TR 65-58

# TECHNICAL REPORT NO. 65-58

# OPERATION OF THREE OBSERVATORIES

Final Report, Project VT/1124, 1 July 1963 through 30 April 1965
and
Semiannual Report No. 3, 1 July 1964 through 30 April 1965

Code 1

GEOTECH

THE GEOTECHNICAL CORPORATION

3401 SHILOH ROAD
GARLAND, TEXAS

TECHNICAL REPORT NO. 65-58

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THE GEOTECHNICAL CORPORATION
3401 Shiloh Road
Garland, Texas

1 July 1965

# IDENTIFICATION

| | |
|---|---|
| AFTAC Project No: | VT/1124 |
| Project Title: | Operation of Three Observatories |
| ARPA Order No: | 104-60 |
| ARPA Project Code No: | 8100 |
| Name of Contractor: | The Geotechnical Corporation |
| Date of Contract: | 1 July 1963 |
| Amount of Contract: | $568,521 |
| Amount of Supplemental Agreements to the Contract: | |
| Supplemental Agreement No. 1: | $ - |
| Supplemental Agreement No. 2: | $248,512 |
| Supplemental Agreement No. 3: | $190,000 |
| Supplemental Agreement No. 4: | $ 86,400 |
| Supplemental Agreement No. 5: | $ 86,400 |
| Amount of Total Contract: | $1,179,833 |
| Contract Number: | AF 33(657)-12373 |
| Contract Expiration Date: | 30 April 1965 |
| Program Manager: | B. B. Leichliter, BR-8-8102 |

# ABSTRACT

The operation of the Blue Mountains Seismological Observatory, Cumberland Plateau Seismological Observatory, and Uinta Basin Seismological Observatory between 1 July 1963 and 30 April 1965 is discussed in this report. Modifications and additions to the observatory instrumentation are described and tests to improve the operation of the observatories are reported.

Also discussed in the report is the progress of special investigations designed to evaluate and improve the detection capability of the observatories.

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# OPERATION OF THREE OBSERVATORIES

Final Report, Project VT/1124, 1 July 1963 through 30 April 1965
and
Semiannual Report No. 3, 1 July 1964 through 30 April 1965

## 1. INTRODUCTION

This is both a final report of the work done under Project VT/1124 from 1 July 1963 through 30 April 1965 and a semiannual report of the work of the project between 1 July 1964 and 30 April 1965. Because of the partial coincidence of reporting periods, the two reports have been combined. Project VT/1124 includes the operation, evaluation, and improvement of the Blue Mountains Seismological Observatory (BMSO), Cumberland Plateau Seismological Observatory (CPSO), and the Uinta Basin Seismological Observatory (UBSO). BMSO, CPSO, and UBSO are located near Baker, Oregon; McMinnville, Tennessee; and Vernal, Utah; respectively.

### 1.1 AUTHORITY

Authority for the operation of BMSO, CPSO, and UBSO from 1 July 1963 through 30 April 1965 was contained in Contract AF 33(657)-12373, Project VT/1124, "Operation of Three Observatories," dated 1 July 1963, and in five supplemental agreements. The Air Force Technical Applications Center (AFTAC) has technical supervision of the contract as part of Project VELA-UNIFORM, which is under the overall direction of the Advanced Research Projects Agency (ARPA).

### 1.2 PURPOSE OF BMSO, CPSO, AND UBSO

The purpose of BMSO, CPSO, and UBSO is multifold. First, seismometric data are recorded, analyzed, and reported to the United States Coast and Geodetic Survey (USC&GS) daily, and the standard instrumentation of the observatory is maintained and continually evaluated. Second, the VT/1124 seismological observatories are used as field laboratories where newly developed instruments and techniques are field tested and evaluated to determine their usefulness at an observatory. Third, the data recorded at the VT/1124 observatories are studied in an effort to improve and refine earthquake detection and source-mechanism identification capabilities. The recorded data are also made available to groups and individuals outside the VT/1124 framework for use in their investigations.

## 1.3 HISTORY OF PROJECT VT/1124

The three seismological observatories operated under Project VT/1124 were constructed under Contract AF 33(657)-7185. Site selection and noise surveys for each observatory were accomplished by The Geotechnical Corporation; the final decision on locations for the observatories was made by AFTAC. Texas Instruments Incorporated (TI) was responsible for the construction of all physical facilities.

Contract AF 33(600)-43486, issued to TI, contained the authority for equipping and operating the observatories. The instrumentation was supplied by Geotech and was installed under the direction of Geotech personnel under subcontract to TI. The observatories became operational on the following dates:

| Observatory | Operational date |
|---|---|
| BMSO | 13 August 1962 |
| UBSO | 26 November 1962 |
| CPSO | 22 December 1962 |

## 1.4 WORK OF CONTRACT 12373

During the 22-month period from 1 July 1963 through 30 April 1965, the work of Contract 12373 was very similar to the work performed at the Wichita Mountains Seismological Observatory (WMSO), near Lawton, Oklahoma, under Projects VT/036 and VT/4054. In fact, when reasonable, operating procedures, observatory instrumentation improvements, and special investigations were accomplished simultaneously for WMSO and the VT/1124 observatories. The work conducted during the last 22 months can be subdivided into four categories:

a. Continued operation of BMSO, CPSO, and UBSO;

b. Evaluation of standard and experimental detection equipment to provide more efficient and effective observatories;

c. Testing and evaluation of new instrumentation;

d. Routine and special analysis of resulting seismometric data.

The detailed work statement for the contract is included in this report as appendix 1.

### 1.5 BMSO, CPSO, AND UBSO FACILITY CLEARANCE

Early in the reporting period, application for facility clearance for each observatory was filed with the Department of Defense. After inspection of the facilities and approval of the security procedures, each observatory was granted SECRET facility clearance.

## 2. OPERATION OF BMSO, CPSO, AND UBSO

### 2.1 GENERAL

Data were recorded at BMSO, CPSO, and UBSO on a continuous basis. The observatories were normally manned between 8 and 10 hours a day, 5 days a week. On weekends and holidays, the observatories were manned by a skeleton crew 8 hours a day; however, additional personnel were on call in the event that an emergency situation arose. Figure 1 is the organization chart for Project VT/1124.

As the result of findings and recommendations made under other projects and developments during the term of this contract, some changes and additions were made to the instrumentation at the observatories after approval had been received from the Project Officer.

Initial arrival times from earthquakes were reported to the USC&GS daily. Earthquake phase-arrival times recorded at BMSO, CPSO, and UBSO were reported in a five-station earthquake bulletin, published monthly.

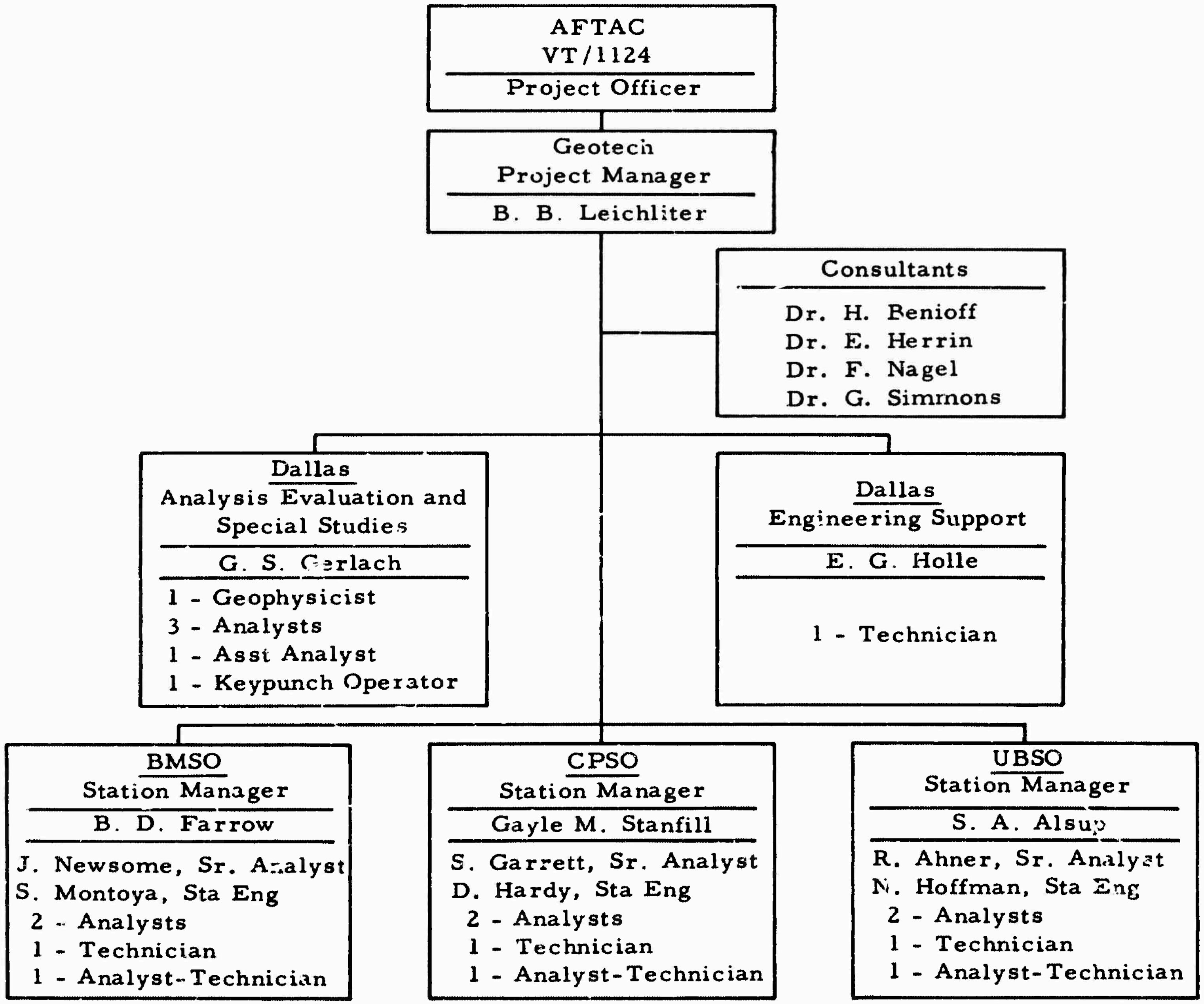


Figure 1. Organization of Project VT/1124

Analysis studies were conducted using data from the VT/1124 observatories. Throughout the contract period, technical assistance, observatory facilities, and the accumulated data were made available to other interested groups and individuals approved by the Project Officer.

## 2.2 TRANSFER OF MANAGEMENT

Geotech assumed responsibility for the operation of BMSO, CPSO, and UBSO on 1 July 1963. E. G. Holle and G. S. Gerlach were temporarily assigned to CPSO and UBSO, respectively, as station managers to effect the official transfer of responsibility for the observatories from TI to Geotech. Texas Instruments field personnel at CPSO and UBSO were very cooperative, and assisted Geotech personnel in the transfer of information, equipment, and facilities. The operation of BMSO, previously operated by Geotech under subcontract to TI, continued without interruption in management.

Joint inventories were made by TI and Geotech personnel at both observatories, and all transfers were finalized by 5 July. Supplies adequate for operation through 30 Septem r (film, magnetic tape, etc.) had been ordered by TI prior to 1 July and were received at each observatory early in July.

## 2.3 STANDARDIZATION OF OPERATIONS AMONG THE VT/1124 OBSERVATORIES AND WMSO

### 2.3.1 General

The routine operating and analysis procedures used at the VT/1124 observatories were made the same as the operating procedures used at WMSO wherever possible. A series of 18 "Seismological Observatory Preliminary Standard Operating Procedures" (SOP's) were developed and put into effect. Copies of each of these preliminary SOP's were forwarded to the Project Officer as they were adopted. A final manual of seismological observatory SOP's (TR 64-59) was published under Project VT/036 on 20 June 1964. This manual was adopted at the VT/1124 observatories and was used throughout the remainder of Project VT/1124. Based on several months' experience in operating under the specifications contained in TR 64-59, revisions are being made jointly under Contracts 12373 and 13562. This revised SOP will be published during the last half of 1965.

### 2.3.2 Operating Parameters and Tolerances of the Routine Seismographs

The operating parameters of the standard seismographs used at the observatories during the reporting period are given in table 1. Also given in the table are the tolerances on these parameters and the filter settings used with each seismograph.

The parameters are checked and reset, if necessary, when the special calibration of the frequency response is made each month. The specified frequency response tolerances of each seismograph as operated throughout the reporting period, are given in table 2. Figure 2 shows the responses of the seismographs as operated at the end of the period.

### 2.3.3 Standardization of Calibration Procedures

In June 1963, a request was received from AFTAC to review the proposed AFTAC "Standardization of Calibration Procedures" for VELA-UNIFORM observatories. After they were reviewed by the Geotech staff, changes in the procedures were recommended in a letter report to AFTAC dated 14 August 1963. Early in October 1963, we received a copy of Seismograph Calibration Standards, Project VELA-UNIFORM, AFTAC Technical Report VU-63-5. The procedures specified in this report were adopted on 10 October 1963, as requested by the Project Officer.

In general, the procedures proved to be satisfactory for routine use. After the observatories had been operated for some 10 months using these procedures, they were again reviewed by the Geotech staff. On the basis of this second review, changes in the standards and in the logs were recommended in a letter report to AFTAC dated 26 January 1965.

Early in April 1965, we received a copy of "Revision to Seismograph Calibration Standards" from AFTAC. This letter changed some of the standards and logs established in AFTAC Technical Report VU-63-5. As requested, the revised calibration standards were adopted on 6 April. The new logs are being adopted as stocks of the old logs are depleted.

The changes in calibration standards are as follows:

a. In the monthly special calibration to check the frequency responses of the short-period seismographs, calibrations at 8 Hz and at 10 Hz have been deleted from the table of frequencies.

## Table 1. Operating parameters and tolerances of seismographs at BMSO, CPSO, and UBSO

| Seismograph | | | | Operating parameters and tolerances | | | | | Filter settings | |
|---|---|---|---|---|---|---|---|---|---|---|
| System | Comp | Type | Model | $T_s$ | $\lambda_s$ | $T_g$ | $\lambda_g$ | $\sigma^2$ | Bandpass at 3 dB cutoff (sec) | Cut off rate at SP side (dB /oct) |
| SP | Z and H | Johnson-Matheson | 7515<br>6480 | 1.25 ±2% | 0.51 ±5% | 0.33 ±5% | 0.65 ±5% | 0.03 | 0.1-100 | 12 |
| SP | SZ | Geotech | 18300 | 1.25 ±2% | 0.51 ±5% | 0.33 ±5% | 0.65 ±5% | 0.033 | 0.1-100 | 12 |
| SP | H | Benioff | 6102A | 1.0 ±5% | 1.0 ±5% | 0.2 ±5% | 1.0 ±5% | 0.06 | 0.1-100 | 12 |
| SP | Z | UA Benioff | 1051 | 1.0 ±5% | 1.0 | 0.083 ±5% | ≈1.4 | 1.0 | - | - |
| IB | Z | Melton | 10012 | 2.5 ±5% | 0.65 ±5% | 0.64 ±5% | 1.2 ±5% | 0.018 | 0.05-100 | 12 |
| IB | H | Geotech | 8700B | 2.5 ±5% | 0.65 ±5% | 0.64 ±5% | 1.2 ±5% | 0.001 | 0.05-100 | 12 |
| BB | Z | Geotech | 7505A | 12.5 ±5% | 0.485 ±5% | 0.64 ±5% | 9.0 ±5% | 0.0007 | 0.05-100 | 12 |
| BB | H | Geotech | 8700A | 12.5 ±5% | 0.485 | 0.64 ±5% | 9.0 ±5% | 0.0007 | 0.05-100 | 12 |
| LP | Z | Geotech | 7505A | 20.0 ±5% | 0.74 ±5% | 110 ±10% | 1.0 ±10% | 0.175 | 25-1000 | 12 |
| LP | H | Geotech | 8700A | 20.0 ±5% | 0.74 ±5% | 110 ±10% | 1.0 ±10% | 0.175 | 25-1000 | 12 |

KEY

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

| | |
|---|---|
| $T_s$ | Seismometer free period (sec) |
| $T_g$ | Galvanometer free period (sec) |
| $\lambda_s$ | Seismometer damping constant |
| $\lambda_g$ | Galvanometer damping constant |
| $\sigma^2$ | Coupling coefficient |

## Table 2. Calibration norms and operating tolerances for frequency responses of the standard seismographs at BMSO, CPSO, and UBSO

| SP Johnson-Matheson Vertical and Horizontal | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| f | T | Jul 63-Feb 64 | | Mar 64-Nov 64 | | Nov 64-Mar 65 | | Apr 65 | |
| (Hz) | (sec) | R. M. | A. T. (±%) | R. M. | A. T. (±%) | R. M. | A. T. (±%) | R. M. | A. T. (±%) |
| 0.2 | 5.0 | 0.012 | 15 | 0.0120 | 10 | 0.0112 | 10 | 0.0113 | 10 |
| 0.4 | 2.5 | 0.095 | a | 0.0950 | 7.5 | 0.0950 | 7.5 | 0.0950 | 7.5 |
| 0.8 | 1.25 | 0.685 | 5 | 0.685 | 5 | 0.685 | 5 | 0.685 | 5 |
| 1.0 | 1.0 | 1.0 | - | 1.0 | - | 1.0 | - | 1.0 | - |
| 1.5 | 0.67 | 1.52 | 5 | 1.52 | 5 | 1.52 | 5 | 1.52 | 5 |
| 2.0 | 0.5 | 1.90 | 5 | 1.90 | 5 | 1.90 | 5 | 1.90 | 5 |
| 3.0 | 0.33 | 2.12 | 10 | 2.12 | 7.5 | 2.12 | 7.5 | 2.12 | 7.5 |
| 4.0 | 0.25 | 2.00 | 15 | 1.87 | 12 | 1.87 | 12 | 1.87 | 12 |
| 6.0 | 0.167 | 1.15 | a | 1.15 | 20 | 1.15 | 20 | 1.15 | 20 |
| 8.0 | 0.125 | 0.64 | a | 0.640 | 25 | 0.640 | 25 | | |
| 10.0 | 0.100 | 0.37 | a | 0.370 | 25 | 0.370 | 25 | | |

| SP Benioff Horizontal | | | |
|---|---|---|---|
| f | T | Jul 63-Oct 63 | |
| (Hz) | (sec) | R. M. | A. T. (±%) |
| 0.2 | 5.0 | 0.01 | 15 |
| 0.5 | 2.0 | 0.15 | 10 |
| 0.8 | 1.25 | 0.56 | 5 |
| 1.0 | 1.0 | 1.0 | - |
| 1.5 | 0.67 | 2.15 | 5 |
| 2.0 | 0.5 | 2.8 | 5 |
| 3.0 | 0.33 | 3.2 | 10 |
| 4.0 | 0.25 | 3.0 | 15 |
| 5.0 | 0.2 | 2.4 | 20 |

| IB Vertical and Horizontal | | | | | |
|---|---|---|---|---|---|
| f | T | Jul 63-Feb 64 | | Feb 64-Apr 65 | |
| (Hz) | (sec) | R. M. | A. T. (±%) | R. M | A. T. (±%) |
| 0.1 | 10.0 | 0.0090 | 20 | 0.0090 | 25 |
| 0.2 | 5.0 | 0.068 | 15 | 0.068 | 20 |
| 0.3 | 3.3 | 0.25 | 10 | 0.25 | 15 |
| 0.4 | 2.5 | 0.46 | 5 | 0.46 | 10 |
| 0.5 | 2.0 | 0.64 | 5 | 0.64 | 5 |
| 0.7 | 1.43 | 0.86 | 5 | 0.86 | 5 |
| 1.0 | 1.0 | 1.0 | - | 1.0 | - |
| 1.5 | 0.67 | 1.04 | 5 | 1.04 | 5 |
| 2.0 | 0.5 | 1.0 | 5 | 1.0 | 10 |
| 3.0 | 0.33 | 0.89 | 10 | 0.89 | 15 |
| 5.0 | 0.2 | 0.66 | 10 | 0.66 | 20 |

| BB Vertical and Horizontal | | | | | |
|---|---|---|---|---|---|
| f | T | Jul 63-Feb 64 | | Mar 64-Apr 65 | |
| (Hz) | (sec) | R. M. | A. T. (±%) | R. M. | A. T. (±%) |
| 0.04 | 25.0 | 0.104 | a | 0.104 | 20 |
| 0.06 | 16.7 | 0.350 | a | 0.350 | 20 |
| 0.08 | 12.5 | 0.775 | 10 | 0.775 | 15 |
| 0.1 | 10.0 | 0.950 | 5 | 0.950 | 10 |
| 0.2 | 5.0 | 1.0 | 5 | 1.0 | 5 |
| 0.4 | 2.5 | 1.0 | 5 | 1.0 | 5 |
| 0.8 | 1.25 | 1.0 | - | 1.0 | - |
| 1.6 | 0.625 | 1.0 | 5 | 1.0 | 5 |
| 3.2 | 0.312 | 1.0 | 10 | 1.0 | 10 |
| 6.4 | 0.156 | 0.980 | 15 | 0.980 | 15 |

| LP Vertical and Horizontal | | | |
|---|---|---|---|
| f | T | Jul 63-Apr 65 | |
| (Hz) | (sec) | R. M. | A. T. (±%) |
| 0.01 | 100 | 0.246 | 20 |
| 0.0125 | 80 | 0.377 | 20 |
| 0.0167 | 60 | 0.589 | 15 |
| 0.02 | 50 | 0.745 | 15 |
| 0.025 | 40 | 0.899 | 10 |
| 0.033 | 30 | 1.06 | 5 |
| 0.04 | 25 | 1.0 | - |
| 0.05 | 20 | 0.822 | 5 |
| 0.0667 | 15 | 0.506 | 10 |
| 0.10 | 10 | 0.173 | 20 |
| 0.143 | 7 | b | a |

KEY

R. M. Relative magnification
A. T. Amplitude tolerance
a Tolerance not established in the period
b Measurements not reliable due to interference from microseismic background noise

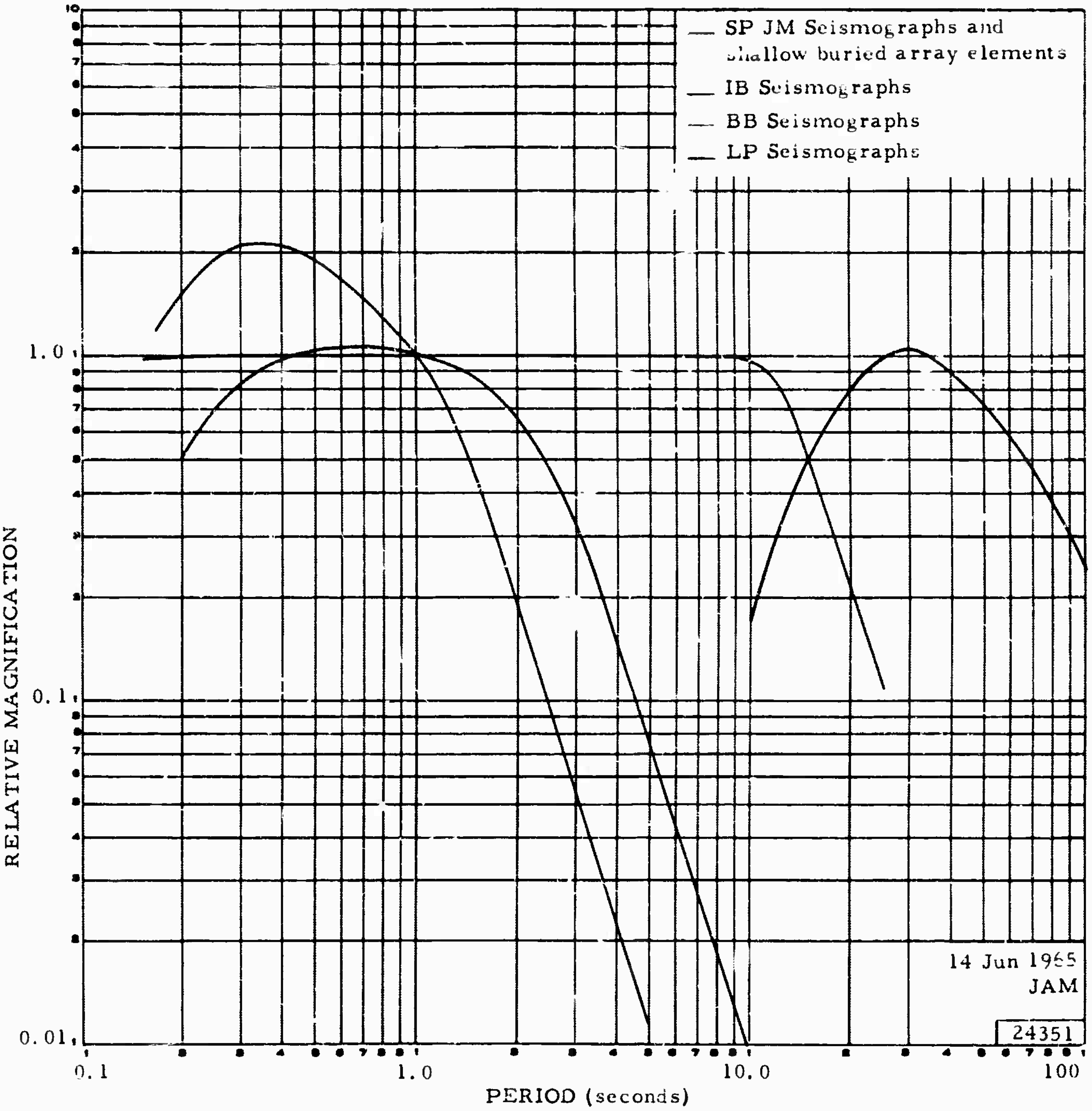


Figure 2. Normalized response characteristics of the routine seismographs at BMSO, CPSO, and UBSO at the end of the reporting period

b. In the monthly long-period seismograph frequency response check, the calibration current may be increased by a factor of 5 at 0. 1 Hz and a factor of 10 at 0. 143 Hz relative to the current at the other frequencies.

c. In the daily calibration of long-period seismographs, the table of equivalent ground motions has been revised to include 0. 5 micron for magnifications above 45K.

The four calibration logs have been revised. Examples of the revised "Special Calibration Log," "Daily Calibration Log," "Tape Recorder Log," and "Daily Operating Log" are given in appendix 2.

### 2. 3. 4 Seismograph Polarity Assurance

In an effort to prevent inadvertent polarity reversals at the observatories, a procedure for checking seismograph polarities was initiated in September 1963. The procedures adopted for the polarity check are:

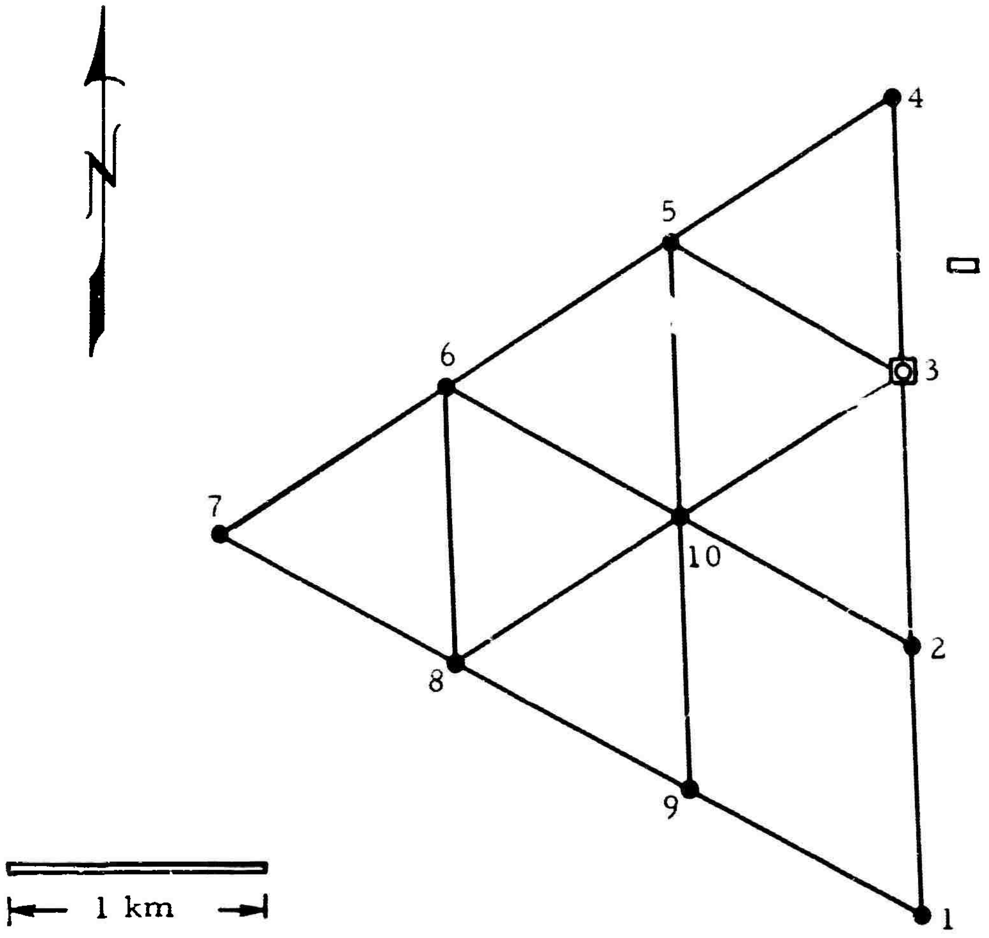
a. Three dc pulses are applied to each seismograph every Monday. The pulses are recorded immediately before the daily sine-wave calibrations. The station engineer checks the pulses on the Helicorder records and on magnetic tape (by oscilloscope) to assure that the polarity of each seismograph is correct.

b. The senior analyst also checks the pulses on the film records. If the senior analyst detects any polarity discrepancy, weight lifts are made to assure that the polarity of the seismograph in question is correct.

c. Magnetic-tape records for this day are monitored by the Quality Control Group in Dallas to assure correct polarity, i. e. , pulse-off yields decrease in carrier frequency of the FM signal.

### 2. 3. 5 Standardization and Identification of Recording Formats

The arrangement of data on the primary Develocorder has been standardized at each observatory. The earth-powered seismograph is recorded on channel 1. The next three channels are the corners of the triangular array; in the case of BMSO, Z1, Z4, and Z7 (see figure 3). The summation of the array is on channel 12 and the filtered summation on channel 11. Seismometers comprising the three-component SP system are recorded on channels 13, 14, and 15.



◎ Tank farm
▭ Central recording building
● Array seismometers

Coordinates of tank farm: 44°50'56"N 117°18'20"W
Elevation: 1189 meters above sea level

Figure 3. Orientation and configuration of the BMSO array

The Project Officer requested that each data format for the Develocorders and the magnetic-tape recorders be assigned a three-digit data group number. These were started on 1 November 1963. When a data format was changed, a new data group number was assigned and the information recorded on the data format assignment form. The data block numbers were extended to four-digit numbers on 1 February 1964. In addition, the data format assignment form was standardized to the form then used at TFSO. An example of the present data format assignment form is shown in appendix 2.

### 2.3.5.1 BMSO

The data channel assignments for each of the Develocorders and for the magnetic-tape recorders at BMSO are given in table 3. Each is identified by its data group number.

A secondary fast-speed Develocorder was activated at BMSO on 10 February 1964. The data recorded on the secondary Develocorder have proved to be valuable during the preliminary analysis of seismograms. The summations of the 1-km triangles at the apexes of the array ($\Sigma A$, $\Sigma B$, and $\Sigma C$) are used in determining the azimuth of signals and in signal detection in the event of malfunctions of the primary Develocorder. The low-gain three-component short-period seismograph system is useful as an intermediate magnification system for large signals.

Figures 4 through 6 are examples of the primary, secondary, and long-period data formats currently recorded on the Develocorders at BMSO.

### 2.3.5.2 CPSO

The data channel assignments for each of the Develocorders and the magnetic-tape recorders at CPSO are given in table 4. Each is identified by a data group number. The CPSO array configuration is shown in figure 7.

The secondary fast-speed Develocorder, activated at CPSO on 20 December 1963, has generally been used for several types of summations (see table 4).

Figures 8 through 10 are examples of the primary, secondary, and long-period data formats currently recorded on Develocorders at CPSO.

Table 3. Data channel assignments and normal operating m [illegible] and

DEVELOCORDERS

Fast-speed, 30 mm/minute

| | Primary data | | | | | Secondary data | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Channel | DG 402[a]<br>1 July 63-<br>31 Jan 64 | Mag | DG 4002<br>1 Feb 64-<br>30 Apr 5 | Mag | Channel | DG 4006<br>10 Feb 64-<br>10 Mar 65 | Mag | DG 4008<br>10 Mar 65-<br>12 Mar 65 | Mag | DG 4009<br>12 Mar 65-<br>30 Apr 65 | M |
| 1 | V | 19K | V | 19K | 1 | - | - | - | - | - | |
| 2 | Z1 | 750K | Z1 | 750K | 2 | Z8L | 70K | Z3 | 1500K | Z3 | 15 |
| 3 | Z4 | 750K | Z4 | 750K | 3 | Z8 | 750K | Z3L | 70K | Z3L | |
| 4 | Z7 | 750K | Z7 | 750K | 4 | ΣQ | 1060K | NSL | 70K | NSL | |
| 5 | Z2 | 750K | Z2 | 750K | 5 | Z3L | 70K | ESL | 70K | ESL | |
| 6 | Z5 | 750K | Z5 | 750K | 6 | NSL | 70K | ΣQ | 1000K | ΣQ | 10 |
| 7 | Z6 | 750K | Z6 | 750K | 7 | ESL | 70K | ΣA | 1000K | ΣA | 1 |
| 8 | Z8 | 750K | Z8 | 750K | 8 | ΣA | 1000K | ΣB | 1000K | ΣB | 10 |
| 9 | Z9 | 750K | Z9 | 750K | 9 | ΣB | 1000K | ΣC | 1000K | ΣC | 10 |
| 10 | Z10 | 750K | Z10 | 750K | 10 | ΣC | 1000K | MS | - | MS | - |
| 11 | ΣSF | 5000K | ΣSF | 5000K | 11 | MS | - | WI | - | WI | |
| 12 | ΣS | 2000K | ΣS | 2000K | 12 | A or WI | - | ΣS | 4000K | ΣS | 40 |
| 13 | Z3 | 750K | Z3 | 750K | 13 | ZIB | 60K | ZIB | 60K | ZIB | |
| 14 | NSP | 750K | NSP | 750K | 14 | NIB | 60K | NIB | 60K | NIB | |
| 15 | ESP | 750K | ESP | 750K | 15 | EIB | 60K | EIB | 60K | EIB | |
| 16 | WWV | | WWV | - | 16 | WWV | - | WWV | - | WWV | |

MAGNETIC-TAPE RECORDERS

| | No. 1 | | | No. 2 | |
|---|---|---|---|---|---|
| Channel | DG 400[a]<br>1 July 63-<br>31 Jan 64 | DG 4000<br>1 Feb 64-<br>3 Aug 64 | DG 4007<br>4 Aug 64-<br>30 Apr 65 | DG 401<br>1 July 63-<br>31 Jan 64 | DG 4001<br>1 Feb 64-<br>30 Apr 65 |
| 1 | STS | STS | TCMDG | STS | STS or TCMDG |
| 2 | Z1 | Z1 | Z1 | ZLP | ZLP |
| 3 | Z2 | Z2 | Z2 | NLP | NLP |
| 4 | Z3 | Z3 | Z3 | ELP | ELP |
| 5 | Z4 | Z4 | Z4 | NSP | NSP |
| 6 | Z5 | Z5 | Z5 | ESP | ESP |
| 7 | Comp | Comp | Comp | Comp | Comp |
| 8 | Z6 | Z6 | Z6 | ZIB | ZIB |
| 9 | Z7 | Z7 | Z7 | NIB | NIB |
| 10 | Z8 | Z8 | Z8 | EIB | EIB |
| 11 | Z9 | Z9 | Z9 | ZBB | ZBB |
| 12 | Z10 | Z10 | Z10 | NBB | NBB |
| 13 | Z10L | Z10L | ΣSF | EBB | EBB |
| 14 | WWV | WWV | WWV | WWV | WWV |

| | |
|---|---|
| Z | Amplified verti<br>from a site ide |
| Z6L | Amplified vert<br>seismograph - |
| V | Unamplified ve |
| ZLP | Vertical long-p |
| ZLL | Vertical long-p |
| ZBB | Vertical broad- |
| ZIB | Vertical intern |
| NSP | Amplified nort |
| NLP | North-south lo |
| NLL | North-south lo |
| NBB | North-south br |
| NIB | North-south in |
| ESP | Amplified east- |
| ELP | East-west long |
| ELL | East-west long- |
| EBB | East-west bro |
| EIB | East-west inte |
| ΣS | Summation of |
| ΣSF | ΣS filtered |
| ΣA | Summation of |

A

and normal operating magnifications of seismographs at BMSO

DEVELOCORDERS

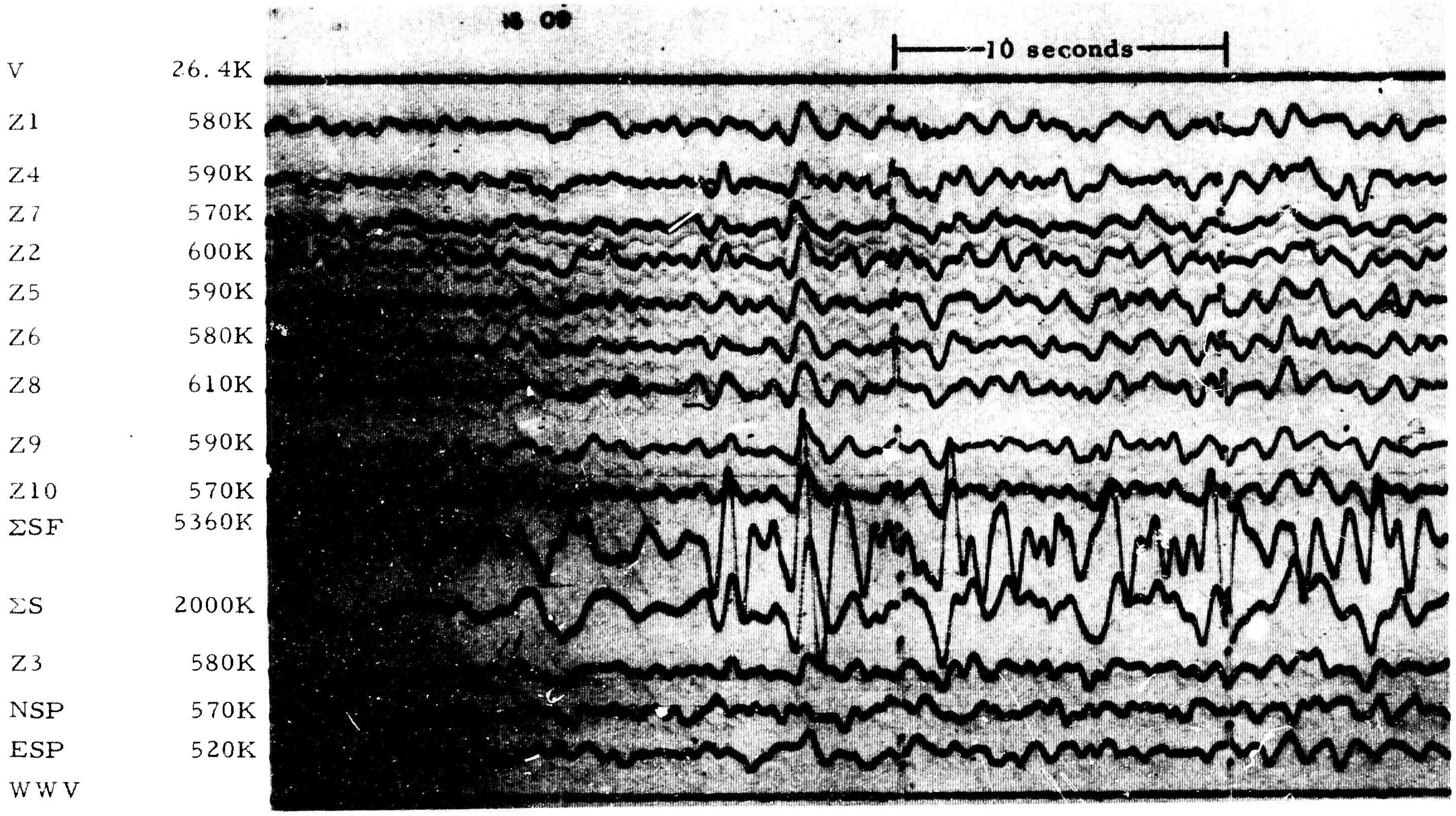
|  |  |  |  | Slow-speed, 3 mm/minute |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mag | DG 4009<br>12 Mar 65-<br>30 Apr 65 | Mag | Channel | DG 403[a]<br>1 July 63-<br>17 Dec 63 | Mag | DG 404<br>17 Dec 63-<br>31 Jan 64 | Mag | DG 4004<br>1 Feb 64-<br>10 Feb 64 | Mag | DG 4005<br>10 Feb 64-<br>30 Apr 65 | Mag |
| - | V | 1K | 1 | ZLL | 1K | A | - | W1 | - | W1 | - |
| 1500K | Z3 | 1500K | 2 | NLL | 1K | ZLL | 1K | ZLL | 1K | MS | - |
| 70K | Z3L | 70K | 3 | ELL | 1K | NLL | 1K | NLL | 1K | ZLL | 1K |
| 70K | NSL | 70K | 4 | ZLP | 30K | ELL | 1K | ELL | 1K | NLL | 1K |
| 70K | ESL | 70K | 5 | NLP | 10K | ZLP | 35K | ZLP | 35K | ELL | 1K |
| 1000K | ΣQ | 1000K | 6 | ELP | 10K | NLP | 10K | NLP | 10K | ZLP | 40K |
| 1000K | ΣA | 1000K | 7 | ZBB | 5K | ELP | 10K | ELP | 10K | NLP | 10K |
| 1000K | ΣB | 1000K | 8 | NBB | 5K | ZBB | 5K | ZBB | 5K | ELP | 10K |
| 1000K | ΣC | 1000K | 9 | EBB | 5K | NBB | 5K | NBB | 5K | ML | - |
| - | MS | - | 10 | Z8 | 600K | EBB | 5K | EBB | 5K | ZBB | 5K |
| - | WI | - | 11 | ZIB | 60K | Z8 | 600K | Z8 | 600K | NBB | 5K |
| 4000K | ΣS | 4000K | 12 | NIB | 60K | ZIB | 60K | ZIB | 60K | EBB | 5K |
| 60K | ZIB | 60K | 13 | EIB | 60K | NIB | 60K | NIB | 60K | Z8 | 600K |
| 60K | NIB | 60K | 14 | WWV | - | EIB | 60K | EIB | 60K | WWV | - |
| 60K | EIB | 60K | 15 | - | - | WWV | - | WWV | - | - | - |
| - | WWV | - |  |  |  |  |  |  |  |  |  |

KEY

|  |  |
|---|---|
| Z | Amplified vertical short-period seismograph from a site identified by a suffix number |
| Z6L | Amplified vertical short-period low gain seismograph - number denotes seismometer site |
| V | Unamplified vertical short-period seismograph |
| ZLP | Vertical long-period seismograph |
| ZLL | Vertical long-period low-gain seismograph |
| ZBB | Vertical broad-band seismograph |
| ZIB | Vertical intermediate-band seismograph |
| NSP | Amplified north-south short-period seismograph |
| NLP | North-south long-period seismograph |
| NLL | North-south long-period low-gain seismograph |
| NBB | North-south broad-band seismograph |
| NIB | North-south intermediate-band seismograph |
| ESP | Amplified east-west short-period seismograph |
| ELP | East-west long-period seismograph |
| ELL | East-west long-period low-gain seismograph |
| EBB | East-west broad-band seismograph |
| EIB | East-west intermediate-band seismograph |
| ΣS | Summation of Z1 through Z10 |
| ΣSF | ΣS filtered |
| ΣA | Summation of Z1, Z2, Z9 |

|  |  |
|---|---|
| ΣB | Summation of Z3, Z4, and Z5 |
| ΣC | Summation of Z6, Z7, and Z8 |
| ΣQ | Summation of Z6, Z8, Z9, and Z10 |
| A | Anemometer - wind speed only |
| W1 | Anemometer - wind speed and direction |
| M | Microbarograph |
| ML | Microbarograph long-period |
| MS | Microbarograph short-period |
| WWV | Radio time |
| STS | Primary and secondary timing only |
| TCMDG | Time code management data group |
| Comp | Compensation |
| Mag | Magnification (see note) |
| DG | Data group number |
| Note: | Magnifications of:<br>Short-period measured at 1 Hz<br>Intermediate-band measured at 1 Hz<br>Broad-band measured at 0.8 Hz<br>Long-period measured at 0.04 Hz |
| a | Data group effective from 1 Nov 63 |

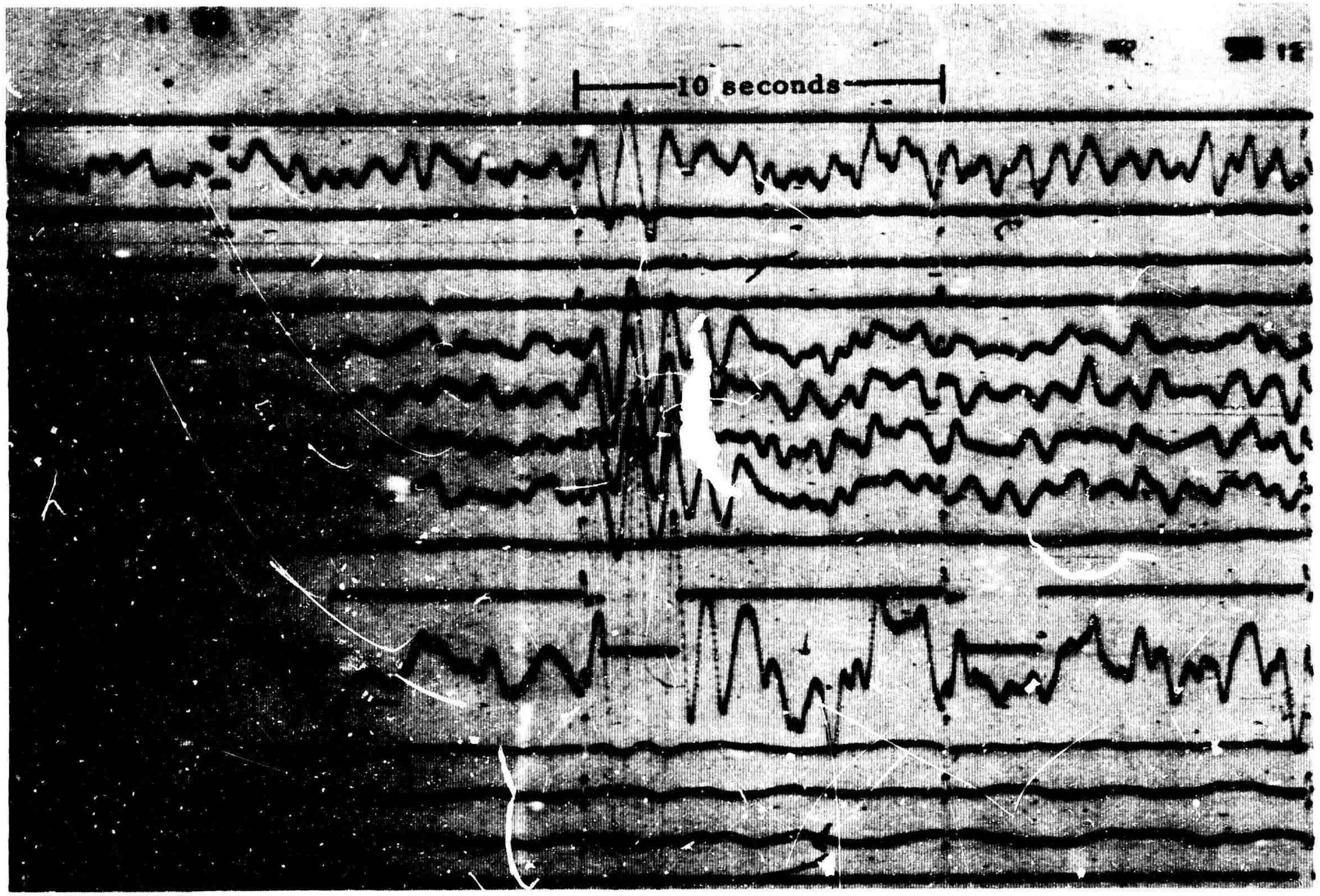
B



BMSO
Run 120
30 April 1965
Data group 4002

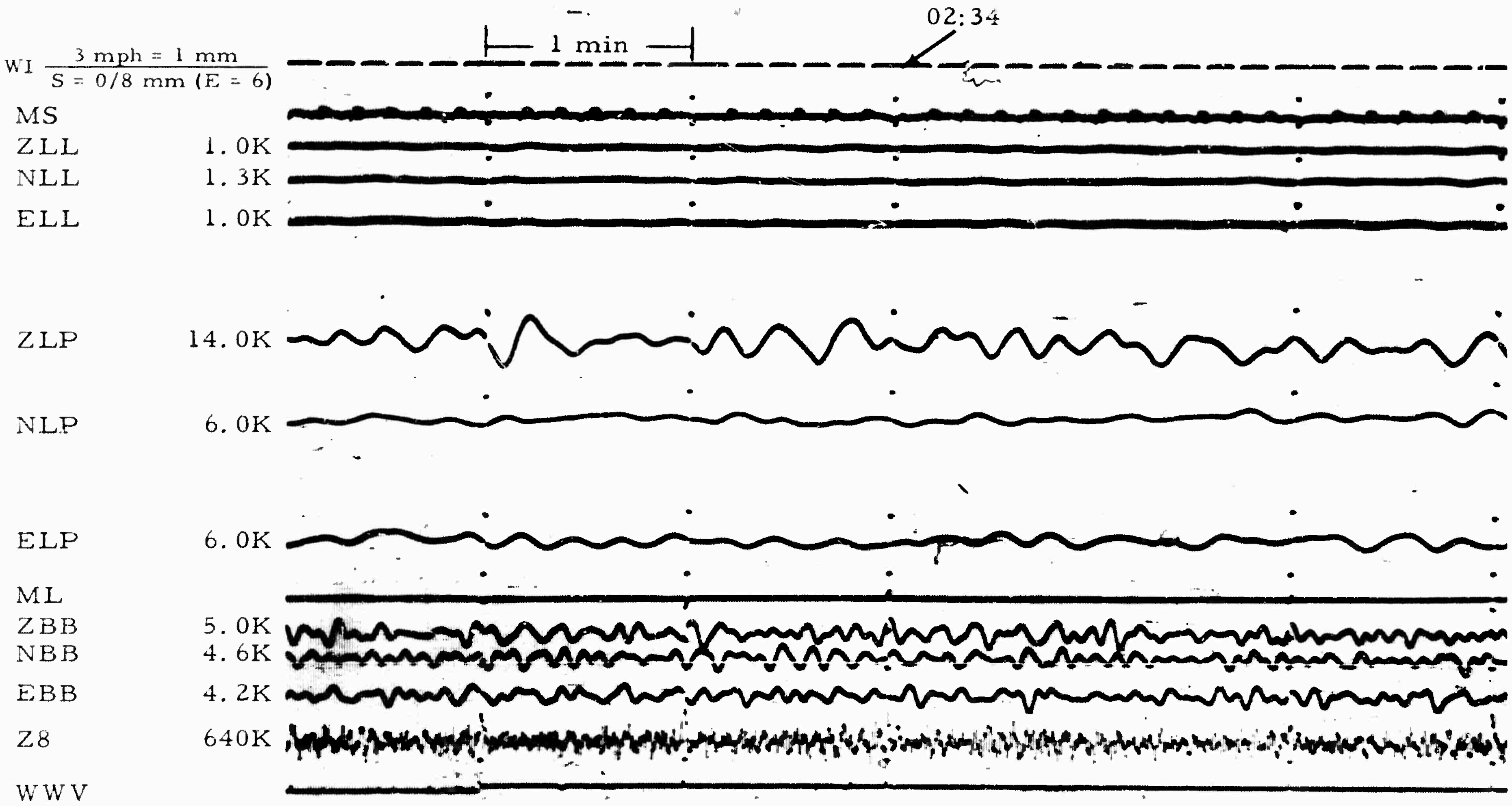
Figure 4. Seismogram illustrating the presentation of Data Group 4002 for BMSO primary fast-speed Develocorder. Epicenter unknown. (X10 enlargement of 16-mm film)

| | |
|---|---|
| V | 26.4K |
| Z3 | 1240K |
| Z3L | 70.0K |
| NSL | 60.0K |
| ESL | 60.0K |
| ΣQ | 1020K |
| ΣA | 1000K |
| ΣB | 1020K |
| ΣC | 1000K |
| MS | |
| WI $\frac{3\ \text{mph} = 1\ \text{mm}}{S = 0/8\ \text{mm}\ (E = 6)}$ | |
| ΣS | 4040K |
| ZIB | 54.0K |
| NIB | 74.0K |
| EIB | 60.0K |
| WWV | |



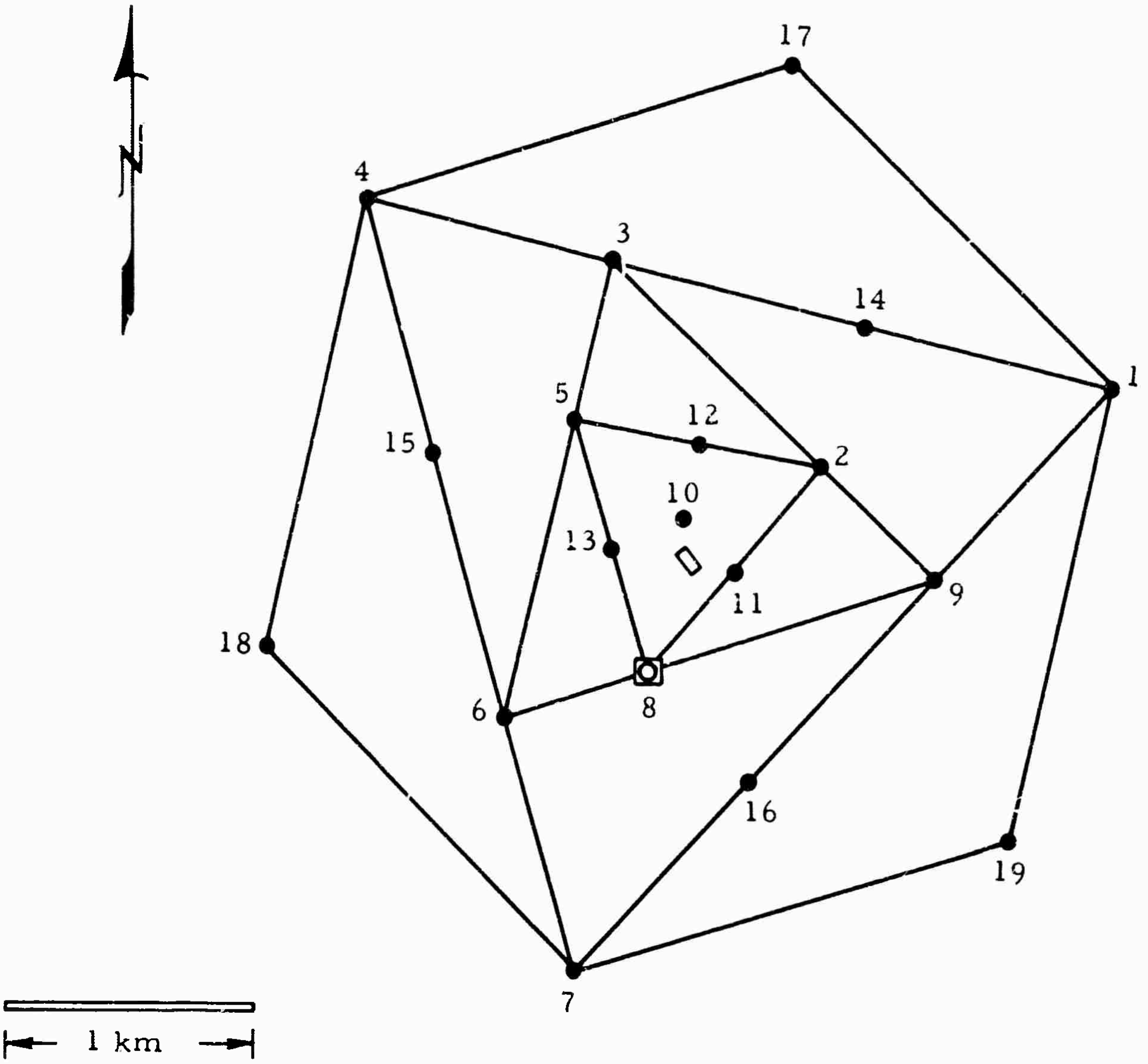
BMSO
Run 130
30 April 196
Data group 4009

Figure 5. Seismogram illustrating the presentation of Data Group 4009 for BMSO secondary fast-speed Develocorder. P arrival from near the coast of Venezuela, Δ≃57.1°, h≃86 km, O = 11:45:27.1, m = 5.0 (USC&GS). (X10 enlargement of 16-mm film)



BMSO
Run 116
26 April 1965
Data group 4005

Figure 6. Seismogram illustrating the presentation of Data Group 4005 for BMSO slow-speed Develocorder. Rayleigh train associated with event from Gulf of Alaska, Δ ≈ 12°, h ≈ 33 km, O = 01:57:14.4, m = 5.3 (USC&GS). (X10 enlargement of 16-mm film)



◙ Tank farm

□ Central recording building

● Array seismometers

Coordinates of tank farm: 35°35'41"N 85°34'13"W
Elevation: 574 meters above sea level

Figure 7. Orientation and configuration of the CPSO array

## Table 4. Data channel assignments and normal operat[illegible]al o

DEVELOCORDERS

Fast-speed, 30 mm/minute

Primary data

| Channel | DG 600[a] 1 Jul 63-31 Jan 64 | Mag | DG 6000 1 Feb 64-20 Aug 64 | Mag | DG 6010 20 Aug 64-5 Nov 64 | Mag | DG 6000 5 Nov 64-15 Apr 65 | Mag | DG 6022 1[illegible] Apr 65-21 Apr 65 | Mag | DG 6023 21 Apr 65-28 Apr 65 | Mag | DG 6300 28 Apr 65-30 Apr 65 | Mag |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | V | 20K | V | 20K | V | 25K | V | 25K | V | 25K | V | 25K | V | 25K |
| 2 | Z7 | 400K | Z7 | 400K | Z7 | 400K | Z7 | 400K | Z7 | 400K | Z7 | 400K | Z7 | 400K |
| 3 | Z1 | 400K | Z1 | 400K | Z1 | 400K | Z1 | 400K | Z1 | 400K | Z1 | 400K | Z1 | 400K |
| 4 | Z4 | 400K | Z4 | 400K | Z4 | 400K | Z4 | 400K | Z4 | 400K | Z4 | 400K | Z4 | 400K |
| 5 | Z2 | 400K | Z2 | 400K | Z2 | 400K | Z2 | 400K | Z2 | 400K | Z2 | 400K | Z2 | 400K |
| 6 | Z3 | 400K | Z3 | 400K | Z3 | 400K | Z3 | 400K | Z3 | 400K | Z3 | 400K | Z3 | 400K |
| 7 | Z5 | 400K | Z5 | 400K | Z5 | 400K | Z5 | 400K | Z5 | 400K | Z5 | 400K | Z5 | 400K |
| 8 | Z6 | 400K | Z6 | 400K | Z6 | 400K | Z6 | 400K | Z6 | 400K | Z6 | 400K | Z6 | 400K |
| 9 | Z9 | 400K | Z9 | 400K | Z9 | 400K | Z9 | 400K | ΣS | 400K | ΣS | 400K | Z9 | 400K |
| 10 | ΣS | 400K | ΣS | 400K | ΣL | 400K | ΣS | 400K | ΣTWF$_1$ | 3000K | ΣTWF$_2$ | 3000K | ΣS | 400K |
| 11 | ΣTF | 2100K[b] | ΣTF | 2100K[b] | ΣMF | 2200K | ΣTF | 2200K | ΣTF | 2500K | ΣTF | 2500K | ΣTF | 2500K |
| 12 | ΣT | 1000K | ΣT | 1000K | ΣM | 1000K | ΣT | 800K | ΣT | 1000K | ΣT | 1000K | ΣT | 900K |
| 13 | Z8 | 400K | Z8 | 400K | Z8 | 400K | Z8 | 400K | Z8 | 400K | Z8 | 400K | Z8 | 400K |
| 14 | NSP | 400K | NSP | 400K | NSP | 400K | NSP | 400K | NSP | 400K | NSP | 400K | NSP | 400K |
| 15 | ESP | 400K | ESP | 400K | ESP | 400K | ESP | 400K | ESP | 400K | ESP | 400K | ESP | 400K |
| 16 | WWV | - | WWV | - | WWV | - | WWV | - | WWV | - | WWV | - | WWV | - |

| Channel | DG 605 20 Dec 63-31 Jan 64 | Mag | DG 6005 1 Feb 64-20 Aug 64 | Mag |
|---|---|---|---|---|
| 1 | Z10L | 40K | Z10L | 40K |
| 2 | Z10 | 400K | Z10 | 400K |
| 3 | ΣD | 400K | ΣD | 400K |
| 4 | ΣE | 400K | ΣE | 400K |
| 5 | ΣG | 400K | ΣG | 400K |
| 6 | ΣH | 400K | ΣH | 400K |
| 7 | ΣI | 400K | ΣI | 400K |
| 8 | ΣJ | 400K | ΣJ | 400K |
| 9 | ΣK | 400K | ΣK | 400K |
| 10 | MS | - | MS | - |
| 11 | A | - | A or WI | - |
| 12 | ZIB | 50K | ZIB | 50K |
| 13 | NIB | 50K | NIB | 50K |
| 14 | EIB | 50K | EIB | 50K |
| 15 | WWV | - | WWV | - |
| 16 | - | - | - | - |

LOCORD

| DG 1 Feb 6 20 Aug |
|---|
| Z10L |
| Z10 |
| ΣD |
| ΣE |
| ΣG |
| ΣH |
| ΣI |
| ΣJ |
| ΣK |
| MS |
| A or |
| ZIB |
| NIB |
| EIB |
| WWV |
| - |

MAGNETIC-TAPE RECORDERS

No. 1

| Channel | DC 602[a] 1 Jul 63-31 Jan 64 | DG 6002 1 Feb 64-10 Aug 64 | DG 6005 10 Aug 64-11 Aug 64 | DG 6007 11 Aug 64-13 Aug 64 | DG 6006 14 Aug 64-19 Aug 64 | DG 6007 19 Aug 64-20 Aug 64 | DG 6011 21 Aug 64-2 Nov 64 | DG 6014 3 Nov 64-5 Nov 64 | DG 6006 6 Nov 64-8 Mar 65 | DG 6017 9 Mar 65-30 Apr 65 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | STS | STS | STS | STS | STS | STS | STS | STS | STS | TCMDG |
| 2 | Z1 | Z1 | Z1 | Z1 | Z1 | Z1 | Z1 | Z1 | Z1 | Z1 |
| 3 | Z2 | Z2 | Z2 | Z2 | Z2 | Z2 | Z2 | Z2 | Z2 | Z2 |
| 4 | Z3 | Z3 | Z3 | Z3 | Z3 | Z3 | Z3 | Z3 | Z3 | Z3 |
| 5 | Z4 | Z4 | Z4 | Z4 | Z4 | Z4 | Z4 | Z4 | Z4 | Z4 |
| 6 | Z5 | Z5 | Z5 | ΣT | Z5 | ΣT | Z5 | Z5 | Z5 | Z5 |
| 7 | Comp | Comp | Comp | Comp | Comp | Comp | Comp | Comp | Comp | Comp |
| 8 | Z6 | Z6 | Z6 | Z6 | Z6 | Z6 | Z6 | Z6 | Z6 | Z6 |
| 9 | Z7 | Z7 | Z7 | Z7 | Z7 | Z7 | Z7 | Z7 | Z7 | Z7 |
| 10 | Z8 | Z8 | Z8 | Z8 | Z8 | Z8 | Z8 | Z8 | Z8 | Z8 |
| 11 | Z9 | Z9 | Z9 | Z9 | Z9 | Z9 | Z9 | Z9 | Z9 | Z9 |
| 12 | Z10 | Z10 | Z10 | Z10 | Z10 | Z10 | Z10 | Z10 | Z10 | Z10 |
| 13 | Z8L | Z8L | ΣTF | ΣTF | ΣTF | ΣTF | ΣTF$_1$ | ΣTF$_2$ | ΣTF | ΣTF |
| 14 | WWV | WWV | WWV | WWV | WWV | WWV | WWV | WWV | WWV | WWV |

No. 2

| Channel | DC 603[a] 1 Jul 63-31 Jan 64 | DG 6003 1 Fab 64-13 Aug 64 | DG 6009 14 Aug 64-19 Aug 64 | DG 6003 20 Aug 64-26 Oct 64 | DG 6012 26 Oct 64-2 Nov 64 | DG 6015 3 Nov 64-5 Nov 64 | DG 6016 6 Nov 64-3 Dec 64 | DG 6 4 Dec 8 Mar |
|---|---|---|---|---|---|---|---|---|
| 1 | STS | STS | STS | STS | STS | STS | STS | STS |
| 2 | ZLP | ZLP | Z11 | ZLP | ZLP | ZLP | ZLP | ZL |
| 3 | NLP | NLP | Z12 | NLP | NLP | NLP | NLP | NL |
| 4 | ELP | ELP | Z13 | ELP | NLP$_1$ | NLP$_1$ | NLP$_1$ | NL |
| 5 | NSP | NSP | NSP | NSP | NSP | NSP | NSP | NS |
| 6 | ESP | ESP | ESP | ESP | ESP | ESP | ESP | ES |
| 7 | Comp | Comp | Comp | Comp | Comp | Comp | Comp | Co |
| 8 | ZIB | ZIB | Z14 | ZIB | ZIB | ZIB | ZIB | ZIB |
| 9 | NIB | NIB | Z15 | NIB | NIB | ΣH | ΣH | NIB |
| 10 | EIB | EIB | Z16 | EIB | EIB | ΣI | ΣI | EIB |
| 11 | ZBB | ZBB | Z17 | ZBB | ZBB | ΣM | ΣM | ZB |
| 12 | NBB | NBB | Z18 | NBB | NBB | ΣT$_1$ | ΣT | NB |
| 13 | EBB | EBB | Z19 | EBB | EBB | Z10 | Z10 | EB |
| 14 | WWV | WWV | WWV | WWV | WWV | WWV | WWV | WW |

| DG 601 6 Nov 6 3 Dec 6 |
|---|
| STS |
| ZLP |
| NLP |
| NLP$_1$ |
| NSP |
| ESP |
| Comp |
| ZIB |
| ΣH |
| ΣI |
| ΣM |
| ΣT |
| Z10 |
| WWV |

A

# al operating magnifications of seismographs at CPSO

LOCORDERS

Secondary data

| DG 6005<br>1 Feb 64-<br>20 Aug 64 | Mag | DG 6009<br>20 Aug 64-<br>5 Nov 64 | Mag | DG 6005<br>5 Nov 64-<br>8 Mar 65 | Mag | DC 6019<br>8 Mar 65-<br>12 Mar 65 | Mag | DG 6021<br>12 Mar 65-<br>30 Apr 65 | Mag |
|---|---|---|---|---|---|---|---|---|---|
| Z10L | 40K | Z10L | 30K | Z10L | 40K | Z8L | 30K | V | 1K |
| Z10 | 400K | Z10 | 400K | Z10 | 400K | Z8 | 800K | Z6L | 35K |
| ΣD | 400K | Z10-1 | 400K | ΣD | 400K | ΣD | 400K | Z8 | 800K |
| ΣE | 400K | ΣE | 400K | ΣE | 400K | ΣE | 400K | ΣD | 400K |
| ΣG | 400K | ΣG | 400K | ΣG | 400K | ΣG | 400K | ΣE | 400K |
| ΣH | 400K | ΣH | 400K | ΣH | 400K | ΣH | 400K | ΣG | 400K |
| ΣI | 400K | ΣI | 400K | ΣI | 400K | ΣI | 400K | ΣH | 400K |
| ΣJ | 400K | ΣN | 400K | ΣJ | 400K | ΣK | 400K | ΣI | 400K |
| ΣK | 400K | ΣK | 400K | ΣK | 400K | MS | - | ΣK | 400K |
| MS | - | MS | - | MS | - | WI | - | MS | - |
| A or WI | - | WI | - | WI | - | ΣT | 1800K | WI | - |
| ZIB | 50K | ZIB | 50K | ZIB | 50K | ZIB | 50K | ΣT | 2000K |
| NIB | 50K | NIB | 50K | NIB | 50K | NIB | 50K | ZIB | 50K |
| EIB | 50K | EIB | 50K | EIB | 50K | EIB | 50K | NIB | 50K |
| WWV | - | WWV | - | WWV | - | WWV | - | EIB | 50K |
| - | - | - | - | - | - | - | - | WWV | - |

Slow-speed, 3 mm/minute

| Channel | DG 601[a]<br>1 Jul 63-<br>18 Dec 63 | Mag | DG 604<br>18 Dec 63-<br>31 Jan 64 | Mag | DG 6004<br>1 Feb 64-<br>26 Oct 64 | Mag | DG 6013<br>26 Oct 64-<br>9 March 65 | Mag | DG 6004<br>9 Mar 65-<br>30 Apr 65 | Mag |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ZLL | 1K | A or WI | - | WI | - | WI | - | WI | - |
| 2 | NLL | 1K | MS | - | MS | - | MS | - | MS | - |
| 3 | ELL | 1K | ZLL | 1K | ZLL | 1K | ZLL | 1K | ZLL | 1K |
| 4 | ZLP | 20K | NLL | 1K | NLL | 1K | NLL | 1K | NLL | 1K |
| 5 | NLP | 15K | ELL | 1K | ELL | 1K | NL[illegible] | 1K | ELL | 1K |
| 6 | ELP | 15K | ZLP | 15K | ZLP | 15K | ZLP | 35K | ZLP | 15K |
| 7 | ZBB | 6K | NLP | 10K | NLP | 10K | NLP | 10K | NLP | 10K |
| 8 | NBB | 6K | ELP | 5K | ELP | 5K | NLP$_1$ | 10K | ELP | 5K |
| 9 | EBB | 6K | ML | - | ML | - | ML | - | ML | - |
| 10 | Z8 | 160K | ZBB | 3K | ZBB | 3K | ZBB | 3K | ZBB | 3K |
| 11 | ZIB | 30K | NBB | 3K | NBB | 3K | NBB | 3K | NBB | 3K |
| 12 | NIB | 30K | EBB | 3K | EBB | 3K | EBB | 3K | EBB | 3K |
| 13 | EIB | 30K | Z8 | 150K | Z8 | 150K | Z8 | 170K | Z8 | 150K |
| 14 | WWV | - | WWV | - | WWV | - | WWV | - | WWV | - |

| DG 6016<br>6 Nov 64-<br>3 Dec 64 | DG 6012<br>4 Dec 64-<br>8 Mar 65 | DG 6018<br>9 Mar 65 | DG 6020<br>10 Mar 65-<br>30 Apr 65 |
|---|---|---|---|
| STS | STS | TCMDG | TCMDG |
| ZLP | ZLP | ZLP | ZLP |
| NLP | NLP | NLP | NLP |
| NLP$_1$ | NLP$_1$ | NLP$_1$ | ELP |
| NSP | NSP | NSP | NSP |
| ESP | ESP | ESP | ESP |
| Comp | Comp | Comp | Comp |
| ZIB | ZIB | ZIB | ZIB |
| ΣH | NIB | NIB | NIB |
| ΣI | EIB | EIB | EIB |
| ΣM | ZBB | ZBB | ZBB |
| ΣT | NBB | NBB | NBB |
| Z10 | EBB | EBB | EBB |
| WWV | WWV | WWV | WWV |

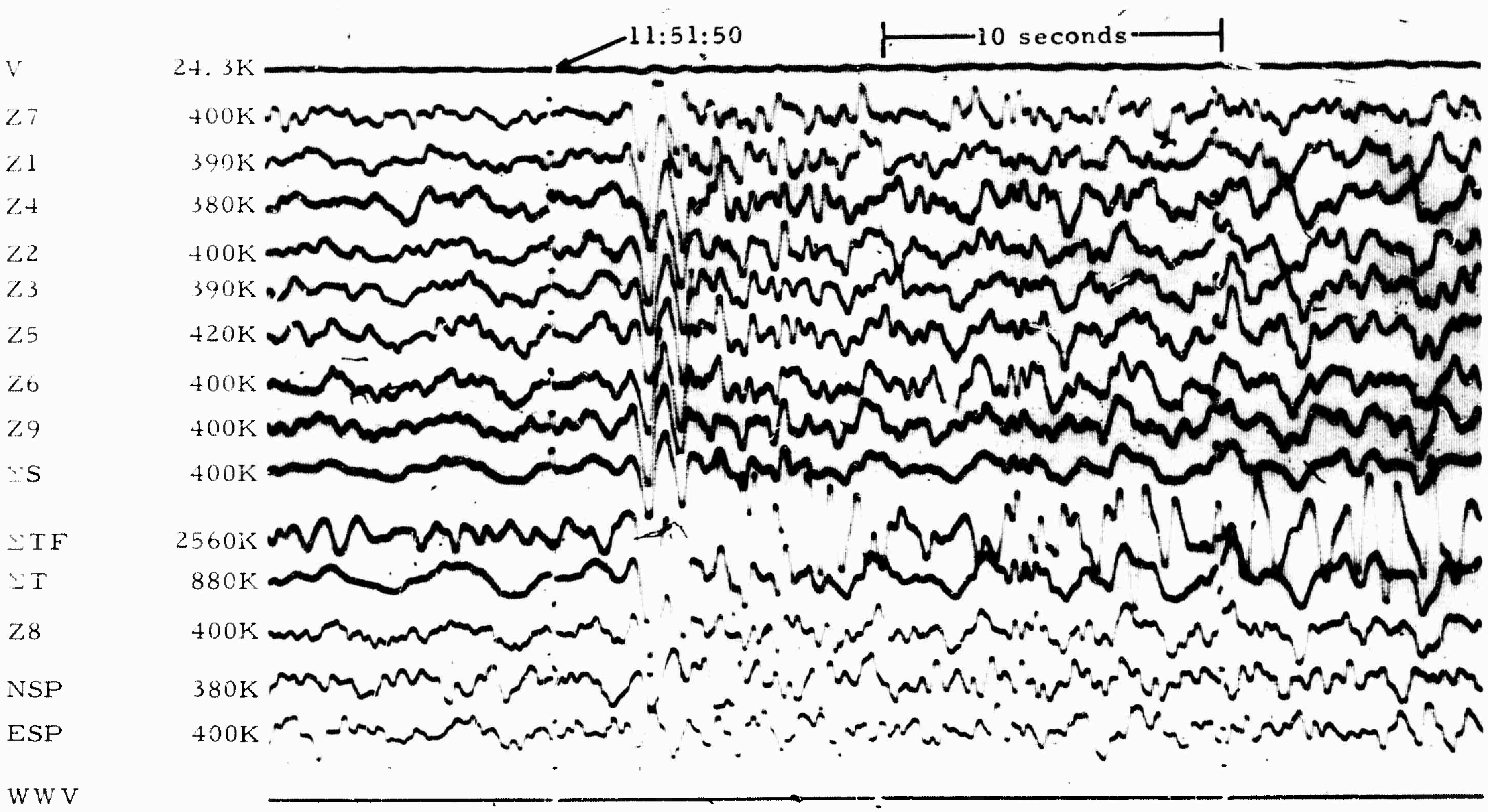
KEY

| | |
|---|---|
| Z | Amplified vertical short-period seismograph from a site identified by a suffix number |
| Z6L | Amplified vertical short-period low-gain seismograph - number denotes seismometer site |
| Z10-1 | Vertical short-period seismograph with special 1 Hz PTA galvanometer |
| V | Unamplified vertical short-period seismograph |
| ZLP | Vertical long-period seismograph |
| ZLL | Vertical long-period low-gain seismograph |
| ZBB | Vertical broad-band seismograph |
| ZIB | Vertical intermediate-band seismograph |
| NSP | Amplified north-south short-period seismograph |
| NLP | North-south long-period seismograph |
| NLP$_1$ | ELP placed NS for tests |
| NLL | North-south long-period low-gain seismograph |
| NBB | North-south broad-band seismograph |
| NIB | North-south intermediate-band seismograph |
| ESP | Amplified east-west short-period seismograph |
| ELP | East-west long-period seismograph |
| ELL | East-west long-period low-gain seismograph |
| EBB | East-west broad-band seismograph |
| EIB | East-west intermediate-band seismograph |

| | |
|---|---|
| ΣT | Summation of all 19 short-period array seismographs |
| ΣTF | ΣT filtered - subnumber indicates change in filter setting |
| ΣTWF | Special weighted ΣTF |
| ΣS | Summation of Z10 through Z19 |
| ΣSF | ΣS filtered |
| ΣM | Z1-Z10 and Z12-Z19 |
| ΣMF | ΣM filtered |
| ΣL | Summation of Z10, and Z12-Z19 |
| ΣD | Summation of Z11, Z12, and Z13 |
| ΣE | Summation of Z1, Z7, Z17, and Z18 |
| ΣG | Summation of Z4, Z7, Z17, and Z19 |
| ΣH | Summation of Z1, Z4, Z7, Z17, Z18, and Z19 |
| ΣI | Summation of Z3, Z6, Z9, Z14, Z15, and Z16 |
| ΣJ | Summation of Z2, Z5, Z8, Z11, Z12, and Z13 |
| ΣK | Summation of Z1, Z3, Z4, Z6, Z7, Z9, Z10, Z14, Z15, and Z16 |
| ΣN | Summation of Z2, Z5, Z8, Z12, and Z13 |
| A | Anemometer - wind speed only |
| WI | Anemometer - wind speed and direction |
| M | Microbarograph |

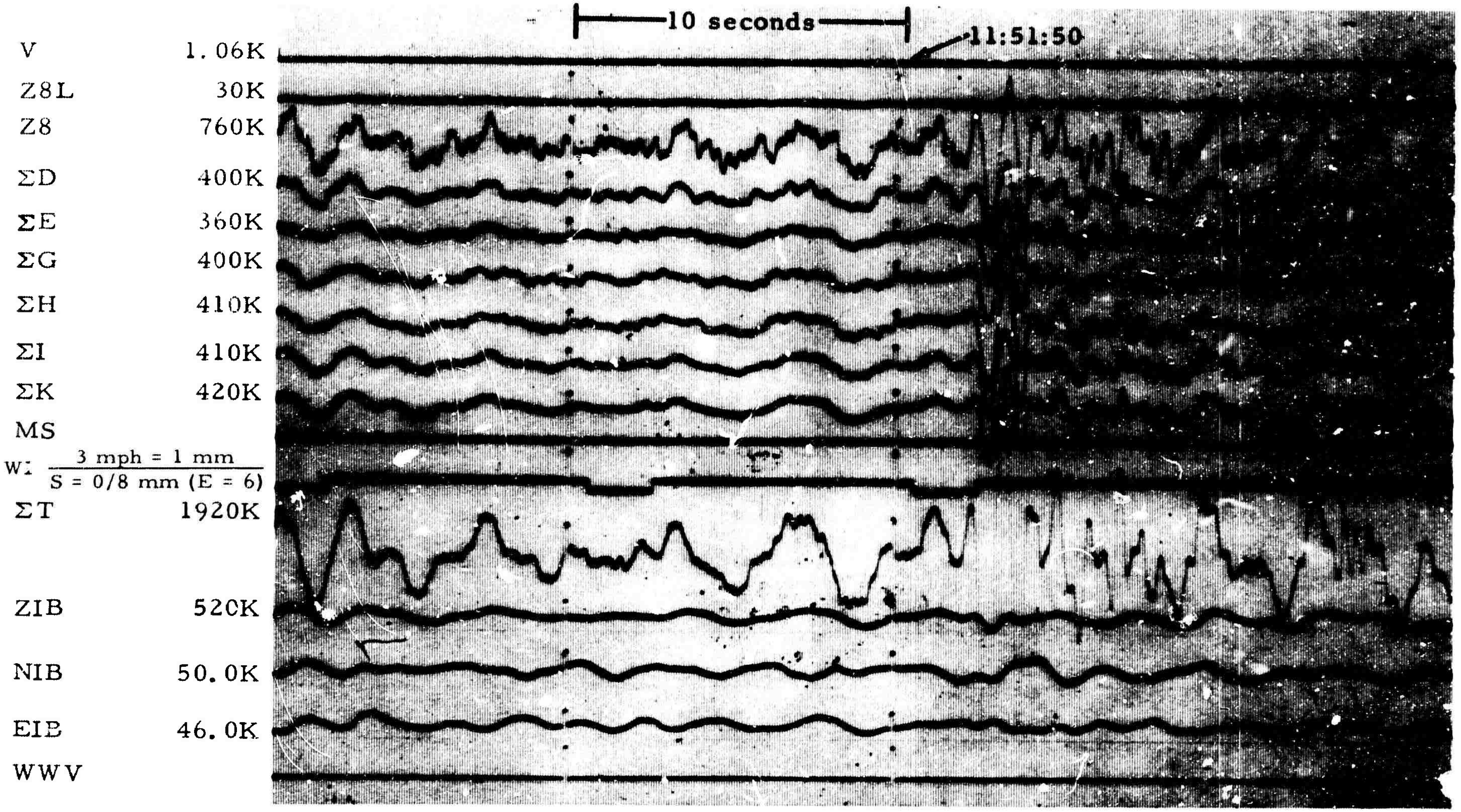
| | |
|---|---|
| ML | Microbarograph long-period |
| MS | Microbarograph short-period |
| WWV | Radio time |
| STS | Primary and secondary timing only |
| TCMDG | Time code management data group |
| Comp | Compensation |
| Mag | Magnification (see note) |
| DG | Data group number |
| Note: | Magnifications of:<br>Short-period measured at 1 Hz<br>Intermediate-band measured at 1 Hz<br>Broad-band measured at 0.8 Hz<br>Long-period measured at 0.04 Hz |
| a | Data group effective from 1 Nov 63 |
| b | Gains previously reported as 3300K due to an error (1 Jul 63-7 Aug 64) |

B



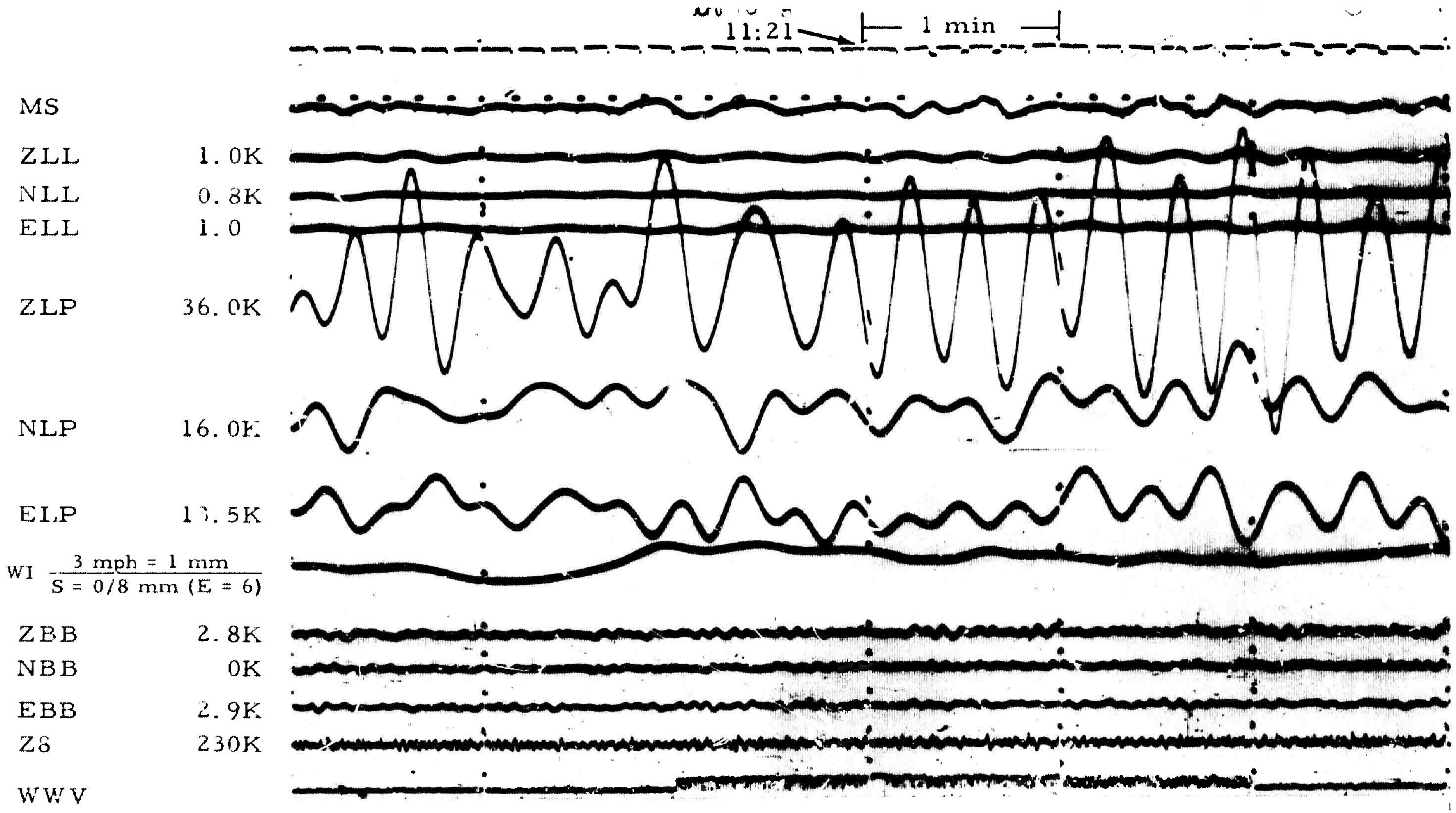
CPSO
Run 120
30 April 1965
Data group 6000

Figure 8. Seismogram illustrating the presentation of Data Group 6000 for CPSO primary fast-speed Develocorder. P arrival from near coast of Venezuela, $\Delta \simeq 32°$, $h \simeq 86$ km, O = 11:45:27.1, m = 5.0 (USC&GS). (X10 enlargement of 16-mm film)



CPSO
Run 120
30 April 1965
Data group 6021

Figure 9. Seismogram illustrating the presentation of Data Group 6021 for CPSO secondary fast-speed Develocorder. P arrival from near the coast of Venezuela, $\Delta \simeq 32°$, $h \simeq 86$ km, O = 11:45:27.1, m = 5.0 (USC&GS). (X10 enlargement of 16-mm film)



CPSO
Run 108
18 April 1965
Data group 6004

Figure 10. Seismogram illustrating the presentation of Data Group 6004 for CPSO slow-speed Develocorder. Phases from unknown epicenter. (X10 enlargement of 16-mm film)

#### 2.3.5.3 UBSO

The data channel assignments for each of the UBSO Develocorders and the magnetic-tape recorders, identified by data group number, are given in table 5.

At UBSO the apexes of the triangular array (see figure 11) are located at Z1, Z3, and Z5. These were recorded on channels 2, 3, and 4 of the primary Develocorders.

The secondary fast-speed Develocorder was activated at UBSO on 1 February 1964, and was originally used to record several combinations of array seismograph summations. Since 9 April 1964, this Develocorder has been used mainly for recording data from the shallow-hole and deep-hole seismometers. A third fast-speed Develocorder was activated at UBSO on 21 December 1964 to record data from the shallow-buried array (see section 2.4.16 and TR 65-28). Examples of the data recorded on each of the four Develocorders at UBSO are shown in figures 12 through 15.

### 2.3.6 Shipment of Data to Seismic Data Laboratory

All magnetic-tape seismograms recorded at the VT/1124 observatories between 1 July 1963 and 30 March 1965 were shipped to Seismic Data Laboratory (SDL) with the regular LRSM data shipments, approximately 15 days after the end of the month during which they were recorded.

Sixteen-millimeter film seismograms recorded prior to 1 March 1965 were also sent to SDL. Film seismograms and corresponding operating logs were shipped to SDL as soon as data for the monthly five-station earthquake bulletin were compiled.

### 2.3.7 Component Failure Reports

A procedure for reporting component failures was adopted in December 1963, and complete component failure data are available starting with 1 January 1964. A special IBM card (form 273) was designed for use in reporting component failures. It was hoped that data written on this card at an observatory could then be keypunched onto the same card in Garland. This proved to be impractical because the design of the card does not allow data entered on the card to be read as they are punched; therefore, the data on form 273 are now coded in Garland before being punched onto standard 80-column IBM cards.

