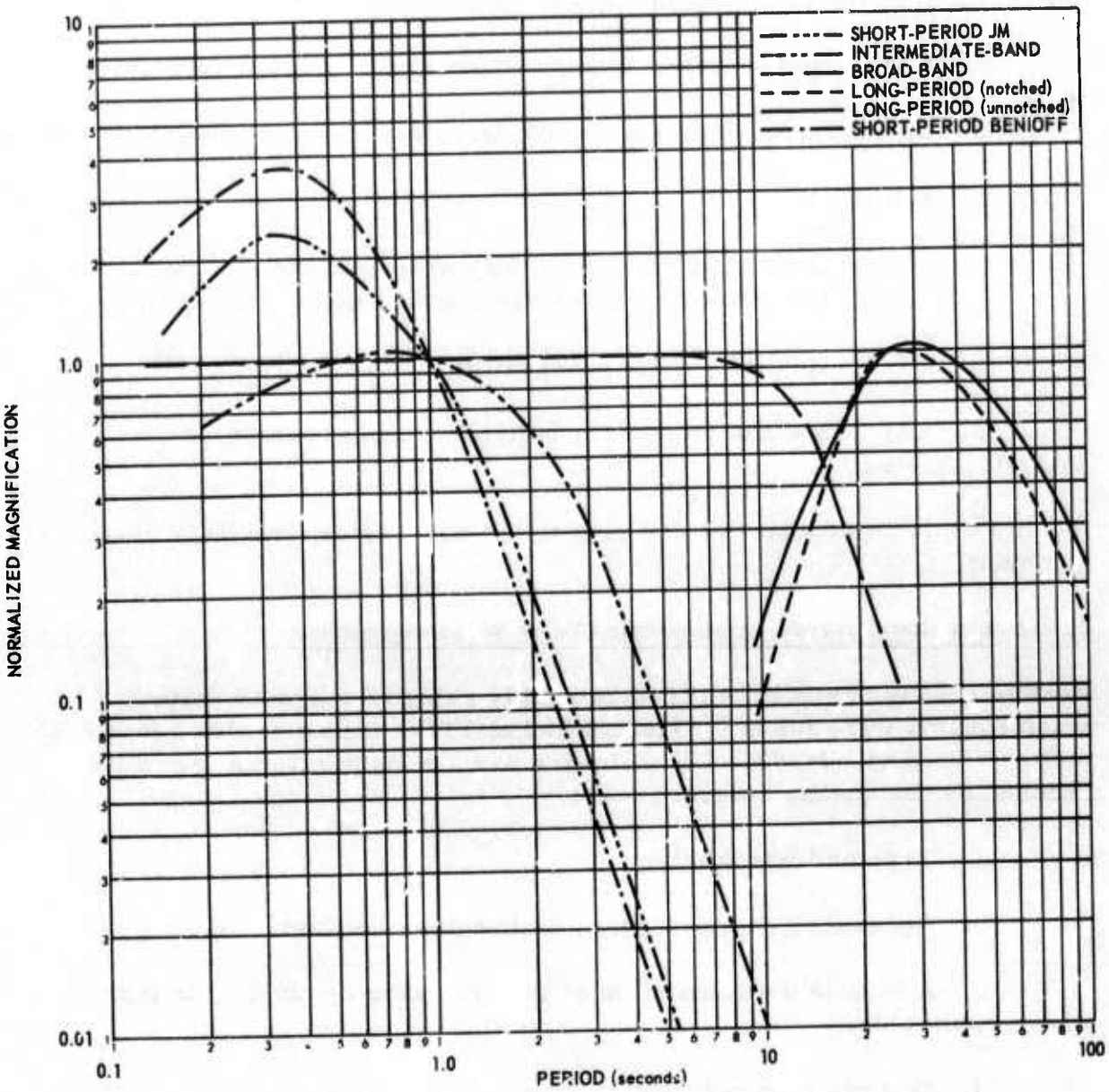



**Figure 2. Normalized response characteristics of standard seismographs at TFSO**

G 1418

## 2.5 QUALITY CONTROL

### 2.5.1 Quality Control of 16-Millimeter Film Seismograms

Quality-control checks of randomly selected runs of 16-millimeter film from Data Trunks 1, 2, and 8, and the accompanying 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 the analysis sheets.

Results of these evaluations are sent to the observatory for their review and comment.

### 2.5.2 Quality Control of Magnetic-Tape Seismograms

Routine quality control checks of randomly selected magnetic-tape seismograms were made in Garland and at TFSO to assure that recordings met specified standards. The following are among the items that were checked by the quality control group:

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 calibration signals;

f. Relative phase shift between array seismographs;

g. Level of the microseismic background noise;

h. Level of the system noise;

i. PTA dc balance;

j. Oscillator alignment;

k. Quality of the recorded WWV signal where applicable;

l. Time-pulse carrier;

m. Binary coded digital time marks.

## 2.6 SECURITY INSPECTION

Mr. M. R. Cray, Industrial Security Chief from Phoenix, Arizona, made a routine security inspection of the observatory on 10 January 1967. All security procedures were found to be in order. New Standard Security Procedures for the station were approved.

## 2.7 SMALL BUSINESS ADMINISTRATION VISIT

Mr. C. P. Fink and Mr. H. E. Klindert from the Phoenix Office of the Los Angeles Defense Contract Administration Services Region (DCASR) visited TFSO on 30 January and 10 March 1967. The visits were in compliance with the regulations of the Small Business Administration.

## 2.8 EMERGENCY POWER GENERATOR

The emergency power generator was operated for several hours each month in this reporting period. All operating time was for test and maintenance purposes.

# 3. MAINTENANCE OF TFSO EQUIPMENT

## 3.1 SPIRAL-FOUR CABLE REPLACEMENT

Rain and snow increased the line leakage problems in December 1966 and it was necessary to replace seven reels of spiral-four cable. Leakage problems also occurred in one vault and one protector box.

## 3.2 ROUTINE TESTS

### 3.2.1 Phase-Shift Checks

Routine phase-shift checks were performed on all Johnson-Matheson (JM) seismometers during this reporting period. Only two seismograph systems showed excessive phase-shift. One seismograph was corrected by replacing the PTA, and the other was corrected by replacing the seismometer. Both the out-of-tolerance PTA and seismometer are being repaired.

### 3.2.2 Test Equipment Calibrations

The annual test equipment calibration at TFSO was started during March 1967. This task is approximately 50 percent complete.

### 3.2.3 Semiannual Seismometer Motor-Constant Check

The results of the seimannual seismometer motor-constant checks made during March 1967 are listed in table 2. Minor adjustments were required on five of the instruments.

## 3.3 MAINTAIN TFSO FACILITIES

The humidity in the central recording building is controlled by a series of humidifiers which are mounted directly in the building air ducts. Two of these units required replacement because of burned-out motors.

# 4. EVALUATE DATA AND DETERMINE OPTIMUM OPERATIONAL CHARACTERISTICS

## 4.1 MODIFICATIONS TO TFSO INSTRUMENTATION

### 4.1.1 TFSO Long-Period Response Change

On 18 January 1967, the TFSO standard long-period response was changed to match that of the LRSM portable long-period systems. Two Model 8530-2 Harris galvanometers and a Model 6000 Lehrner-Griffith galvanometer were incorporated in the system to facilitate the change. The frequency response of the modified system is shown in figure 3. Two seismograms illustrating the operation of the long-period system with the new frequency response are shown in figures 4 and 5.

Table 2. TFSO semiannual motor constant checks

| System | Previous "G" | First "G" | Adjusted "G" | "G" used for calibration |
|---|---|---|---|---|
| Z60 | 0.2975 | 0.304 | | 0.296 |
| E99SP | 0.2995 | 0.304 | | 0.296 |
| N100SP | 0.2965 | 0.296 | | 0.296 |
| Z38BB | 0.186 | 0.185 | | 0.188 |
| E39BB | 0.186 | 0.176 | 0.189 | 0.188 |
| N40BB | 0.190 | 0.1815 | 0.1868 | 0.188 |
| Z41IB | 0.0212 | 0.02005 | | 0.0206 |
| E42IB | 0.0474 | 0.0474 | | 0.0474 |
| N43IB | 0.0482 | 0.0462 | | 0.0474 |
| Z44LP | 0.030 | 0.030 | | 0.030 |
| E45LP | 0.030 | 0.0312 | 0.030 | 0.030 |
| N46LP | 0.030 | 0.03135 | 0.0303 | 0.030 |
| Z47BF | 2.385 | 2.375 | | 2.43 |
| E48BF | 2.31 | 2.355 | 2.303 | 2.26 |
| N49BF | 2.305 | 2.295 | | 2.26 |
| Z74 | 0.2985 | 0.3035 | | 0.296 |
| 1A | 2.10 | 2.155 | | 2.12 |
| 1B | 2.20 | 2.26 | | 2.20 |
| 1C | 2.18 | 2.20 | | 2.20 |