## Table 5. Data channel assignments and normal opera

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOCORDERS | | | | | | | | | | | | | | |
| Fast speed, 30 mm/minute | | | | | | | | | | | | | | |
| Primary data | | | | | | Secondary data | | | | | | | | |
| Channel | DG 500[a] 1 Jul 63-31 Jan 64 | Mag 1 Jul 63-4 Jul 63 | Mag 4 Jul 63-31 Jan 64 | DG 5000 1 Feb 64-30 Apr 65 | Mag | Channel | DG 5006 1 Feb 64-8 Apr 64 | Mag | DG 5008 9 Apr 64-14 Aug 64 | Mag | DG 5010 15 Aug 64-16 Oct 64 | Mag | DG 5012 16 Oct 64-9 Apr 65 | Ma |
| 1 | V | - | 15K | V | 25K | 1 | - | - | Z2L | 60K | Z1B | 50K | Z1B | 50 |
| 2 | Z1 | 400K | 600K | Z1 | 600K | 2 | Z2L | 60K | Z2 | 600K | NIB | 50K | NIB | 50 |
| 3 | Z3 | 400K | 600K | Z3 | 600K | 3 | Z2 | 600K | ΣQ | 1000K | EIB | 50K | EIB | 50 |
| 4 | Z5 | 400K | 600K | Z5 | 600K | 4 | ΣQ | 1000K | Z1 | 600K | ΣQ | 1000K | ΣQ | 100 |
| 5 | Z2 | 400K | 600K | Z2 | 600K | 5 | Z1 | 600K | SH1H | ? | Z1 | 600K | Z1 | 600 |
| 6 | Z4 | 400K | 600K | Z4 | 600K | 6 | ΣA | 1000K | SH1L | ? | SH1H | 2500K | SH1H | 250 |
| 7 | Z6 | 400K | 600K | Z6 | 600K | 7 | ΣB | 1000K | ΣS | 1800K | SH1L | 600K | SH1L | 600 |
| 8 | Z7 | 400K | 600K | Z7 | 600K | 8 | ΣC | 1000K | DH2H | ? | ΣS | 2000K | ΣS | 180 |
| 9 | Z8 | 400K | 600K | Z8 | 600K | 9 | - | | ΣSF | 3200K | DH2H | 2500K | Test | - |
| 10 | Z9 | 400K | 600K | Z9 | 600K | 10 | ΣS | 1800K | DH2L | ? | DH2L | 600K | Test | - |
| 11 | ΣSF | - | 5000K | ΣSF | 3000K[b] | 11 | MS | - | MS | - | ΣSF | 2700K | ΣSF | 250 |
| 12 | ΣS | 1000K | 2000K | ΣS | 1200K | 12 | A or WI | - | A or WI | - | DH1H | 2700K | DH1H | 180 |
| 13 | Z10 | 400K | 600K | Z10 | 600K | 13 | Z1B | 45K | Z1B | 50K | DH1L | 600K | DH1L | 50 |
| 14 | NSP | 400K | 600K | NSP | 600K | 14 | NIB | 45K | NIB | 50K | MS | - | MS | - |
| 15 | ESP | 400K | 600K | ESP | 600K | 15 | EIB | 45K | EIB | 50K | WI | - | WI | - |
| 16 | WWV | - | - | - | - | 16 | WWV | - | WWV | - | WWV | - | WWV | - |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| MAGNETIC-TAPE RECORDERS | | | | | | | | | |
| | No. 1 | | | No. 2 | | | | | Shallow-buried array |
| Channel | DG 501[a] 1 Jul 63-31 Jan 64 | DG 5001 1 Feb 64-5 Aug 64 | DG 5007 6 Aug 64-30 Apr 65 | DG 503 1 Jul 63-31 Jan 64 | DG 5003 1 Feb 64-8 Apr 64 | DG 5005 9 Apr 64-14 Aug 64 | DG 5009 15 Aug 64-15 Oct 64 | DG 5011 16 Oct 64-30 Apr 65 | DG 5013 23 Jan 65-30 Apr 65 |
| 1 | STS | STS | STS or TCMDG | STS | STS | STS | STS | STS or TCMDG | TCMDG |
| 2 | Z1 | Z1 | Z1 | ZLP | ZLP | ZLP | ZLP | ZLP | SZ1 |
| 3 | Z2 | Z2 | Z2 | NLP | NLP | NLP | NLP | NLP | SZ2 |
| 4 | Z3 | Z3 | Z3 | ELP | ELP | ELP | ELP | ELP | SZ3 |
| 5 | Z4 | Z4 | Z4 | NSP | NSP | NSP | NSP | NSP | SZ4 |
| 6 | Z5 | Z5 | Z5 | ESP | ESP | ESP | ESP | ESP | SZ5 |
| 7 | Comp | Comp | Comp | Comp | Comp | Comp | Comp | Comp | Comp |
| 8 | Z6 | Z6 | Z6 | Z1B | Z1B | Z1B | Z1B | Z1B | SZ6 |
| 9 | Z7 | Z7 | Z7 | NIB | NIB | NIB | DH2H | Test | SZ7 |
| 10 | Z8 | Z8 | Z8 | EIB | EIB | EIB | Z1 | Z1 | SZ8 |
| 11 | Z9 | Z9 | Z9 | ZBB | ZBB | ZBB | ZBB | ZBB | SZ9 |
| 12 | Z10 | Z10 | Z10 | NBB | NBB | SH | SH1H | SH1 | SZ10 |
| 13 | Z10L | Z10L | ΣSF | EBB | EBB | DH | DH1H | DH1 | ΣSSF |
| 14 | WWV | WWV | WWV | WWV | WWV | WWV | WWV | WWV | WWV |

| | |
|---|---|
| Z | Amplified vertical sho from a site identified |
| Z6L | Amplified vertical sho mograph - number den |
| SZ | Amplified vertical sho a borehole at a depth |
| SZ6L | Amplified vertical sho seismograph in a bor |
| V | Unamplified vertical |
| ZLP | Vertical long-period |
| ZLL | Vertical long-period |
| ZBB | Vertical broad-band s |
| Z1B | Vertical intermediate |
| NSP | Amplified north-south |
| NLP | North-south long-per |
| NLL | North-south long-per |
| NBB | North-south broad-ba |
| NIB | North-south intermed |
| ESP | Amplified east-west s |
| ELP | East-west long-perio |
| ELL | East-west long-period |

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t-west

## rmal operating magnifications of seismographs at UBSO

**DEVELOCORDERS**

| DG 5012 16 Oct 64- 9 Apr 6: | Mag | DG 5018 9 Apr 65- 30 Apr 65 | Mag |
|---|---|---|---|
| ZIB | 50K | V | - |
| NIB | 50K | Z 10 | 1200K |
| EIB | 50K | ΣQ | 1200K |
| ΣQ | 1000K | Z 1 | 600K |
| Z 1 | 600K | SH 1 | 2400K |
| SH1H | 2500K | SH 1L | 500K |
| SH 1L | 600K | ΣSF | 6000K |
| ΣS | 1800K | DH 1 | 2000K |
| Test | - | DH1L | 600K |
| Test | - | ΣS | 3000K |
| ΣSF | 2500K | ZIB | 50K |
| DH1H | 1800K | NIB | 50K |
| DH1L | 500K | EIB | 50K |
| MS | - | MS | - |
| WI | - | WI | - |
| WWV | - | WWV | - |

Shallow-buried array

| Channel | DG 5014 21 Dec 64- 22 Jan 65 | Mag | DG 5016 23 Jan 65- 3C Apr 65 | Mag |
|---|---|---|---|---|
| 1 | Test | - | SZ 10L | 100K |
| 2 | SZ 10L | 100K | SZ 1 | 600K |
| 3 | Z 4 | 1000K | SZ 3 | 600K |
| 4 | Z 10 | 1000K | SZ 5 | 600K |
| 5 | Z 7 | 1000K | SZ 2 | 600K |
| 6 | Z 1 | 1000K | SZ 4 | 600K |
| 7 | Test | - | SZ 6 | 600K |
| 8 | ΣG | 2000K | Test | - |
| 9 | ΣGF | 2800K | ΣSSF | 6700K |
| 10 | Test | - | ΣSS | 1600K |
| 11 | SZ 4 | 900K | SZ 7 | 600K |
| 12 | SZ 10 | 1000K | SZ 8 | 600K |
| 13 | SZ 7 | 900K | SZ 9 | 600K |
| 14 | SZ 1 | 1000K | SZ 10 | 600K |
| 15 | Test | - | WI | - |
| 16 | WWV | - | WWV | - |

Slow speed, 3 mm/minute

| Channel | DG 502[a] 1 Jul 63- 31 Jan 64 | Mag 1 Nov 63- 31 Jan 64 | DG 5004 1 Feb 64- 30 Apr 65 | Mag |
|---|---|---|---|---|
| 1 | A | - | A or WI | - |
| 2 | ZLL | 0.7K | MS | - |
| 3 | NLL | 0.7K | ZLL | 1K |
| 4 | ELL | 0.7K | NLL | 1K |
| 5 | ZLP | 10.0K | ELL | 1K |
| 6 | NLP | 8.0K | ZLP | 40K |
| 7 | ELP | 8.0K | NLP | 20K |
| 8 | ZBB | 2.5K | ELP | 20K |
| 9 | NBB | 2.5K | Test | - |
| 10 | EBB | 2.5K | ML | - |
| 11 | Z2 | 350K | ZBB | 2.5K |
| 12 | Z1B | 65K | NBB | 2.5K |
| 13 | N1B | 65K | EBB | 2.5K |
| 14 | E1B | 65K | Z2 | 350K |
| 15 | WWV | - | Test | - |
| 16 | - | - | WWV | - |

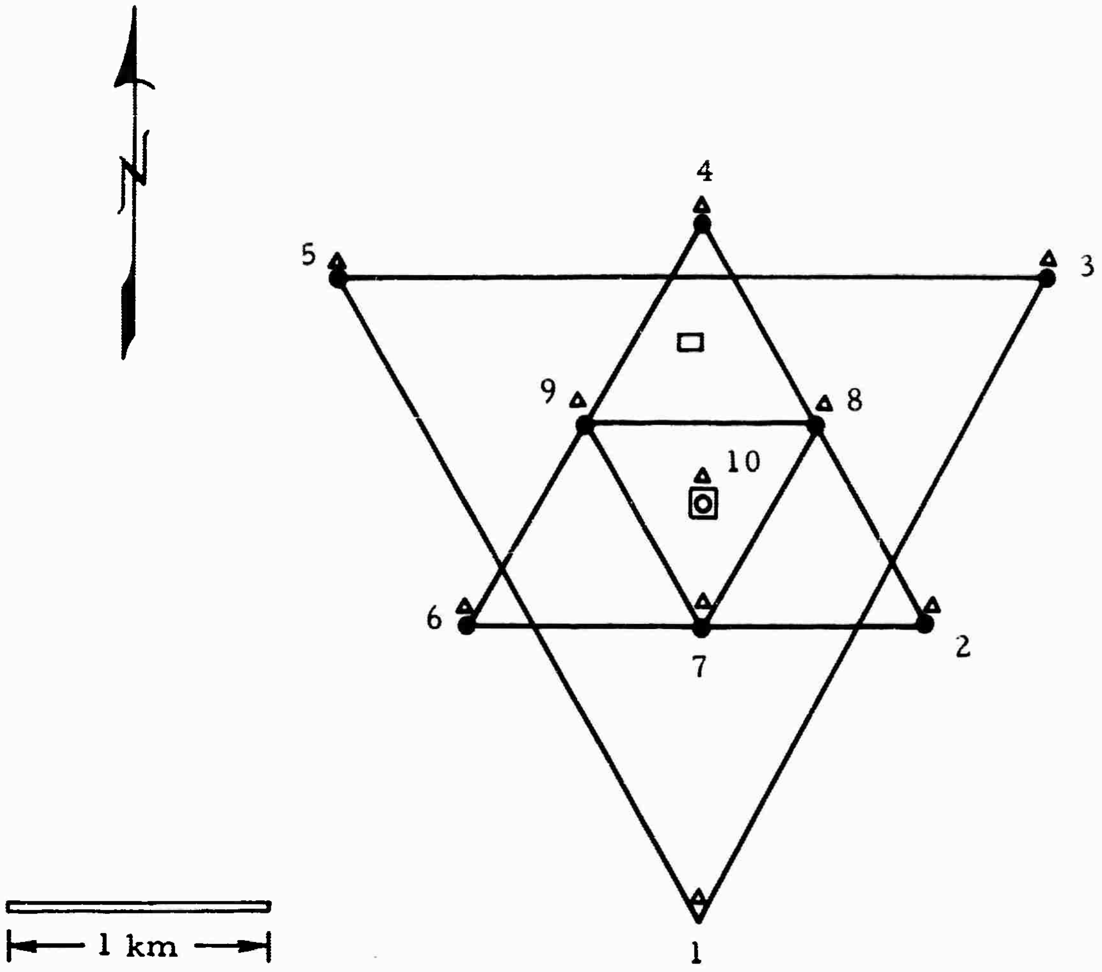
### KEY

plified vertical short-period seismograph
m a site identified by a suffix number
plified vertical short-period low-gain seis-
graph - number denotes seismometer site
plified vertical short-period seismograph in
orehole at a depth of 200 ft
plified vertical short-period low-gain
smograph in a borehole
amplified vertical short-period seismograph
rtical long-period seismograph
rtical long-period low-gain seismograph
rtical broad-band seismograph
rtical intermediate-band seismograph
plified north-south short-period seismograph
th-south long-period seismograph
th-south long-period low-gain seismograph
th-south broad-band seismograph
th-south intermediate-band seismograph
plified east-west short-period seismograph
t-west long-period seismograph
t-west long-period low-gain seismograph

| | |
|---|---|
| EBB | East-west broad-band seismograph |
| EIB | East-west intermediate-band seismograph |
| ΣS | Summation of Z 1 through Z 10 |
| ΣSF | ΣS filtered |
| ΣSS | Summation of SZ 1 through SZ 10 |
| ΣSSF | ΣSS filtered |
| ΣA | Summation of Z1, Z3, & Z5 |
| ΣB | Summation of Z2, Z4, & Z6 |
| ΣC | Summation of Z7, Z8, Z9, & Z10 |
| ΣQ | Summation of Z4, Z5, & Z8 |
| ΣG | Summation of SZ 1, SZ4, SZ7, & SZ10 |
| ΣGF | ΣG filtered |
| SH | Seismometer in 500-f. borehole |
| DH | Seismometer in 10,000-ft borehole;<br>Number with SH or DH indicates 1st or 2nd seismometer in hole.<br>H or L with SH or DH indicates high or low gain |
| A | Anemometer - wind speed only |
| WI | Anemometer - wind speed & direction |
| M | Microbarograph |
| ML | Microbarograph - long period |

| | |
|---|---|
| MS | Microbarograph - short period |
| WWV | Radio time |
| STS | Primary & secondary time |
| TCMDG | Time code management data group |
| Comp | Compensation |
| Test | Test instrumentation |
| ig | Magnification (see note) |
| DG | Data group number |
| Note | Magnifications of:<br>Short period measured at 1 Hz<br>Intermediate band measured at 1 Hz<br>Broad band measured at 0.8 Hz<br>Long period measured at 0.04 Hz |
| a | Data group effective from 1 Nov 63 |
| h | Gains previously reported as 6000K due to an error (21 Aug 64 - 19 Feb 65) |

B

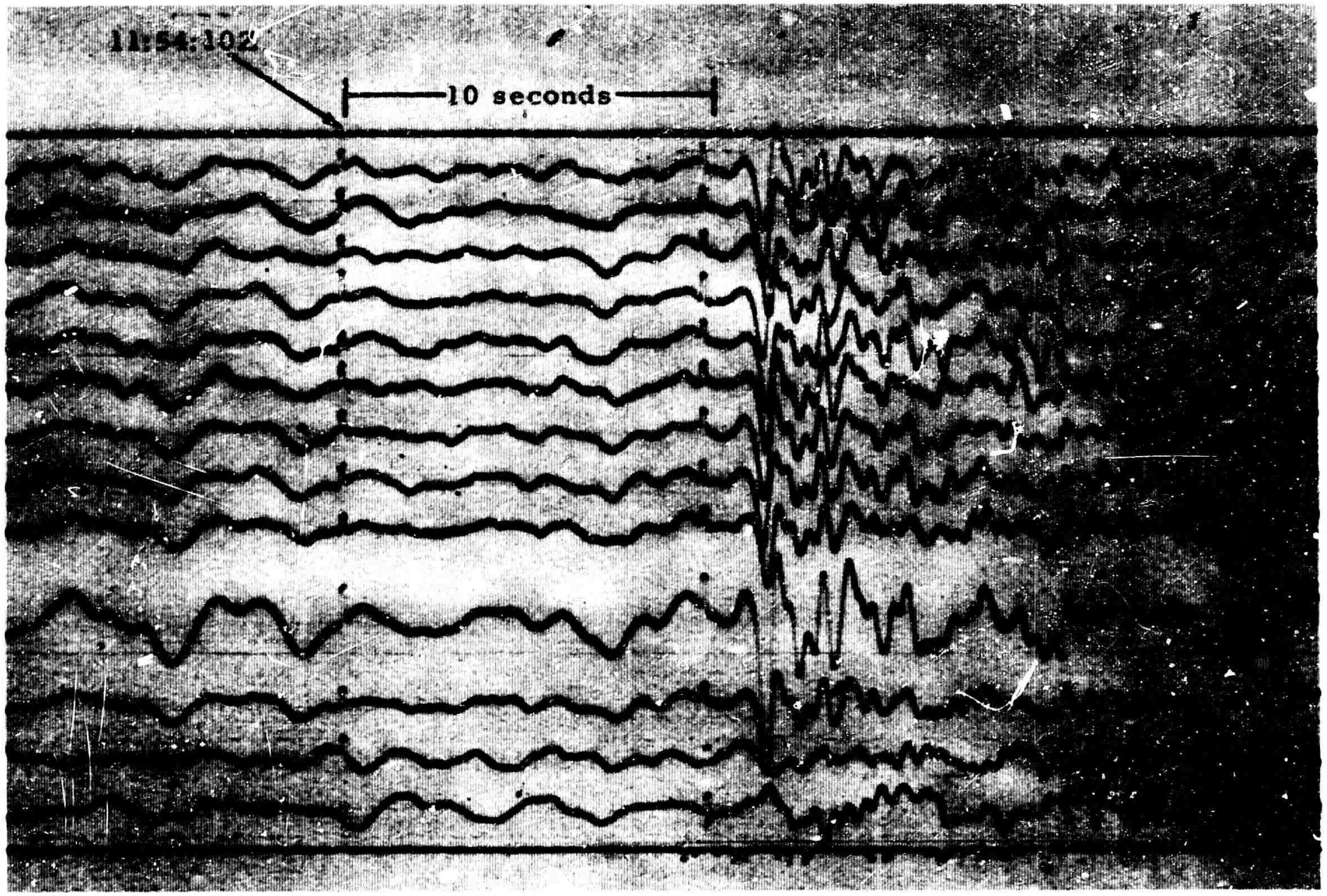


◙ Tank farm
▭ Central recording building
● Surface array seismometers (Z)
△ Buried array seismometers (SZ)

Coordinates of tank farm: 40°19'18"N 109°34'07"W
Elevation: 1600 meters above sea level

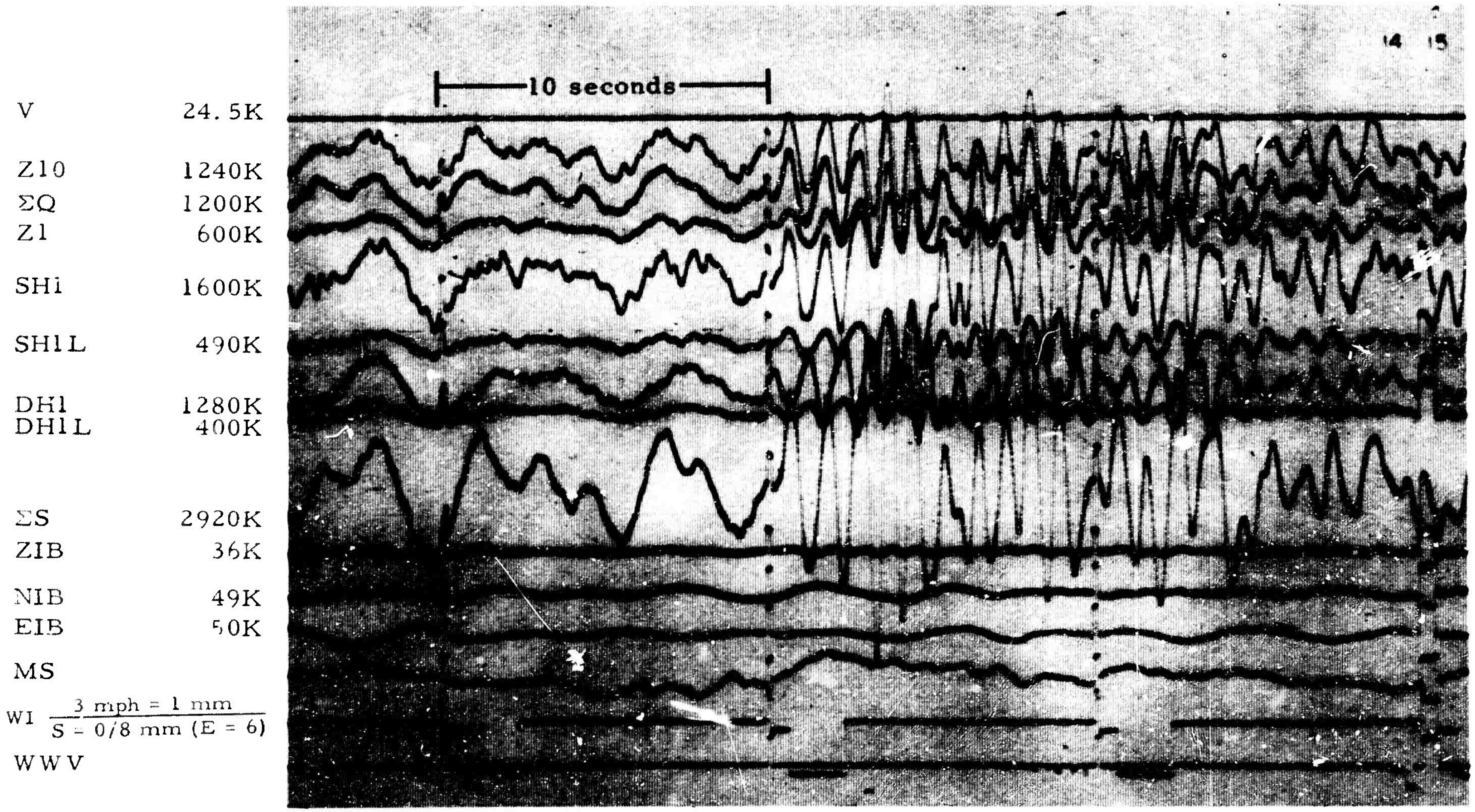
Figure 11. Orientation and configuration of the UBSO array

| | |
|---|---|
| V | 24.5K |
| Z1 | 560K |
| Z3 | 620K |
| Z5 | 580K |
| Z2 | 620K |
| Z4 | 630K |
| Z6 | 620K |
| Z7 | 610K |
| Z8 | 590K |
| Z9 | 560K |
| ΣS | 1480K |
| Z10 | 590K |
| NSP | 640K |
| ESP | 610K |
| WWV | |



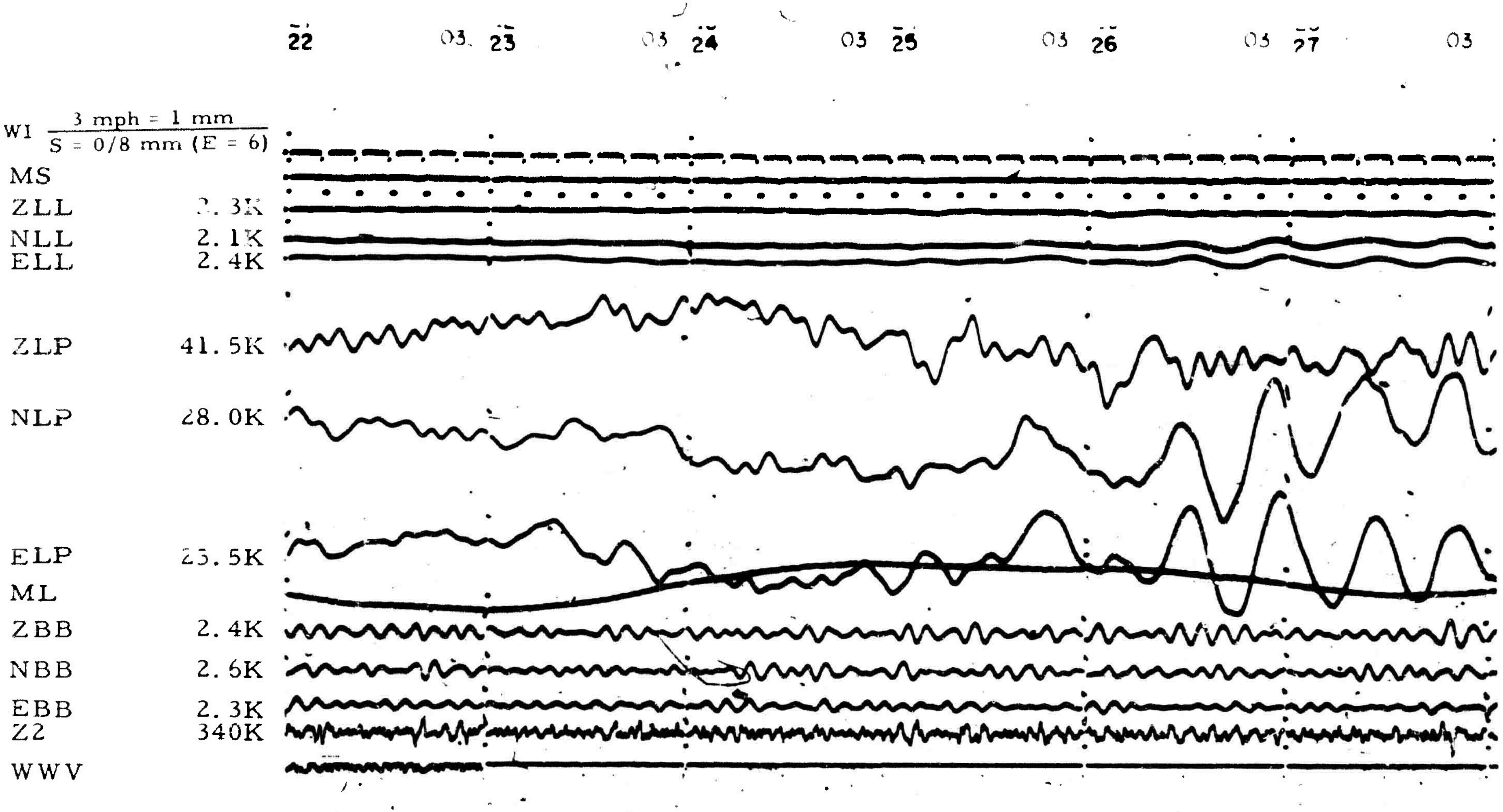
UBSO
Run 120
30 April 1965
Data group 5000

Figure 12. Seismogram illustrating the presentation of Data Group 5000 for UBSO primary fast-speed Develocorder. P arrival from near the coast of Venezuela, $\Delta = 52°$, $h \approx 86$ km, $O = 11:45:27.1$, $m = 5.0$ (USC&GS). (X10 enlargement of 16-mm film)



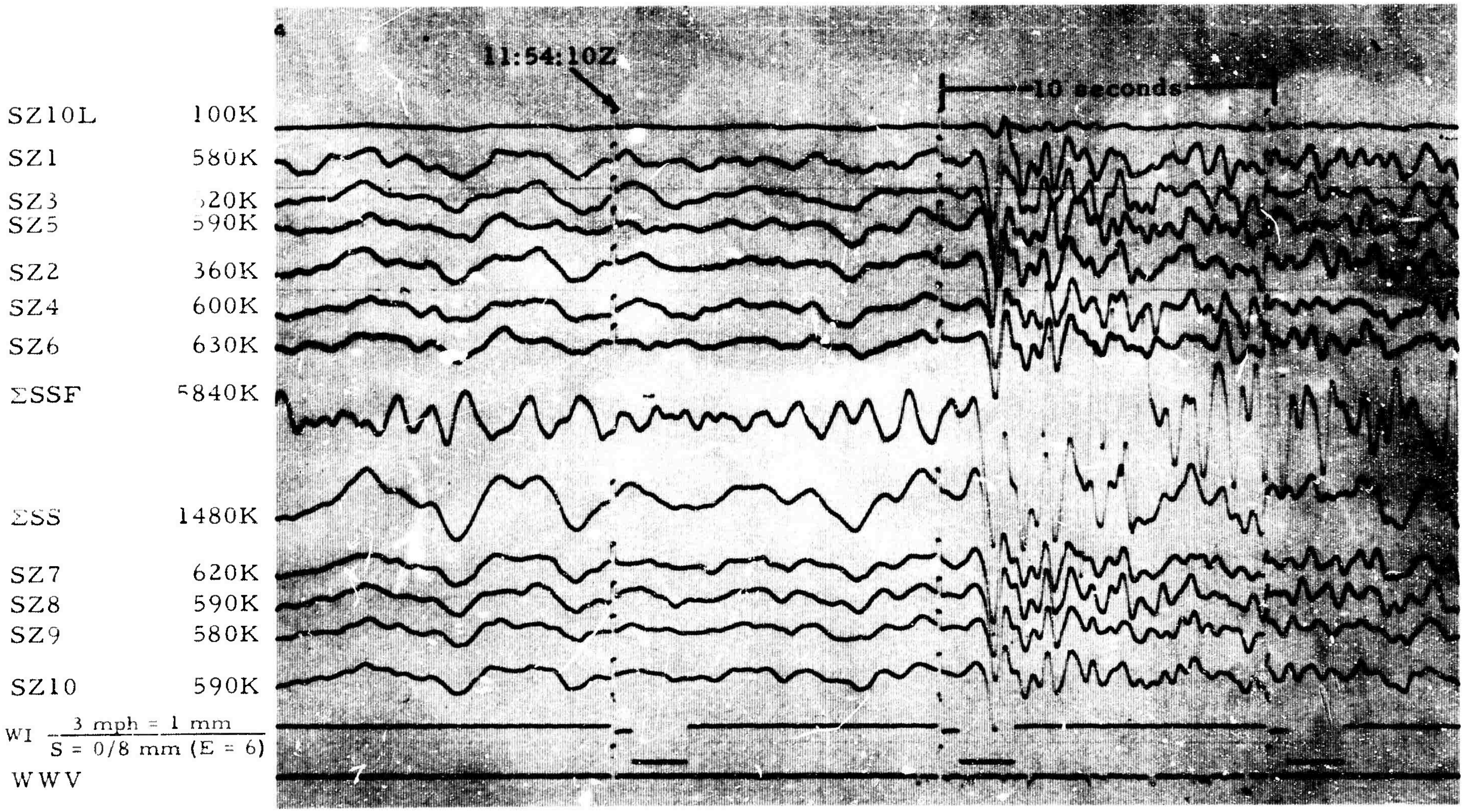
UBSO
Run 119
29 April 1965
Data group 5018

Figure 13. Seismogram illustrating the presentation of Data Group 5013 for UBSO secondary fast-speed Develocorder. P arrival from the Bering Sea, $\Delta \simeq 56°$, $h \simeq 33$ km, O = 14:05:06.9, m = 4.6 (USC&GS). (X10 enlargement of 16-mm film)



UBSO
Run 99
09 April 1965
Data group 5004

Figure 14. Seismogram illustrating the presentation of Data Group 5004 for UBSO slow-speed Develocorder. Phases from unknown epicenter. (X10 enlargement of 16-mm film)



UBSO
Run 120
30 April 1965
Data group 5016

Figure 15. Seismogram illustrating the presentation of Data Group 5016 for UBSO shallow-buried array Develocorder. P arrival from near coast of Venezuela, $\Delta \approx 52°$, $h \approx 86$ km, O = 11:45:27.1, m = 5.0 (USC&GS). (X10 enlargement of 16-mm film)

The keypunch format used in showing these data is given in appendix 3. This format includes the revisions given in the letter report of 17 March 1965, and therefore supersedes all other formats.

Some difficulties have been experienced in standardizing the data upon transferring them from a written to a punched form. The following are among the criteria that have been established to make the data consistent.

a. General Equipment (columns 9-12). The keypunch format is comprehensive enough to cover all items. The main difficulty has been the differentiation between subassemblies and major assemblies. The subassemblies in use at the observatories have been defined and are listed in appendix 3. If an item does not appear on this list it is classed as a major assembly.

b. Component Symbol or Description (columns 43-53). If Electrical and Electronic Reference Designations in Military Standard 16C are meaningful and in common usage, these symbols are used. Examples of this are: R for resistor; C for capacitor; DS for lamp; and V for vacuum tube. If the 16C symbol is uncommon, the name of the component is spelled out (e.g., a galvanometer for which "GALVO" is written). A complete list of the symbols used is given in appendix 3. Mechanical components are always spelled out and are preceded by an M in column 42.

c. Manufacturer's Part Number (columns 54-63). The part number given in the particular operation and maintenance (O&M) manual is used, except for items such as resistors and capacitors. For these items the actual value is recorded; e.g., a 25-microfarad capacitor rated at 200 volts dc is coded 25M200VDC.

d. Component Manufacturer Code (columns 64-68). Some of the larger manufacturers have federal codes for each division. The common codes used are listed in appendix 3.

e. Hours to Repair (columns 69-71). Every component is judged to require at least 0.1 hour for repair or replacement.

f. Time Inoperative (columns 74-78). Care has been taken to allot time inoperative to the item that caused the failure; all other items that are replaced are then given zero time inoperative. An example of this is the failure of a lamp which causes a fuse to blow; the fuse is given zero time inoperative.

g. If data are missing in an alphanumeric field, "XXX" is placed in that field, left justified. This can be combined with the component symbol if that is known, e. g. DSXXX.

Form 273 and the format were adequate for itemizing component failures at the observatories; however, no means are provided for recording losses of data when the failures of components are not involved. Typical examples of frequently occurring losses of this type are jammed film in Develocorders and open lines caused by failure of lightning protection fuses.

A program has been written to tabulate some of the data on the cards. This is discussed in section 3 of this report.

## 2.4 CHANGES AND ADDITIONS TO THE STANDARD INSTRUMENTATION

### 2.4.1 Modification of Minneapolis-Honeywell Magnetic-Tape Recorder Oscillators

The high and low deviations of the carrier frequencies of the oscillators in the Minneapolis-Honeywell (MH) magnetic-tape recorder were originally aligned with a single control. Because alignment was very time consuming, a modification (M1) that provides separate controls for adjusting the high and low deviations was developed in 1963 and all magnetic-tape recorder oscillators at the VT/1124 observatories were modified.

Initially, the modification proved to be very helpful; later, other problems appeared that again increased the time necessary to align the oscillators. These problems are attributed in part to modification M1 and in part to the fact that the characteristics of recently acquired vacuum tubes vary greatly. The range of adjustment of deviations for which the modification was designed was not wide enough; therefore, the range of center-frequency adjustment was inadequate for aligning many of the oscillators when the vacuum tubes were used.

Additional tests indicated that a minor modification (M2) of the oscillator center frequency divider circuit would improve tube versatility by providing a wider range of adjustment of the center frequency. This modification, consisting of changing one resistor in the center frequency divider circuit, was made. To control properly the linearity of the VCO with the M2 modification, it was necessary, when changing tubes, to selectively screen the input dc amplifier tubes (12AX7) by using a five-point linearity check (-40, -20, 0, +20, and +40 percent deviation), instead of the normal three-point check (-40, 0, and +40 percent) used in daily calibration. Field experience indicated that the screening procedure was very time consuming and that calibration of the VCO was cumbersome.

A third modification (M3), which provides improved linearity and eliminates the need for screening the input 12AX7 tube, has been designed and field tested at BMSO. The M3 modification also simplifies the VCO calibration by utilizing a fixed-bias arrangement on the oscillator tube (6U8) instead of the grid-leak-bias technique previously used. Figure 16 is a schematic diagram which shows the M3 modification.

In the future, we plan to modify three additional VCO's to the M3 configuration and to test them briefly under field conditions. If these three units perform as well as the oscillator initially modified has performed, we will recommend that all Minneapolis-Honeywell oscillators in use at the observatories be modified to the M3 configuration.

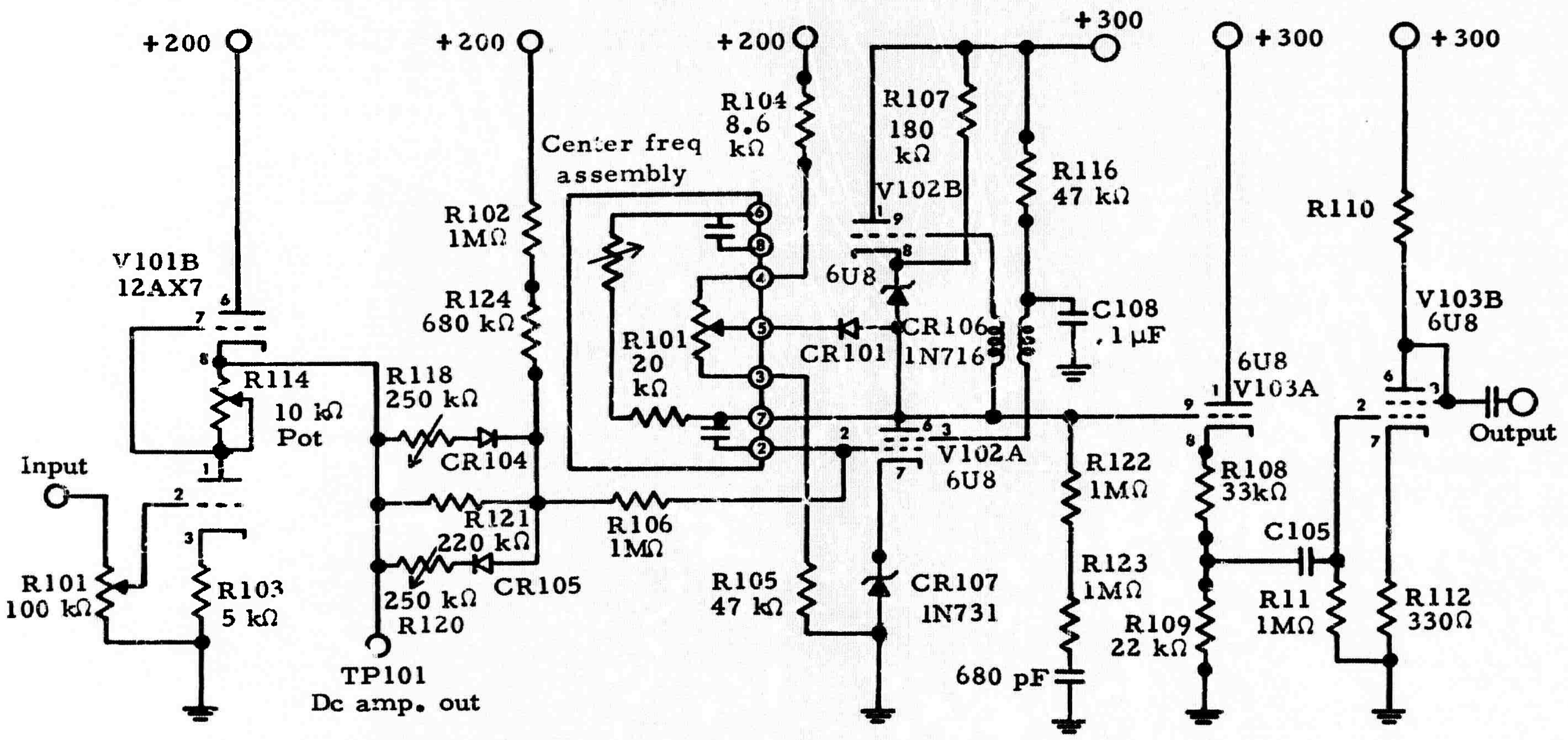
### 2.4.2 Develocorder Modifications

#### 2.4.2.1 Film Transport Modifications

Each observatory was supplied with film transport kits, consisting of a new bearing block assembly, torque motors, wiring harness, and mounting hardware, for modifying the Develocorder transports. This modification eliminates an intermittently operating motor, dc clutches, and chain drives, thereby producing a smoother and more reliable film transport system. One kit was installed at BMSO for evaluation. The modifications proved to be satisfactory except for a problem with the bearing block assembly. The new assembly made it difficult to obtain and to maintain the proper film pressure against the rollers. A new bearing block assembly, developed under another program, was tried without significant improvement. The original bearing block assembly was incorporated into the kit. Kits were installed in all Develocorders during November and December 1964. The benefits of this modification are:

a. Spiking caused by the take-up motors has been eliminated.

b. Occurrences in which the film runs off the rollers have been greatly reduced.



Components added (R124, CR106, CR107) or changed R104, R108, R109, R114, R116) are shown in red. Components deleted are shown in blue.

24350

Figure 16. Honeywell FM Record Oscillator, Model 4215, modification M3

Minor film slippages, which cause narrow blank spaces on the records, can occur if the new film transports are not precisely adjusted. A method is being developed to make this adjustment less critical and to eliminate the slippages.

### 2.4.2.2 Installation and Testing of a Peristaltic Chemical Pump at CPSO and UBSO

An experimental peristaltic chemical pump was installed at CPSO in December 1963. The pump operated without trouble until April 1964 when a punctured tube leaked corrosive fluids onto the shafts of the rotor. Corrosion of the rotor shafts resulted causing the rollers to jam. A new rotor utilizing shafts made of noncorrosive material was installed in the pump and the pump was returned to operation. No further problems are expected with this pump at CPSO, provided that the tube is rotated regularly to prevent excessive wear of any one part of the tube by the rotor.

The Develocorder installed at UBSO to record data from the shallow-buried array had a peristaltic pump already installed. No problems have been experienced with this unit. Because more uniform film processing is obtained and fewer outages due to processing failures occur on Develocorders equipped with the peristaltic pumps, we recommend that these units be furnished for all Develocorders operated at the VT/1124 observatories.

### 2.4.3 Increased Sensitivity of Long-Period Vertical Seismographs

The sensitivity of the long-period vertical seismograph at each observatory was increased by a factor of at least three by installing a more sensitive Pencil Galvanometer, Geotech Model 4915-10, in the Develocorder. The long-period vertical seismographs are now routinely operated at gains as high as 45K with sufficient attenuation between the seismometer and the PTA to prevent a significant change in the frequency response.

### 2.4.4 Revision of Outdoor Cable Identification

The use of colored tape for outdoor cable coding, established when the observatories were installed, is impractical because the colors fade. In some instances, it is nearly impossible to read the cable code, and in other instances, the strips of tape were lost. A new method of coding outdoor cable has been adopted. Similar to the one used at WMSO, the new method is to attach to the cable an aluminum tag stamped with the appropriate code. The code is easily put on the tag by using a figure and letter set and a stamp jig. The new system is used at each lightning protector, each vault, on both sides of every connector, and wherever additional identification is needed. These tags are inexpensive and easily attached, and should be readable for the life of the cable. Outdoor coding of cables at BMSO, CPSO, and UBSO was completed during August 1964. The cable code used at the VT/1124 observatories is given in appendix 4

### 2.4.5 Addition of Data Controls

Data controls for the operation of a second fast-speed Develocorder were installed at CPSO in December 1963, and at UBSO and BMSO in February 1964. Additions included a relay rack, 2 data control frames, and 16 data control modules. One change affected the primary Develocorder. This consisted of removing the single-channel Develocorder Switching Unit, Model 5970, and replacing it with a dual-channel Develocorder Switching Unit, Model 18162. The new dual-channel switching unit accommodates two complete sets of data which can be simultaneously switched to either of two Develocorders, e.g., primary and secondary. No problems were encountered when these additions were made. Each observatory is now recording data on three Develocorders daily (four at UBSO). Data formats currently active are shown in tables 3, 4, and 5.

### 2.4.6 Installation of Earth-Powered Seismographs

The earth-powered seismograph at each observatory consists of a vertical Benioff Seismometer, Geotech Model 1051, located on the experimental pier in the Central Recording Building (CRB), and a special 12-Hz recording galvanometer in the Develocorder on which primary short-period data are recorded. Figure 17 shows the frequency response and lists the operating parameters of the earth-powered seismograph. The maximum magnification available from this seismograph is approximately 20K at 1 Hz.

Noise is present on the earth-powered seismographs at each observatory during some periods of operation. This noise is attributed to two primary sources. When the air conditioning units are operating, a continuous high-frequency noise is generated. Intermittent noise pulses, of greater amplitude than the air conditioner-induced noise, result from the movement of personnel inside the CRB in the vicinity of the pier room. Efforts to reduce the effects of the high-frequency noise at CPSO showed that capacity filtering was most effective, so capacity filtering was incorporated in the earth-powered seismograph circuits at BMSO and UBSO

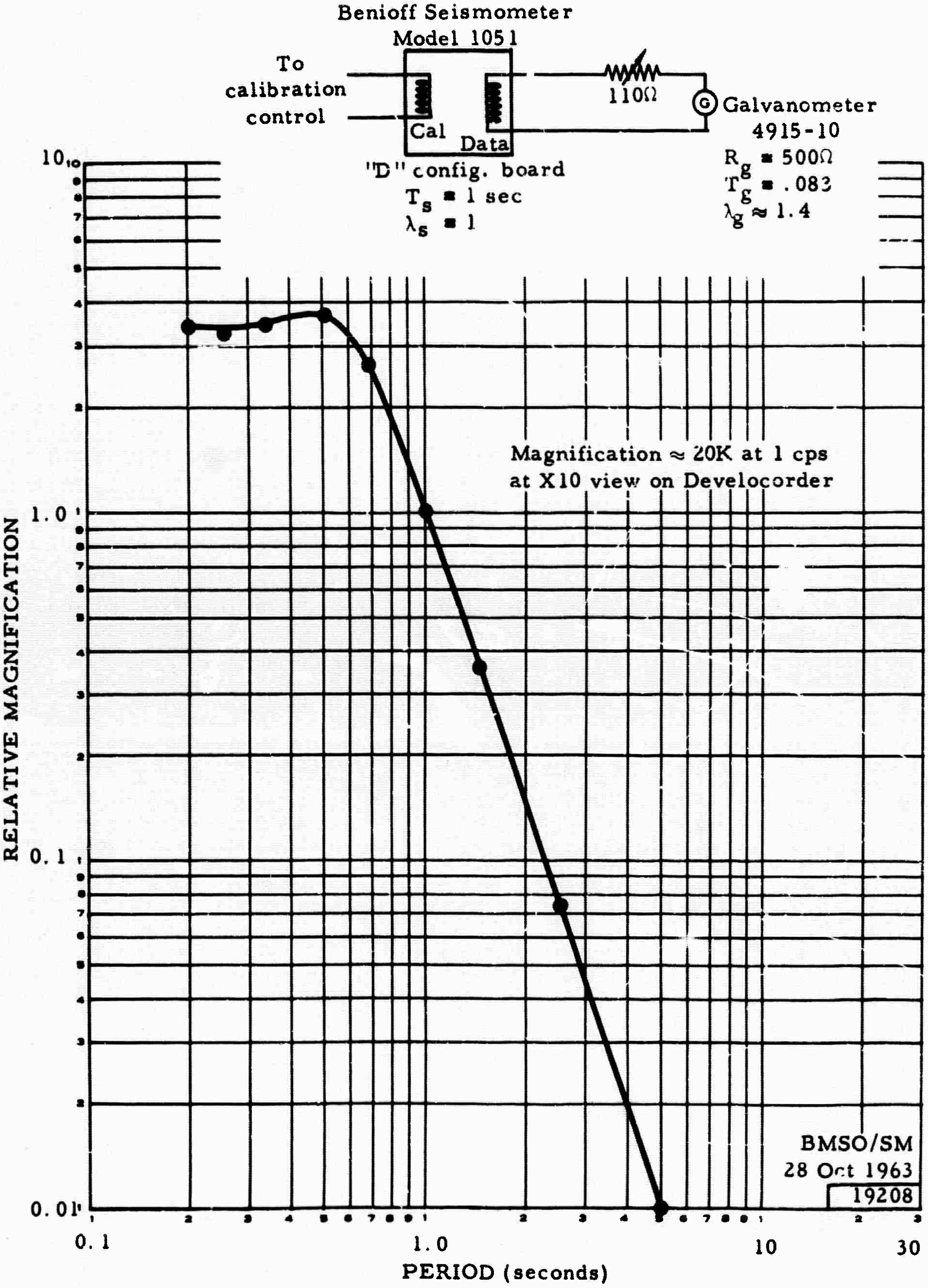


Figure 17. Frequency response of earth-powered seismograph

It is desirable to have two earth-powered seismographs operating simultaneously at two magnification levels. Initially, both 5K and 50K earth-powered seismographs were proposed for the VT/1124 observatories. The 20K seismograph was installed as a compromise to expedite the activation of the earth-powered seismographs, because no galvanometer was available that was sensitive enough to yield a magnification of 50K in an earth-powered system.

The development of a more sensitive galvanometer that can be utilized in a 50K earth-powered system was considered. Little benefit would be gained, however, from a 50K system unless the level of the noise can be reduced.

In March 1965, the earth-powered trace was added to the secondary fast-speed Develocorder at BMSO, CPSO, and UBSO. A 20-30K earth-powered seismograph is now recorded on trace 1 of one fast-speed Develocorder and a 1K earth-powered seismograph is recorded on trace 1 of a second fast-speed Develocorder. These two seismographs are not routed through the Develocorder switching unit, and therefore, always remain on the same Develocorders. The low-gain, earth-powered traces are useful in recording large magnitude signals, such as that shown in figure 18. The magnification of the earth-powered seismographs is checked weekly by manual weight lift.

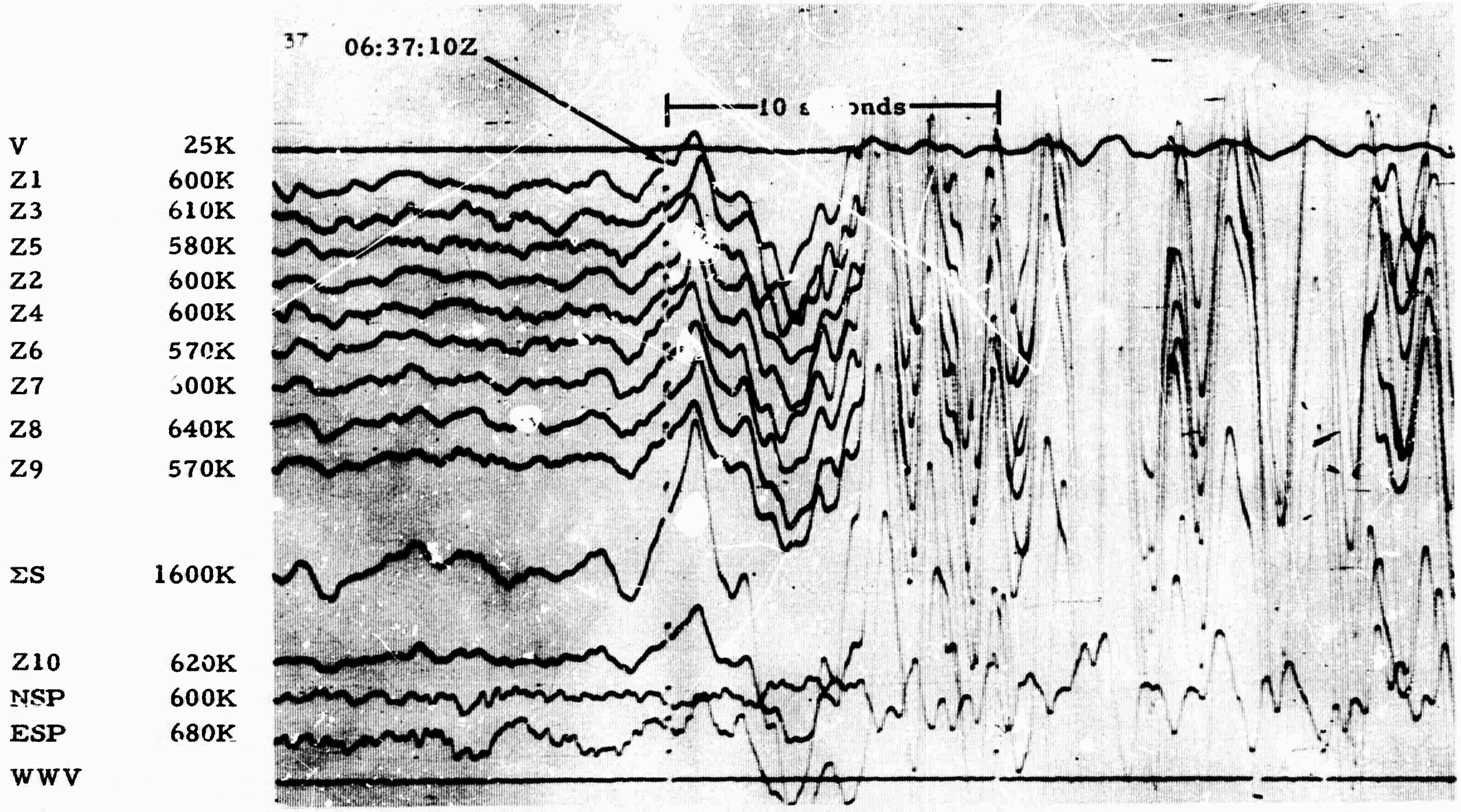
### 2.4.7 Installation of Microbarograph

A microbarograph system was installed at each observatory during the reporting period. This system consists of the following components:

1 Microbarograph Transducer, Geotech Model 10741
1 Transducer Can, Geotech Model 11057
1 Oscillator, Geotech Model 10380
1 FM Discriminator, Geotech Model 10821
1 Filter Amplifier, Geotech Model 11982
1 Filter Amplifier, Geotech Model 12020
1 Power Distributor, Geotech Model 12322
1 Power Supply, Lambda Model C281-M

The can, transducer, and oscillator are located at the tank farm; the discriminator, filter amplifiers, power distributor, and power supply are installed in the CRB.

The can supplies a reference pressure, and the transducer senses differences between the atmospheric pressure and the reference pressure. A signal is generated by the transducer, which is frequency modulated by the oscillator,



UBSO
Run 108
18 April 1965
Data group 5000

Figure 18. UBSO primary short-period seismogram illustrating the advantage of an earth-powered vertical short-period seismograph for recording a very large amplitude event. P arrival from off the coast of northern California, $\Delta \simeq 16°$, $h \simeq 20$ km, O = 06:33:58.8, m = 5.6 (USC&GS).
(X10 enlargement of 16-mm film)

and transmitted to the discriminator where the FM signal is transformed into analog form. The resulting analog signal is fed to the two amplifiers, which divide the signal into high- and low-frequency bands. The frequency-response curves predicted for the high- and low-frequency systems are shown in figure 19.

All cable and equipment necessary for operation of a microbarograph system were installed at CPSO in December 1963, and at UBSO and BMSO in February 1964. An example of the high-frequency data (designated MS) and the low-frequency data (designated ML) is shown in figures 9 and 10, respectively.

### 2.4.8 Installation and Activation of Wind Indication Systems

A wind-direction-indication system was designed, assembled and installed at each observatory. It includes an anemometer, a Wind Direction Indicator, Texas Electronics Model 616P, and a Wind Indicator, Geotech Model 18515. The system records both the speed and the direction of the wind on the same data channel. The wind speed is recorded by an upward deflection of the trace for a 7-second interval, followed by a 1-second baseline. The baseline is followed by a 2-second downward trace deflection indicating wind direction.

This wind-indication system was activated at CPSO in December 1963, at BMSO in January 1964, and at UBSO in February 1964.

The wind-indication data (designated WI) as recorded on the secondary fast-speed Develocorders are shown in figures 5, 9, and 13.

### 2.4.9 Installation of Johnson-Matheson Horizontal Short-Period Seismometers

Early in November 1963, the Benioff Horizontal Seismometers, Geotech Model 6102A, used at BMSO, CPSO, and UBSO, were replaced by Johnson-Matheson Horizontal Seismometers, Model 7515. This change allows the horizontal SP seismographs to be operated with a frequency response identical to that of the vertical SP array instruments. In addition, the calibrators of these new seismometers are more stable than those of the Benioff horizontal seismometers. No problems have occurred in the operation of these new instruments.

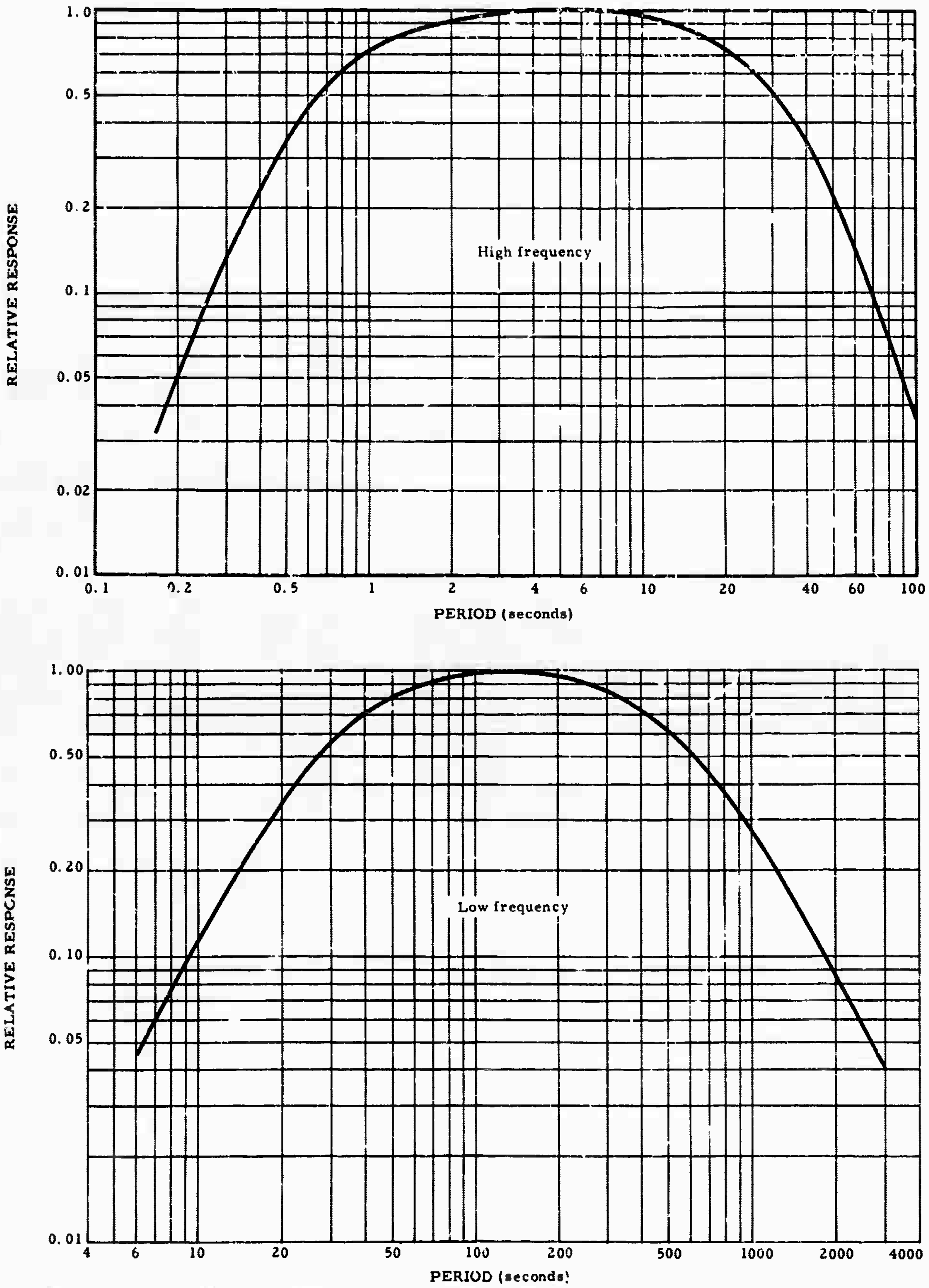


Figure 19. Frequency responses of the high-frequency and low-frequency microbarograph system

### 2.4.10 Installation of Frequency Counters

A Digital Time and Frequency Counter, General Radio Model 1151-A, was purchased for each observatory. The counters were modified by adding a switch to permit measurement of periods greater than 10 seconds and by adding a small coupling transformer to the input connector to increase the input sensitivity. This unit is a solid-state device and operates from an ac source.

The frequency counters have proved very helpful at the observatories in performing the following tasks:

Seismograph frequency response checks
Tape recorder oscillator alignment
Routine seismograph calibration.

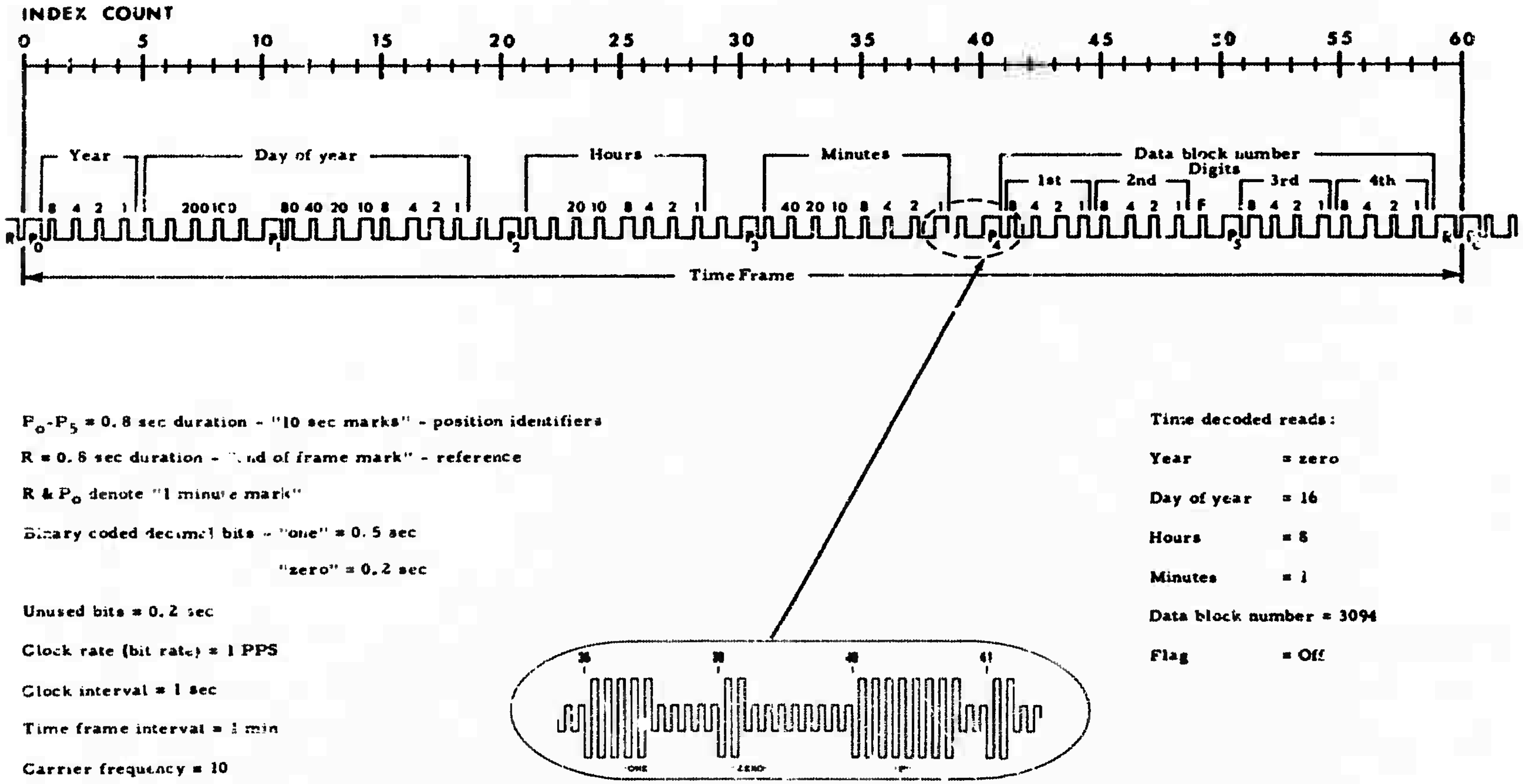
Before the frequency counter was used, numerous frequency responses appeared to be out of tolerance due to inaccurate calibration frequencies. Time was needlessly consumed in adjusting the seismograph parameters to correct for the apparent deviations in frequency response. Now that frequency counters are used, this problem has been eliminated.

Less time is required to align tape recorder oscillators because the carrier frequency can be determined more rapidly with the frequency counter. In addition, seismograph magnification is more accurately determined because the calibration frequency can be set precisely when monitored with the frequency counter.

### 2.4.11 Installation of Time Encoders

A Time Encoder, Model 15925M1, and a Time Encoder Auxiliary Output Unit, Model 19783, were sent to BMSO and UBSO. The outputs of the time encoder and the auxiliary unit are recorded on channel 1 of magnetic-tape recorders No. 1 and No. 2, respectively. The two time encoders provide separate time-coded outputs with independent data identification and control information. The program, shown in figure 20, is coded in accordance with the standard VELA-UNIFORM Time Code.

The time encoder, a solid-state digital device, operates from a dc power source and generates a time-coded output. The auxiliary output unit is also a solid-state digital device operating from a dc source. It takes the time-code



$P_0$-$P_5$ = 0.8 sec duration - "10 sec marks" - position identifiers

R = 0.8 sec duration - "End of frame mark" - reference

R & $P_0$ denote "1 minute mark"

Binary coded decimal bits - "one" = 0.5 sec

"zero" = 0.2 sec

Unused bits = 0.2 sec

Clock rate (bit rate) = 1 PPS

Clock interval = 1 sec

Time frame interval = 1 min

Carrier frequency = 10

Data block number = 4 digits

Flag bit - F - denotes abnormal recording format when value is "one". (See index count 49)

Time decoded reads:

| | |
|---|---|
| Year | = zero |
| Day of year | = 16 |
| Hours | = 8 |
| Minutes | = 1 |
| Data block number | = 3094 |
| Flag | = Off |

24349

Figure 20. VELA UNIFORM standard time code for use with magnetic-tape recording

signals from the time encoder and generates a time-coded output identical to the output of the time encoder, but generates independent identification and control information. The number of outputs from the auxiliary output unit can be increased to four by the installation of additional printed circuit boards and associated wiring.

The time encoders installed at BMSO and UBSO had been troublesome because of time changes experienced in the digital logic circuits. Some modifications were made in October 1964 to correct these problems; however, occasional time changes were still being experienced. In December 1964, circuits were installed in the auxiliary encoder output unit at UBSO to provide an additional output of data management information for the buried array data. At this time different wiring and grounding techniques were applied to the internal wiring and external cabling of the encoder units; this has been very helpful in eliminating the time changes.

Decoupling capacitors and low resistance fuses were also added to the encoders. In January, changes that were made in the UBSO encoder units were made in the BMSO units. No further time changes have been experienced since these modifications were made.

A dual-channel digital Time Encoder, Model 13159, which was available from Project VT/036 (WMSO), was sent to CPSO. This unit is an ac-operated solid-state device but performs the same general functions as the Model 15925M1 encoder. The unit performed satisfactorily at WMSO except when commercial ac power failed. Before emergency power became available after a failure, the encoder would cease to be synchronized with the timing system. For this reason a 50-VA dc-to-ac Inverter, Electronic Research Associates Model IT 254B, was purchased so that power for the encoder could be drawn from the continuously available dc power system. The Model 13159 time encoder and the inverter were installed at CPSO in February 1965. No further problems were encountered and the encoder operated satisfactorily at CPSO for the remainder of the reporting period.

### 2.4.12 Installation of Recording Thermometers

During the early part of May 1964, Taylor recording thermometers were installed at the three observatories. These instruments provide 7-day paper records of temperature fluctuations.

### 2.4.13 Installation of Barometers and Pressure Gauges

During the reporting period, each observatory was supplied with a Taylor barometer and a Fisher pressure gauge to aid in measuring the time constants of the LP vaults in the continuing experiments to reduce LP noise.

### 2.4.14 Installation of Beckman Ac Line Voltage Regulators

Because the Stevens-Evans Model 760R ac line voltage regulator at UBSO performed well after it was installed under the previous contract, similar regulators were installed at BMSO in February 1964 and at CPSO in March 1964. These regulators supply power to the PTA's and the magnetic-tape recorder electronics. The two regulators are identical to the one at UBSO, but are sold under the name of Beckman. The specifications for this regulator are given in table 6; an evaluation of the performance of the three regulators is given in section 3.

### 2.4.15 Installation of Automatic Tape Capstan Switch

In December 1964, automatic switching relays were installed in the power circuits of the magnetic-tape recorders so that, if the primary frequency-regulated power fails, the tape recorder capstan motors will automatically switch to commercial power. This switching relay is supplied with a dual indicator lamp assembly. This modification has proved helpful in avoiding losses of data when the frequency-regulated power fails.

### 2.4.16 Installation of an Array of Buried Seismographs at UBSO

Studies had indicated that the effect of wind-generated noise on an array of seismometers is significantly reduced if the individual elements of the array are buried to a depth of approximately 200 feet. Geotech recommended the installation of such an array at UBSO, and a supplemental agreement for the installation of a 10-element buried array was made to the contract. The array was installed in the fall of 1964 and became fully operational on 28 January 1965. The installation is described in detail in Technical Report 65-28.

Major considerations in such an undertaking included the selection of the most effective array pattern and the most suitable instrumentation to be used. In addition, the drilling, logging, and casing of the holes is outlined, and a brief section on the local geology is included. TR 65-28 does not attempt to evaluate

Table 6. Specifications for Ac Line Voltage Regulator, Beckman Model 760R

| | |
|---|---|
| Input ranges | 95-115 Vac<br>105-125 Vac<br>115-135 Vac |
| Input frequency | 60 cps ±1 cps |
| Input current | 12 amperes maximum |
| Input harmonics | 8% maximum |
| Output range | 110-120 Vac |
| Output pc | 0-1 kva |
| Regulation (line and load) | 0.1% |
| Output harmonics | Less than 0.25% |
| Harmonic attenuation | 40 dB |
| Transient rejection | 40 dB |
| Input/output isolation | 100 dB |
| Response time | 150 μsec |
| Power factor ranges | Full current rating up to 0.7 leading or lagging<br>Half current rating to 0 leading or lagging |
| Operating temperature | 0-40°C |

the effectiveness of the shallow-buried array, but merely documents the procedures and considerations utilized in the installation of a shallow-buried array.

Evaluation of the performance and effectiveness of the buried array is planned for the future. Preliminary data indicate that, as anticipated, the capabilities of the surface and buried arrays are about equal for wind speeds up to about 20 mph. The capability of the buried array is superior to that of the surface array when wind speeds exceed 20 mph and wind-induced noise is present on the surface array seismogram.

## 2.5 CALIBRATION OF TEST EQUIPMENT

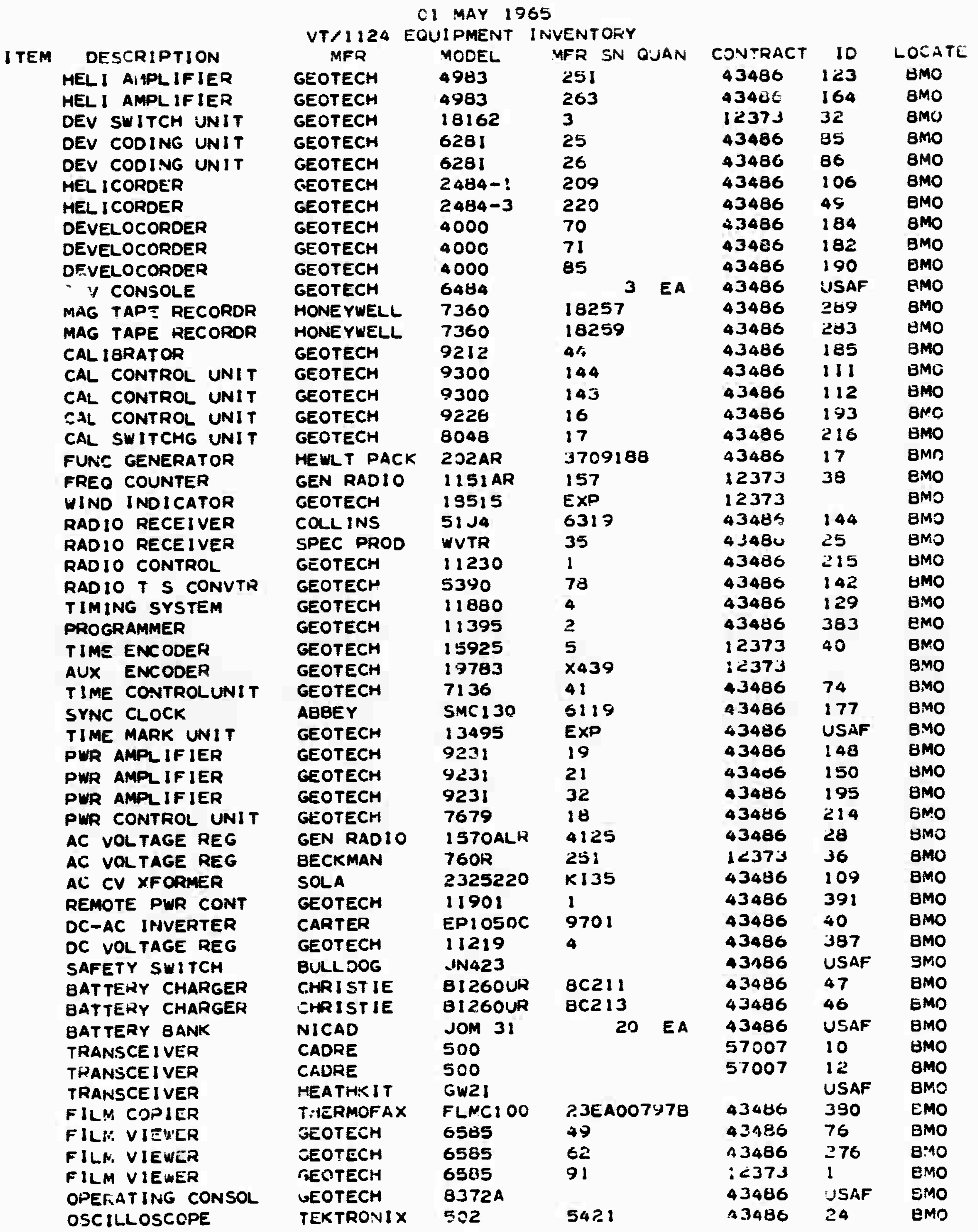
A procedure which does not require that each item be sent to the Garland laboratory for calibration, has been established for checking and calibrating the observatory test equipment. Observatory personnel now check and calibrate a major portion of the test equipment.

A 1 percent standard meter was supplied to the observatories for calibration of test equipment only. The meter is a Multimeter, Weston Model 80, with an accuracy of 1 percent of full scale.

Since February 1965, a dual equipment calibration record/log,for each item of test equipment,has been kept up-to-date by the observatory and Garland laboratory personnel. An example of the record/log is shown in appendix 2.