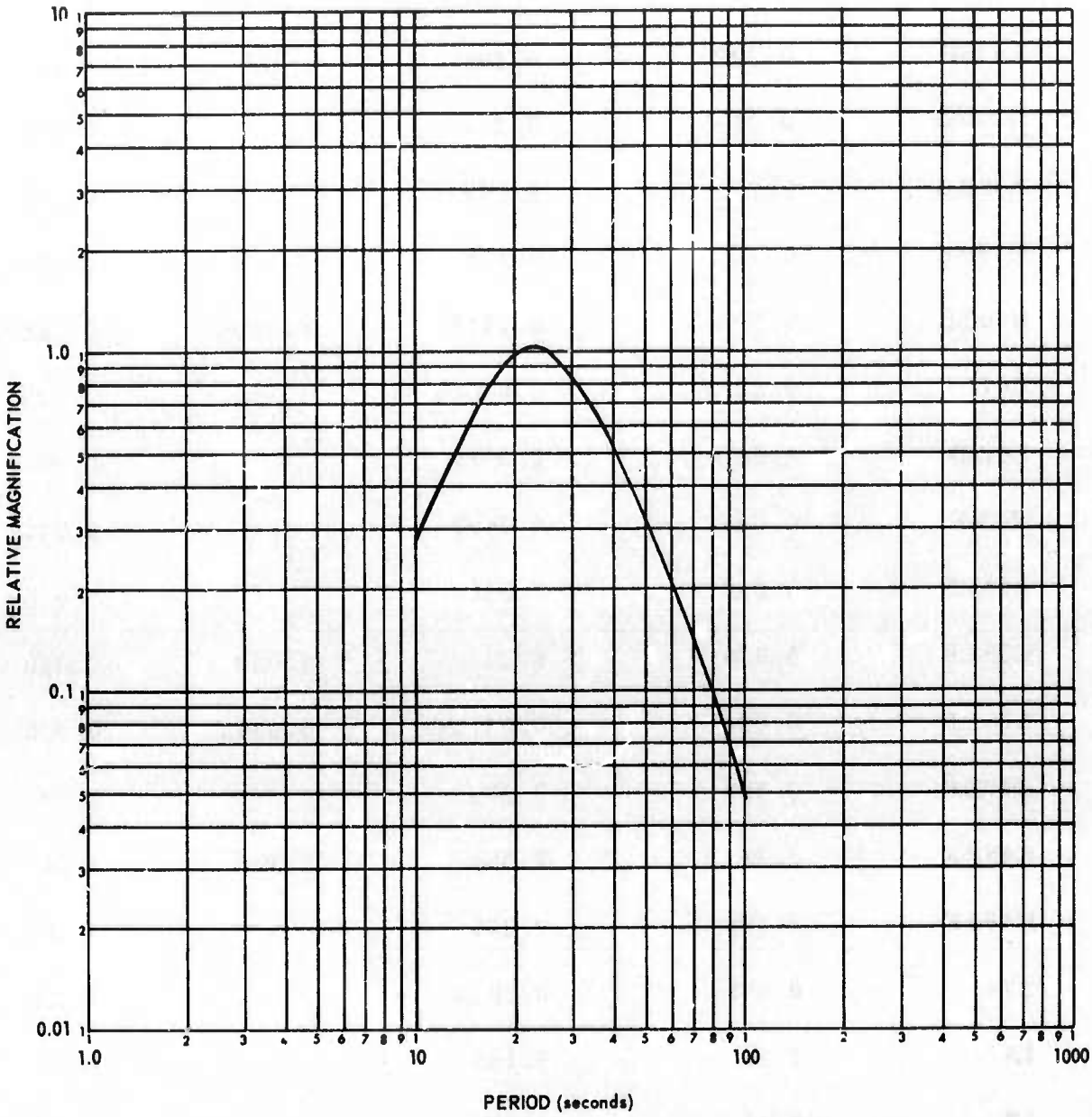
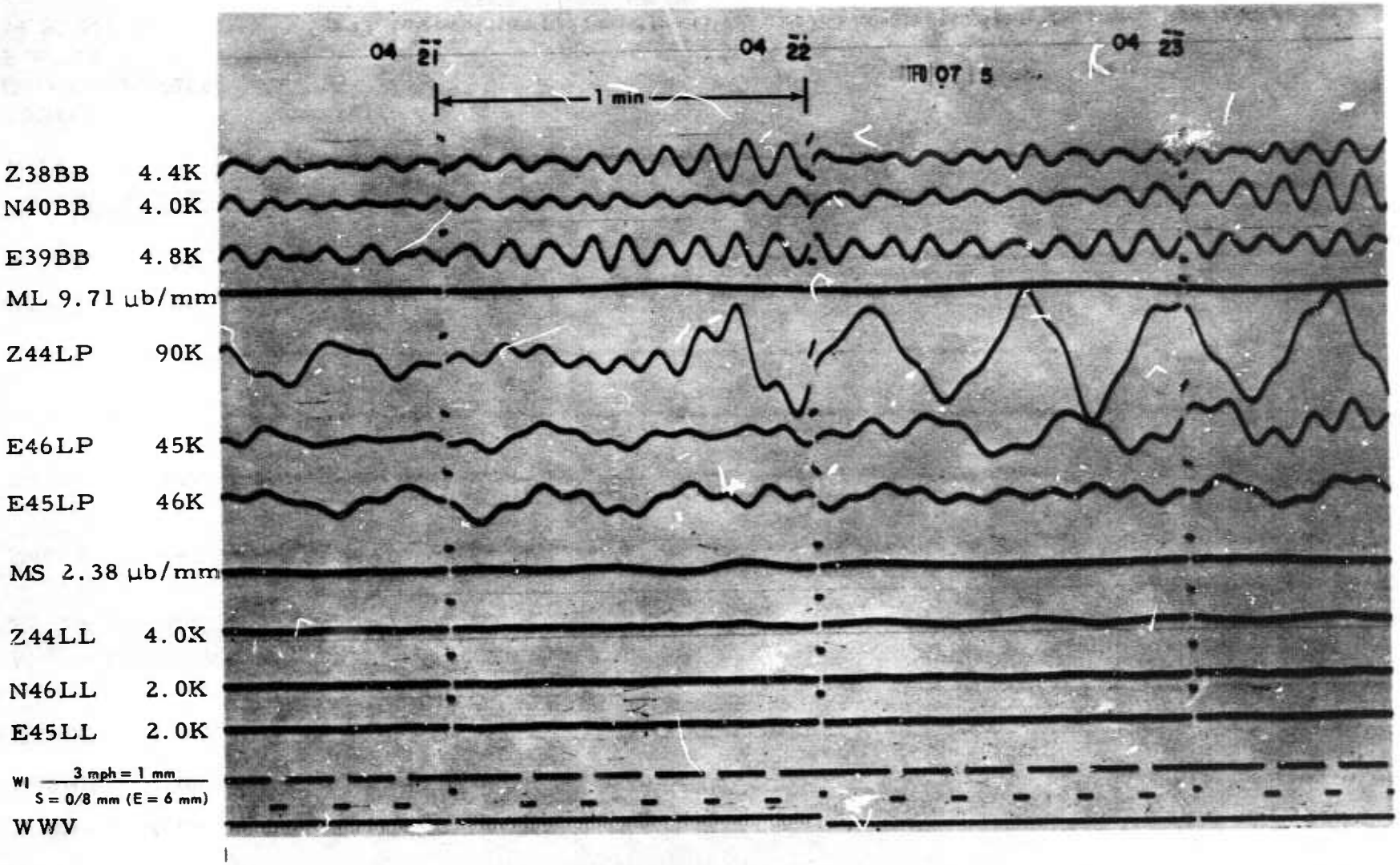



**Figure 3. Typical response of TFSO three-component long-period system as modified on 18 January 1967**

G 2642

**Figure 4. Long-period seismogram showing format of data group 7205 during long-period noise study project. Signal is from unknown epicenter. (X10 enlargement of 16-millimeter film)**

G 2643




TFSO
Data Group 7205
Run 075
16 March 1967

**Figure 5. Long-period seismogram showing response of instruments to surface waves from unknown epicenter. (X10 enlargement of 16-millimeter film)**

G 7644

### 4.1.2 Deletion of Elements from the 31-Element and Crossed-Linear Arrays

A number of elements of the 31-element and crossed-linear arrays were deleted to provide instruments and cable for the first phases of the installation of the new 37-element array. The field cables for the deleted elements have been retrieved and tested, and the seismometers are currently being modified and tested for installation in the 37-element array.