## 2.6 EQUIPMENT INVENTORY

To simplify the task of maintaining accurate records of observatory instrumentation, inventory information is now routinely stored on IBM cards. A keypunch format was devised and the system was established in February 1965. A typical page from a printout of the inventory is shown in figure 21. An up-to-date printout is sent to each observatory each month so the inventory can be checked.



```
                                    01 MAY 1965
                            VT/1124 EQUIPMENT INVENTORY
ITEM   DESCRIPTION           MFR          MODEL     MFR SN QUAN      CONTRACT  ID     LOCATE
       HELI AMPLIFIER        GEOTECH      4983      251              43486     123    BMO
       HELI AMPLIFIER        GEOTECH      4983      263              43486     164    BMO
       DEV SWITCH UNIT       GEOTECH      18162     3                12373     32     BMO
       DEV CODING UNIT       GEOTECH      6281      25               43486     85     BMO
       DEV CODING UNIT       GEOTECH      6281      26               43486     86     BMO
       HELICORDER            GEOTECH      2484-1    209              43486     106    BMO
       HELICORDER            GEOTECH      2484-3    220              43486     49     BMO
       DEVELOCORDER          GEOTECH      4000      70               43486     184    BMO
       DEVELOCORDER          GEOTECH      4000      71               43486     182    BMO
       DEVELOCORDER          GEOTECH      4000      85               43486     190    BMO
       [illegible] V CONSOLE GEOTECH      6484                 3 EA  43486     USAF   BMO
       MAG TAPE RECORDR      HONEYWELL    7360      18257            43486     289    BMO
       MAG TAPE RECORDR      HONEYWELL    7360      18259            43486     283    BMO
       CALIBRATOR            GEOTECH      9212      44               43486     185    BMO
       CAL CONTROL UNIT      GEOTECH      9300      144              43486     111    BMO
       CAL CONTROL UNIT      GEOTECH      9300      143              43486     112    BMO
       CAL CONTROL UNIT      GEOTECH      9228      16               43486     193    BMO
       CAL SWITCHG UNIT      GEOTECH      8048      17               43486     216    BMO
       FUNC GENERATOR        HEWLT PACK   202AR     3709188          43486     17     BMO
       FREQ COUNTER          GEN RADIO    1151AR    157              12373     38     BMO
       WIND INDICATOR        GEOTECH      19515     EXP              12373            BMO
       RADIO RECEIVER        COLLINS      51J4      6319             43486     144    BMO
       RADIO RECEIVER        SPEC PROD    WVTR      35               43486     25     BMO
       RADIO CONTROL         GEOTECH      11230     1                43486     215    BMO
       RADIO T S CONVTR      GEOTECH      5390      78               43486     142    BMO
       TIMING SYSTEM         GEOTECH      11880     4                43486     129    BMO
       PROGRAMMER            GEOTECH      11395     2                43486     383    BMO
       TIME ENCODER          GEOTECH      15925     5                12373     40     BMO
       AUX  ENCODER          GEOTECH      19783     X439             12373            BMO
       TIME CONTROLUNIT      GEOTECH      7136      41               43486     74     BMO
       SYNC CLOCK            ABBEY        SMC130    6119             43486     177    BMO
       TIME MARK UNIT        GEOTECH      13495     EXP              43486     USAF   BMO
       PWR AMPLIFIER         GEOTECH      9231      19               43486     148    BMO
       PWR AMPLIFIER         GEOTECH      9231      21               43486     150    BMO
       PWR AMPLIFIER         GEOTECH      9231      32               43486     195    BMO
       PWR CONTROL UNIT      GEOTECH      7679      18               43486     214    BMO
       AC VOLTAGE REG        GEN RADIO    1570ALR   4125             43486     28     BMO
       AC VOLTAGE REG        BECKMAN      760R      251              12373     36     BMO
       AC CV XFORMER         SOLA         2325220   K135             43486     109    BMO
       REMOTE PWR CONT       GEOTECH      11901     1                43486     391    BMO
       DC-AC INVERTER        CARTER       EP1050C   9701             43486     40     BMO
       DC VOLTAGE REG        GEOTECH      11219     4                43486     387    BMO
       SAFETY SWITCH         BULLDOG      JN423                      43486     USAF   BMO
       BATTERY CHARGER       CHRISTIE     B1260UR   8C211            43486     47     BMO
       BATTERY CHARGER       CHRISTIE     B1260UR   8C213            43486     46     BMO
       BATTERY BANK          NICAD        JOM 31              20 EA  43486     USAF   BMO
       TRANSCEIVER           CADRE        500                        57007     10     BMO
       TRANSCEIVER           CADRE        500                        57007     12     BMO
       TRANSCEIVER           HEATHKIT     GW21                                 USAF   BMO
       FILM COPIER           THERMOFAX    FLMC100   23EA007978       43486     390    BMO
       FILM VIEWER           GEOTECH      6585      49               43486     76     BMO
       FILM VIEWER           GEOTECH      6585      62               43486     276    BMO
       FILM VIEWER           GEOTECH      6585      91               12373     1      BMO
       OPERATING CONSOL      GEOTECH      8372A                      43486     USAF   BMO
       OSCILLOSCOPE          TEKTRONIX    502       5421             43486     24     BMO
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Figure 21. Typical page of observatory inventory printout

# 3. EVALUATION OF STANDARD INSTRUMENTATION AT THE VT/1124 OBSERVATORIES

## 3.1 CALIBRATOR MOTOR CONSTANTS

### 3.1.1 Determination of Seismograph Motor Constants

The motor constants (G)[1] are determined by comparing the seismogram trace deflection produced by manual weight lift and deflections produced by pulses generated by dc currents of known value. Weight lifts are made with the smallest practical weight with which a high signal-to-noise ratio can be obtained. The smallest weight used on any of the seismographs is 0.2 gram; however, except for the short-period Johnson-Matheson (JM) seismometers, larger weights are used when necessary because of the level of the background noise.

The 0.2-gram weight was specified for use on short-period JM seismographs because it is the smallest weight that could be lifted manually without introducing significant error, and because dc current required to produce trace deflections equivalent to the deflections produced by larger weights falls within the nonlinear range of the calibration actuator used in the JM seismometers at the VT/1124 observatories. A new type of calibration actuator that is linear over a greater range of dc currents is now available for the JM seismometer. Tests of this calibrator conducted at CPSO are discussed in section 3.13.

The motor constants of the calibration actuators of all seismographs were set to their specified values during the last 6 months of 1962 when the seismographs were installed. Since that time, the motor constants of the short-period array instruments have been determined annually and the motor constants of the seismographs in the three-component system have been determined semiannually. Calibrator motor constants were also determined when seismometers were replaced or repaired and for special tests.

The motor constants were adjusted when their measured values deviated from the specified values shown in table 7 by more than 3 percent. This was accomplished for the various seismometers as follows:

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[1] The motor constant "G" is defined as the force in newtons exerted on the mass per ampere of current passed through the calibrator coil.

## Table 7. Values specified for calibrator motor constants at the VT/1124 observatories

| | BMSO | | | | | CPSO | | | | | UBSO | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Seismograph | Installation to Nov 63 check | Nov 63 to Jun 64 check | Jun 64 to Sept-Oct 64 check | Sept-Oct 64 to Mar-May 65 check | Mar-May 65 check | Installation to Jul-Aug 63 check | Jul-Aug 63 to Apr 64 check | Apr 64 to Jul-Oct 64 check | Jul-Oct 64 to Apr 65 check | Apr 65 check | Installation to Sept-Nov 63 check | Sept-Nov 63 to May-Jul 64 check | May-Jul 64 to Sept-Nov 64 check | Sept-Nov 64 to Jan-Apr 65 check | Jan-Apr 65 check |
| Johnson-Matheson short-period vertical | 0.430 | 0.423 | 0.423 | 0.423 | 0.423 | 0.432 | 0.432 | 0.432 | 0.432 | 0.432 | 0.426 | 0.428 | 0.428 | 0.434 | 0.434 |
| Johnson-Matheson short-period horizontal | a | 0.423 | 0.423 | 0.423 | 0.423 | a | a | 0.432 | 0.432 | 0.432 | a | a | 0.428 | 0.434 | 0.434 |
| Benioff short-period horizontal | 0.352 | b | b | b | b | 0.355 | 0.355 | b | b | b | 0.348 | 0.348 | b | b | b |
| Intermediate-band vertical | 0.1028 | 0.0994 | 0.0994 | 0.0994 | 0.0994 | 0.0865 | 0.0865 | 0.0865 | 0.0865 | 0.0865 | 0.0853 | 0.0891 | 0.0883 | 0.0946 | 0.0946<br>0.0903[c] |
| Intermediate-band horizontal | 4.94 | 4.94 | 4.94 | 4.94 | 4.94 | 4.94 | 4.94 | 4.92 | 4.92 | 4.92 | 4.94 | 4.91 | 4.91 | 5.06 | 4.96 |
| Broad-band vertical and horizontal | 86.1 | 86.1 | 86.1 | 86.1 | 86.1 | 83.0 | 83.0 | 83.0 | 83.0 | 83.0 | 80.4 | 81.9 | 81.9 | 80.3 | 80.3 |
| Long-period vertical and horizontal | 0.305 | 0.305 | 0.291 | 0.293 | 0.293 | 0.320 | 0.320 | 0.320 | 0.320 | 0.320 | 0.326 | 0.334 | 0.338 | 0.326 | 0.323 |

[a] Benioff horizontal seismometers used at this time

[b] Replaced by JM horizontal seismometers

[c] Intermediate-band vertical G UBSO after 23 April 1965

a. Short-period JM - by adjusting the outer pole piece of the calibration actuator;

b. Three-component long-period, broad-band, and intermediate-band vertical - by adding magnetic shunts to or by removing them from the appropriate magnet;

c. Intermediate-band horizontal - by adjusting a resistive shunt in the line termination module at the CRB.

### 3.1.2 Variation in the Motor Constants of the Short-Period Seismographs

The variations that occurred in the motor constants of the short-period seismographs before July 1964 were reported in TR 64-3 and TR 64-87. The percentage changes since July 1964 are listed in tables 8, 9, and 10.

The average changes in motor constants for all short-period instruments between the 1963 and the 1964 annual G determinations were 2.8, 2.6, and 2.1 percent, respectively, for BMSO, CPSO, and UBSO. The average changes in motor constants for the three-component short-period systems that occurred between the 1964 annual check and the 1965 semiannual G determinations were 1.6 and 1.7 percent, respectively, for BMSO and UBSO. The 1965 semiannual motor constant determination for CPSO were not scheduled during this reporting period.

The most serious changes, 12.3 percent on Z6 and 7.9 percent on Z19 at CPSO, are attributed to the fact that the 1964 check of G's was made before we started degaussing the short-period seismographs after lightning storms. The values of these earlier G's probably include both the effects of magnetic changes induced in the calibrator pole pieces by lightning current pulses and normal motor constant variations. Changes in the values of G for the other short-period seismometers at CPSO were less than 6 percent, as were the changes for all short-period instruments at both BMSO and UBSO

### 3.1.3 Variations in the Motor Constants of the Intermediate-Band, Broad-Band, and Long-Period Seismographs

The percentages of change in intermediate-band, broad-band, and long-period motor constants found when the 1964 annual G's and the 1965 semiannual G's were determined are given for each observatory in tables 8, 9, and 10. The average change in motor constants for each system is presented in table 11. Changes that occurred earlier during the contract were reported in TR 64-3

# Table 8. Annual and semiannual motor constants determined at BMSO

| Seismograph | | G's at installation | Annual G's Sept-Nov 1963 | | Semiannual June 1964 | | Annual G's Sept-Oct 1964 | | | Semiannual G's Mar-May 1965 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Nov-Dec 1962 | As found | After adjustment | As found | After adjustment | As found | Percentage change from previous G | After adjustment | As found | Percentage change from previous G | After adjustment |
| SP | Z1 | 0.437 | 0.427 | 0.427 | | | 0.406 | -4.9 | 0.423[a] | | | |
| | Z2 | 0.428 | 0.424 | 0.424 | | | 0.404 | -5.3 | 0.429[a] | | | |
| | Z3 | 0.436 | 0.425 | 0.425 | 0.426 | 0.426 | 0.423 | -0.7 | 0.423 | 0.431 | +1.9 | 0.431 |
| | Z4 | 0.428 | 0.414 | 0.414 | | | 0.429 | +3.5 | 0.429 | | | |
| | Z5 | 0.436 | 0.423 | 0.423 | | | 0.448 | +5.9 | 0.424[a] | | | |
| | Z6 | 0.433 | 0.448 | 0.413[a] | | | 0.404 | -1.6 | 0.423[a] | | | |
| | Z7 | 0.424 | 0.395 | 0.417[a] | | | 0.414 | -0.7 | 0.414 | | | |
| | Z8 | 0.438 | 0.441 | 0.428[a] | | | 0.446 | +4.2 | 0.426[a] | | | |
| | Z9 | 0.428 | 0.415 | 0.415 | | | 0.419 | +0.9 | 0.419 | | | |
| | Z10 | 0.429 | 0.440 | 0.422[a] | | | 0.404 | -4.2 | 0.419[a] | | | |
| Benioff | NSP | 0.350 | 0.349 | | | | | | | | | |
| Benioff | ESP | 0.357 | 0.378 | | | | | | | | | |
| JM | NSP | | | 0.424 | 0.418 | 0.418 | 0.419 | +0.2 | 0.419 | 0.428 | +2.1 | 0.428 |
| JM | ESP | | | 0.419 | 0.422 | 0.422 | 0.416 | -1.4 | 0.416 | 0.419 | +0.7 | 0.419 |
| | ZIB | 0.103 | 0.101 | 0.101 | 0.0986 | 0.0986 | 0.099 | +0.4 | 0.099 | 0.0998 | +0.8 | 0.0998 |
| | NIB | 4.92 | 5.20 | 4.95[a] | 5.03 | 5.03 | 5.00 | -0.6 | 5.00 | 5.56 | +11.2 | 4.93[a] |
| | EIB | 5.03 | 4.95 | 4.95 | 4.89 | 4.89 | 5.32 | +8.6 | 4.92[a] | 4.58 | -6.8 | 4.97[a] |
| | ZBB | 87.4 | 86.9 | 86.9 | 88.2 | 88.2 | 80.8 | -8.4 | 84.5[a] | 84.8 | +0.4 | 84.8 |
| | NBB | 85.0 | 82.[illegible] | 85.3[a] | 85.1 | 85.1 | 84.6 | -0.6 | 84.6 | 86.4 | +2.1 | 86.4 |
| | EBP | 85.6 | 86.2 | 86.2 | 86.1 | 86.1 | 95.7 | +11.1 | 85.8[a] | 87.3 | +1.7 | 87.3 |
| | ZLP | 0.300 | 0.284 | 0.284 | 0.290 | 0.290 | 0.301 | +3.7 | 0.290[a] | 0.300 | +3.4 | 0.300 |
| | NLP | 0.310 | 0.298 | 0.298 | 0.298 | 0.298 | 0.295 | -1.0 | 0.295 | 0.302 | +1.8 | 0.302 |
| | ELP | 0.303 | 0.310 | 0.293[a] | 0.269 | 0.293[a] | 0.285 | -2.7 | 0.293[a] | 0.293 | 0.0 | 0.293 |

[a] Only motor constants requiring adjustment

## Table 9. Annual and semiannual motor constants determined at CPSO

| Seismograph | | G's at installation | Annual G's Sept-Nov 1963[c] | | Semiannual G's May-July 1964 | | Annual G's Sept-Nov 1964 | | | G checks Jan-Apr 1965 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Nov-Dec 1962 | As found | After adjustment | As found | After adjustment | As found | Percentage change from previous G | After adjustment | After adjustment |
| SP | Z1 | 0.431 | 0.432 | 0.432 | | | 0.439 | +1.6 | 0.439 | a 0.441 |
| | Z2 | 0.430 | 0.433 | 0.433 | | | 0.435 | +0.5 | 0.435 | a 0.440 |
| | Z3 | 0.436 | 0.411 | 0.428[d] | | | 0.443 | +3.5 | 0.443 | a 0.435 |
| | Z4 | 0.428 | 0.427 | 0.427 | | | 0.435 | +1.9 | 0.435 | |
| | Z5 | 0.434 | 0.371 | 0.432[d] | | | 0.421 | -2.6 | 0.421 | |
| | Z6 | 0.432 | 0.451 | 0.426[d] | a | 0.439 | 0.492 | +12.3 | 0.438[d] | a 0.433 |
| | Z7 | 0.437 | a | 0.444 | b | 0.432 | 0.432 | 0.0 | 0.432 | a 0.441 |
| | Z8 | 0.432 | 0.431 | 0.431 | 0.448 | 0.436[d] | 0.444 | +1.9 | 0.444 | |
| | Z9 | 0.429 | 0.475 | 0.432[d] | | | a | | 0.438 | |
| | Z10 | 0.456 | 0.432 | 0.432 | a | 0.432 | 0.434 | +0.5 | 0.434 | |
| | Z11 | 0.435 | 0.424 | 0.424 | | | 0.444 | +4.6 | 0.444 | |
| | Z12 | 0.431 | 0.466 | 0.423[d] | | | 0.426 | +0.7 | 0.426 | |
| | Z13 | 0.436 | 0.432 | 0.432 | | | 0.420 | -2.8 | 0.420 | a 0.427 |
| | Z14 | 0.432 | 0.479 | 0.445[d] | | | 0.441 | -0.9 | 0.441 | |
| | Z15 | 0.428 | 0.500 | 0.433[d] | | | 0.444 | +2.6 | 0.444 | |
| | Z16 | 0.429 | 0.448 | 0.432[d] | | | 0.440 | +1.9 | 0.440 | a 0.429 |
| | Z17 | 0.435 | 0.492 | 0.437[d] | | | 0.434 | -0.7 | 0.434 | |
| | Z18 | 0.430 | 0.408 | 0.435[d] | | | 0.459 | +5.6 | 0.431[d] | |
| | Z19 | 0.439 | 0.463 | 0.432[d] | | | 0.466 | +7.9 | 0.437[d] | a 0.444 |
| Benioff | NSP | 0.354 | 0.294 | | | | | | | |
| Benioff | ESP | 0.357 | 0.294 | | | | | | | |
| JM | NSP | | | 0.432 | 0.473 | 0.423[d] | 0.424 | +0.2 | 0.424 | |
| JM | ESP | | | 0.432 | 0.463 | 0.432[d] | 0.432 | 0.0 | 0.432 | |
| | ZIB | 0.0865 | 0.0825 | 0.0825 | 0.0867 | 0.857 | 0.0844 | -2.6 | 0.0844 | |
| | NIB | 4.90 | 4.91 | 4.91 | 5.20 | 4.89[d] | 4.93 | +0.8 | 4.93 | |
| | EIB | 4.89 | 3.12 | 4.85 | 4.85 | 4.85 | 4.95 | +2.1 | 4.95 | |
| | ZBB | 84.3 | 80.7 | 80.7 | 80.7 | 80.7 | 80.7 | 0.0 | 80.7 | |
| | NBB | 83.0 | 80.6 | 80.6 | 81.4 | 81.4 | 80.5 | -1.1 | 80.5 | |
| | EBB | 82.8 | 84.7 | 84.7 | 80.5 | 80.5 | 80.5 | 0.0 | 80.5 | |
| | ZLP | 0.324 | 0.312 | 0.312 | 0.327 | 0.327 | 0.318 | -2.7 | 0.318 | |
| | NLP | 0.320 | 0.333 | 0.333 | 0.322 | 0.322 | 0.321 | -0.3 | 0.321 | |
| | ELP | 0.325 | 0.319 | 0.319 | 0.322 | 0.322 | 0.314 | -2.5 | 0.314 | |

[a] Damaged seismometer was replaced or repaired

[b] A JM seismometer with a new calibrator was installed 1 April 1964; several intermediate G's not shown in this table were determined

[c] Some of these determinations were delayed until early 1964 due to extreme weather conditions

[d] Only motor constants requiring adjustment

## Table 10. Annual and semiannual motor constants determined at UBSO

| Seismograph | | G's at installation Nov-Dec 1962 | Annual G's July-Aug 1963 | | Semiannual G's April 1964 | | Annual G's July-Oct 1964 | | | Semiannual G's April 1965 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | As found | After adjustment | As found | After adjustment | As found | Percentage change from previous G | After adjustment | As found | Percentage change from previous G | After adjustment |
| SP | Z1 | 0.436 | 0.426 | 0.426 | | | 0.424 | -0.5 | 0.424 | | | |
| | Z2 | 0.433 | 0.421 | 0.421 | | | 0.444 | +5.4 | 0.444 | | | |
| | Z3 | 0.430 | 0.425 | 0.425 | | | 0.423 | -0.5 | 0.423 | | | |
| | Z4 | 0.431 | 0.437 | 0.437 | | | 0.432 | -1.2 | 0.432 | | | |
| | Z5 | 0.429 | 0.432 | 0.432 | | | 0.438 | +1.4 | 0.438 | | | |
| | Z6 | 0.434 | 0.430 | 0.430 | | | 0.432 | +0.5 | 0.432 | | | |
| | Z7 | 0.420 | 0.421 | 0.421 | | | 0.427 | +1.4 | 0.427 | | | |
| | Z8 | 0.422 | 0.420 | 0.420 | | | 0.445 | +5.9 | 0.445 | | | |
| | Z9 | 0.436 | 0.434 | 0.434 | | | 0.429 | -1.2 | 0.429 | | | |
| | Z10 | 0.432 | 0.432 | 0.432 | 0.403 | 0.428[a] | 0.438 | +2.4 | 0.438 | 0.428 | -2.4 | 0.428 |
| Benioff | NSP | 0.548 | 0.283 | | | | | | | | | |
| Benioff | ESP | 0.348 | 0.432 | | | | | | | | | |
| JM | NSP | | | 0.427 | 0.487 | 0.429[a] | 0.443 | +3.3 | 0.443 | 0.435 | -1.9 | 0.435 |
| JM | ESP | | | 0.424 | 0.439 | 0.439 | 0.434 | +1.2 | 0.434 | 0.431 | -0.7 | 0.431 |
| | ZIB | 0.0853 | 0.0891 | 0.0891 | 0.0946 | 0.946 | 0.0941 | -0.5 | 0.0941 | 0.0903 | -4.0 | 0.0903 |
| | NIB | 4.94 | 4.59 | 4.94[a] | 5.03 | 5.03 | 4.97 | -1.2 | 4.97 | 5.08 | -2.2 | 5.08 |
| | EIB | 4.94 | 4.80 | 4.80 | 5.10 | 5.10 | 5.03 | -1.4 | 5.03 | 4.90 | -2.6 | 4.90 |
| | ZBB | 80.4 | 80.4 | 80.4 | 78.4 | 78.4 | 78.8 | +0.5 | 78.8 | 79.1 | +0.4 | 79.1 |
| | NBB | 80.4 | 82.5 | 82.5 | 78.9 | 78.9 | 80.6 | +2.1 | 80.6 | 81.8 | +1.5 | 81.8 |
| | EBB | 80.4 | 83.5 | 83.5 | 98.2 | 82.2[a] | 80.0 | -2.7 | 80.0 | 82.7 | +3.4 | 82.7 |
| | ZLP | 0.327 | 0.339 | 0.339 | 0.329 | 0.329 | 0.328 | -0.3 | 0.328 | 0.330 | +0.6 | 0.330 |
| | NLP | 0.329 | 0.333 | 0.333 | 0.319 | 0.323[a] | 0.324 | +0.3 | 0.324 | 0.341 | +5.2 | 0.328[a] |
| | ELP | 0.330 | 0.329 | 0.329 | 0.305 | 0.333[a] | 0.318 | -4.5 | 0.318 | 0.321 | +0.[illegible] | 0.321 |

[a] Only motor constants requiring adjustment

Table 11. Average percentage changes in motor constants for the IB, BB, and LP systems at the observatories

| Station | System | Average percentage change in system G's<br>Found when 1964 annual G's were determined | Average percentage change in system G's<br>Found when 1965 semiannual G's were determined |
|---|---|---|---|
| UBSO | IB | 1.0 | 2.9 |
| UBSO | BB | 1.7 | 1.8 |
| UBSO | LP | 1.7 | 2.2 |
| BMSO | IB | 3.2 | 6.3 |
| BMSO | BB | 6.7 | 1.4 |
| BMSO | LP | 2.5 | 1.7 |
| CPSO | IB | 1.8 | Not scheduled |
| CPSO | BB | 0.4 | Not scheduled |
| CPSO | LP | 1.8 | Not scheduled |

and TR 64-87. At UBSO the greatest average change was 2.9 percent for the intermediate-band system. This change occurred between October 1964 and April 1965. The maximum change for an individual component, 5.2 percent for the long-period north-south seismometer, also occurred during this period.

At CPSO the 1965 semiannual G determinations were not scheduled during this reporting period. The average changes in G between July and November 1964, the time of the 1964 annual motor constant check, were all less than 2.0 percent, and the maximum change for an individual component was 2.7 percent (determined for the long-period vertical seismograph).

The BMSO data show that the motor constants for the broad-band and intermediate-band seismographs were not as stable as they were at the other observatories. The greatest average change for these systems was 6.7 percent for the borad-band system and the maximum change of an individual seismograph (11.1 percent) occurred on the broad-band east-west. The reasons for these larger variations are not known; however, it is probable that several factors are responsible for the poorer stability of these BMSO seismographs.

### 3.1.4 Application of the Degaussing Procedure to the Short-Period Johnson-Matheson Seismographs at CPSO

Under Project VT/036, we developed a procedure to improve the stability of the short-period JM seismographs by degaussing the calibrator before the motor constants were measured and adjusted, and after each lightning storm. The development and laboratory tests of this procedure were reported in TR 64-118.

Field tests to determine the improvement in the operational stability of calibrator motor constants that could be obtained by routine use of the degaussing technique were begun in May 1964 at CPSO, the observatory that experienced the most electrical storms and sustained the most extensive equipment damage as a result of these storms.

When the semiannual check of the motor constants of the three-component systems were made in May 1964, the calibration actuator of Z8 (vertical component of the three-component short-period system) was degaussed before the motor constant was adjusted and after subsequent lightning storms. The degaussing procedure was adopted for all other short-period JM seismometers when the annual motor constant checks of all array elements were made in September and October 1964. Determinations of motor constants of the array elements before and after degaussing the calibrators indicated that, between the check at installation and the 1964 check, the pole pieces of the JM calibration actuators had been magnetized by lightning-induced current pulses to a degree adequate to alter some of the motor constants by more than 5 percent.

Between the May and the September-October 1964 checks of the motor constant of Z8, its motor constant changed only 1.9 percent. This could not be attributed to lightning-induced current pulses because the change was not compensated by degaussing the Z8 calibrator. The 1.9-percent change in the motor constant of Z8 is within the limits of accuracy of measurement.

The results of these field tests at CPSO substantiated the fact that the operational stability of short-period JM calibrator motor constants can be improved by routine use of the degaussing procedure, initially indicated by the laboratory tests and parallel field tests conducted at WMSO. We recommend that routine degaussing of the JM calibrators after electrical storms and before motor constant checks be continued at CPSO and that the procedure be adopted at BMSO and UBSO.

### 3.1.5 Stability of Seismograph Motor Constants

Figure 22 is the frequency distribution of the absolute value of the percentage deviation of G's from the previous G for 105 determinations made at the three observatories before July 1964 and 95 determinations made since July 1964. The data from the 105 G determinations made before July 1964 show that the deviation was greater than 5.9 percent for 22 determinations, but the absolute value of the percentage deviation exceeded 5.9 percent for only seven of the determinations made since July. This improvement is the result of several procedures adopted to improve the stability of the motor constants of the observatory seismographs. These procedures include:

a. The installation of Model 7515 horizontal short-period seismometers. The calibrator of these seismometers is more stable than those of the Model 6102A seismometers previously used;

b. Periodic detailed testing and checking of the calibrator circuits;

c. Refinement of measuring techniques.

These procedures and techniques are outlined in the standard operating procedures manual (TR 64-59). An addition will be made when the manual is

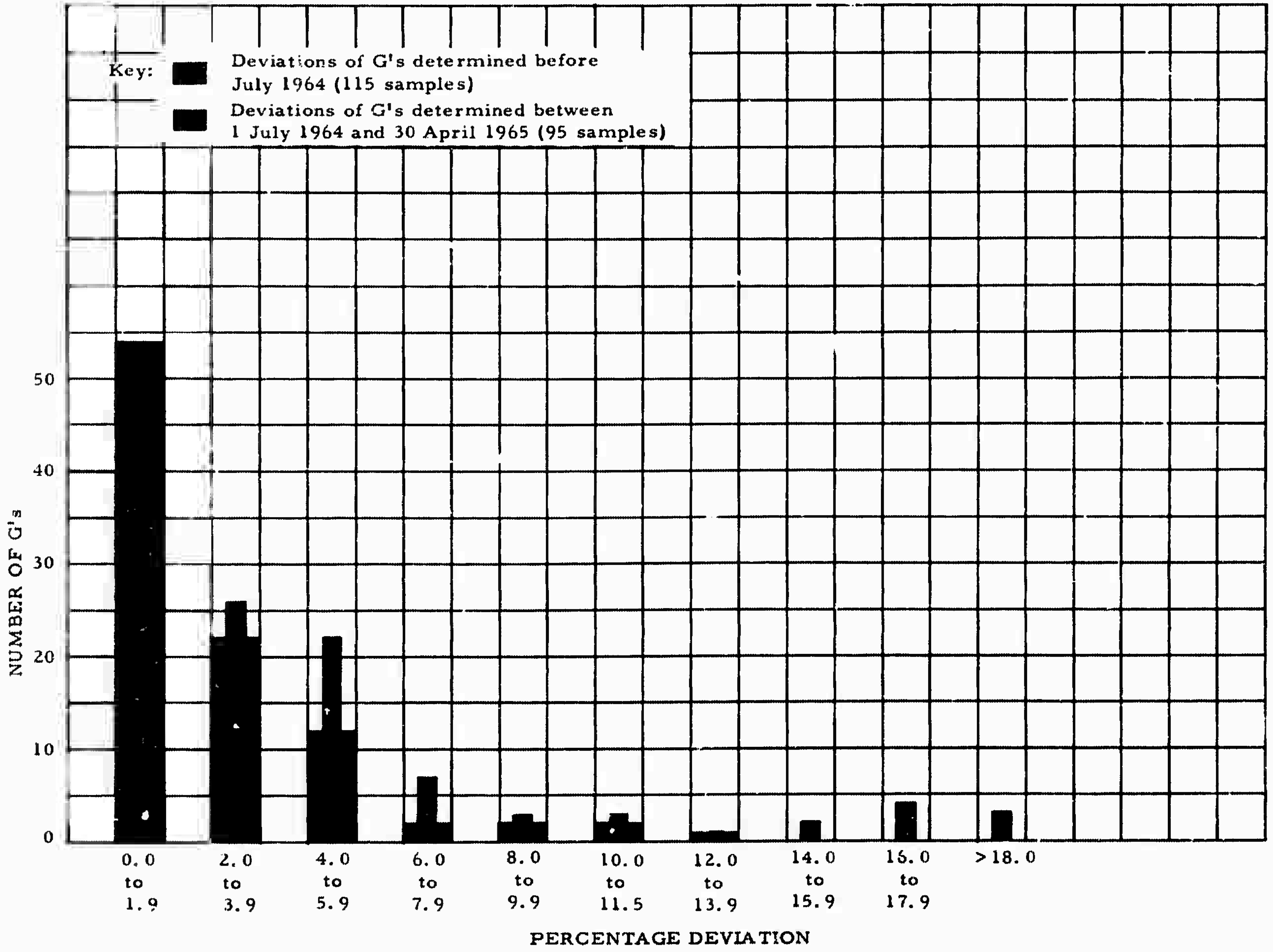


Figure 22. Frequency distribution of the absolute value of the percentage deviation of G's between successive determinations (Z10 determinations made between 1 July 1963 and 30 April 1965)

revised to require an immediate and thorough investigation to determine the cause of motor constant deviations that exceed 4 percent. This, in addition to the degaussing procedure recommended for all short-period seismographs, is expected to further improve the stability of the motor constants.

## 3.2 LIGHTNING PROTECTION

### 3.2.1 Summary of Lightning Damage

Seismograph damage resulting from lightning storms continues to be a major problem at some of the observatories. Many of these storms resulted in losses of data because of damage to the instrumentation. Figures 23 and 24 show the distribution of the storms and the resulting damage to instrumentation; blown fuses, shorted carbon blocks, and flipped mirrors in the galvanometers (not shown in figures 23 and 24) accounted for many of the data losses.

### 3.2.1.1 BMSO

Damage from lightning is not serious at BMSO; throughout the recording period there were only five storms. Damage to 1 seismometer data coil and 3 PTA galvanometers resulted from these storms. Two of the galvanometers, damaged in a storm in April 1965, were experimental models of an adjustable period galvanometer. Examination of the damaged experimental galvanometers yielded no evidence that they are more susceptible to damage by lightning than are the standard 3-Hz galvanometers, and in our opinion, the fact that two of the experimental galvanometers were damaged is coincidental. Few fuses were blown or carbon blocks damaged during Project VT/1124.

### 3.2.1.2 CPSO

Lightning is a major problem at CPSO; there were 164 electrical storms during the reporting period. A total of 79 inches of rain also added to the problems at the observatory. The distribution of the storms is shown in figure 23, which also shows the distribution of the damage to seismometers, PTA galvanometers, and magnetic-tape recorders. A summary of the other damage is given in the insert to figure 23. Data were lost on 92 occasions because of blown fuses or because of flipped galvanometer mirrors.

Damage caused by major storms in this recording period included:

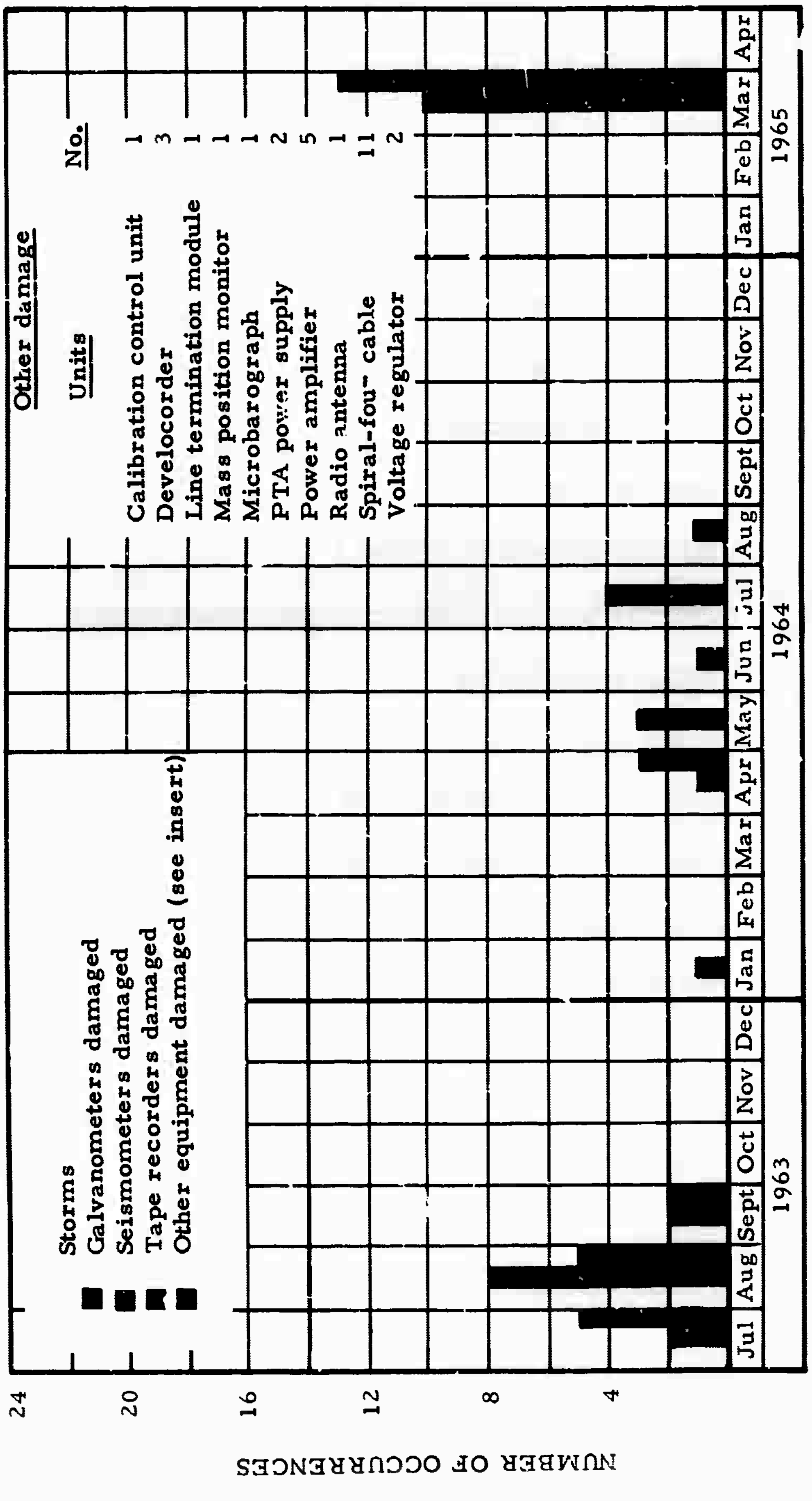


Figure 23. Number of occurrences and extent of damage produced by lightning storms at CPSO from July 1963 to April 1965

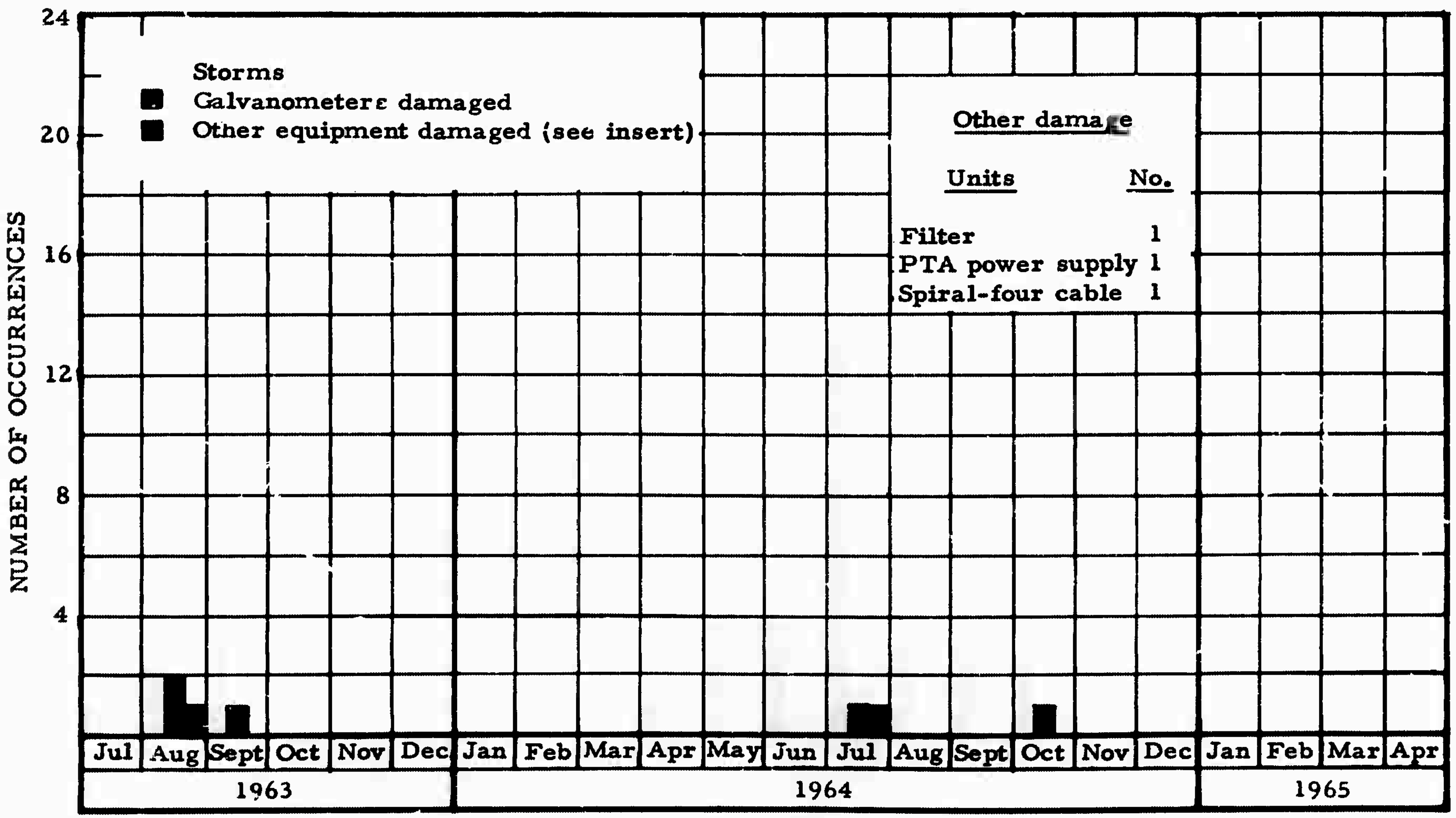


Figure 24. Number of occurrences and extent of damage produced by lightning storms at UBSO from July 1963 to April 1965

| | |
|---|---|
| 13 May 1964: | In addition to damage shown in figure 23, all data traces were lost except the earth-powered seismograph. The microbarograph was out of operation for 7 hours. |
| 25 March 1965: | This was the most severe storm that occurred at CPSO during the contract, and the damage to the instrumentation was the most extensive from a single storm. In addition to the damage indicated in figure 23, eleven sections of spiral-four data cable were damaged or destroyed. A Lightning Protector, Cook Model 36, used in one of the station protectors, and a Lightning Protector, Reliable Electric Model 2000H, used at one of the seismometer vaults were destroyed. |

### 3.2.1.3 UBSO

Forty-five electrical storms occurred at UBSO during the reporting period, but damage to instrumentation was light. The damage and the distribution of the storms are given in figure 24. No lightning protection fuses were blown.

On 22 April 1964, the main line supplying commercial power to UBSO was struck by lightning resulting in a power failure of 14 hours and 16 minutes. Secondary power from the Nicad battery bank was available for only 3.25 hours instead of the normal 6 hours, because during an earlier power failure, the batteries were used and sufficient time had not elapsed for the batteries to be fully recharged. Data were lost for about 11 hours.

### 3.2.2 Recommendations for Improvements in Lightning Protection Systems

Figures 23 and 24 show that the frequency of electrical storms and the severity of the damage to instrumentation resulting from the storms varied greatly among the three observatories. In all instances, however, the damage to instrumentation was low compared to the frequency of the storms. Many losses of data, not reflected in figures 23 and 24, were caused by blown fuses, shorted carbon blocks, and flipped mirrors in the galvanometers.

We recommend that the present protector systems to replaced with Associated Electrical Industries, Ltd. (AEI) Type 16A protectors in critical circuits operated in observatories that experience frequent severe lightning storms. The AEI protector is a three-electrode gas-filled tube. Two of the electrodes are placed across a pair of conductors, and the third electrode is grounded. If the breakdown voltage (150-350 volts) is reached across one pair of electrodes, the gas in the tube is ionized and the second pair of electrodes will break down within about 1 microsecond.

These protectors have been installed experimentally at WMSO and have been laboratory tested to some degree in Garland. The protection offered by the AEI protectors at WMSO is greatly improved over the protection afforded by the conventional carbon blocks previously used. Even in circuits in which AEI protectors are used, a small voltage (less than 150-350 volts) with a fast rise time can cause a galvanometer mirror to flip before the potential has been discharged. We believe that protection can be further increased by the use of inductances and/or faster operating diodes in the circuits associated with the AEI protectors. Efforts will be made under Project VT/5054 to develop improved associated circuitry.

In view of the difficulties experienced at CPSO, we recommend that the critical circuits in this observatory be equipped with the AEI protectors. We do not presently recommend that BMSO and UBSO be equipped with the AEI protectors. After the evaluation of the AEI protectors being conducted at WMSO is complete, the merits of installing them at BMSO and UBSO will be reconsidered.

## 3.3 OPERATIONAL CHARACTERISTICS OF FREQUENCY RESPONSE

### 3.3.1 General

The frequency response of each seismograph was measured monthly at each observatory. Adjustments were made when a response deviated beyond the specified tolerances (table 2) at any frequency.

Data collected from December 1963 through December 1964 were used to compile statistics for each seismograph system to determine the average and the "worst case" positive and negative deviations at each frequency from the norms specified in table 2.

Only data from the initial monthly measurements (before adjustment of response when adjustment was required) were selected for use in this study. These data were used to show the annual average maximum range of frequency response characteristics within which the seismographs were operated. A computer program was written to calculate the data for these average deviations. The program subtracts the norm at each calibration frequency from the normalized value of the observed magnification at that frequency, cumulatively sums the positive and the negative deviations at each frequency, and divides the cumulative sums by the number of values summed in each "cell." Zero deviations are tabulated separately and the number in each cell is divided equally between the positive and negative deviations.

### 3.3.2 Short-Period Frequency Responses

### 3.3.2.1 Variations in Short-Period Frequency Responses

The norms at two points on the short-period frequency response were changed during the reporting period. The magnification at 4.0 Hz (0.25 second) was changed from 2.0 to 1.87 relative to the magnification at 1 Hz and the magnification at 0.2 Hz (5 seconds) was changed from 0.0120 to 0.0113 relative to the magnification at 1 Hz. The allowable tolerances were also reduced at some frequencies, as shown in table 2. The norm value used to calculate the average deviation data was, of course, the norm specified at the time the response was checked; however, the norm and tolerance data plotted in the curves presented in this section are the values specified at the end of the project. Frequency response deviation data were calculated in percent of the norm to facilitate accurate plotting relative to the values used in April 1965.

3.3.2.1.1 BMSO. All short-period seismographs for the period December 1963 through December 1964 were considered at BMSO.

An average of 6.3 of the 12 short-period seismographs required minor adjustments monthly to bring them back within the allowable tolerances. Figure 25 shows the allowable tolerances from the norms for short-period seismographs, the envelope of the maximum positive and negative deviations from the norm at each frequency, and the envelope of the average maximum positive and negative deviations.

3.3.2.1.2 CPSO. At CPSO, the variations in 10 of the 19 short-period vertical seismographs (Z1-Z10) and the two horizontal seismographs were considered in this study.

An average of 2.7 of the 12 seismometers under consideration required minor adjustments each month.

In late March and early April 1964, the damping of the short-period PTA's was corrected. This proved to be a major factor in decreasing the number of out-of-tolerance points in the frequency responses and the range of the deviations.

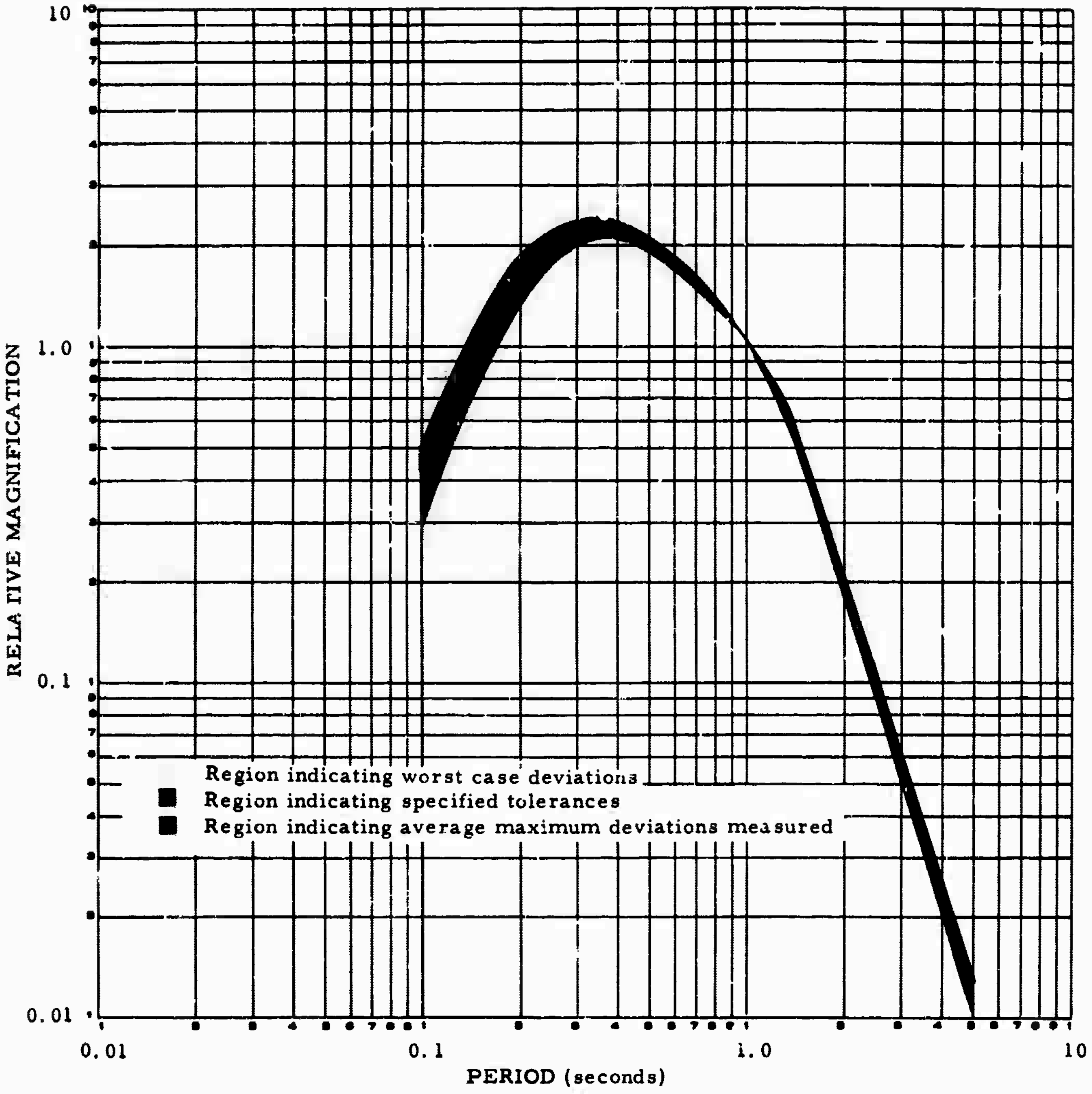


Figure 25. BMSO short-period seismograph frequency response illustrating worst case deviations, specified tolerances, and average maximum deviations measured during the period December 1963 through December 1964

This can be clearly seen in figure 26. Figure 26 shows the allowable tolerances, the maximum deviations before and after correction of the PTA parameters, and the envelope of the average maximum positive and negative deviations from the norm.

3.3.2.1.3 UBSO. All short-period surface seismographs were considered at UBSO.

An average of 3.1 of the 12 seismographs required minor adjustments each month. During the last 2 months of the project, the frequency response of only one UBSO seismograph of any type deviated beyond the allowable tolerances.

Figure 27 shows the allowable tolerances from the norms, the envelope of the maximum positive and negative deviations at each frequency, and the envelope of the average maximum positive and negative deviations from the norm.

#### 3.3.2.2 Causes of Variations in Short-Period Frequency Response

Figures 25, 26, and 27 show that the frequency responses of the seismographs change from month to month. The task of correcting the responses that drifted out of the allowable tolerance has been rather time consuming, especially with the tighter tolerance that was imposed in March 1964. This task was lessened somewhat during the latter part of the reporting period by the use of improved techniques, adjustments in the frequency response norms, and better control of parameters.

The following factors are considered to be the primary causes of the instability of the frequency responses:

a. Seismometer damping variations. These are the primary cause of actual changes in the frequency responses. (Seismometer damping control is discussed in section 3.3.2.3.)

b. Seismometer free period. This parameter is usually quite stable and is usually not a problem; however, on rare occasions malfunctions have caused deviations in this parameter. Deviation of the seismometer free period from the specified value contributes significantly to the deviations of frequency response. The malfunctions that have occurred were caused when the seismometer was being moved or by condensation that had accumulated inside the seismometer case.

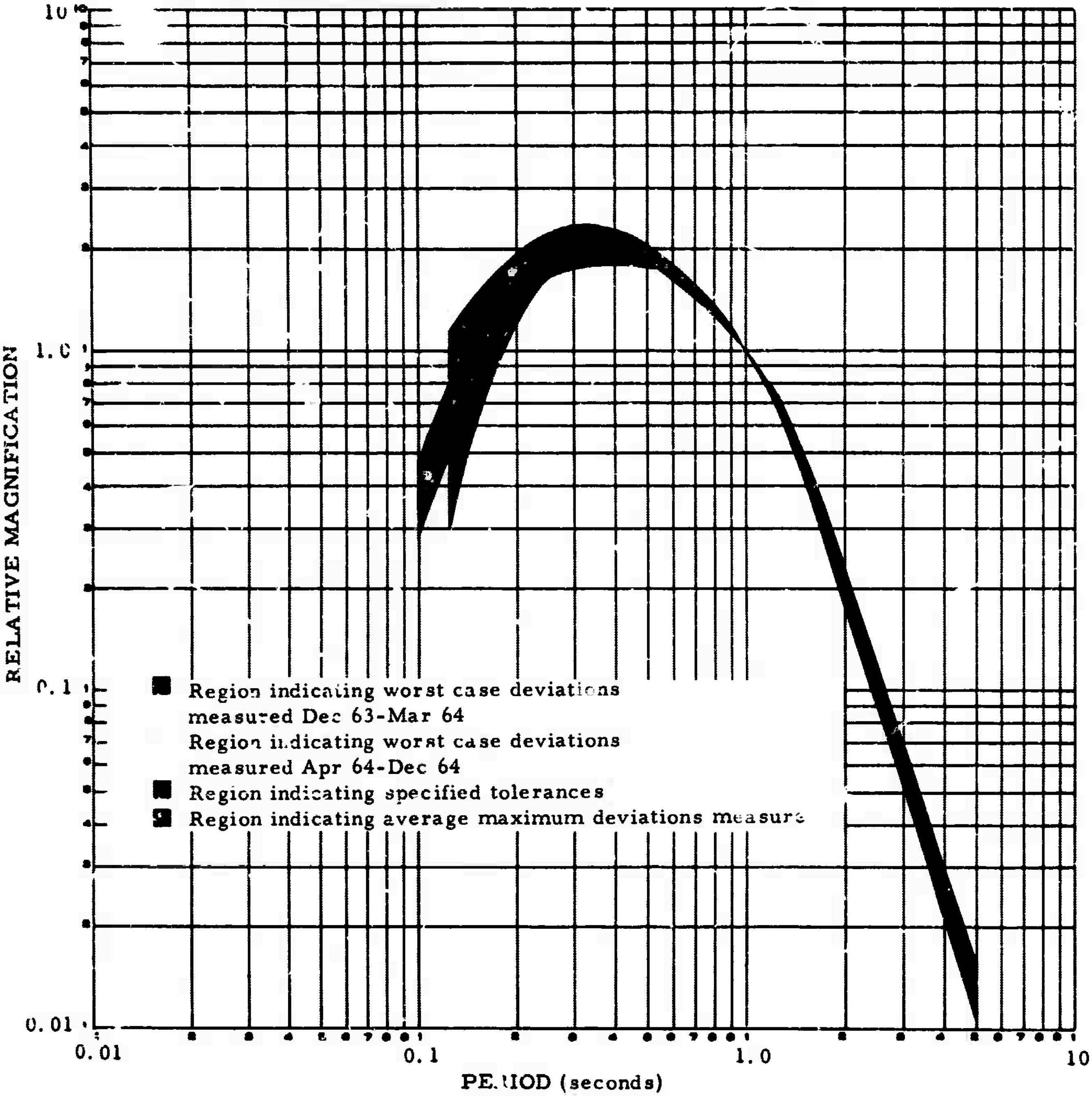


Figure 26. CPSO short-period seismograph frequency response illustrating specified tolerances, worst case deviations measured during the period December 1963 through March 1964, worst case deviations measured from April through December 1964, and average maximum deviations measured in the period December 1963 through December 1964

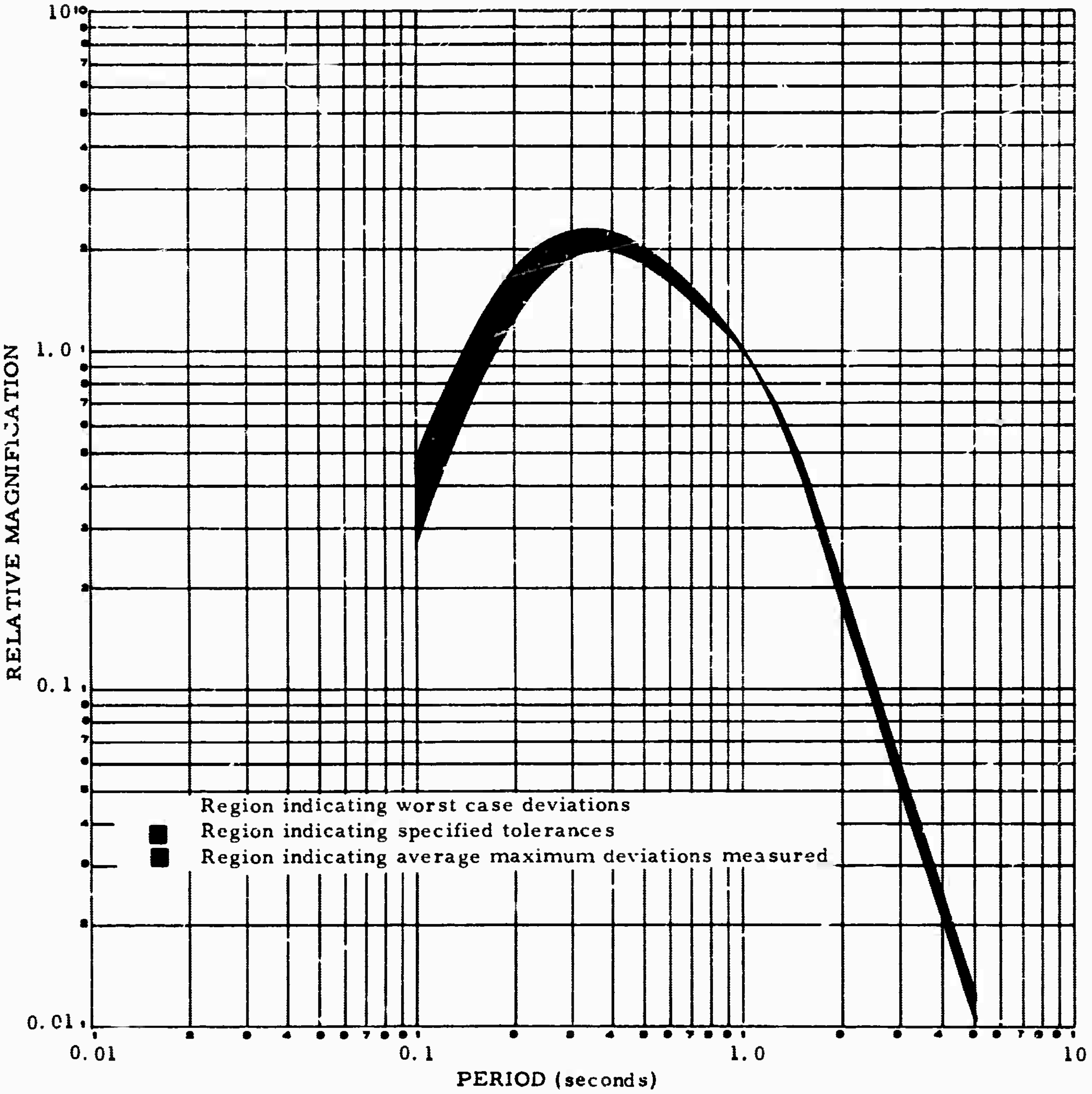


Figure 27. UBSO short-period seismograph frequency response illustrating worst case deviations specified tolerances, and average maximum deviations measured during the period December 1963 through December 1964

c. Galvanometer damping and free period. Figures 25, 26, and 27 show that a major deviation occurred in the average frequency response between 0.25 and 0.6 second, the area most affected by variations in the galvanometer free period and damping. Indications are that these parameters are stable, although no recent study has been made of actual stability of the galvanometer. If these parameters could be readily adjusted in the field, they could be maintained with less deviation from the desired values and would be less of a problem.

d. Measurement inaccuracies. A check of possible errors in measuring the frequency responses showed that this could be a major source of the "instabilities." Table 12 shows that the estimated measurement error at X10 view on a Develocorder (usually about 0.5 mm) can be of the same order as the allowed deviation from the mean at some frequencies. In other words, the changes in magnification from in-tolerance one month to out-of-tolerance the next month could be due entirely to measurement error. This is particularly true at 8.0 and 10.0 Hz, where the signal-to-noise ratio is very low. In January 1965 we recommended that calibration at 8.0 and 10 Hz no longer be required. The Project Officer approved this recommendation and calibration at these frequencies was stopped in April 1965.

### 3.3.2.3 Seismometer Damping Control

Early in the project, considerable interest was expressed in reducing deviations in the frequency responses of the short-period seismographs at all observatories. Tests showed that changes in seismometer damping ($\lambda_S$) were among the major contributors to the deviations in short-period frequency responses. We decided to check the damping of all seismographs at all observatories weekly.

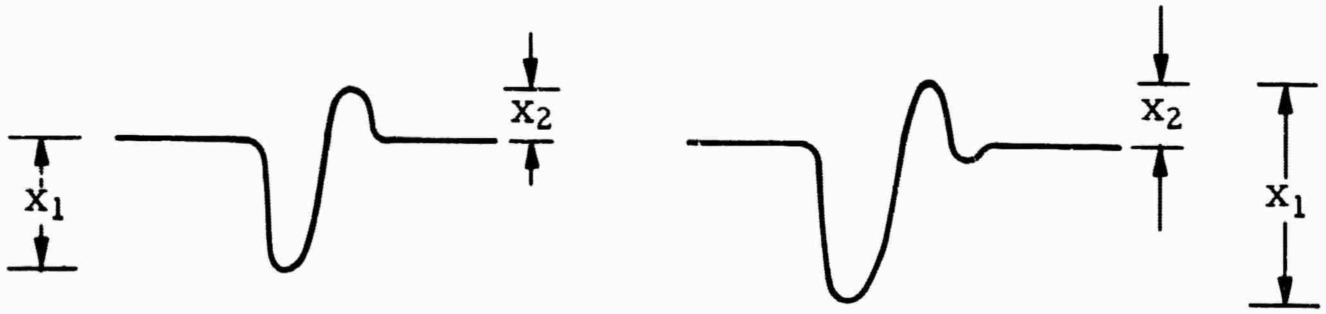
Checks were made and the seismometer damping calculated from the overshoot ratio ($X_1/X_2$) of dc pulses applied to the seismometer (figure 28). An overshoot ratio of 6.5 to 1 gives the nominal seismometer damping of 0.51 so limits of 5.5 to 1 and 7.5 to 1 were set.

Table 12. Limits of measurement error and estimated measurement error at each frequency in the short-period frequency response

| Frequency of calibration (Hz) | Present PTA attenuator setting | Computed amplitude limits (mm) on Develocorder corrected to nearest 0.5 mm | Margin of error about mean to remain inside tolerances (mm) | Estimated measurement error between monthly measurements | |
|---|---|---|---|---|---|
| | | | | mm | % |
| 0.2 | 30 | 13.0<br>11.0 | ±1.0 | 0.5 | 4.2 |
| 0.4 | 30 | 25.5<br>22.0 | ±1.8 | 0.5 | 2.1 |
| 0.8 | 30 | 45.0<br>41.0 | ±2.0 | 0.5 | 1.2 |
| 1.0 | 30 | 40.0 | Amplitude assumed at normalizing frequency. | | |
| 1.5 | 30 | 28.5<br>25.5 | ±1.5 | 0.5 | 1.9 |
| 2.0 | 30 | 20.0<br>18.0 | ±1.0 | 0.5 | 2.6 |
| 3.0 | 18 | 40.5<br>35.0 | ±2.8 | 0.5 | 1.3 |
| 4.0 | 18 | 21.0<br>16.5 | ±2.3 | 0.5 | 2.7 |
| 6.0 | 6 | 24.5<br>16.5 | ±4.0 | 1.0 | 4.9 |
| 8.0 | 6 | 8.0<br>5.0 | ±1.5 | 0.8 | 12.0 |
| 10.0 | 6 | 3.0<br>2.0 | ±0.5 | 0.5 | 20.0 |

$X_1$ = Average initial deflection amplitude resulting from a series of dc pulses measured on Develocorder as shown. In method A, deflection is center to peak; in method B, peak to peak.

$X_2$ = Average overshoot amplitude of a series of dc pulses.



Method A

Method B

Figure 28. Pulse amplitude measurements from which seismometer damping was calculated

Initially, method A (figure 28) was adopted but the reduction in the number of out-of-tolerance frequency response points was less than anticipated. A review of the procedures used at the observatories revealed that different values of damping were being measured by different personnel for the same seismometer at a given time. The revised method of measurement, method B, was adopted. Because the method of measurement was clearly specified, more nearly consistent measurement of the overshoot ratio resulted.

Sometimes it is not possible to maintain the seismograph frequency response in tolerance using the specified overshoot ratio range. The overshoot ratio range in which in-tolerance frequency responses are obtained, varies from seismometer to seismometer; therefore, in February 1965, we began adjusting the seismometer damping to the values required to maintain in-tolerance frequency responses. This seismograph-to-seismograph variation in seismometer damping is attributed, at least in part, to the fact that variations in galvanometer free period, galvanometer damping, and seismometer free period contribute to frequency response deviation, and these variations are all being compensated by adjustments of seismometer damping. Since this procedure was adopted, the weekly damping checks have been more effective; however, their usefulness in controlling the seismometer damping is still limited by measurement accuracies.

On numerous occasions, the contact resistances of the damping and gain trim potentiometers in the line termination module vary. The effects of these variations are compounded by changes in the data line resistance due to temperature variations. This changes the damping resistance of the seismometer, which in turn changes the frequency response of the seismograph.

Based on these observations, a test designed to control the seismometer damping resistance of the short-period seismographs was initiated at UBSO in February 1965. An "ideal value" of data line resistance was selected for each seismograph by measuring the damping resistance of each seismometer when its response was near the center of the tolerance range. These measurements were taken by opening the data line circuit at the line termination module and measuring the resistance of the data line looking toward the seismometer and also toward the PTA (infinitely attenuated). A weekly line resistance check was then made in place of the weekly damping check, and the line resistance adjusted to the ideal value, if necessary. Line resistance adjustments were made by resetting the damping trim potentiometer. Using this method to maintain seismometer damping, the number of the recalibrations necessary to obtain in-tolerance responses at UBSO has been reduced considerably. The following tabulation compares the number of recalibrations required during the first 2 months in which damping resistance control was used and the number required during 3 months in which the overshoot ratio was used to control seismometer damping.

| Method | Month | Recalibrations |
|---|---|---|
| Overshoot | September 1964 | 4 |
| Overshoot | October | 3 |
| Overshoot | November | 3 |
| Resistance | March 1965 | 1 |
| Resistance | April | 0 |

Based on the favorable results obtained from the tests at UBSO, we recommend that in place of the presently used overshoot ratio check, the weekly data line resistance check be adopted at all observatories as a control parameter for seismograph frequency responses. In addition, we plan to modify the line termination module to permit measurement of damping resistance without removal of he line termination module from its mounting frame, and to replace the present damping and gain trim controls with more stable multiturn potentiometers. We also recommend that a more accurate device, such as a resistance bridge, be procured for use in making precise line resistance measurements at each observatory.

### 3.3.2.4 Stability of Short-Period Frequency Responses

We believed that there was a relationship between the month-to-month changes in seismograph frequency response and the number of out-of-tolerance points measured for a particular seismograph. Data were compiled for the three observatories for the period December 1963 through December 1964. The pattern of the variations was the same for each observatory. Because CPSO is the observatory at which the most lightning occurs and is subject to the greatest changes in frequency responses, only CPSO data are shown in this report. Table 13 shows two groups of CPSO seismographs, those that were most frequently out-of-tolerance and those that were least frequently out-of-tolerance. Note that there is little difference between the mean percentage change at each frequency for each group. In fact, the overall average monthly change was of the same order as the estimated measurement errors between monthly measurements given in both tables 12 and 13. The number of out-of-tolerance deviations is a function of the proximity of the measured response to the tolerance limits, rather than a function of the month-to-month changes in relative magnification.

### 3.3.2.5 Summary of Changes in and Recommendations for the Short-Period Frequency Response

3.3.2.5.1 In summary, the following changes that affected the short-period frequency response stability were made during Project VT/1124.

a. The allowable tolerances were narrowed on 1 March 1964 (see table 2).

b. In April 1964, frequency counters were installed at each observatory to facilitate precise setting of the calibration frequency.

c. The norms (table 2) at 4.0 Hz and 0.2 Hz were corrected in March and November 1964, respectively. Before these corrections were made, the useable range of tolerances was considerably less than the allowable range of tolerances specified.

Table 13. A comparison of the monthly change in magnification at CPSO of those seismographs most frequently out-of-tolerance and those least frequently out-of-tolerance and a comparison of these changes with the estimated errors made in measuring sine-wave calibrations

| Frequency (Hz) | Average percentage monthly change in relative magnification Dec 63-Dec 64 | | | | | | | | | | | | | | Overall mean percent change | Estimated percentage measurement error between monthly measurement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Seismographs most frequently out-of-tolerance | | | | | | | Seismographs least frequently out-of-tolerance | | | | | | | | |
| | Z3 | Z5 | Z6 | Z8 | Z10 | ESP | Mean | Z1 | Z2 | Z4 | Z7 | Z9 | NSP | Mean | | |
| 0.2 | 2.0 | 5.0 | 2.9 | 4.2 | 4.0 | 3.9 | 3.7 | 3.7 | 5.8 | 3.4 | 2.5 | 3.7 | 2.9 | 3.7 | 3.7 | 4.2 |
| 0.4 | 2.3 | 4.6 | 3.2 | 2.9 | 2.4 | 4.6 | 3.3 | 2.4 | 2.7 | 2.5 | 2.8 | 3.4 | 1.6 | 2.6 | 2.9 | 2.1 |
| 0.8 | 1.9 | 1.6 | 1.9 | 1.6 | 1.1 | 2.2 | 1.7 | 1.6 | 2.1 | 1.3 | 1.6 | 0.8 | 1.2 | 1.4 | 1.6 | 1.2 |
| 1.0 | Normalizing frequency | | | | | | | | | | | | | | | |
| 1.5 | 1.8 | 1.7 | 1.9 | 2.7 | 1.4 | 2.7 | 2.0 | 1.[illegible] | 2.1 | 1.5 | 1.4 | 1.8 | 2.7 | 1.8 | 1.9 | 1.9 |
| 2.0 | 1.8 | 2.1 | 2.9 | 3.7 | 1.6 | 3.0 | 2.5 | 2.3 | 1.5 | 1.4 | 3.3 | 3.2 | 3.3 | 2.5 | 2.5 | 2.6 |
| 3.0 | 2.9 | 3.9 | 4.[illegible] | 2.9 | 2.8 | 4.0 | 3.4 | 2.7 | 3.2 | 2.3 | 3.5 | 4.1 | 5.5 | 3.6 | 3.5 | 1.3 |
| 4.0 | 5.3 | 2.8 | 4.0 | 9.5 | 4.2 | 4.8 | 5.1 | 4.0 | 5.1 | 4.9 | 5.4 | 4.2 | 4.7 | 4.7 | 4.9 | 2.7 |
| 6.0 | 8.7 | 4.8 | 10.1 | 7.9 | 4.5 | 11.3 | 7.8 | 8.1 | 9.2 | 8.1 | 5.8 | 6.8 | 6.5 | 7.4 | 7.6 | 4.9 |
| 8.0 | 9.4 | 3.7 | 10.1 | 7.3 | 19.5 | 19.4 | 11.5 | 6.6 | 13.0 | 7.3 | 10.0 | 11.5 | 8.0 | 9.4 | 10.5 | 12.0 |
| 10.0 | 10.2 | 10.0 | 9.1 | 8.4 | 11.1 | 21.0 | 11.6 | 9.6 | 13.5 | 8.5 | 16.6 | 8.9 | 13.7 | 11.8 | 11.7 | 20.0 |
| Total number of out-of-tolerance points | 27 | 19 | 21 | 21 | 13 | 35 | - | 3 | 5 | 14 | 14 | 8 | 4 | - | | |

The reduction in frequency response deviations that resulted from the changes listed in items a, b, and c are not reflected in the worst case deviations shown in figures 25, 26, and 27, because they were made after the beginning of the sampling interval from which data were selected.

3.3.2.5.2 We recommend the following to improve the stability of the frequency responses:

a. Retain the tolerances presently specified for the short-period frequency responses because closer tolerances will be of little or no value unless improved techniques are developed for more accurately measuring the sine wave calibrations.

b. Modify the short-period PTA's at CPSO and UBSO by installing a resistive control to facilitate accurate adjustment of the galvanometer damping. A network of this type was installed in all short-period PTA's at BMSO in February and March of 1965 in conjunction with pulse-cancellation experiments.

c. Modify the short-period PTA galvanometers at the three observatories to allow accurate adjustment of the galvanometer free period in the field. Three prototype galvanometers with adjustable free periods, purchased under Project VT/4054, were evaluated at BMSO as part of the tests of the pulse-cancellation procedure. Variations in galvanometer damping and free period can cause frequency responses to deviate over more than half of the allowable tolerance range at some frequencies and still be in tolerence (see section 3.15). If this occurs, at these frequencies, the remaining allowable response deviations due to measurement inaccuracies and deviations in seismometer parameters are very small. If the galvanometer parameters could be more accurately controlled, the other parameters that affected frequency response stability could deviate more without causing the frequency response to exceed tolerances.

d. Use the weekly measurement of seismometer damping resistance to control seismometer damping, replacing the overshoot ratio measurement.

e. Make minor modifications to the line termination modules and supply an accurate resistance measurement device to each observatory to facilitate precise measurement and adjustment of damping resistance.

f. Investigate a more suitable potentiometer whose stability is not adversely affected by variations in environmental conditions.

### 3.3.3 Variations in Intermediate-Band Frequency Responses

Data similar to those compiled for the short-period seismographs were compiled for the intermediate-band seismographs. The period sampled was again December 1963 through December 1964. Data were taken for the three-component intermediate-band seismographs at the observatories. In March 1964, the allowable tolerances were increased as shown in table 2 because too much time was required to maintain tolerances previously specified.

Figures 29, 30, and 31 show the allowable tolerances, the worst case positive and negative deviations, and the average maximum deviations from the norms at each frequency for the intermediate-band seismographs at BMSO, CPSO, and UBSO, respectively.

As shown, the major deviations occurred at CPSO. Some of the large deviations in the intermediate-band system at CPSO were due to faults in the east-west horizontal seismograph that developed in January 1964. Lightning damaged a potentiometer in the Line Termination Module, Model 5874C, and this produced large changes in the damping of the seismometer. These large changes in seismometer damping were one of the main causes of the variations that occurred in the long-period portion of the response curves. Difficulties were also experienced with the optical system of one of the PTA's. These problems resulted in the large worst-case deviations observed between 0.2 to 0.3 second.

### 3.3.4 Variations in Broad-Band Frequency Responses

Broad-band frequency response variations were calculated from the frequency response data measured from the three-component broad-band seismographs at each observatory from December 1963 through December 1964. The allowable tolerances for the broad-band system were widened in March 1964 (see table 2), because the previously specified tolerances were too narrow to be practically maintained.

Figures 32, 33, and 34 show the allowable tolerances, the worst case positive and negative deviations, and the average maximum deviations observed at each frequency for the broad-band seismographs at BMSO, CPSO, and UBSO, respectively, during the sampling interval.

These data show that, on the average, the frequency responses of the broad-band seismographs were quite stable. The largest deviations occurred in the 8- to

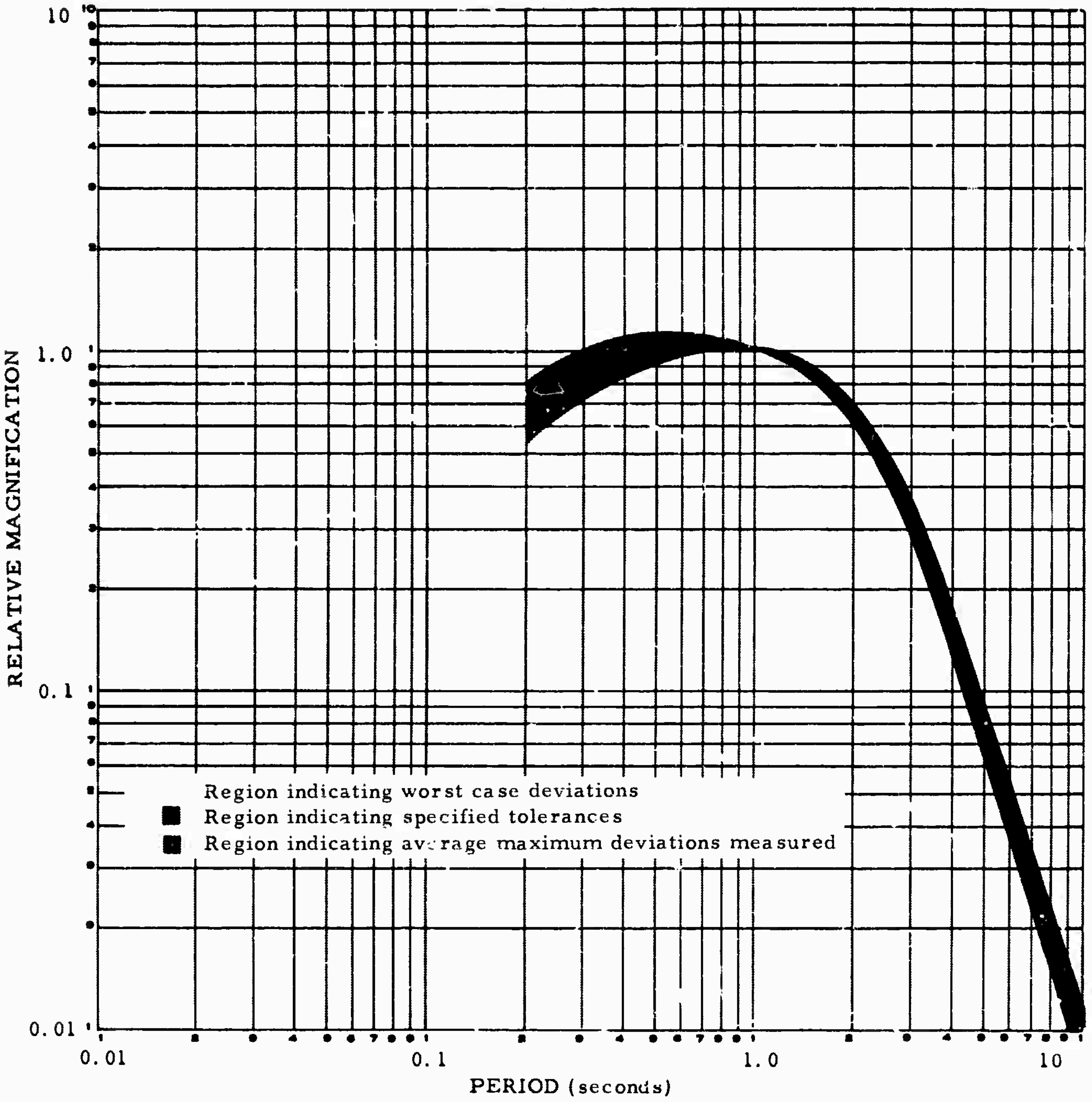


Figure 29. BMSO intermediate-band seismograph frequency response illustrating worst case deviations specified tolerances, and average maximum deviations measured in the period December 1963 through December 1964

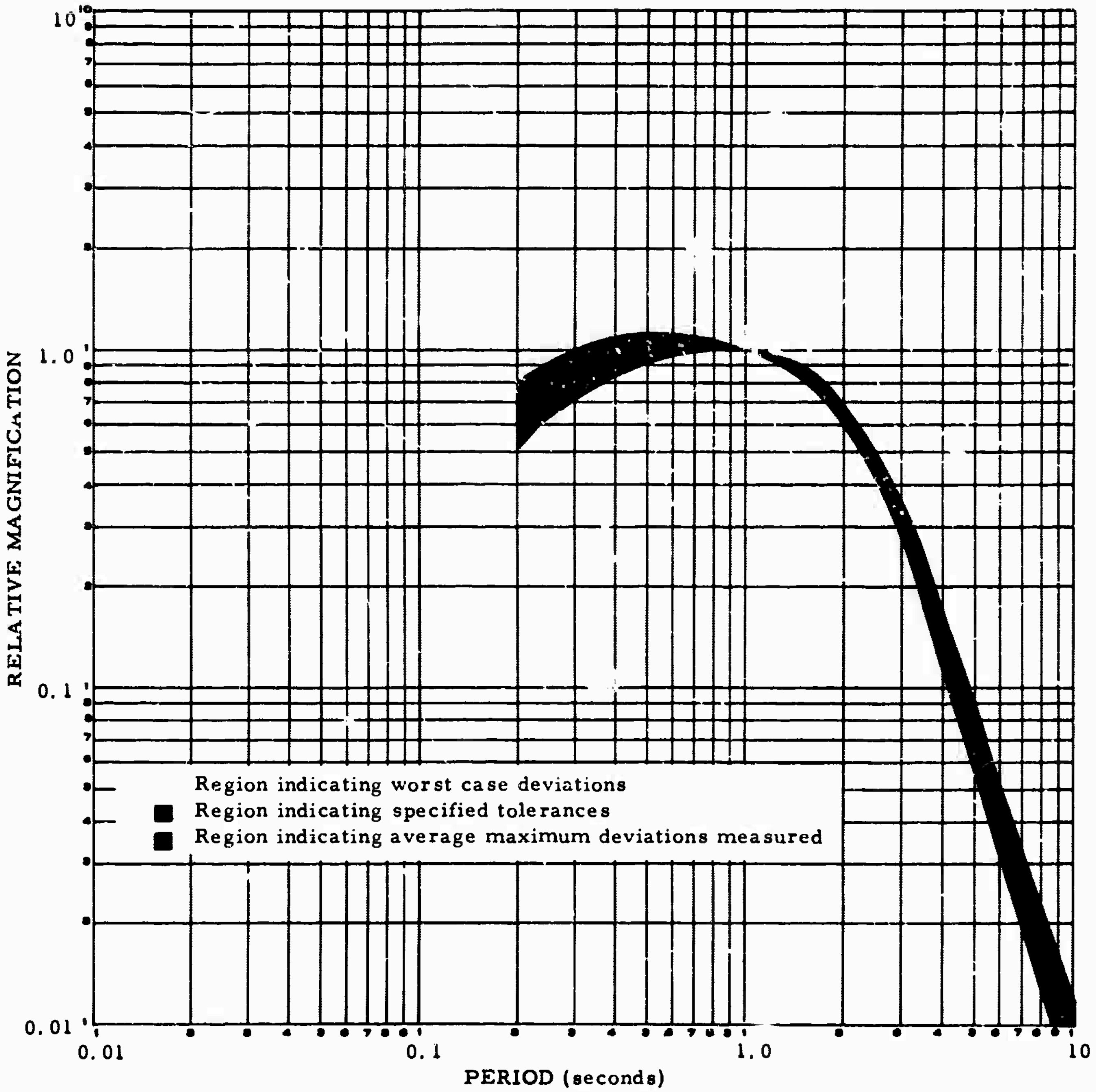


Figure 30. CPSO intermediate-band seismograph frequency response illustrating worst case deviations, specified tolerances, and average maximum deviations measured in the period December 1963 through December 1964

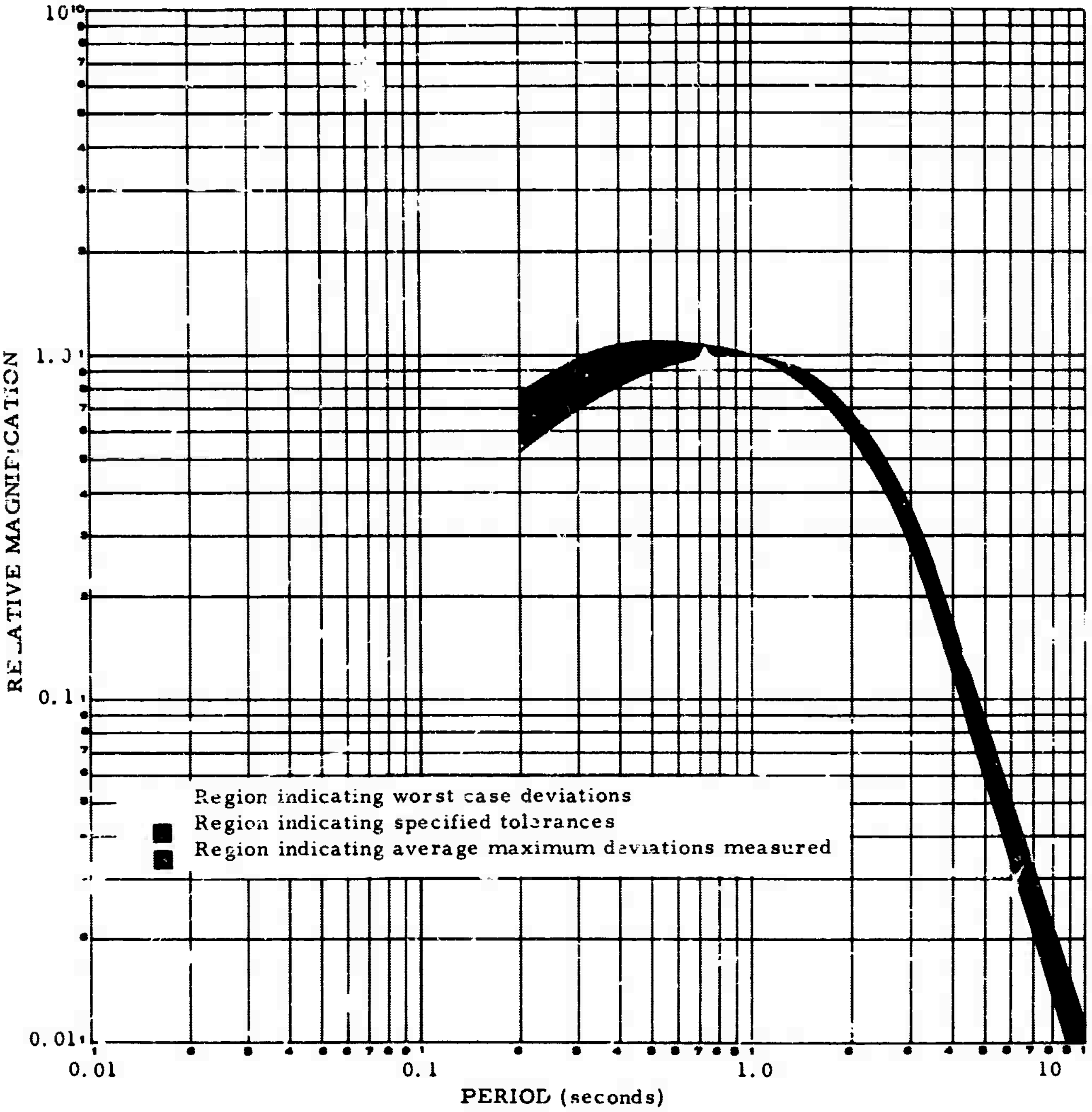


Figure 31. UBSO intermediate-band seismograph frequency response illustrating worst case deviations, specified tolerances, and average maximum deviations measured in the period December 19 through December 1964

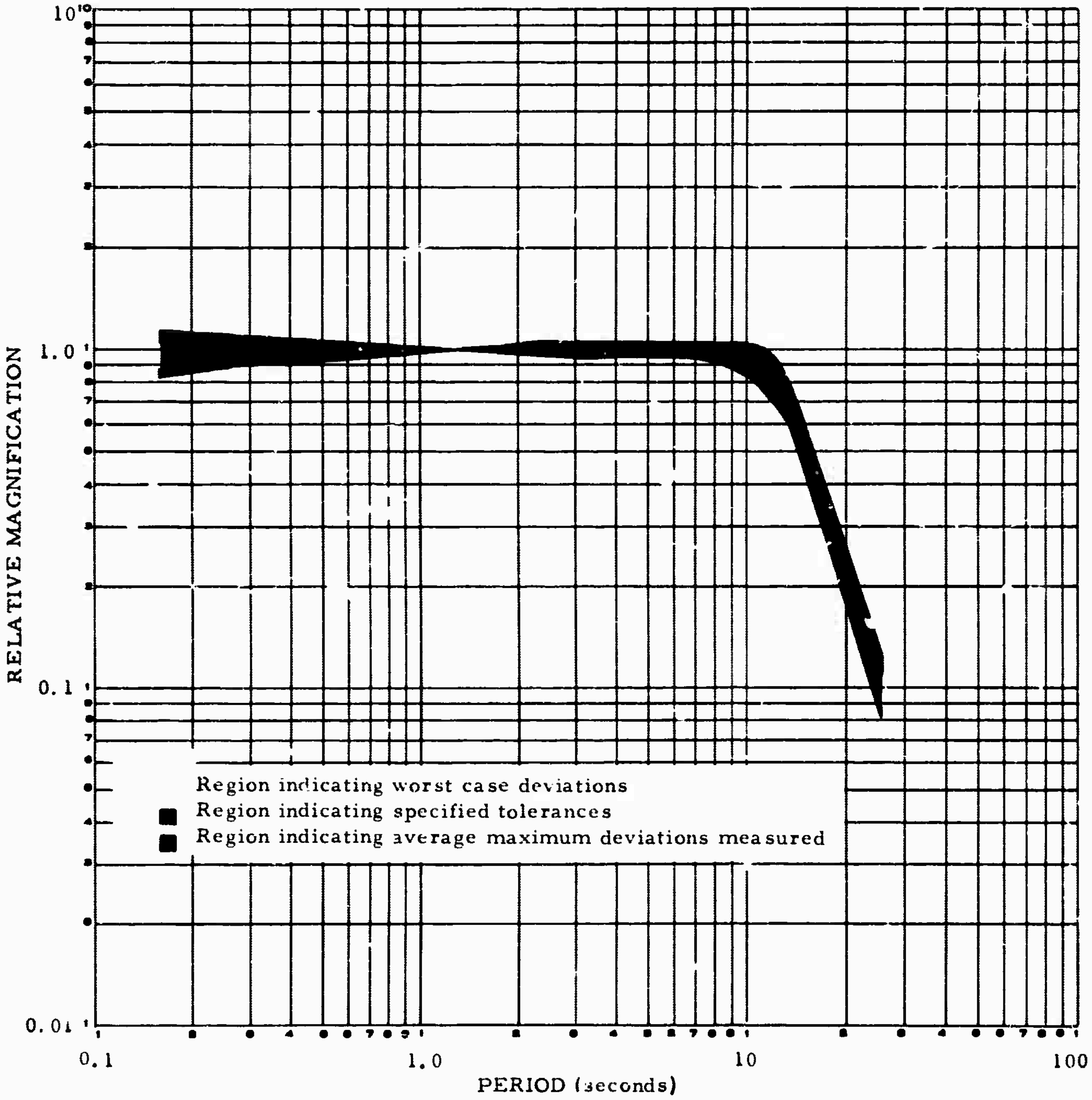


Figure 32. BMSO broad-band seismograph frequency response illustrating worst case deviations, specified tolerances, and average maximum deviations measured in the period December 1963 through December 1964

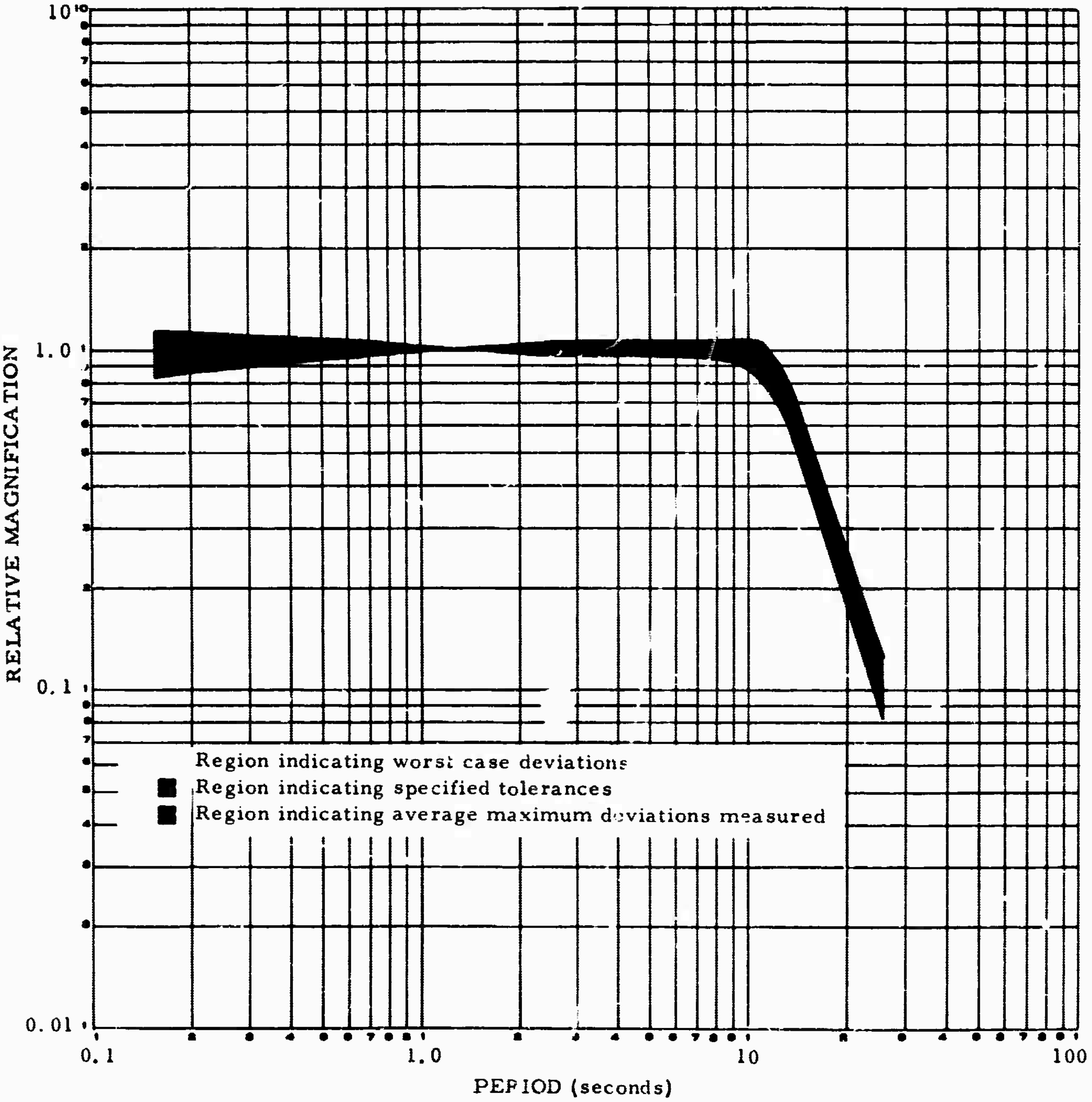


Figure 33. CPSO broad-band seismograph frequency response illustrating worst case deviations, specified tolerances, and average maximum deviations measured in the period December 1963 through December 1964

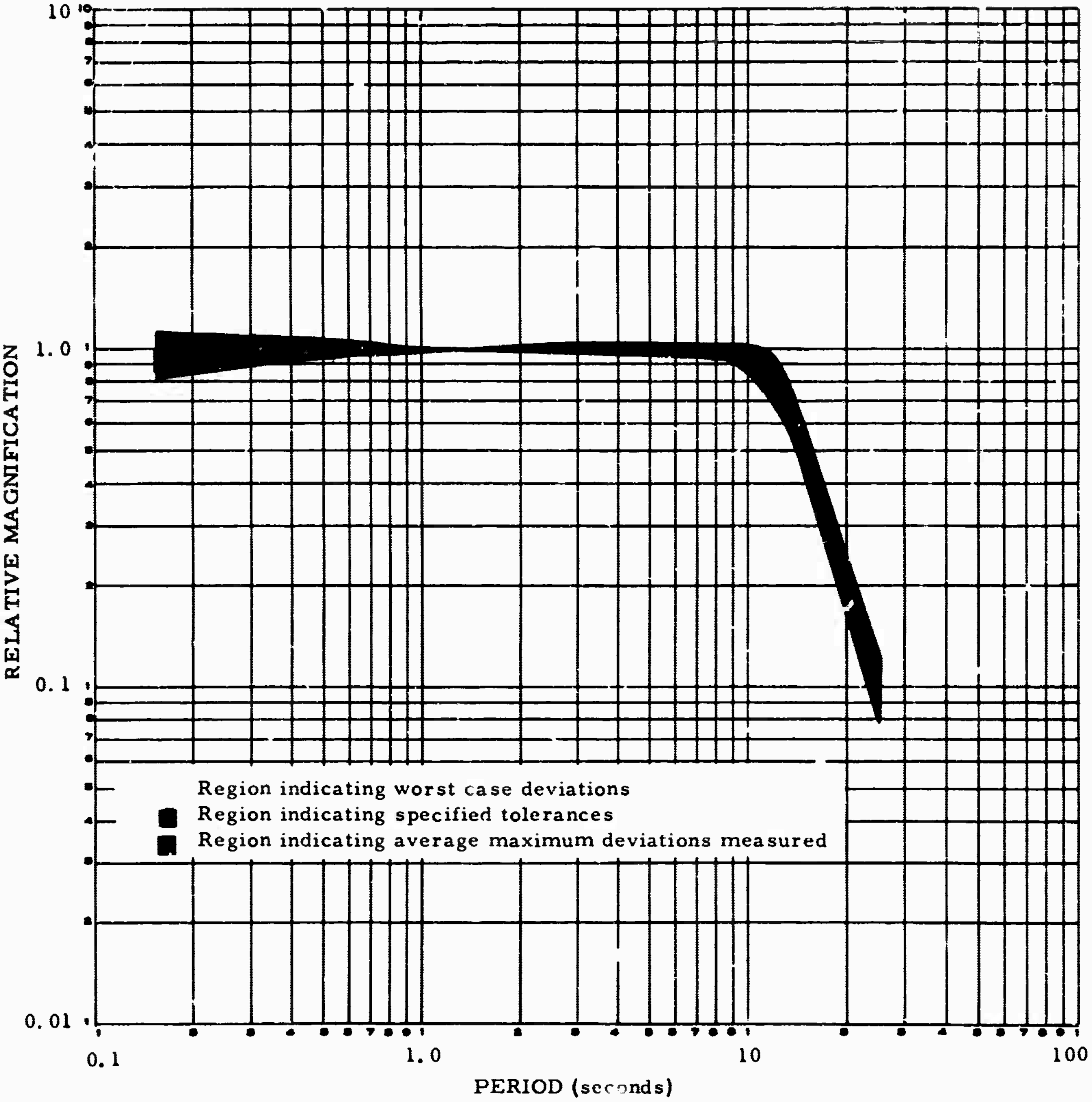


Figure 34. UBSO broad-band seismograph frequency response illustrating worst case deviations, specified tolerances, and average maximum deviations measured in the period December 1963 through December 1964

25-second period range, the range in which variations in seismometer damping and free period have the greatest effect on seismograph frequency response.

### 3.3.5 Variations in Long-Period Frequency Responses

Data similar to those presented for the short-period, intermediate-band, and broad-band seismographs were calculated for the three-component long-period seismographs at each observatory from December 1963 through December 1964.

Figures 35, 36, and 37 show the allowable tolerances, the worst case deviations, and the average maximum deviations measured for the long-period seismographs at BMSO, CPSO, and UBSO, respectively.

In general, the operational stability of the long-period seismographs at CPSO and UBSO was quite satisfactory. Figure 35, however, shows that some problems existed at BMSO. A major factor causing these deviations is that this observatory was subjected to very heavy and frequent snowfalls during the winter of 1963-1964. The accumulation of snow made it impractical to uncover the vaults to reset the seismometer free period and no adjustments were made at the vaults during the winter. During this interval the seismometer free periods changed from 20 to about 17 seconds, and the frequency responses of the long-period seismographs at BMSO were only marginally in-tolerance even after adjustment.

To prevent a recurrence of some of these problems, we recommend that remotely controlled seismometer free period adjustment devices be added to the long-period seismometer so that this parameter can be more practically controlled during the winter.

## 3.4 OPERATIONAL STABILITY OF SEISMOGRAPH MAGNIFICATION

### 3.4.1 Operational Stability of Short-Period, Intermediate-Band, Broad-Band, and Long-Period Seismograph Magnification

Daily calibration checks were performed on the seismographs at each observatory to determine the system magnification. If the deviation from the standard magnification exceeded the specified operational tolerance (table 14), adjustments and recalibrations were performed. The calibration logs for April 1965 were examined to determine the average deviation from the standard magnification, and the number of times adjustment and recalibration were necessary. These data are shown in table 14. Only 12 of the short-period instruments at

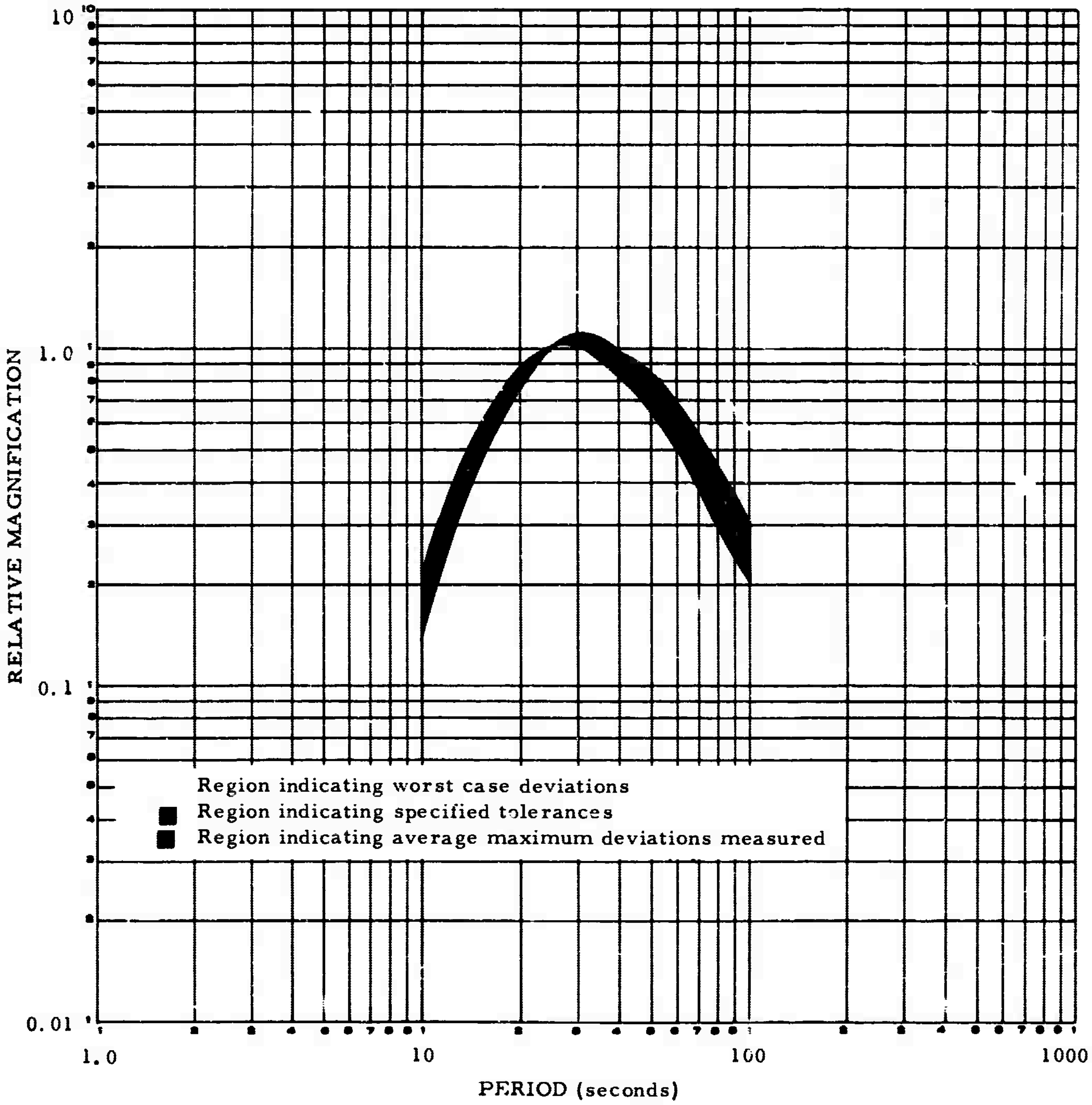


Figure 35. BMSO long-period seismograph frequency response illustrating worst case deviations, specified tolerances, and average maximum deviations measured in the period December 1963 through December 1964

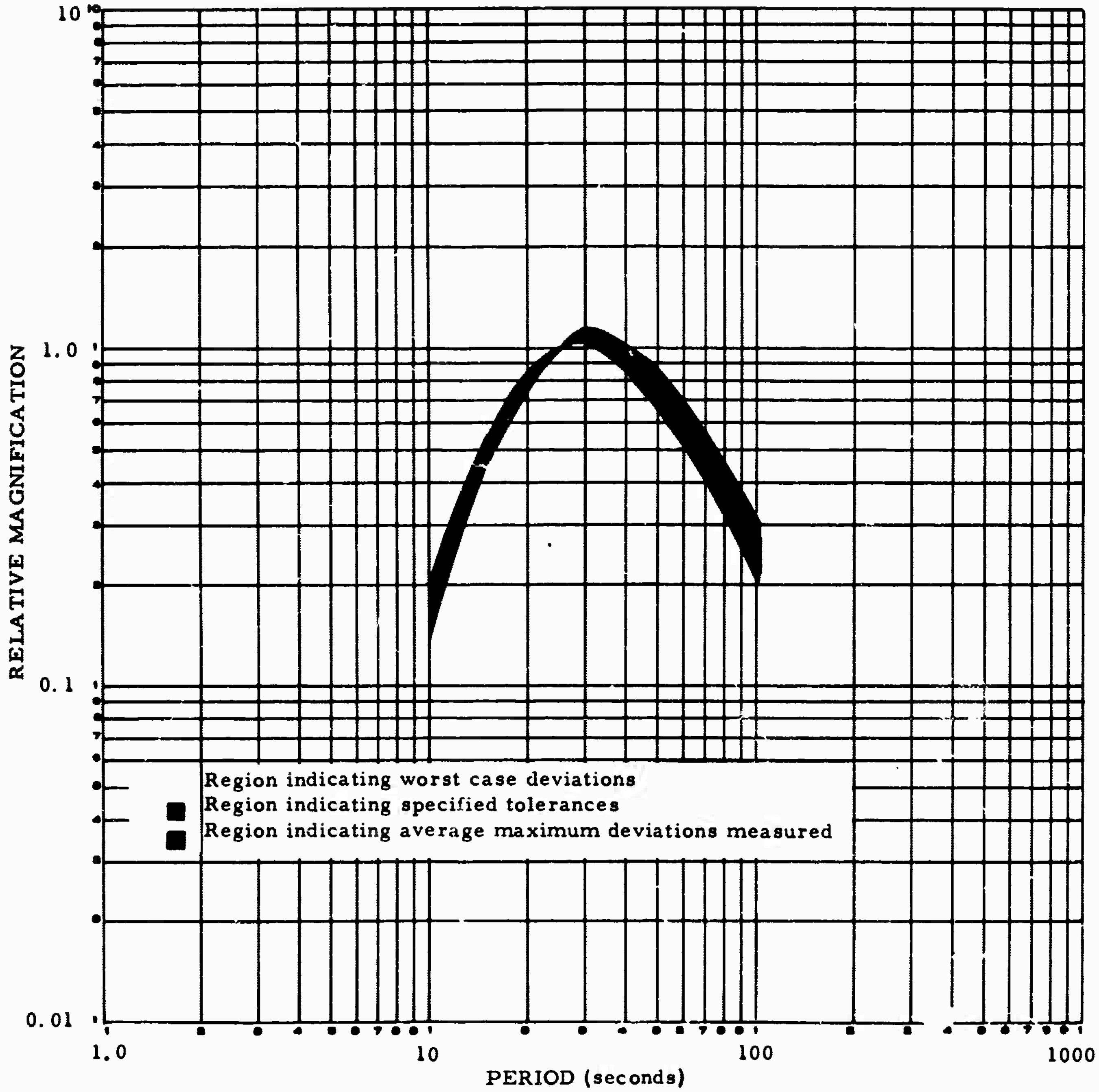


Figure 36. CPSO long-period seismograph frequency response illustrating worst case deviations, specified tolerances, and average maximum deviations measured in the period December 1963 through December 1964

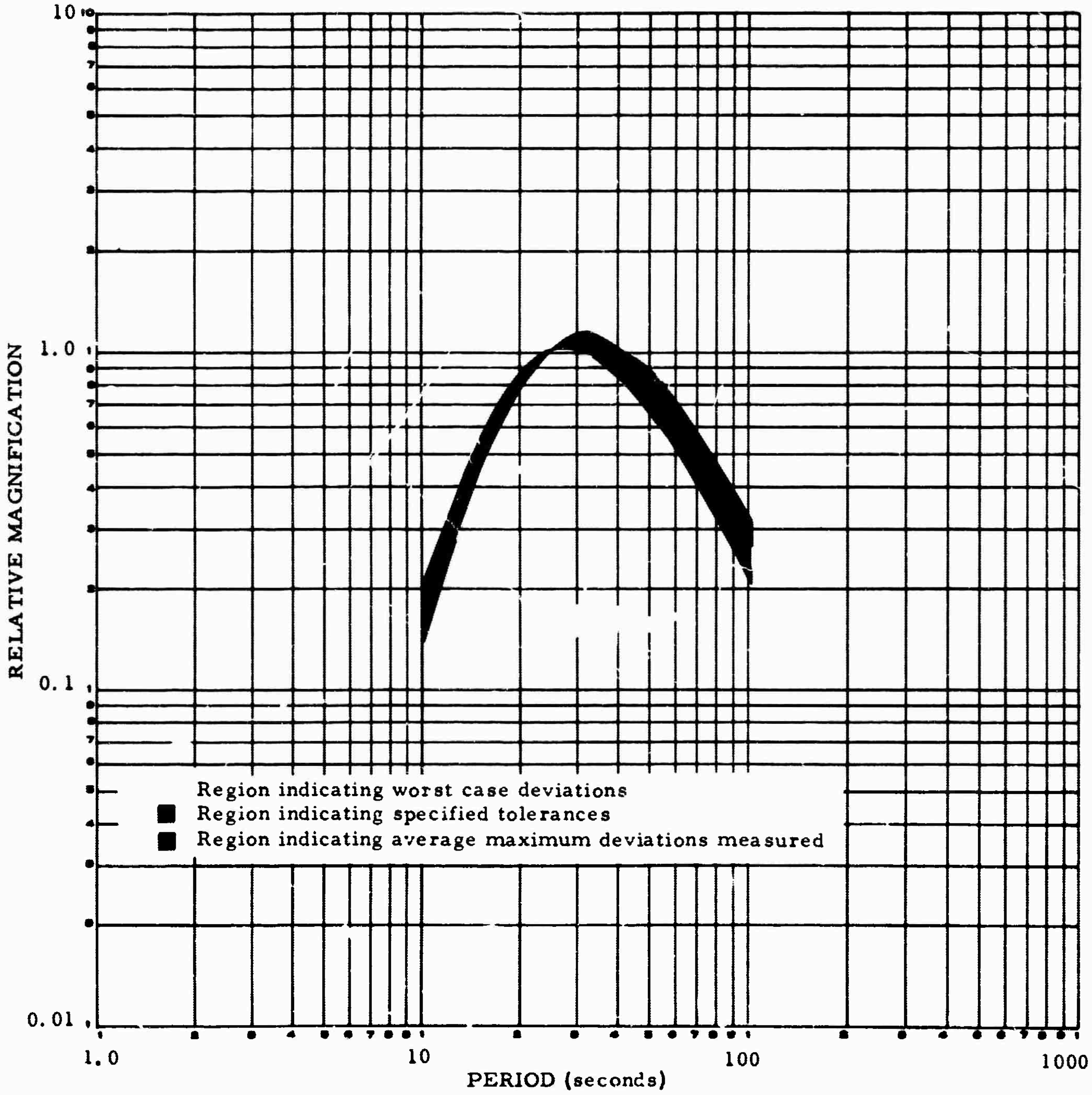


Figure 37. UBSO long-period seismograph frequency response illustrating worst case deviations, specified tolerances, and average maximum deviations measured in the period December 1963 through December 1964

## Table 14. Operational stability of seismograph magnification during April 1965

| | | BMSO | | | CPSO | | | UBSO | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Seismograph | Operating tolerance (percent) | [a]Standard magnification | Required recalibrations | Average deviation (percent) | [a]Standard magnification | Required recalibrations | Average deviation (percent) | [a]Standard magnification | Required recalibrations | Average deviation (percent) |
| SP | ± 5 | 650K | 49 | 3.9 | 400K | 17 | 4.6 | 600K | 44 | 5.0 |
| IB | ±10 | 50K | 4 | 7.8 | 50K | 0 | 4.2 | 50K | 5 | 4.6 |
| BB | ±10 | 4K | 0 | 6.0 | 3K | 0 | 5.6 | 2.5K | 5 | 4.6 |
| ZLP | ±15 | 15K | 0 | 8.3 | 35K | 0 | 4.2 | 40K | 0 | 2.5 |
| LP horizontals | ±15 | 10K | 0 | 8.6 | 12K | 0 | 6.8 | 25K | 0 | 6.3 |

[a] This magnification value represents the value chosen as most suitable for the observatory due to prevailing local microseismic activity.

each observatory were used in the tabulation of data. The maximum average deviation on the short-period seismographs (5 percent) occurred at UBSO where difficulty was experienced with the PTA in the north-south seismograph. During April, 13 of the 44 adjustments and recalibrations required were made on this seismograph.

Data from the last 2 weeks of April from the long-period seismographs at UBSO were not considered because the vaults and seismometers were being serviced.

### 3.4.2 Error in Trace Magnification for the Filtered Summation at UBSO and CPSO

When daily calibrations are made at each observatory to determine the magnification of the very high-gain traces, such as the summation or summation filtered for the short-period array, attenuation at the data control module is necessary to prevent clipping. The use of a smaller calibration signal without attenuation at the data control module will prevent clipping; however, this is not practical because the signal-to-noise ratio is too low for accurate measurements.

#### 3.4.2.1 UBSO

During December 1964 and January 1965, a review of measurements of background noise trace amplitudes indicated that on or about 19 August 1964 an abrupt change occurred in the magnification of the filtered summation seismograph channel ($\Sigma TF$) recorded in the primary data group. No corresponding change in the level of the background noise was found on the other UBSO seismograms. This indicated a malfunction so tests were conducted at UBSO to determine the cause. These tests showed that the low range of the attenuator (not used prior to August 1964) in the data control module for the filtered summation was not functioning correctly; therefore, an incorrect attenuation factor had been used in calculating the magnification of the seismograph. A new module was tested and installed. Properly calibrated data for filtered summation was re-established 0000Z on 24 February 1965.

In an effort to determine the magnification error, the amplitudes of events recorded on the primary filtered summation seismograph were compared with the amplitudes of the same events recorded on other seismograms, including the filtered summation recorded in the secondary data group. These comparisons indicated an error of approximately 6 dB (that is, previously indicated magnification was twice the actual magnification). Doubt still exists, however, regarding the validity of this correction factor.

### 3.4.2.2 CPSO

Prior to August 1964, the filtered summation channel at CPSO was calibrated using an equivalent ground motion of 100 mμ. On 6 August, when recording of the filtered summation on magnetic tape was begun, the calibration level of the filtered summation was lowered to 25 m μ. Later in August 1964, the filtered summation seismograph became inoperative due to a faulty power supply unit, and remained inoperative until October 1964. The power supply was replaced and minor circuit changes were made in the seismograph to prevent clipping; normal recording was resumed on 5 October.

During February 1965, noise studies indicated that the background noise recorded prior to August 1964, when the filtered summation was operating at about 3000K, appeared to be about equal in amplitude to background noise recorded after August when the operating magnification was about 2000K. In addition, no decrease in the level of the background noise was noted on the other seismograms. The circuit conditions of the filtered summation seismograph prior to August were reconstructed and tests conducted. No conclusive results were obtained; however, it is possible that the discrepancy was caused by a combination of filter clipping when it was calibrated at 100 mμ, a faulty control module, or a malfunction of the filter power supply.

Our best estimate of a correction factor for CPSO magnifications, based on signal comparisons with other seismographs, is that the magnifications of the filtered summation seismograph reported before August 1964 be corrected by a factor of 0.7 (that is, reported magnifications should be reduced 30 percent).

### 3.4.2.3 Modifications to Calibrations Procedures

To prevent problems of the type experienced at CPSO and UBSO, a special calibration procedure has been adopted. This procedure includes decreasing calibration levels and decreasing attenuation at the control modules as tabulated below:

| EQM (mm) | Relative attenuator settings (dB) |
|---|---|
| 50 | -18 |
| 25 | -12 |
| 12.5 | - 6 |
| 6.2 | 0 (normal operate level) |

The amplitude resulting from each of the four settings should be equal. Periodic checking in this manner is expected to prevent future problems of these types from being undetected for extended intervals.

## 3.5 RELIABILITY OF SEISMOGRAPHS

The average outage time for the short-period, intermediate-band, and broad-band seismographs at the three observatories was much less than 1 percent, including outages required to perform frequency response checks, motor constant checks, and polarity tests. Most of the outages occurred as a direct result of lightning storms which blew fuses and/or damaged components. An outage time estimate for the long-period systems is not given because many of the interruptions were the result of tests to the long-period seismographs.

## 3.6 DC STABILITY OF PHOTOTUBE AMPLIFIERS

The balance of the first and last stages of the short-period and long-period PTA's were checked each day and a log kept for each (refer to form 331-1, appendix 2). The short-period PTA's were adjusted whenever the first stage was unbalanced by more than ±0.5 volt (±2 volts for the long-period PTA) or when the last (output) stage was unbalanced by more than 0.05 volt (both long- and short-period PTA's). The April 1965 logs for the 12 short-period PTA's and the three long-period PTA's at BMSO and UBSO were examined and the number of recalibrations required follow:

| | BMSO | | | UBSO | |
|---|---|---|---|---|---|
| | Input | Output | | Input | Output |
| Short period | 38 | 1 | Short period | 16 | 0 |
| Long period | 9 | 10 | Long period | 1 | 12 |

Inbalances in the output stages are attributed primarily to filter leakage currents. Inbalances as great as 2.5 volts that are caused primarily by electrical potentials generated in the long data lines or admitted by leakage into the data lines from ground potentials have been observed at the first stage under normal conditions. If the PTA's were moved to the vault, the inbalance due to line potentials would be eliminated; however, the control of the present inbalance is not considered to be enough of a problem to justify moving the PTA's to the vault.

Phototube amplifier stability data from CPSO were not readily available. Because the leakage to ground in the data lines is greater at CPSO than at BMSO and UBSO, it is probable that more PTA adjustments were required at CPSO. Resistance between the data lines and ground are generally about 200 kohms at CPSO.

## 3.7 LONG-PERIOD SEISMOGRAPHS

### 3.7.1 General

A three-component long-period seismograph system was operated at each VT/1124 observatory. One Long-Period Vertical Seismometer, Geotech Model 7505, and two Long-Period Horizontal Seismometers, Geotech Model 8700A, each housed in a separate sealed bottomless tank vault, were used in the system. The tank vaults, installed under Contract 43486, were embedded in a concrete pier coupled to bedrock. The tops of the vaults were buried to a depth of about 2 feet below the level of the ground.

The magnifications at which the long-period seismograph could be usefully operated, especially the horizontal components, were limited by noise other than that normally associated with microseismic activity. This noise was most troublesome during periods of large changes in the ambient temperature and/or large fluctuations in atmospheric pressure (windy periods).

We postulated the following possible sources of this nonseismic noise:

a. If the vault is not well sealed:

(1) Turbulence of the air around the seismometer resulting from changes in atmospheric pressure;

(2) Distortion of sealed seismometer case resulting from fluctuations in atmospheric pressure;

(3) Direct effects on the vertical seismometer boom resulting from motion of air through a partially sealed seismometer case;

b. If the vault is well sealed, pressure changes may distort the tank vault, tilting the concrete base;

c. Local disturbances in the earth near the vaults, resulting from changes in atmospheric pressure;

d. Air turbulence inside the vaults and/or expansion and contraction of the parts of the seismometers resulting from changes in temperature;

e. Instability in the contact between the seismometer feet and the pier.

In an effort to determine optimum conditions under which to operate long-period seismographs, and to develop methods to reduce the effects of non-seismic noise, tests designed to improve the long-period seismometer installations were conducted at BMSO, CPSO, and UBSO. Among the environmental conditions checked were the merits of the presence or absence of vault and/or seismometer-case heat, vault insulation, the value and method of mounting the seismometers on glass plates, vault design, and vault installation techniques

### 3.7.2 Tests of the Importance of Sealing the Vaults

Tests were made at UBSO in January 1964 to determine how well the long-period vaults were sealed. The tests were made by connecting a 0 to 8600 Newtons/meter$^2$ (0 to 20 oz/in.$^2$) pressure gauge to the vault, pumping air into the vault to increase the pressure to approximately 4300 Newtons/meter$^2$ (10 oz/in.$^2$), and reading the pressure at specified intervals to determine the vault leakage rate. Readings from the pressure gauge were corrected for changes in atmospheric pressure. The initial test showed that the air leakage time constants were 3 hours, essentially zero, and 5 minutes for the vertical, north-south, and east-west vaults, respectively.

The gasket on the lid of the north-south vault was carefully replaced with new gaskets and sealed with RTV silastic compound. The time constant was rechecked and found to have increased to 26 minutes. This still indicated a serious leak in the vault which could not be attributed to the seal on the vault cover.

The noise on the long-period north-south seismogram was greater than on the east-west seismogram both before and after the tests and there was no significant change in noise level on either seismogram while the tests were in progress. If the noise observed on the horizontals was associated primarily with the time constant of the vault, some reduction in noise level on the north-south seismogram might have been expected. This was not considered conclusive, however, because noise from more than one of the postulated sources may actually have been present, and the vault was only partially sealed. If noise resulting from different sources have similar characteristics, one might erroneously conclude from these tests that the noise was primarily the result of a source dependent on complete vault sealing because the noise level observed under the unsealed and semisealed conditions remained unchanged.

Early in 1964 the long-period vaults were serviced at BMSO in an effort to improve the vault seal, and in January 1965 resealing of the long-period vaults at CPSO was completed. No gauge was available with which to determine the time constants of the vaults at BMSO. Time constants of 300, 30, and 180 minutes were measured for the vertical, north-south, and east-west CPSO vaults, respectively.

In general, good vault sealing has improved the performance of the long-period vertical seismographs at each observatory, but no significant reduction in nonseismic noise has been obtained on the horizontal seismograms. At CPSO, after the long-period vertical vault was resealed and a time constant of 300 minutes obtained, the level of the nonseismic noise decreased by a factor of more than 6 dB. This degree of improvement in the operation of the vertical seismographs is attributed at least in part to the fact that the seal on the seismometer case is not complete.

Because no significant reduction in the level of the nonseismic noise was obtained by sealing the horizontal vaults, only a minimum amount of effort was spent in attempting to obtain long time constants for the horizontal vaults.

At the present time we consider a time constant of 1 hour to be adequate for long-period vaults. A vault with a 1-hour time constant will attenuate external pressure changes at periods of 100, 200, and 400 seconds by factors of 220, 110, and 55, respectively. Noise due to buoyance and air jet effects are essentially eliminated even if the cases of the vertical seismometers are only partly sealed. Also, good vault sealing reduces the problems that stem from moisture condensing inside the vaults.

Pressure gauges and fittings were provided for each observatory in April 1965 to facilitate periodic checking of the degree of sealing of the long-period vaults. Difficulty in maintaining good sealing of the vaults has been experienced at all three observatories.

### 3.7.3 Tests of Seismometer Installation Techniques

3.7.3.1 To stabilize the temperature of the seismometers and to minimize temperature air turbulence around the seismometers, the vaults have been filled with insulating material. UBSO long-period vaults were filled with loose insulation material and the BMSO vaults were filled with bagged insulation. At each observatory a plywood retaining case was installed over the seismometers to prevent the insulating material from bearing directly on the instruments.

A hybrid method of insulating the seismometers was employed at CPSO (see figure 38). Loose insulation was used to fill the vaults up to the top of the retaining case and the remaining portion of the vault was filled with bagged insulation.

The value of vault heaters and case heaters in reducing the nonseismic noise by stratifying the air in the vault and the seismometer case was tested. At UBSO, the noise was reduced when seismometer case heat was used; whereas, the level of the nonseismic noise increased on the BMSO seismograms when either the vault or the case was heated. Tests at CPSO, where the most extensive study of effects of insulating and heating the vaults and seismometers was made, indicated that a combination seismometer case heat (about 4 watts) and vault heat at a point above the retaining case (about 30 watts), reduced the level of the noise relative to the level of the noise observed when no heat was used or when either vault heat or case heat were used separately.

In our opinion, the conflict of results obtained at BMSO and UBSO can be attributed to the differences in the manner in which the insulation was installed at the two observatories, and the method used at CPSO is most satisfactory.

3.7.3.2 The seismometers were installed on glass plates cemented to the pier in order to provide a smooth bearing surface for the instruments. When the instruments were originally installed, we found that if Chico A5 cement was used to bond the plates to the pier, the seismographs were noisy; therefore, limestone cement was used. We also found that the seismographs were noisy if the plates were cracked or if large air bubbles were trapped between the glass plates and the pier. To evaluate the use of glass plates, tests in which two of the

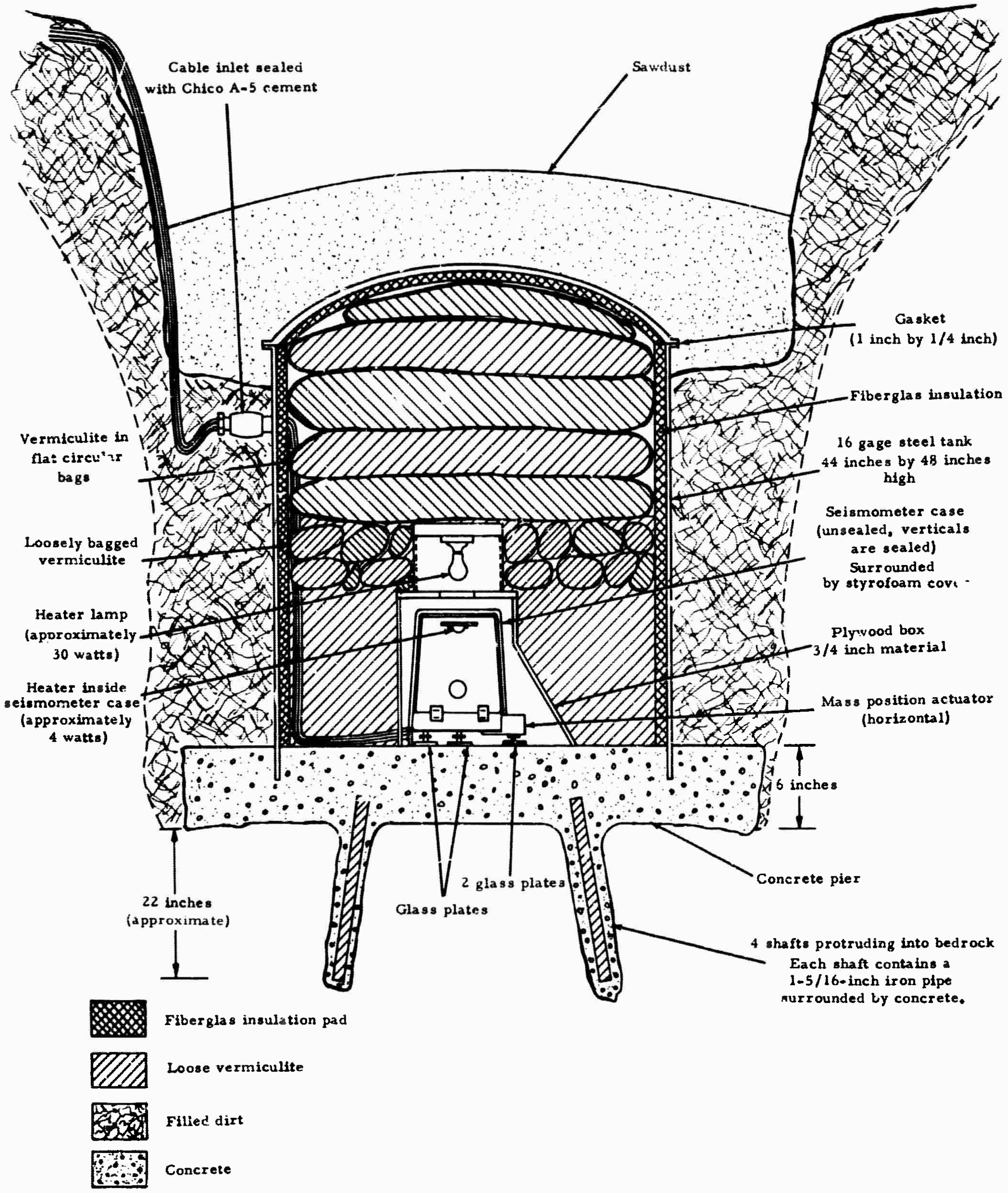


Figure 38. Sketch of the CPSO long-period seismometer installation

three seismometer feet bore directly on the pier were conducted at BMSO and UBSO (a plate is required under the third foot which is part of the remote mass positioning unit). No change in the level of the noise resulted from this method of installation.

### 3.7.4 Vault Installation Tests at CPSO

We postulated that overburden resting directly against a steel tank vault, in which a long-period horizontal seismometer is housed, might increase the noise level of the seismograph. An experiment designed to test this theory was conducted at CPSO. The earth was removed from the top and sides of the vault that houses the long-period east-west seismograph, and a wooden barrier was constructed around and over the vault. The space between the vault and the barrier was loosely filled with insulation bats.

During the initial 10 days of the experimental period, no other covering was used on the vault; however, the long-period east-west seismograph which previously had a noise level comparable to the noise level of the long-period north-south seismograph, exhibited a noise level that was significantly higher than the noise level of north-south seismograph. After the east-west seismograph had been operated in this environment for 10 days, a large plastic sheet was placed over the barrier, and was covered by 2 feet of sawdust. This additional covering of the vault generally reduced the noise on the east-west seismograph to a level approximately equivalent to the level of the noise on the north-south seismograph.

During the rainy period in late winter of 1963 and early spring of 1964, the noise of the east-west seismograph increased gradually so that late in April the magnification had been reduced from 15K to approximately 3K. The vault was uncovered and it was found that approximately 2 feet of water had accumulated in the insulated area around the vault. The buoyant force of the water probably caused the vault to be more susceptible to disturbance by atmospheric pressure changes, causing the increased noise on the east-west seismograph. It was expected that the condition of the east-west vault could be restored to normal by imbedding the vault in concrete so that the effect of the buoyant forces on the vault would be eliminated, and that the vault would also be stabilized against possible distortion if the concrete were bonded to the vault.

In May 1964, the retainer, insulation, and water were removed from around the vault, the vault was cleaned with muratic acid, and concrete was filled around the vault to within 6 inches of its lid. The vault was then covered with approximately 2 feet of sawdust. After the concrete had cured and the earth adjacent to the vault had stabilized, the level of the noise on the east-west seismograph decreased.

In November, the modified vault was evaluated by a series of controlled tests. The seismometer in the east-west vault was rotated so that its boom was oriented the same as the boom of the north-south seismometer (NLP) and was designated $NLP_1$. Figures 39, 40, and 41 are seismograms recorded during periods of varying degrees of fluctuation in atmospheric pressure, showing that the seismograph in the modified vault ($NLP_1$) is less noisy than the seismograph in the unmodified vault (NLP).

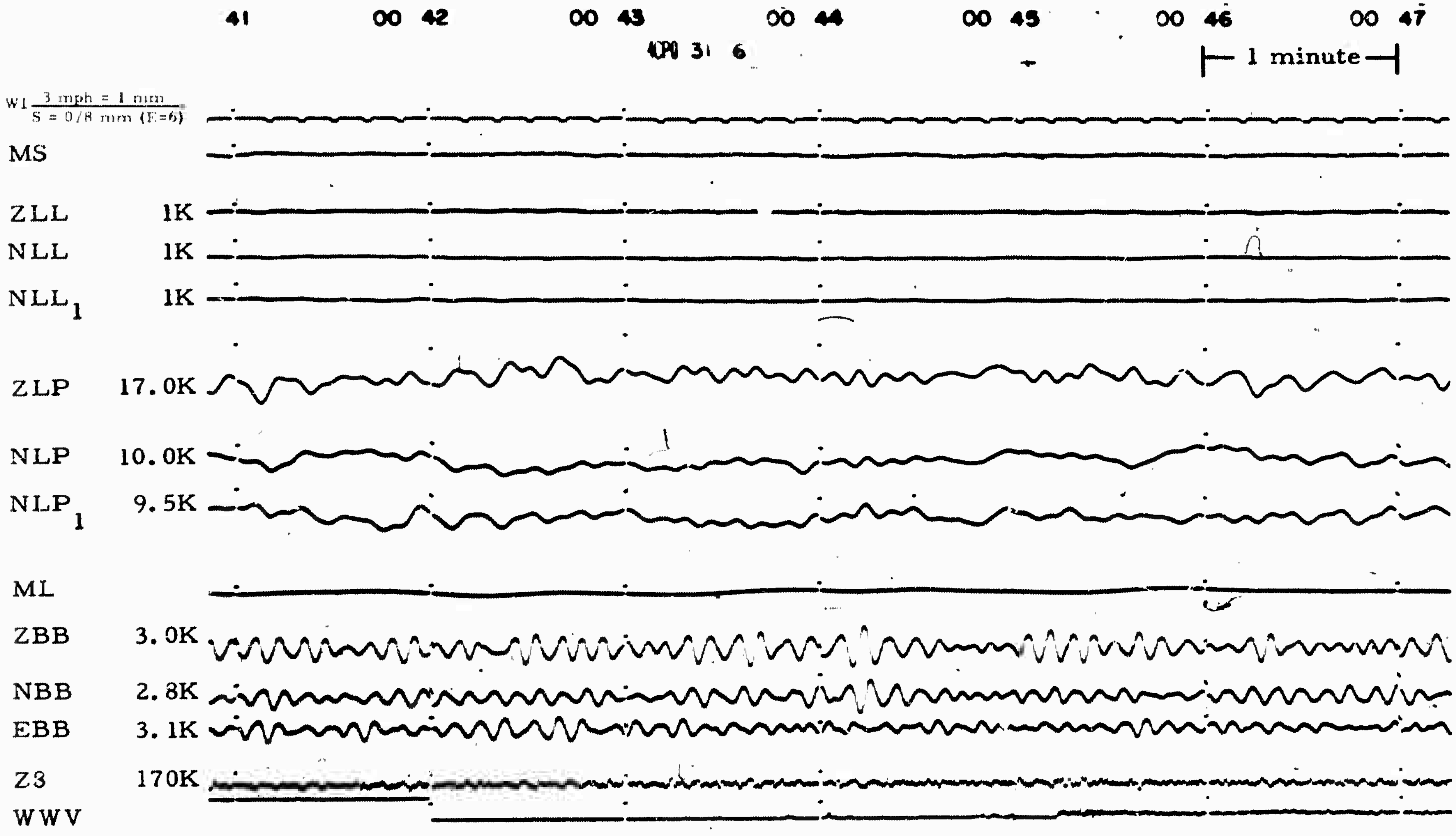
The noise that correlates between the two seismographs is attributed to probable wind-induced ground disturbances that affect both vaults identically. The noise that does not correlate between the two seismographs is thought to be the result of one or more of the following phenomena:

a. Differences in the coupling between the pier and the bedrock;

b. Reduction in the degree of distortion of the modified tank vault by direct action of atmospheric pressure changes on the vault or by indirect action of atmospheric pressure changes coupled through the overburden surrounding the vault because of the increased rigidity of the vault resulting from the concrete jacket;

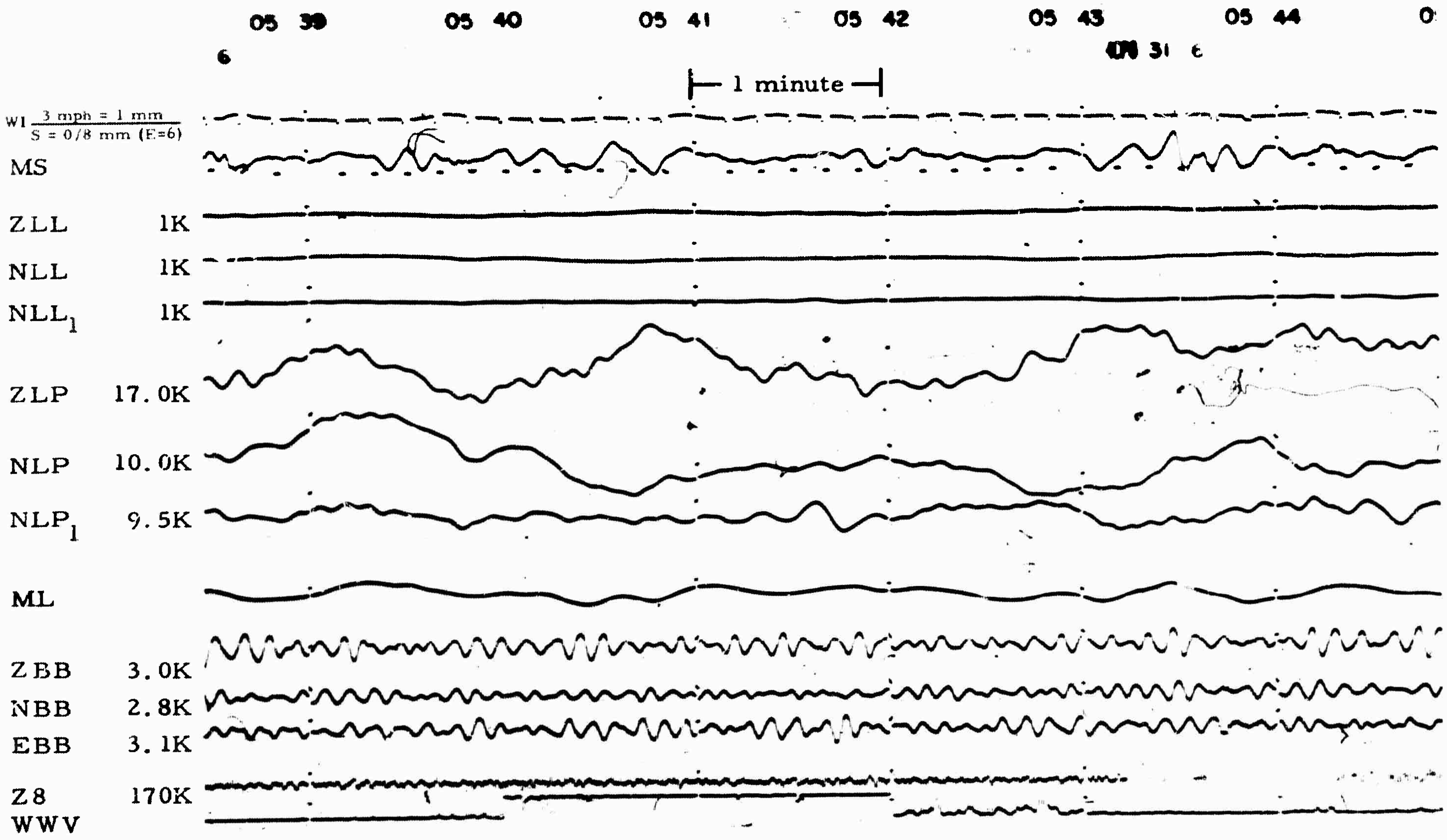
c. Ground disturbances that are not identical at the two vault locations.

Because phenomena a through c are associated with disturbances near the surface of the earth, and the modified vault reduced the level of the nonseismic noise, we conclude that a substantial portion of the noise induced by atmospheric pressure changes recorded by the tilt-sensitive horizontal seismographs is associated with near surface effects. In our opinion, a sealed vault containing a pier isolated from the sides and the floor of the vault installed at a depth of about 20 feet would greatly attenuate the noise due to one or more of the surface effects. Regional or subregional disturbances in the earth apparently affect both seismometers (located about 20 feet apart) identically. We do not expect that installation of long-period seismometers at a depth of 20 feet will completely attenuate these disturbances; however, some reduction in this noise would probably result.



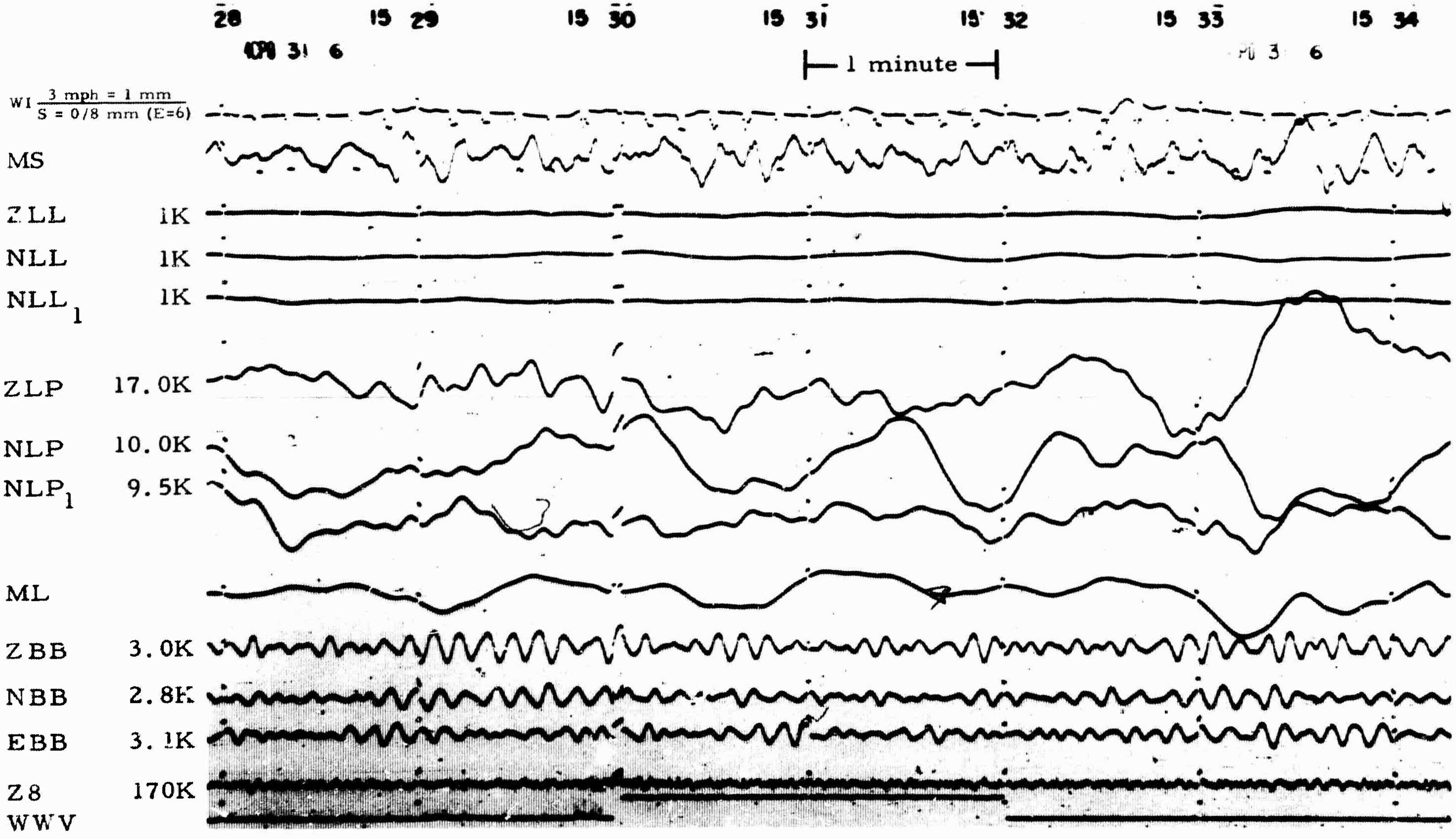
CPSO
Run 316
11 Nov 1964
Data Group 6013

Figure 39. CPSO slow-speed seismogram illustrating the level of background noise during a period of negligible atmospheric pressure fluctuations. Note that the noise levels on NLP and NLP$_1$ are nearly identical.
(X10 enlargement of 16-mm film)



CPSO
Run 316
11 Nov 1964
Data Group 6013

Figure 40. CPSO slow-speed seismogram illustrating the effects of moderate fluctuations in atmospheric pressure. Note that the level of noise on $NLP_1$ is lower than on NLP; the correlation between the two traces is poor. (X10 enlargement of 16-mm film)



CPSO
Run 316
11 Nov 1964
Data Group 6013

Figure 41. CPSO slow-speed seismogram illustrating the effects of large fluctuations in atmospheric pressure. Note that although the level of noise on NLP is considerably greater than on $NLP_1$, there is some correlation between the two traces.

(X10 enlargement of 16-mm film)

### 3.7.5 Effects of Surface Irregularities

When the long-period vaults were installed at UBSO, the overburden excavated for their installation was mounded adjacent to the vault. Early in the contract period we leveled these mounds of dirt and filled the excavation from the top of the vault to the surface of the ground with sawdust. After this was done, the noise level of the long-period horizontal seismographs during windy periods was noticeably less [illegible] before the mounds were leveled. It is probable that the turbulence of the wind had been reduced by leveling the ground. The fact that at BMSO, where the long-period horizontal seismographs are among those most sensitive to wind-induced pressure changes, the vaults are installed on a hillside, also suggests that the degree of irregularity in the local topography around the vaults strongly influences the level of the noise observed on the seismograms during the windy periods.

In our opinion small irregularities in the surface of the ground near the vaults may also affect the response of the long-period horizontal seismographs to wind-induced noise. This is a part substantiated by the fact that during the 1964-65 winter season, the noise generated on the horizontal seismographs by wind was additionally decreased after the surface had been "leveled" by a layer of snow. It is probable that the snow served as an insulator, but the fact that the greatest difference in noise level was observed during windy periods suggests that leveling of the ground surface also was a factor.

### 3.7.6 Recommendations

We recommend the following to improve and to test methods to improve the operating characteristics of the long-period seismographs.

a. Install dual output PTA power supplies and filter amplifiers like those operated at WMSO. This would:

(1) Provide more available system gain;

(2) Facilitate the operation of two long-period seismograph responses, one with a narrow response nearly the inverse of the noise providing maximum useful operating magnification within the band that signals are most frequently observed, and the other with a wide response for the study of longer period noise and signal components.

b. Equip the seismometers with remote-controlled actuators to adjust the seismometer free period without disturbing the seismometer installation.

c. Install a sealed vault containing a pier isolated from the sides of the vault and buried at least 20 feet below the surface of the ground. Do this at one of the observatories (probably UBSO) to test the degree of isolation of the horizontal seismometers from localized distrubances resulting from wind-induced pressure changes. This type of vault is also expected to be thermally more stable than a surface installation.

## 3.8 TIMING CIRCUITS

### 3.8.1 Primary Timing

Primary time at each observatory is furnished by a Timing System, Model 11880, and a Programmer, Model 11395. Observatory primary time was normally adjusted twice daily, if necessary, to maintain the time differential between the observatory time and Radio Station WWV at less than 50 milliseconds. If the time differential exceeds 50 milliseconds, the correction required to realign the observatory time with WWV was entered in the station logs. On some occasions, excessive timing system drift has caused an error of 50 milliseconds to accumulate during the night when the station was unattended. The average daily time corrections and average drift rates which occurred at each observatory during this reporting period follow:

| Observatory | Average daily time drift (milliseconds) | Average drift rate (milliseconds/hour) |
|---|---|---|
| BMSO | 12.5 | 0.52 |
| CPSO | 71.0 | 2.95 |
| UBSO | 57.4 | 2.21 |

These data show that BMSO had the minimum average drift rate. This is attributed in part to the fact that BMSO used drift rate charts as guides for adjusting their frequency standard. Drift in the frequency standards used at CPSO and UBSO made it difficult to duplicate the performance obtained at BMSO. UBSO, for example, experienced problems with the frequency adjust control of their frequency standard during the early part of the contract period. If the 60-day period, during which the UBSO frequency adjust control was the greatest problem were eliminated, the UBSO average daily drift rate would be 26 milliseconds. The maximum drift rate observed at CPSO was not sufficient to cause time errors of 50 milliseconds or more during unattended periods.

### 3.8.2 Secondary Timing

Secondary time for each observatory is furnished by a synchronome clock which generates a time mark every 30 seconds. The average daily drift rate of the secondary timing systems at CPSO and UBSO was less than 200 milliseconds while BMSO experienced a daily drift rate of 750 milliseconds. No significant problems were encountered with secondary timing systems during this contract period.

## 3.9 POWER CIRCUITS

### 3.9.1 Commercial Power

Commercial power for each observatory is supplied by local power companies. During this reporting period a total of 7 power failures were experienced at BMSO, 8 failures at CPSO, and 34 failures at UBSO. A considerable number of power fluctuations occurred at BMSO which were not of sufficient duration to constitute failures.

### 3.9.2 Emergency Power

A rotary inverter, driven by two banks of nickel-cadmium batteries, supplies emergency power for the observatories during commercial power failures. These batteries, when fully charged, are adequate to operate the seismograph systems for about 6 hours. Except for one prolonged failure at UBSO, emergency power systems have been adequate during this reporting period for all observatories.

On 22 April 1964 lightning struck the power line at UBSO, causing a commer- power outage of 14 hours and 21 minutes. The emergency system supplied power for only 3 hours and 15 minutes instead of the expected 6 hours because the batteries had not been fully recharged after emergency power was used during several short commercial power failures that occurred on previous days.

### 3.9.3 Frequency-Regulated Power

Frequency-regulated power is used to drive the capstan motors of the magnetic-tape recorders, and the capstan motor and date timers of the Develocorders at all observatories. BSMO and CPSO each have three Power Amplifiers, Model 9231, and UBSO has four.

During the early part of this reporting period, a large number of failures occurred in the power amplifiers that supply the square wave power used to drive the Develocorders. In an effort to eliminate these failures, the ventilation of the amplifiers was increased, but no significant reduction in the number of failures resulted. Later we found that the failures were primarily caused by large current spikes drawn from the power amplifiers by two capacitors (C302 and C902) located in each of the Develocorder circuits. These capacitors are normally installed in the Develocorder to correct the power factor when sinusoidal power is supplied to these circuits. The capacitors were removed and the failure rate of the amplifier was greatly reduced.

### 3.9.4 Evaluation of Techniques Used to Reduce Voltage Fluctuations Observed on Seismograms

When the observatories were initially installed, regulated power was supplied to the PTA's and the tape recorder electronics by a Sola constant voltage transformer; power for the tape recorder transports was taken from line power. Under these conditions, pulses were recorded on the film and magnetic-tape seismograms. These pulses appeared to correlate with the cycling of the air conditioning units and the operation of the Develocorder take-up motors and clutches.

Tests at UBSO and BMSO, under the previous contract, using an ac Line Voltage Regulator Stevens-Evans (S&E), Model 760R, showed that these pulses were reduced when better voltage regulation was provided for the PTA's, the tape recorder electronics, and the recorder transports. As a result of these tests, the S&E regulator was installed at UBSO to regulate the power supplied to the PTA's and the tape recorder electronics; the tape recorder transport was driven by Sola-regulated power. This resulted in a considerable reduction in the amplitude of the pulses.

Similar regulators, now sold under the name of Beckman, were installed at BMSO and CPSO during this reporting period. The regulators reduced the amplitude of the pulses at BMSO and CPSO as it had at UBSO, but the percentage reduction in the amplitude of the pulses at CPSO was not as great as at the other two observatories.

Tests at CPSO have shown that the remaining pulses primarily were generated in the data lines, not in the instrumentation. These tests, made primarily on the short-period seismographs, showed the following:

a. The pulses were eliminated when the data line was disconnected either at the station protector, at the line termination module, or at the PTA.

b. The pulses were still present both when the fuses were removed from the vault protector, and when the line was connected normally and the PTA attenuator set to infinity.

c. The character of the pulses was considerably changed but not entirely eliminated when the inputs to the line termination modules were disconnected.

Throughout the reporting period the shields of the spiral-four data cable were grounded only at the vault end. During the initial installation of the observatory the cables had been grounded at both ends; later when the shield at the CRB end was disconnected from ground, a considerable reduction in the amplitude of the pulses was observed.

The best ground for a power system that can be practically obtained at an observatory is not ideal. We believe that energy from an ac source is being capacitively-coupled into the data line conductors from the grounded or partially grounded, shield. The ac energy in the conductors is then rectified by solder joints, connectors, etc., into low frequency signals to which the PTA galvanometers can respond. We believe that improved techniques of grounding or isolation from ground may be effective in eliminating these noise pulses. If these techniques are not helpful, we recommend that the air-conditioning system be modified so that the motors and the compressors operate continuously and the compressor loads cycle as necessary for temperature control. With this arrangement the heavy currents required to start the motors and compressors would be eliminated.

### 3.9.5 Performance of Beckman ac Voltage Regulators

Except for an initial manufacturing defect that required that the Beckman regulator delivered to BMSO be returned to the factory for repair, the performance of the S&E and Beckman regulators was satisfactory until the console instrumentation was rearranged in the spring of 1964. The addition of instrumentation to the operating console made it necessary to place the regulator in a place where ventilation proved to be inadequate, and failures began to occur in the regulator. This problem was reduced by the addition of a blower and by more frequent cleaning of the heat sinks in the regulator. Occasional failures are still occurring but we think that these can be eliminated by the installation of an additional relay rack. The instrumentation can then be arranged so th + proper ventilation can be provided for the Beckman regulator.

One failure of the Beckman regulator at CPSO was due to lightning. The manufacturer was contacted regarding a possible solution to lightning susceptibility; however, none was available. To prevent loss of data, an external relay was installed at CPSO so that, in the event of a regulator failure, its load automatically switches to its input power source. This modification is also being made at BMSO and UBSO. All observatories now have an adequate supply of spare parts to reduce the duration of outages resulting from regulator failures.

## 3.10 EQUIPMENT MALFUNCTIONS

A computer program, PROGRAM MISERABLE, was written to compile some of the component failure data stored on IBM cards. Recording of the cards by observatory, general function, and subassemblies pertaining to a general function (see punch card format in appendix 3), and transcription of the card images onto digital magnetic tape are required before the data can be processed. If when more data are accumulated it is necessary, we will write a program for computer sorting so that the data stored on magnetic tape can be updated at periodic intervals.

The program can handle 10 different types of subassemblies and 25 different components for each subassembly. It outputs data similar to those shown in tables 15, 16, and 17, which give an overall picture of the equipment malfunctions experienced at the VT/1124 observatories from 1 January 1964 through 30 April 1965. (Note that the column heading "No. Serviced" is incorrect. This column is a cumulative total of the number of failures that occurred under each specific function code.)

## Table 15. Summary of equipment malfunctions at BMSO

STATION BMD

| SPECIFIC FUNCTION | MODEL NO. | SUB ASSEMBLY | NO. SERVICED | REPAIR TIME | TIME INOP. | PREVENT. | CATAS. | COMPONENT | NO. |
|---|---|---|---|---|---|---|---|---|---|
| HE | ( 4983) | | 1 | .1 | .1 | 1 | 0 | V1 | 1 |
| PTA | ( 4300) | | 38 | 21.4 | 68.3 | 32 | 6 | AT101 | 2 |
| | | | | | | | | V101 | 16 |
| | | | | | | | | V102 | 9 |
| | | | | | | | | V103 | 8 |
| | | | | | | | | DS501 | 1 |
| | | | | | | | | GALVO | 2 |
| PTA | ( 5240) | | 3 | 1.3 | 1.7 | 3 | 0 | V103 | 1 |
| | | | | | | | | V102 | 1 |
| | | | | | | | | V101 | 1 |
| PTA | ( 5240A) | | 1 | .2 | .2 | 1 | 0 | V101 | 1 |
| C | ( 9212) | | 2 | .9 | 1.1 | 2 | 0 | S2 | 2 |
| CC | ( 9228) | | 1 | .7 | .7 | 0 | 1 | DS3 | 1 |
| FG | ( 202A) | | 1 | .1 | .1 | 1 | 0 | V18 | 1 |
| DCM | ( 5792) | | 1 | .2 | .8 | 1 | 0 | R2 | 1 |
| LTM | ( 5874A) | | 1 | .2 | .5 | 1 | 0 | H2 | 1 |
| FC | ( 1151A) | DDU | 2 | .2 | .5 | 0 | 2 | DSXXX | 2 |
| PCU | ( 7679) | | 1 | .5 | 1.5 | 0 | 1 | K1 | 1 |
| PCU | ( 2322) | | 1 | .1 | 17.6 | 0 | 1 | F104 | 1 |
| PS | ( 4304) | | 28 | 6.3 | 13.3 | 23 | 5 | V101 | 3 |
| | | | | | | | | V201 | 23 |
| | | | | | | | | V202 | 2 |
| VR | ( 7606) | | 4 | 4.3 | 14.6 | 0 | 4 | Q33 | 2 |
| | | | | | | | | Q32 | 1 |
| | | | | | | | | DS1 | 1 |
| DEV | ( 4000) | | 10 | 4.2 | 13.2 | 2 | 8 | DS601 | 5 |
| | | | | | | | | DS301 | 2 |
| | | | | | | | | S101 | 1 |
| | | | | | | | | B304 | 1 |
| | | | | | | | | R202 | 1 |
| | | DT | 2 | 2.7 | 44.5 | 0 | 2 | CR901 | 1 |
| | | | | | | | | V801 | 1 |
| TR | ( 7360) | AMP | 2 | .2 | .2 | 2 | 3 | V101 | 1 |
| | | | | | | | | V103 | 1 |
| | | DISC | 11 | 7.9 | 18.2 | 3 | 8 | DS101 | 2 |
| | | | | | | | | V101 | 2 |
| | | | | | | | | V107 | 2 |
| | | | | | | | | V113 | 1 |
| | | | | | | | | CR117C | 1 |
| | | | | | | | | CR117D | 1 |
| | | | | | | | | V108 | 1 |
| | | | | | | | | F101 | 1 |
| | | OSC | 105 | 47.6 | 78.9 | 100 | 5 | V102 | 64 |
| | | | | | | | | V101 | 31 |
| | | | | | | | | V103 | 8 |
| | | | | | | | | R118 | 2 |
| | | PS | 4 | .6 | 7.7 | 0 | 4 | F101 | 3 |
| | | | | | | | | V101 | 1 |
| | | TSP | 2 | .2 | .3 | 1 | 1 | BELT | 1 |
| | | | | | | | | DS102 | 1 |

## Table 15, Continued

STATION BMO

| SPECIFIC FUNCTION | MODEL NO. | SUB ASSEMBLY | NO. SERVICED | REPAIR TIME | TIME INOP. | PREVENT. | CATAS. | COMPONENT | NO. |
|---|---|---|---|---|---|---|---|---|---|
| PA | ( 9231) | | 26 | 11.0 | 23.7 | 3 | 23 | CR1 | 1 |
| | | | | | | | | F1 | 8 |
| | | | | | | | | Q3 | 5 |
| | | | | | | | | Q4 | 8 |
| | | | | | | | | F3 | 2 |
| | | | | | | | | CR2 | 1 |
| | | | | | | | | Q1 | 1 |
| PR | ( 11395) | DDU | 5 | .8 | 17.6 | 0 | 5 | DSXXX | 5 |
| RR | ( 51J4) | | 7 | 14.0 | 21.0 | 7 | 0 | DS101 | 1 |
| | | | | | | | | DS102 | 1 |
| | | | | | | | | DS103 | 1 |
| | | | | | | | | V101 | 1 |
| | | | | | | | | V106 | 1 |
| | | | | | | | | V113 | 1 |
| | | | | | | | | V115 | 1 |
| RR | ( WVTR) | | 1 | .1 | 3.5 | 0 | 1 | F101 | 1 |
| TE | ( 19783) | | 1 | .5 | 9.3 | 0 | 1 | Q1 | 1 |
| TS | ( 11880) | | 2 | .4 | .9 | 2 | 0 | DS401 | 1 |
| | | | | | | | | Q405 | 1 |
| FV | ( 6585) | | 15 | 5.7 | 19.2 | 0 | 15 | DS201 | 6 |
| | | | | | | | | F102 | 6 |
| | | | | | | | | T101 | 1 |
| | | | | | | | | CR101 | 1 |
| | | | | | | | | F101 | 1 |
| MDC | ( 10380) | | 1 | .5 | 3.5 | 1 | 0 | V102 | 1 |
| MPD | ( 12322) | | 2 | .2 | 36.0 | 0 | 2 | F107 | 1 |
| | | | | | | | | F108 | 1 |

## Table 16. Summary of equipment malfunctions at CPSO

STATION CPO

| SPECIFIC FUNCTION | MODEL NO. | SUB ASSEMBLY | NO. SERVICED | REPAIR TIME | TIME INDP. | PREVENT. | CATAS. | COMPONENT | NO. |
|---|---|---|---|---|---|---|---|---|---|
| HE | ( 4983) | | 10 | 2.8 | 1.4 | 3 | 7 | | |
| | | | | | | | | V4 | 2 |
| | | | | | | | | V1 | 5 |
| | | | | | | | | V5 | 2 |
| | | | | | | | | DS1 | 1 |
| PTA | ( 4300) | | 60 | 17.4 | 21.8 | 51 | 9 | | |
| | | | | | | | | V103 | 15 |
| | | | | | | | | V102 | 16 |
| | | | | | | | | GALVO | 3 |
| | | | | | | | | V101 | 21 |
| | | | | | | | | V201 | 1 |
| | | | | | | | | DS101 | 3 |
| | | | | | | | | G101 | 1 |
| PTA | ( 5240) | | 14 | 5.9 | 3.4 | 14 | 0 | | |
| | | | | | | | | V103 | 3 |
| | | | | | | | | V101 | 8 |
| | | | | | | | | V102 | 3 |
| C | ( 9212) | | 4 | 23.6 | 20. | 1 | 3 | | |
| | | | | | | | | S2 | 3 |
| | | | | | | | | Y1 | 1 |
| CC | ( 9228) | | 6 | 1.9 | .9 | 1 | 5 | | |
| | | | | | | | | F1 | 3 |
| | | | | | | | | CR3 | 2 |
| | | | | | | | | CR4 | |
| FG | ( 202A) | | 8 | 1.[illegible] | 1.2 | [illegible] | [illegible] | | |
| | | | | | | | | V20 | [illegible] |
| | | | | | | | | V4 | [illegible] |
| | | | | | | | | V15 | 1 |
| | | | | | | | | V16 | 1 |
| | | | | | | | | V5 | 1 |
| | | | | | | | | V19 | 1 |
| | | | | | | | | V18 | 1 |
| DCM | ( 5792E) | | 1 | .1 | .1 | 1 | 0 | | |
| | | | | | | | | [illegible] | 1 |
| LTM | ( 5874C) | | 2 | .7 | 320.3 | 1 | 1 | | |
| | | | | | | | | H6 | 1 |
| | | | | | | | | H2 | 1 |
| LTM | ( 5874A) | | 4 | 2.0 | 15.5 | 1 | 3 | | |
| | | | | | | | | S1 | 4 |
| SDF | ( 12025) | | 6 | .7 | .6 | 5 | 1 | | |
| | | | | | | | | V1 | 2 |
| | | | | | | | | V2 | 1 |
| | | | | | | | | V3 | 1 |
| | | | | | | | | V4 | 1 |
| | | | | | | | | V6 | 1 |
| FC | ( 1151A) | | 16 | 1.9 | 2.3 | 1 | 15 | | |
| | | | | | | | | DSXXX | 16 |
| | | DDU | 5 | .4 | .8 | 0 | 5 | | |
| | | | | | | | | DSXXX | 5 |
| OS | ( 120A) | | 3 | 1.5 | .6 | 3 | 0 | | |
| | | | | | | | | V201 | 1 |
| | | | | | | | | V202 | 1 |
| | | | | | | | | V205 | 1 |
| OS | ( 502) | | 2 | 1.6 | 72.1 | 0 | 2 | | |
| | | | | | | | | V444 | 2 |
| PCU | ( 7679) | | 1 | 2.0 | 2.0 | 1 | 0 | | |
| | | | | | | | | K5 | 1 |
| PCU | ( 11901) | | 1 | .1 | 82.0 | 0 | 1 | | |
| | | | | | | | | H101 | 1 |
| PS | ( 4304) | | 47 | 13.2 | 10.3 | 37 | 10 | | |
| | | | | | | | | V201 | 41 |
| | | | | | | | | V202 | 5 |
| | | | | | | | | V101 | 1 |
| RPC | ( 11901) | | 1 | .1 | .1 | 0 | 1 | | |
| | | | | | | | | OS1 | 1 |
| VR | ( 760R) | | 10 | 29.6 | 355.5 | 0 | 10 | | |

## Table 16, Continued

STATION CPC

| SPECIFIC FUNCTION | MODEL NC. | SUB ASSEMBLY | NO. SERVICED | REPAIR TIME | TIME INOP. | PREVENT. | CATAS. | COMPONENT | NO. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Q29 | 1 |
| | | | | | | | | Q31 | 1 |
| | | | | | | | | Q33 | 1 |
| | | | | | | | | Q56 | 1 |
| | | | | | | | | Q81 | 1 |
| | | | | | | | | Q28 | 1 |
| | | | | | | | | Q82 | 1 |
| | | | | | | | | Q37 | 1 |
| | | | | | | | | Q36 | 1 |
| | | | | | | | | Q80 | 1 |
| VR | ( 11219) | | 4 | 3.4 | 4.0 | 2 | 2 | Q105 | 1 |
| | | | | | | | | Q101 | 1 |
| | | | | | | | | Q102 | 1 |
| | | | | | | | | Q106 | 1 |
| DEV | ( 4000) | | 57 | 14.3 | 87.5 | 20 | 37 | DS601 | 17 |
| | | | | | | | | CHECK VALVE | 6 |
| | | | | | | | | ROLLER | 3 |
| | | | | | | | | O-RING | 3 |
| | | | | | | | | B304 | 2 |
| | | | | | | | | DS301 | 3 |
| | | | | | | | | O RING | 1 |
| | | | | | | | | DS801 | 1 |
| | | | | | | | | DS602 | 3 |
| | | | | | | | | S101 | 1 |
| | | | | | | | | BEARN BLOCK | 1 |
| | | | | | | | | FLANGE RRNG | 1 |
| | | | | | | | | PLATE | 1 |
| | | | | | | | | SHAFT | 1 |
| | | | | | | | | WASHER | 1 |
| | | | | | | | | FOLLOWER | 2 |
| | | | | | | | | RING RETAIN | 2 |
| | | | | | | | | R202 | 1 |
| | | | | | | | | FOLL ROLLER | 4 |
| | | | | | | | | TENS ROLLER | 3 |
| | | DT | 7 | 14.8 | 10.6 | 0 | 7 | T901 | 1 |
| | | | | | | | | V802 | 3 |
| | | | | | | | | V801 | 2 |
| | | | | | | | | S807 | 1 |
| | | PASY | 6 | 4.8 | .8 | 0 | 6 | O RING | 2 |
| | | | | | | | | VALVE | 4 |
| HE | ( 2484) | | 1 | .1 | 10.5 | 0 | 1 | F2 | 1 |
| HE | ( 2484-1) | | 3 | 5.7 | 1.2 | 0 | 3 | STYLUS | 2 |
| | | | | | | | | GALVO | 1 |
| HE | ( 2484-3) | | 2 | .6 | 8.0 | 0 | 2 | STYLUS | 1 |
| | | | | | | | | Q1 | 1 |
| TR | ( 7360) | | 5 | 8.2 | 4.2 | 1 | 4 | BEARING | 4 |
| | | | | | | | | V101 | 1 |
| | | AMP | 6 | 3.6 | 1.2 | 3 | 3 | V103 | 2 |
| | | | | | | | | V102 | 2 |
| | | | | | | | | V101 | 2 |
| | | DISC | 14 | 7.2 | 2.3 | 11 | 3 | V104 | 3 |
| | | | | | | | | V102 | 2 |
| | | | | | | | | V105 | 2 |
| | | | | | | | | V108 | 1 |
| | | | | | | | | V109 | 1 |
| | | | | | | | | V111 | 2 |
| | | | | | | | | V106 | 1 |
| | | | | | | | | V101 | 1 |
| | | | | | | | | F101 | 1 |
| | | OSC | 138 | 60.2 | 126.0 | 133 | 5 | V102 | 88 |
| | | | | | | | | V103 | 10 |
| | | | | | | | | V101 | 36 |
| | | | | | | | | C108 | 2 |
| | | | | | | | | R102 | 1 |
| | | | | | | | | C103 | 1 |
| TR | ( 7360) | PS | 15 | 1.8 | 24.6 | 2 | 13 | V101 | 1 |
| | | | | | | | | V102 | 2 |
| | | | | | | | | F101 | 10 |
| | | | | | | | | C103 0. | 1 |
| | | | | | | | | V105 | 1 |

## Table 16, Continued

STATION CPO

| SPECIFIC FUNCTION | MODEL NO. | SUB ASSEMBLY | NO. SERVICED | REPAIR TIME | TIME INOP. | PREVENT. | CATAS. | COMPONENT | NO. |
|---|---|---|---|---|---|---|---|---|---|
| | | TSP | 21 | 2.8 | 25.3 | 2 | 19 | | |
| | | | | | | | | BELT | 9 |
| | | | | | | | | DS102 | 4 |
| | | | | | | | | DS101 | 3 |
| | | | | | | | | CR101 | 1 |
| | | | | | | | | F101 | 3 |
| | | | | | | | | F104 | 1 |
| SP | ( 6480) | | 10 | 14.5 | 721.0 | 0 | 10 | | |
| | | | | | | | | CALIBR COIL | 3 |
| | | | | | | | | DATA COIL | 4 |
| | | | | | | | | CANTILV ROD | 3 |
| SP | ( 7515) | | 2 | 1.5 | 6.6 | 0 | 2 | | |
| | | | | | | | | ELECT COIL | 1 |
| | | | | | | | | XXX | 1 |
| LP | ( 8700A) | | 1 | .5 | 177.0 | 0 | 1 | | |
| | | | | | | | | COIL ASSY | 1 |
| OS | ( 502) | | 1 | .8 | 1.0 | 0 | 1 | | |
| | | | | | | | | V414 | 1 |
| PA | ( 9231) | | 115 | 77.6 | 328.1 | 1 | 114 | | |
| | | | | | | | | F3 | 30 |
| | | | | | | | | Q3 | 30 |
| | | | | | | | | Q4 | 34 |
| | | | | | | | | F1 | 13 |
| | | | | | | | | Q1 | 1 |
| | | | | | | | | Q2 | 1 |
| | | | | | | | | CR1 | 2 |
| | | | | | | | | MOUNTINGKIT | 1 |
| | | | | | | | | DS1 | 2 |
| | | | | | | | | CR2 | 1 |
| PR | ( 11395) | | 6 | 1.8 | .3 | 0 | 6 | | |
| | | | | | | | | DSXXX | 6 |
| RR | ( WVTR) | | 5 | 3.4 | 6.9 | 0 | 5 | | |
| | | | | | | | | F101 | 1 |
| | | | | | | | | F1 | 2 |
| | | | | | | | | Q12 | 1 |
| | | | | | | | | Q13 | 1 |
| TCU | ( 7136) | | 3 | .3 | .3 | 0 | 3 | | |
| | | | | | | | | F4 | 1 |
| | | | | | | | | F3 | 1 |
| | | | | | | | | F1 | 1 |
| TS | ( 11880) | SSCP | 1 | .8 | 4.0 | 0 | 1 | | |
| | | | | | | | | DS401 | 1 |
| FV | ( 6585) | | 39 | 5.0 | 3.0 | 0 | 39 | | |
| | | | | | | | | DS201 | 18 |
| | | | | | | | | F102 | 17 |
| | | | | | | | | R101 | 1 |
| | | | | | | | | R102 | 1 |
| | | | | | | | | F101 | 1 |
| | | | | | | | | DS601 | 1 |
| AWI | ( 18515) | | 4 | .4 | 5.7 | 0 | 4 | | |
| | | | | | | | | F101 | 4 |
| DSC | ( 10821) | | 1 | .1 | 14.0 | 0 | 1 | | |
| | | | | | | | | V303 | 1 |

# Table 17. Summary of equipment malfunctions at UBSO

STATION UBO

| SPECIFIC FUNCTION | MODEL NO. | SUB ASSEMBLY | NO. SERVICED | REPAIR TIME | TIME INOP. | PREVENT. | CATAS. | COMPONENT | NO. |
|---|---|---|---|---|---|---|---|---|---|
| HE | ( 4983) | | 8 | 1.7 | .8 | 8 | 0 | V1 | 2 |
| | | | | | | | | V2 | 1 |
| | | | | | | | | V3 | 1 |
| | | | | | | | | V5 | 2 |
| | | | | | | | | V4 | 1 |
| | | | | | | | | V7 | 1 |
| PTA | ( 4300) | | 26 | 11.3 | 16.4 | 19 | 7 | G101 | 3 |
| | | | | | | | | GALVO | 1 |
| | | | | | | | | V101 | 7 |
| | | | | | | | | V102 | 7 |
| | | | | | | | | V103 | 6 |
| | | | | | | | | DS601 | 2 |
| PTA | ( 5240A) | | 5 | 2.4 | 3.0 | 4 | 1 | MXXX | 1 |
| | | | | | | | | DS601 | 1 |
| | | | | | | | | V101 | 1 |
| | | | | | | | | V102 | 1 |
| | | | | | | | | V103 | 1 |
| PTA | ( 12613-1) | | 2 | .6 | .6 | 0 | 2 | DS101 | 2 |
| C | ( 9212) | | 1 | 1.0 | .2 | 0 | 1 | V1 | 1 |
| CC | ( 9228) | | 3 | 1.5 | .8 | 0 | 3 | CR2 | 1 |
| | | | | | | | | CR4 | 1 |
| | | | | | | | | F1 | 1 |
| SDF | ( 3304R8) | | 2 | .9 | .9 | 1 | 1 | V201 | 1 |
| | | | | | | | | V101 | 1 |
| SDF | ( 12025) | | 11 | 1.4 | 1.5 | 11 | 0 | V1A | 1 |
| | | | | | | | | V2A | 1 |
| | | | | | | | | V3A | 1 |
| | | | | | | | | V4A | 2 |
| | | | | | | | | V5A | 1 |
| | | | | | | | | V2B | 1 |
| | | | | | | | | V3B | 1 |
| | | | | | | | | V5B | 1 |
| | | | | | | | | V6A | 1 |
| | | | | | | | | V6B | 1 |
| OS | ( 102AR) | | 1 | .5 | .5 | 0 | 1 | V202 | 1 |
| OS | ( 502) | | 2 | .4 | .2 | 0 | 2 | V145 | 1 |
| | | | | | | | | V464 | 1 |
| BAT | ( 10176A) | | 3 | .9 | 33.3 | 0 | 3 | F3 | 1 |
| | | | | | | | | F2 | 1 |
| | | | | | | | | F1 | 1 |
| PS | ( 4334) | | 21 | 8.7 | 8.2 | 11 | 10 | V201 | 17 |
| | | | | | | | | V202 | 4 |
| VR | ( 760R) | PCB | 2 | 1.3 | 96.1 | 0 | 2 | 024 | 1 |
| | | | | | | | | 020 | 1 |
| | | | 6 | .9 | 60.0 | 0 | 6 | 036 | 1 |
| | | | | | | | | 037 | 1 |
| | | | | | | | | 033 | 1 |
| | | | | | | | | 032 | 1 |
| | | | | | | | | 031 | 1 |
| | | | | | | | | 029 | 1 |
| VR | ( 11219) | | 11 | 5.6 | 68.2 | 1 | 10 | Q105 | 2 |
| | | | | | | | | 0108 | 2 |
| | | | | | | | | 0106 | 2 |
| | | | | | | | | F101 | 2 |
| | | | | | | | | Q101 | 1 |
| | | | | | | | | F102 | 1 |
| | | | | | | | | Q102 | 1 |

# Table 17, Continued

STATION UBO

| SPECIFIC FUNCTION | MODEL NO. | SUB ASSEMBLY | NO. SERVICED | REPAIR TIME | TIME INOP. | PREVENT. | CATAS. | COMPONENT | NO. |
|---|---|---|---|---|---|---|---|---|---|
| VR | ( 1570AL) | | 5 | .9 | .9 | 5 | 0 | | |
| | | | | | | | | V1 | 1 |
| | | | | | | | | V2 | 1 |
| | | | | | | | | V4 | 1 |
| | | | | | | | | V5 | 1 |
| | | | | | | | | V3 | 1 |
| DEV | ( 4000) | | 17 | 7.1 | 41.6 | 4 | 13 | | |
| | | | | | | | | B304 | 1 |
| | | | | | | | | B305 | 3 |
| | | | | | | | | S101 | 1 |
| | | | | | | | | DS601 | 10 |
| | | | | | | | | DS301 | 1 |
| | | | | | | | | DS602 | 1 |
| | | DT | 1 | 4.0 | 4.0 | 1 | 0 | | |
| | | | | | | | | V802 | 1 |
| DEV | ( 4000C) | | 3 | .7 | 1.5 | 1 | 2 | | |
| | | | | | | | | DS601 | 2 |
| | | | | | | | | DS301 | 1 |
| HF | ( 2484) | | 1 | .3 | .5 | 0 | 1 | | |
| | | | | | | | | STYLUS | 1 |
| TR | ( 7360) | DISC | 7 | 6.2 | 5.3 | 5 | 2 | | |
| | | | | | | | | V108 | 2 |
| | | | | | | | | V107 | 1 |
| | | | | | | | | Q102 | 1 |
| | | | | | | | | Q101 | 1 |
| | | | | | | | | CR102 | 1 |
| | | | | | | | | CR107 | 1 |
| | | OSC | 25 | 10.8 | 9.7 | 22 | 3 | | |
| | | | | | | | | V102 | 6 |
| | | | | | | | | V101 | 17 |
| | | | | | | | | R118 | 1 |
| | | | | | | | | V103 | 1 |
| | | PS | 4 | .4 | 1.7 | 1 | 3 | | |
| | | | | | | | | V104 | 1 |
| | | | | | | | | F101 | 2 |
| | | | | | | | | V101 | 1 |
| | | TSP | 5 | 1.4 | 24.7 | 0 | 5 | | |
| | | | | | | | | BELT | 1 |
| | | | | | | | | DS102 | 1 |
| | | | | | | | | F104 | 3 |
| PA | ( 9231) | | 16 | 10.4 | 27.9 | 0 | 16 | | |
| | | | | | | | | Q3 | 5 |
| | | | | | | | | Q4 | 5 |
| | | | | | | | | F3 | 1 |
| | | | | | | | | Q1 | 2 |
| | | | | | | | | CR1 | 1 |
| | | | | | | | | Q2 | 1 |
| | | | | | | | | F1 | 1 |
| PR | ( 11395) | DDU | 9 | .8 | .9 | 9 | 0 | | |
| | | | | | | | | DS | 9 |
| RR | ( 5104) | | 1 | .1 | .5 | 0 | 1 | | |
| | | | | | | | | V001 | 1 |
| RR | ( WVTR) | | 2 | .2 | .1 | 0 | 2 | | |
| | | | | | | | | F1 | 2 |
| TS | ( 11880) | FOV | 1 | .1 | .1 | 0 | 1 | | |
| | | | | | | | | Q401 | 1 |
| | | SSCP | 8 | 6.3 | 8.0 | 0 | 8 | | |
| | | | | | | | | C404 | 1 |
| | | | | | | | | C403 | 1 |
| | | | | | | | | Q401 | 1 |
| | | | | | | | | Q402 | 2 |
| | | | | | | | | Q405 | 1 |
| | | | | | | | | Q403 | 1 |
| | | | | | | | | Q404 | 1 |
| FV | ( 6585) | | 39 | 5.6 | 5.5 | 1 | 38 | | |
| | | | | | | | | DS201 | 15 |
| | | | | | | | | F102 | 17 |
| | | | | | | | | F101 | 5 |
| | | | | | | | | SCREEN | 1 |
| | | | | | | | | R102 | 1 |
| DSC | ( 10821) | | 3 | 4.7 | 2.0 | 3 | 0 | | |
| | | | | | | | | V104 | 1 |
| | | | | | | | | V107 | 1 |
| | | | | | | | | V105 | 1 |
| DSC | ( 15210) | | 1 | .3 | 10.[illegible] | 0 | 1 | | |
| | | | | | | | | R309 | 1 |

## 3.11 TEST OF BELL AND HOWELL SIXTEEN-MILLIMETER FILM

During August 1963, Bell and Howell film was purchased for the observatories. This film was used in the Develocorders but it proved to be inferior to the Recordak film which had been used previously. The contrast of the Bell and Howell film was not as good as that of the Recordak film, and the level of light intensity and the focussing of the light beams was much more critical for the production of good records. After we had tested this film for several weeks, the unused Bell and Howell film was returned to the manufacturer and the use of Recordak film was resumed late in September or early in October 1963.

## 3.12 SEISMIC AND SYSTEM NOISE FOR SHORT-PERIOD MAGNETIC-TAPE DATA

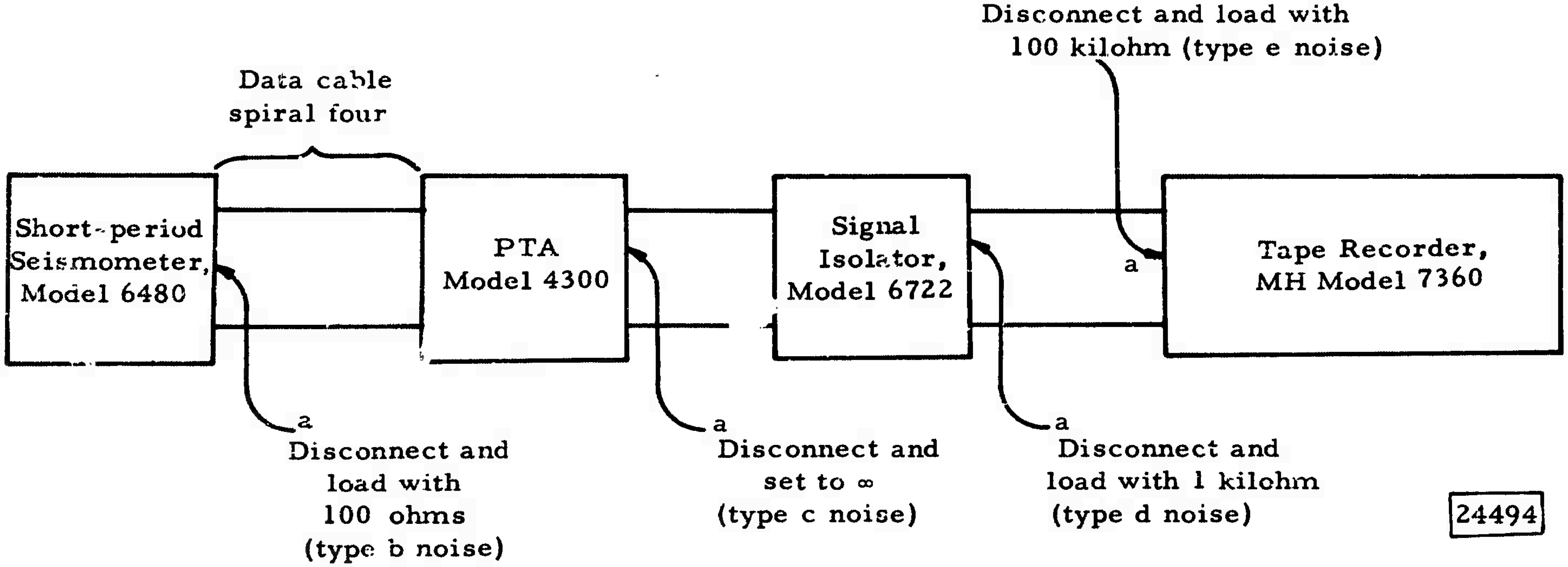
### 3.12.1 Purpose of the Study

The sensitivities of magnetic-tape recorders at the observatories were originally set and normally maintained by visually comparing the ratio of the level of seismic noise to system noise on an oscilloscope. The sensitivity level was normally set so that the average microseismic background at frequencies above 0.3 Hz was recorded at a level approximately 5 to 10 times greater than the expected magnetic-tape recorder noise. It was normally considered that the tape recorders we [illegible] a major source of system noise.

Figure 42 is a block diagram of a short-period magnetic-tape seismograph system, the following components of which were considered to be possible sources of system noise:

Data cables from seismometer to PTA (spiral-four cable)
Phototube Amplifier, Model 4300
Signal Isolator, Model 6722
Tape Recorder, Minneapolis-Honeywell Model 7360.

To determine whether the sensitivities of the magnetic-tape recorders were at the correct level, and to determine the relative contribution of these four sources of noise to the total system noise, data were collected from BMSO, CPSO, and UBSO.



[a] Arrangements for recording each of four types of system noise.

Figure 42. Block diagram of a typical observatory tape recorder seismograph system

### 3.12.2 Data Selection

Two short-period seismographs, widely separated in the array and having long data lines, were selected at each observatory. The following types of noise were recorded on both magnetic-tape and 16-millimeter film from each seismograph selected:

a. Typical microseismic background noise plus system noise;

b. System noise from the entire seismograph system excluding the seismometer; the seismometer was replaced by a dummy load of 100 ohms.

c. System noise from the entire seismograph system excluding the seismometer and data cable; the PTA was disconnected from the line and attenuated [illegible] unity.

d. System noise generated by the signal isolator and tape recorder; the signal isolator input was disconnected and loaded with a 1 kilohm resistor.

e. System noise generated by the tape recorder only; the input to the tape recorder was disconnected from the signal isolator and loaded with a 100-kilohm resistor.

To reduce the tape-recorder noise with respect to other types of noise, the recording sensitivity of each tape recorder oscillator was doubled for each of the chosen seismographs prior to recording these data.

### 3.12.3 Special Analysis Procedures

The Develocorder seismograms containing the same data that were recorded on magnetic tape were reviewed in order to select samples suitable for analysis. The selected samples were analyzed in two different ways:

a. Amplitude-frequency analysis of analog data using a Geotech analog spectrum analyzer;

b. Power-frequency analysis of digitized data using a power spectrum analysis program, PROGRAM BLACKY.

### 3.12.3.1 Analog Spectrum Analysis

For analog spectrum analysis, the data, the wow-and-flutter compensation channel, and the WWV channel from the original magnetic-tape seismogram were dubbed onto hard-base magnetic tape.

A typical 27.5-second segment of data, free of oxide dropouts and other anomalies, was selected by viewing it on an oscilloscope. The full window width of 27.5 seconds was then analyzed at a repetition rate of 40 times per second using a spinning reproducer and an audio wave analyzer. The analyzer output signal was recorded on an X-Y plotter. The abscissa of the plotter was driven by a logarithmic function generator to produce a logarithmic frequency scale on the spectrogram.

The spectrograms produced by the plotter are of the form shown in section 3.12.4.1. The spectrograms consist of a series of vertical spikes, the amplitudes of which are proportional to the coefficients, $A_n$, of the Fourier series.

$$g(t) = \sum_{n}^{k} A_n \cos (2\pi\, nf_o t - \alpha_n) ,$$

where g(t) is the sample.

$n$ = harmonic integer

$f_o$ = fundamental frequency of the analyzer = $\frac{1}{T}$

$\alpha_n$ = relative phase angle of frequency, $nf_o$.

The values of $A_n$ are given by:

$$A_n = \left| \frac{2}{T} \int_0^T g(t) \exp (-i2\pi n f_o t)\, dt \right| \text{ for } n \neq 0 .$$

The $A_n$ are the absolute values of the resultant vectors of the Fourier sine and cosine components for the frequency corresponding to n.

### 3.12.3.2 Power Spectrum Analysis

As an alternative and as a comparison to analog spectrum analysis, power spectra of some data were produced. Two-minute data samples were selected from the original magnetic tapes digitized directly onto paper tape at a digitizing rate of 50 samples per second. The digitized data were converted from binary to binary-coded decimal data to make them suitable for computation b the Blackman-Tukey power spectrum program, PROGRAM BLACKY. This program produced a smoothed power spectral density estimate and the autocorrelation functions, and stored this information on magnetic tape.

The power spectral density at a frequency f is given by

$$\frac{\text{Average power in frequency bandwith } \Delta f}{\Delta f}$$

By the use of a CDC 160A computer, the data stored on magnetic tape were printed out and plotted by a log-log X-Y plotter.

### 3.12.4 Comparison of Results

Data from the two analytic methods have been used to produce two comparisons of seismic and system noise.

Power spectra are essentially the square of amplitude spectra, but PROGRAM BLACKY also smooths the power spectra according to a predetermined formula. Analog spectra are a series of discrete Fourier amplitudes (that is, $A_n$) where power spectra represent the variance of these amplitudes in a band around a particular frequency. The band is smoothed by multiplying the autocorrelation by a preselected weighting function prior to the computation of the Fourier coefficients.

### 3.12.4.1 Amplitude Spectra

All the data collected were analyzed using the Geotech analog spectrum analyzer. Some of the spectrograms, and the seismogram for BMSO showing the seismic data that were analyzed, are shown in figures 43 and 44. Similar data for CPSO and UBSO are shown in figures 45 through 48. Comparisons between seismic noise and total system noise are given for one short-period seismograph for each observatory. Also shown, figure 47, are spectrograms of each of the types of system noise recorded at UBSO. All of these spectrograms were made using wow-and-flutter compensation except the second spectrogram of tape-recorder noise at UBSO.

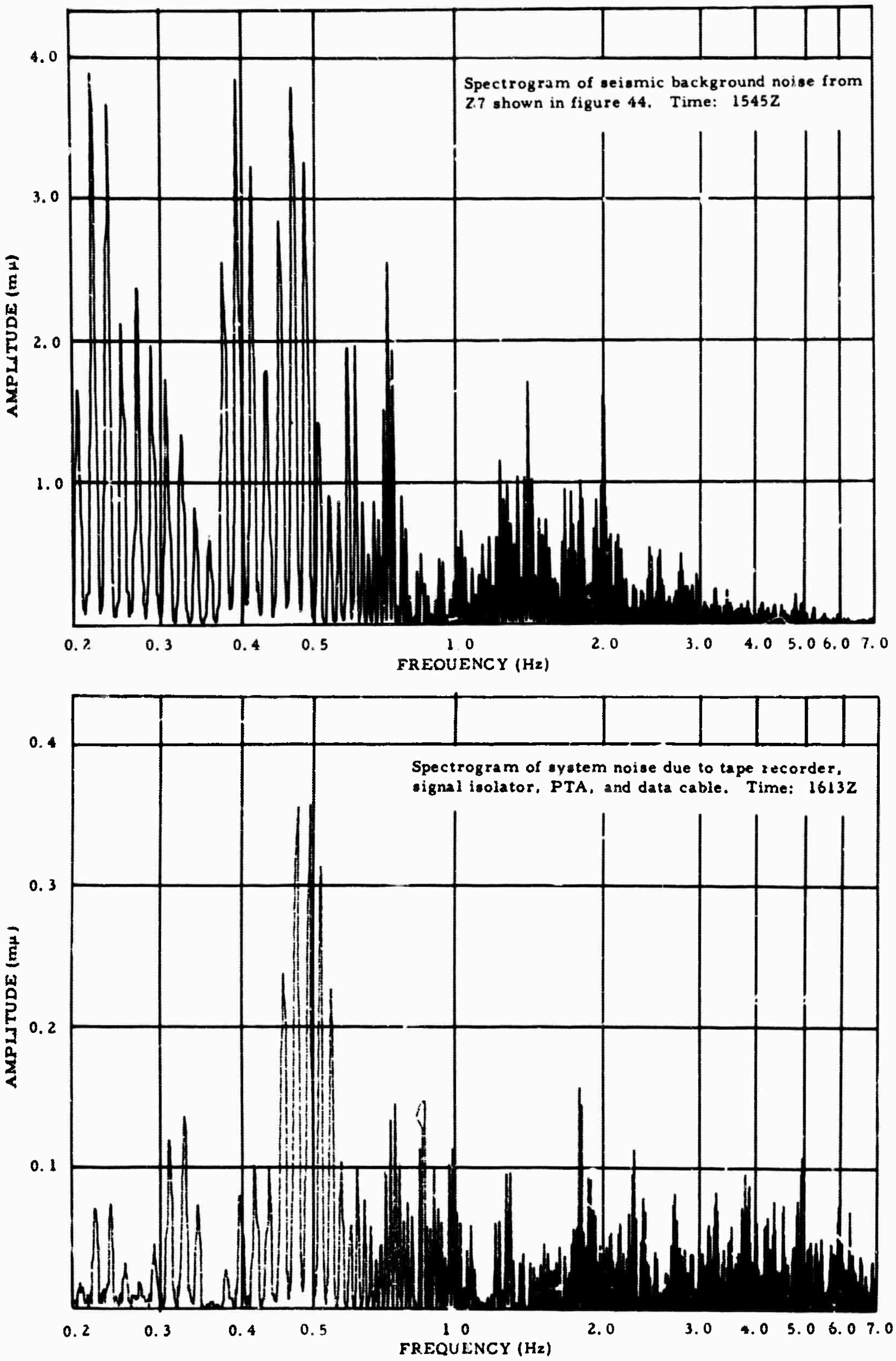


Figure 43. Analog spectra of data from channel 9, tape recorder No. 1, BMSO, 30 June 1964. All data samples were 27.5 seconds long; amplitudes uncorrected for frequency response; calibrated by 25 mμ sine wave at 1.0 Hz

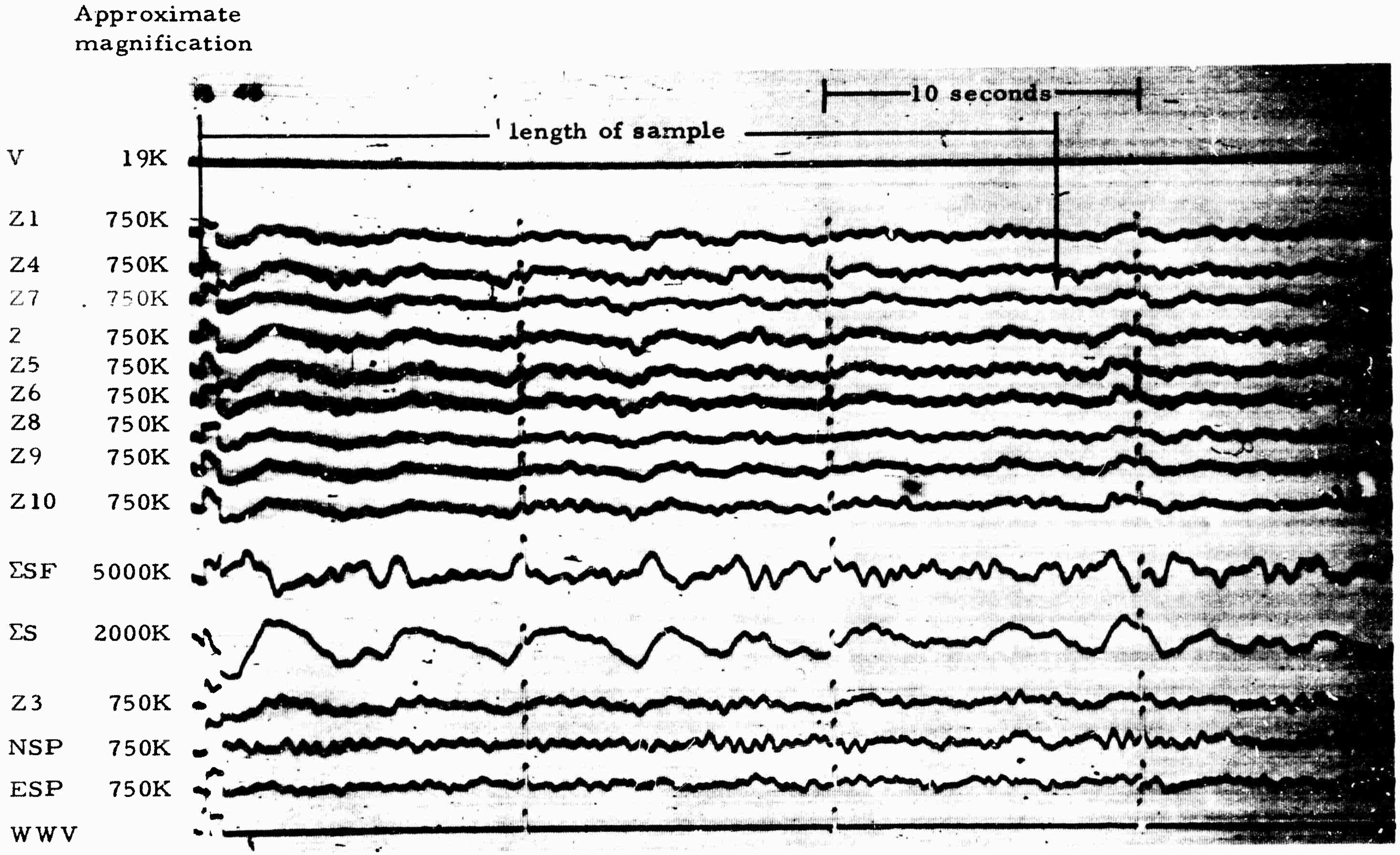
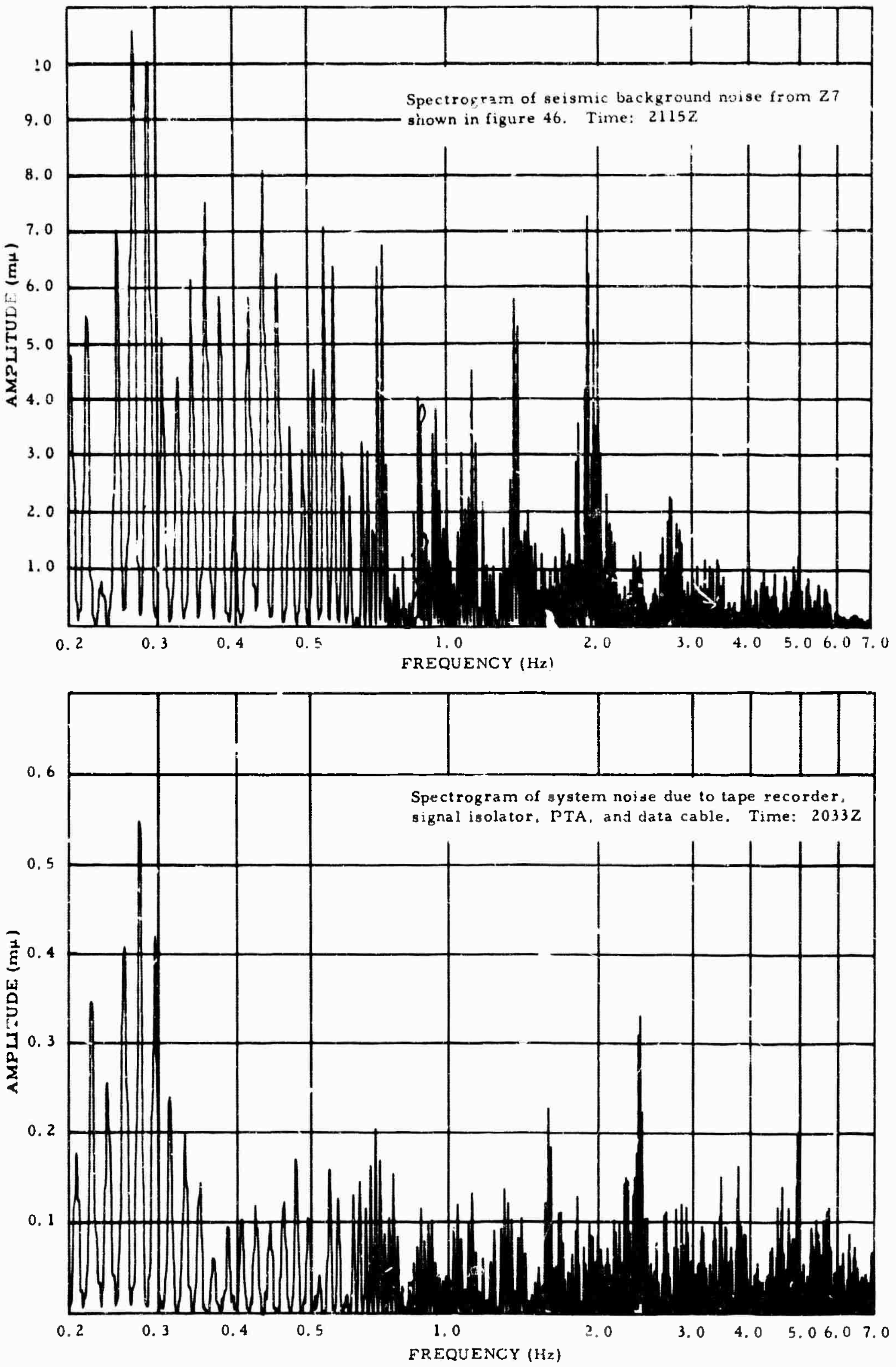


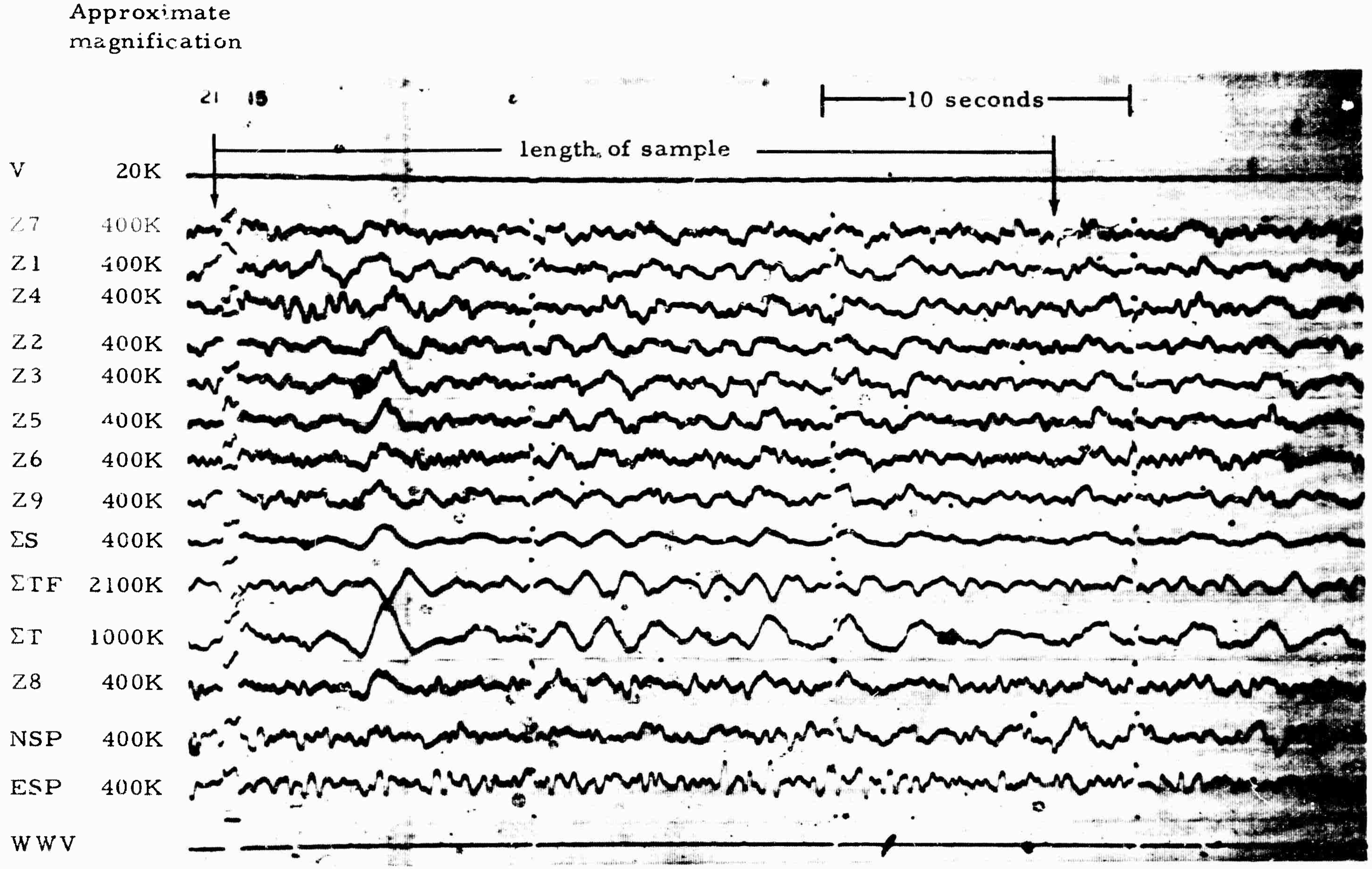
Figure 44. BMSO primary fast speed seismogram showing the 27.5 second sample of seismic data from Z7 which was analyzed using the Geotech analog spectrum analyzer on tape data. The resultant spectrogram is shown in figure 43 . (X10 enlargement of a 16-mm film)

BMSO
Run 182
30 June 1964
Data Group 4002

 
Spectrogram of seismic background noise from Z7 shown in figure 46. Time: 2115Z

Spectrogram of system noise due to tape recorder, signal isolator, PTA, and data cable. Time: 2033Z

Figure 45. Analog spectra of data from channel 9, tape recorder No. 1, CPSO, 29 June 1964. All data samples were 27.5 seconds long; amplitudes uncorrected for frequency response; calibrated by 50 mμ sine wave at 1.0 Hz



CPSO
Run 181
29 June 1964
Data Group 6000

Figure 46. CPSO primary fast speed seismogram showing the 27.5 second sample of seismic data from Z7 which was analyzed using the Geotech analog spectrum analyzer on tape data. The resultant spectrogram is shown in figure 45. (X10 enlargement of a 16-mm film)

3. 12. 4. 1. 1 When comparing the relative levels of seismic noise to system noise in figures 43, 45, and 47, the following considerations must be made:

a. Care should be taken to note the differences in gains between spectrograms.

b. The tape recorder sensitivities were normally set 6 dB lower than the sensitivities used during these tests, and were approximately twice the values shown in the spectrograms.

c. The data considered in this study were a small sample of the total data recorded at the observatories and should not be weighted heavily; however, we believe these data are generally representative.

d. At frequencies below 0. 3 Hz, some doubt exists regarding the validity of the data because of the shortness of the data samples.

3. 12. 4. 1. 2 In general, the analog spectrograms indicated the following:

a. The ratio of seismic noise to system noise in the band 0. 3 Hz to approximately 2. 5 Hz was about 5.

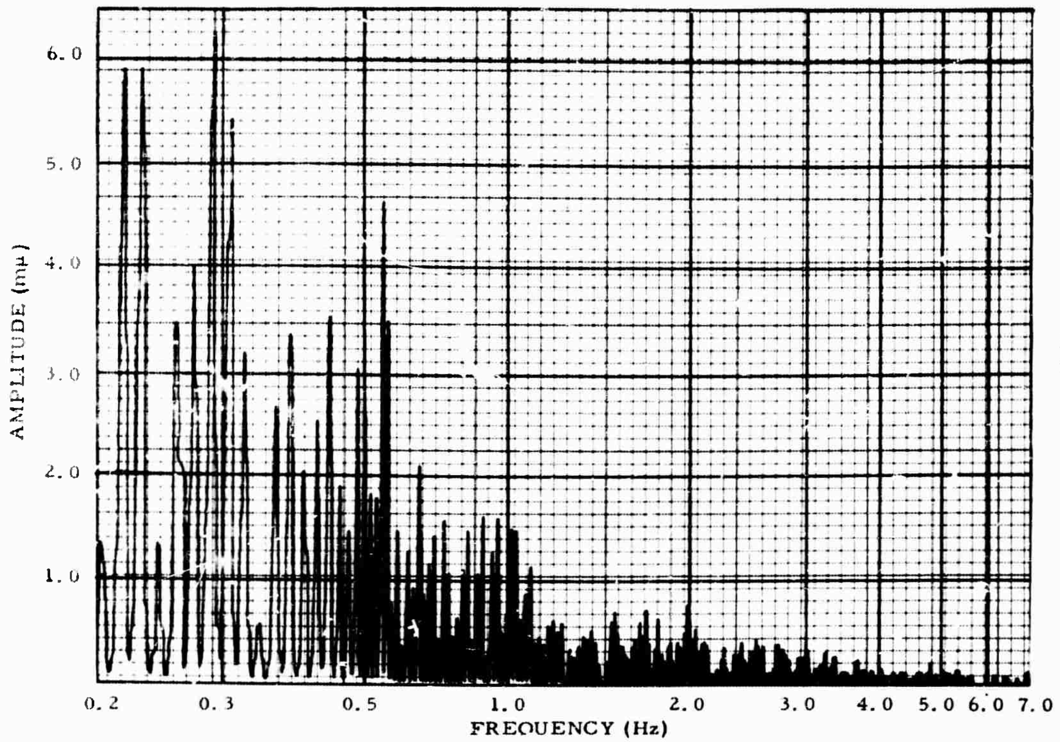
b. The ratio of seismic noise to system noise varies between 5 and 1 from approximately 2. 5 to 5 Hz.

c. The ratio of seismic noise to system noise is less than 1 at frequencies above 5 Hz.

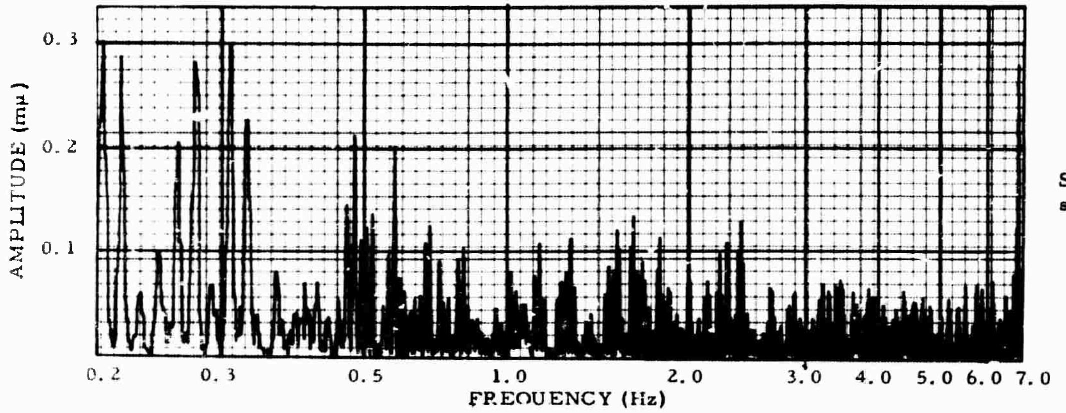
d. At normal operating settings the system noise is composed primarily of tape-recorder noise with little or no contribution from other sources.

e. With the increased tape recorder sensitivity, PTA noise at 0. 5 Hz was detected at BMSO; this noise was due to a faulty vacuum tube. The level of the noise was such that it essentially did not interfere with the seismic background noise.

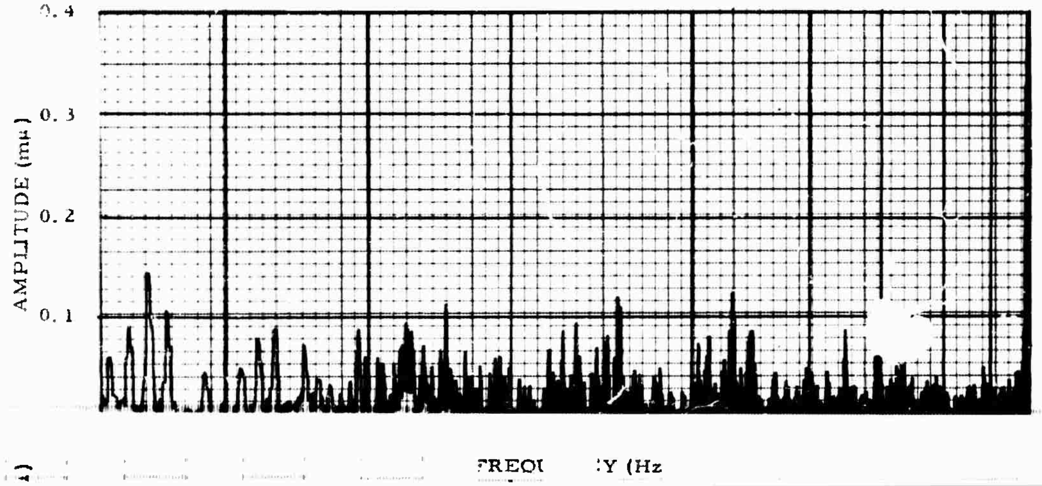
f. With the increased tape recorder sensitivity, data line noise was detected on one of the UBSO seismograms studied; this was not present on the other seismogram.



Spectrogram of seismic background noise from Z3 shown in figure 48. Time: 2250Z

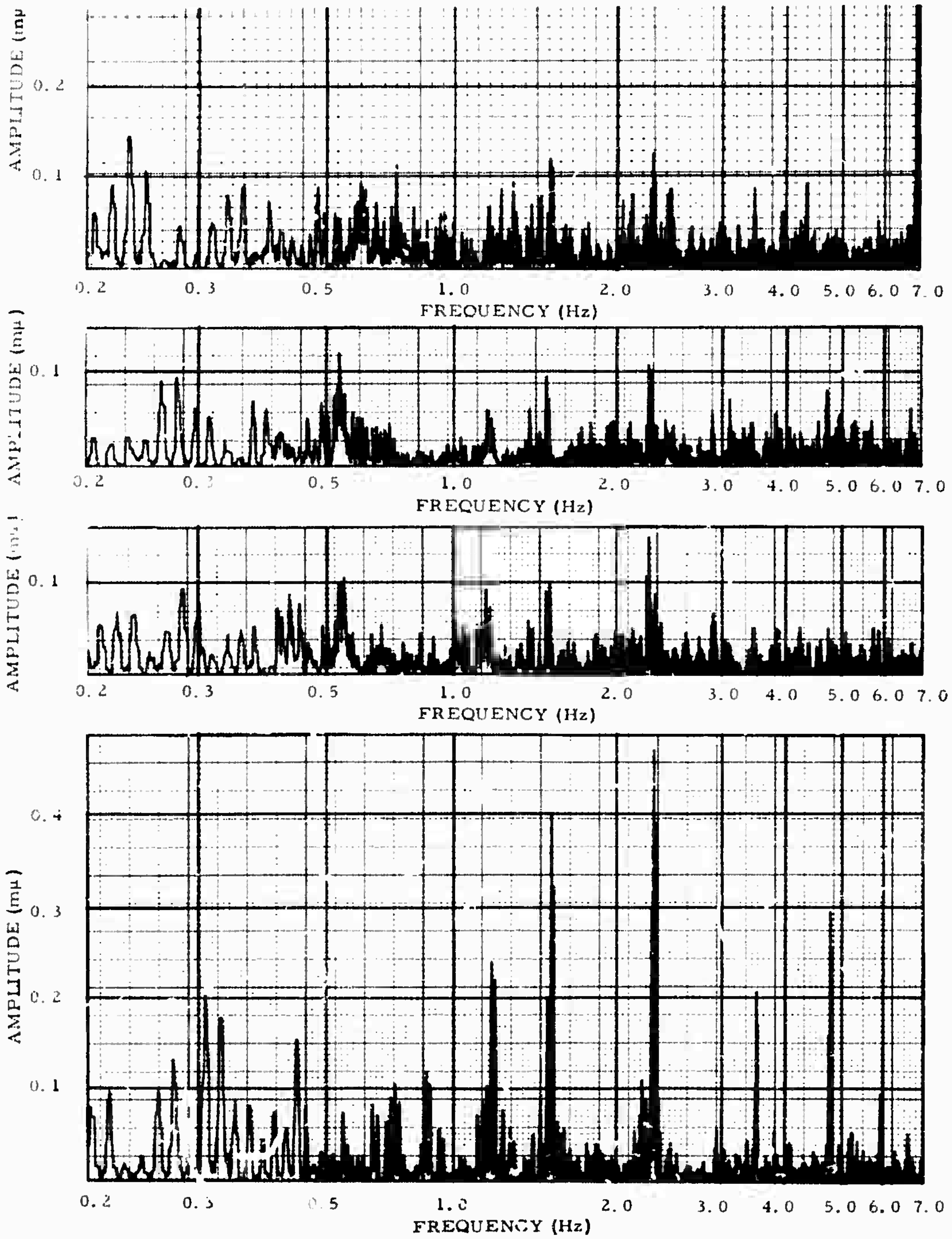


Spectrogram of system noise due to tape recorder, signal isolator, PTA, and data cable. Time: 2137Z



Spectrogram of system noise due to tape recorder, signal isolator, and PTA. Time: 2200Z

A



Spectrogram of system noise due to tape recorder, signal isolator, and PTA. Time: 2200Z

Spectrogram of system noise due to tape recorder and signal isolator. Time: 2205Z

Spectrogram of system noise due to tape recorder only with wow-and-flutter compensation. Time: 2212Z

Spectrogram of system noise due to tape recorder only without wow-and-flutter compensation. Time: 2212Z

Figure 47. Analog spectra of data from channel 4, tape recorder No. 1 UBSO, 28 June 1964. All data samples were 27.5 seconds long; amplitudes uncorrected for frequency response; calibrated by 25 mμ sine wave at 1.0 Hz

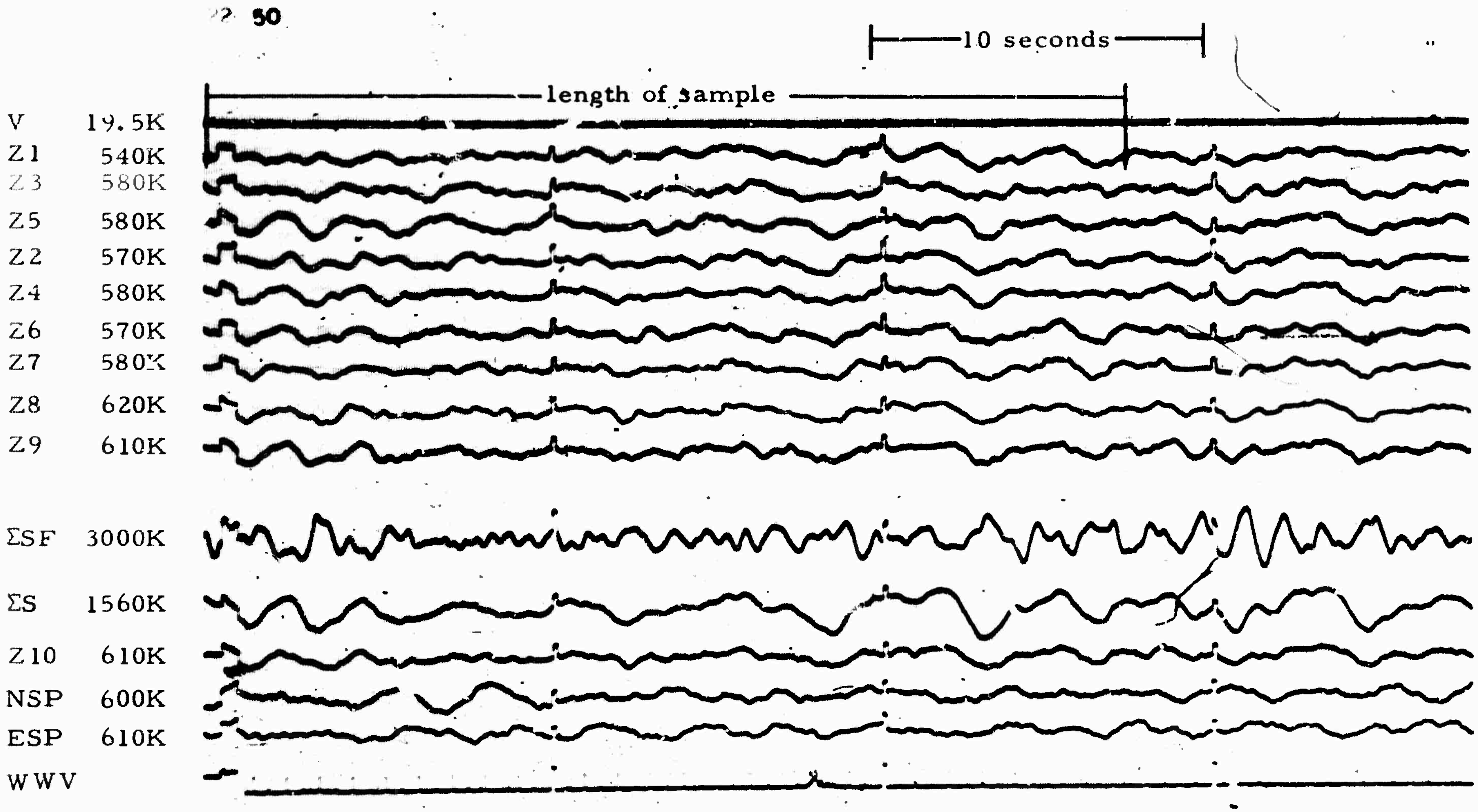


Figure 48. UBSO primary fast speed seismogram showing the 27.5 second sample of seismic data from Z3 which was analyzed using the Geotech analog spectrum analyzer on the tape data. The resultant spectrogram is shown in figure 47. (X10 enlargement of a 16-mm film)

UBSO
Run 180
28 June 1964
Data Group 5000

g. The last spectrogram of figure 47 shows the same sample of tape recorder noise (type e) as the spectrogram just above it; however, wow-and-flutter compensation was not used during playback. Use of compensation reduced noise by a factor of about three.

### 3.12.4.2 Power Spectra

Power spectrograms were computed for the Z7 channel from UBSO. Analyses were made with compensated data. The spectrograms for seismic noise (type a), PTA-signal isolator-tape recorder noise (type c), and tape-recorder noise (type e) have been combined onto one axis and are shown in figure 49. Figure 50 is a seismogram of the 2 minutes of seismic data that were used to produce the power spectrogram in figure 49. Note that the level of the microseismic background noise on the seismogram in figure 50 at approximately 3 Hz is higher than the level shown on the seismogram in figure 48. This is due to the fact that construction work on highway 40, near the UBSO array stopped between 19:57Z and 22:50Z. The spectrograms changed very little after removal of the data line and after removal of the signal isolator; therefore, these spectrograms are not shown. The power spectrograms for Z7 at UBSO indicate that at normal recording sensitivity the ratio of seismic noise to system noise at frequencies below 2.5 Hz is a factor of approximately five for this seismograph (that is, a factor of 10 times or of 20 dB at the increased tape recorder sensitivity); a ratio of less than one is indicated at frequencies above 5 Hz. Because of the increased tape-recorder sensitivity during these tests, low-frequency PTA noise is over emphasized.

### 3.12.5 Conclusions

The sample of data used in the tests was too small to permit definite conclusions to be made from them; however, the following preliminary conclusions can be made:

a. Seismic noise in the frequency band below 2.5 Hz is normally at least five times the level of the highest type of system noise. At frequencies above about 5 Hz, however, seismic background is immersed in the tape-recorder noise.

b. The sensitivity levels normally used for the PTA's and the tape recorders are satisfactory for general purpose recording. To take advantage of the fact that the PTA has a much greater dynamic range than the magnetic-tape recorder, the sensitivity of one tape-recorder channel was normally set so

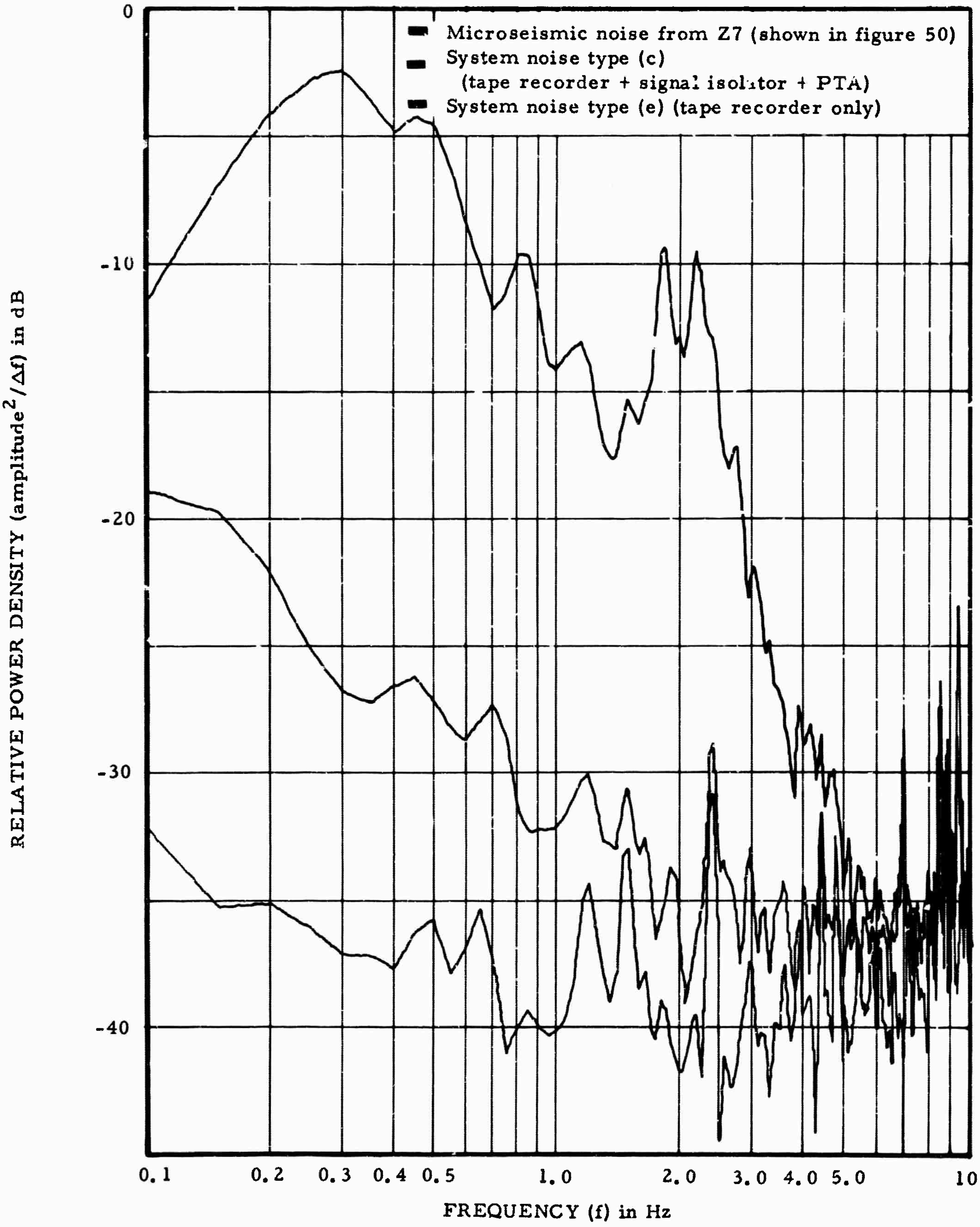


Figure 49. Power spectra of data from channel 9 of tape recorder No. 1 at UBSO recorded on 28 June 1964. All data samples were 2 minutes long

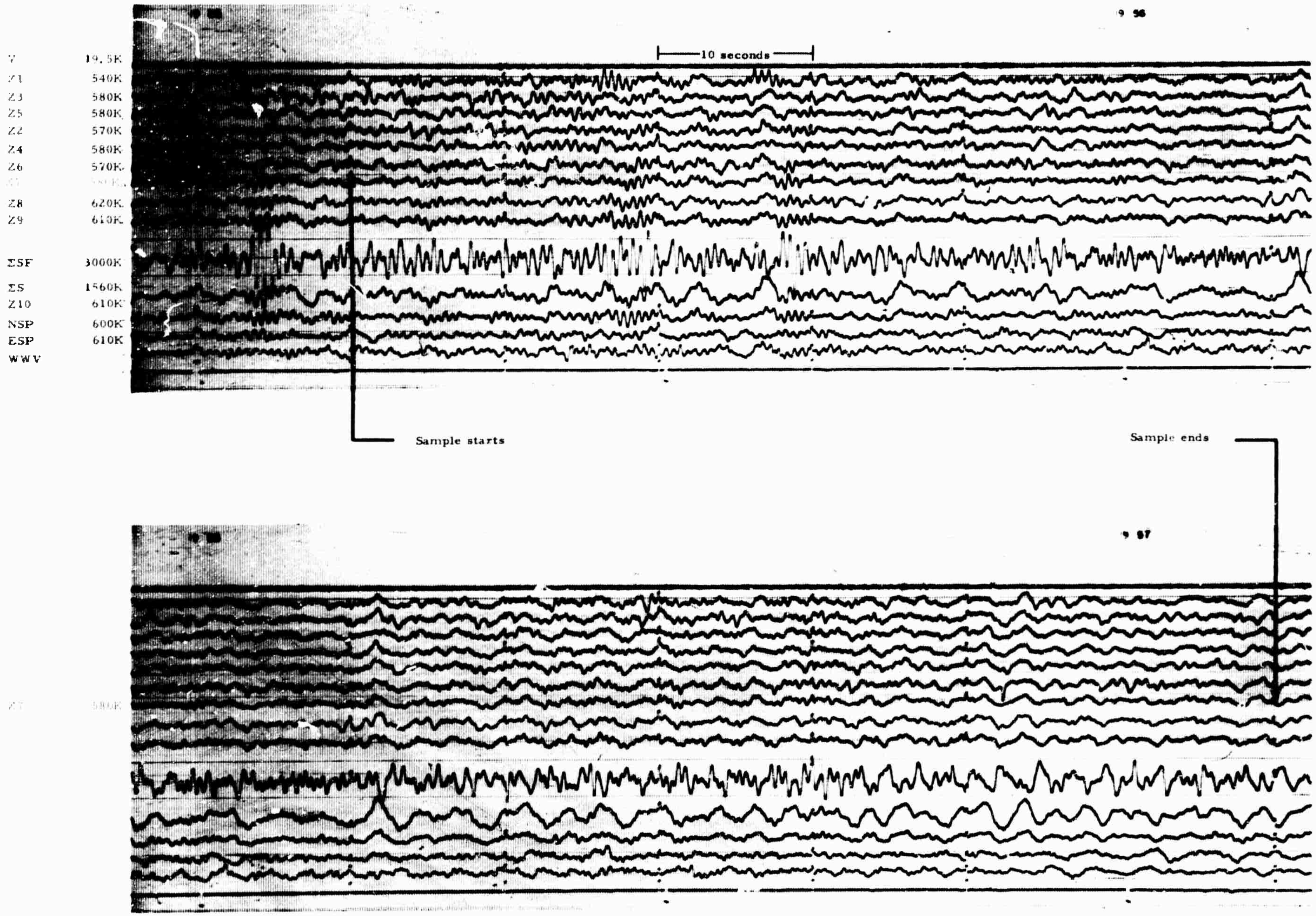


Figure 50. UBSO primary fast-speed seismogram showing the 2-minute sample of seismic data from Z7 which was digitized for computation by PROGRAM BLACKY. The resultant power spectrogram is shown in figure 49. (X5 enlargement of 16-mm film)

that the PTA noise level was only slightly below the level of the tape-recorder noise. The added dynamic range of the PTA, therefore, was available to record some large events which clipped on the tape recorder channels operated at normal sensitivity.

c. The tape recorders studied in these tests appeared to be the predominant source of system noise.

d. Even at the more sensitive recording levels used in these tests, the signal isolator did not contribute to the seismograph system noise. Some instances of noise due to deteriorated data lines or PTA components was observed; however, they were not of sufficient amplitude to degrade the seismic background data or to increase significantly the system noise when the tape recorders were operated at the normal sensitivities.

e. As expected, compensation generally reduced the tape-recorder noise level by a factor of approximately three.

### 3.12.6 Recommendations

We recommend that, in addition to the checks of system noise specified in the SOP's, noise tests of the signal isolators, PTA's, and other circuitry in the CRB except the magnetic-tape recorders be made routinely at 3-month intervals to control the level of system noise not detectable on the visual seismograms. We also recommend that periodic spectral analyses of seismic noise be performed in order to better describe and evaluate the operational conditions at the observatories.

## 3.13 EFFECTIVENESS OF NEW CALIBRATION ACTUATOR AND NEW DATA COIL TESTED AT CPSO

In July 1964, a new calibration actuator (Calibration Actuator Kit, Model 18351) and a new data coil (assembly No. 18521), both of which were furnished under another contract, were installed at CPSO in JM seismometer Z7. The stability of the calibration actuator and the resistance of the calibration and data coils to damage by lightning strikes were tested as follows:

a. The seismometer in which the actuator was being tested was installed in an area of intense lightning activity.

b. The seismometer case was grounded at the vault.

c. The seismometer feet were placed in direct contact with the vault floor (that is, glass isolation plates were not used).

d. Very long data lines were used.

During this test period, monthly G checks were made to determine the stability of the calibrator. The degaussing procedure was not used during the series of G checks and the calibrator was not adjusted during the test period. Results of the test are shown in table 18. All variations observed during the test period were less than 1.0 percent, indicating excellent stability.

Special tests were made during the initial installation to determine if G changed significantly with changes of mass position or with different values of current. With the mass position displaced at various positions within ±25 percent of the center of its full range, no significant change in G was observed. Also, the G determined with 0.2-gram and 1-gram weight lifts and equivalent dc current pulses differed by less than 2 percent.

Table 18. Results of stability tests of the new calibrator actuator in Z7 at CPSO

| Date of test | G as found | Percentage change from previous G |
|---|---|---|
| 28 July 1964 | 0.432 | - |
| 25 August 1964 | 0.432 | 0.0 |
| 29 September 1964 | 0.432 | 0.0 |
| 4 November 1964 | 0.435 | +0.7 |
| 4 January 1965 | 0.431 | -0.9 |
| 3 February 1965 | 0.432 | +0.2 |

Similar tests at WMSO, using two calibration actuators of the type used in the CPSO tests, are discussed in TR 65-52.

In March 1965, the field cables for Z7 were hit directly by lightning, destroying the lightning protectors and nine sections of cable. The seismometer was returned to Garland for examination; it was found that neither the calibrator nor the data coil was damaged. Because the new calibration actuators are more stable and less susceptible to lightning damage, we recommended that they be installed at all observatories where continued use of the JM seismometer is anticipated and lightning is a significant problem.

During the test, the new data coils performed satisfactorily and were highly resistant to lightning-induced damage. We do not recommend their installation in the seismometers now used at the observatories, however, for the following reasons:

a. The original problem, that of excessive lightning damage to coils presently in use, has been circumvented to a large degree by isolating the seismometer from ground potential (placing it on glass plates), and the installation of improved lightning protectors is expected to further reduce this problem.

b. The installation of improved lightning protection devices is considerably less expensive than installing the new data coils, because installation of the data coils requires major disassembly of the seismometers in Garland.

## 3.14 TESTS OF JOHNSON-MATHESON ONE-HERTZ GALVANOMETER AT CPSO

Tests were conducted from 20 August to 5 November 1964, to compare and evaluate a standard JM vertical seismograph system with a 3-Hz PTA galvanometer (Z10) and a JM vertical seismograph with a 1-Hz PTA galvanometer (Z10-1). Figure 51 shows the frequency responses of the two seismographs; the two seismometers were operated in the same vault. Evaluation of the data from the two systems was completed on 15 December. The results of the tests essentially agree with similar tests that were conducted at WMSO. The 1-Hz system does not respond to microseisms in the period range 0.2 to 0.7 sec as well as the 3-Hz system, but responds slightly more to microseisms with periods greater than 1.5 to 2.0 seconds. In our opinion, the 3-Hz system is the more suitable system for present observatory purposes, because the majority of the teleseismic P waves observed have periods of about 1 second. The short-period microseisms are effectively cancelled when summations of at least nine of the individual 3-Hz seismographs are used at CPSO. With the high frequency component attenuated, the summation seismographs provide a better ratio of signal to longer period noise than does the 1-Hz system, because the long-period component of the

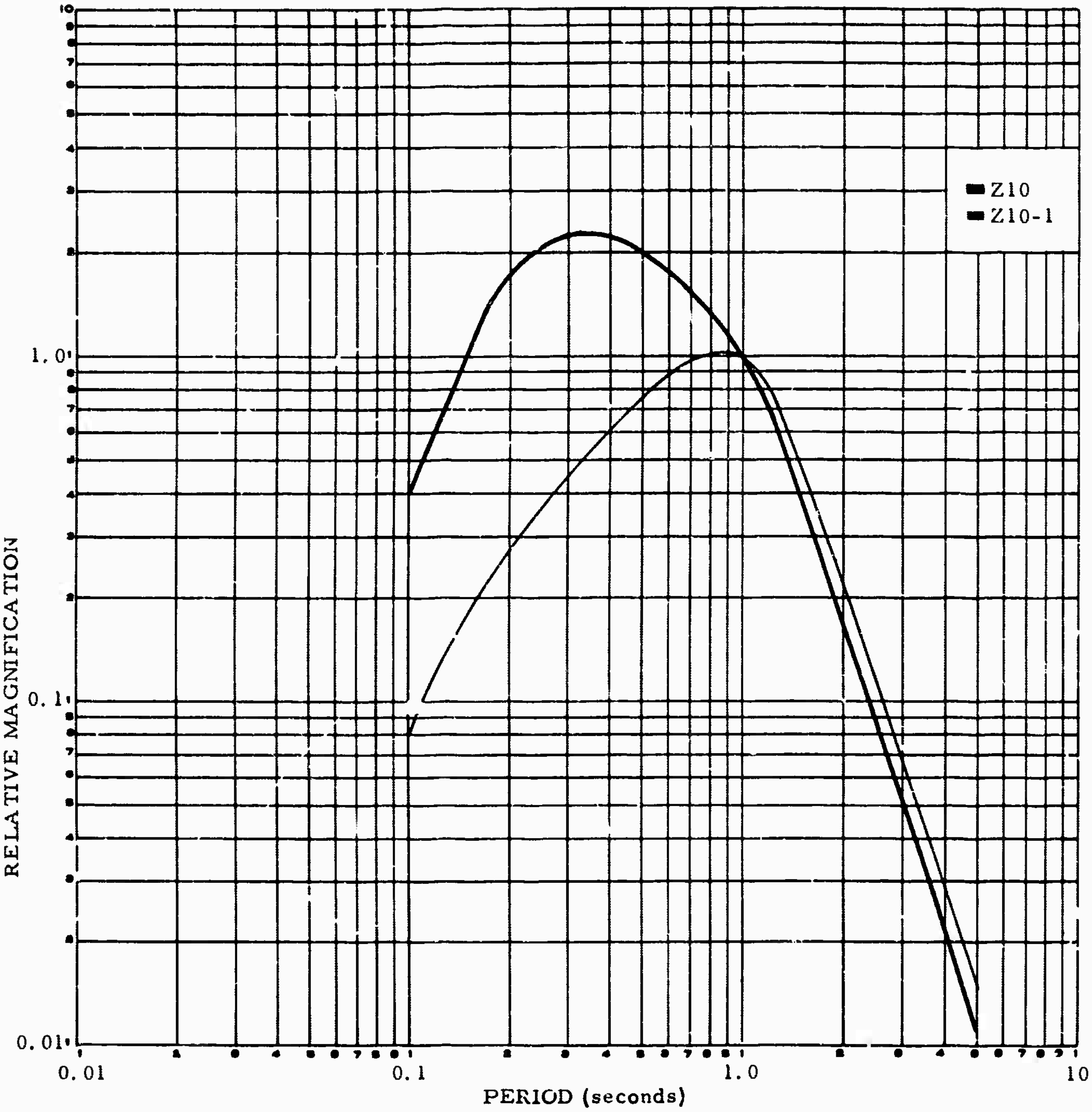


Figure 51. Average relative frequency response of the Johnson-Matheson 3-Hz galvanometer seismograph (Z10) and of the Johnson-Matheson 1-Hz galvanometer seismograph (Z10-1) as operated at CPSO in the period 20 August 1964 through 5 November 1964

microseismic background is attenuated more relative to 1 Hz by the 3-Hz seismograph than by the 1-Hz seismograph. Figure 52 is a CPSO seismogram which illustrates the responses of Z10 and Z10-1 to a teleseismic signal with period of about 1.0 second.

## 3.15 PULSE CANCELLATION CALIBRATION PROCEDURE

The present method for equalizing and calibrating the seismographs of the observatory arrays is to measure and adjust the phase and amplitude response of each instrument within specified tolerances. This procedure is time consuming and may not be the best method for matching the instrument for subsequent machine processing. The pulse cancellation method was proposed as a more rapid and perhaps more accurate means of equalizing the array instruments. With this method, each instrument of the array is successively compared with a standard instrument. The comparison is made by driving the calibration coils of the standard seismographs and a second seismograph being compared to it simultaneously with a step function and recording the difference between the output signals of the two seismographs. The difference signal is then reduced to a minimum by adjusting magnification and if necessary the parameters of the second seismograph. One drawback of this method is that it is not immediately obvious which parameters of the second system should be changed to reduce the difference signal to a minimum.

To evaluate the pulse cancellation calibration method, laboratory tests were conducted using two seismographs. It was found that when the parameters of each of the seismographs were set within the established tolerances the outputs could be cancelled within about 5 percent. This is a ratio of 20 to 1 between the zero-to-peak output of the reference seismograph and the peak-to-peak difference between the outputs of the reference and test seismographs This procedure and the results of the laboratory tests are described in detail in TR 64-87.

Based on the laboratory tests, a field evaluation of the pulse cancellation method was made at BMSO. Initial tests indicated that when the amplitude and phase response of each of the seismographs were adjusted within the allowable tolerances, the pulse cancellation ratios ranged from 10 to 1 to 20 to 1, with an average of 13 to 1. An investigation indicated that the poor cancellation was primarily due to nonlinearities in the seismograph system and to inadequate control of galvanometer damping. After reworking the phototube amplifiers and installing vernier controls for galvanometer damping, the resulting ratios ranged from 12 to 1 to 50 to 1, with an average of 23 to 1. A subsequent check

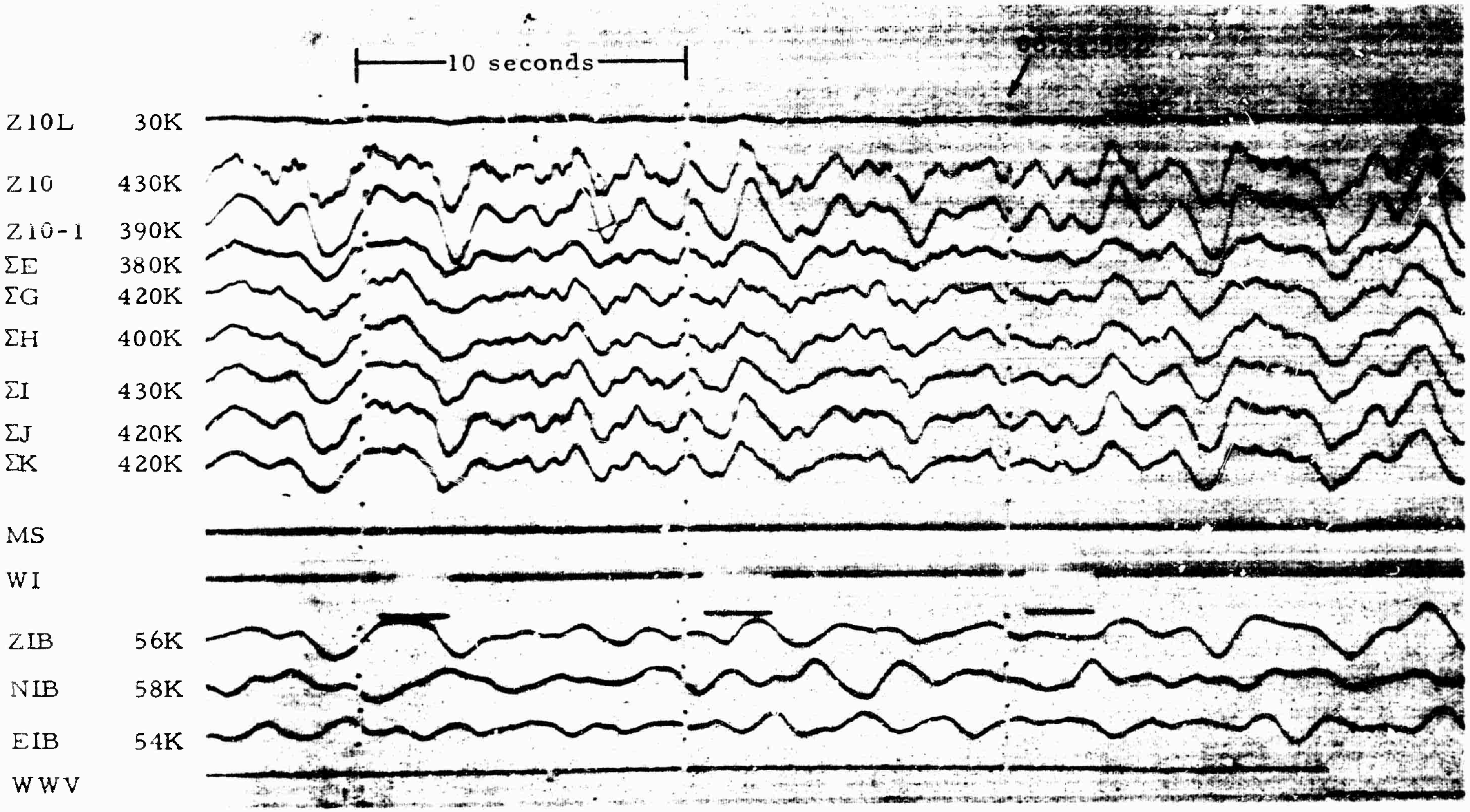


Figure 52. CPSO fast-speed seismogram illustrating the response of Z10-1 and Z10 seismographs to a low-level teleseismic signal with a period of about 1.0 second, epicenter unknown. (X10 enlargement of 16-mm film seismogram)

CPSO
Run 309
4 Nov 1964
Data Group 6009