## 4.2 TESTING OF TFSO INSTRUMENTATION

### 4.2.1 Long-Period Surface Vault

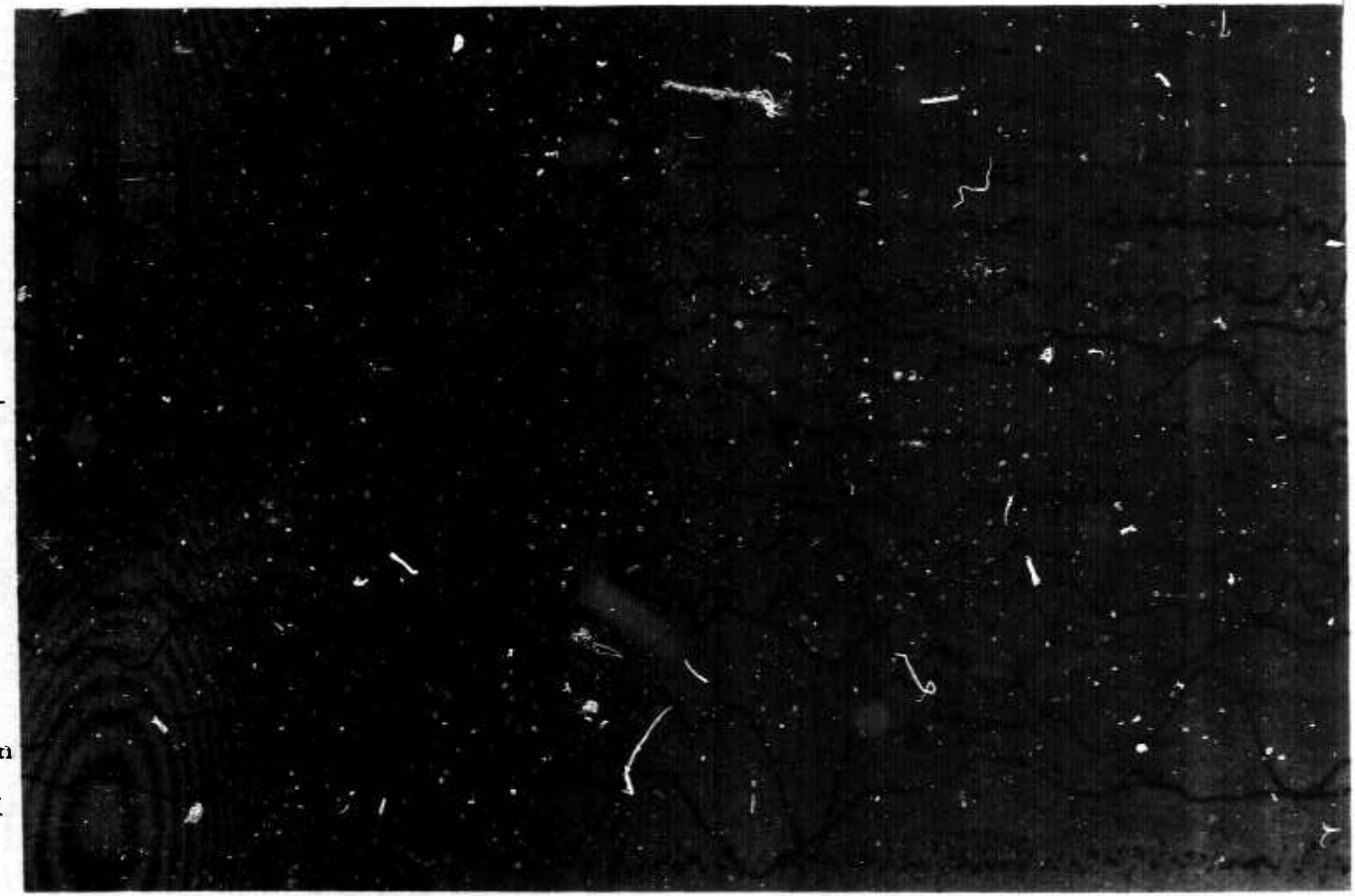
We continued to operate a long-period vertical seismometer in the surface-type vault until 26 January 1967. The seismograph (Z45LP) utilizing this seismometer exhibited essentially the same response to background noise as the Z44LP seismograph when the wind velocities were less than 20 miles per hour. The seismometer for the Z44LP seismograph was operated in the underground long-period vault. A seismogram illustrating the operation of these instruments is shown in figure 6.

On 26 January, the vertical long-period seismometer was removed and a horizontal long-period seismometer with wire hinges was installed in the surface-type vault. However, because the response of the standard long-period seismographs had been changed for the noise survey on 18 January, a comparative analysis of the operation of the horizontal instrument in the surface vault and the north-south horizontal instrument in the underground vault has not been made. The notched and unnotched outputs of the seismograph utilizing the seismometer in the surface vault are designated N54LPX and N57LPX, respectively. A seismogram illustrating the operation of these seismographs during a period of normal seismic background is shown in figure 7.

Occasional spikes, as shown in figure 8, have originated from the horizontal seismometer in the surface-type vault. We plan to "heat-cycle" this instrument before the comparative analysis is done.

### 4.2.2 Tests of Johnson-Matheson Seismometers with High-Impedance Coils

Because solid-state amplifiers are to be used in the seismographs of the 37-element array, the seismometers must be equipped with high-impedance coils. Standard high-impedance coils are available; however, the seismometers would have to be returned to the Garland plant for modification to use these coils. To eliminate the expense and delay which would be involved, we designed special high-impedance coils which could be installed at the observatory.



STS

Z57LP 34K

Z51LP 34K
N53LP 26K

E52LP 26K

WI 3 mph = 1 mm
S = 0/8 mm (E = 6 mm)

Z54LP 66K

Z44LP 72K
N46LT 47K

E45LP 49K

ML 9.71 μb/mm

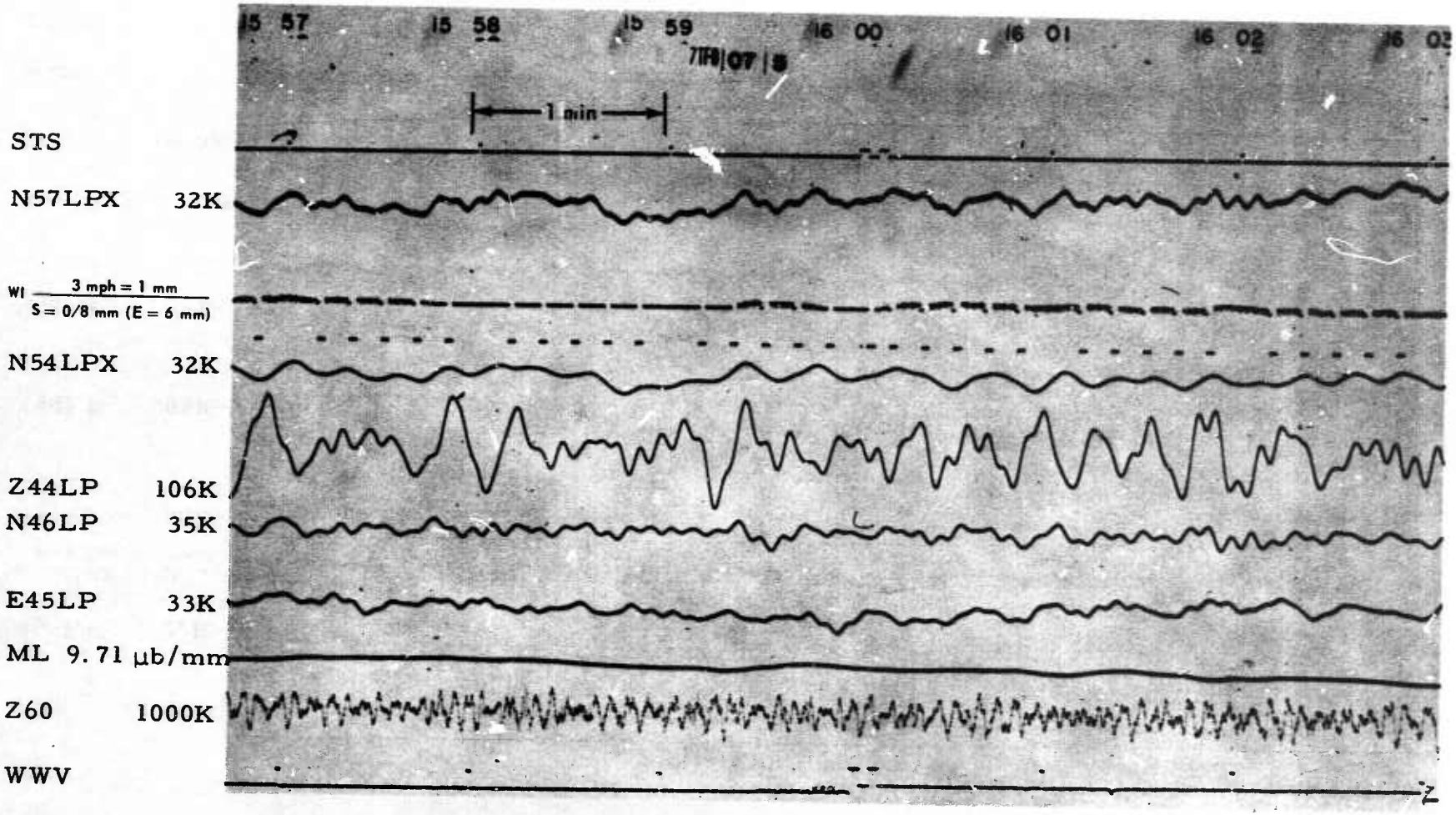
Z60 1000K

WWV

TFSO
22 Dec 1966
Run 356
DG LP Exp

**Figure 6. TFSO long-period experimental seismogram illustrating the response of Z57LP and Z54LP (housed in a surface tank-type vault) and Z51LP and Z44LP (located in a large walk-in concrete vault) during a period of atmospheric pressure changes and winds of about 10 mph. (X10 enlargement of 16-millimeter film)**

G 2645




TFSO
LP Experimental
Run 075
16 March 1967

Figure 7. Long-period seismogram comparing response of horizontal component located in a surface tank vault (N 57 LPX and N 54 LPX) with the response of a standard horizontal component located in a walk-in concrete vault (N 46 LP) to low-level background noise. (X10 enlargement of 16-millimeter film)

G 2646

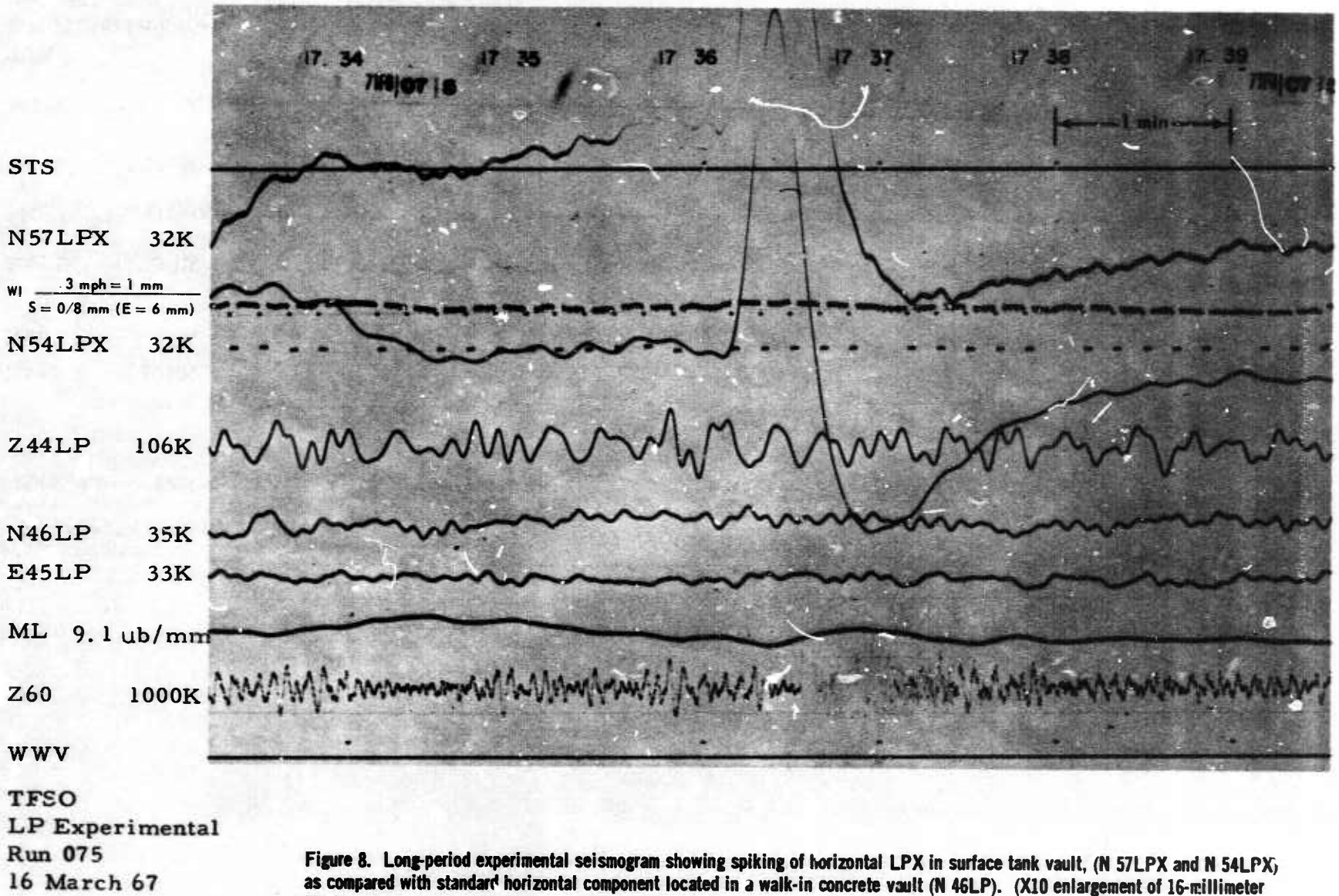



Figure 8. Long-period experimental seismogram showing spiking of horizontal LPX in surface tank vault, (N 57LPX and N 54LPX) as compared with standard horizontal component located in a walk-in concrete vault (N 46LP). (X10 enlargement of 16-millimeter film)

G 2647

A seismograph utilizing a JM seismometer with one of the special high-impedance coils and a Model 25220 solid-state amplifier (Z103X) was operated during February 1967 on a pier in the underground experimental vault. A seismograph utilizing a JM seismometer with a standard high-impedance coil and a Model 25220 solid-state amplifier (Z102X) was installed on the same pier. Careful visual analysis of the seismograms indicated that the electronic noise of the two systems was essentially the same. Figures 9 and 10 show seismograms produced by these systems.

## 5. ANALYZE DATA

### 5.1 REPORT EVENTS TO COAST AND GEODETIC SURVEY

Analysts daily report the time of arrival, period, and peak amplitude of events recorded at TFSO to the Director of the Coast and Geodetic Survey (C&GS) in Washington, D.C. The number of events reported by TFSO during each month of the reporting period is shown in table 3 by type. Lists of hypocenters located by the C&GS for these months are still incomplete.

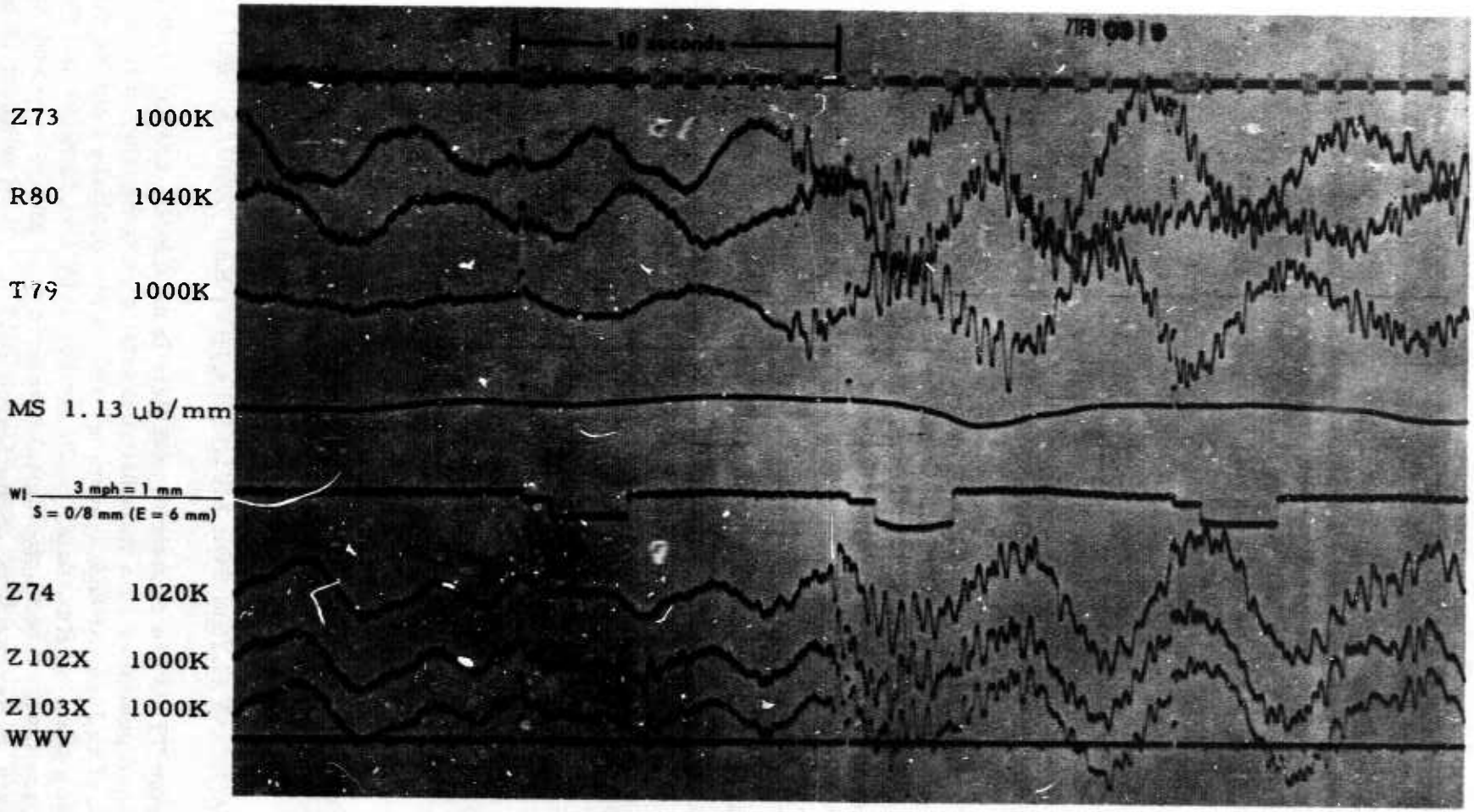
Table 3. Number of earthquakes reported to the C&GS by TFSO between 1 January and 31 March 1967

| January 1967 | | | | | February 1967 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| L | N | R | T | Total | L | N | R | T | Total |
| 12 | 149 | 10 | 1510 | 1681 | 25 | 139 | 7 | 902 | 1073 |

| March 1967 | | | | |
|---|---|---|---|---|
| L | N | R | T | Total |
| 40 | 141 | 17 | 1422 | 1620 |