of the frequency response and the phase response of the seismographs showed that in two cases the seismographs were out of tolerance yet the cancellation ratio was still more than 20 to 1. This would indicate that there were perhaps compensating nonlinearities. As a result of these tests, it was not clear whether the pulse cancellation method or the setting of individual amplitude and phase responses offered the most reliable method for matching the instruments of the array.

To better understand the affect of various system parameters on the characteristics of the seismograph and on the pulse cancellation, a theoretical study was undertaken using our CDC-160A computer. The computer was programmed to calculate the response of a seismograph for various combinations of seismometer and galvanometer parameters. The seismometer period, galvanometer period, seismometer damping, and galvanometer damping were varied and the deviation of response characteristic from the ideal response was determined as a function of frequency. The results are shown in figure 53. The variation in the parameters were selected to cause maximum deviations in the response yet still stay within the specified response tolerances.

The difference between the output of two seismographs as the parameters of one of the seismographs is changed is shown in figure 54. A study of the waveforms show several interesting features of the pulse cancellation method.

a. Six different variables contribute to the cancellation pulse. A pulse caused by a combination of these variables is difficult to analyze by visual methods. It is possible that by calculating cancellation pulses for a series of seismograph parameters that the shape of the cancellation pulse can be used as a guide to determine how the parameters should be changed to properly match the seismographs.

b. Variations of different parameters which cause equally important changes in the frequency response do not have equivalent effects on the cancellation pulse. In particular, the effect of a 4 percent deviation in the seismometer free period on the cancellation pulse is more than twice as great as the affect caused by a 7 percent deviation in seismometer damping.

c. Minor system nonlinearities cause a serious problem. A 2.5 percent nonlinearity, based on the best zero based straight line in one of the two seismographs gives rise to a cancellation pulse approximately as large as that caused by the maximum allowable deviations in the basic seismograph parameters.

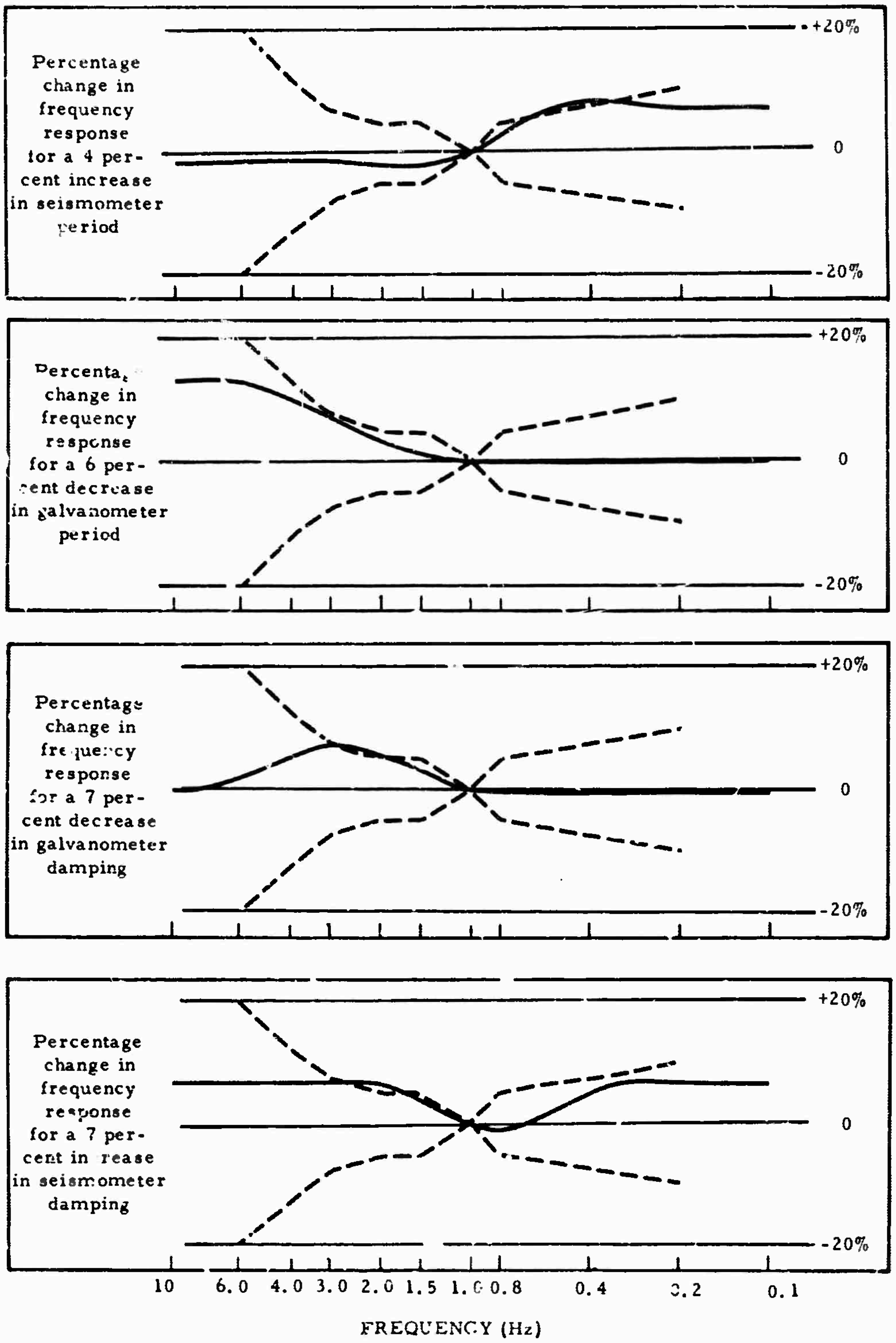


Figure 53. Percentage changes in the normalized frequency response of a Johnson-Matheson seismograph caused by deviations in the system parameters. The frequency response tolerances are shown as dashed lines and the percentage change in solid lines

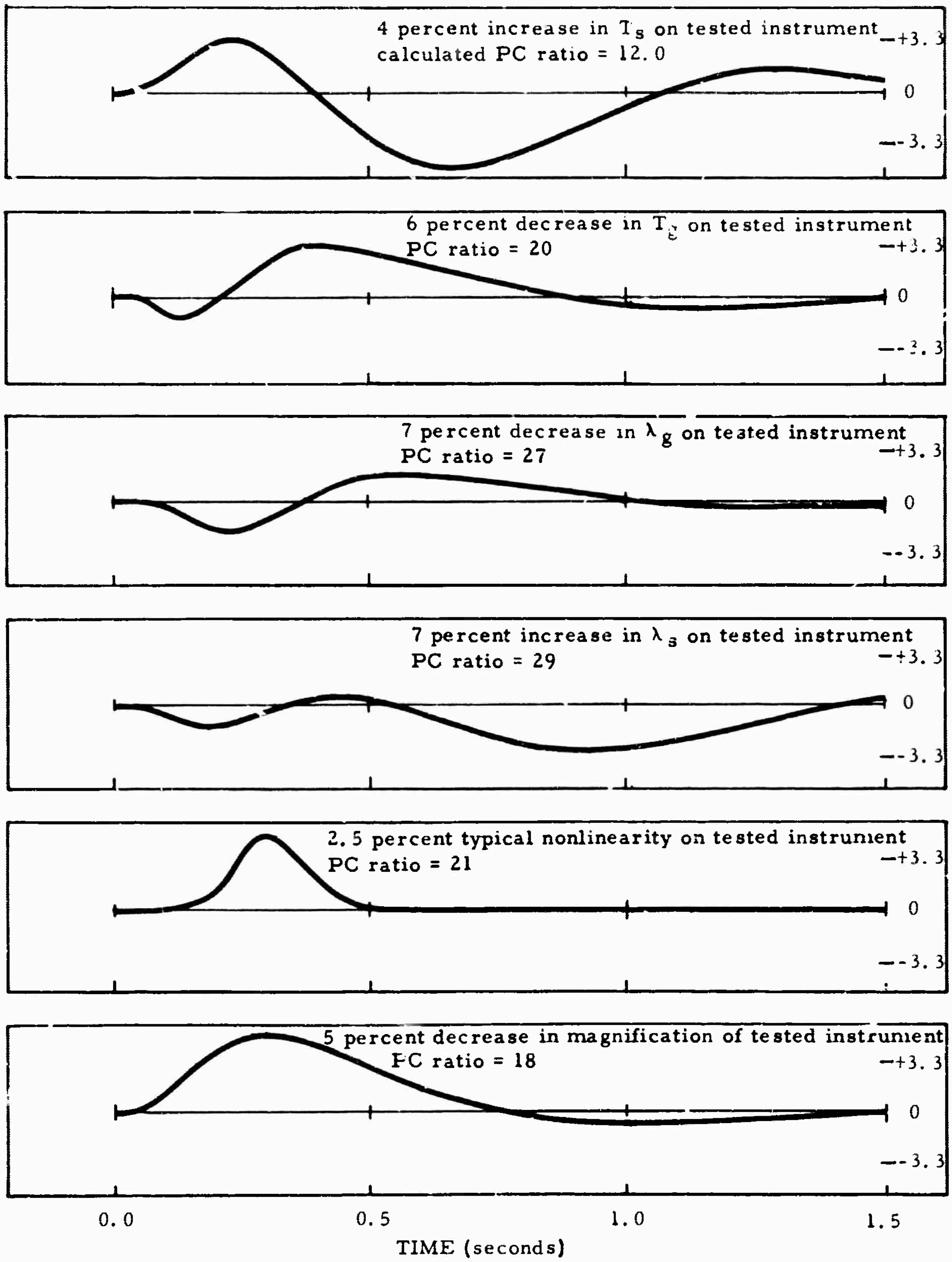


Figure 54. Cancellation pulses for various conditions of the tested seismograph. Each pulse represents the output of the tested seismograph minus the output of an ideal seismogram and is given in percent of the zero-to-peak amplitude of the pulse from the ideal seismograph

It is possible that another method which is intermediate between the two might be even more useful. For example, sine wave signals at three frequencies, probably 0.8, 1.0, and 3.0 Hz, could be applied simultaneously to a standard seismograph and to a seismograph under test. The parameters of the test instrument would then be adjusted to minimize the difference signal at the three frequencies. Another possibility is the use of pulses with special shapes.

Because our objective is to develop a rapid method of calibrating and equalizing the seismographs in an array, we propose to continue field evaluation of several techniques. As a test, we propose to calibrate the surface array and the buried array at UBSO using two different methods. The surface array will be calibrated using the pulse cancellation or another cancellation method and the subsurface array will be calibrated using the conventional technique. The resulting data will then be examined to determine possible differences in enhancement of P-wave signals by the two arrays.

## 3.16 EVALUATION OF ADJUSTABLE FREQUENCY GALVANOMETERS AT BMSO

Three modified 3-Hz galvanometers, Model 4100-Z13 (figure 55), whose natural frequency is adjustable within a ±10 percent range, was developed under Project VT/4054 to facilitate better equalization and maintenance of short-period seismograph frequency responses. These galvanometers were installed in PTA's at BMSO and tested in conjunction with the pulse cancellation method of seismograph response equalization. Results to date indicate that the galvanometers are satisfactory and that equalization of frequency responses either by the normal method or by the pulse cancellation method is significantly improved using these galvanometers.

Two of these galvanometers were damaged by lightning at BMSO. Examination of the structural features of the damaged galvanometers showed no evidence that they may be more susceptible to damage by lightning than are the standard 3-Hz units. Additional testing of the adjustable galvanometers to more fully determine its susceptibility to lightning damage relative to the standard galvanometer will be done.

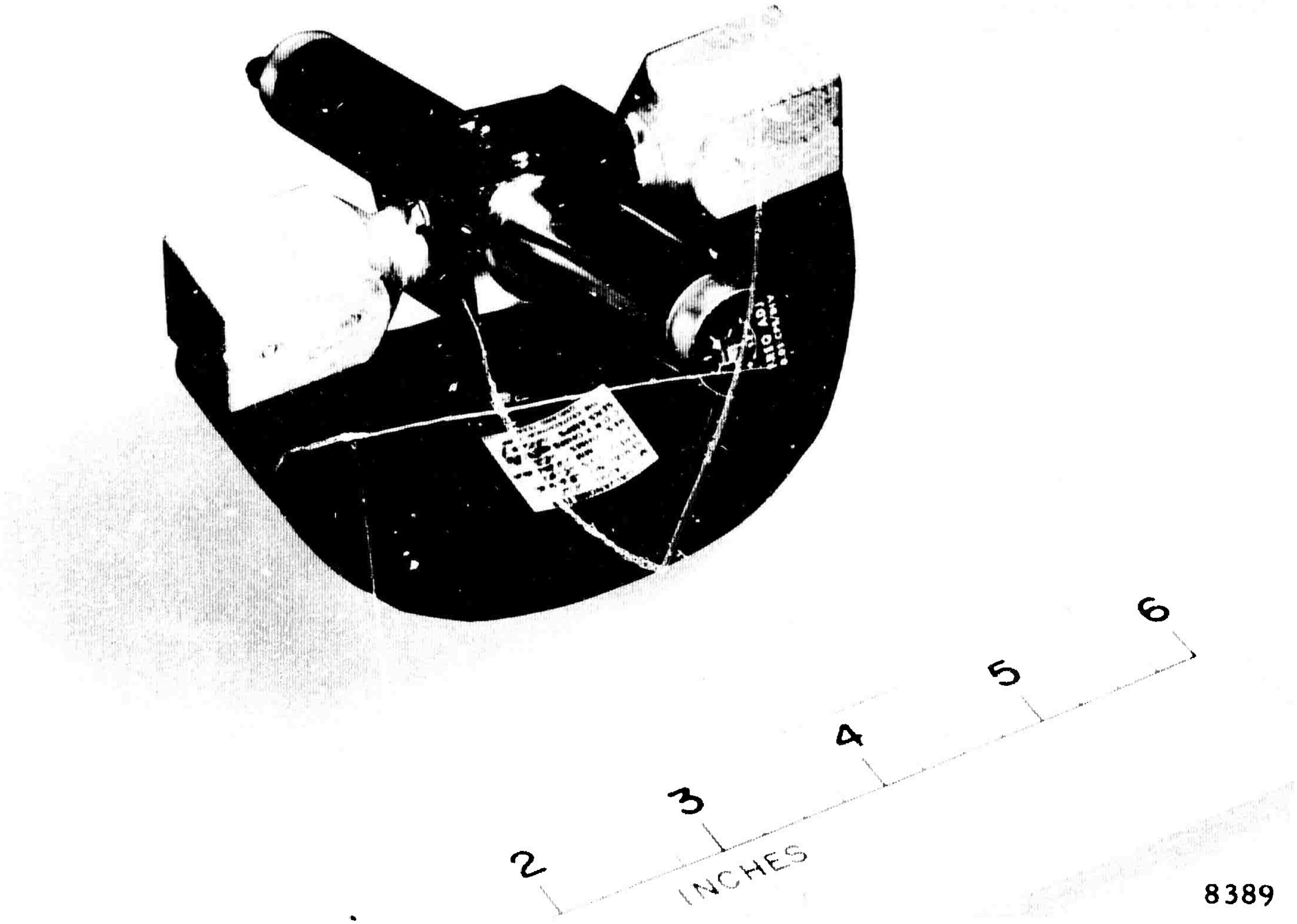


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Figure 55. Modified Galvanometer, Model 4100-213

## 4. ROUTINE ANALYSIS AND ANALYSIS EVALUATION

### 4.1 INTRODUCTION

The VT/1124 observatories recorded seismometric data on a continuous basis during this reporting period. The recorded data were routinely analyzed, the analysis checked, and a tabulation of initial arrival times of earthquake signals transmitted to the United States Coast and Geodetic Survey (USC&GS) daily. Analysis data were finalized when the USC&GS Preliminary Determination of Epicenter (PDE) cards were received, and a monthly earthquake bulletin was prepared using these data.

Sixteen-millimeter film seismograms and preliminary analysis data were routinely selected on a random basis, about every 2 weeks, and forwarded to our Garland laboratory for review by a quality control analyst. The data recorded were also used to evaluate the seismograph systems operated and tested at the observatories, and to conduct special research studies (see sections 3 and 5).

### 4.2 ROUTINE ANALYSIS PROCEDURES

#### 4.2.1 Preliminary Analysis

Seismograms recorded at each observatory were studied during each 24-hour period. Preliminary analysis was done on an "on-line" basis at the Develocorders and was recorded on worksheets (appendix 2). The worksheet was designed to be compatible to both station use in preliminary analysis and direct transcription of data to IBM cards. The data on these sheets were used to compile information for the USC&GS daily reports, the monthly earthquake bulletin, and for various statistical analyses. The IBM card format and instructions for use of the analysis form are given in Geotech TR 64-59, Standard Operating Procedures for Seismological Observatories.

#### 4.2.2 Checking of Preliminary Analysis

The seismograms were reviewed by a second analyst who checked the arrival times, period, and amplitude measurements recorded on the worksheets, and reviewed events classified as "possible signal" by the preliminary analyst. After the preliminary analysis had been verified, the appropriate data were coded and transmitted to the USC&GS. At BMSO and UBSO, these checks were made and the message sent to the USC&GS on the same day during which the data were recorded; however, because of the different time zone at CPSO, the checking of preliminary analysis and the transmittal of the message was delayed until the morning following the recording day

### 4.2.3 Daily Reports to the USC&GS

Arrival times and period and amplitude measurements of events recorded at each observatory were reported daily to the Director of the USC&GS in Washington, D. C. In July 1963, a reporting format that was compatible with automated data storage was adopted at the request of the USC&GS. Data transmitted using this format are automatically stored on magnetic tape and are later recovered and used by the USC&GS to locate hypocenters.

In mid-September 1963, the Project Officer requested that we begin reporting the arrival times of all naturally occurring events to the USC&GS. (Prior to the receipt of this request, only regionals, teleseisms, and large local or near-regional events were reported.) When the observatories began reporting all natural events, the normal length of the daily message increased by a factor of 2 or 2.5; however, the Project Officer approved the reporting of arrival times for swarms of aftershocks from local and near-regional events by air mail letter. The number of events of each type reported to the USC&GS by BMSO, CPSO, and UBSO from July 1963 through February 1965 are tabulated in table 19. Also given in table 19 are the number of events for which hypocenters were located by the USC&GS and the percentage of the located events that were recorded at each observatory.

The number of earthquakes detected by BMSO, CPSO, and UBSO and located by USC&GS are listed in table 20.

Arrangements were made for UBSO and CPSO to transmit their daily messages to the USC&GS by way of the General Service Administration (GSA) TWX operators in Denver, Colorado, and Nashville, Tennessee, respectively. The GSA operators relayed the daily messages to USC&GS in Washington, D. C. Messages were transmitted through the GSA operator 5 days a week but were transmitted directly to the USC&GS in Washington, D. C., by Western Union on weekends and holidays, when the GSA offices were closed.

The daily message from BMSO to the USC&GS was transmitted to Washington, D. C., by personnel of the 821st Air Force Radar Squadron Communications

Group, located near BMSO. On weekends and holidays, the message was transmitted to the USC&GS by Western Union.

### 4.2.4 Final Analysis - Epicenter and Phase Association

Prior to September 1964, phase arrivals recorded at the VT/1124 observatories were manually associated with hypocentral information reported by the USC&GS in the PDE cards. Prior to the preparation of data for March 1964, all event associations and phase identifications were made in Garland; however, beginning with preparation of the March data, the associations were made at the observatories at the request of the Project Officer. The review of seismograms in Garland was limited to those events for which data on the analysis sheets appeared anamalous and which in the analyst's opinion should be checked. This procedure for final analysis reduced the effort required for association of observatory data with PDE data, however, it is probable that the association data was not as complete as it was when all seismograms were reanalyzed.

Beginning with the data for September 1964, all event associations and phase identifications were made by the Automated Bulletin Process (ABP). The ABP output is checked for anamalous associations before the publication of the multistation bulletin.

### 4.2.5 Report on the Registration of Earthquakes

#### 4.2.5.1 Storage of Bulletin Data on IBM Cards

An IBM card format for the storage of earthquake bulletin data was adopted in September 1963. An analysis form (appendix 2) designed from the format was supplied to the VT/1124 observatories and WMSO. Semiautomation of preparation of the earthquake bulletin was achieved when card storage of data began. Semiautomation of bulletin preparation facilitated incorporation of data from several observatories into one monthly bulletin.

Data from the VT/1124 observatories were combined with data from WMSO and published in a four-station bulletin. The bulletin for February 1963, published in November 1963, was the first to contain data from the four observatories. Tonto Forest Seismological Observatory (TFSO) data were added to the bulletin in the April 1963 issue. A total of 22 multistation earthquake bulletins that cover the period February 1963 through November 1964 were published during the contract period. The data for September through November 1964 were associated and compiled by the Automated Bulletin Process (ABP) described in section 5.1.

Table 19. Locals (L), near regionals (N), regionals
USC&GS by BMSO, CPSO, and UBSO 1 July

July 1963

| | L | N | R | T | Per[a] |
|---|---|---|---|---|---|
| BMSO | b | b | b | b | 77.9 |
| CPSO | b | b | b | b | 43.5 |
| UBSO | b | b | b | b | 80.7 |
| USC&GS signals located | | 317 | | | |

August 1963

| | L | N | R | T | Per[a] |
|---|---|---|---|---|---|
| BMSO | b | b | b | b | 81.6 |
| CPSO | b | b | b | b | 45.0 |
| UBSO | b | b | b | b | 84.0 |
| USC&GS signals located | | 300 | | | |

September 1963

| | L | N | R |
|---|---|---|---|
| BMSO | b | b | b |
| CPSO | b | b | b |
| UBSO | b | b | b |
| USC&GS signals located | | 422 | |

December 1963

| | L | N | R | T | Per[a] |
|---|---|---|---|---|---|
| BMSO | 104 | 393 | 26 | 782 | 82.1 |
| CPSO | 0 | 23 | 2 | 377 | 48.2 |
| UBSO | 48 | 195 | 20 | 564 | 80.3 |
| USC&GS signals located | | 392 | | | |

January 1964

| | L | N | R | T | Per[a] |
|---|---|---|---|---|---|
| BMSO | 78 | 371 | 19 | 584 | 79.4 |
| CPSO | 0 | 7 | 6 | 376 | 50.3 |
| UBSO | 60 | 255 | 20 | 539 | 78.5 |
| USC&GS signals located | | 344 | | | |

February 1964

| | L | N | R |
|---|---|---|---|
| BMSO | 53 | 228 | 15 |
| CPSO | 3 | 12 | 15 |
| UBSO | 25 | 189 | 31 |
| USC&GS signals located | | 312 | |

May 1964

| | L | N | R | T | Per[a] |
|---|---|---|---|---|---|
| BMSO | 107 | 101 | 8 | 584 | 80.9 |
| CPSO | 1 | 36 | 40 | 444 | 53.1 |
| UBSO | 90 | 188 | 25 | 748 | 81.9 |
| USC&GS signals located | | 394 | | | |

June 1964

| | L | N | R | T | Per[a] |
|---|---|---|---|---|---|
| BMSO | 86 | 65 | 3 | 449 | 77.5 |
| CPSO | 3 | 76 | 13 | 411 | 57.2 |
| UBSO | 62 | 178 | 18 | 646 | 84.7 |
| USC&GS signals located | | 348 | | | |

July 1964

| | L | N | R |
|---|---|---|---|
| BMSO | 85 | 95 | 17 |
| CPSO | 4 | 125 | 22 |
| UBSO | 83 | 182 | 38 |
| USC&GS signals located | | 388 | |

October 1964

| | L | N | R | T | Per[a] |
|---|---|---|---|---|---|
| BMSO | 74 | 67 | 13 | 630 | 75.0 |
| CPSO | 5 | 73 | 14 | 325 | 42.9 |
| UBSO | 30 | 212 | 33 | 794 | 73.0 |
| USC&GS signals located | | 364 | | | |

November 1964

| | L | N | R | T | Per[a] |
|---|---|---|---|---|---|
| BMSO | 47 | 39 | 16 | 708 | 76.1 |
| CPSO | 0 | 80 | 9 | 359 | 46.1 |
| UBSO | 51 | 201 | 29 | 746 | 73.0 |
| USC&GS signals located | | 356 | | | |

December 1964

| | L | N | R |
|---|---|---|---|
| BMSO | 47 | 45 | 12 |
| CPSO | 7 | 51 | 2 |
| UBSO | 62 | 242 | 38 |
| USC&GS signals located | | 303 | |

[a] Percentage of those events located by the USC&GS that were reported by the indicated observatory - compiled from earthquake bulletin data

[b] Data not routinely tabulated prior to 1 October 1963

[c] Based on USC&GS' "Earthquake Data Report"

[d] Not available

A

## ionals [illegible]als (N), regionals (R), and teleseisms (T) reported to the 1 July [illegible], and UBSO 1 July 1963 through 28 February 1965

| r 1963 | | September 1963 | | | | |
|---|---|---|---|---|---|---|
| R | | L | N | R | T | Per[a] |
| b | | b | b | b | b | 81.0 |
| b | | b | b | b | b | 35.1 |
| b | | b | b | b | b | 80.3 |
| | GS | | | | | |
| 22 | s | | 422 | | | |
| | d | | | | | |

| October 1963 | | | | | |
|---|---|---|---|---|---|
| | L | N | R | T | Per[a] |
| BMSO | 185 | 605 | 31 | 1180 | 85.2 |
| CPSO | 0 | 20 | 10 | 667 | [illegible] |
| UBSO | 91 | 303 | 43 | 1991 | 85.2 |
| USC&GS signals located | | 705 | | | |

| November 1963 | | | | | |
|---|---|---|---|---|---|
| | L | N | R | T | Per[a] |
| BMSO | 87 | 373 | 39 | 757 | 79.5 |
| CPSO | 2 | 31 | 9 | 484 | 55.6 |
| UBSO | 28 | 160 | 68 | 763 | 75.7 |
| USC&GS signals located | | 391 | | | |

| 1964 | | February 1964 | | | | |
|---|---|---|---|---|---|---|
| R | | L | N | R | T | Per[a] |
| 15 | | 53 | 228 | 15 | 501 | 79.8 |
| 15 | | 3 | 12 | 15 | 331 | 47.9 |
| 31 | | 25 | 189 | 31 | 471 | 77.2 |
| | GS | | | | | |
| 2 | s | | 312 | | | |
| | d | | | | | |

| March 1964 | | | | | |
|---|---|---|---|---|---|
| | L | N | R | T | Per[a] |
| BMSO | 95 | 203 | 20 | 1621 | 87.8 |
| CPSO | 0 | 30 | 16 | 913 | 69.1 |
| UBSO | 69 | 197 | 26 | 1571 | 87.3 |
| USC&GS signals located | | 641 | | | |

| April 1964 | | | | | |
|---|---|---|---|---|---|
| | L | N | R | T | Per[a] |
| BMSO | 216 | 110 | 11 | 1240 | 90.7 |
| CPSO | 1 | 23 | 49 | 601 | 63.5 |
| UBSO | 103 | 228 | 26 | 1212 | 87.6 |
| USC&GS signals located | | 614 | | | |

| 964 | | July 1964 | | | | |
|---|---|---|---|---|---|---|
| R | | L | N | R | T | Per[a] |
| 17 | | 85 | 95 | 17 | 683 | 80.6 |
| 22 | | 4 | 125 | 22 | 449 | 62.1 |
| 38 | | 83 | 182 | 38 | 825 | 86.5 |
| | GS | | | | | |
| 38 | s | | 388 | | | |
| | d | | | | | |

| August 1964 | | | | | |
|---|---|---|---|---|---|
| | L | N | R | T | Per[a] |
| BMSO | 79 | 65 | 17 | 668 | 76.5 |
| CPSO | 4 | 107 | 14 | 401 | 55.4 |
| UBSO | 72 | 208 | 36 | 651 | 81.1 |
| USC&GS signals located | | 350 | | | |

| September 1964 | | | | | |
|---|---|---|---|---|---|
| | L | N | R | T | Per[a] |
| BMSO | 79 | 73 | 9 | 606 | 75.5 |
| CPSO | 2 | 87 | 13 | 252 | 43.4 |
| UBSO | 39 | 256 | 38 | 696 | 79.1 |
| USC&GS signals located | | 336 | | | |

| 1964 | | December 1964 | | | | |
|---|---|---|---|---|---|---|
| R | | L | N | R | T | Per[a] |
| 12 | | 47 | 45 | 12 | 484 | 64.4[c] |
| 2 | | 7 | 51 | 2 | 374 | 43.6[c] |
| 38 | | 62 | 242 | 38 | 710 | 79.5[c] |
| | GS | | | | | |
| 3 | s | | 303 | | | |

| January 1965 | | | | | |
|---|---|---|---|---|---|
| | L | N | R | T | Per[a] |
| BMSO | 74 | 49 | 7 | 484 | 61.2[c] |
| CPSO | 2 | 41 | 2 | 407 | 45.8[c] |
| UBSO | 21 | 280 | 25 | 738 | 67.8[c] |
| USC&GS signals located | | 358 | | | |

| February 1965 | | | | | |
|---|---|---|---|---|---|
| | L | N | R | T | Per[a] |
| BMSO | 108 | 24 | 4 | 1037 | d |
| CPSO | 0 | 44 | 3 | 1426 | d |
| UBSO | 34 | 244 | 37 | 3015 | d |
| USC&GS signals located | | d | | | |

B

Table 20. Earthquakes detected by BMSO, CPSO, and UBSO and earthquakes reported by USC&GS between 1 July 1963 and 30 November 1964

| Observatory | Number (Degrees) | Number Reported by USC&GS | Number Detected by Observatory | Percent Detected by Observatory |
|---|---|---|---|---|
| BMSO | 0 - 16.0 | 532 | 419 | 78.7 |
| | 16.1 - 30.0 | 1175 | 1112 | 94.6 |
| | 30.1 - 60.0 | 1158 | 1008 | 87.1 |
| | 60.1 - 90.0 | 2353 | 2133 | 90.6 |
| | 90.1 - 104.0 | 1089 | 657 | 60.3 |
| | 104.1 - 110.0 | 230 | 57 | 24.7 |
| | 110.1 - 180.0 | 437 | 292 | 66.8 |
| | Total | 6974 | 5678 | 81.4 |
| CPSO | 0 - 16.0 | 28 | 26 | 92.8 |
| | 16.1 - 30.0 | 908 | 519 | 57.2 |
| | 30.1 - 60.0 | 1816 | 1371 | 75.5 |
| | 60.1 - 90.0 | 1543 | 1189 | 77.1 |
| | 90.1 - 104.0 | 790 | 118 | 14.9 |
| | 104.1 - 110.0 | 483 | 17 | 3.5 |
| | 110.1 - 180.0 | 1406 | 483 | 34.4 |
| | Total | 6974 | 3723 | 53.4 |
| UBSO | 0 - 16.0 | 548 | 479 | 37.4 |
| | 16.1 - 30.0 | 431 | 408 | 94.7 |
| | 30.1 - 60.0 | 1770 | 1669 | 94.3 |
| | 60.1 - 90.0 | 2225 | 2044 | 91.9 |
| | 90.1 - 104.0 | 1117 | 583 | 52.2 |
| | 104.1 - 110.0 | 243 | 53 | 21.8 |
| | 110.1 - 180.0 | 640 | 462 | 72.2 |
| | Total | 6974 | 5698 | 81.7 |

The five-station earthquake bulletin distribution list is included as appendix 5 to this report.

### 4.2.5.2 Semiautomation of Bulletin Preparation

To expedite the preparation of data for the monthly bulletin as much as possible, all phases of bulletin preparation that were readily adaptable to processing on the Control Data Corporation 160-A Computer at Geotech were automated. Station-to-epicenter azimuth, station-to-epicenter distance, ground displacement, and station magnitudes were calculated, using the computer.

In addition, two error-check programs (BCK 1 and BCK 2) were written for the CDC 160-A computer. These programs were used to check the bulletin data twice; once before ground displacement and station magnitude calculations were made, and once after all data were compiled. These programs checked for data-sequencing errors, anomalous data values, and incomplete data. Errors and potential errors were flagged and checked manually. These programs reduced the effort required for proofreading of the bulletin prior to publication and significantly increased the reliability and accuracy of data published in the bulletins. After all data were compiled, punched onto IBM cards and checked, multilith offset masters were prepared on an IBM 407 Printer and the bulletin was printed. All bulletins published from October 1963 through August 1964 were prepared and checked using these semiautomated procedures.

### 4.2.5.3 Automation of Bulletin Preparation

Beginning with the September 1964 bulletin, all bulletin preparation and checking procedures became fully automated. Data from each observatory were punched on IBM cards, directly from the analysis sheets. The cards were processed on the CDC 160-A computer using a program that checked for proper sequencing, anomalous data values, and incomplete data. The data were then transcribed onto magnetic tape and shipped to SDL where the data were used as input to the ABP. The bulletin was prepared, written on magnetic tape, and the tape returned to Garland. The prepared bulletin data was transcribed onto IBM cards by the CDC 160-A computer and another program was used to check the data. Multilith offset masters were then prepared on an IBM 407 Printer and the bulletin was printed. A complete description of the ABP is included in section 5.1 of this report.

## 4.3 ROUTINE ANALYSIS EVALUATION - QUALITY CONTROL

Short-period and long-period 16-millimeter film seismograms and magnetic tapes from tape recorders 1 and 2 were routinely checked in Garland. We found that these quality control checks were valuable to both observatory personnel and the Garland support personnel by helping to detect equipment malfunctions and areas of misunderstanding that might otherwide have gone undetected for extended periods of time.

### 4.3.1 Quality Control of Sixteen-Millimeter Film Seismograms

Short-period and long-period 16-millimeter film seismograms and routine analysis of these seismograms performed at the VT/1124 observatories were routinely checked and evaluated in Garland on a random basis. Following is a tabulation of the major items that were checked by the quality control analysts:

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

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

c. Sixteen-millimeter film seismograms:

(1) Quality of the over-all appearance of the record (e.g., trace spacing and trace intensity);

(2) Quality of film processing;

d. Analysis:

(1) Completeness and accuracy of the analysis:

For reporting to the USC&GS
For preparation of data for the earthquake bulletin

(2) Accuracy of all measurements;

(3) Completeness of analysis sheets:

Completeness of entries
Legibility of entries
Neatness of analysis sheets.

When the quality control check had been completed, a critique, the seismograms, the logs, and the analysis sheets were returned to the observatory for review and comment by the observatory personnel.

### 4. 3. 2 Quality Control of Magnetic-Tape Seismograms

Routine quality control checks of randomly selected magnetic-tape seismograms from each magnetic-tape recorder were made in Garland to assure that recordings met specified standards. The following are among the itsms that were checked by the quality control group - detailed quality control specifications for magnetic-tape seismograms are given in appendix 5 to TR 64-118.

a. Tape and box labeling;

b. Accuracy, completeness, and neatness of logs;

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

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;

l. Time pulse carrier;

m. Digital time marks.

# 5. EVALUATION AND SPECIAL INVESTIGATIONS

## 5.1 AUTOMATED BULLETIN PROCESS

### 5.1.1 General

On 25 November 1963, we received the VT/1124 automated bulletin system manual and one set of IBM cards, which comprised the object and source decks of the (ABP) programs, from Texas Instruments (TI). The programs and associated data, as expected, were incompatible with the CDC 1604 computer at SDL. Initially, we planned to update and debug the program, and make it compatible with the CDC 1604 computer (and many other comparable computers) by writing the program in FORTRAN language as described in Geotech's Technical Proposal P-218; however, after reviewing the TI ABP we concluded that complete rewriting of the program would be more efficient.

### 5.1.2 Review of the Previous Automated Bulletin Process

5.1.2.1 We reviewed TI's Status Report, Automated Bulletin and Seismic Data Retrieval Systems and made a cursory comparison of a portion of the ABP associated and the manually associated bulletins for January 1963. The ABP programs written by TI were designed to update hypocentral data obtained from the USC&GS PDE cards, to associate earthquake phase arrivals with the hypocentral data, and to identify the earthquake phases. The TI programs were written for computers with relatively small numbers of storage locations (IBM 1401 and IBM 7074) and were comprised of 11 separate programs that require 13 passes for execution. Of the 11 programs, 5 were written in IBM 1401 machine language and, therefore, were compatible to no other computer. The programs that were written in FORTRAN language would have required updating in order to be made compatible with the present CDC 1604 FORTRAN.

5.1.2.2 During the cursory comparisons of the automatically associated and manually associated bulletins from January 1963, a few discrepancies were noted in the bulletin prepared using the ABP that were not discussed in TI's status report. Following are some of the major discrepancies noted:

a. Some initial arrivals that fit within the prescribed identification and association window and appeared to satisfy the required secondary criteria were not associated with located epicenters (for example, P phases 1 to 4 seconds late).

b. In some instances, phases that were recorded most strongly on the vertical component of a seismograph system were identified as shear phases (for example, long-period vertical phases identified as S, SS, or SSS).

c. Several phase arrivals observed on the short-period seismograms were identified as phases that are predominantly recorded by long-period systems (for example, SSP and PPP).

d. Some phases that exceeded the apparent identification window widths were erroneously identified.

5.1.2.3 Because of several factors concerning the TI ABP programs and associated data, we recommended that the most economical and expeditious way to revise the ABP programs was to rewrite and consolidate the association programs. The major factors that influenced this decision, and some of our recommendations for rewriting and consolidating the programs are as follows:

a. Detailed logic diagrams and/or descriptions of the major programs were not available.

b. No curves were fitted to the travel-time tables of phases included in the ABP; instead, at each of 14 depths, selected points from 35 travel-time tables (including branches of some phases) were read into the computer. The points selected from the travel-time tables were inadequate for accurate phase identification and association. The number of points selected for use was increased at each depth (for example, the total number of points used for P at each depth was increased from approximately 25 to 50).

c. The hypocenter updating of the program offered essentially no improvement of the data reported in the PDE cards, because it is unlikely that data from four or five stations in one quadrant are adequate to improve the PDE data. We suggested that the USC&GS data be utilized as they are received.

d. We recommended that the criteria for phase identification and association be examined and re-evaluated based on results obtained in the January 1963 ABP associated bulletin, and that the crtieria be changed or updated as required.

e. Consolidating the main association programs and rewriting the program in FORTRAN language was recommended so that the program would be compatible with many large computers. This was planned in order to minimize the time required for bulletin preparation and because reconstruction of logic diagrams for the existing programs prior to debugging was thought to be more time consuming and less efficient than rewriting the program.

The TI program allowed a maximum of 10 days data to be processed at one time (13 passes). We recommended that the new ABP program allow data from a full month (except for months during which an abnormally high level of seismic activity occurs) to be processed during one series of production runs (4 passes).

f. We also recommended that an effort be made to develop an ABP capable of utilizing "normal" analysis data received from each observatory, and insofar as possible, possess logic whereby it could benefit from the ability of a trained analyst to base interpretations on seismogram "character." (The original ABP required that the observatory analyst's report period and amplitude data from each component of each seismograph system for each recorded seismic phase arrival.)

g. We suggested that the identification-time-window widths and secondary association criteria recommended for use in the new ABP be based on statistical data of time residuals observed for each phase of interest, and that specification of travel-time tables and travel-time table values be accomplished in conjunction with the determination of identification-time-window widths because of the close relation between the two.

5.1.2.4 Early in January 1964, the Project Officer requested that we direct effort toward rewriting of the ABP program. AFTAC agreed basically with our recommended approach to the rewriting of the ABP; however, they thought that effort should be divided between Projects VT/1124 and VT/2037. AFTAC requested that we assume responsibility for the "seismological aspect" of the task, and that we submit recommendations for the new program (to be written by SDL under Project VT/2037).

### 5.1.3 Determination of Association Window Widths and Secondary Criteria

Because hypocentral data reported by the USC&GS in their PDE cards were to be used in the ABP, and because these data are based on the 1958 "Jeffreys-Bullen Travel-Time Tables." We decided to use selected values from these travel-time tables in the ABP program. In February 1964, we began a study to determine which phases were most commonly recorded, the mean arrival time residual of each of the more commonly recorded phases, and the secondary association criteria for each of these phases.

Hypocentral depth, station-to-epicenter distance, station code, and phase arrival time for all identified phases from 1613 known hypocenters that were recorded in April, May, June, and October 1963 were recorded on digital magnetic tape. From these data the more commonly recorded phases were determined, and the mean arrival time residual for each of 23 of the most often recorded phases were calculated. The 23 phases (including branches of P', PKKP, SKP, and SKS) for which travel-time residuals were determined, and the number of occurrences of each of these phases are listed in table 21.

After the most often recorded phases were determined, a "maximum allowable" residual value was established for each phase (see table 21). This maximum allowable residual was based on the distribution of observed residual values, and on the commonly observed periods of the phase. Any residual that exceeded the maximum allowable window was assumed to be the result of inaccuracy in the PDE data, data transcription errors, or questionable phase identifications, and was not used in the determination of the mean residual and standard deviation for that phase. Travel-time table values for use with the ABP (appendix 6) were selected, tested, and used in the determination of mean travel-time residuals for each of the 23 phases. Association residual time windows were based on the mean residual and standard deviation for each phase. All associated windows are approximately equivalent to the mean residual plus or minus twice the standard deviation, except P and PKP where the windows are equivalent to the mean residual plus or minus three times the standard deviation (table 22).

Secondary criteria have been established for each phase; however, these criteria were designed so they did not appreciably increase the analysis work load at the observatories. The criteria specified for each phase are given in table 23.

During our consideration of the problem of specification of association criteria, it became evident that not all criteria used by analysts during seismogram analysis can readily be reduced to quantitative terms; therefore, not all criteria lend themselves to translation into language compatible with automatic processing. In those cases where phase identifications and/or event

Table 21. Statistical data used to determine the phase association window widths for the ABP

| Phase name | Number of arrivals | Maximum allowable residual (seconds) | Number of arrivals not used | Mean residual (seconds) | Standard deviations (seconds) |
|---|---|---|---|---|---|
| P | 5127 | ±15.0 | 70 | + 0.4 | 2.4 |
| PKP$_1$ and PKP$_2$ | 454 | ±20.0 | 25 | + 1.6 | 4.6 |
| PKKP$_1$, PKKP$_2$ and PKKP$_3$ | 246 | ±40.0 | 19 | + 3.8 | 10.1 |
| PP | 564 | ±30.0 | 33 | - 1.1 | 9.1 |
| S | 549 | -15.0 to +30.0 | 35 | + 8.6 | 6.6 |
| pP | 674 | ±30.0 | 18 | - 1.6 | 4.7 |
| PcP | 320 | ±30.0 | 7 | - 0.5 | 6.6 |
| SKP$_1$, SKP$_2$ | 100 | ±40.0 | 4 | - 0.9 | 10.1 |
| SKS$_1$, SKS$_2$ | 135 | ±30.0 | 14 | + 6.6 | 7.7 |
| SS | 296 | ±30.0 | 45 | + 8.3 | 10.7 |
| P'P' | 131 | ±30.0 | 14 | - 1.9 | 12.3 |
| PS | 111 | ±30.0 | 10 | + 0.1 | 9.5 |
| SSS | 135 | ±40.0 | 18 | +11.6 | 14.9 |
| SPP | 146 | ±30.0 | 17 | + 8.0 | 10.5 |
| PPP | 194 | ±30.0 | 18 | - 0.6 | 11.5 |
| SP | 281 | ±30.0 | 17 | + 5.6 | 7.8 |
| PPS | 159 | ±30.0 | 18 | + 2.5 | 11.3 |
| ScS | 142 | ±30.0 | 3 | + 4.8 | 8.4 |

Table 22. ABP phase association window values, and percentages of events available and events used in the study that would have been associated by an ABP using these association window values

| Phase name | ABP association window values (seconds) | Percentage association for arrivals used to determine mean residuals | Percentage association including all arrivals |
|---|---|---|---|
| P | - 6.0, + 7.0 | 96.6 | 95.3 |
| PKP (1 and 2) | -12.0, +15.0 | 94.0 | 91.4 |
| PKKP (1, 2, and 3) | -14.0, +22.0 | 95.1 | 87.8 |
| PP | -18.0, +20.0 | 93.6 | 88.0 |
| S | - 6.0, +22.0 | 92.4 | 86.5 |
| pP | -11.0, + 9.0 | 94.2 | 91.7 |
| PcP | -13.0, +12.5 | 94.2 | 92.2 |
| SKP (1 and 2) | -21.0, +19.0 | 92.7 | 89.0 |
| SKS (1 and 2) | - 9.0, +22.0 | 94.1 | 84.6 |
| SS | -13.0, +29.0 | 96.2 | 80.1 |
| P'P' | -27.0, +23.0 | 95.7 | 85.5 |
| PS | -20.0, +20.0 | 94.1 | 85.6 |
| SSS | -18.0, +40.0 | 97.4 | 84.5 |
| SPP | -13.0, +29.0 | 94.6 | 83.6 |
| PPP | -23.5, +22.5 | 94.3 | 85.6 |
| SP | -10.0, +22.5 | 94.7 | 89.0 |
| PPS | -20.0, +25.0 | 92.2 | 88.1 |
| ScS | -12.0, +21.5 | 92.8 | 91.8 |

Table 23. Secondary phase identification and associated criteria for use in the ABP program

| Phase name | Distance range at which the phase may be recorded (degrees) | System on which the phase may be recorded | Component on which the phase should be recorded best | Other criteria for identification and association of phases |
|---|---|---|---|---|
| P | .0001-110.0 | Any | Z | |
| PKP1 | 110.0-180.0 | Any | Z | |
| PKP2 | 143.1-180.0 | Any | Z | |
| PKKP1 | 20.0-162.0 | SP IB | Z | |
| PKKP2 | 105.1-126.0 | SP IB | Z | |
| PKKP3 | 94.1-126.0 | SP IB | Z | |
| PP | 10.0-180.0 | Any | Z | Doubtful if period is less than P |
| S | 0.1-110.0 | Any | H | Period must be greater than P |
| pP | 20.5-100.0 | Any | Z | Period must be equal to or greater than P. Must be deeper than 50 km. Doubtful if the absolute value of (P residual - pP residual) is greater than 5 sec. Doubtful if P phase of the event is not recorded. |
| PcP | 1.0- 80.0 | Any | Z | Doubtful if period greater than P |
| SKP1 | 104.1-180.0 | Any | Z | |
| SKP2 | 130.1-148.0 | Any | Z | |
| SKS1 | 63.0-133.0 | Any | H | |
| SKS2 | 101.0-180.0 | Any | H | |
| SS | 25.0-180.0 | BB LP | H | |
| P'P' | 1.0-140.0 | SP IB | Z | |
| PS | 45.0-145.0 | BB LP | H | |
| SSS | 45.0-180.0 | BB LP | H | |
| SPP | 45.0-180.0 | BB LP | Z | |
| PPP | 10.1-180.0 | BB LP | Z | |
| SP | 45.0-145.0 | BB LP | Z | |
| PPS | 45.0-180.0 | BB LP | H | |
| ScS | 5.0- 80.0 | Any | H | |

KEY:

SP - Short period
IB - Intermediate band
BB - Broad band

LP - Long period
Z - Vertical component
H - Horizontal component

type identifications are primarily based on qualitative criteria, we recommended that the station analyst's opinion override the ABP decision. Instances in which analyst's opinion should prevail follow.

a. For events not associated with hypocenters reported on the USC&GS' PDE cards, the analyst's phase identifications and event type designations are used.

b. If the first arrival of a phase sequence that has been identified as a local (L) or near regional (N) event by the analyst falls within the expected arrival time window of a located teleseismic (T) or regional (R) event, the station analyst's identification is used and no association of the phase sequence is made. The predicted P phase travel time must be equal to or less than 88 seconds (plus the P phase association window) in order for an event identified as L or N to be associated with a PDE location.

c. For events that have been identified as either L, N, or R either by the ABP or the station analyst, the analyst's identification of the surface waves is used.

d. The ABP does not attempt to identify or associate Love (L) or Rayleigh (R) phases; when these phases can be identified, they are identified by the station analyst during the preliminary seismogram analysis.

e. All phase arrivals recorded by different seismograph systems that are identified by the same phase number during analysis at the observatories are identified by the ABP as the same phase.

f. If the first identifiable arrival of an observed phase sequence has been identified by the observatory analyst as L, R, or surface (Sur) the event sequence is not associated with a USC&GS hypocenter.

Except for the specific cases in which the ABP relies on the interpretations of the station analysts, identification of phase arrivals in arrival sequences associated with USC&GS hypocenters is completely dependent on the ABP. If the analyst has attempted to identify a phase arrival and his identification does not agree with the ABP identification, the identification is changed. If the ABP is unable to identify an observed arrival, the analyst's identification (if any) is deleted and the arrival is reported as either "e" or "i."

### 5.1.4 Areas in which ABP Modifications were Required

Although we attempted to anticipate and compensate for as many of the problems of automatic earthquake-phase association and identification as possible, some problem areas that were not fully anticipated became evident as testing of the ABP and routine processing of data using the ABP progressed. Some of the problem areas are still present in the ABP; however, many have been resolved, modifications designed to correct others have been recommended, and some refinements are under consideration. Brief descriptions of the major problem areas and modifications recommended for resolving some of them follow.

#### 5.1.4.1 Association of Arrival Sequences in which P or PKP are not Observed First Arrivals

If the first observed arrival of a phase sequence failed to fall within the P phase association window ($\Delta \leq 110°$) or the PKP phase association window ($\Delta > 110°$), the entire phase sequence was considered unassociated. In our initial meeting with SDL at VSC, we recommended that logic to associate event arrivals based on P or PKP phase data be developed and that this logic be changed later to allow the association of events from which P or PKP were not recorded. The program logic will be modified to check and attempt to associate each sequence based on one of the first three observed arrivals. If none of the first three observed arrivals can be associated, the arrival sequence will be reported as unassociated; however, if one of the first three arrivals is associated, the ABP will test all arrivals of that sequence for identification. These changes were recommended late in April 1965 and the effects of this change should be reflected in the December 1964 or January 1965 bulletins.

#### 5.1.4.2 Problems of Identifying Phases Whose Predicted Arrival Times Overlap

Within some distance ranges near the points at which travel-time curves for different phases cross, the association windows of two or more phases may overlap. In some instances after all secondary criteria are satisfied, predicted phase arrival times may still overlap, creating a problem for the computer in phase identification. Several processes designed to resolve these problems have been considered. A brief description of each follows.

a. Arrival Sequence Method. If there are an equal number of observed arrivals and qualified predicted arrivals, the correct sequence of arrivals should be determined and the observed arrivals should be identified accordingly.

b. Elimination Method. If there are more observed arrivals than there are qualified predicted arrivals, or if there are fewer observed arrivals than qualified predicted arrivals, the observed arrival with the smallest absolute residual value should be identified first and removed from contention. Next, of the remaining arrivals, the one that has the smallest absolute residual value should be identified, etc.

c. Blanking of Phases Previously Identified. If the program wishes to change the identification of an observed arrival previously identified because the the observed arrival currently being considered has a smaller residual for the phase in question, the program should determine whether there was an alternate qualified predicted arrival for the observed arrival previously identified. If an alternate identification were available, the first observed arrival in question should be reidentified. If no alternate identification is possible, the first observed arrival in question should be reported as either e or i.

After SDL checked the effects of these solutions, it was decided that we would incorporate the "Elimination Method" and the solution to the "Blanking Problem" in the program because it appeared that these two would resolve the remaining phase overlap problems. These two sets of criteria will be incorporated into the ABP and evaluated.

### 5.1.5 Future Testing and Refinement of the ABP

After the pending modifications of the ABP have been implemented and tested and the backlog of bulletins processed, the bulletins for July and August 1964 will be processed by the ABP. The outputs will be closely checked against the manually associated data for those months and discrepancies between the two bulletins will be checked. Based on the review of these bulletins, additional criteria may be recommended to resolve problems that remain. In addition, criteria are presently being considered to circumvent some of the problems now present in the ABP (for example, misassociation of Love and/or Rayleigh during preliminary analysis) and to reduce the time required to check the output of the ABP.

## 5.2 PRELIMINARY INVESTIGATIONS OF AR

An investigation of the area under the surface wave envelope (AR) for explosion signals and earthquake signals was begun during the reporting period. Twenty-six explosion signals and 15 earthquake signals of approximately the same magnitude, recorded at BMSO and UBSO, were selected for the comparison. Preliminary measurements of AR were made from these signals on the short-period and intermediate-band systems; however, the investigation was suspended at the request of the Project Officer because it was a duplication of work being done on another project. No conclusions can be drawn from the investigation at this time because work was suspended before the collection of data was complete.

## 5.3 DETECTION CAPABILITY STUDY

On 27 March 1964, approval of the study to determine the detection capabilities of BMSO, CPSO, UBSO, and WMSO that was recommended on 4 October 1963 was received from the Project Officer. This study is being conducted jointly under Projects VT/1124 and VT/4054. Specific plans for the study and an estimated schedule for completion of the study were discussed with the Project Officer by G. S. Gerlach during a visit to VSC during the week of 20 April.

In May 1964, we began the investigation to refine estimates of the detection capabilities of the observatories operated under Projects VT/4054 and VT/1124. Because the detection capability of an observatory cannot readily be expressed in absolute terms, we adopted a statistical approach to the problem.

The probability of teleseismic P-wave signal detection at BMSO, CPSO, UBSO, and WMSO as a function of signal amplitude, amplitude-to-period ratio, and signal-to-noise ratio is being determined empirically for each type of predominant microseismic noise recorded on the short-period seismograms at each of the observatories. The accuracy of first motion determination, amplitude measurements, and period measurements also is being determined for various signal amplitudes under different microseismic noise conditions.

The probability of detection of teleseismic signals superimposed on microseismic noise is being determined for three seismograph systems for each observatory, as follows:

a. Individual short-period vertical seismograph;

b. Four short-period vertical seismographs (corner and center elements of the array) and an unfiltered summation seismograph;

c. Four short-period vertical seismographs, unfiltered summation seismograph, and filtered summation seismograph.

Sixteen-millimeter film seismograms have been synthesized for this study by superimposing signals randomly at various levels on microseismic noise samples representative of the background noise at each observatory (see figures 56, 57, and 58). The nine signals selected for use in this study are shown in figure 59. Each of the nine was played back eight times at each of seven levels and summed into each background noise sample selected to obtain the equivalent of many low-level signals of known amplitude. In addition, each signal occurrence was recorded on a reference trace, free of noise, to facilitate accurate timing of arrivals and measurement of amplitudes and periods. The resulting synthetic seismograms were copied without the reference trace and the copies were analyzed by analysts at each observatory and in Garland.

At the request of the Project Officer, preliminary data regarding the detection capability of the observatories were reported to AFTAC on 30 January 1965, and a brief report covering the selection of microseismic noise types (including examples of each) was submitted on 31 March 1965.

The detection capability study has been assigned top priority and is progressing as rapidly as feasible.

Plotting of power spectra of the noise samples is approximately 65 percent complete. Power spectra are being plotted for the individual vertical seismograph and for the summation seismograph for each noise type. In addition, noise statistics (visual) have been compiled from 12 months of routine data for each observatory. These statistics will be compared to similar data from the detection study noise samples and to the spectral data.

Plotting of the detection probability of each signal is complete for all systems and noise types for ground displacement (A), and approximately 50 percent complete for ground displacement-to-period ratio (A/T). We shall also present detection probability as a function of input trace amplitude.

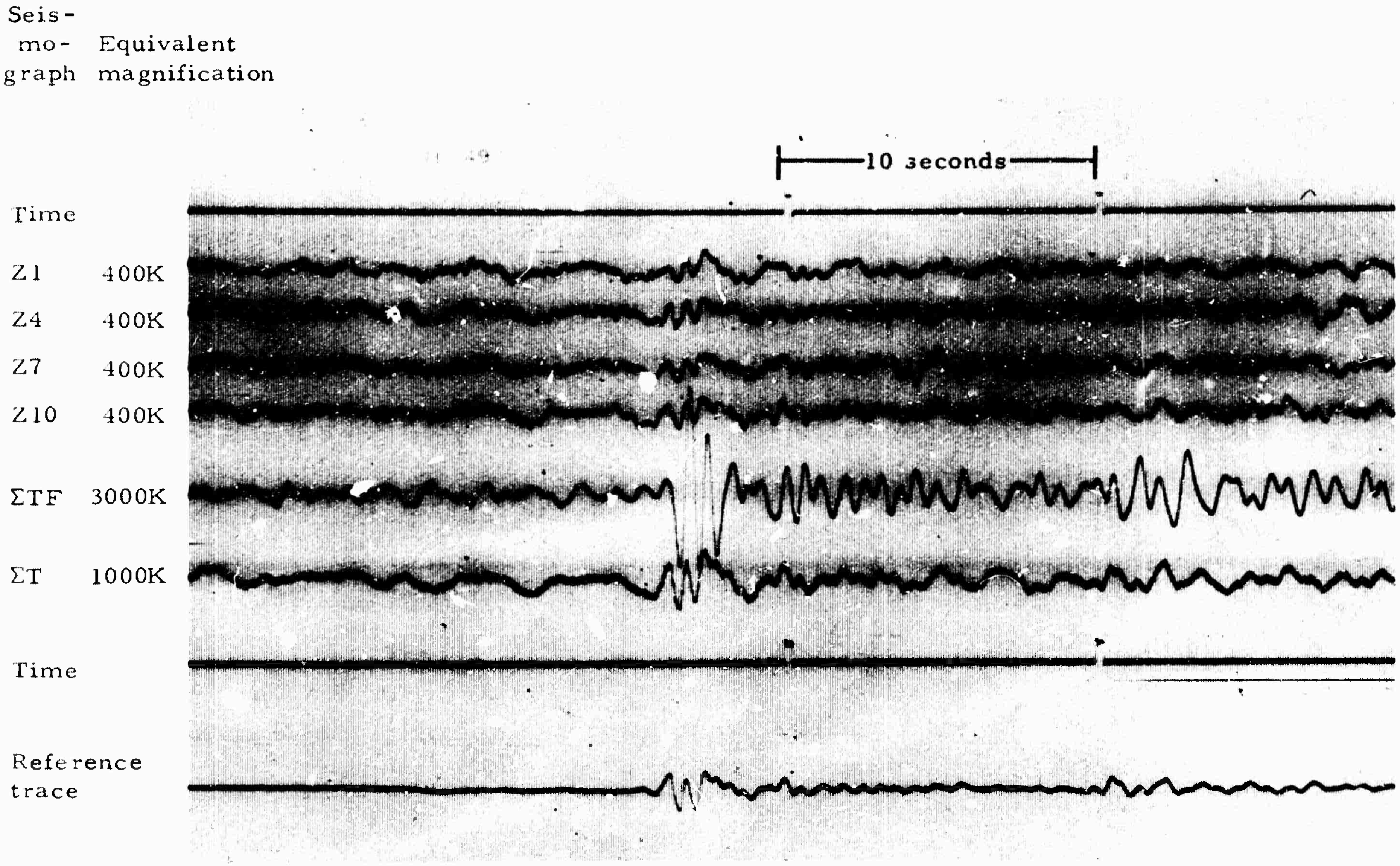


Figure 56. Synthesized detection study seismogram illustrating the maximum amplitude at which Signal No. 6 was superimposed on low level CPSO microseismic background noise. Note input signal level on reference trace 6 dB higher than on ZSP's. (X10 enlargement of 16-mm film playback from magnetic tape)

CPSO
Detection Study
Run 092

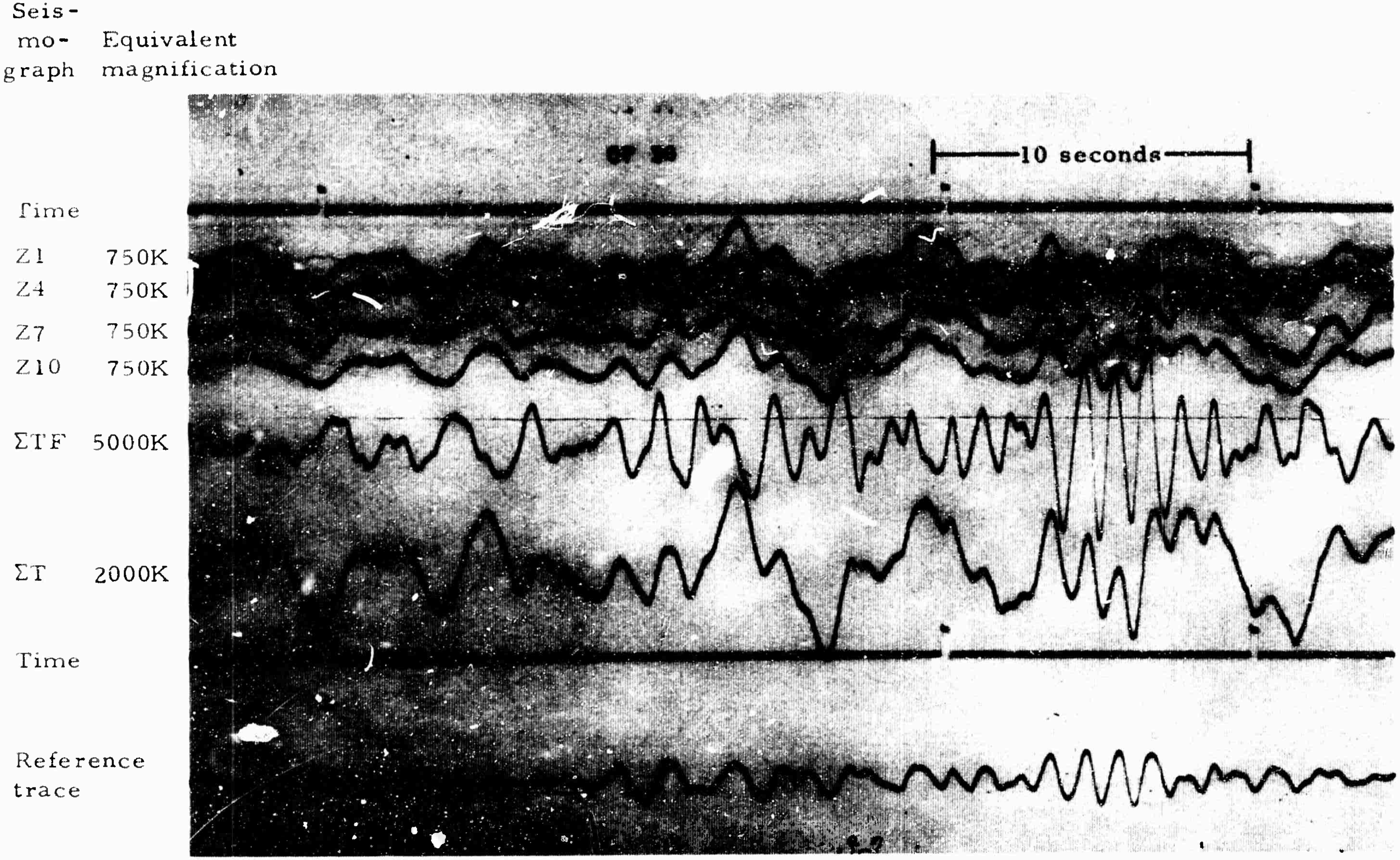


Figure 57. Synthesized detection study seismogram illustrating the maximum amplitude at which Signal No. 3 was superimposed on intermediate level BMSO microseismic background noise. Note input signal level on reference trace 6 dB higher than on ZSP's.
(X10 enlargement of 16-mm film playback from magnetic tape)

BMSO
Detection Study
Run 022

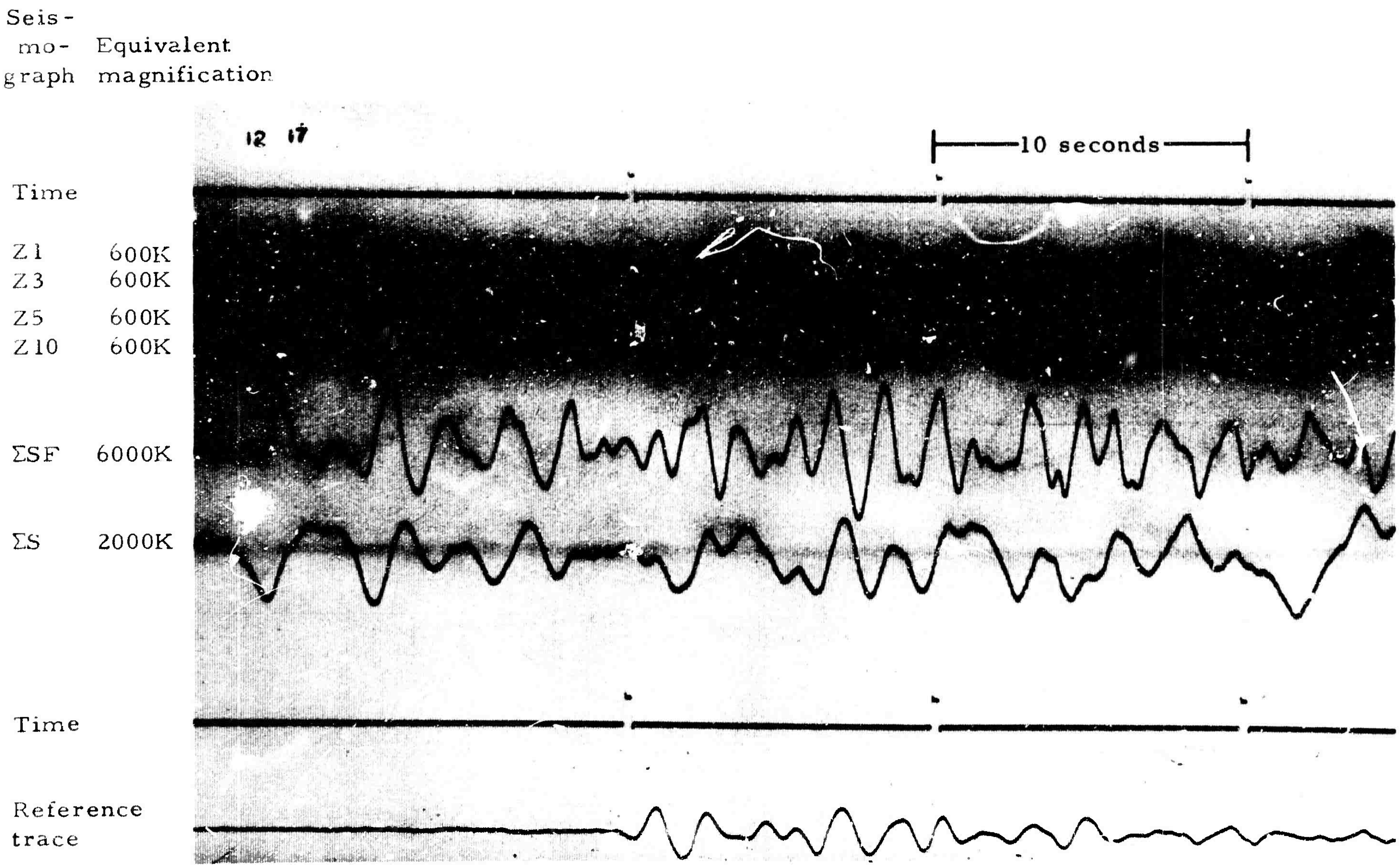


Figure 58. Synthesized detection study seismogram illustrating the maximum amplitude at which Signal No. 7 was superimposed on high level UBSO microseismic background noise. Note input signal level on reference trace 6 dB higher than on ZSP's.
(X10 enlargement of 16-mm film playback from magnetic tape)

UBSO
Detection Study
Run 057

Analysis and evaluation of data are proceeding as rapidly as the data are reduced. We plan to complete this study late in August, as reported to the Project Officer on 31 March.

## 5.4 WEIGHTED SUMMATION AT CPSO

### 5.4.1 Theoretical Considerations

Noise studies by Texas Instruments indicate that noise at CPSO is composed predominantly of vertically polarized shear modes. Any Rayleigh energy appearing in the noise spectrum is at least 9 dB below the shear modes. The spectrum at 0.6 Hz indicates that the predominant coherent noise is occurring at a wavelength of 6.5 kilometers and is propagating across the array from an azimuth of 110 degrees. The spectrum at 1.0 Hz shows that the predominant coherent noise wavelengths are 3.9 kilometers from 110 degrees and 3.0 kilometers from 333 degrees. Thus, based on TI indications, the predominant wavelengths of coherent noise at CPSO in the frequency range 0.6-1.0 Hz are in the range 3.0-6.5 kilometers and approach from directions of 110 degrees and 333 degrees.

The apparent velocities of compressional signal waves across the array are in the range 8 kilometers per second to ∞. At a frequency of 1.0 Hz this would correspond to a wavelength range of 8.0 kilometers to ∞. The fact that the apparent wavelengths of signals are greater than the apparent wavelengths of the noise suggests a method of improving signal-to-noise ratio by changing the wavelength response of the array. This can be done by summing the elements of the array in such a way as to lower the response of the summation in the 0- to 8-kilometer wavelength range while maintaining (or lowering by a lesser amount) the response in the 8 kilometer to ∞ wavelength range.

The response of a summation to a particular wavelength is determined by the geometry and weighting of the array of elements included in the summation. Different wavelength reponses can be obtained at CPSO by unequal weighting of the contributions of the individual elements to the summation. To preserve the omnidirectional response of the array to teleseismic P-wave signals, weighting should be done so that all elements having equal weight form a pattern that has radial symmetry with respect to the center of the array.

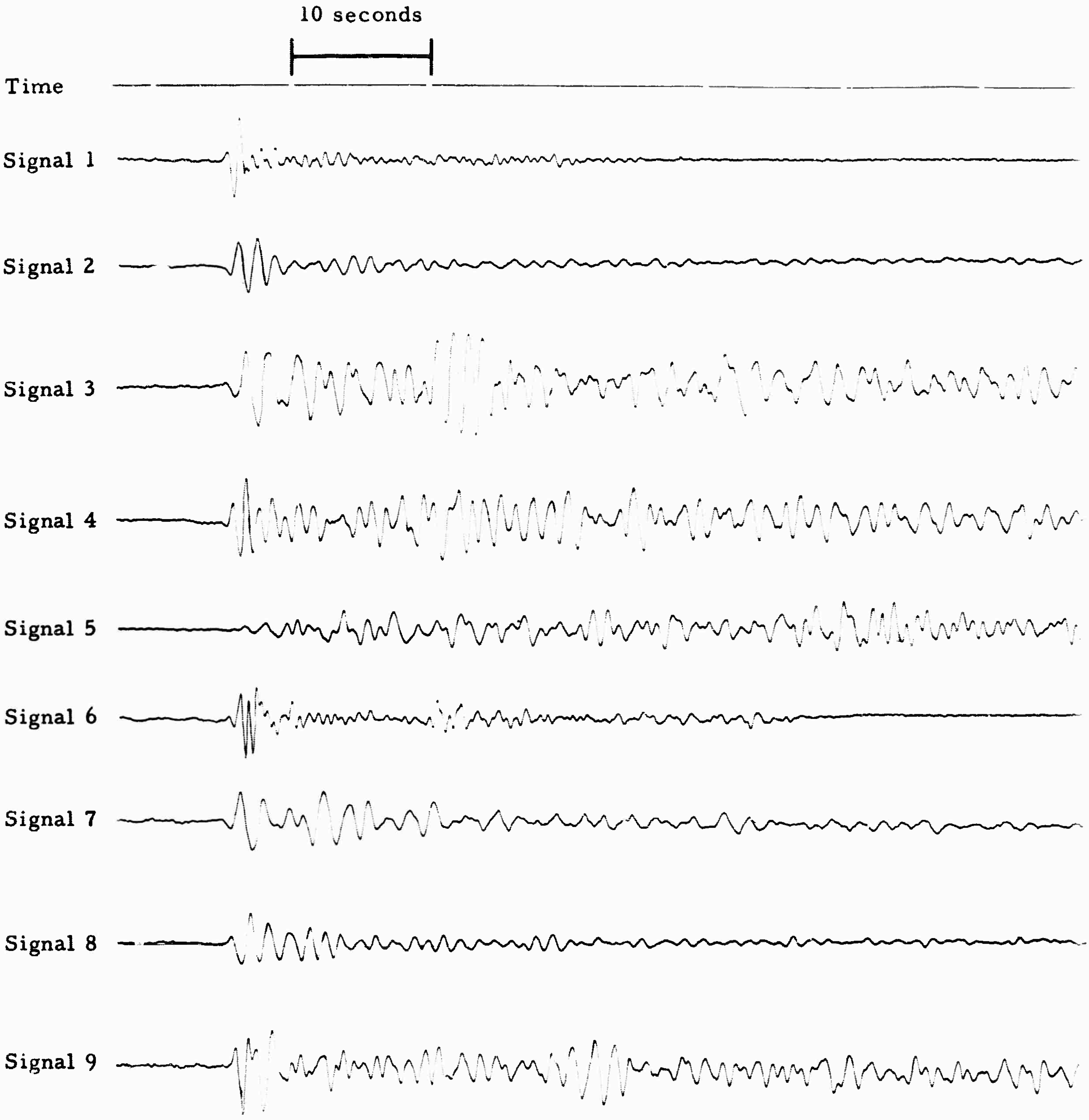
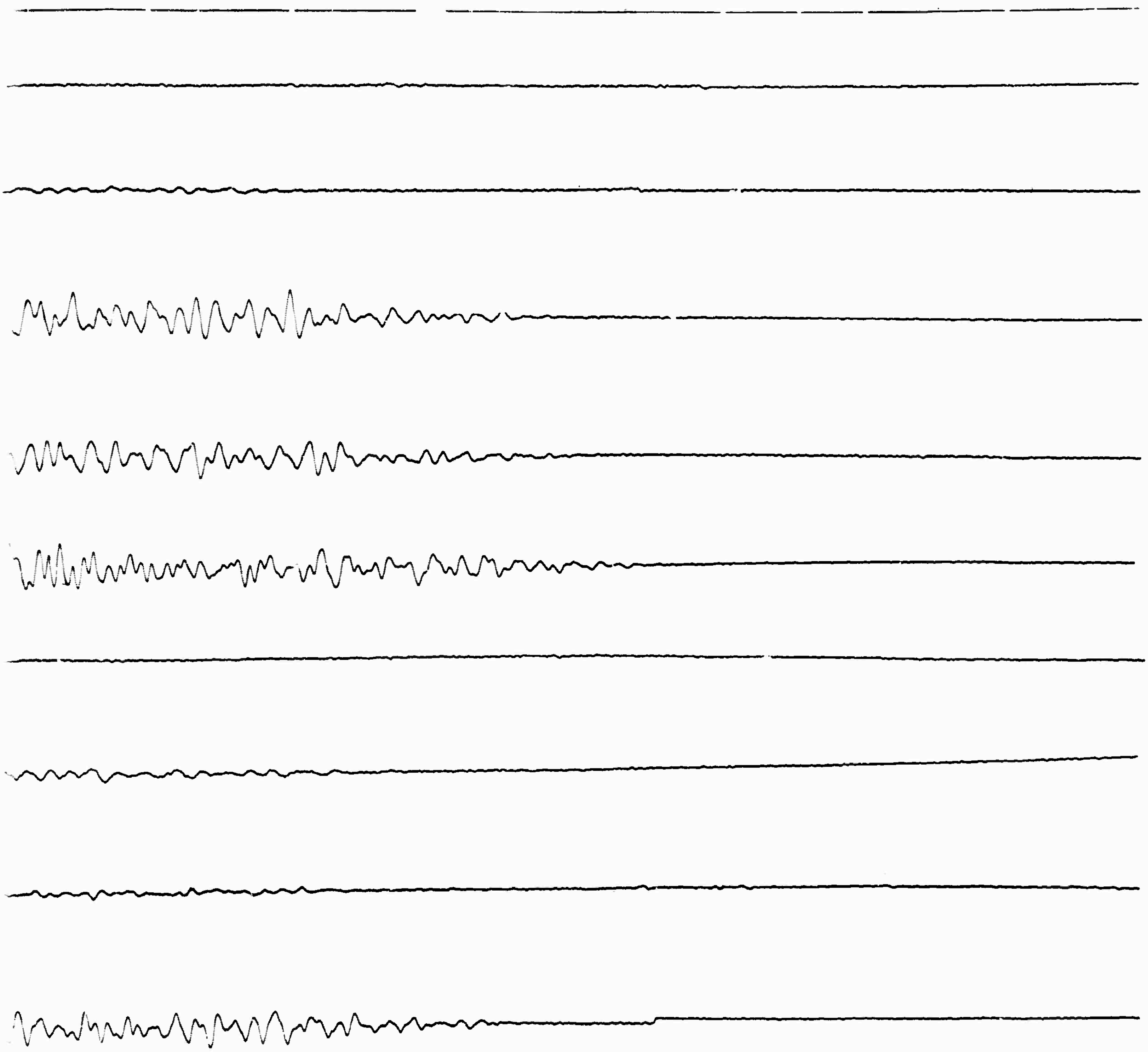


Figure 59. Nine P-wave signals, recorded at BMSO, CPSO, UBSO or WMSO, eac levels in each of the microseismic noise samples used in the detection capabil from magnetic tape)

A



BSO or WMSO, each of which was superimposed randomly eight times at each of seven he detection capability study. (X5 enlargement of 16-millimeter film playback from magnetic tape)

B

Summing in such a manner is equivalent to unequally weighted summing of the summations of different symmetrical configurations of elements within the 19-element array. The relative response of each of these subgroups as a function of wavelength can be calculated and used to determine which subgroups could be combined in a weighted summation to give the best approximation to the desired wavelength response.

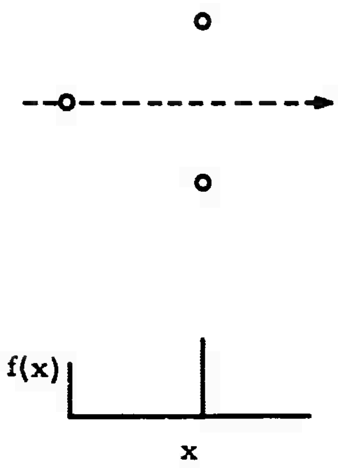
The relative response of a geometric pattern of seismometers as a function of wave number (reciprocal of wavelength) can be calculated by means of the Fourier transform. The Fourier transform is not restricted to the dimension of time (frequency in reciprocal seconds and time in seconds); it can be applied to the dimension of distance (wave number in reciprocal kilometers and distance in kilometers).

The general expression of the transform pair is

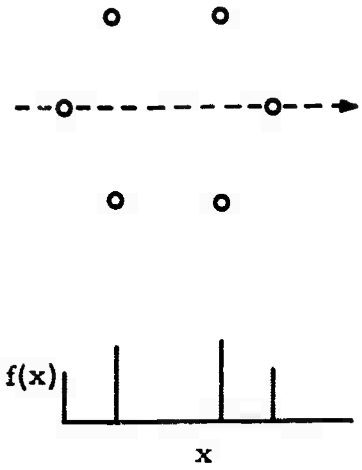
$$f(p) = \int_{q=-\infty}^{q=+\infty} F(q)\, e^{2\pi iqp}\, dq \qquad (1)$$

$$F(q) = \int_{p=-\infty}^{p=+\infty} f(p)\, e^{-2\pi iqp}\, dp \qquad (2)$$

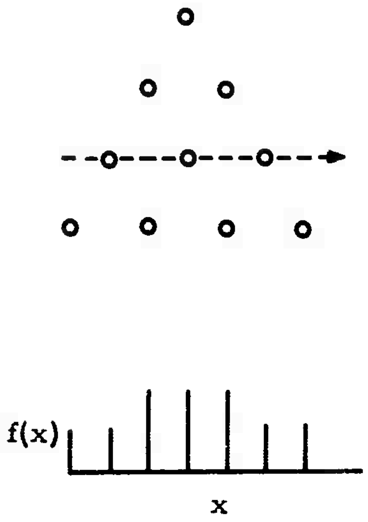
An array can be expressed as a function of distance (along some particular direction) by dropping perpendiculars from each element location to a line parallel to the direction of interest. Note the three following examples.



(a) 3-element triangular array



(b) hexagonal array



(c) 10-element triangular array

These distance functions can be expressed as wave number functions by expressing (1) and (2) in the following manner.

$$f(x) = \int_{k=-\infty}^{k=+\infty} F(k) e^{2\pi ikx} \, dk$$

$$F(k) = \int_{x=-\infty}^{x=+\infty} f(x) e^{-2\pi ikx} \, dx$$

where k is the wave number.

F(k) may be written (symbolically) as

$$F(k) = G(k) e^{i\theta(k)}$$

where G(k) is the amplitude spectrum and $\theta$ (k) is the phase spectrum.

Since

$$e^{-2\pi ikx} = \cos 2\pi kx - i \sin 2\pi kx$$

then F(k) can be rewritten as

$$F(k) = \int_{x=-\infty}^{x=+\infty} f(x) \left[\cos 2\pi kx - i \sin 2\pi kx\right] dx$$

and

$$F(k) = \int_{x=-\infty}^{x=+\infty} f(x) \cos 2\pi kx dx - i \int_{x=-\infty}^{x=+\infty} f(x) \sin 2\pi kx dx \, .$$

F(k) has thus been resolved into its real and imaginary parts. Calling the real part of the function P and the imaginary part Q,

$$P = \int_{x=-\infty}^{x=+\infty} f(x) \cos 2\pi kx dx$$

$$Q = \int_{x=-\infty}^{=+\infty} f(x) \sin 2\pi kx dx \, .$$

In a problem in which f(x) represents amplitudes at discrete values of x rather than a continuous function, P and Q may be expressed as finite summations in order than f(x) be of consequence only at the discrete values of x at which f(x) exists. To conveniently express x in the argument of the sine and cosine functions, directions are selected so that the values of x in the distance functions fall on a reasonable number of equally spaced points. This allows x to be given by the product of the indexing number and the interval between two adjacent points. The direction of interest in this study satisfies this condition. Therefore,

$$P = \Delta x \sum_{n=1}^{M} f(x_n) \cos (2\pi k n \Delta x)$$

$$Q = \Delta x \sum_{n=1}^{M} F(x_n) \sin (2\pi k n \Delta x)$$

where $M$ = number of points

$\Delta x$ = interval between points.

Since P is the component of F(k) along the real axis in the complex plane and Q is the component along the imaginary axis

$$\underset{i=1,2,\ldots}{\Theta(k_i)} = \tan^{-1} \frac{Q}{P}$$

$$\underset{i=1,2,\ldots}{G(k_i)} = \sqrt{P_i^2 + Q_i^2}$$

A plot of G(k) therefore gives the relative response of an array of seismometers as a function of wave number, and a plot of $\Theta(k)$ gives the phase shift of the summation output relative to the output of a particular seismometer.

### 5.4.2 Tests of Theoretical Conclusions

The transformation was programmed for the CDC 160A computer, and several wave number responses were calculated. Figures 60a, 60b, 61a, and 61b are four examples of plots of G(k). Due to symmetry of the distributions, the output of each summation is in phase (or 180 degrees out of phase) with the center of the array. A summation of the elements of the outer hexagon gives the best attenuation of the predominant wave numbers of 0.6-1.0 Hz noise. This suggests that a summation of the 19 elements in which each of the outer 6 elements is given heavy weight relative to each of the inner 13 might produce a summation trace with a better signal-to-noise ratio than the simple summation.

Magnetic tapes recorded at CPSO were played back in such a way that each of the elements of the outer hexagon was given twice the weight of each of the inner 13, and later, 10 times the weight of each of the inner 13. Giving the outer elements twice the weight did not significantly change the appearance of the summation as compared to the simple summation. Figure 62 shows that giving 10 times the weight to the outer six successfully attenuated 1.0-Hz microseisms but failed to provide attenuation of 2.0-Hz microseisms. This summation was played back through a bandpass bilter with cutoff frequencies of 2.0 Hz and 0.8 Hz at rates of 24 dB/octave. This filtered, weighted summation appeared promising and was given a 2-week trial at CPSO.

### 5.4.3 Results

The weighted, filtered summation ($\Sigma$TWF) showed less 1.0-Hz noise than the simple filtered summation ($\Sigma$TF) but more 2.0-Hz noise when recorded at the same magnification. Figure 63 shows a teleseismic P-wave arrival on $\Sigma$TWF and $\Sigma$TF. For this 1.7-Hz signal there is a greater contrast of signal frequency to noise frequency on $\Sigma$TF than on $\Sigma$TWF. This situation was observed often during the 2-week trial period. Figure 64 whows the arrival of a teleseismic P wave in which $\Sigma$TWF has cancelled a 1.0-Hz noise pulse immediately before the arrival. Had the P wave arrived with less energy and a longer period, the start of the signal would have been lost much more easily on $\Sigma$TF than on $\Sigma$TWF.

Figure 65 shows a 1.0-Hz teleseismic P-wave arrival recorded better on $\Sigma$TWF than on $\Sigma$TF because of the greater frequency difference between the signal and the 2.0-Hz background on 2TWF than with the 1.0-Hz background on $\Sigma$TF.

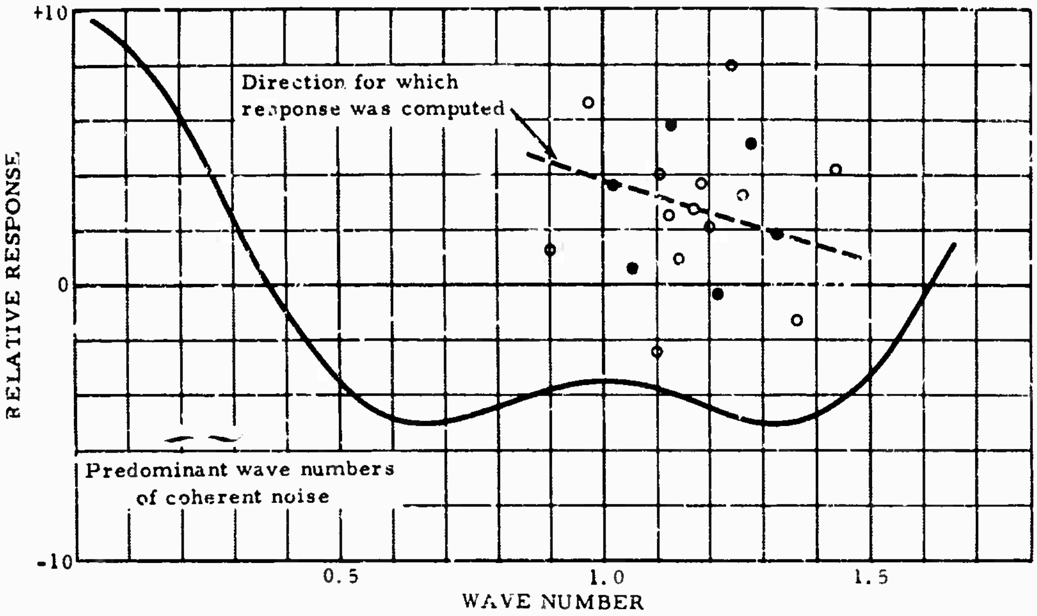


Figure 60a. Wave number response of the summation of the elements of the inner hexagon

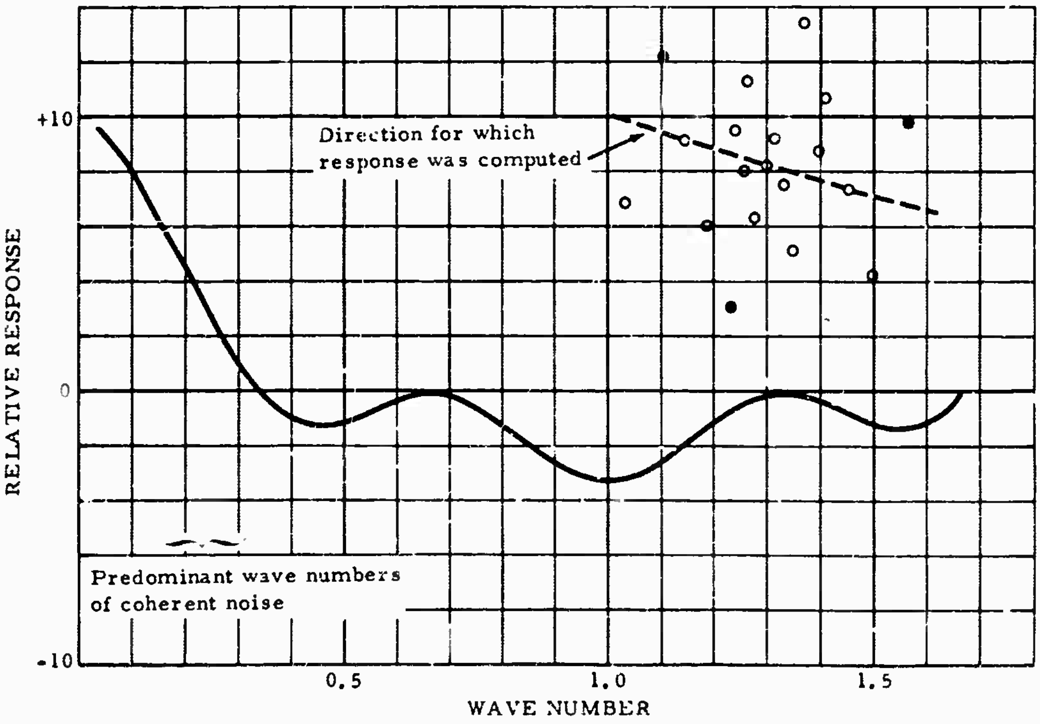


Figure 60b. Wave number response of the summation of Z1, Z4, and Z7

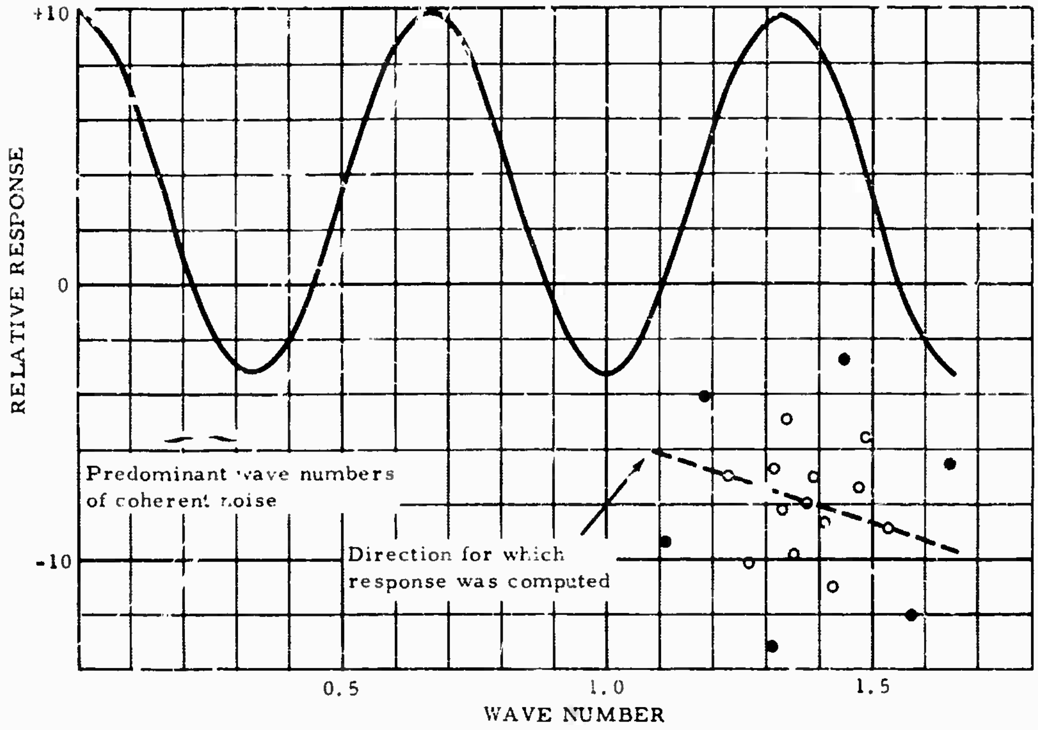


Figure 61a. Wave number response of the summation of the elements of the outer hexagon

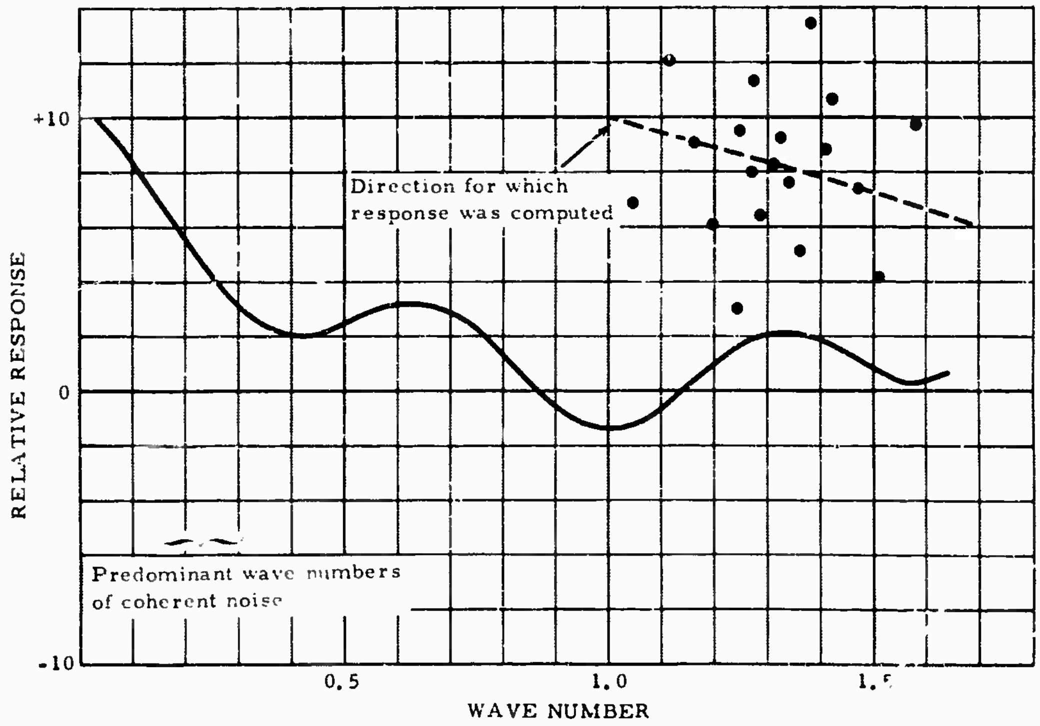


Figure 61b. Wave number response of the simple summation of all 19 elements

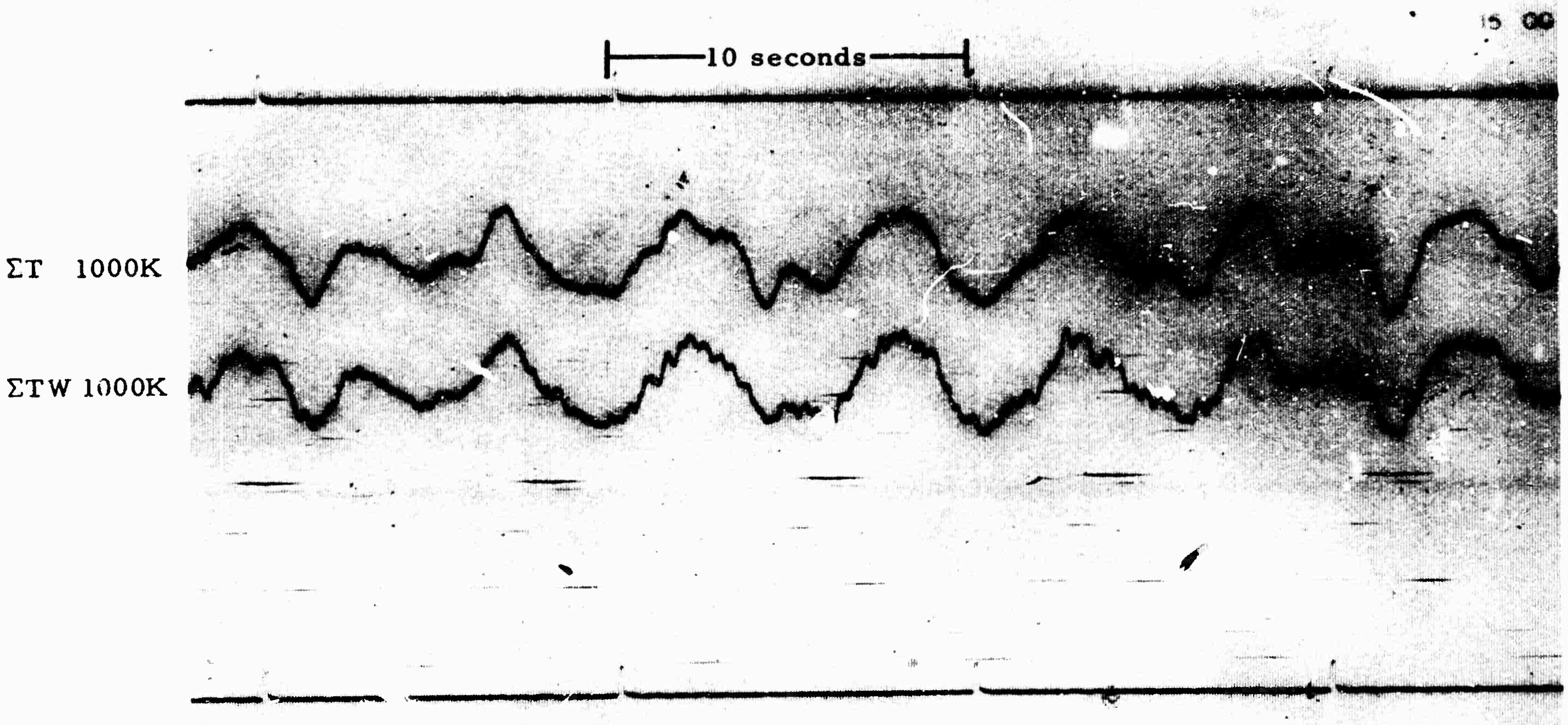


Figure 62. Develocorder recording of magnetic-tape playback from CPSO showing ΣTW attenuating 1.0 Hz microseisms but failing to attenuate 2.0 Hz microseisms. ΣTW has elements of outer hexagon (Z1, 4, 7, 17, 18, and 19) weighted ten times each of the other elements. (X10 enlargement of 16-mm film playback from magnetic tape)

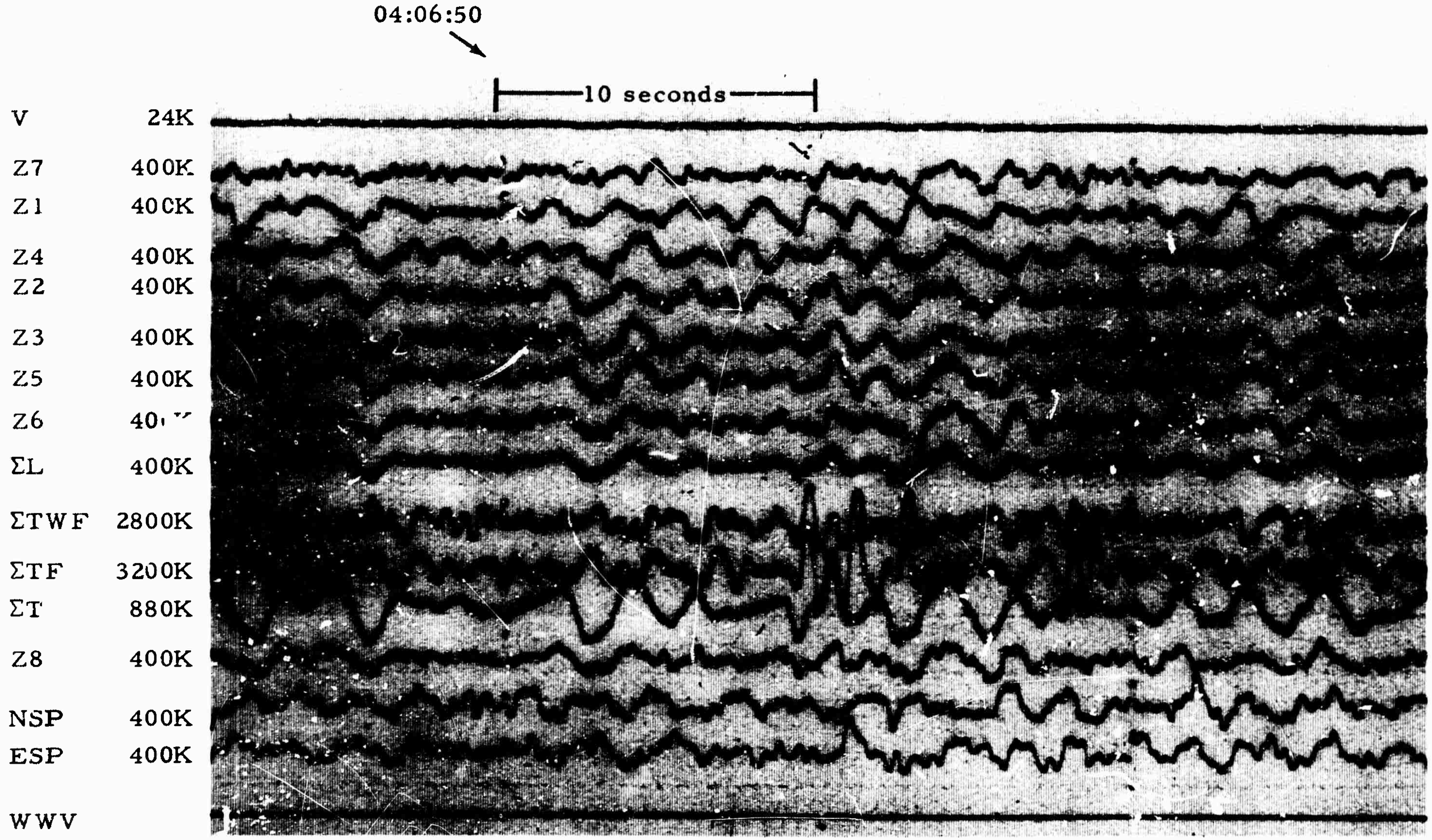


Figure 63. CPSO short-period seismogram illustrating the greater signal-to-noise frequency contrast on ΣTF than on ΣTWF for a 1.7-Hz teleseismic P-wave arrival. South of Panama, $\Delta \simeq 29^\circ$, $h \simeq 68$ km, 0 = 04:01:07, m = 4.0 (USC&GS) (X10 enlargement of 16-mm film)

CPSO
Run 118
28 April 1965
Data Group 6022

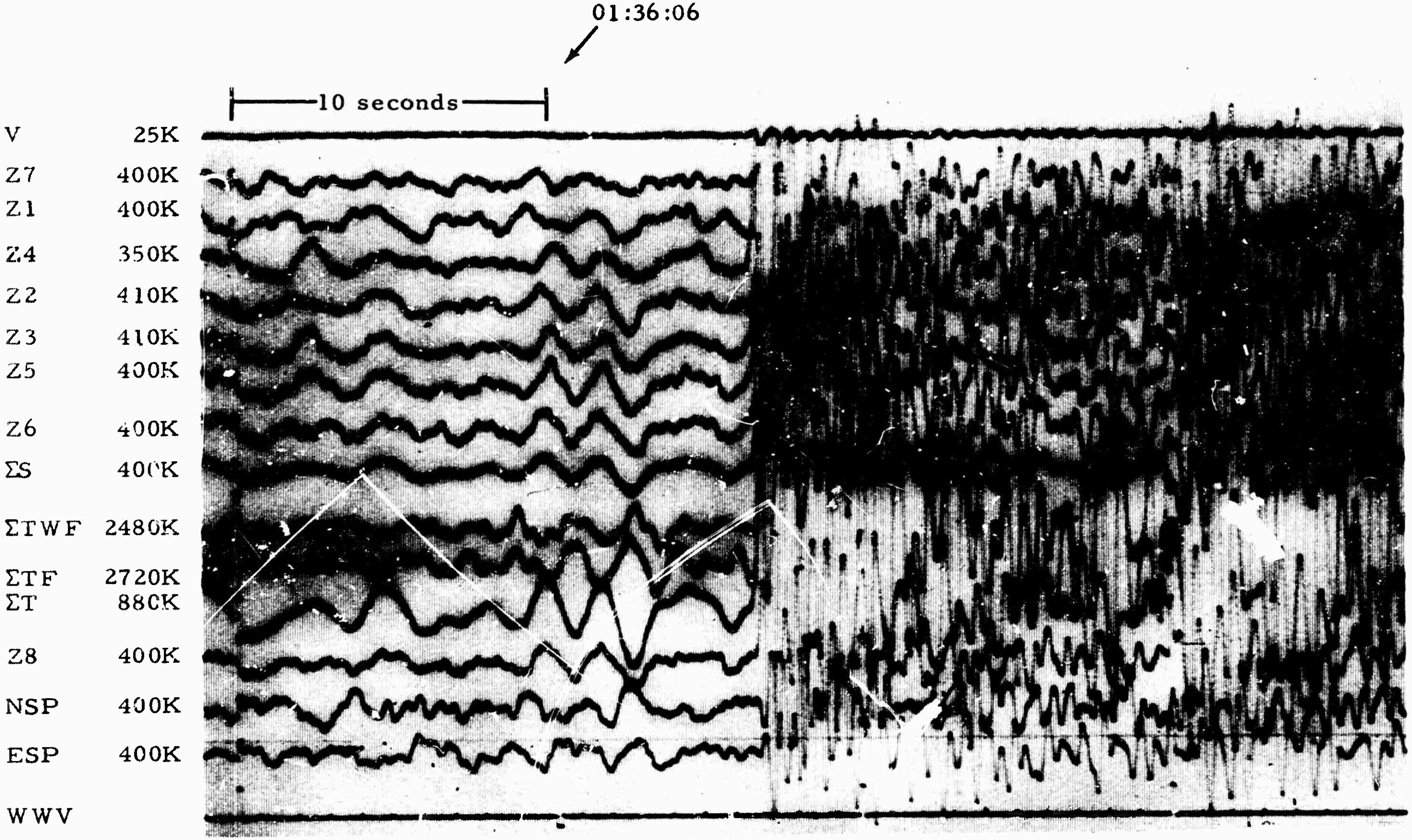


Figure 64. CPSO short-period seismogram illustrating the cancellation of a 1-Hz noise pulse by ΣTWF immediately before the arrival of a teleseismic P wave. Epicenter unknown (X10 enlargement of 16-mm film)

CPSO
Run 117
27 April 1965
Data Group 6022

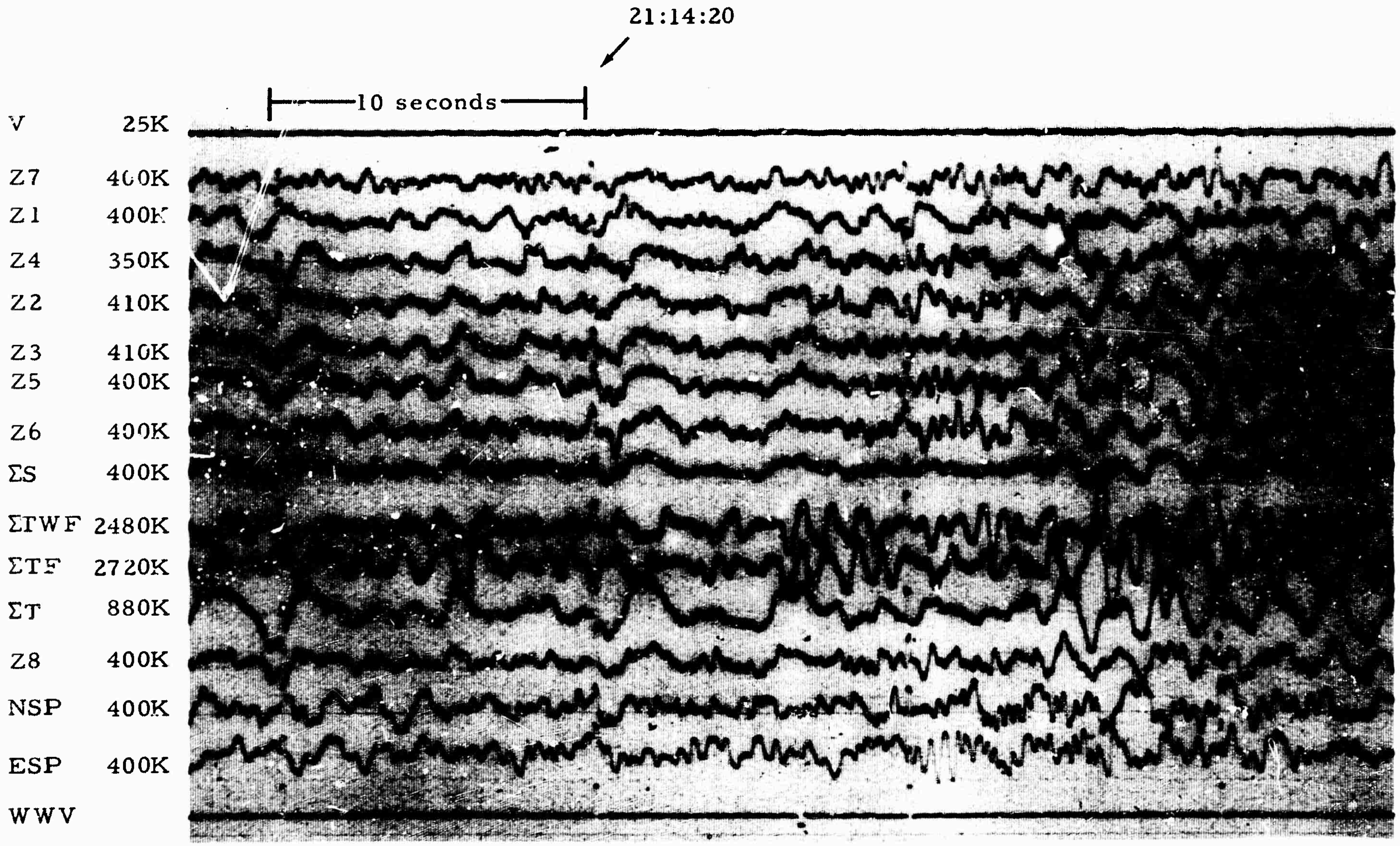


Figure 65. CPSO short-period seismogram illustrating the enhancement of a 1-Hz teleseism by ΣTWF compared with ΣTF. Fox Islands, Aleutian Islands $\Delta \approx 56^{\circ}$, $h \simeq 33$ km, 0 = 21:04:4.6, m = 4.5 (USC&GS) (X10 enlargement of 16-mm film)

CPSO
Run 117
27 April 1965
Data Group 6022

### 5.4.4 Conclusions and Recommendations

The filtered, weighted summation did not prove to be a better all-around teleseismic flag trace than the simple filtered summation currently in use. This was primarily due to the fact that most teleseismic P-wave signals recorded during the test interval had an apparent period on the filtered seismograms of nearer 0.5 second than to 1.0 second. As a result, there was usually a greater signal-to-noise period contrast on the simple summation trace than on the weighted summation trace. The weighted trace was very useful in eliminating 1.0-cps noise pulses that appeared on the simple summation trace to be a signal possibility. In the opinion of the analysts at CPSO, it was a great help to have both summations available side by side, and we recommend that ΣTWF be recorded adjacent to ΣTF in the place of Z9.

## 5.5 EFFECTS OF WIND ON THE SHORT-PERIOD SEISMOGRAPHS AT BMSO, CPSO, AND UBSO

A comprehensive study of wind-generated seismic noise is divided into two sections. First, the distribution of the wind at any observatory must be determined as a function of wind speed and direction. Second, the noise generated by the wind at each seismometer must be evaluated as a function of wind speed and direction.

A study of this nature was begun during the latter part of the reporting period; however, because of a lack of data for the second portion of the study, no conclusive results can be determined. As requested by the Project Officer, we shall continue to gather data until sufficient data are obtained on which to base final results.

The distribution of wind speed and direction has been determined for June 1964 through March 1965 for all observatories except BMSO. The data for March 1965 from BMSO were not obtained because of a malfunctioning wind-speed indicator. A 1-year data sample from each observatory is considered adequate to determine the wind distribution. The distributions were obtained by daily measuring wind speed and direction at intervals of 3 hours. In some instances, the seismograms for several days during a month were not available; however, each observatory averaged about 225 measurements each month. A computer program was written to classify the measurements for a given month into 1 of 8 direction sectors as a function of wind speed. The resulting distributions were plotted on polar graph paper, and the data contoured on percentage of occurrence. Figure 66 is a sample plot of the BMSO data for January 1965.

The responses of the 10 primary short-period seismographs and their summations to wind-generated noise are determined by plotting trace amplitude measurements as a function of wind speed and direction. All direction determinations are referenced to the eight direction sectors and wind speed is grouped in increments of 3 mph. Ten amplitude measurements are made for each wind speed increment in each of the eight directions. Amplitude measurements are made peak-to-trough in the 1/2 period (T/2) range 0.1 second through 0.8 second. Intervals when the wind speed is constant for several minutes are used to assure that all seismometers are subjected to wind of the same speed. A plot of trace amplitude versus wind speed for each of the eight directions is then plotted for each seismograph. This portion of the study has not been completed because of a lack of data at wind speeds exceeding 30-40 mph. Ten months of data have been examined, and several additional months will be required before sufficient data will be obtained. It is not possible to accurately estimate the volume of additional data that will have to be examined in order to finish this study; however, we anticipate that at least 4 months of data will be required.

## 5.6 DISTRIBUTION OF EARTHQUAKE MAGNITUDES

5.6.1 For each of the four observatories, BMSO, CPSO, UBSO, and WMSO, and for the net composed of these four observatories, the distribution of earthquakes recorded and not recorded as a function of magnitude and epicentral distance was compiled for the 20-month period, February 1963 through September 1964. A count was made of the number of earthquakes located by the USC&GS, grouped by 2.5-degree increments of distance and 0.2 magnitude unit increments, over the distance range 16 degrees to 110 degrees for the individual observatories and 16 degrees to 180 degrees for the net.

5.6.2 The data for the individual observatories are given in tables 1, 2, 3, and 4 of appendix 7. Each table is presented in three parts, as follows:

Part a. Number of earthquakes located by the USC&GS from which the observatory recorded a short-period P-wave signal (magnitudes determined from observatory data);

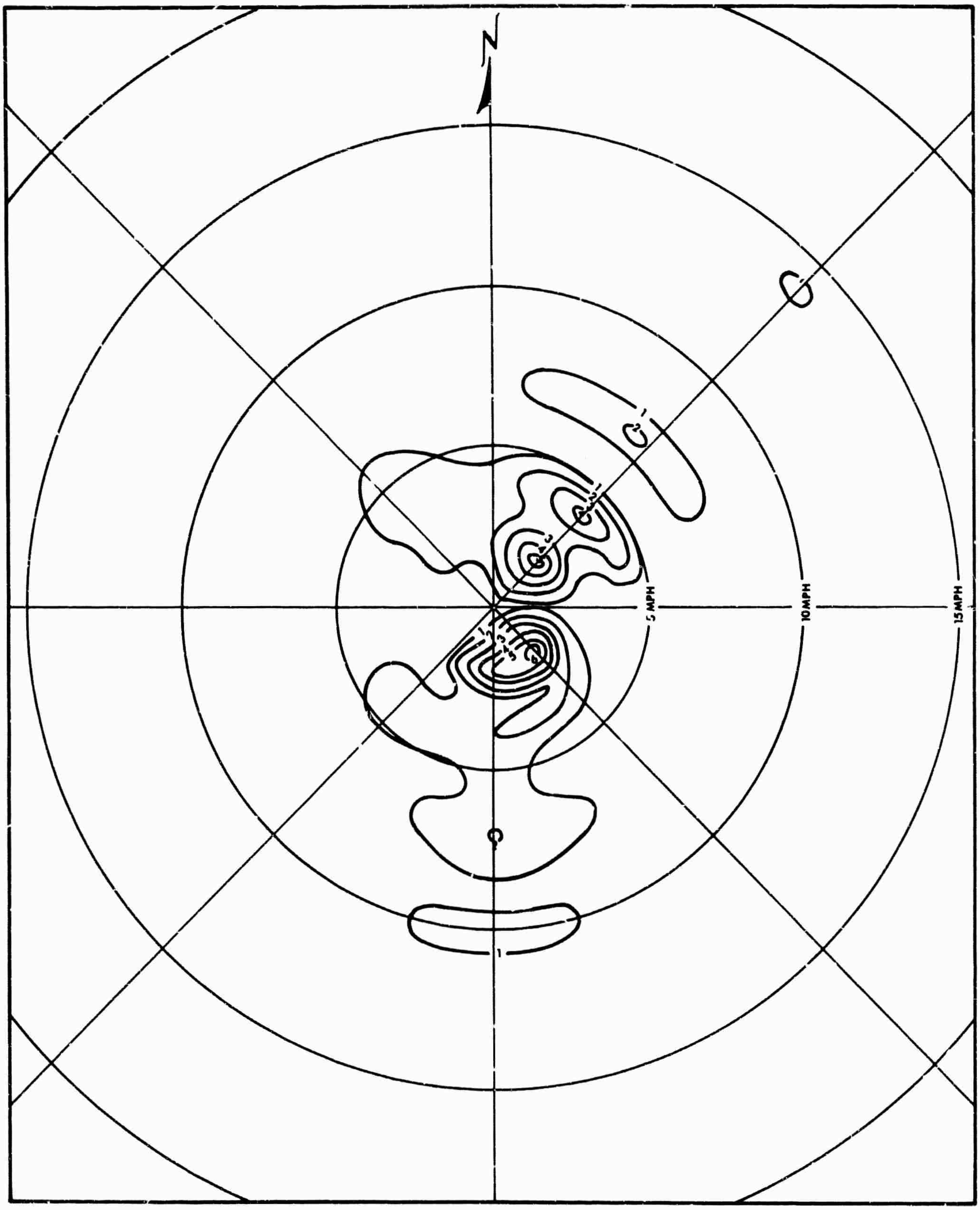


Figure 66. Polar plot of the wind speed distribution for January 1965 from BMSO. The contour interval is 1.0 percent. The wind was calm 32.7 percent of the month

Part b. Number of earthquakes located by the USC&GS from which the observatory recorded a short-period P-wave signal and for which the USC&GS computed a magnitude (magnitudes computed by the USC&GS);

Part c. Number of earthquakes located by the USC&GS from which the observatory did not record a short-period P-wave signal and for which the USC&GS computed a magnitude (magnitudes computed by the USC&GS).

5.6.3 Table 5 in appendix 7 lists the corresponding data for the four-observatory net, as follows:

Part a. Number of earthquakes located by the USC&GS from which at least one observatory recorded a short-period P-wave signal (magnitudes determined from the arithmetic mean of the observatory magnitudes), and distance from the greatest epicenter-observatory distance at which a short-period P or P' signal was recorded;

Part b. Number of earthquakes located by the USC&GS for which the USC&GS computed a magnitude and from which at least one observatory recorded a short-period P or P'signal (magnitudes determined by the USC&GS) and distance from the greatest epicenter-observatory distance at which a short-period P or P' signal was recorded;

Part c. Number of earthquakes located by the USC&GS for which the USC&GS computed a magnitude and from which none of the four observatories recorded a short-period P or P' signal (magnitudes determined by the USC&GS) and distance from the smallest epicenter-observatory distance.