### 5.2 DAILY ANALYSIS FOR MULTISTATION EARTHQUAKE BULLETIN

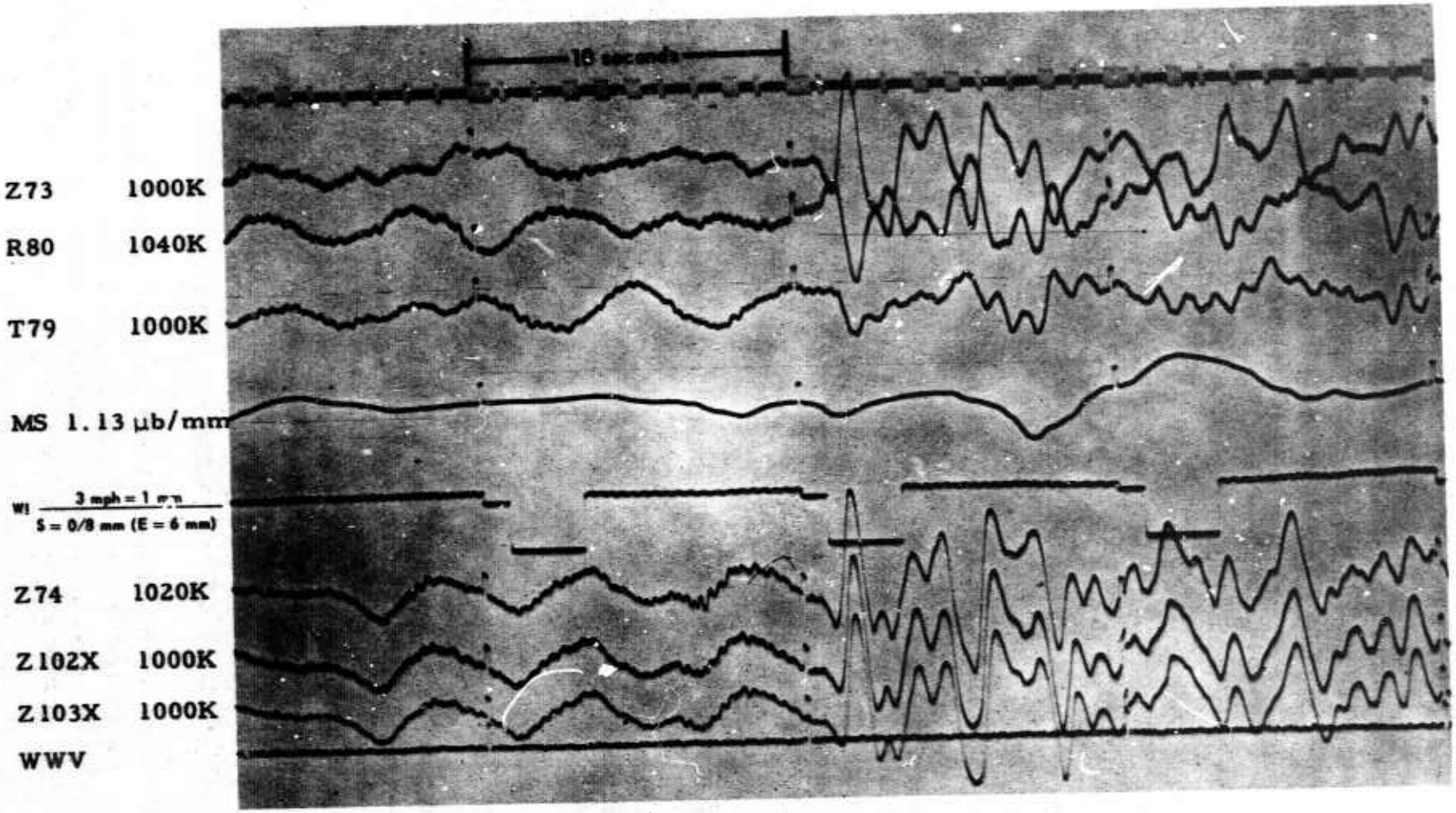
Data from TFSO are combined with data from CPSO, BMSO, UBSO, and WMSO and published in a monthly multistation earthquake bulletin. The bulletins for June through November 1966 were published during this reporting period. Raw data for December 1966 and January and February 1967 were transcribed onto digital magnetic tape and sent to SDL for processing. Keypunching of the March 1967 raw data is about 50 percent complete.




TFSO
Data Group 7207
Run 039
8 February 67

**Figure 9. Short-period seismogram comparing the response of Z102 and Z103X to a near regional event. (X10 enlargement of 16-millimeter film)**

G 2648




TFSO
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Figure 1d. Short-period seismogram comparing the response of Z102X and Z103X with Z4 epicenter OAXACA, Mexico. $\Delta \cong 23.30$; AZ = SSE; h = 46 km, o = 19 39 14.2, m = 4.7 (C&GS). (X10 enlargement of 16-millimeter film)

G 2649

## 5.3 CONTINUE NOISE SURVEY

Measurements of ambient noise in the 0.4- to 1.4-second period range are made daily at TFSO. Data are processed in Garland, and monthly cumulative probability curves of trace amplitude and ground displacement as recorded on the Z60, $\Sigma$T, and $\Sigma$TF seismograms are published. Curves for months of November and December 1966 and January 1967 were sent to the Project Officer during this reporting period.

# 6. PROVIDE OBSERVATORY FACILITIES AND ASSISTANCE TO OTHER ORGANIZATIONS

## 6.1 ASTRODATA DATA ACQUISITION SYSTEM (ASDAS)

Two relays in the Datamec tape transports of the Astrodata system were replaced because of burned contacts, and one lamp failed in the digital clock during February 1967. Adjustments were made in one of the tape transports in an effort to clear up a problem in the rewind cycle which causes occasional tape damage. This problem has not yet been completely resolved.

## 6.2 RECORDINGS FOR THE CALIFORNIA INSTITUTE OF TECHNOLOGY

Weekly shipments of 16-millimeter film, Data Group 7199, were sent to the California Institute of Technology (Cal Tech), except for data requested by VSC which are sent to SDL.

## 6.3 TELEMETRY TO MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Telemetry of seven seismograph channels to Lincoln Labs, Massachusetts Institute of Technology (MIT), continued throughout this reporting period. MIT is notified when the seismographs are attenuated for special tests. Repairs were made to one channel of the telemetry equipment and the center frequency and deviation of all channels was checked during February 1967.

## 6.4 ASTROGEOLOGICAL DEPARTMENT OF USGS

TFSO has continued to support Dr. Harold Krivoy of the Astrogeological Department of the United States Geological Survey (USGS) in Flagstaff, Arizona. Dr. Krivoy receives copies of the daily station message routinely and prints of special interest on request.

## 6.5 SONIC BOOM STUDY

Assistance was provided to the personnel recording field data during the NASA sponsored sonic boom tests at TFSO. Three of eight scheduled missions were flown on 16 February, and four were flown on 21 February. Standard JM seismometers were replaced with JM seismometers equipped with high-impedance coils at locations Z63, Z64, Z66, Z67, Z70, and Z72. Solid-state amplifiers were installed in the vaults to amplify the signals from these transducers. Data from the modified systems were recorded on a station Develocorder at five times the normal film speed and on a station tape recorder which operated with a tape speed of 0.6 inches per second. We also supplied station time (BCD) for the Philco Corporation (NASA) acoustic team.

A 900-foot reversed refraction profile line was surveyed by the Geotech sonic boom team.

## 6.6 COPIES OF C&GS MESSAGE TO BMSO

TFSO terminated sending copies of its daily message to BMSO on 16 January. This was requested by the Station Manager at BMSO.

## 6.7 VISITORS

### 6.7.1 Sonic Boom Program

Mr. George Gerlach, Geotech, and Mr. H. R. Henderson, NASA, Langley Research Center, visited TFSO on 24 and 25 January. The purpose of the visit was to organize the preliminary groundwork for the acoustic sonic boom study to be made on 16 and 21 February 1967.

### 6.7.2 Visits by School Groups

Students and teachers from three area high schools visited TFSO during this reporting period. A tour of the facilities and a lecture on seismology were given to each group.

# 7. RESEARCH PROGRAMS

## 7.1 TESTS OF LONG-PERIOD SEISMOMETERS IN AN EVACUATED SPHERICAL CHAMBER

We plan to conduct tests on both vertical and horizontal long-period seismographs at TFSO with the seismometers installed in a spherical chamber evacuated to a pressure of about one-thousandth of an atmosphere. This environment should eliminate or greatly reduce the effects from several potential sources of nonseismic noise.

The spherical chamber to be used to house the seismometers was obtained on a loan basis from the Ocean Bottom Seismograph Program conducted by Texas Instruments, Inc.

The following tasks were completed in the Garland laboratory in preparation for the tests:

a. Refinishing of the mating surfaces of the sphere which had been corroded by salt water;

b. Procurement of "O" rings and sealing materials;

c. Construction of a fixture to pass 37 conductors into the sphere;

d. Procurement of a vacuum pump, gauge, and other components;

e. Development of a vacuum system and an evacuation technique;

f. Construction and installation of a transducer base plate.

After completion of these tasks, the sphere and vacuum system were shipped to the observatory on 24 March.

## 7.2 TECHNIQUE FOR SEALING SPIRAL-FOUR CABLE CONNECTORS

In the past, a major portion of the problems with the field cables has been caused by electrical leakage at the cable connectors. To reduce leakage problems in the cable systems for the new arrays, we are investigating a technique to provide improved sealing of the spiral-four cable connectors. This technique employs "Scotchkote" compound and plastic electrical tape. The results of initial tests are very encouraging.

## 7.3 COMMUNICATIONS SYSTEM

A communications system to be used in the installation and operation of the expanded arrays at TFSO was ordered from Motorola Communications and Electronics, Inc. in February 1967. The system consists of two mobile transceivers, a base transceiver, a control console, and associated hardware. The base transceiver will be installed about 5 miles northeast of the observatory at Diamond Point and operated from the control console at the observatory. Because of the elevation at Diamond Point (6300 feet), we expect to achieve good communications throughout the array area.

A Special Use Permit was filed with the U. S. Forest Service and U. S. Corps of Engineers to cover the operation of this system. Permission for installation of the antenna tower and cable was received from the District Ranger. The installation of the tower and equipment building at Diamond Point was started in March. Figure 11 shows a photograph of this installation.

**Figure 11. TFSO communication systems antenna tower and equipment building installed at Diamond Point** G 2650

## 7.4 DESIGN AND INSTALL A SHORT-PERIOD ARRAY

### 7.4.1 Land Permitting

The directive authorizing land procurement for the new 37-element short-period array was received by the U. S. Army Corps of Engineers, Project Real Estate Office, Phoenix, Arizona, on 29 March 1967. A meeting will be held in Phoenix on 3 April between the U. S. Forest Service, Corps of Engineers, and TFSO personnel to discuss and finalize plans prior to issuing a "Memorandum of Agreement" between the Forest Service and Corps of Engineers. It is expected that clearance will be granted at the 3 April meeting for TFSO to proceed with construction of the array.

### 7.4.2 Archeological Control

Contact has been established with Mr. Alexander J. Lindsay, Curator of Anthropology, Museum of Northern Arizona. Mr. Lindsay will be in charge of inspection of the surface disturbance area. He has stated that probably all instrument sites and cable trails will have to be visually inspected. They can start this inspection between the middle of April and the first of May 1967.

### 7.4.3 Arizona State Highway Permits

The Arizona State Highway Department was contacted in regards to permitting necessary prior to laying cable across or along highway right-of-way and the use of existing culverts for crossing highways with cable. It is not anticipated that any problems will exist in obtaining the necessary permits.

### 7.4.4 Preliminary Operation Plan

A preliminary plan outlining the order and estimated time needed for various phases of the preparation and installation of the array was drawn up in February. The array was divided into five main array segments (figure 12). Each type of work (e.g., site selection, trail building) started in a segment is to be completed before that work type is started in another segment.

### 7.4.5 Site Selection

Site locations Z1, Z2, Z3, Z20, Z21, Z22, Z36, and Z37 have been selected and marked on the ground. Only Z8 and Z19 remain to be selected within segment V of the array which is to be the first segment installed. Figure 13 shows the array orientation with "to-date" progress.

### 7.4.6 Cable Trail Selection

Cable trails have been selected and flagged in segment V from a point along the present southwest linear trail to Z1, from the end of the present northwest

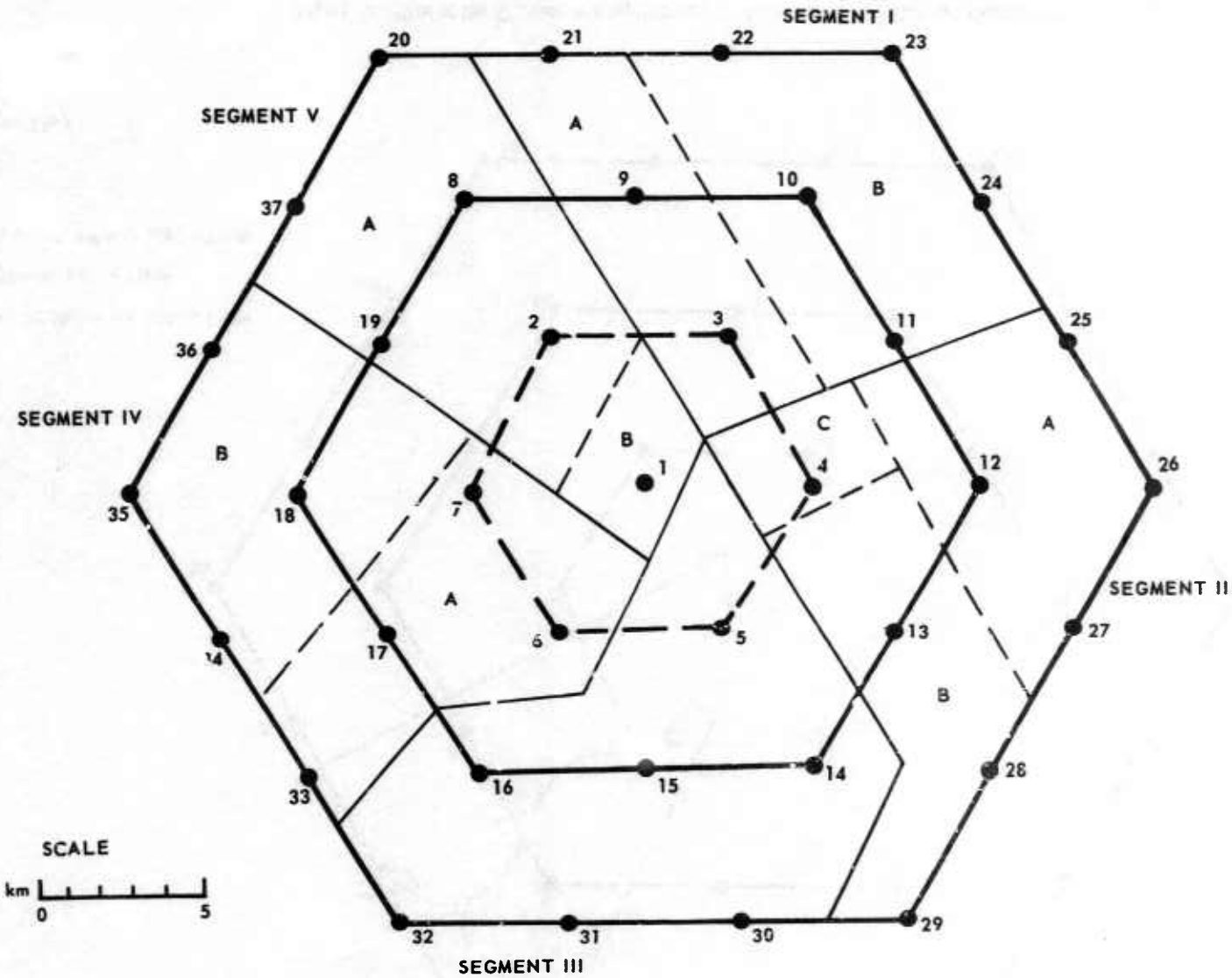


Figure 12. Plan for the 37-element array at TFSO showing the fire main array segments