5.6.4 The same data are presented in the form of contoured distributions in figures 67 through 71. Each figure is given in three parts - a, b, and c, corresponding to the tables in appendix 7. Figures 67 through 70 give the data for the individual observatories and figure 71 gives the data for the four-observatory net. In each figure, each contour represents a constant number of earthquakes and adjacent contours differ by a factor of two.

5.6.5 Although the plots presented show the contribution of the net of stations and the individual stations to the epicentral determinations made by the USC&GS, they should not be interpreted as a measure of true detection capabilities. If all earthquakes that occur were located by USC&GS, capabilities could be determined. The plots do give a relative comparison of detection capability among the stations based on USC&GS located epicenters, and it is assumed that this relative relationship will not change appreciably in regard to true detection capability.

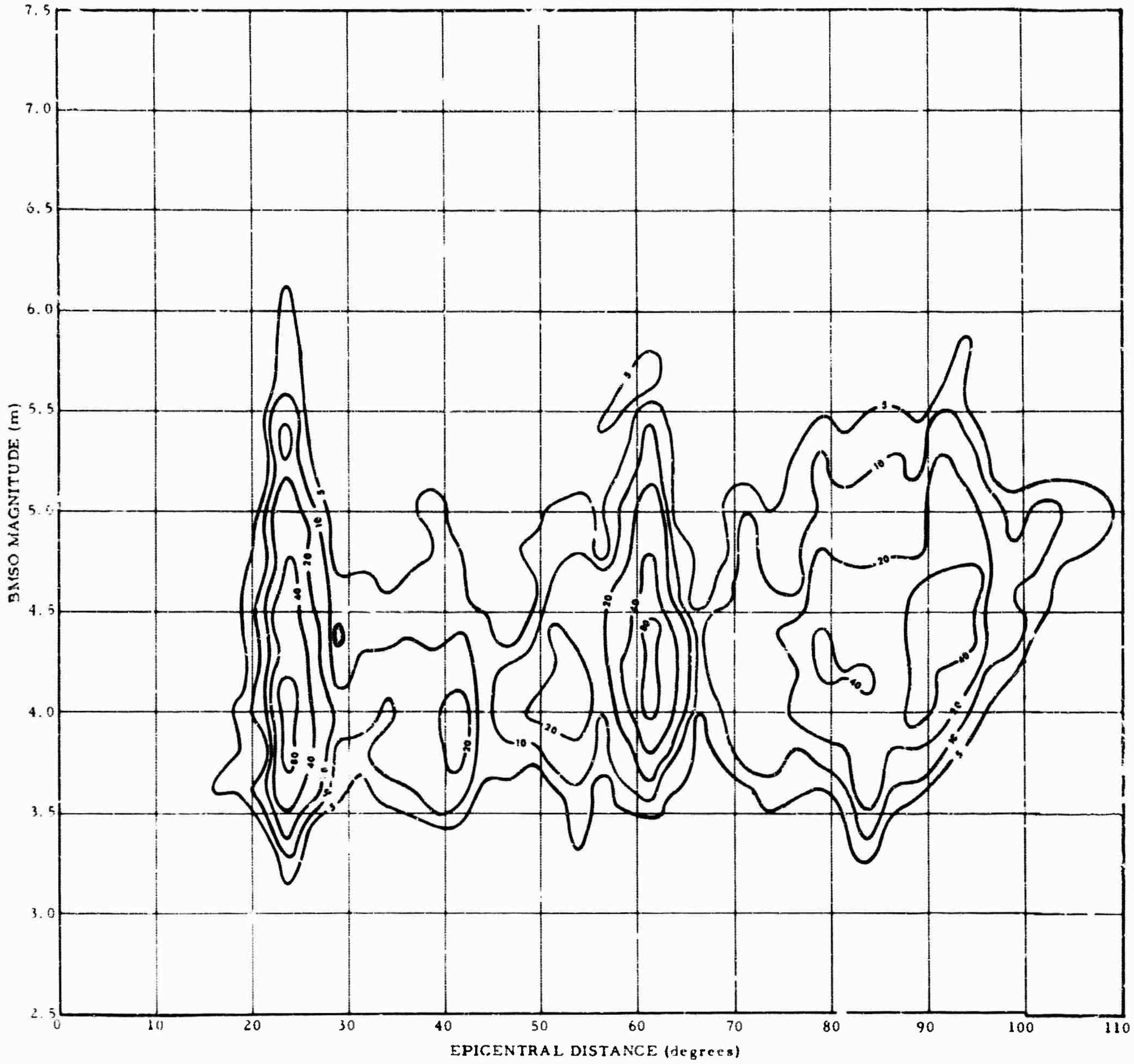


Figure 67a. Number of earthquakes located by the USC&GS from which P phase was recorded at BMSO, as a function of BMSO magnitude and epicentral distance, February 1963 through September 1964

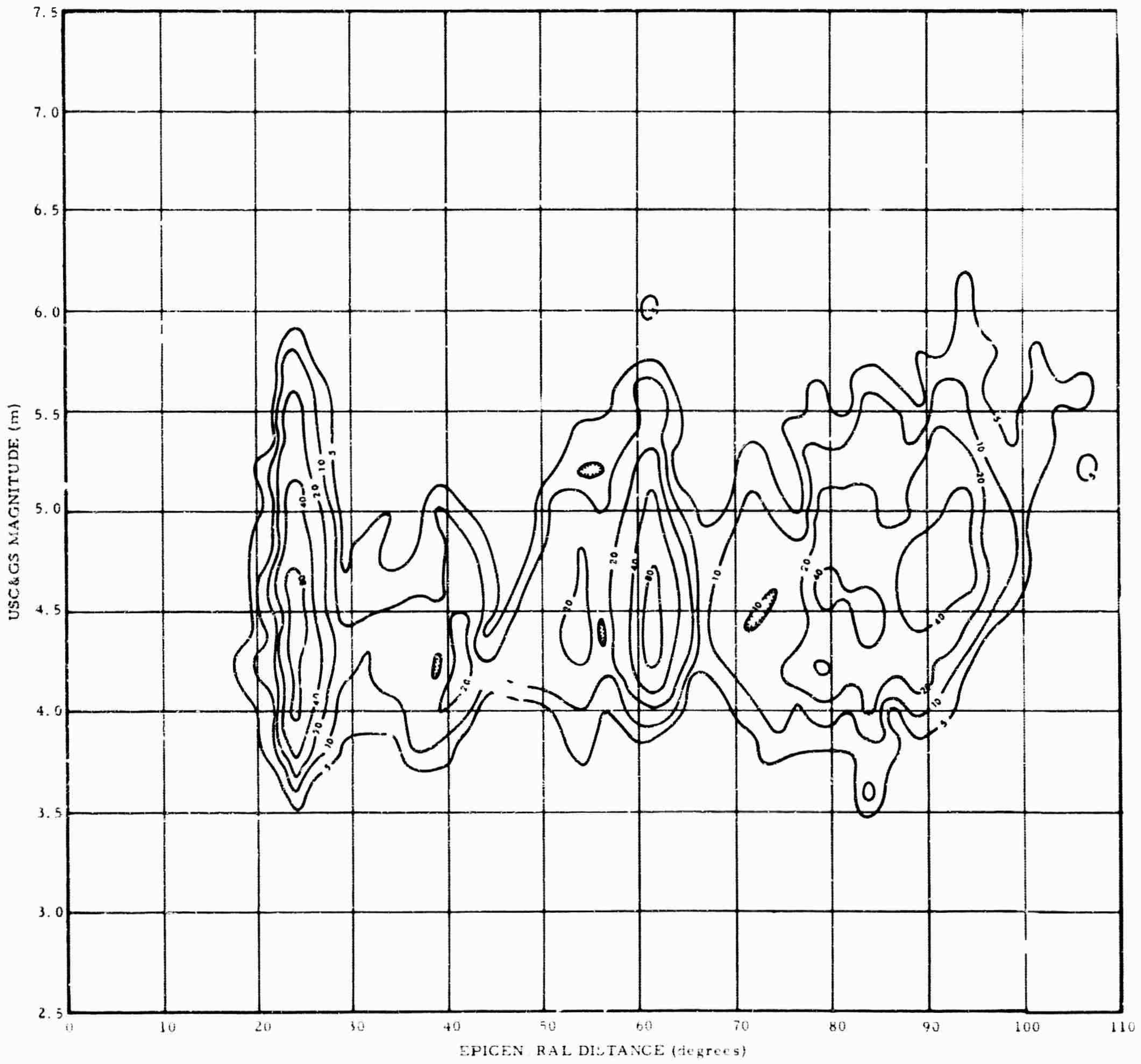


Figure 67b. Number of earthquakes located by the USC&GS from which P phase was recorded at BMSO and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and epicentral distance, Feburary 1963 through September 1964

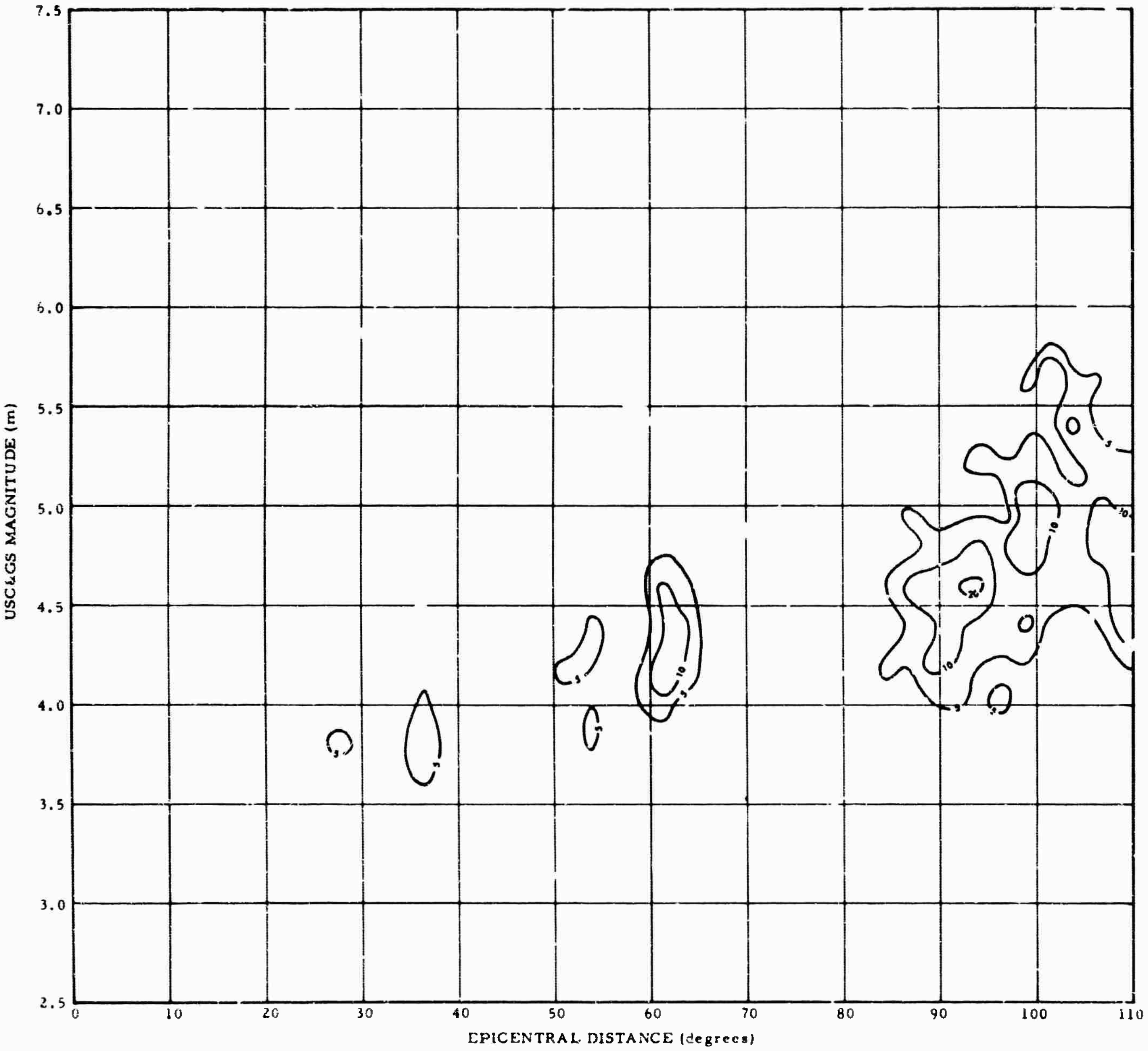


Figure 67c. Number of earthquakes located by the USC&GS from which P phase was not recorded at BMSO and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and epicentral distance, February 1963 through September 1964

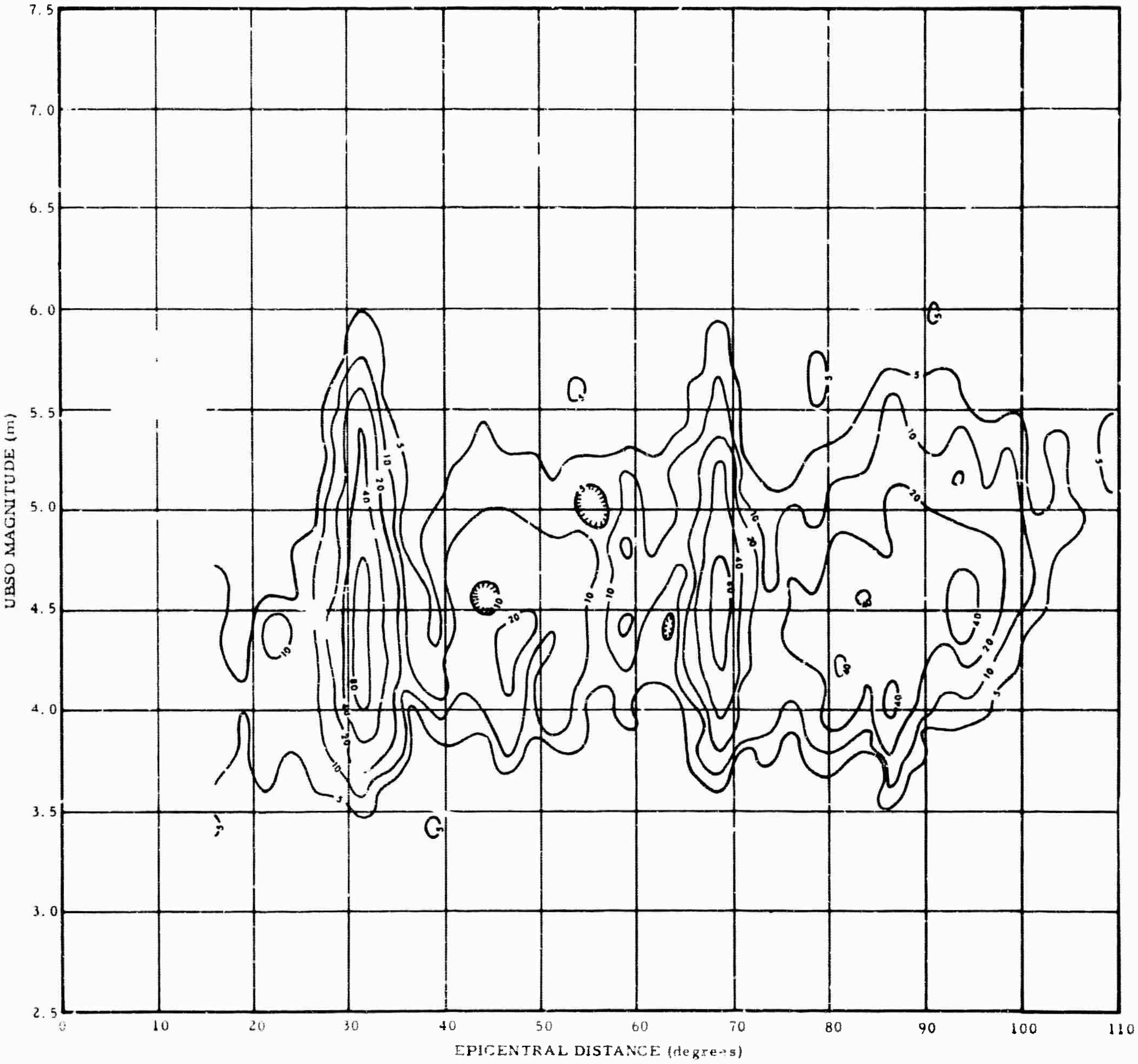


Figure 68a. Number of earthquakes located by the USC&GS from which P phase was recorded at UBSO, as a function of UBSO magnitude and epicentral distance, February 1963 through September 1964

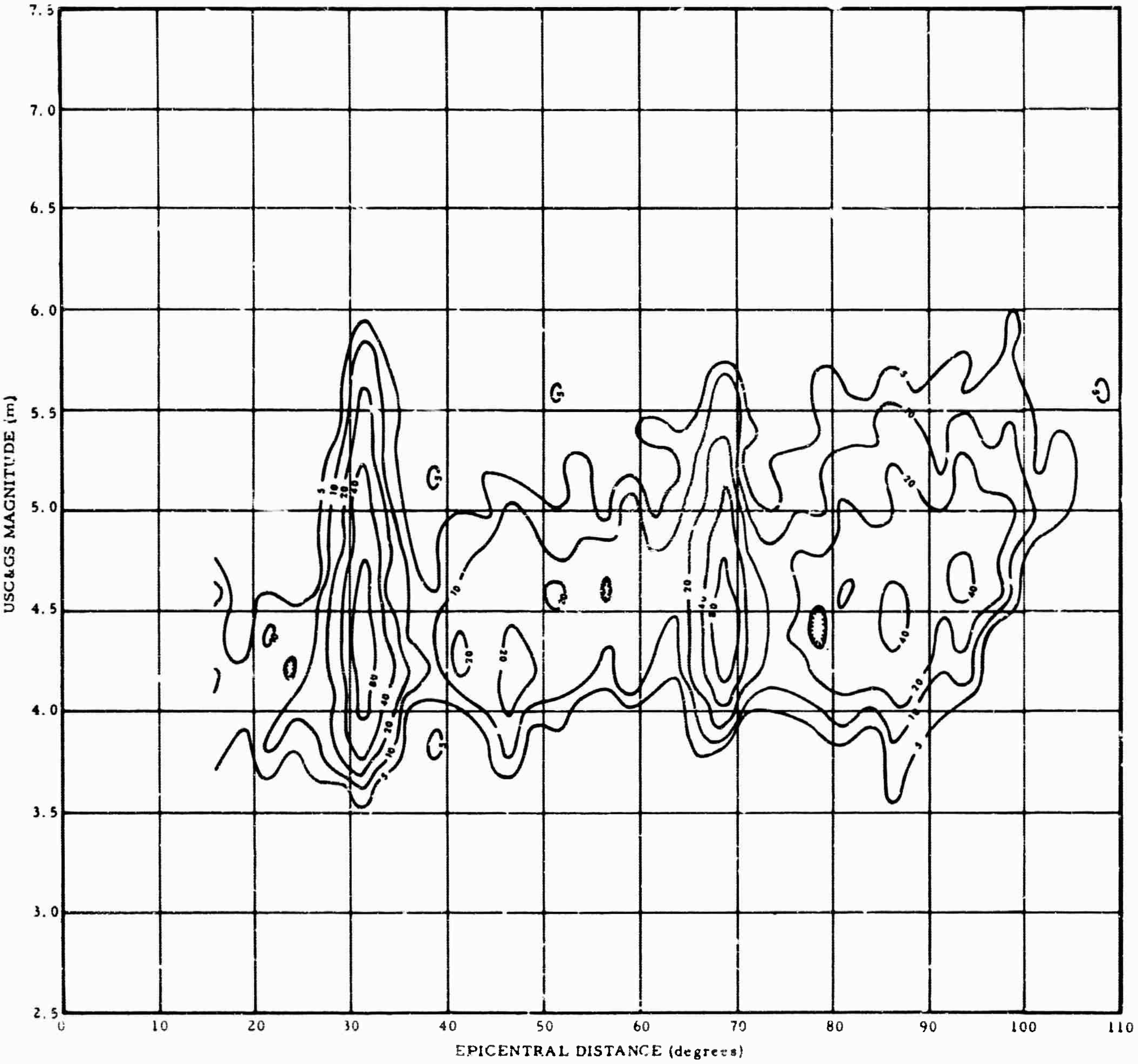


Figure 68b. Number of earthquakes located by the USC&GS from which P phase was recorded at UBSO and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and epicentral distance, February 1963 through September 1964

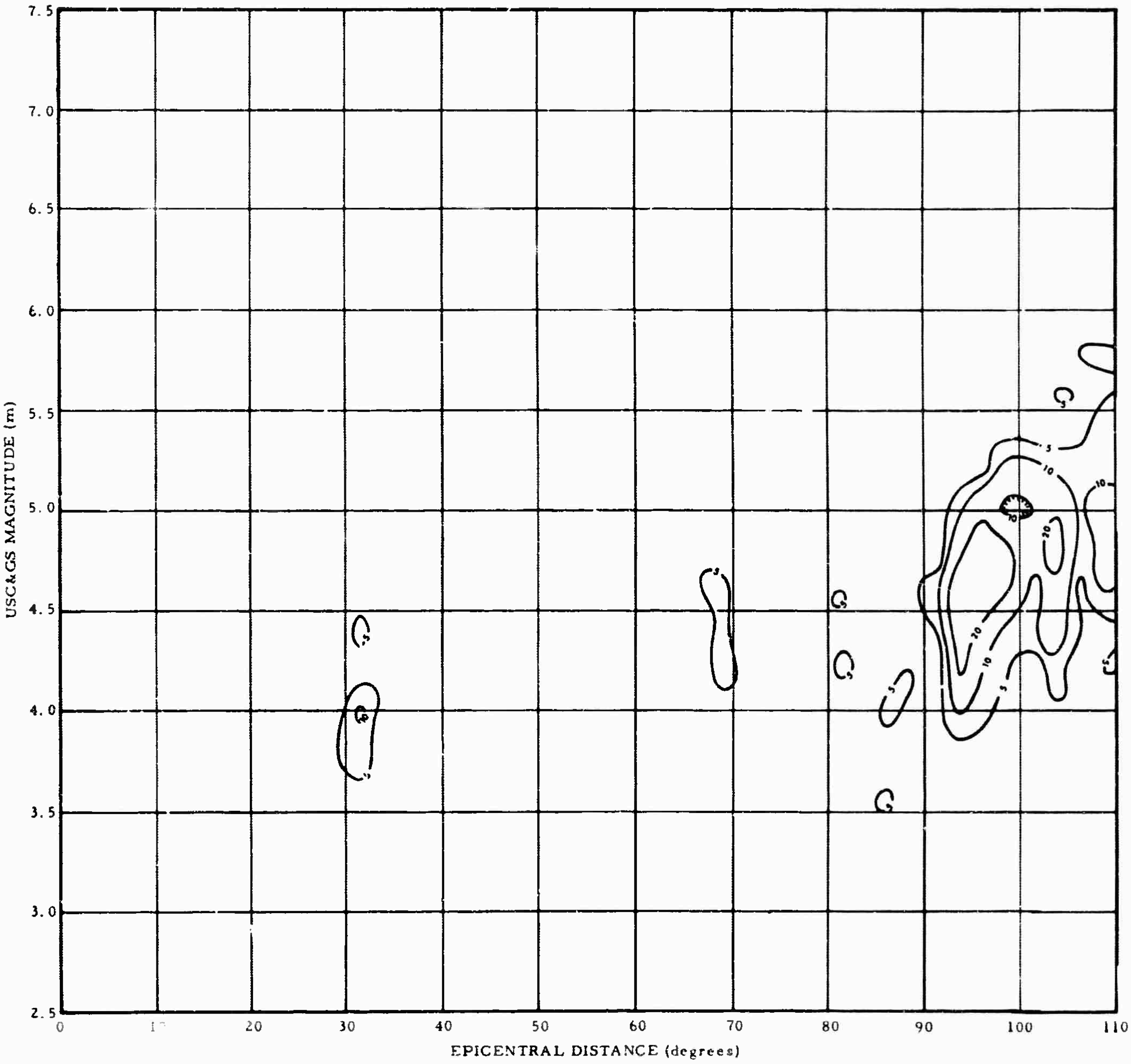


Figure 68c. Number of earthquakes located by the USC&GS from which P phase was not recorded at UBSO and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and epicentral distance, February 1963 through September 1964

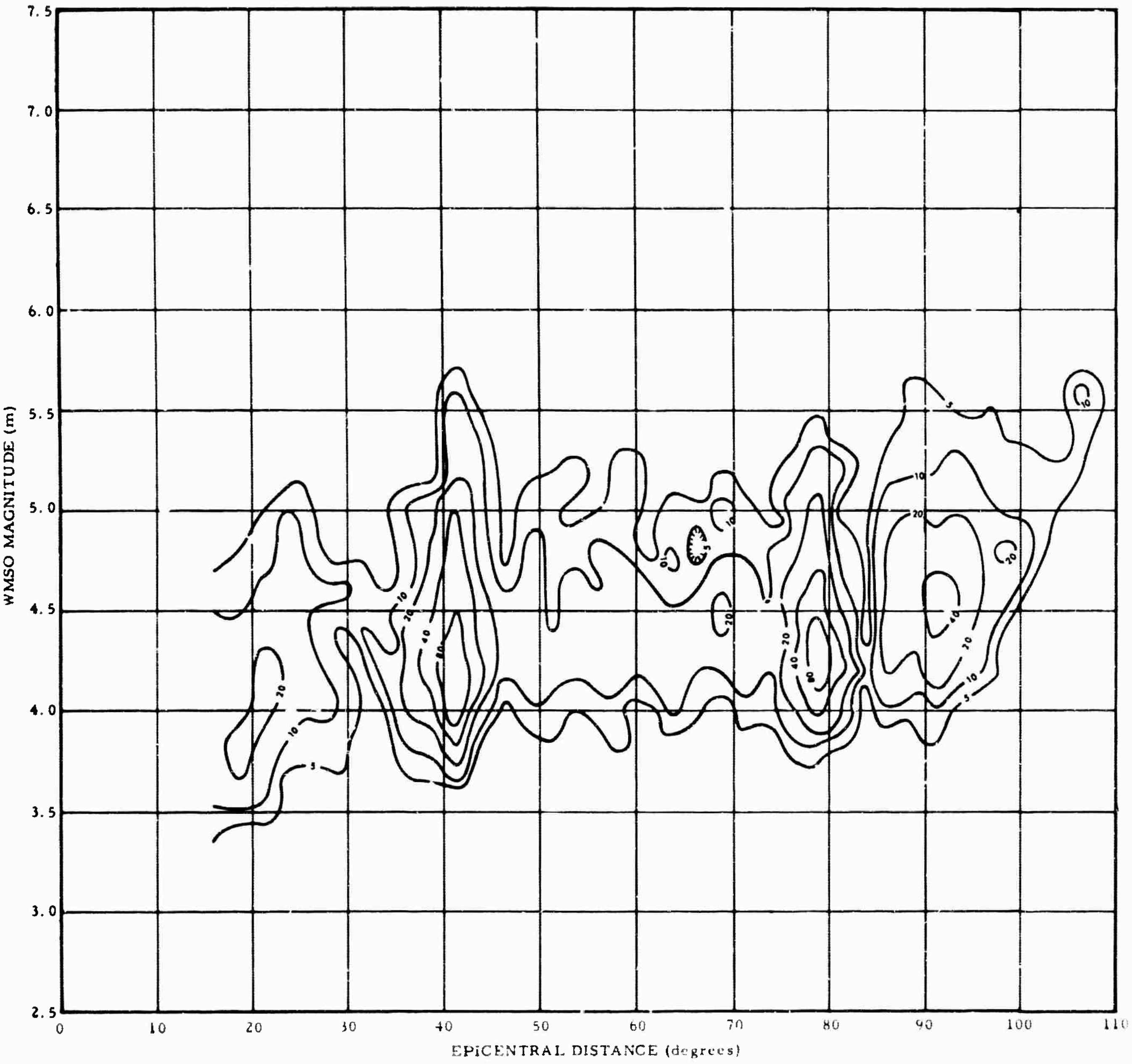


Figure 69a. Number of earthquakes located by the USC&GS from which P phase was recorded at WMSO, as a function of WMSO magnitude and epicentral distance, February 1963 through September 1964

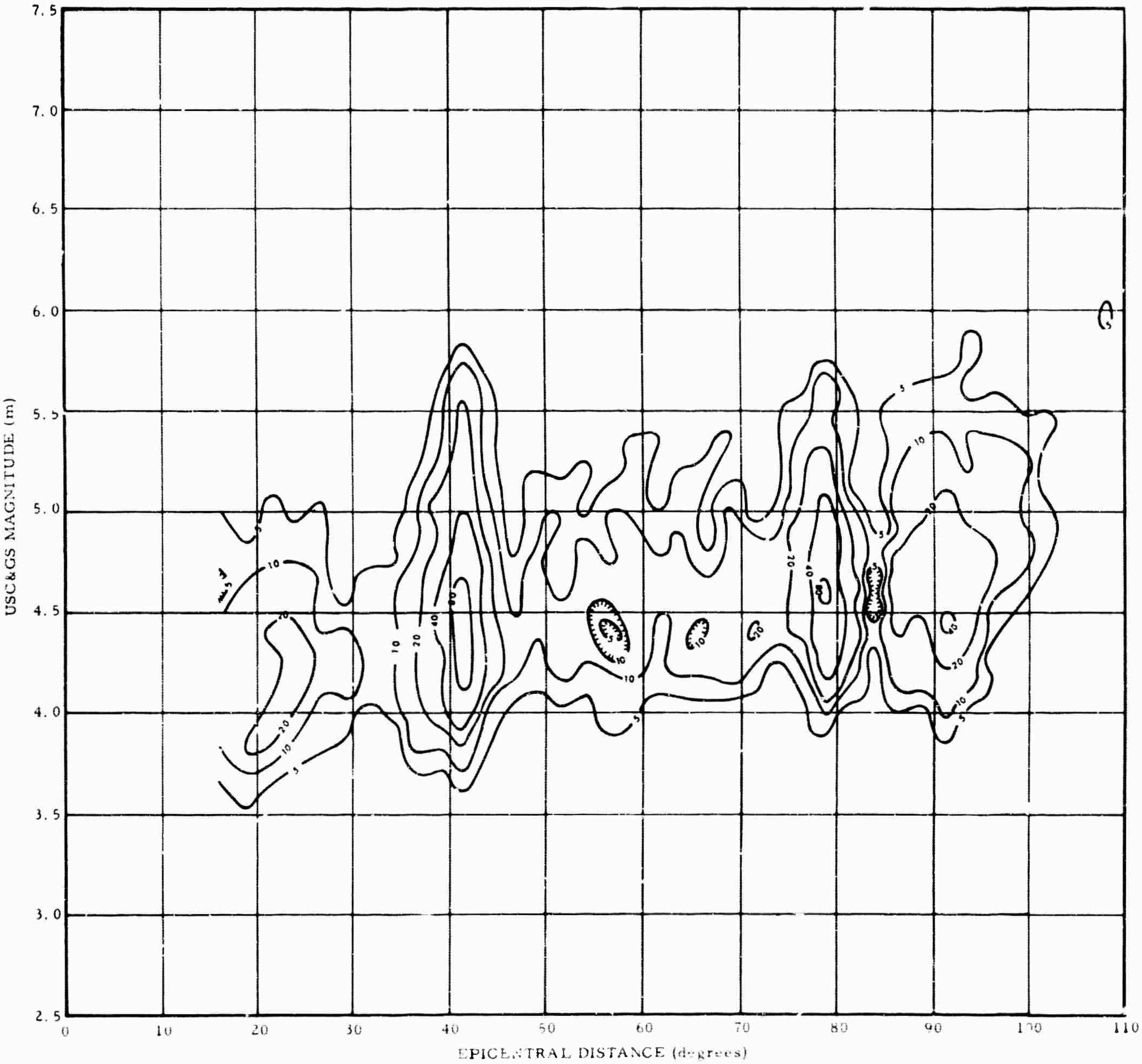


Figure 69b. Number of earthquakes located by the USC&GS from which P phase was recorded at WMSO and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and epicentral distance, February 1963 through September 1964

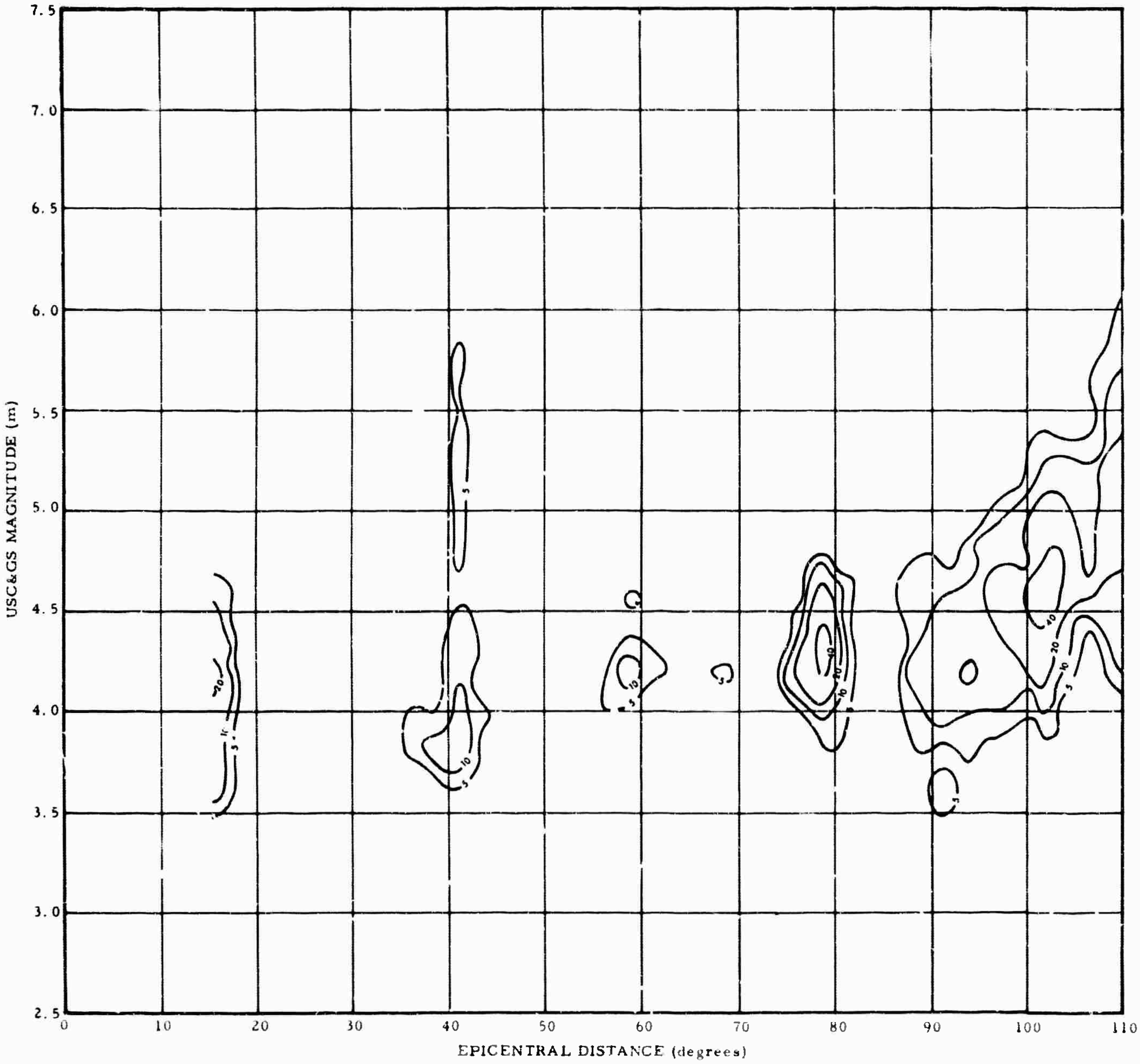


Figure 69c. Number of earthquakes located by the USC&GS from which P phase was not recorded at WMSO and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and epicentral distance, February 1963 through September 1964

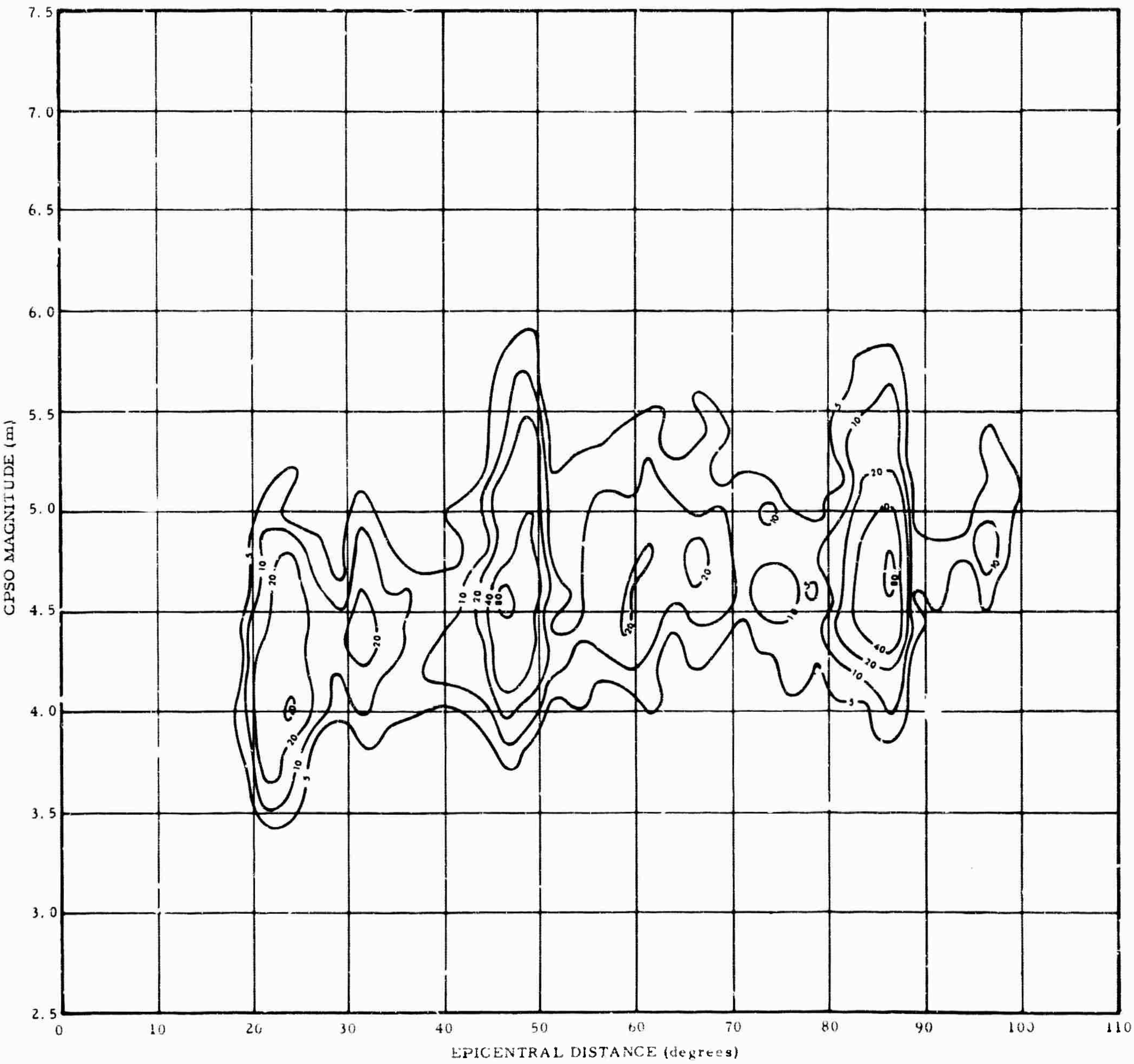


Figure 70a. Number of earthquakes located by the USC&GS from which P phase was recorded at CPSO, as a function of CPSO magnitude and epicentral distance, February 1963 through September 1964

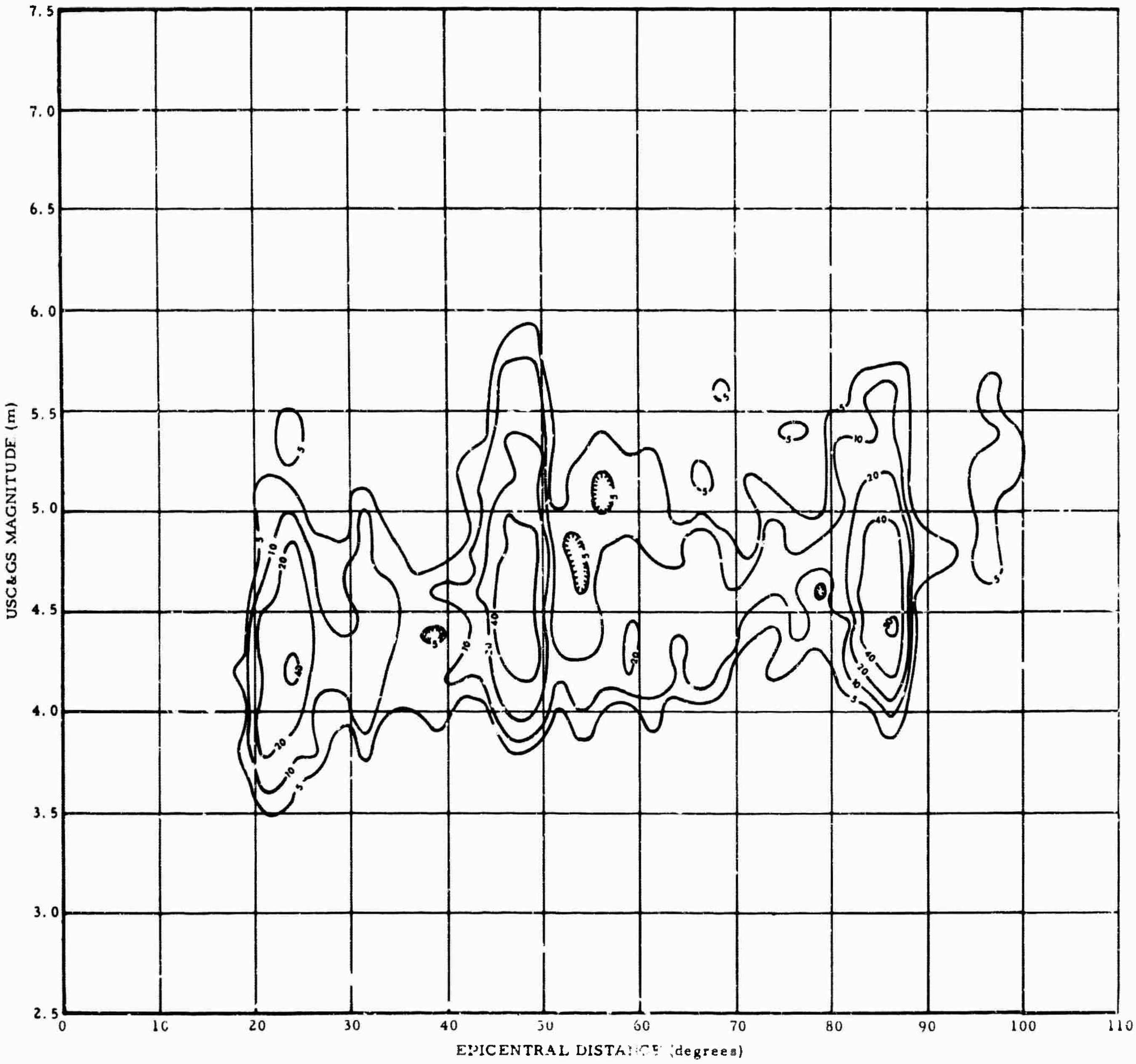


Figure 70b. Number of earthquakes located by the USC&GS from which P phase was recorded at CPSO and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and epicentral distance, February 1963 1 September 1964

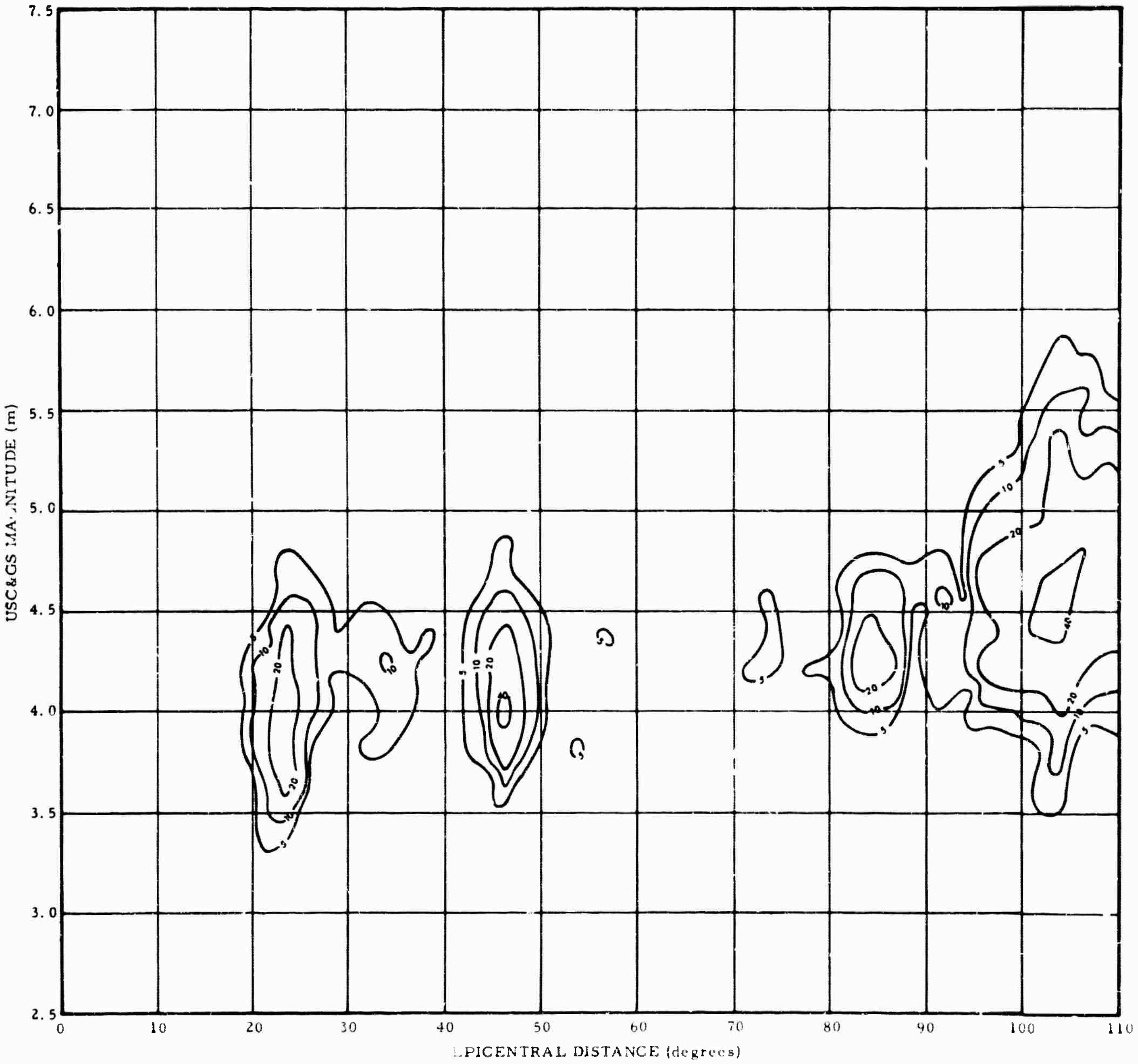


Figure 70c. Number of earthquakes located by the USC&GS from which P phase was not recorded at CPSO and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and epicentral distance, February 1963 through September 1964

## 5.7 PERCENTAGE OF DETECTION OF RAYLEIGH WAVES

Data recorded from February 1963 to August 1964 at BMSO, UBSO, WMSO, CPSO, and TFSO were studied to determine the percentage of Rayleigh waves that are currently being detected. The ratio of number of associated Rayleigh wave detections to the total number of events located by the USC&GS was computed as a function of epicentral distance, USC&GS magnitude, and magnification of the recording instrument. The studv was made with the control data 160-A digital computer.

Figure 72 shows the percentage of Rayleigh waves detected as a function of magnitude for instruments operating at gains of 10K, 20K, and 30K. Figure 73 shows the 50-percent detection level as a function of magnitude and epicentral distance for gains of 10K, 20K, and 30K.

The following conclusions were reached:

a. There is a continuous change in percentage of detection with changing magnitude. Because there is no discontinuity in the detection-percentage curve even at magnitudes less than 4.0, we concluded that small-magnitude earthquakes generate Rayleigh waves.

b. The increase in percentage of detection with increasing magnitude is closer to linear than to exponential.

c. Percentage of detection is relatively insensitive to changes in distance as compared to changes in magnitude. For example, a change in magnitude of 0.2 unit almost always results in a change in percentage of detection. A change of 10 degrees in distance, however, will not result in an appreciable change in percentage of detection.

A full report of this study is included in Geotech TR 65-68.

## 5.8 COMPARISON OF THE DETECTION OF TELESEISMIC P WAVES BY THE DEEP-HOLE, SHALLOW-HOLE, AND SURFACE-ARRAY SEISMOGRAPHS AT UBSO

In April 1964, we received AFTAC Analysis Assignment SEB-3-64 to determine the relative capabilities of the surface-array, deep-hole, and shallow-hole seismographs at UBSO. This has been done and a report of the results is being prepared.

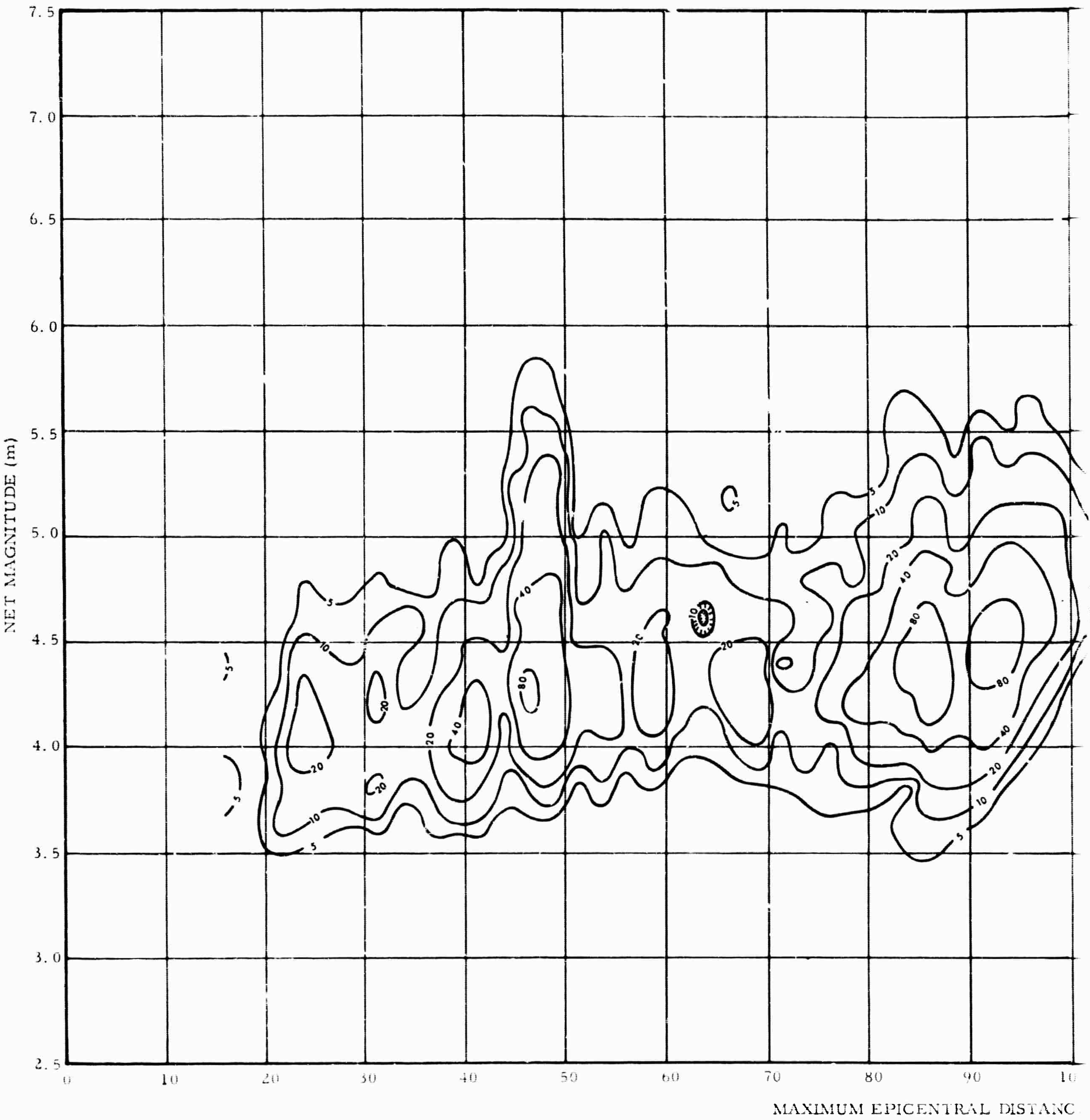


Figure 71a. Number of earthquakes located by the USC&GS from which P phas as a function of net magnitude and maximum epicentral distance at wi February 1963 through September 1

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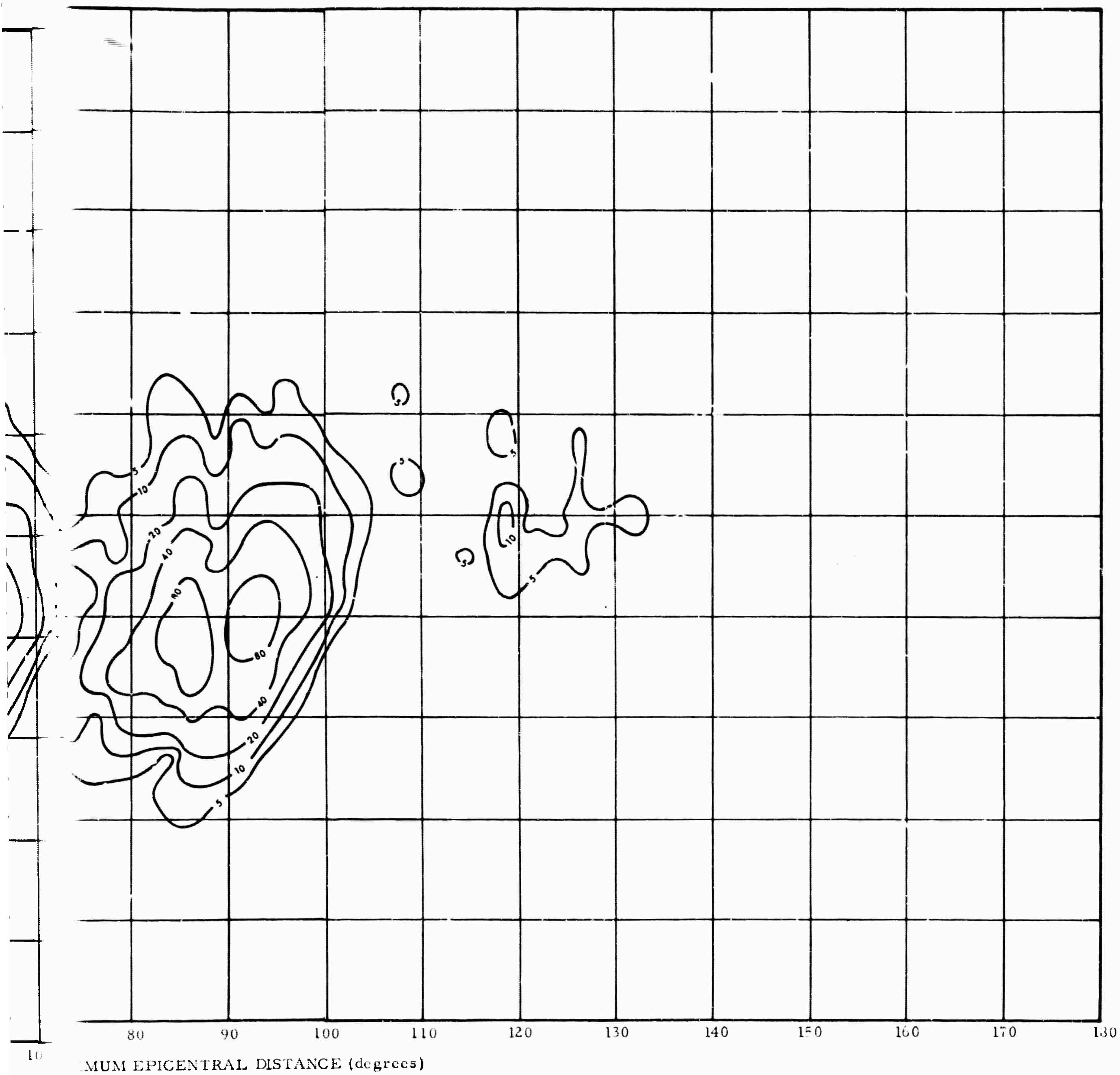

ANC

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&GS from which P phase was recorded by at least one observatory,
epicentral distance at which P or P' phase was recorded,
63 through September 1964

**B**

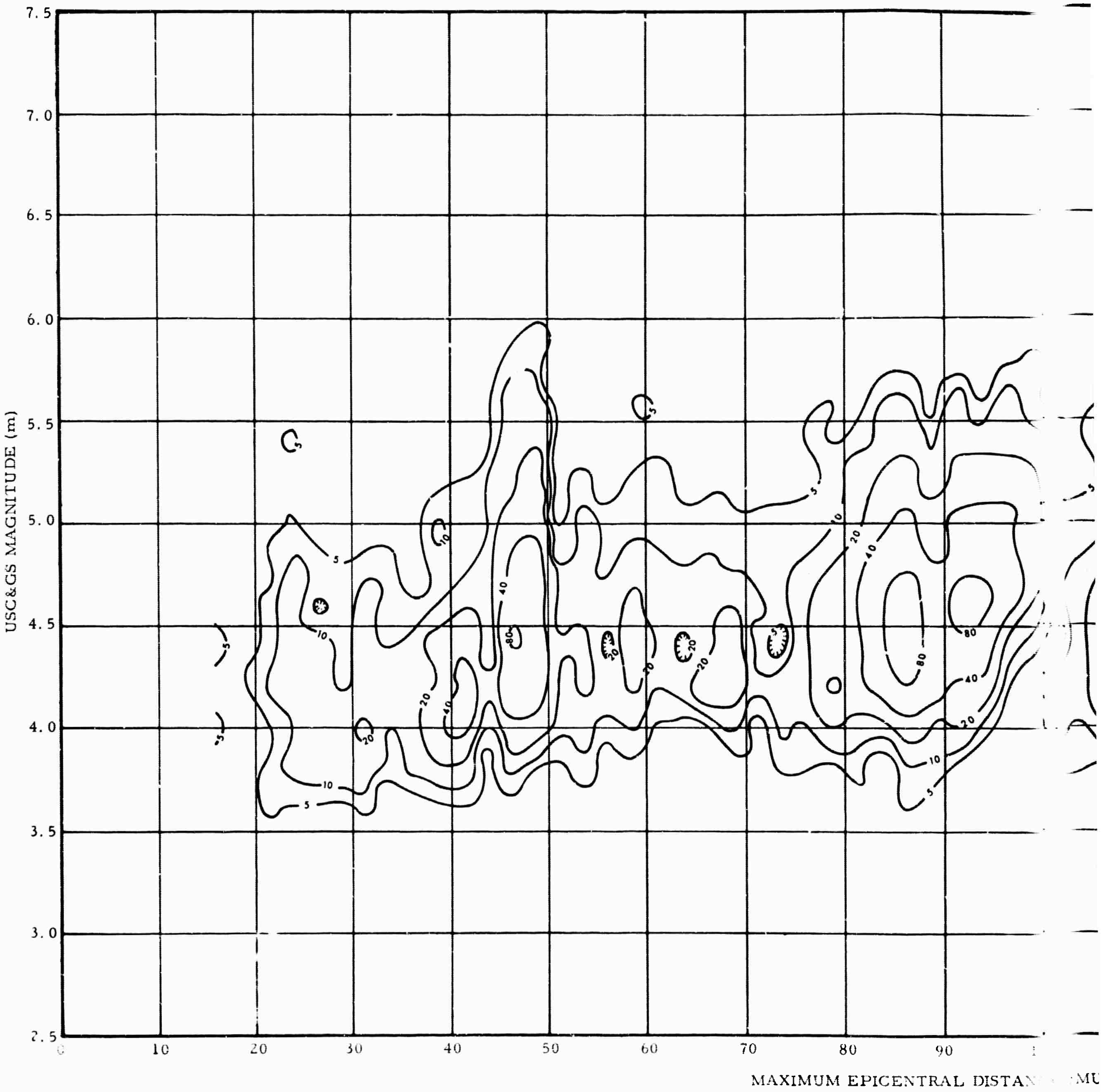

Figure 71b. Number of earthquakes located by the USC&GS from which either
and for which the USC&GS computed a magnitude, as a function of USC&GS
either P or P' phase was recorded, February 19

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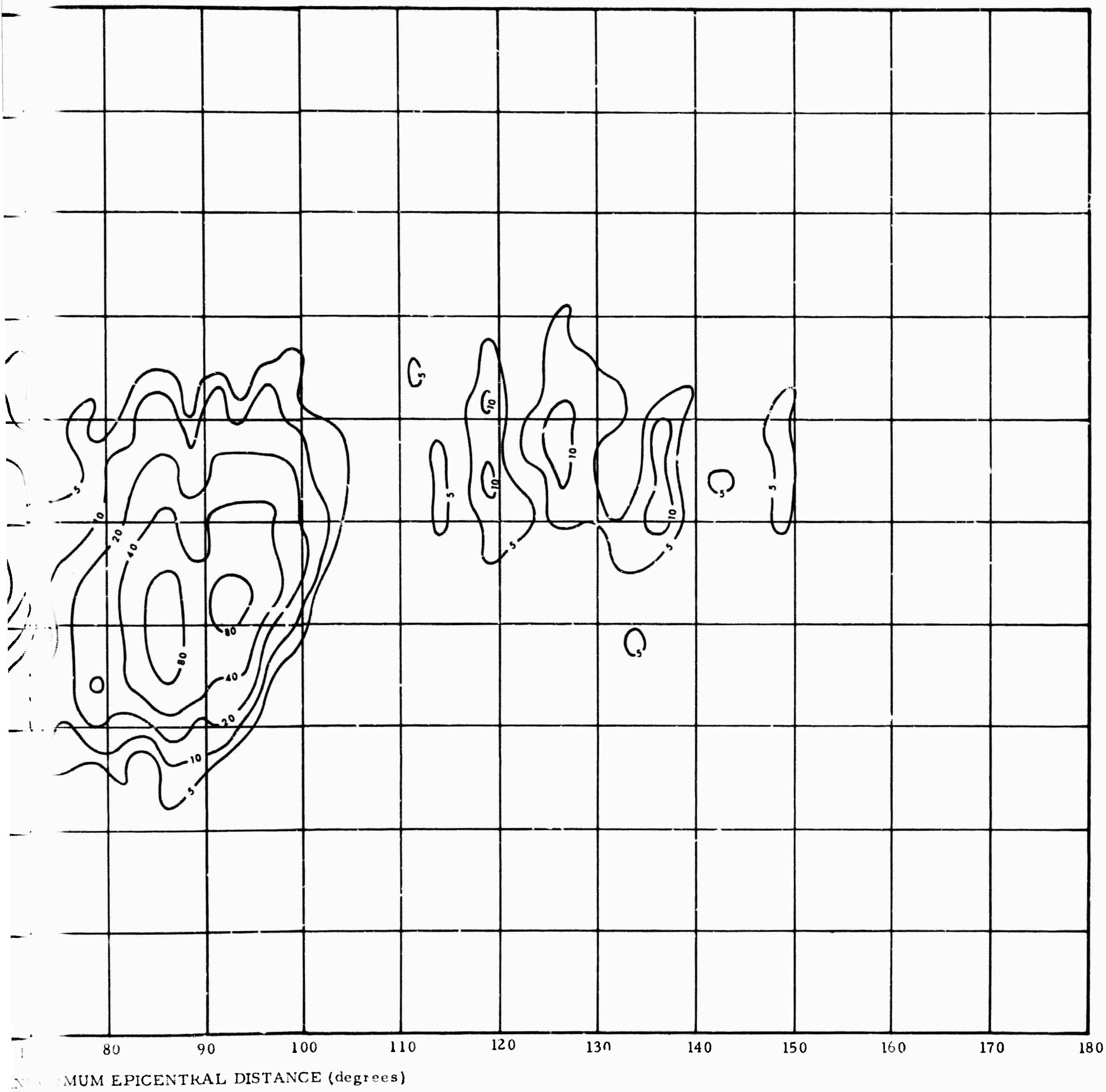

GS from which either P or P' phase was recorded by at least one observatory
function of USC&GS magnitude and maximum epicentral distance at which
ecorded, February 1963 through September 1964

**B**

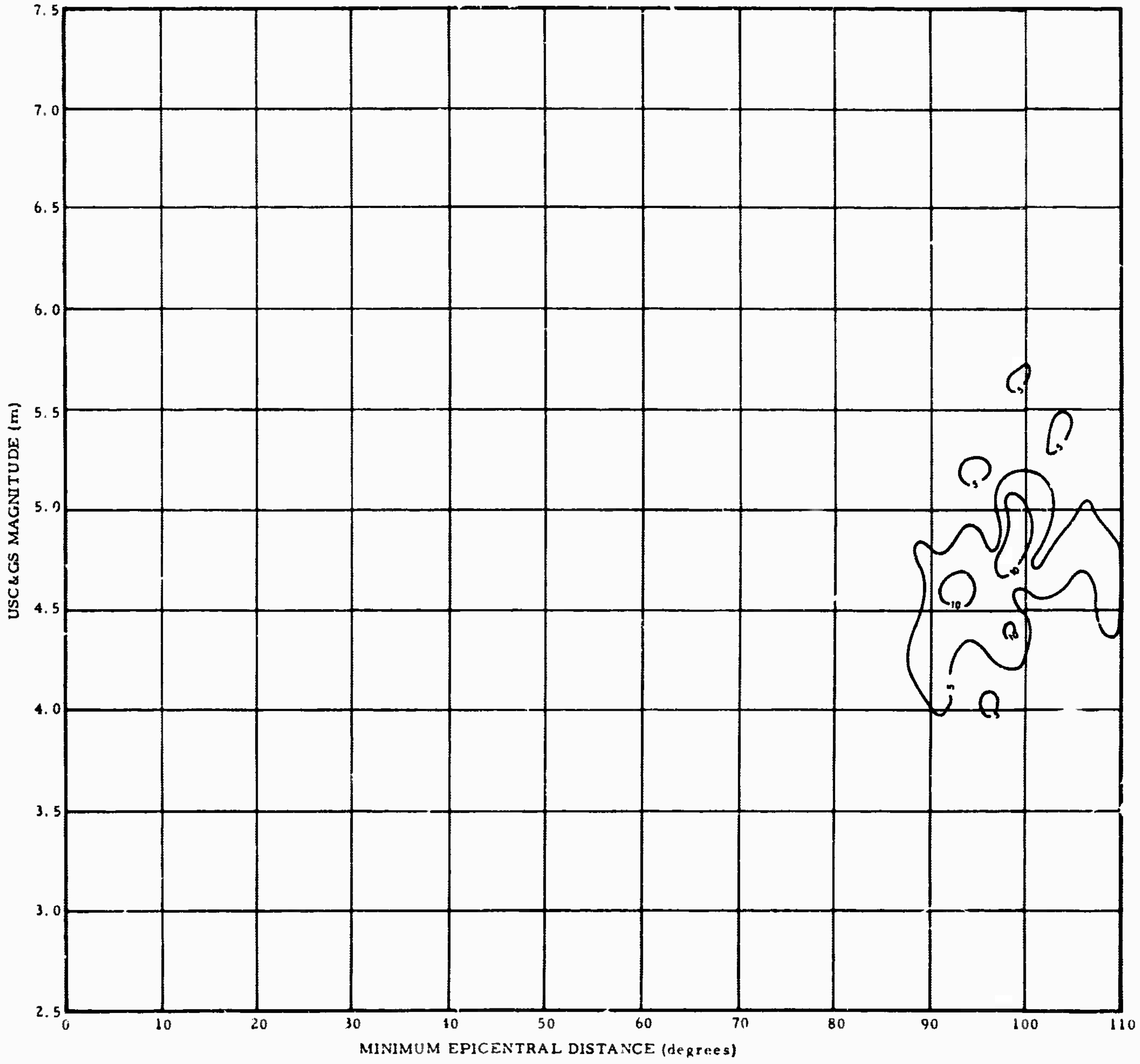

Figure 71c. Number of earthquakes located by the USC&GS from which no observatory recorded a P or P' phase and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and minimum epicentral distance, February 1963 through September 1964

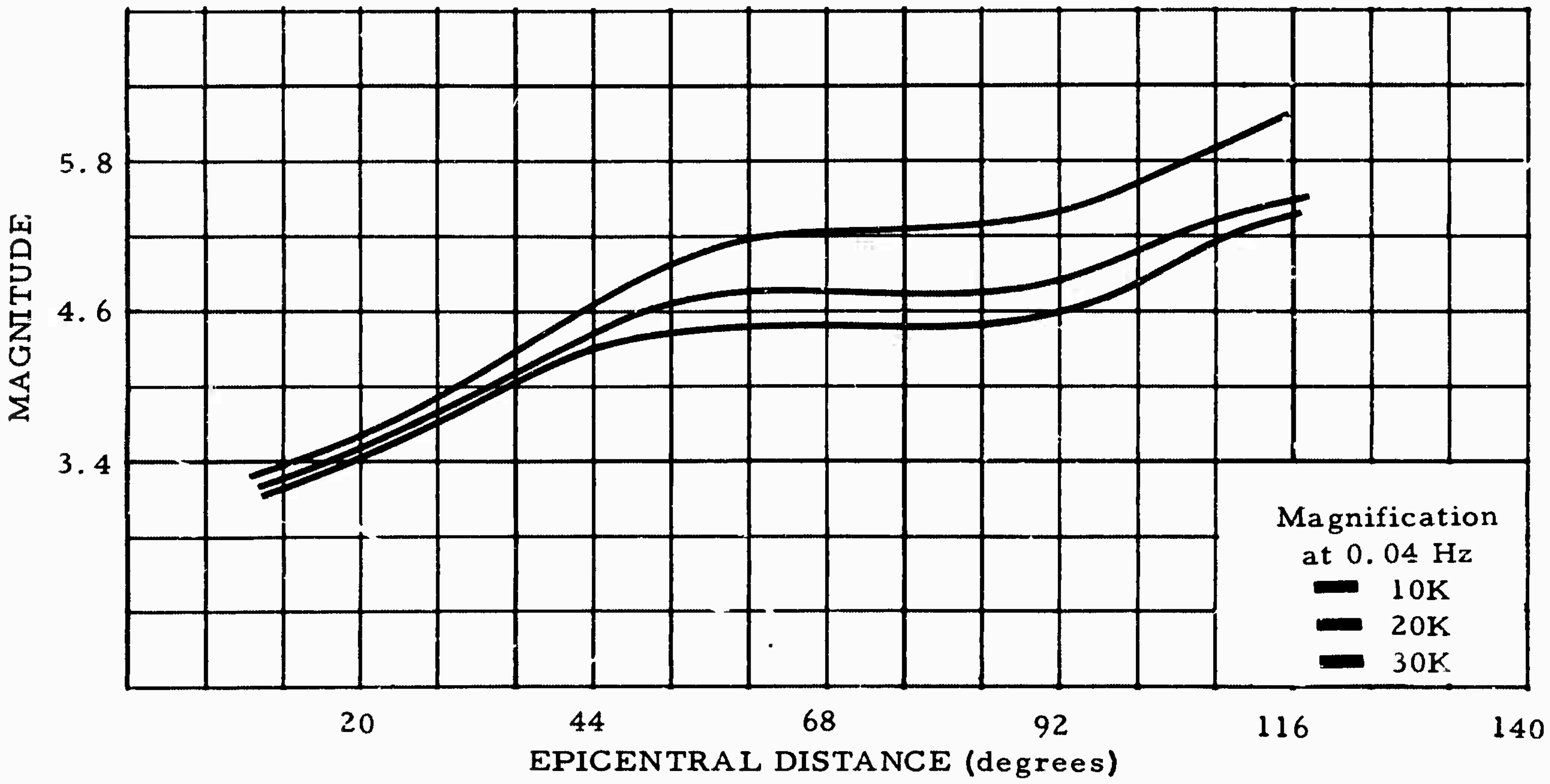

Figure 73. Fifty percent detection level Rayleigh waves

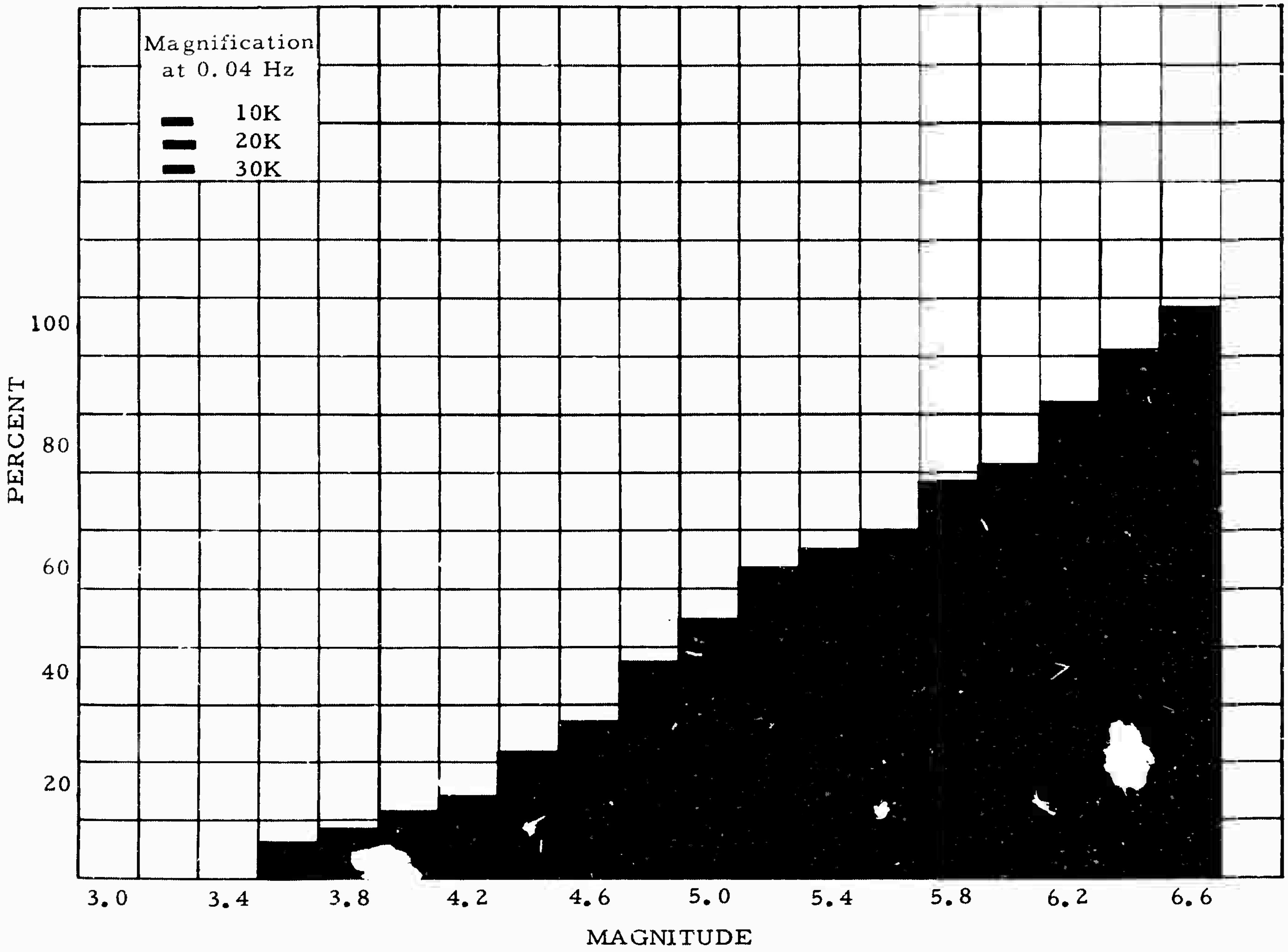

Figure 72. Percent detection of Rayleigh waves

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To evaluate the systems as objectively as possible, a "Geneva Type" evaluation, similar to that reported in section 6.1.4 of TR 63-54, was conducted using UBSO film seismograms recorded between 16 August and 21 September 1964, the time that the deep-hole seismometer was operated at its optimum depth of 2702 meters (8860 feet). In addition to determining the relative capabilities of the three systems, the study was designed to evaluate the following:

a. Relative accuracy of timing first arrivals and agreement among systems in determining direction of first motion;

b. Comparison of magnitude computed from data recorded by each system and magnitudes reported by the USC&GS;

c. Distribution of amplitudes and periods of all teleseismic signals recorded;

d. Comparisons of the signal-to-noise ratios computed from the various systems. For this study the signal-to-noise ratio was defined as the ratio of the maximum amplitude in the first few cycles of the signal to the average amplitude of the microseismic noise at the period of the signal ±0.3 second, during the 10 seconds immediately preceding the arrival of the signal.

e. Comparison of the characteristics of the microseismic noise, both during quiet and windy periods, recorded by each system.

## 5.9 ROUTINE MICROSEISMIC NOISE DATA

The microseismic noise within the period range of 0.4 to 1.4 seconds at BMSO, UBSO, and CPSO was sampled and studied on a routine basis.

Samples of noise were taken every 8 hours. The time of sampling was rotated in such a manner that each hour was sampled 3 or 4 times a month. Data for the maximum pulse in each of three consecutive 5-second intervals were recorded at each sample time. Data consist of the maximum amplitude in the specified period range (measured visually to the nearest 0.5 mm peak-to-peak at X10 view) and the corresponding period (measured to the nearest 0.2 second). Data were collected from each of three short-period seismographs at each station: the vertical component of the three-component system (Z), the summation of the array elements ($\Sigma$T), and the filtered summation ($\Sigma$TF).

The cumulative probability of occurrence of trace amplitude (in millimeters) normalized to the standard operating magnification of the seismograph and observatory and ground displacement (in millimicrons) were computed for each system.

Routine noise data for BMSO and UBSO for September 1963 and January 1964 through February 1965, and for CPSO for September 1963 and March 1964 through February 1965 have been sent to the Project Officer. CPSO data for January and February 1964 are being processed and will be sent during July 1965. In the future, routine noise data will be submitted to the Project Officer routinely.

Curves are presented for trace amplitude at a normalized gain and for ground displacement for each sampled seismograph at each observatory.

Figures 1a through 6c in appendix 8 show cumulative probability of occurrence curves for 12 months' routine data (March 1964-February 1965, inclusive) and curves for the months having maximum and minimum ground displacement on the individual vertical seismograph.

Values of normalized trace amplitude and ground displacement at the 50-percent probability level for January 1964 to March 1965 are given in figures 74 to 76. Minimum values occur during summer or early fall months at all observatories. The high amplitude noise at BMSO in June 1964 is probably related in some way to the spring runoff. This noise recurred in December 1964, and January through March 1965. The maximum trace amplitudes and ground displacements due to microseismic noise occurred in February or March at all three observatories. The minimum noise occurred in May 1964 at UBSO, in June 1964 at CPSO, and in August 1964 at BMSO. The amplitude of microseismic noise indicates a seasonal correlation. The high noise values of October through December 1964 at CPSO occurred when hurricanes and storms passed onto or near the eastern and southeastern coasts of the United States. The maximum at BMSO in February 1965 probably can be correlated with the severe storms and floods that occurred in Oregon at that time.

The distribution of trace amplitude normalized to standard magnification with respect to period within the period range 0.4 to 1.4 seconds was determined for each seismograph at each observatory and data plotted as probability of occurrence at or less than a given amplitude and at a given period (figures 7a through 9c, appendix 8). The data are presented in this form because, in our

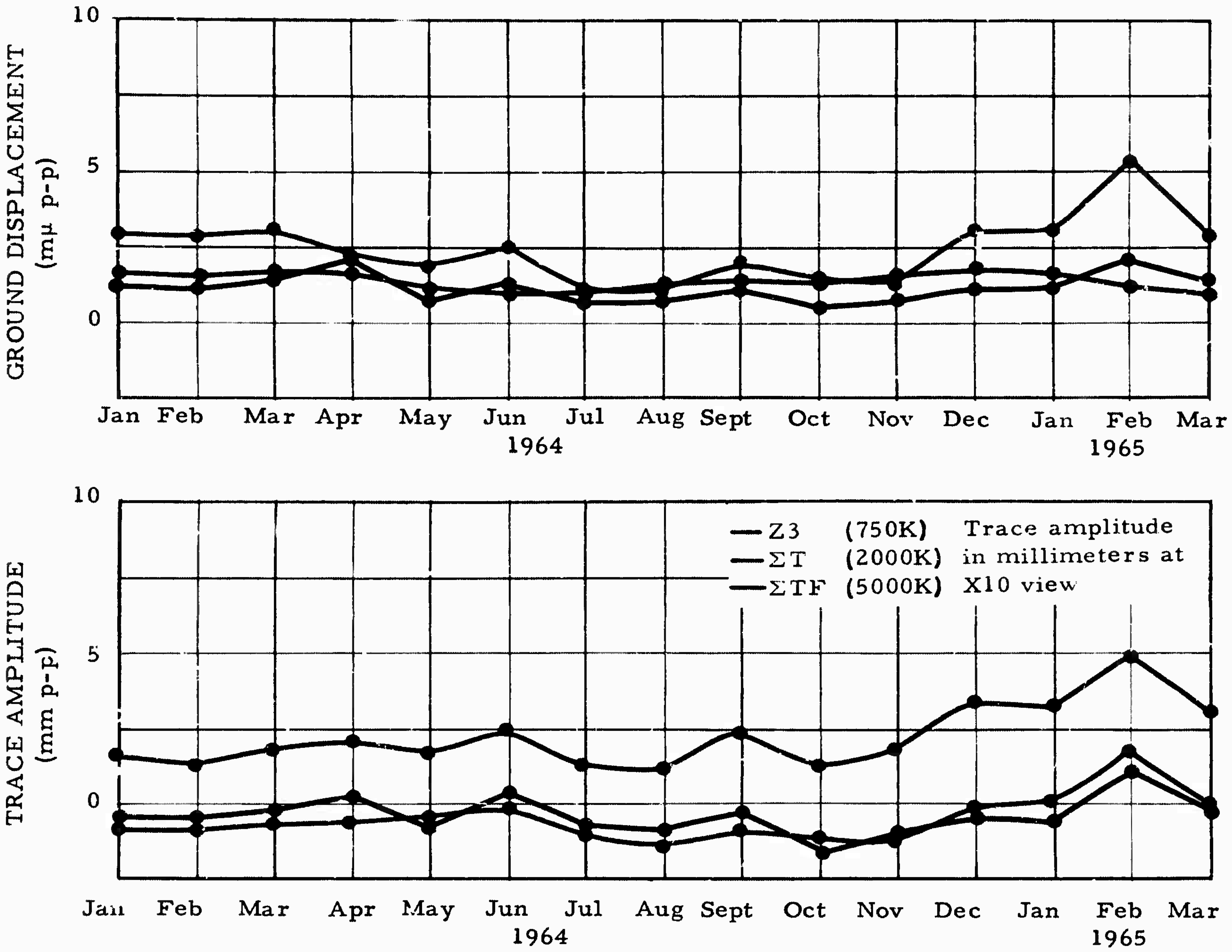

Figure 74. Monthly 50 percent probability level of microseismic noise at BMSO in the period range 0.4 to 1.4 seconds, January 1964 through March 1965

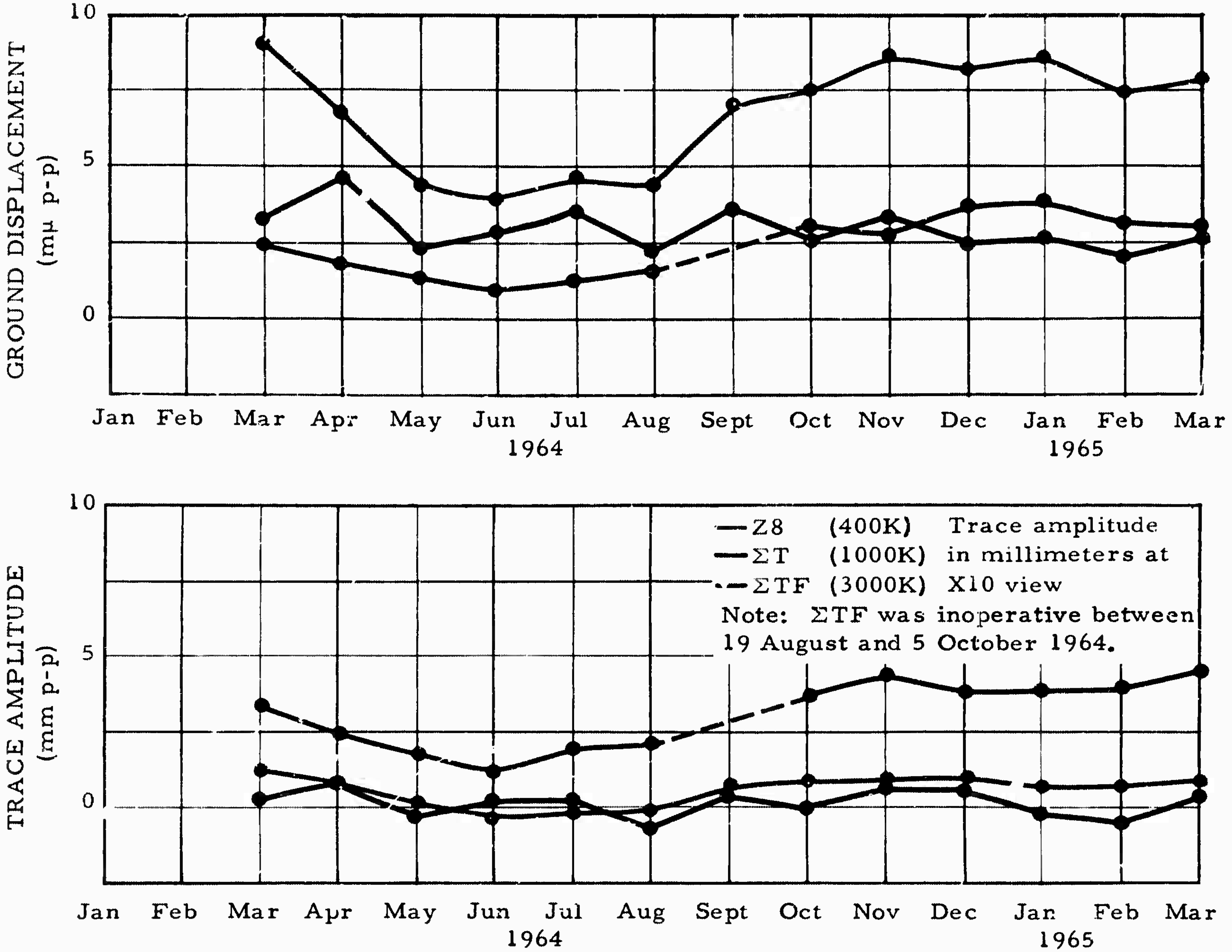

Figure 75. Monthly 50 percent probability level of microseismic noise at CPSO in the period range 0.4 to 1.4 seconds, January 1964 through March 1965

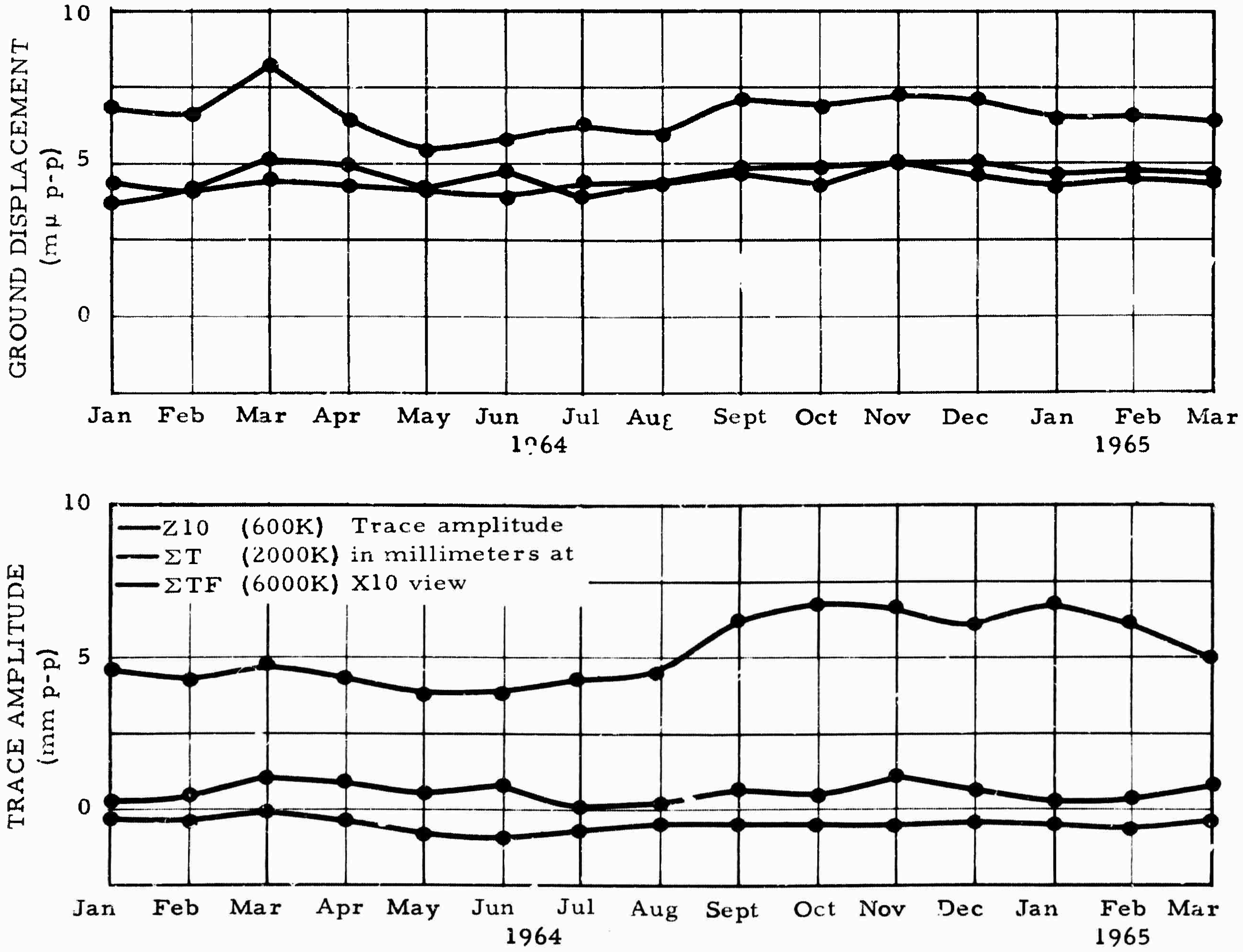

Figure 76. Monthly 50 percent probability level of microseismic noise at UBSO in the period range 0.4 to 1.4 seconds, January 1964 through March 1965

opinion, the detectability of a signal in seismic noise is a function of both the amplitude and period of the signal and noise. This form of presentation preserves the noise period data lost when the data are presented as cumulative probability-of-occurrence curves over the entire period band of interest. We hope that noise data presented in this form coupled with data from the detection capability study will increase understanding of the way in which noise amplitude and period affect the detection of seismic signals.

Discrepancies were found in the reported magnifications for the filtered summation seismographs at UBSO and CPSO. Data prior to 7 August 1964 for the CPSO filtered summation were adjusted and corrected curves were submitted. Only adjusted data were included in material for this report. Data for the filtered summation seismograph at UBSO from 21 August 1964 through 19 February 1965 were erroneous. Corrections of previous data were issued, and only corrected data were used in the preparation of this report. The UBSO data in figure 76 appear anomalous. This indicates that there still may be a residual error in the corrected filtered summation seismograph magnifications used for UBSO during this period of time. The difficulties with these two seismographs are discussed in section 3.4.2.

## 6. REPORTS AND DOCUMENTS PUBLISHED DURING PROJECT VT/1124

Several reports and documents were prepared under Project VT/1124 and submitted to AFTAC. A list of these reports with a brief description of each follows.

a. A letter report on the proposed AFTAC Standardization of Calibration Procedures was sent to AFTAC in August 1963. The report contained comments on and changes recommended to the proposed procedures.

b. Master information block diagrams for each observatory (figures 77, 78, and 79) were submitted to AFTAC late in September 1963 at the request of Mr. Ben Melton. The diagrams showed the array configuration and instrumentation at each observatory. Additions to the instrumentation which were to be made under the contract were also shown.

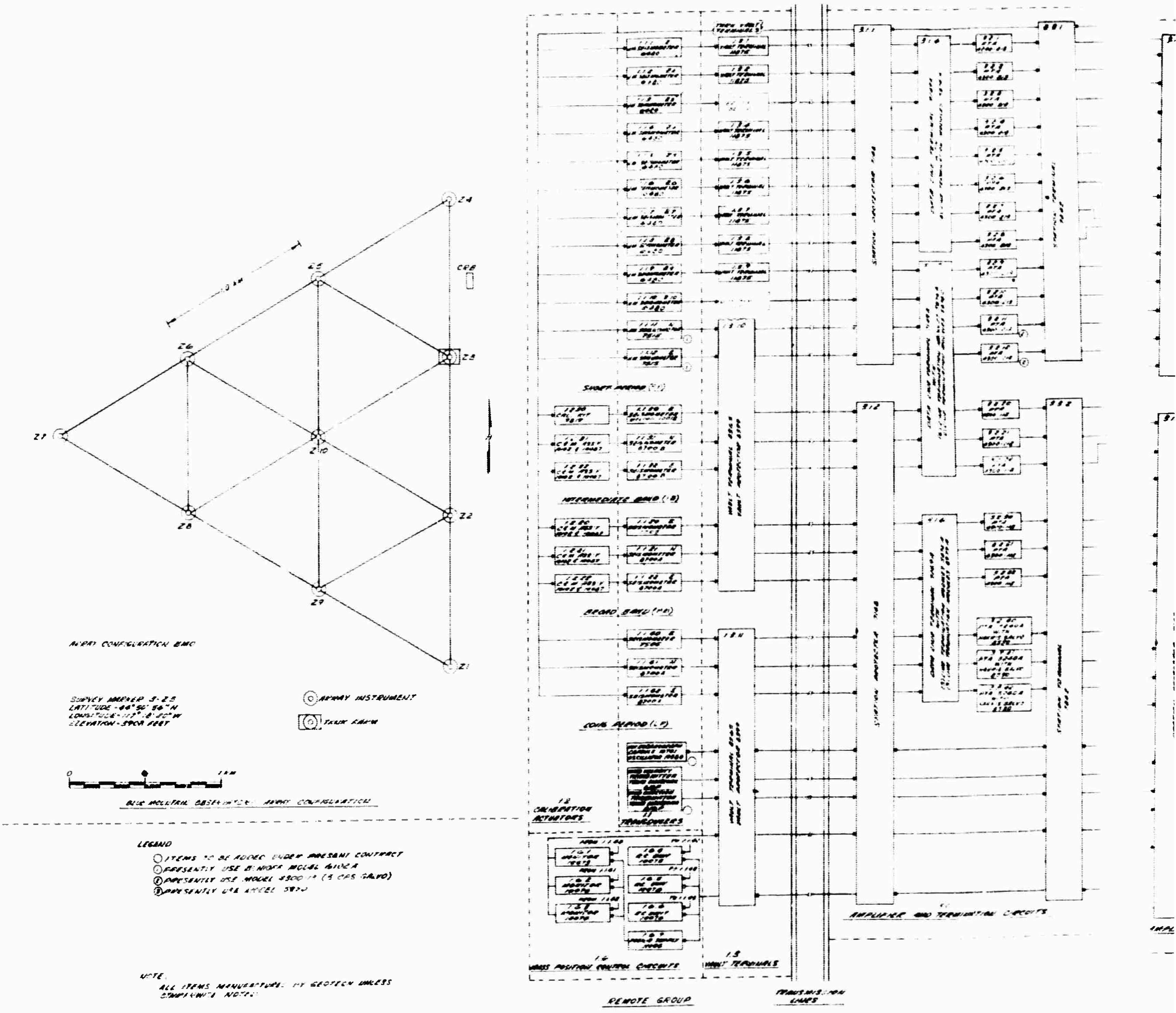

Figure 77. BMSO master information

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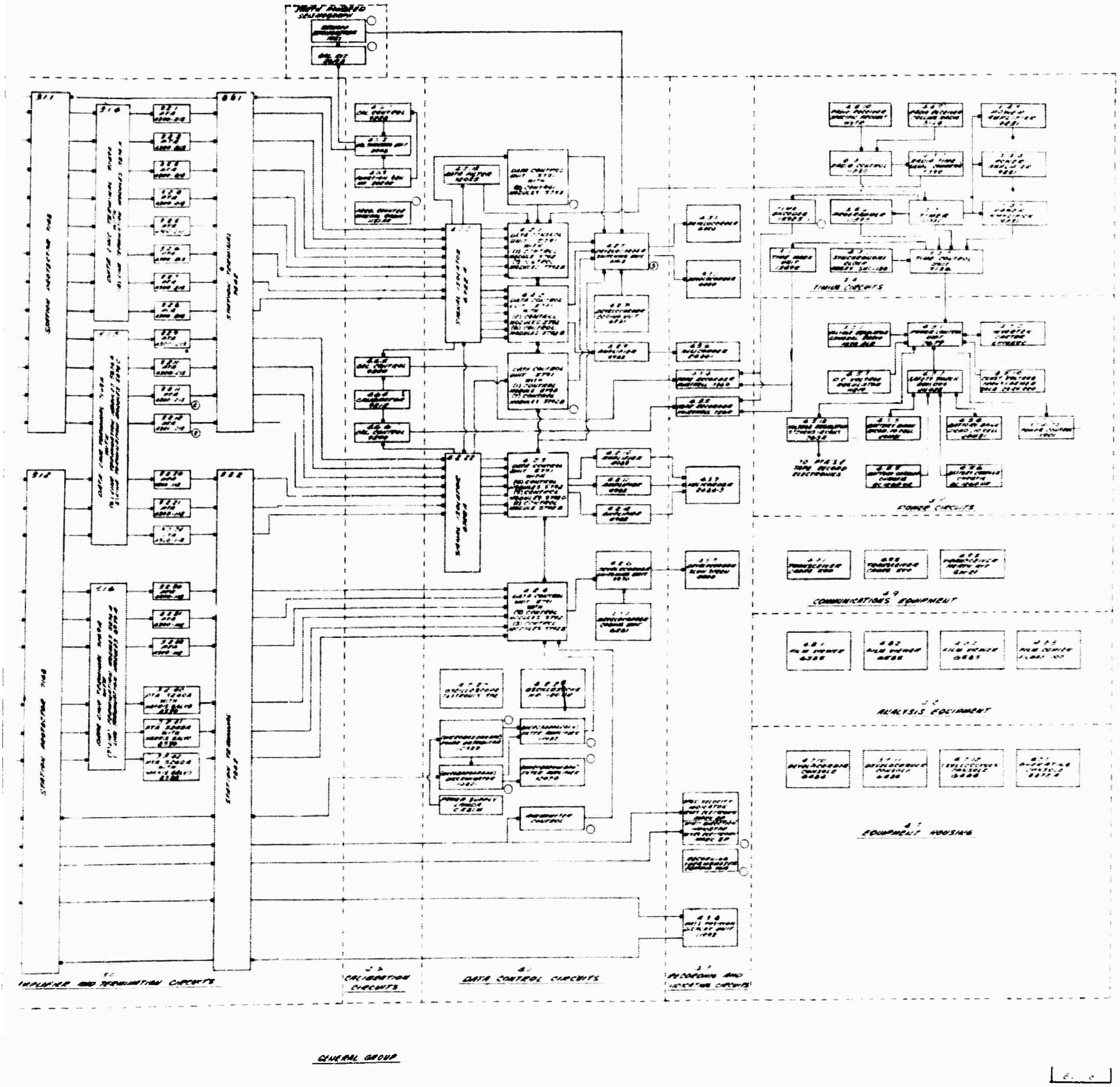

O master information block diagram

B

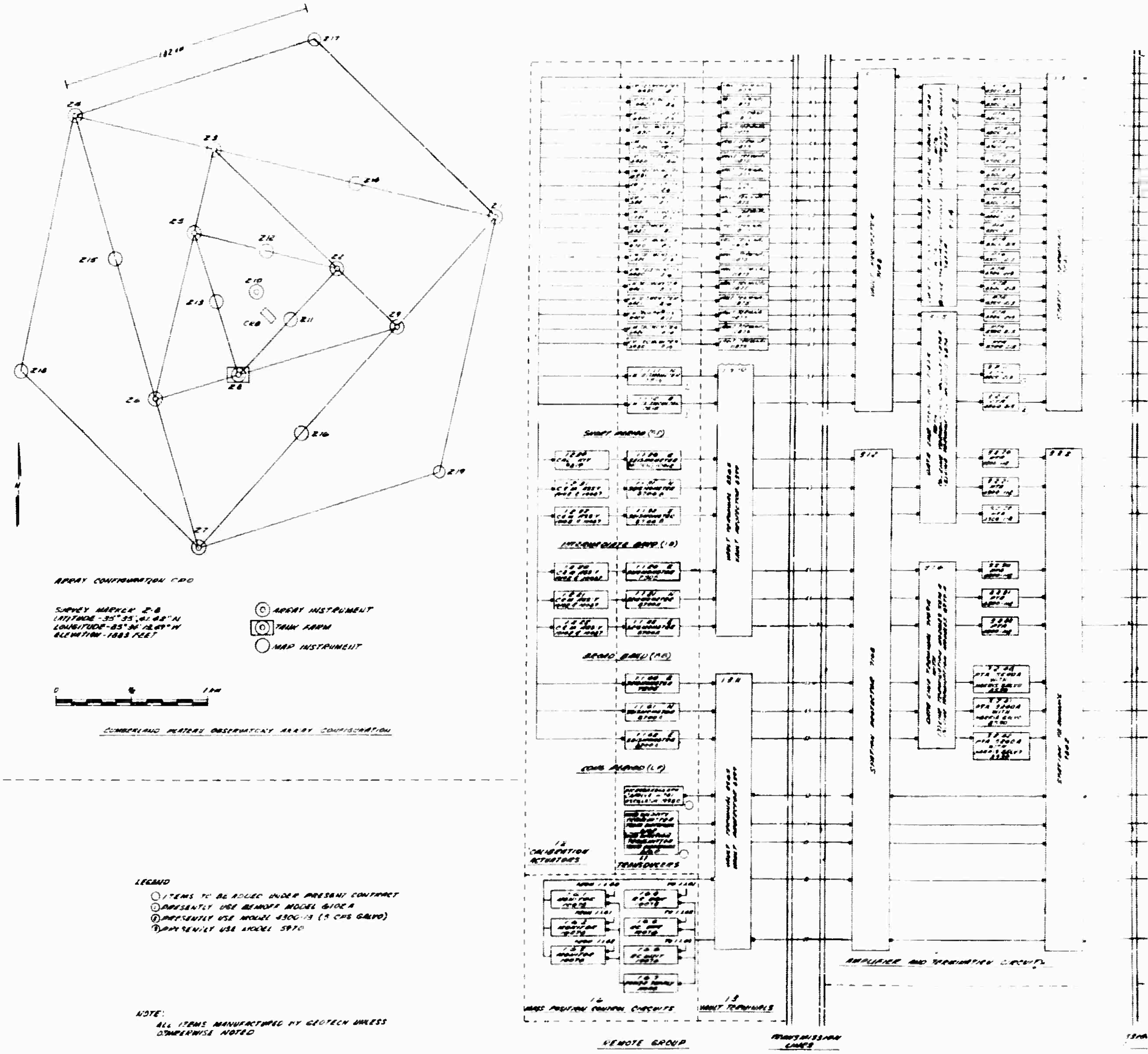

Figure 78. CPSO master informatio

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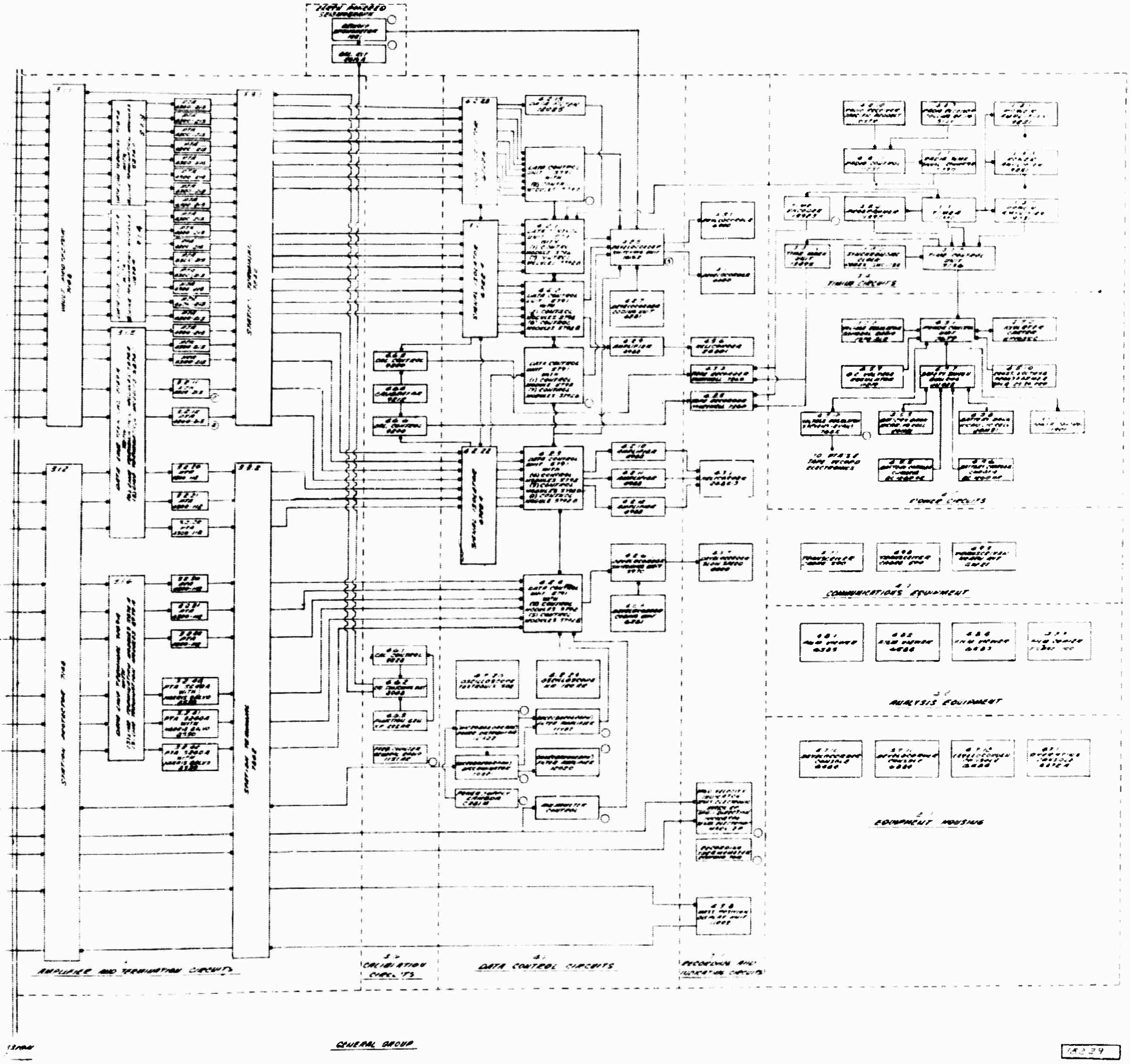

PSO master information block diagram

B

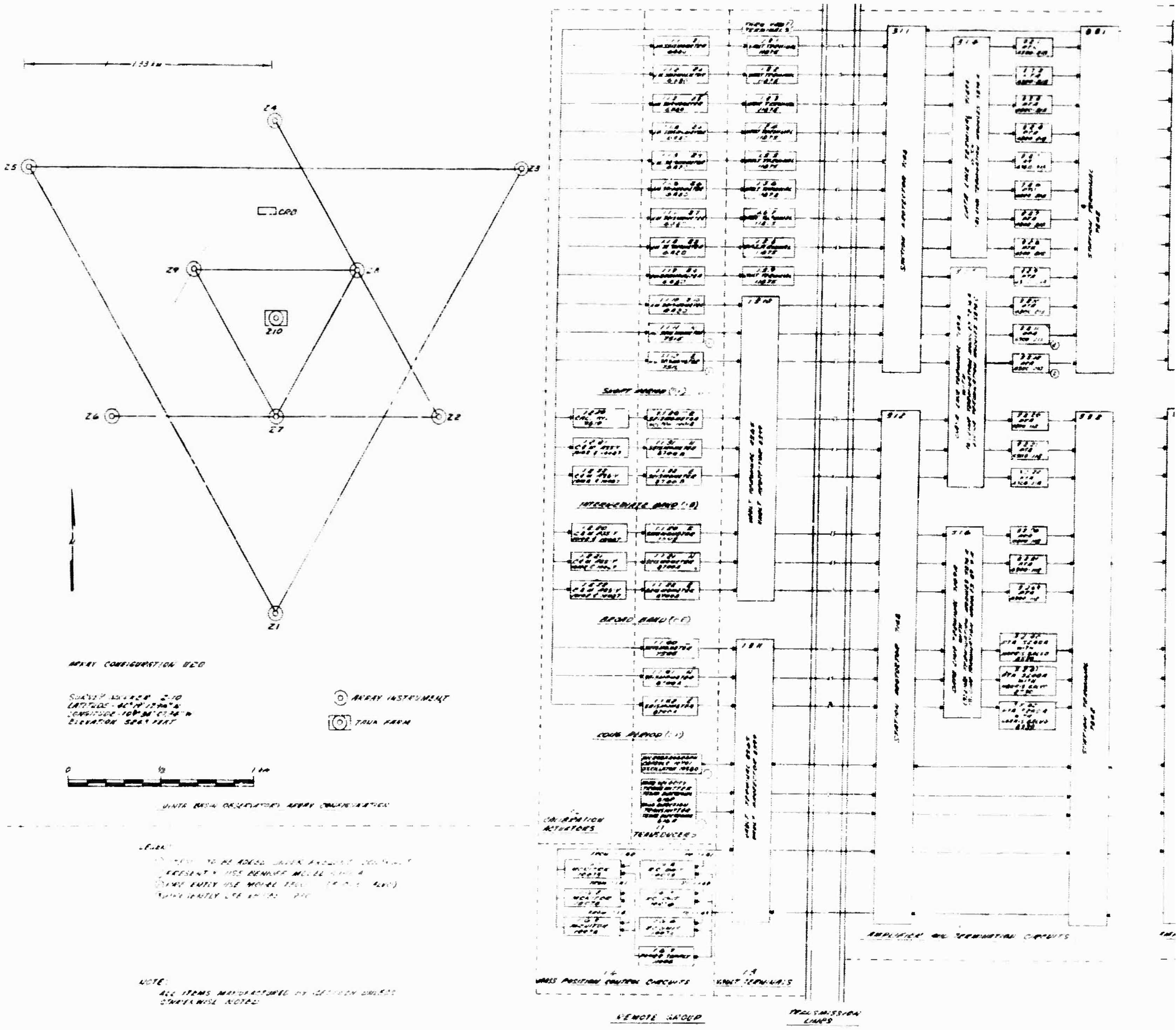

Figure 79. UBSO master informatio

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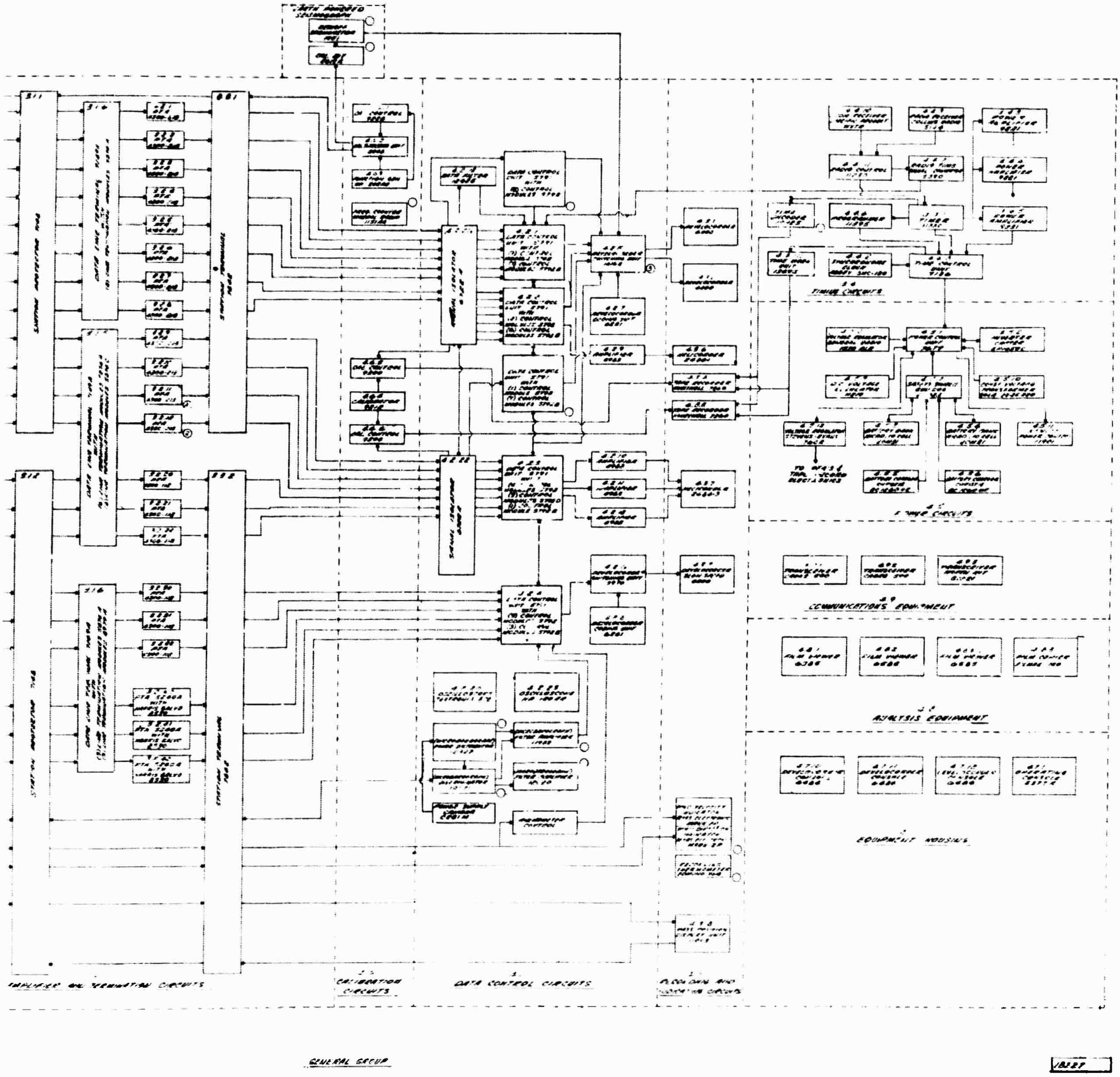


O master information block diagram

**B**

c. A cost estimate for the modification of the design of the Time Encoder, Geotech Model 15925, which was installed at each observatory, was submitted to the Project Officer on 30 October at his request. This was an estimate of the cost of including outputs of date-time management information to allow recording of this information on Develocorders and on magnetic-tape recorders.

d. Geotech's Technical Report No. 63-124, Advantages of Seismic Data Filters, Geotech Models 11760 and 12025, in Preliminary Seismic Analysis, was published under Project VT/036 on 30 December 1963. This report included an evaluation of the filter as used at BMSO, CPSO, and UBSO. Data are presented which demonstrate that the filter effectively attenuated low-frequency background noise. Attenuation of the low-frequency background noise allows the filtered seismographs to be operated effectively at magnifications 2 to 3 times those at which comparable unfiltered seismographs can be operated. The filtered seismograph assists in the detection of low-level teleseismic signals that would probably not be detected on unfiltered seismograms. Figures 80, 81, and 82 illustrate the value of the filtered seismograph at BMSO, CPSO, and UBSO, respectively.

e. Semiannual Report No. 1, Project VT/1124, 1 July through 31 December 1963. Geotech Technical Report No. 64-3 was published on 15 January 1964. The operation of BMSO, CPSO, and UBSO, modifications to the observatory equipment, and plans for special investigations are discussed in this report.

f. A letter report, Deviations in Frequency Response Characteristics of Array Seismographs in Seismological Observatories, was published jointly under Projects VT/036 and VT/1124 in April 1965. Discussed in this report are:

(1) Inequalities in recording characteristics of array seismographs at the VT/1124 and VT/036 observatories;

(2) Past efforts to reduce and minimize these inequalities;

(3) Recommended methods of reducing these inequalities to be tested in the future.

g. Geotech Project Recommendation P-258, Shallow Buried Array at UBSO, was submitted on 4 June 1964. A recommendation to install an array of buried short-period vertical seismographs and a general outline of plans for accomplishing this task at UBSO were included in this document.

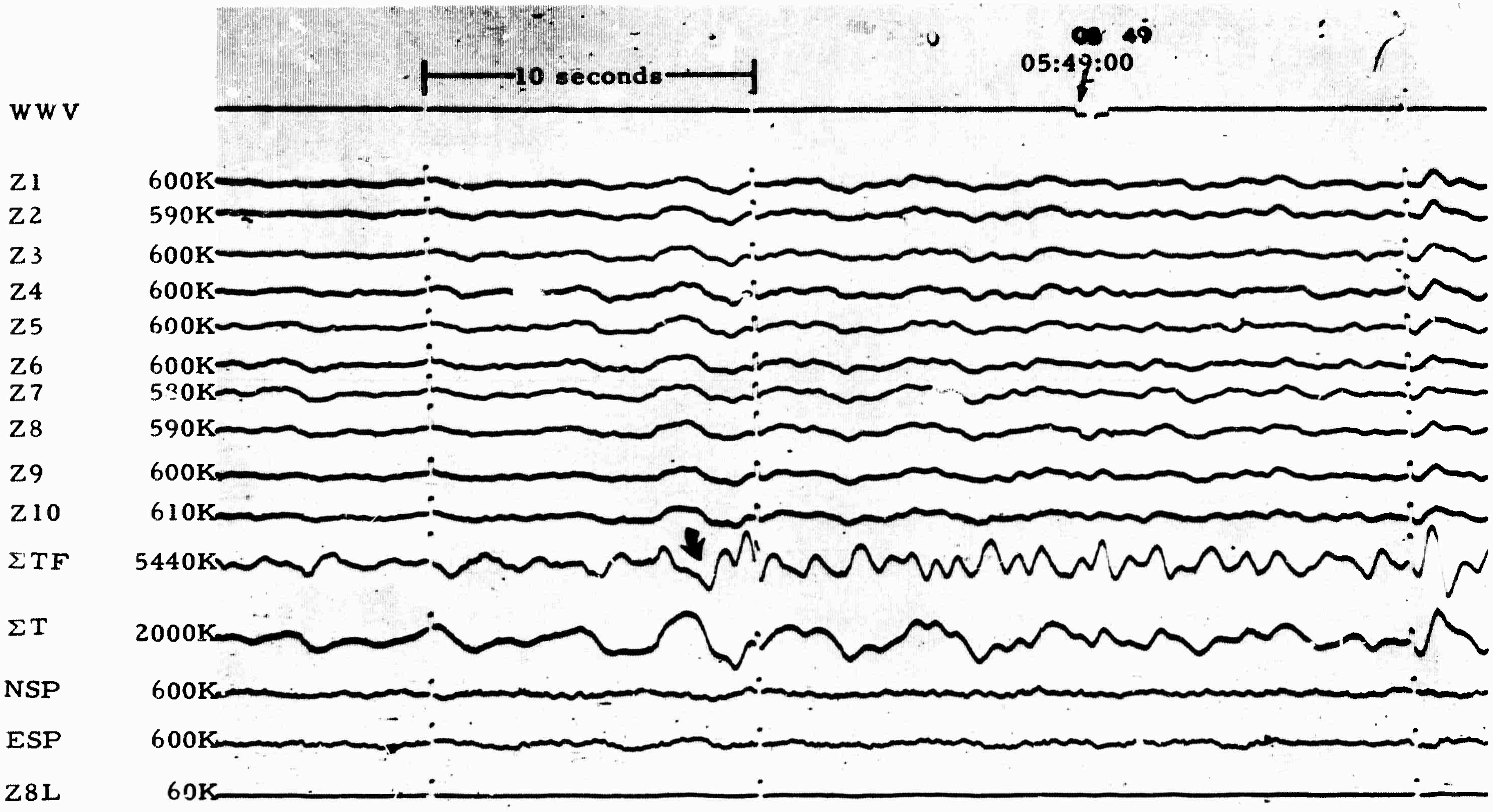
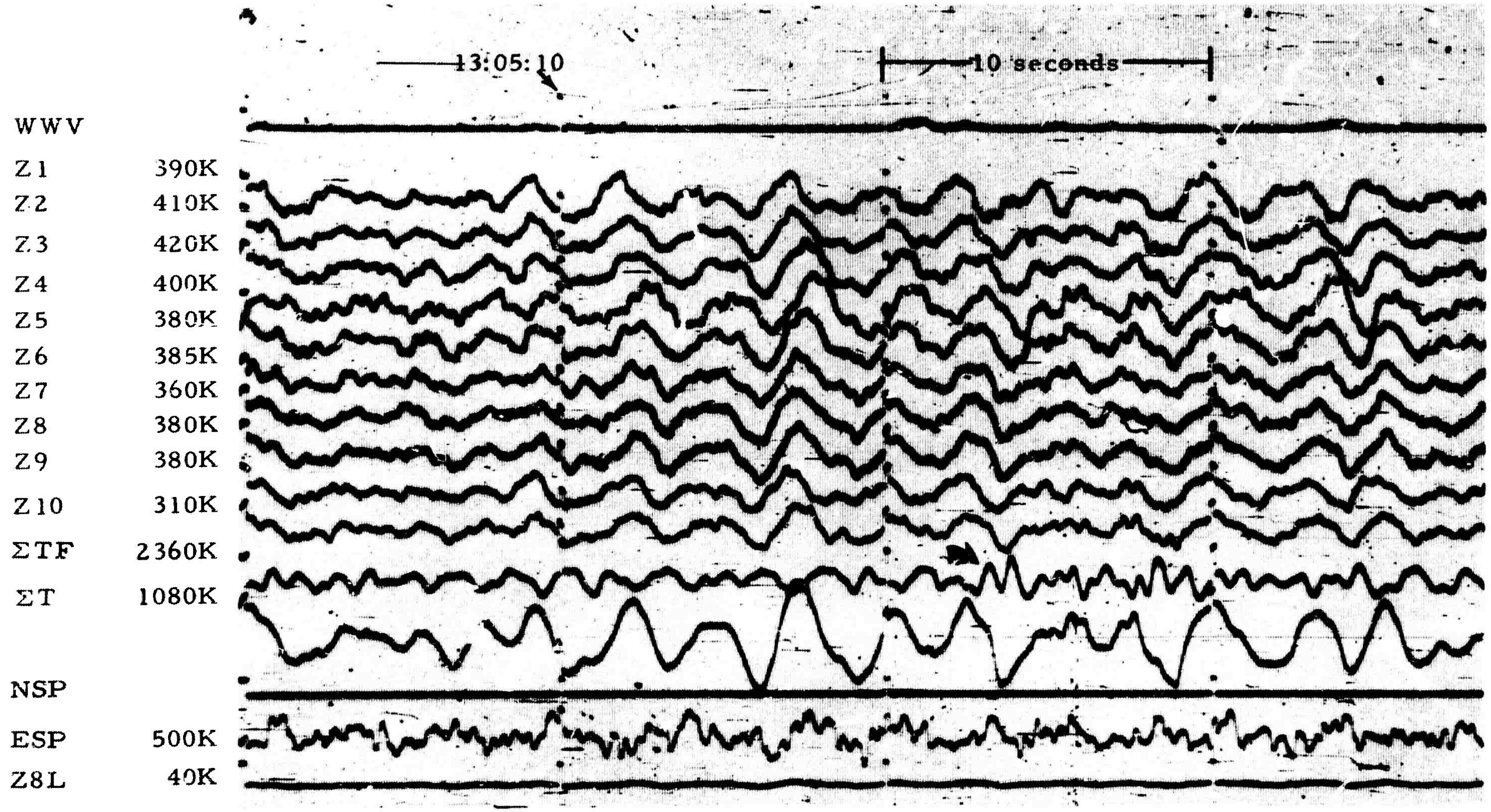


Figure 80. Short-period seismogram from BMSO showing signal enhancement by filtered summation seismograph. Kurile Islands Region, O = 05:38:46.6, $\Delta = 59.2$, $h \simeq 33$ km, $m = 4.4$ (USC&GS). (X10 enlargement of 16-mm film)

BMSO
Run 195
14 July 63



CPSO
Run 227
15 Aug 63

Figure 81. Short-period seismogram from CPSO illustrating signal masked by microseismic background noise on elements of array. Note attenuation of the microseisms and enhancement of signal on the filtered summation seismogram. Epicenter unknown. (X10 enlargement of 16-mm film)

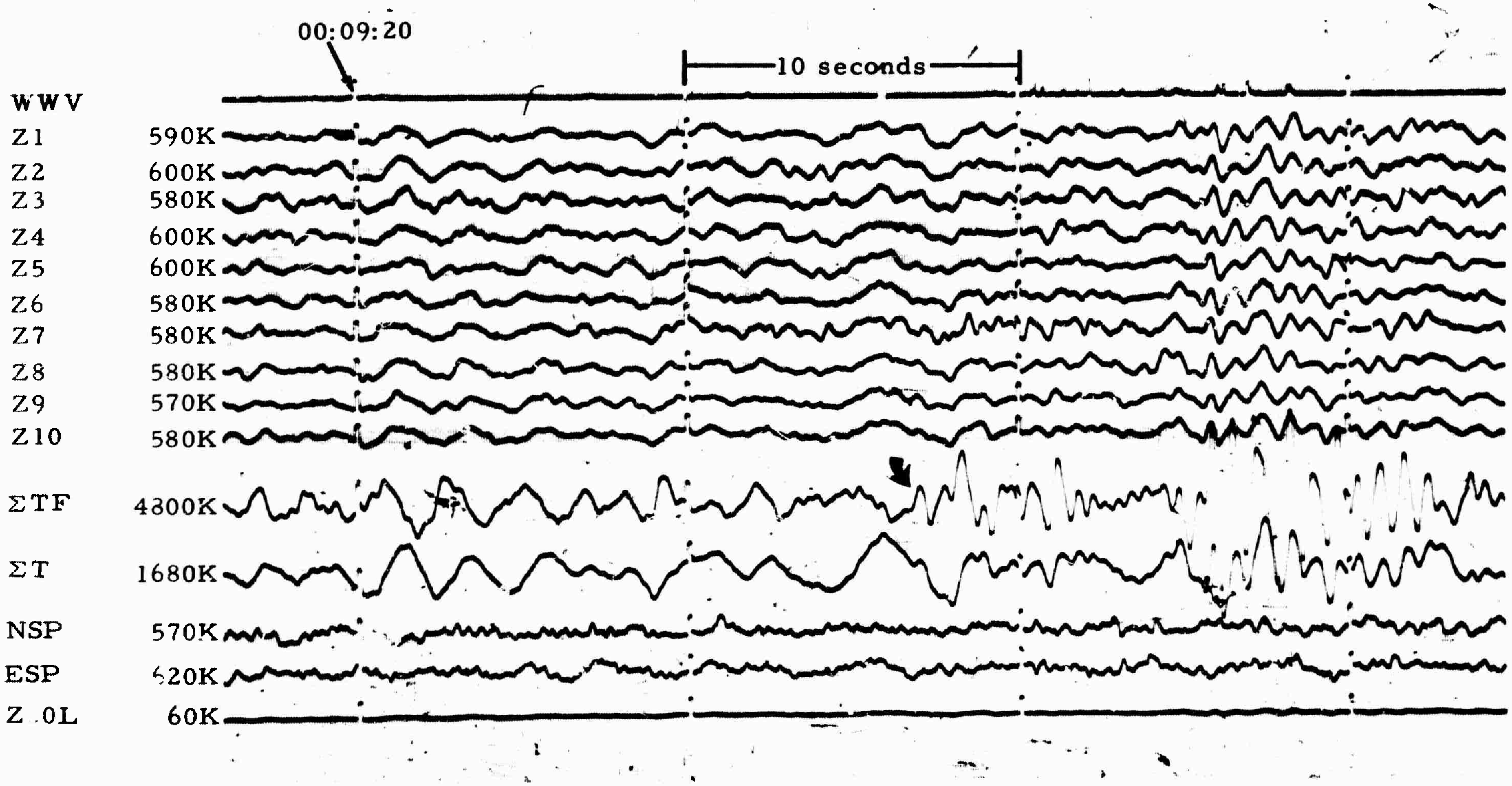


Figure 82. UBSO short-period seismogram demonstrating a signal apparent on filtered summation prior to its appearance on individual short-period seismograms. Epicenter unknown. (X10 enlargement of 16-mm film)

UBSO
Run 222
10 Aug 63

h. Operation of Three Observatories - Semiannual Report No. 2, Project VT/1124, 1 January through 30 June 1964. Geotech Technical Report No. 64-87 was published on 19 August 1964. Discussed in this report are the operation of BMSO, CPSO, and UBSO, modifications or additions to the observatory equipment, and progress of special investigations.

i. A letter report, Comparison of the Operating Characteristics, Availability, and Shop Level Cost of Hall-Sears, Model HS 10-1 - Texas Instruments, Model RA3 and Geotech Model 18300-Geotech, Model 12613-1 Seismograph Systems, was published on 4 September 1964. This report contains a comparison of the Hall-Sears HS 10-1-TI RA3 and Geotech 18300-12613-1 seismograph systems, recommendations for UBSO buried array instrumentation, and a summary of the major factors on which the recommendations were based.

j. A letter report, Recommended Configuration for a Buried Array at UBSO, was published on 11 September 1964. Presented in this report are our recommendations for several configurations of the UBSO buried array, brief discussions of each configuration, and data on which the recommendations were based.

k. Logging Program Report from UBSO with copies of well logs, a letter report dated 24 November, contains a description of the logging of selected holes drilled for the installation of the UBSO buried array.

l. A letter report, Preliminary Data from the Detection Capability Study being Conducted Jointly under Projects VT/1124 and VT/4054, was published on 30 January 1965. Presented in this report are preliminary data showing detection probability for system 3 (SPZ, $\Sigma$, and $\Sigma F$) as a function of average ground displacement and average ground-displacement-to-period ratio for some of the noise types selected for the study.

m. Several letter reports containing an evaluation, comments, and recommended refinements for the ABP were submitted to AFTAC or SDL. These letters were based on observations made during reviews of test or production runs of the ABP.

n. The following computer programs, written in FORTRAN language by Project VT/1124 personnel were submitted to AFTAC. A brief description of each program accompanied the program listing.

(1) PROGRAM SOBUL - for calculating ground displacement and magnitude for the five-station earthquake bulletins for incorporation into the ABP;

(2) PROGRAM ANALYSIS - for preliminary processing of detection capability study data;

(3) PROGRAM RESIDUAL - for compilation of preliminary P-phase travel-time residual data for the VELA-UNIFORM observatories;

(4) PROGRAM MISERABLE - for compilation and tabulation of component failure card data.

o. Geotech Technical Report No. 65-28, Installation of a 10 Element Shallow-Buried Array at the Uinta Basin Seismological Observatory, Vernal, Utah, was published on 5 May 1965. This report describes the installation of the array of buried seismographs at UBSO, and summarizes the major considerations in such an undertaking.

## 7. USE OF OBSERVATORY FACILITIES AND DATA BY OTHER GROUPS AND ORGANIZATIONS

### 7.1 BMSO

### 7.1.1 Preparations for the Operation of a Spectrum Analyzer

In October 1963, a request was received to operate a classified Bell Telephone Laboratories (BTL) spectrum analyzer at BMSO. The necessary security measures were taken and BMSO was ready to receive the equipment in December 1963. The installation was postponed until March 1964 and then postponed indefinitely. At the end of the reporting period the spectrum analyzer had not been received for installation.

### 7.1.2 Other Assistance Provided

The Stanford Research Institute (SRI) has been notified by telephone of any earthquakes detected that occurred in the continental United States whose magnitude was four or greater. Also, since August 1964, copies of the daily letters to USC&GS have been mailed to SRI each week.

## 7.2 CPSO

### 7.2.1 Operation of a Multiple Array Processor

Texas Instruments Inc. (TI) operated a Multiple Array Processor (MAP) at CPSO from 1 July 1963 to 18 October 1963. TI was provided with office space in the utility building, operating space in the conference room, and with air conditioning. Also additional time was expended by the CPSO staff keeping the vertical array seismographs to the close frequency response similarity demanded by the MAP.

Throughout the operation relations with TI were good and no problems existed between the two groups.

### 7.2.2 Other Assistance Provided

#### 7.2.2.1 Assistance to Other VELA UNIFORM Participants

7.2.2.1.1 USC&GS. USC&GS frequently requested information on earthquakes by telephone before the routine message was sent. CPSO personnel routinely interpreted large events recorded on the Helicorder upon arrival at the observatory.

7.2.2.1.2 Mandrel Industries, Houston. AFTAC authorized the installation of a shallow buried array consisting of seven seismographs. Mr. Wu of Mandrel Industries located the array in the area recommended by the CPSO staff on 27 April 1965.

7.2.2.1.3 United States Geological Survey. Mr. Benton Tibbetts of the United States Geological Survey used CPSO as a base while working in the area from 10 February 1965 to 20 February 1965. Mr. Tibbetts was told that CPSO could provide office space in the future if the USGS desired.

7.2.2.1.4 Research Triangle Institute. Dr. John W. Minior visited CPSO and arrangements were made to provide him with CPSO data for use in his research studies.

#### 7.2.2.2 Assistance to Colleges and Universities

7.2.2.2.1 Stanford Research Institute. The Stanford Research Institute (SRI) has been notified by telephone of any earthquakes detected that occurred in the continental United States, whose magnitude was four or greater.

7.2.2.2.2 Georgia Institute of Technology. Georgia Tech staff frequently requested information on close events. An arrangement was made with Mr. John Husted where, in return for coordinates and origin times of quarry blasts, CPSO would supply phase arrival times. Before the end of the reporting period, information on one quarry blast had been received.

7.2.2.2.3 Xavier University. CPSO supplied Father Bradley of Xavier University with the arrival times of phases from quarry blasts. Data supplied by CPSO influenced Father Bradley's decision to install a linear array in Kentucky.

7.2.2.2.4 Tennessee Division of Water Resources. Mr. John M. Wilson of the Tennessee Division of water Resources used CPSO data to correlate the relationship between changes in the Tennessee water table and the occurrence of large earthquakes. He gave a paper on the results at a meeting of the Academy of Science.

7.2.2.2.5 Other Universities. The Universities of Mississippi, St. Louis, and Kansas were provided with CPSO data at various times throughout the contract.

## 7.3 UBSO

### 7.3.1 Installation and Operation of Prototype Deep- and Shallow-Hole Seismometers

A deep hole (2745 meters, 9000 feet) already present and a newly drilled shallow hole (152.5 meters, 500 feet) at UBSO have been used for various tests in this reporting period. The deep hole (DH) is about 100 meters southeast of Z1, and the shallow hole (SH) is about midway between Z1 and DH. Seismographs installed in these holes were used in a series of tests to determine the character of seismic noise at these depths and to assess the stability of these instruments over long operating periods providing information for further seismometer developments.

The block diagram of the deep- and shallow-hole operations are shown in figure 83. Project VT/1139 was responsible for the operation of these seismograph systems; but UBSO staff and an AFTAC representative were made fully conversant with the installation and operation of the systems. UBSO provided recording and calibration facilities. UBSO assumed responsibility

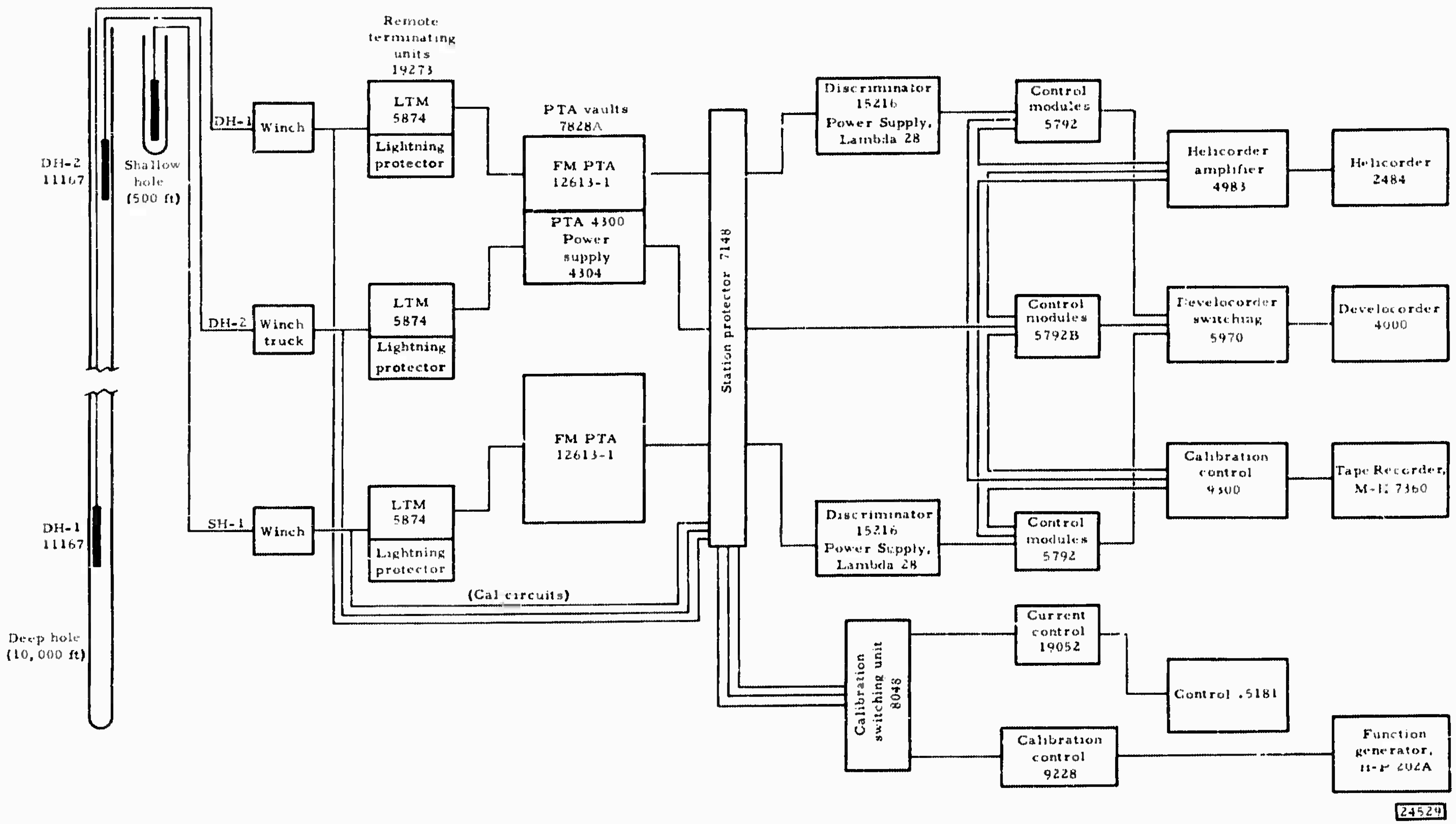


Figure 83. Block diagram of the deep- and shallow-hole operations at UBSO

for the routine testing and operation of the equipment on 31 May 1964. Except for minor repairs and modifications these seismographs were in continuous operation from 31 May 1964 through 30 April 1965.

The various relocations of the seismometers are shown in table 24.

### 7.3.2 Operation of Texas Instruments Digital Field System

Texas Instruments Inc. (TI) operated a digital field system at UBSO from 16 August 1964 through 15 October 1964. UBSO provided data outputs from the array seismometers, array summations, the shallow- and deep-hole seismometers, the anemometer, and station time. UBSO also provided the cabling and the necessary recording and calibrating facilities. Minor modifications had to be made to the standard instrumentation to accommodate the digital field system. The levels of signal from the shallow and deep-hole seismographs were too low for the digital system; therefore, the four Line Termination Modules, Model 5792B, controlling DH-1, DH-1L, SH-1, and SH-1L were modified to the Model 5792 configuration. This resulted in a loss of gain in the normal operation, but the loss was not sufficient to affect the over-all system capability.

UBSO also provided TI with original film seismograms, copies of logs and copies of the messages to USC&GS in support of their operation.

The TI program also required various adjustments in the vertical position of SH and DH seismographs. Equipment including a winch truck and cable, and additional seismometer, a PTA, and top-hole equipment for a dual-seismometer operation was supplied by Project VT/5051. The shallow-hole seismometer was maintained at (57 meters, 188 feet) throughout the operation while the deep-hole seismometers were moved as shown in table 24.

Texas Instruments returned to UBSO with their digital field system on 24 March 1965. Between 26 March and 31 March they recorded buried array data.

### 7.3.3 Other Assistance Provided

Since January 1964, phase arrivals for small local and near regional events have been sent to the Universities of Utah and of Colorado. Beginning in August of 1964, the University of Wyoming was included in the program.

## Table 24. Summary of shallow-hole and deep-hole seismometer moves at UBSO

| Hole | Deep hole No. 1 | | | | Shallow hole No. 1 | | |
|---|---|---|---|---|---|---|---|
| Inst designator | DH1 | | DH2 | | SH1 | | |
| Position | From | To | From | To | From | To | Remarks |
| Date | | | | | | | |
| Apr 20 | | | | | 0 | 31 | Original setup |
| Apr 22 | 0 | 8900 | | | | | Original setup |
| Apr 29 | 8900 | 7506 | | | | | Normal move and setup |
| May 5 | 7506 | 6009 | | | | | Normal move and setup |
| May 10 | 6009 | 4510 | | | | | Normal move and setup |
| May 11 | | | | | 31 | 219 | Normal move and setup |
| May 15 | 4510 | 2985 | | | 219 | 310 | Normal move and setup |
| May 19 | 2985 | 1485 | | | | | Normal move and setup |
| May 21 | | | | | 310 | 406 | Normal move and setup |
| May 25 | | | | | 406 | 434 | Normal move and setup |
| May 28 | 1485 | 8880 | | | | | Normal move and setup |
| June 4 | 8880 | 7501 | | | | | Normal move and setup |
| June 6 | | | | | 434 | 31 | Normal move and setup |
| June 10 | 7501 | 6005 | | | 31 | 62 | Normal move and setup |
| June 22 | | | | | 62 | 124 | Normal move and setup |
| June 29 | | | | | 124 | 155 | Normal move and setup |
| July 7 | | | | | 155 | 188 | Normal move and setup |
| July 12 | 6005 | 3013 | | | | | Normal move and setup |
| July 21 | 3013 | 8860 | | | | | Normal move and setup |
| Aug 16 | | | 0 | 6905 | | | Original setup |
| Sep 10 | | | 6905 | 903 | | | Reset shunts and test |
| Sep 15 | | | 903 | 2893 | | | Normal move and setup |
| Sep 18 | | | 2893 | 4913 | | | Normal move and setup |
| Sep 21 | 8860 | 6893 | | | | | Normal move and setup |
| Sep 23 | | | 4913 | 903 | | | Replace mass-lock motor |
| Sep 28 | | | 903 | 2897 | | | Normal move and setup |
| Sep 30 | | | 2897 | 4914 | | | Normal move and setup |
| Oct 3 | 6893 | 4899 | 4914 | 2897 | | | Normal move and setup |
| Oct 5 | | | 2897 | 907 | | | Normal move and setup |
| Oct 7 | 4899 | 2915 | | | | | Normal move and setup |
| Oct 11 | 2915 | 8860 | 907 | 6894 | | | Replace hole-lock motor, DH1 |
| Oct 14 | | | 6894 | 0 | | | Operation complete |
| Oct 15 | 8860 | 6962 | | | | | Normal move and setup |
| Nov 3 | 6962 | 6998 | | | | | Repair loose ground wire |
| Dec 13 | 6998 | 0 | | | 188 | 0 | Modify wt. lift cal, seis head |
| Dec 21 | 0 | 6998 | | | 0 | 188 | Normal move and setup |

The data provided to the universities included event analysis for small local and near regional events not normally reported to the USC&GS in the routine daily telegraph message, but ordinarily included in the letter report. These universities have also been placed on the five-station earthquake bulletin mailing list.

In addition to the benefits of association with the academic staffs of the institutions, UBSO is the recipient of the Utah and Colorado earthquake bulletins and reports of progress in seismological research.

### 7.4 TRANSMITTAL OF BULLETIN DATA TO SEISMIC DATA LABORATORY

All data published in the five-station earthquake bulletins are stored on IBM cards. As the bulletins were prepared and published, the data stored on cards were transcribed onto digital magnetic tapes for transmission to Seismic Data Laboratory. Data published for the months of February 1963 through November 1964 were sent to SDL. The December 1964 data are being finalized and will be sent as soon as the bulletin is published.

In addition, beginning with data for July 1964, "raw" analysis data are transmitted to SDL on digital magnetic tape for processing by the ABP. Raw analysis data covering 8 months (July 1964 through 1965) were sent to SDL during the reporting period.

## 8. MAINTENANCE OF AND IMPROVEMENTS IN OBSERVATORY FACILITIES

### 8.1 BMSO

The winter of 1963-64 proved to be a severe hindrance to the staff of BMSO. The access road was snowplowed and graded by the Baker County Highway Department many times during this period.

On 18 June 1964, the surface of the parking lot was improved by spreading 20 cubic yards of gravel over the lot.

The Develocorder drain sump became badly clogged during the first few months of 1964. On 20 July 1964 it was dug out and enlarged.

Between 14 and 28 July 1964, the fencing around the vaults was checked and replaced where necessary.

## 8.2 CPSO

The main access road to CPSO was improved in September 1964 by spreading 97,900 newtons (110 tons) of gravel on the road and digging out the drainage ditches. The back access road to the Rocky River Road was improved on 20 September 1963 to make it a passable thoroughfare even in wet weather.

Gravel, 9790 newtons (11 tons), was spread on the parking lot in September 1964. The drainage ditches were also improved to prevent a washout of the lot in heavy rain.

Eight vaults had originally been installed at such a depth that water continually drained into them. The drainage ditches to these vaults were improved in August 1964 and the problem was alleviated.

An Everpure water filter and chlorinator system was installed on 5 May 1964; this eliminated problems with clogged Develocorder pumps. This filter system required no maintenance except regularly supplying it with chlorine.

Difficulties with the drainage from the kitchen sink and from both lavatories showed that the dry wells and feed lines had not been properly constructed. The wells and feed lines were reconstructed on 26 February 1964 and the problems were solved.

Bleach solution used in the cleaning of Develocorder feed lines caused corrosion of the photographic room sink wash pipe on two occasions and of the kitchen sink wash pipe on one occasion. We recommend that the wash pipe plumbing at these points be replaced with corrosion resistant plastic piping.

## 8.3 UBSO

There was little problem with the access road before the fall of 1964. The drainage ditches were cleared of vegetation in April 1964. There were some abnormally heavy snow falls in the winter of 1964-65 which required that the roads be snowplowed.

Drain clogging problems occurred during the spring and summer of 1964, and we found that the copper drain pipe from the Develocorders was almost entirely corroded. The drains from the dark room, machine room, and lavatory were also not working due to break in the pipe outside the CRB.

The Develocorder drains were reconstructed using three 1/2-inch plastic hoses routed from the Develocorders through the remains of the corroded copper pipe to the outside of the CRB. The three hoses were then inserted in one 1/2-inch plastic pipe, which was in turn, placed in a 10-foot length of perforated orange pipe. A larger capacity dry well was constructed to replace the original well. The drain facilities for the dark room sink, lavatory, and machine room were similarily reconstructed. No 1/2-inch plastic hose was required because the copper pipe was still in useable condition. No further clogging has been experienced since construction of the new drains.

Since the beginning of the contract on 1 July 1963, the lavatory at UBSO had been an Incinomode. In time, the use of this device had become disagreeable and its maintenance was expensive. A review of the comparative costs of maintaining the Incinomode and a standard water closet and urinal showed that the Incinomode was the more expensive. Therefore, it was decided to remove the Incinomode, relocate the lavatory, install a urinal, water closet, septic tank, drainage sump, and a 1500-gallon water supply and pump. Construction of this new facility was completed in February 1965.

# APPENDIX 1 to TECHNICAL REPORT NO. 65-58

## WORK STATEMENT

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# STATEMENT OF WORK TO BE DONE
# AFTAC PROJECT AUTHORIZATION VELA T/1124

1. Tasks.

a. Operation.

(1) Continue operation of the Blue Mountains, Uinta Basin, and Cumberland Plateau Seismological Observatories.

(2) Maintain, repair, protect, and preserve the facilities of the three seismological observatories in good physical condition in accordance with the sound industrial practice. Alterations to the original design of the facilities shall not be considered within the scope of work.

(3) Evaluate the resulting seismic data to determine optimum operating characteristics and make changes in the operating parameters as may be required to provide the most effective observatories possible. Addition and modification of instrumentation are within the scope of work. However, such instrument modifications and additions, data evaluations, and parameter changes shall be subject to the technical approval of the AFTAC project officer.

(4) Transmit daily seismic reports to the US Coast and Geodetic survey, Washington 25, D. C. using the established report format and detailed instructions.

(5) Publish a monthly summary of seismological events during this period with distribution and format as approved by the AFTAC project officer.

(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.

b. Special Investigations. Conduct research investigations as approved or requested by the AFTAC project officer to obtain fundamental information which will lead to improvements in the capabilities of the observatories. For example, these investigations may be of the following nature:

(1) Crustal structure study for each observatory.

(2) Special array studies.

(3) Study of methods to obtain maximum utility of observatory data for detection of seismic signals.

(4) Study of variations in seismic noise at each observatory.

2. Reports.

a. Monthly letter-type progress reports in 12 copies, summarizing work through the 25th of the month, shall be dispatched to AFTAC by the end of the month. Specific topics shall include technical status, major accomplishments, problems encountered, future plans and any action required by AFTAC. Illustrations and photographs shall be included as applicable. In addition, the monthly report submitted for the reporting period occurring 6 months prior to the scheduled contract termination date shall contain specific statements concerning requirements and justifications for extension, modification or expiration of work and changes in cost estimates which are anticipated by the Contractor. The heading of each report shall contain the following information:

AFTAC Project No.
Project Title
ARPA Order No. 104-60
ARPA Project Code No. 8100
Name of Contractor
Date of Contract
Amount of Contract
Contract Number
Contract Expiration Date
Project Scientist or Engineer's Name and Phone Number.

b. A list of suggested milestones shall be dispatched to AFTAC in 12 copies within 2[illegible] days following receipt of the letter contract. (Milestones are defined as points of accomplishments which represent significant progress when completed.) For a given milestone, the list should include the completion date and a brief description, when necessary, to define specifically the accomplishment to be attained. Upon approval of milestone information, copies of SD Form 350 shall be made available for use in reporting progress against the milestone schedule. The SD Form 350 shall be attached to the monthly report.

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

d. An initial technical summary report in 40 copies, covering work performed through the last day of the 5th month following the month in which the letter contract was received, shall be submitted to AFTAC within 15 days after the close of the reporting period. A semiannual technical summary report in 40 copies, covering work performed through each 6-month period following the close of the initial reporting period, shall be submitted to AFTAC within 15 days after the close of the reporting period. These reports shall present a concise and factual discussion of the technical findings and accomplishments of the reporting period. The heading of the report shall contain the heading information indicated in paragraph 2a, above.

e. A final technical report in 50 copies shall be submitted within 60 days following completion of each phase of the work statement. The heading of the reports shall contain the information indicated in paragraph 2a, above.

f. Special reports, as requested by the AFTAC Project Officer shall be required upon completion of various portions of the work.

3. Technical Documents. The Contractor shall be required to furnish the following technical documents:

a. All seismograms and operating logs, to include pertinent information concerning time, date, type of instruments, magnifications, etc., as requested by the AFTAC Project Officer.

b. Technical manuals on the installation and operation of all technical equipment installed during the current operational period.

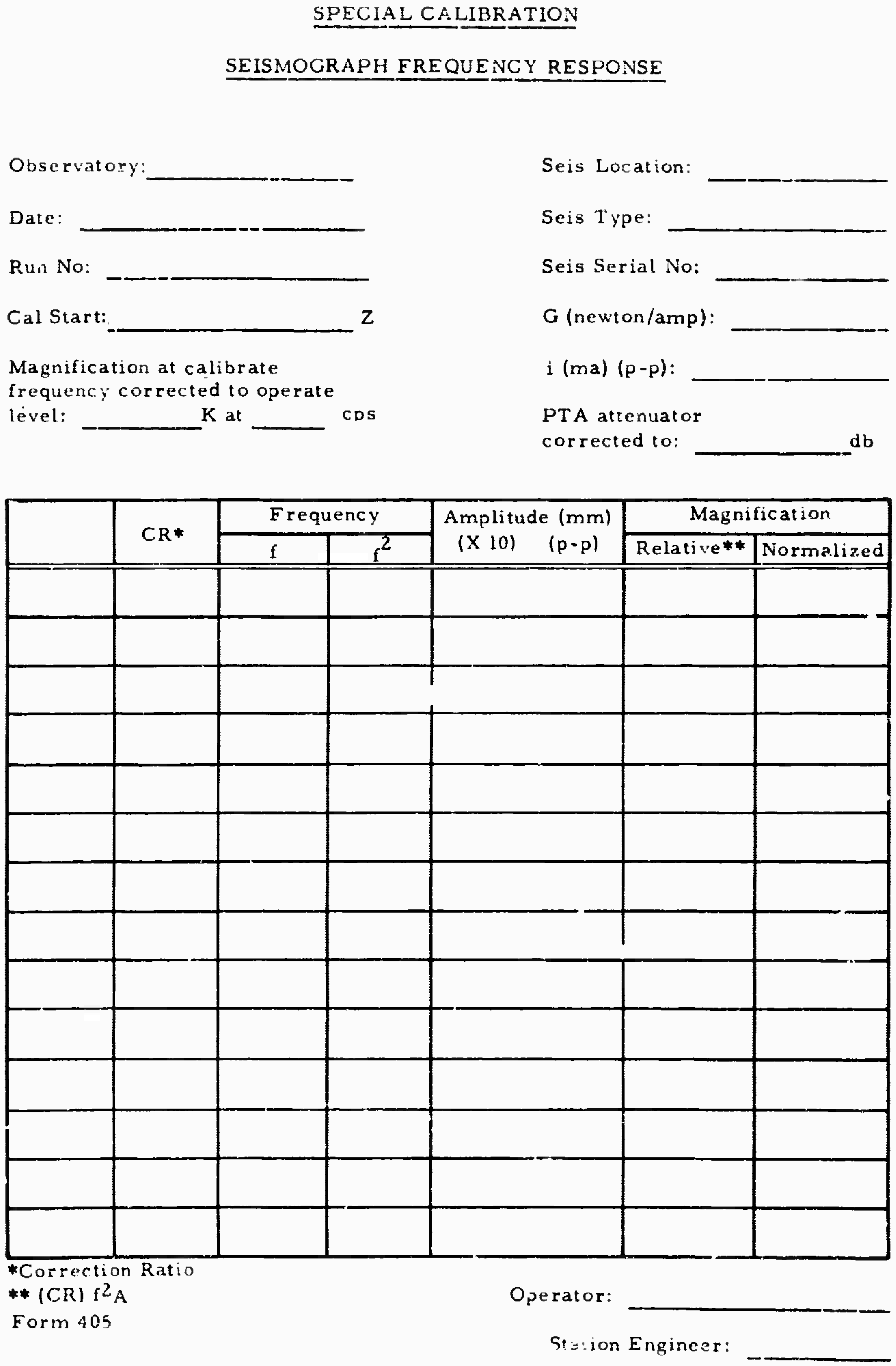
c. Two sets of reproducible engineering drawings and specifications for any changes or modifications in standard operational equipment and instruments and for any new equipment designed, together with one set of prints of these same drawings.

4. Miscellany. All technical reports and documents shall be forwarded to:

Hq USAF (AFTAC/TD-1)
Washington 25, D. C.

# APPENDIX 2 to TECHNICAL REPORT NO. 65-58

## SAMPLE FORMS USED AT THE VT/1124 OBSERVATORIES



SPECIAL CALIBRATION

SEISMOGRAPH FREQUENCY RESPONSE

Observatory: ____________

Date: ____________

Run No: ____________

Cal Start: ____________ Z

Magnification at calibrate frequency corrected to operate level: ________K at ______ cps

Seis Location: ____________

Seis Type: ____________

Seis Serial No: ____________

G (newton/amp): ____________

i (ma) (p-p): ____________

PTA attenuator corrected to: ____________db

| | CR* | Frequency | | Amplitude (mm) (X 10) (p-p) | Magnification | |
|---|---|---|---|---|---|---|
| | | f | $f^2$ | | Relative** | Normalized |
| | | | | | | |
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*Correction Ratio

** (CR) $f^2A$

Form 405

Operator: ____________

Station Engineer: ____________

Figure 1. Revised special calibration log

## DAILY CALIBRATION LOG

Observatory: ____________
Date: ____________
Run No.: ____________
Record starts: ____________ Z
ends: ____________ Z

Develocorder No: ____________
Data Trunk: ** ____________
Data Group: ____________

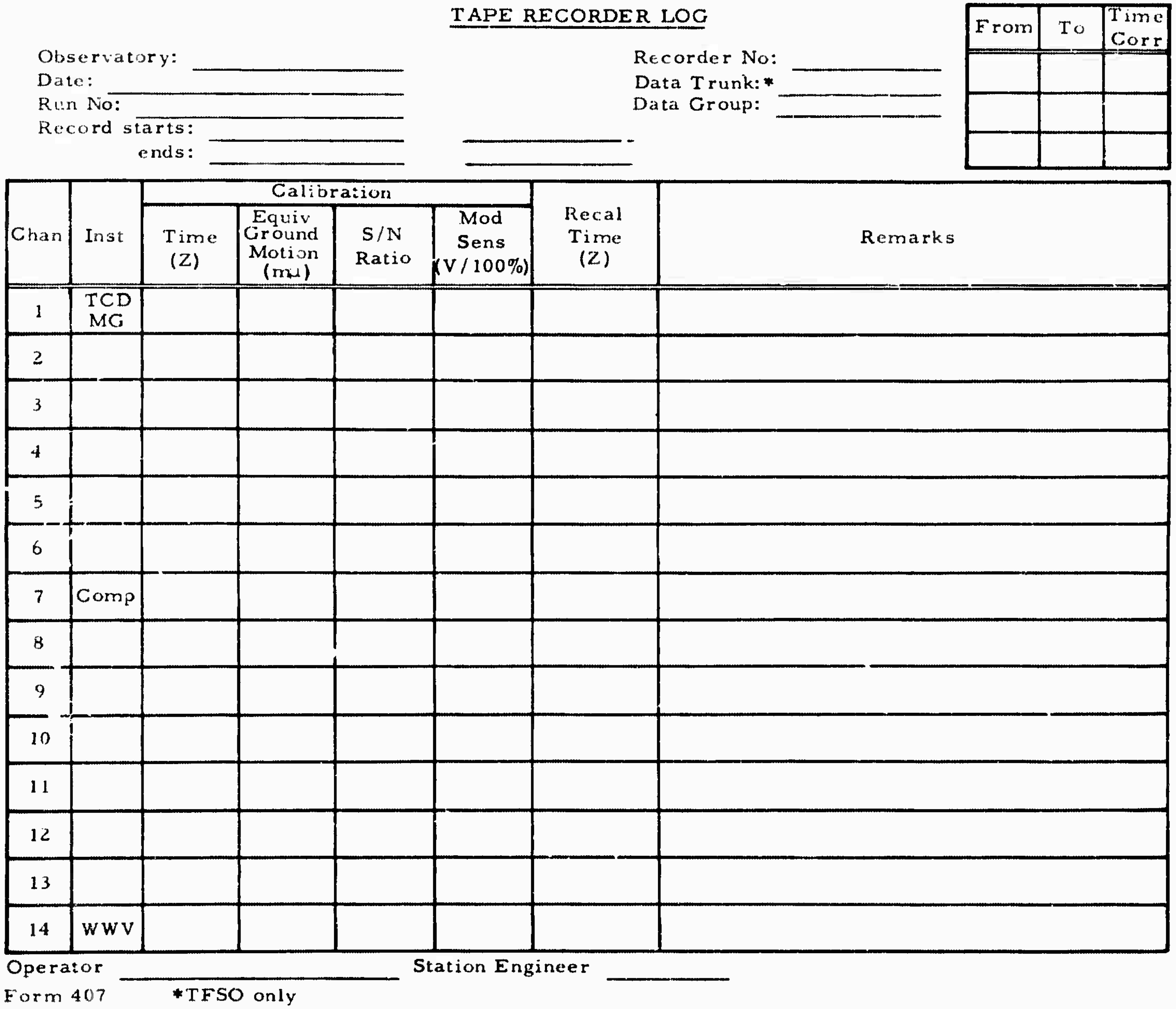
| From | To | Time Corr |
|---|---|---|
| | | |
| | | |
| | | |

| Trace | Inst | Calibration | | | | | | | | | | Recalibration | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Time (Z) | Cal Current (ma) | Equiv Ground Motion (mμ) | Cal Motor Const (n/amp) | PTA Atten (db) | DCM* Atten (db) | Cal Ampl (mm) | Mag Factor | Oper Mag (X 1000) | Time (Z) | Cal Ampl (mm) | Oper Mag (X 1000) | |
| 1 | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | |

Operator ____________ Senior Analyst ____________ Station Engineer ____________

Form 406 *BMSO CPSO UBSO WMSO only **TFSO only

Figure 2. Revised daily calibration log



TAPE RECORDER LOG

Observatory: ______
Date: ______
Run No: ______
Record starts: ______ ______
ends: ______ ______

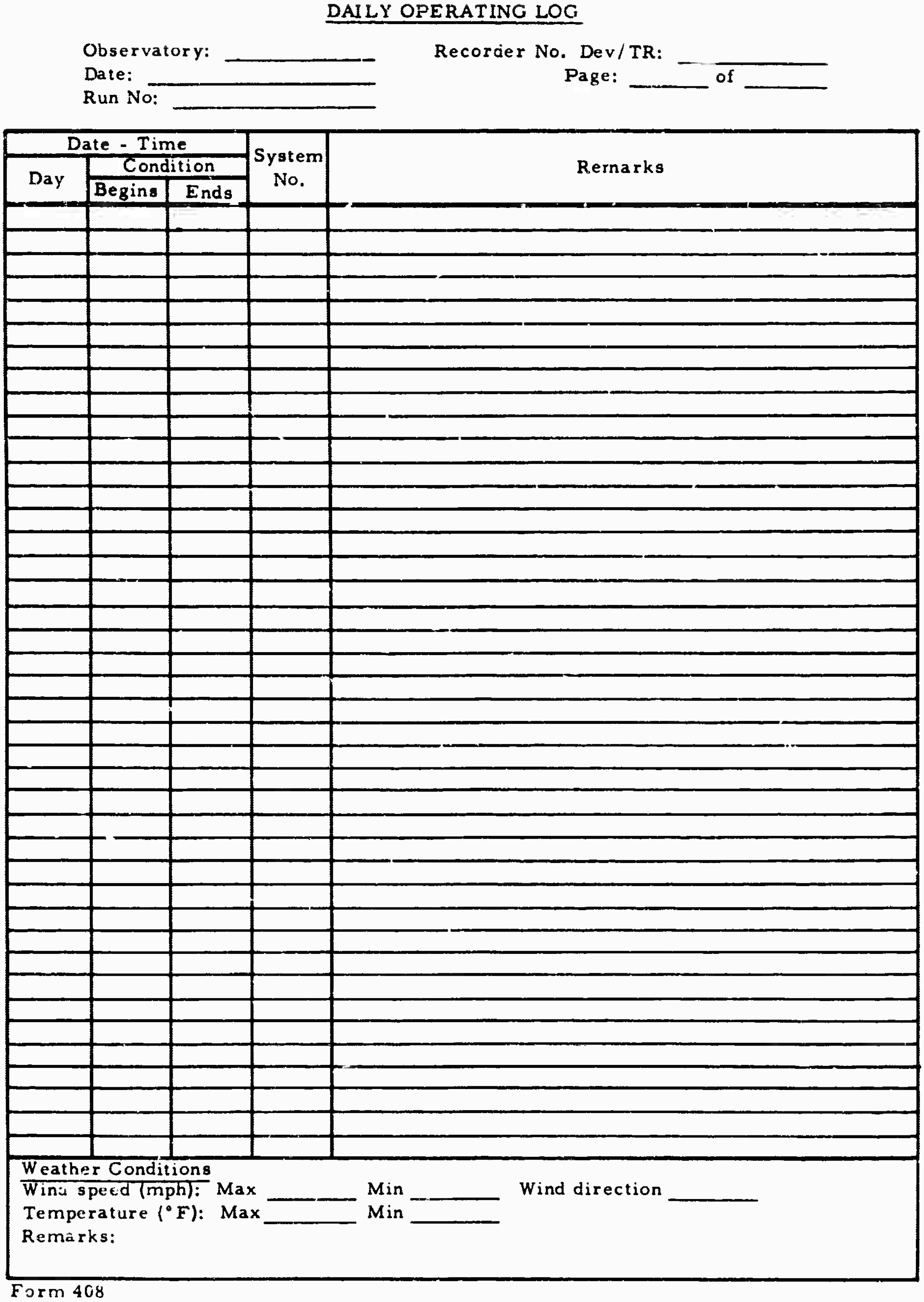
Recorder No: ______
Data Trunk:* ______
Data Group: ______

| From | To | Time Corr |
|---|---|---|
| | | |
| | | |
| | | |

| Chan | Inst | Calibration | | | | Recal Time (Z) | Remarks |
|---|---|---|---|---|---|---|---|
| | | Time (Z) | Equiv Ground Motion (mμ) | S/N Ratio | Mod Sens (V/100%) | | |
| 1 | TCD MG | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | Comp | | | | | | |
| 8 | | | | | | | |
| 9 | | | | | | | |
| 10 | | | | | | | |
| 11 | | | | | | | |
| 12 | | | | | | | |
| 13 | | | | | | | |
| 14 | WWV | | | | | | |

Operator ______ Station Engineer ______
Form 407 *TFSO only

Figure 3. Revised tape-recorder log



DAILY OPERATING LOG

Observatory: ____________ Recorder No. Dev/TR: ____________
Date: ____________ Page: ______ of ______
Run No: ____________

| Date - Time | | | System No. | Remarks |
|---|---|---|---|---|
| Day | Condition | | | |
| | Begins | Ends | | |
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Weather Conditions
Wind speed (mph): Max ______ Min ______ Wind direction ______
Temperature (°F): Max ______ Min ______
Remarks:

Form 408

Figure 4. Revised daily operating log

Effective - From ____________

To ____________

Observatory ____________

Date-Time Group ____________

mber ____________

DATA FORMAT ASSIGNM

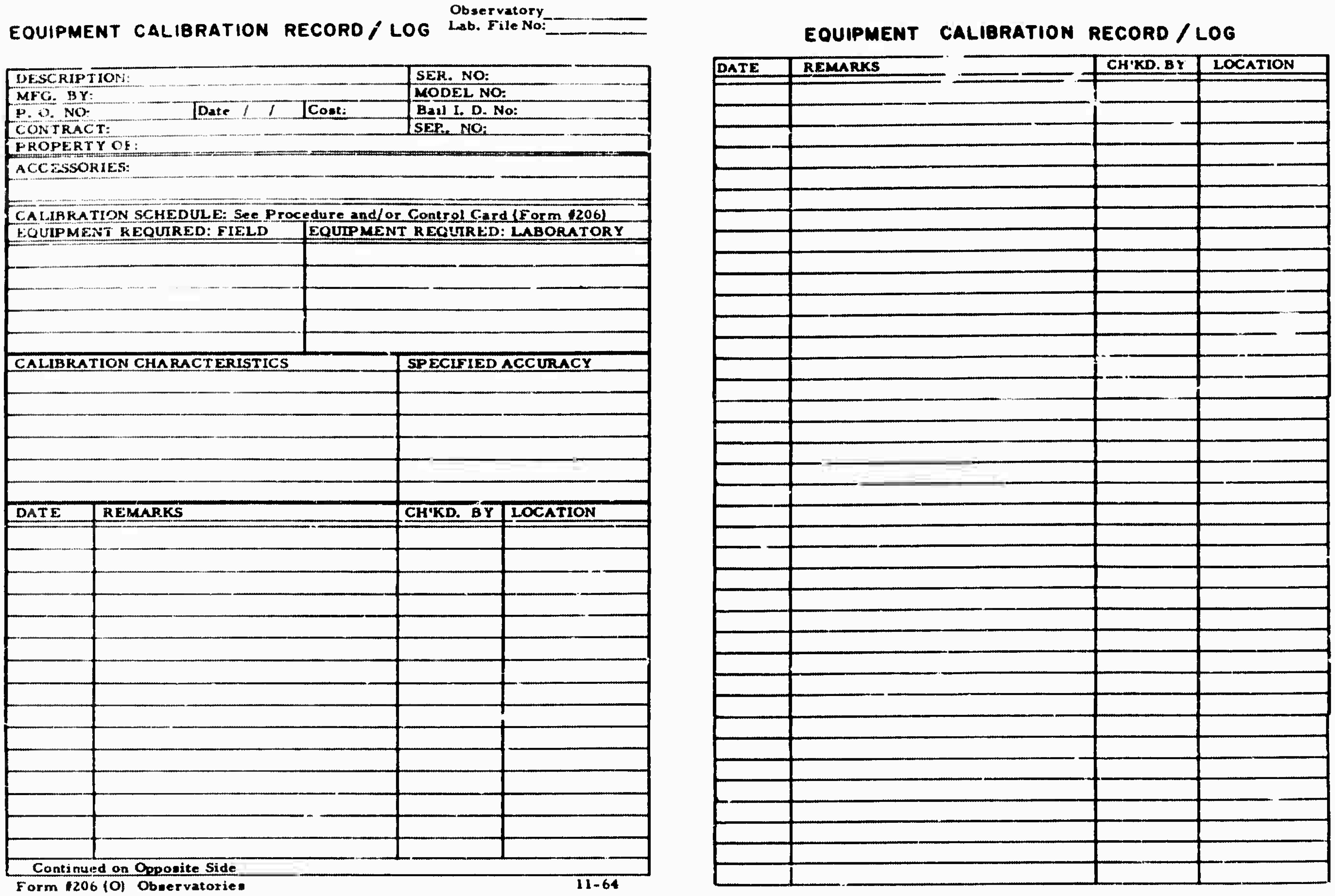
| Channel Number | Develocorders | | | | Magnetic-Tape Recorders | | |
|---|---|---|---|---|---|---|---|
| | Data Group | Data Group | Data Group | Data Group | Data Group | Data Group | Data Group |
| | No. 1 & 2 SP Primary | No. 1 & 2 SP Secondary | No. 3 LP Primary | No. 4[a] | No. 1 | No. 2 | No. 3 |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | Comp.[b] | Comp.[b] | Comp.[b] |
| 8 | | | | | | | |
| 9 | | | | | | | |
| 10 | | | | | | | |
| 11 | | | | | | | |
| 12 | | | | | | | |
| 13 | | | | | | | |
| 14 | | | | | WWV & Voice | WWV & Voice | WWV & Voice |
| 15 | | | | | | | |
| 16 | WWV | WWV | WWV | WWV | | | |

a - Not used at all observatories

b - Compensation

Form 334 (Rev. 2/65)

Figure 5. Sample data format assignment reporting form



EQUIPMENT CALIBRATION RECORD / LOG

Observatory________
Lab. File No:________

DESCRIPTION:
MFG. BY:
P. O. NO: Date / / Cost:
CONTRACT:
SER. NO:
MODEL NO:
Bail I. D. No:
SEP. NO:
PROPERTY OF:
ACCESSORIES:

CALIBRATION SCHEDULE: See Procedure and/or Control Card (Form #206)

| EQUIPMENT REQUIRED: FIELD | EQUIPMENT REQUIRED: LABORATORY |
|---|---|
| | |

| CALIBRATION CHARACTERISTICS | SPECIFIED ACCURACY |
|---|---|
| | |

| DATE | REMARKS | CH'KD. BY | LOCATION |
|---|---|---|---|
| | | | |

Continued on Opposite Side

Form #206 (O) Observatories 11-64

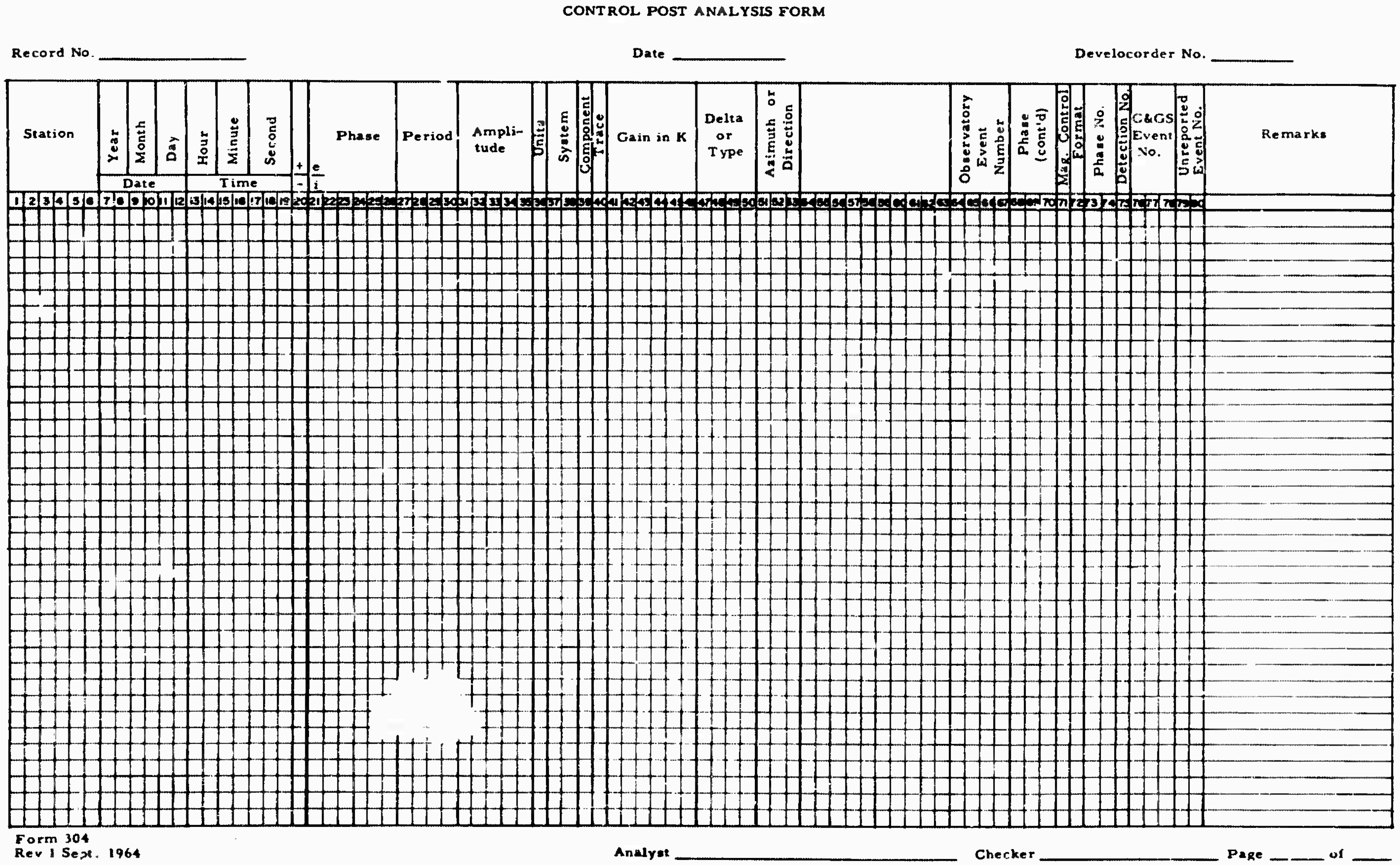
First page

EQUIPMENT CALIBRATION RECORD / LOG

| DATE | REMARKS | CH'KD. BY | LOCATION |
|---|---|---|---|
| | | | |

Second page

Figure 6. Typical equipment calibration record/log used at the VT/1124 observatories



CONTROL POST ANALYSIS FORM

Record No. ________ Date ________ Develocorder No. ________

| Station | Year | Month | Day | Hour | Minute | Second | + / - | e / i | Phase | Period | Amplitude | Units | System | Component Trace | Gain in K | Delta or Type | Azimuth or Direction | | Observatory Event Number | Phase (cont'd) | Mag. Control | Format | Phase No. | Detection No. | C&GS Event No. | Unreported Event No. | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date | | | Time | | | | | | | | | | | | | | | | | | | | | | | |

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

Form 304
Rev 1 Sept. 1964

Analyst ________ Checker ________ Page ____ of ____

Figure 7. Preliminary analysis form used at the VT/1124 observatories

## APPENDIX 3 to TECHNICAL REPORT NO. 65-58

## CODING AND TABULATION OF COMPONENT FAILURE DATA

# CODING AND TABULATION OF COMPONENT FAILURE DATA

1. Observatory or LRSM Team Code (columns 1-3)
   1.1 Observatory Codes
      a. BM0
      b. CP0
      c. TF0
      d. UB0
      e. WM0

2. Date
   Date of failure in years and day of the year (columns 4-8) - e.g., 31 March 1964 - 64091

3. General Equipment Code 1-4 alphabetic characters (columns 9-12)
   See section 2 of this appendix for Alphabetical List of General Equipment Codes.
   3.1 General Function Code (column 9)
      a. S - Sensor
      b. B - Protector
      c. A - Amplifier
      d. D - Data transmission and control
      e. C - Calibration equipment
      f. R - Recorders
      g. T - Timing equipment
      h. P - Power equipment
      i. W - Meteorological equipment
      j. O - Communication equipment
      k. M - Test equipment
      l. V - Analysis equipment
      m. G - Miscellaneous equipment
      n. F - Filter
   3.2 Specific Function Code (columns 10-12, left justified)
      3.2.1 Seismometer Codes
         a. SP - Short-period
         b. IB - Intermediate-band
         c. BB - Broad-band
         d. LP - Long-period
         e. EX - Experimental

3.2.2 Protector Codes
  a. IA - Isolation amplifier
  b. VP - Vault protector
  c. SA - Summation amplifier
  d. STP - Station protector
3.2.3 Amplifier Codes
  a. PTA - Phototube amplifier
  b. HE - Helicorder amplifier
3.2.4 Data Transmission and Control Codes
  a. CA - Cable
  b. DLT - Data line terminal
  c. LTM - Line termination module
  d. SI - Signal isolator
  e. DCM - Data control module
  f. DSU - Develocorder switching unit
  g. TSU - Tape switching unit
3.2.5 Calibration Equipment Control
  a. CC - Calibration control
  b. CSU - Calibration switching unit
  c. FG - Function generator
  d. C - Calibrator
3.2.6 Recorders
  a. DEV - Develocorder
  b. TR - Tape recorder
  c. HE - Helicorder
  d. SC - Strip chart recorder
  e. DR - Drum recorder
3.2.7 Timing Equipment Code
  a. TS - Timing system
  b. PR - Programmer
  c. TCU - Time control unit
  d. RSC - Radio time signal converter
  e. RC - Radio control
  f. RR - Radio receiver
  g. CL - Clock
  h. TE - Time encoder
  i. PA - Power amplifier
  j. TMU - Time mark unit

### 3.2.8 Power Equipment Codes

a. PCU - Power control unit
b. BSW - Battery switch
c. IV - Inverter
d. SXF - Sola transformer
e. VR - Voltage regulator
f. BC - Battery charger
g. BAT - Battery
h. RPC - Remote power control
i. PS - Power supply

### 3.2.9 Meteorological Equipment Codes

a. MK - Microbarograph can
b. MKC - Microbarograph can calibrator
c. MCP - Microbarograph capsule
d. MOC - Microbarograph oscillator
e. DSC - Discriminator
f. MPD - Microbarograph power distributor
g. MFA - Microbarograph filter amplifier
h. AWI - Anemometer wind indicator
i. AWV - Anemometer wind velocity transmitter
j. AWD - Anemometer wind direction transmitter
k. T - Thermometer
l. ACM - Acoustic microphone
m. ACA - Acoustic amplifier
n. B - Barometer

### 3.2.10 Communication Equipment Codes

a. TRC - Transceiver
b. TPH - Telephone

### 3.2.11 Test Equipment

a. OS - Oscilloscope
b. FC - Frequency counter
c. VOM - Volt ohm meter
d. VTM - Vacuum tube volt meter
e. VAM - Voltammeter
f. GM - Gauss meter
g. MEG - Megger
h. BR - Bridge

### 3.2.12 Analysis Equipment Codes

a. FV - Film viewer
b. PV - Pentastrip viewer

3.2.13 Miscellaneous Equipment Codes
a. MPD - Mass position display
b. MPR - Microfilm printer reader
c. CM - Copying machine

3.2.14 Filter Codes
a. SDF - Seismic data filter
b. SF - Summation filter

4. Instrument Model Numbers - Model number of the general equipment malfunctioning. 1-8 numeric characters - right justified (columns 13-20)

5. Instrument Serial Number - Last three digits of the manufacturer's serial number (columns 22-24)

6. Subassembly Code - 1-4 alphabetic characters left justified (columns 25-28) See section 3 of this appendix for Alphabetic List of Subassembly Codes and section 4 for List of Acceptable Subassemblies.
a. PCB - Printed circuit board
b. DDU - Digital display unit
c. BCDU - BCD display unit
d. HSPP - Heat sink power pack
e. MASY - Meter assembly
f. PS - Power supply
g. TSP - Transport
h. AMP - Amplifier
i. CHS - Chassis
j. INVT - Inverter
k. OSCP - Oscilloscope
l. HSPA - Head switching panel assembly
m. PAMP - Power amplifier
n. PFS - Primary frequency standard
o. OSC - Oscillator
p. CSL - Channel selector
q. DISC - Discriminator
r. FDV - Frequency divider
s. SSCP - Storoboscope
t. CMOD - Control module
u. DT - Date timer
v. PASY - Pump assembly
w.. MONT - Monitor
x. RCU - Remote centering unit
y. NKRG - Numeric register

7. Subassembly Model Number - Model number of subassembly 1-8 numeric characters, right justified (columns 29-36)

8. Subassembly Serial Number or Printed Circuit Board position number (columns 37-41)
   - 8.1 Field Codes (column 37)
     - a. No punch - subassembly serial number
     - b. P-printed circuit board position number
   - 8.2 Serial Number or Position Number (columns 38-41)
     - a. Serial number - last 4 digits of manufacturers serial number, right justified
     - b. Position number - four alphanumeric characters, right justified

9. Component Symbol or Description (columns 42-53)
   - 9.1 Type of Component (column 42)
     - a. No punch - electrical or electronic component
     - b. M - mechanical component
   - 9.2 Component Symbol or Description - 1-12 alphanumeric characters, left justified (columns 43-53)
     - a. Electrical or electronic component - use symbols designated in section 5 of this appendix; otherwise use an abbreviated description of component
     - b. Mechanical components - use abbreviated description for component

10. Component Part Number - Manufacturers Part Number 1-10 alphanumeric characters right justified (columns 54-63) Use part number in appropriate O&M manual.

11. Component Manufacturer Code - Federal Code for Manufacturer of Component 5 numeric characters (columns 64-68) Use codes designated in "Federal Supply Code for Manufacturers" Cataloging Handbook H4-1. See section 6 of this appendix for an alphabetic list of the codes for the more common manufacturers.

12. Hours to Repair - Time necessary to correct malfunction in hours and tenths of hours (columns 69-71, right justified).

13. Format - Designates type of card (column 72)
    - a. D - Component failure card

14. Open Column - Column not presently used (column 73)

15. Time Inoperative - Time equipment was inoperative in hours and tenths of hours (column 74-78, right justified)
See section 2.3.7 of this appendix for a correct definition of time inoperative.

16. Failure Type - Type of failure (column 79)
  16.1 C - Catastrophic
  16.2 P - Preventive Action

17. Failure Cause - Cause of failure (column 80)
  17.1 No punch - unknown
  17.2 1 - Normal life
  17.3 2 - Operator error
  17.4 3 - Environmental
  17.5 4 - Defective material

## 2. ALPHABETIC LIST OF GENERAL EQUIPMENT CODES (COLUMNS 9-12)

General equipment codes are given alphabetically on the following page.

| | |
|---|---|
| WACA | Acoustic amplifier |
| WACM | Acoustic microphone |
| WAWI | Anemometer wind indicator |
| WAWD | Anemometer wind direction transmitter |
| WAWV | Anemometer wind velocity transmitter |
| WB | Barometer |
| PBAT | Battery |
| PBC | Battery charger |
| PBSW | Battery switch |
| MER | Bridge |
| DCA | Cable |
| CCC | Calibration control |
| CCSU | Calibration switching unit |
| CC | Calibrator |
| TCL | Clock |
| GCM | Copying machine |
| DDCM | Data control module |
| DDLT | Data line terminal |
| RDEV | Develocorder |
| DDSU | Develocorder switching unit |
| WDSC | Discriminator |
| RDR | Drum recorder |
| VFV | Film viewer |
| MFC | Frequency counter |
| CFG | Function generator |
| MGM | Gauss meter |
| RHE | Helicorder |
| AHE | Helicorder amplifier |
| PIV | Inverter |
| BIA | Isolation amplifier |
| DLTM | Line termination module |
| GMPD | Mass position display |
| MMEG | Megger |
| WMK | Microbarograph can |
| WMKC | Microbarograph can calibrator |
| WMCP | Microbarograph capsule |
| WMFA | Microbarograph filter amplifier |
| WMOC | Microbarograph oscillator |
| WMPD | Microbarograph power distributor |

| | |
|---|---|
| GMPR | Microfilm printer reader |
| MOS | Oscilloscope |
| VPV | Pentastrip viewer |
| APTA | Phototube amplifier |
| TPA | Power amplifier |
| PPCU | Power control unit |
| PPS | Power supply |
| TPR | Programmer |
| TRC | Radio control |
| TRR | Radio receiver |
| TRSC | Radio time signal converter |
| PRPC | Remote power control |
| FSDF | Seismic data filter |
| SBB | Seismometer, broad band |
| SEX | Seismometer, experimental |
| SIB | Seismometer, intermediate band |
| SLP | Seismometer, long period |
| SSP | Seismometer, short period |
| DSI | Signal isolator |
| PSXF | Sola transformer |
| BSTP | Station protector |
| RSC | Strip chart recorder |
| BSA | Summation amplifier |
| FSF | Summation filter |
| RTR | Tape recorder |
| DTSU | Tape switching unit |
| OTPH | Telephone |
| WT | Thermometer |
| TTCU | Time control unit |
| TTE | Time encoder |
| TTMU | Time mark unit |
| TTS | Timing system |
| OTRC | Transceiver |
| MVTM | Vacuum tube volt meter |
| BVP | Vault protector |
| MVOM | Volt ohm meter |
| PVR | Voltage regulator |
| MVAM | Voltammeter |

## 3. ALPHABETIC LIST OF SUBASSEMBLY CODES (COLUMNS 25-28)

Subassembly codes are listed alphabetically below.

| | |
|---|---|
| AMP | Amplifier |
| BCDU | BCD display unit |
| CSL | Channel selector |
| CHS | Chassis |
| CMOD | Control module |
| DT | Date timer |
| DDU | Digital display unit |
| DISC | Discriminator |
| FDV | Frequency divider |
| HSPA | Head switching panel assembly |
| HSPP | Heat sink power pack |
| INVT | Inverter |
| MASY | Meter assembly |
| MONT | Monitor |
| NKRG | Numeric register |
| OSC | Oscillator |
| OSCP | Oscilloscope |
| PAMP | Power amplifier |
| PS | Power supply |
| PFS | Primary frequency standard |
| PCB | Printed circuit board |
| PASY | Pump assembly |
| RCU | Remote centering unit |
| SSCP | Stroboscope |
| TSP | Transport |

## 4 LIST OF ACCEPTABLE SUBASSEMBLIES

### Long-Period Seismometers 7505 and 8700A

| | |
|---|---|
| 10073 | Monitor |
| 10074 | Monitor |
| 10075 | R. C. Unit |
| 10076 | R. C. Unit |

### Develocorder 4000

| | |
|---|---|
| 4800 | Date timer |
| 16042 | Pump assembly |

## Tape Recorder, Minneapolis-Honeywell 7360

| | |
|---|---|
| 3167 | Transport |
| 4215 | Record oscillator |
| 3770 | Power supply |
| 4103 | Direct/PDM record amp |
| 4182 | Bias oscillator |
| | Channel selector |
| 5204 | Signal discriminator |
| (5204 | Signal comp discriminator) |
| 5661 | Voice amplifier |

## Tape Recorder, Ampex 314

| | |
|---|---|
| 48700-01 | Transport |
| 65675 | Motor drive amp |
| 15246-10 | Blower and control circuit power supply |
| 15600-20 | Connecting chassis power supply |
| 48570-010 | Reproduce amplifier |
| 48790-2 | Head Sw. panel assembly |
| 15730-05 | Connecting chassis |
| 48725-010 | FM record amp |

## Timing System, 11880

| | |
|---|---|
| 5479 | Frequency standard |
| 5402 | Frequency divider |
| 5504B | Stroboscope |
| 8444A | Control module |
| 9220A | Inverter |

## Timing System, 19000

| | | |
|---|---|---|
| 00000 | Printed circuit board | Gate 1 |
| | Printed circuit board | Gate 2 |
| | Printed circuit board | Flip flop 1 |
| | Printed circuit board | Flip flop 2 |
| | Printed circuit board | Relay driver |
| | Printed circuit board | Sq amp |
| | Printed circuit board | Light driver |

## Timing System, 19000 (continued)

| | | |
|---|---|---|
| 00000-1 | Printed circuit board | Tuning fork oscillator |
| 00000-2 | Printed circuit board | Tuning fork oscillator |
| | Printed circuit board | Matrix - (different numbers) |
| | Printed circuit board | 1000 watt inverter |
| | Printed circuit board | BCD display unit |
| | Printed circuit board | Osc. scope assembly |
| 00000 | Printed circuit board | Power amp assembly |
| 18247 | Printed circuit board | Primary frequency standard |

## Digital Time Encoder 15925 Subassembly

| | | |
|---|---|---|
| 10948-2 | Printed circuit board | Matrix |
| 10325 | Printed circuit board | +9 V regulator |
| 10345 | Printed circuit board | -9 V regulator |
| 11484-1 | Printed circuit board | 2 input "and" gate |
| 11734-1 | Printed circuit board | 3 input "and" gate |
| 11770 | Printed circuit board | Driver |
| 12068 | Printed circuit board | Saturation amplifier |
| 12137-1 | Printed circuit board | Modulator |
| 12193 | Printed circuit board | Dual monostable |
| 14921 | Printed circuit board | +9 V series regulator |
| 14924 | Printed circuit board | -9 V series regulator |
| 15157 | Printed circuit board | 18 input "or" gate |
| 15221 | Printed circuit board | Dual trigger |
| 16809-1 | Printed circuit board | Dual flip flop |
| 15869 | Printed circuit board | Program |
| 11738-1 | Printed circuit board | Special program |

## Digital Time Encoder Aux Unit

Duplicates many of the printed circuit boards used of the 15925 time encoder.

## Digital Time Encoder 13159

| | | |
|---|---|---|
| 11564-2 | Printed circuit board | Dual flip flop |
| 11734-1 | Printed circuit board | 3 input "and" gate |

## Digital Time Encoder 13159 (continued)

| | | |
|---|---|---|
| 11738 | Printed circuit board | 19 input "or" gate |
| 12868 | Printed circuit board | Saturation amplifier |
| 11484-2 | Printed circuit board | 2 input "or" gate |
| 10948-1 | Printed circuit board | Matrix |
| 10948-2 | Printed circuit board | Matrix |
| 11770 | Printed circuit board | Driver |
| 12193 | Printed circuit board | Dual monostable |
| 11564-3 | Printed circuit board | Trigger |
| 13508 | Printed circuit board | Power supply |
| 13527 | Printed circuit board | + - 12 V regulator |
| 12137 | Printed circuit board | Modulator |
| 11484-1 | Printed circuit board | 2 input "and" gate |

## Programmer, Geotech Model 11395

| | |
|---|---|
| 20989 | Digital display unit |
| 11911 | Printed circuit board |
| 11547 | Printed circuit board |
| 11596 | Printed circuit board |
| 11511 | Printed circuit board |
| 11512 | Printed circuit board |
| 11513 | Printed circuit board |
| 11626 | Printed circuit board |
| 11518 | Printed circuit board |
| 12094 | Printed circuit board |
| 11644 | Printed circuit board |
| 11580 | Printed circuit board |
| 11581 | Printed circuit board |
| 11583 | Printed circuit board |

## G. R. Counter 1151AR

| | | |
|---|---|---|
| 1151-D1 | Printed circuit board | Ring counter |
| 1150-D2 | Printed circuit board | Ring counter |
| 1151-4720 | Printed circuit board | Time base |
| 1151-2730 | Printed circuit board | Program control |
| 1151-2751 | Printed circuit board | Power supply oscillator |
| 1151-4740 | Printed circuit board | Input circuit |
| | Numeric register | |

### Ac Time Voltage Regulator - Beckman 760R

| | |
|---|---|
| 400 | Heat sink power pack |
| 201 | Printed circuit board amplifier No. 1 |
| 202 | Printed circuit board amplifier No. 2 |
| 203 | Printed circuit board amplifier No. 3 |
| 204 | Printed circuit board control |
| 205 | Printed circuit board reference amplifier No. 1 |
| 206 | Printed circuit board reference amplifier No. 2 |
| 207 | Meter assembly |
| 303 | Power supply No. 3 |
| 304 | Power supply No. 4 |

## 5. COMMON AND MEANINGFUL SYMBOLS FROM MILITARY STANDARD 16C (COLUMNS 43-53)

| | |
|---|---|
| Battery | BT |
| Capacitor | C |
| Cell, light-sensitive, photoemissive (photoelectric cell) | V |
| Coil, (all others not classified as transformers) | L |
| Connector, plug, electrical | P |
| Connector, receptacle, electrical | J |
| Crystal detector (semiconductor device, diode) | CR |
| Crystal diode (semiconductor device, diode) | CR |
| Crystal unit (semiconductor device, diode) | CR |
| Cutout, fuse (fuse cutout) | F |
| Detector crystal (semiconductor device, diode) | CR |
| Device, indicating (indicator) except meter or thermometer | DS |
| Disconnecting device (switch) | S |
| Electron tube | V |
| Flasher (circuit interrupter) | DS |
| Fuse | F |
| Indicator (except meter or thermometer) | DS |
| Inductor | L |
| Jack | J |
| Key, telegraph | S |
| Key-switch (telephone usage) | S |
| Lamp, fluorescent | DS |

| | |
|---|---|
| Lamp, glow | DS |
| Lamp, incandescent | DS |
| Lamp, pilot (lamp, incandescent; lamp, glow) | DS |
| Lamp, signal (lamp, incandescent; lamp, glow) | DS |
| Motor | B |
| Neon lamp (lamp, glow) | DS |
| Phototube (photoelectric cell) | V |
| Plug, electrical (connector, plug, electrical) | P |
| Potentiometer (resistor, variable) | R |
| Power supply | PS |
| Rectifier (semiconductor device) | CR |
| Resistor | R |
| Resistor, thermal (thermistor) | R |
| Resistor, variable | R |
| Resist voltage sensitive | R |
| Rhe | R |
| Selenium cell (rectifier) | CR |
| Shunt, instrument | R |
| Switch | S |
| Switch, hook | S |
| Switch, interlock | S |
| Terminal board | TB |
| Transformer | T |
| Transistor | Q |
| Varistor, asymmetrical (semiconductor device, diode; rectifier metallic) | CR |
| Visual signalling device | DS |

## 6. ALPHABETIC LIST OF THE MORE COMMON MANUFACTURER CODES (COLUMNS 64-68)

### Federal codes

| | |
|---|---|
| 00656 | Aerovox |
| 92739 | Ampex |
| 04009 | Arrow-Hart and Hedgeman |
| 82376 | Astron |
| 07829 | Bodine Electric Corp. |
| 80294 | Bourns |

| | |
|---|---|
| 71400 | Bussmann (Fusetron) |
| 71471 | Cinema Engineering |
| 06184 | Con-Elco |
| 14655 | Cornell-Dubilier (capacitor) |
| 88026 | Cutler-Hammer (Los Angeles) |
| 12954 | Dickson Electronics |
| 71400 | Fusetron (Bussman) |
| 03508 | General Electric (semiconductors) |
| 24455 | General Electric (lamps) |
| 33173 | General Electric (tubes) |
| 99019 | Geotech |
| 14160 | Guardian Electric |
| 73061 | Hansen Princeton |
| 28480 | Hewlett-Packard |
| 91929 | Honeywell (Microswitch) |
| 11502 | International Resistance (IRC Boone) |
| 75042 | International Resistance (IRC Philadelphia) |
| 81483 | International Rectifier |
| 81856 | Kemlite |
| 75915 | Littelfuse |
| 38443 | Marlin-Rockwell |
| 91929 | Microswitch (Minneapolis Honeywell) |
| 40931 | Minneapolis-Honeywell Regulator Co. |
| 91929 | Minneapolis-Honeywell (Microswitch) |
| 04713 | Motorola (semiconductor) |
| 92726 | Mullard |
| 44655 | Ohmite |
| 81453 | Raytheon (tubes) |
| 02735 | RCA (semiconductors) |
| 49671 | RCA (tubes) |
| 82742 | Ripley |
| 84970 | Sarkes-Tarzian |
| 06292 | Specific Products |
| 83561 | Stancore (Standard Transformer) |
| 83561 | Standard Transformer (Stancore) |
| 58474 | Superior Electric |
| 82389 | Switchcraft |
| 82219 | Sylvania (tubes) |
| 93332 | Sylvania (semiconductors) |
| 94928 | Telefunken (tubes) |
| 01295 | Texas Instruments (semiconductors) |

| | |
|---|---|
| 87907 | Tilton |
| 94154 | Tung-Sol (lamps) |
| 88870 | Walkirt |
| 63810 | Warner Electric Brake-Clutch |
| 07138 | Westinghouse (tubes) |
| 65035 | Westinghouse Air Brake |

## 7. PRINTOUT OF PROGRAM MISERABLE FOR MAGNETIC-TAPE INPUT