G 2651

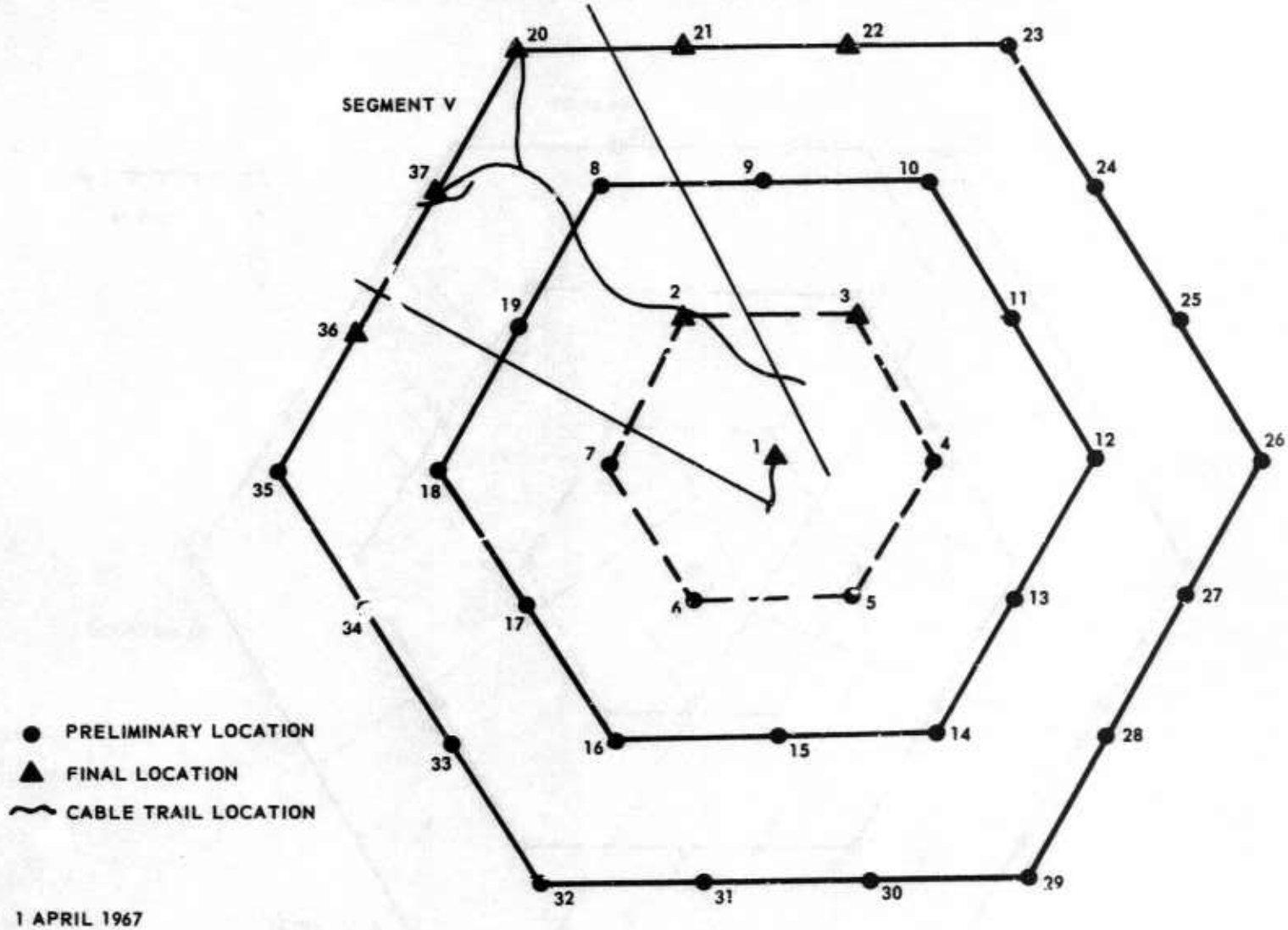


Figure 13. Plan of the 37-element array showing the locations of the sites and cable trails

G 2652

linear trail to Z2, and from Z37 and Z20 south to within approximately 1 mile of Z2. It is expected that the remaining trails in segment V will be flagged during the first week in April.

### 7.4.7 Material Received

We ordered 1100 reels of spiral-four cable for the 37-element array. Some cables in the first partial shipment were found to have electrical shorts and leakage. The supplier was informed, and 44 extra reels were included in the final shipments to replace the defective cables.

Fifteen steel vaults have been received at TFSO and 23 vaults are in transit. Approximately 200 4-inch by 4-inch posts and a quantity of boards have been procured from a local sawmill for use in mounting junction boxes along the cable trails.

### 7.4.8 Cable Installation

Cable installation was started in March along the northwest leg of the cable trail for the present linear array. Approximately 13 miles of cable and 12 new junction boxes have been installed. In addition, one dry stream crossing was rebuilt and a new road crossing constructed. All cables presently in use in the 19-element array which will be used for the 37-element array have been tagged with metal bands showing the new system identification.

### 7.4.9 Array Survey

Approval was received from the Project Officer in March for the survey of the 37-element array by the 1381st Geodetic Survey Squadron. Survey data are required by 1 November 1967.

### 7.4.10 Modification of Array Seismometers

High-impedance coils for 38 JM vertical seismometers were received in January 1967. These coils are required for all seismometers to be used with solid-state amplifiers in the new 37-element array. One coil was found to be defective and was returned to Garland.

High-impedance coils have been installed in 20 seismometers. After installation, the motor constant and mass position of each seismometer was adjusted.

## 7.5 DESIGN AND INSTALL A LONG-PERIOD ARRAY

### 7.5.1 Long-Period Noise Study

To provide data for determination at the optimum configuration for the long-period array at TFSO, five LRSM portable systems were assigned to gather data.

Tank vaults for the long-period seismometers of the portable systems were installed by the end of January (figure 14). Three of the systems were installed and calibrated during this same period. Routine shipment of the long-period array noise data from all sites was begun on 17 February 1967.

Phase response measurements were completed on all systems, including TFSO, during February and a mean phase response curve was established. Any system deviating from the mean by greater than 10 degrees at 18 seconds was corrected and brought into tolerance. Figure 15 is the phase-response curve and figure 16 is the frequency-response curve for the long-period systems.

Special dummy load tests were performed between 21 and 23 March 1967 to determine the level of the portable system noise. During these tests, the east-west horizontal seismometer of each system was replaced by a resistor for a period of approximately 48 hours.

Details on the location, orientation, geology, and vault construction for the long-period noise survey array have been outlined in a separate report.

a. Vaults

b. Area in vicinity of PY3AZ

Figure 14. Long-period noise study vaults during installation and area in the immediate vicinity of PY3AZ