```
         PROGRAM MISERABLE
         DIMENSION KCOMP(3),KSP1(10/,KMOD1(10),KMOD2(10),MSUB(10),ATIME1(10
       1 ),ATIME2(10),KPREV(10),KCAT(10),KOUNT(25,10),MCOMP(25,10,3),
       2 KHOLD(10),NSERV(10)
  101    FORMAT(A3,I2,I3,A1,A3,2A4,4X,A4,14X,2A4,A3,15X,F3.1,2X,F5.1,A1)
         ISTOP=1
         IST=0                                                          1ST 41Y
         IFIN=366                                                       END DAY
         IYR=64                                                         YEAR
         IPRINT=2
         PAUSE 77
         KS=0
   90    ITYPE=1
         KHOLD(1)=1
  100    READ INPUT TAPE 2,101,KOBS,KYR,KDAY,KGEC,KSP,MOD1,MOD2,KSUB,KCOMP(
       1 1),KCOMP(2),KCOMP(3),TIME1,TIME2,KF
         IF(XEOF(2))102,105,102
  102    ISTOP=2
         GO TO 300
  105    IF(IYR-KYR)100,106,100
  106    IF(KDAY-IST)100,107,107
  107    IF(KDAY-IFIN)103,103,100
B 103    IF(KS/KOBS)110,200,110
  110    KS=0
         GO TO(300,1110)IPRINT
 1110    PRINT 109,KOBS
  109    FORMAT(1H1,50X,9HSTATION   ,A4//6X,8HSPECIFIC,17X,3HSUB,9X,3HNO.,6X
       1 ,6HREPAIR,6X,4HTIME/6X,8HFUNCTION,3X,9HMODEL NO.,3X,8HASSEMBLY,
       2 3X,8HSERVICED,5X,4HTIME,7X,5HINOP.,3X,9HPREVENT.  ,4X,6HCATAS.,8X,
       3 9HCOMPONENT,7X,3HNO.//)
         IF(KS)300,111,300
  111    KOM=KGEC
         KS=KOBS
  115    KSP1(ITYPE)=KSP
         KMOD1(ITYPE)=MOD1
         KMOD2(ITYPE)=MOD2
         MSUB(ITYPE)=KSUB
         NSERV(ITYPE)=1
         ATIME1(ITYPE)=TIME1
         ATIME2(ITYPE)=TIME2
         I=ITYPE
```