G 2653

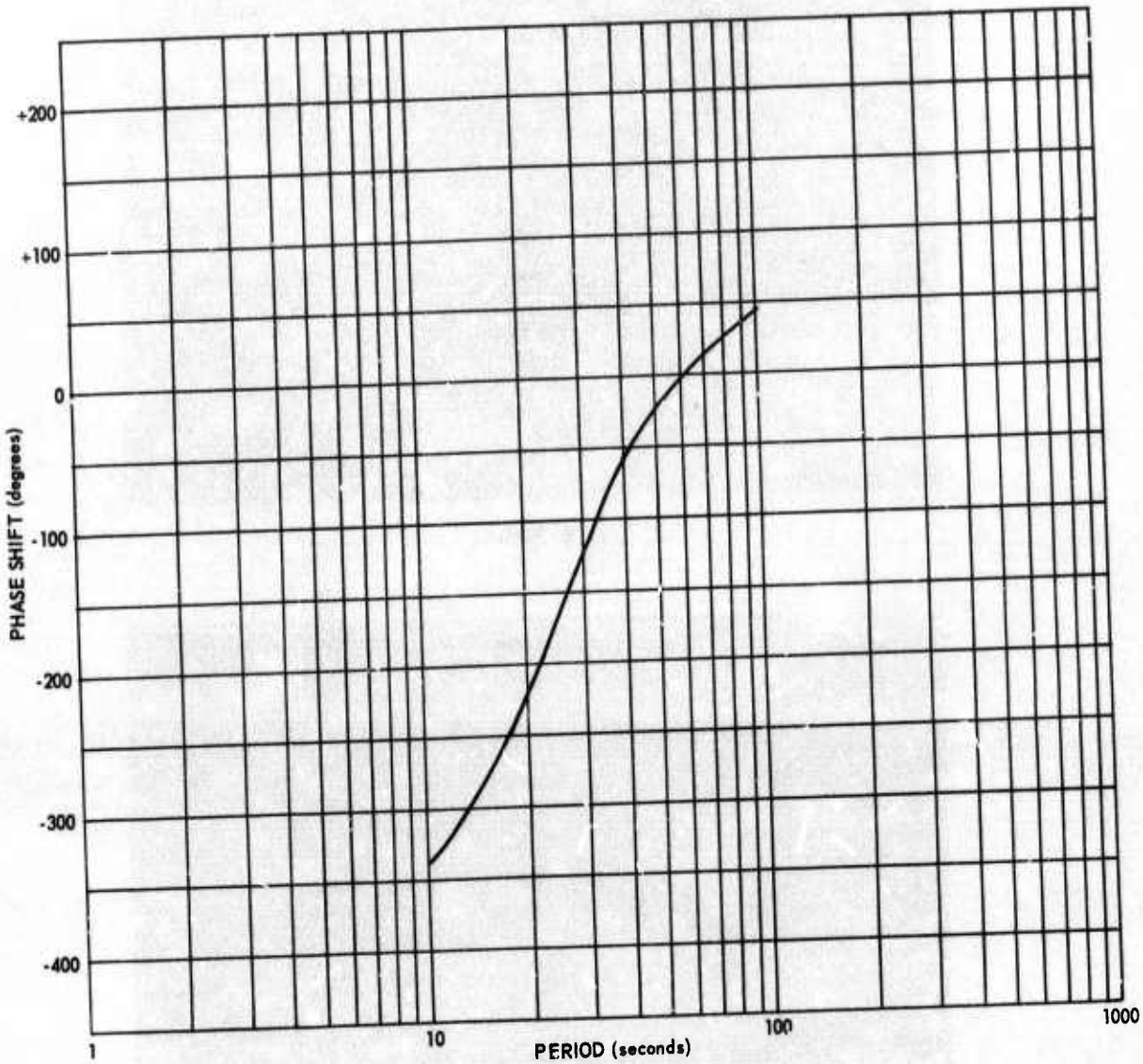


Figure 15. Average phase response for portable LRSM long-period systems G 2654

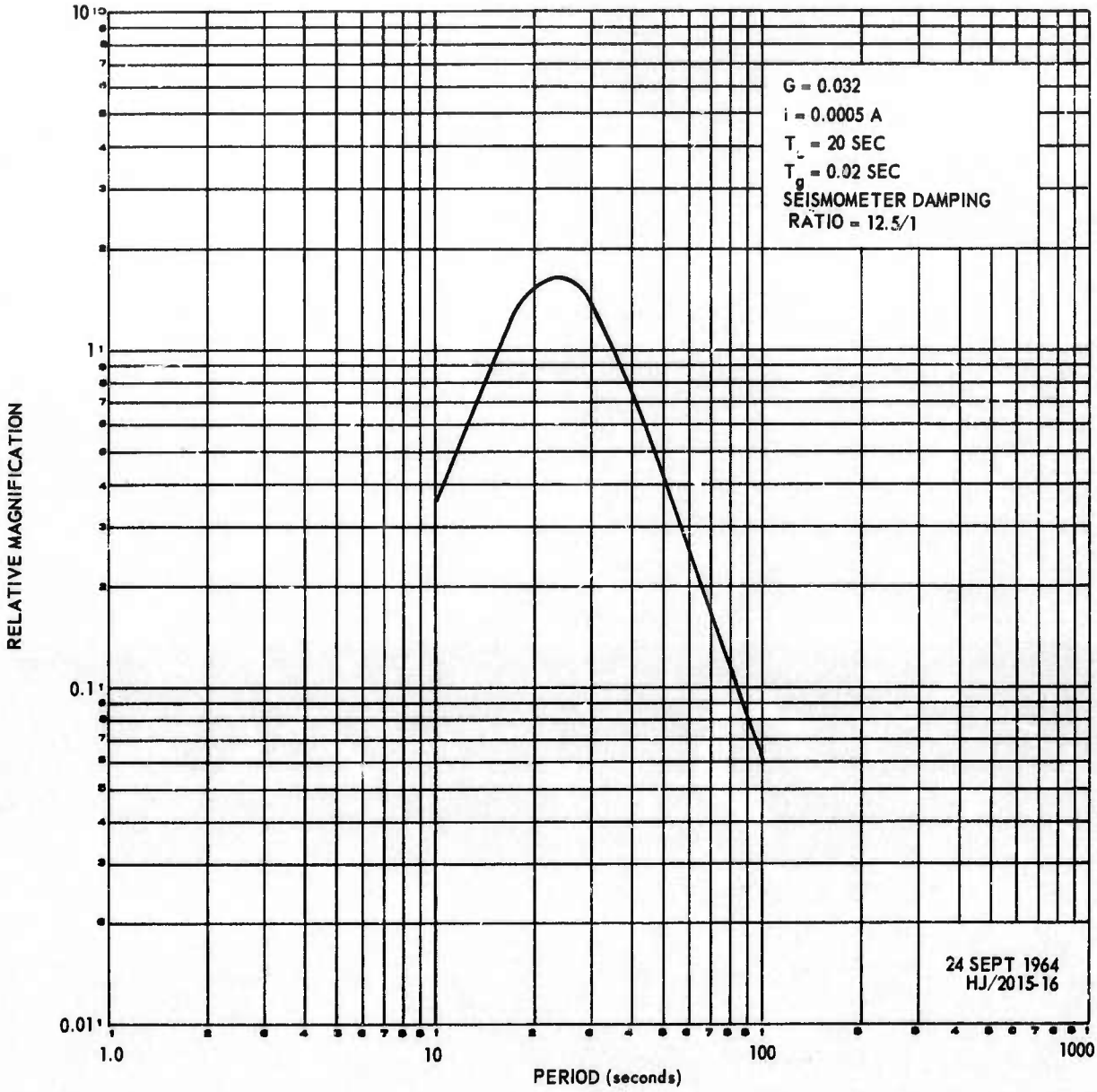


**Figure 16. Typical long-period response of the LRSM portable long-period system**

G 1021

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13. ABSTRACT

This is a report of the work accomplished on Project VT/7702 from 1 January through 31 March 1967. Project VT/7702 includes the operation, evaluation, improvement, and expansion 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.

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| 14. KEY WORDS | LINK A ROLE | LINK A WT | LINK B ROLE | LINK B WT | LINK C ROLE | LINK C WT |
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| Long-Period Seismometer Tests | | | | | | |
| Short-period Array Design and Installation | | | | | | |
| Long-Period Noise Study | | | | | | |

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APPENDIX to TECHNICAL REPORT NO. 67-25

STATEMENT OF WORK TO BE DONE

STATEMENT OF WORK TO BE DONE
(AFTAC Project Authorization No. VELA T/7702/S/ASD) (32)

Tasks:

a. Operation:

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

(2) 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 possible. Addition and modification of instrumentation 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 AFTAC project officer.

(3) Conduct routine daily analysis of seismic data at the observatory and transmit daily seismic reports to the Environmental Science Services Administration, Coast and Geodetic Survey, Wash DC using the established report format and detailed instructions.

(4) Record the results of daily analysis on magnetic tape in a format compatible with the automated bulletin program used by the Seismic Data Laboratory (SDL) in their preparation of the seismological bulletin of the VELA-UNIFORM seismological observatories. The format should be established by coordination with SDL through the AFTAC project officer. The schedule of routine shipments of these prepared magnetic tapes to SDL will be established by the AFTAC project officer.

(5) Establish quality control procedures and conduct quality control, as necessary, to assure the recording of high quality data on both magnetic tape and film. Past experience indicates that a quality control review of one magnetic tape per magnetic tape recorder at the observatory during each week is satisfactory unless quality control tolerances have been exceeded and the necessity of additional quality control arises. Quality control of magnetic tape should include, but need not necessarily be limited to, the following items:

(a) Completeness and accuracy of operation logs.

(b) Accuracy of observatory measurements of system noise and equivalent ground motion.

(c) Quality and completeness of voice comments.

(d) Examination of all calibrations to assure that clipping does not occur.

(e) Determination of relative phase shift on all array seismographs.

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(f) Measurement of DC unbalance.

(g) Presence and accuracy of tape calibration and alignment.

(h) Check of uncompensated noise on each channel.

(i) Check of uncompensated signal-to-noise of channel 7.

(j) Check of general strength and quality of timing data derived from National Bureau of Standards Station WWV.

(k) Check of time pulse modulated 60 cps on channel 14 for adequate signal level and for presence of time pulses.

(l) Check of synchronization of digital time encoder with WWV.

(6) Provide observatory facilities, accompanying technical assistance by observatory personnel, and seismological data to requesting organizations and individuals after approval by the AFTAC project officer.

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

b. Instrument Evaluation: On approval by the AFTAC project officer, 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. Special Investigations:

(1) Conduct research investigations as approved or requested by the AFTAC project officer to obtain fundamental information which will lead to improvements in the detection capability of TFSO. These programs should take advantage of geological, meteorological, and seismological conditions of the observatory. The following special studies should be accomplished:

(a) Design and install an array of approximately 37 short-period vertical seismographs. This array should be about 30 kilometers in diameter. The equipment and detector sites of existing arrays should be used to the extent possible in the design of the extended array.

(b) Design and install a 7 to 10 element array of long-period seismographs. This array should be approximately 30 kilometers in diameter.

(c) Evaluate the beam-steering capabilities of both arrays.



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(2) Research might pursue investigations in, but is not necessarily limited to, the following areas of interest: microseismic noise, signal characteristics, data presentation, detection threshold, and array design (surface and shallow borehole).

(3) Prior to commencing any research investigation, AFTAC approval of the proposed investigation and of a comprehensive program outline of the intended research must be obtained.



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