```
B          IF(KF/63202020)120,130,120
    120    KPREV(ITYPE)=1
           KCAT(ITYPE)=0
           GO TO 140
    130    KPREV(ITYPE)=0
           KCAT(ITYPE)=1
    140    ICOMP=KHOLD(I)
           KOUNT(ICOMP,I)=1
           MCOMP(ICOMP,I,1)=KCOMP(1)
           MCOMP(ICOMP,I,2)=KCOMP(2)
           MCOMP(ICOMP,I,3)=KCOMP(3)
           IPRINT=1
           GO TO 100
    200    GO TO(201,111)IPRINT
B   201    IF(KGEC/KOM)300,210,300
    210    DO 280 I=1,ITYPE
B          IF(KSP/KSP1(I))280,220,280
B   220    IF(MOD1/KMOD1(I))280,230,280
B   230    IF(MOD2/KMOD2(I))280,240,280
B   240    IF(KSUB/MSUB(I))280,250,280
    250    ATIME1(I)=ATIME1(I)+TIME1
           ATIME2(I)=ATIME2(I)+TIME2
           NSERV(I)=NSERV(I)+1
B          IF(KF/63202020)251,252,251
    251    KPREV(I)=KPREV(I)+1
           GO TO 255
    252    KCAT(I)=KCAT(I)+1
    255    LL=KHOLD(I)
           DO 270 L=1,LL
           DO 260 J=1,3
B          IF(KCOMP(J)/MCOMP(L,I,J))270,260,270
    260    CONTINUE
           KOUNT(L,I)=KOUNT(L,I)+1
           GO TO 100
    270    CONTINUE
           KHOLD(I)=KHOLD(I)+1
           IF(KHOLD(I)-25)140,140,271
    271    PAUSE 11
    280    CONTINUE
           ITYPE=ITYPE+1
           IF(ITYPE-10)281,281,282
    281    KHOLD(ITYPE)=1
           GO TO 115
    282    ITYPE=10
    300    BACKSPACE 2
           DO 320 I=1,ITYPE
           IF(I-1)305,305,307
    305    PRINT 306,KSP1(I),KMOD1(I),KMOD2(I),MSUB(I),NSERV(I),ATIME1(I),
         2 ATIME2(I),KPREV(I),KCAT(I)
    306    FORMAT(1H0,7X,A4,4X,1H(,2A4,1H),5X,A4,5X,I5,5X,F6.1,6X,F6.1,3X,I5,
         2 7X,I5)
           GO TO 309
B   307    IF(KSP1(I)/KSP1(I-1))305,1307,305
B 1307    IF(KMOD1(I)/KMOD1(I-1))305,1308,305
B 1308    IF(KMOD2(I)/KMOD2(I-1))305,1309,305
  1309    PRINT 308,MSUB(I),NSERV(I),ATIME1(I),ATIME2(I),KPREV(I),KCAT(I)
   309    L=KHOLD(I)
   308    FORMAT(31X,A4,5X,I5,5X,F6.1,6X,F6.1,3X,I5,7X,I5)
          DO 310 J=1,L
   310    PRINT 311,(MCOMP(J,I,K),K=1,3),KOUNT(J,I)
   311    FORMAT(100X,3A4,I5)
   320    CONTINUE
          IPRINT=2
          GO TO (90,400) ISTOP
   400    END
```

## APPENDIX 4 to TECHNICAL REPORT NO. 65-58

## OUTDOOR CABLE CODES USED AT THE VT/1124 OBSERVATORIES

## OUTDOOR CABLE CODE USED AT THE VT/1124 OBSERVATORIES

### Outdoor cable code identification

Z1D-Z1 Data
thru
Z19D-Z19 Data

NSD - NSP Data
NSC - NSP Cal
ESD - ESP Data
ESC - ESP Cal
Z1BD - ZIB Data
Z1BC - ZIB Cal
N1D - NIB Data
N1C - NIB Cal
E1D - EIB Data
E1C - EIB Cal
ZBD - ZBB Data
ZBC - ZBB Cal
NBD - NBB Data
NBC - NBB Cal
EBD - EBB Data
EBC - EBB Cal
BC - 3 comp BB Cal
ZLD - ZLP Data
ZLC - ZLP Cal
NLD - NLP Data
NLC - NLP Cal
ELD - ELP Data
ELC - ELP Cal
LC - 3 comp LP Cal
DWD - Deep-hole data
DWC - Deep-hole cal
DWBC - Deep-hole ball lift
SPD1 - Spare deep hole
SPS1 - Spare shallow hole

Z1C-Z1 Cal
thru
Z19C-Z19 Cal

ZLAP - ZLP L Amp Power
NLAP - NLP L Amp Power
ELAP - ELP L Amp Power
ZMPA - ZLP Mass-Position Act.
HMPA - N-ELP Mass-Position Act.
NMPA - NLP Mass-Position Act.
EMPA - ELP Mass-Position Act.
ZMBO - ZLP Mass-Position Bridge Out
HMBO - N-ELP Mass-Position Bridge Out
NMBO - NLP Mass-Position Bridge Out
EMBO - ELP Mass-Position Bridge Out
A - Anemometer
WD - Wind Direction
MFP - Microbarograph Filter Power
MPP - Microbarograph Plate Power
AC1 - 115 Vac Service Power TFP No. 1
AC2 - 115 Vac Service Power TFP No. 2
ZVHP - ZLP Vault Heater Power
NVHP - NLP Vault Heater Power
EVHP - ELP Vault Heater Power
LSHP - CRB LP Seis Heater Power
ZSHP - ZLP Seis Heater Power
NSHP - NLP Seis Heater Power
ESHP - ELP Seis Heater Power
SWD - Shallow-hole data
SWC - Shallow-hole cal
SWBC - Shallow-hole ball lift
STP1 - Spare tank farm
STP2 - Spare tank farm

# APPENDIX 6 to TECHNICAL REPORT NO. 65-58

## TRAVEL TIME TABLES FOR USE IN THE AUTOMATED BULLETIN PROCESS

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Table 1. P phase travel times versus distance and depth for use in the automated bulletin process program

| | Travel times (seconds) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Depth (kilometers) | | | | | | | | | | | | |
| Distance (degrees) | Surface | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
| 0 | 6.8 | 5.4 | 13.5 | 21.4 | 29.1 | 36.6 | 43.9 | 51.1 | 58.0 | 64.5 | 70.8 | 76.8 | 82.8 | 88.8 |
| 0.0001 | 6.8 | 5.4 | 13.5 | 21.4 | 29.1 | 36.6 | 43.9 | 51.1 | 58.0 | 64.5 | 70.8 | 76.8 | 82.8 | 88.8 |
| 0.5 | 14.0 | 10.5 | 15.6 | 22.6 | 29.9 | 37.2 | 44.4 | 51.5 | 58.3 | 64.8 | 71.0 | 77.0 | 83.0 | 89.0 |
| 1.0 | 21.1 | 17.7 | 20.4 | 25.8 | 32.2 | 39.1 | 45.9 | 52.7 | 59.3 | 65.7 | 71.8 | 77.7 | 83.6 | 89.5 |
| 1.5 | 28.2 | 24.8 | 26.7 | 30.6 | 36.0 | 42.3 | 48.4 | 54.8 | 61.0 | 67.2 | 73.1 | 78.8 | 84.6 | 90.3 |
| 2.0 | 35.4 | 32.0 | 32.9 | 36.0 | 40.6 | 45.8 | 51.6 | 57.6 | 63.4 | 69.2 | 74.8 | 80.3 | 85.9 | 91.5 |
| 3.0 | 49.7 | 46.3 | 46.7 | 48.4 | 51.3 | 55.2 | 59.7 | 64.6 | 69.7 | 74.8 | 79.8 | 84.7 | 89.8 | 94.9 |
| 4.0 | 63.9 | 60.5 | 60.4 | 61.3 | 63.2 | 66.0 | 69.4 | 73.4 | 77.5 | 81.7 | 86.2 | 90.6 | 95.1 | 99.7 |
| 6.0 | 92.2 | 88.7 | 87.7 | 87.6 | 88.3 | 89.5 | 91.4 | 93.7 | 96.3 | 98.9 | 101.8 | 104.8 | 108.2 | 111.9 |
| 8.0 | 120.3 | 116.7 | 115.2 | 114.3 | 114.0 | 114.2 | 114.9 | 116.1 | 117.1 | 118.3 | 119.8 | 121.7 | 124.0 | 126.5 |
| 10.0 | 148.5 | 144.4 | 142.2 | 140.6 | 139.7 | 139.0 | 132.8 | 139.0 | 138.6 | 138.6 | 138.9 | 139.9 | 141.2 | 142.7 |
| 12.0 | 175.3 | 171.6 | 168.9 | 166.7 | 165.1 | 163.8 | 162.8 | 161.8 | 159.6 | 158.9 | 158.6 | 158.6 | 159.0 | 159.8 |
| 14.0 | 201.9 | 198.1 | 195.0 | 192.3 | 190.0 | 188.1 | 186.3 | 183.6 | 180.9 | 179.2 | 178.2 | 177.6 | 177.2 | 177.3 |
| 15.0 | 215.0 | 211.2 | 207.9 | 204.9 | 202.3 | 200.1 | 197.0 | 194.0 | 191.1 | 189.2 | 187.9 | 197.1 | 186.4 | 186.2 |
| 16.0 | 228.0 | 224.1 | 220.5 | 217.3 | 214.4 | 211.3 | 207.6 | 204.1 | 201.2 | 199.0 | 197.5 | 196.4 | 195.5 | 195.1 |
| 17.0 | 240.7 | 236.7 | 232.9 | 229.5 | 226.0 | 221.9 | 218.0 | 214.2 | 211.2 | 208.7 | 206.9 | 205.5 | 204.5 | 204.0 |
| 18.0 | 253.2 | 249.2 | 245.2 | 241.1 | 236.5 | 232.2 | 228.1 | 224.3 | 221.1 | 218.4 | 216.3 | 214.7 | 213.5 | 212.8 |
| 19.0 | 265.5 | 261.5 | 256.5 | 251.6 | 246.7 | 242.3 | 238.1 | 234.1 | 230.8 | 227.9 | 225.6 | 223.8 | 222.5 | 221.6 |
| 20.0 | 277.0 | 272.5 | 267.1 | 261.9 | 256.9 | 252.2 | 247.9 | 243.8 | 240.3 | 237.3 | 234.8 | 232.8 | 231.3 | 230.3 |
| 22.0 | 297.5 | 292.9 | 287.2 | 281.7 | 276.5 | 271.7 | 267.2 | 262.9 | 259.0 | 255.7 | 253.0 | 250.8 | 249.0 | 247.7 |
| 24.0 | 317.1 | 312.5 | 306.5 | 301.0 | 295.6 | 290.5 | 285.7 | 281.1 | 277.1 | 273.7 | 270.8 | 268.4 | 266.4 | 264.9 |
| 26.0 | 336.2 | 331.6 | 325.5 | 319.7 | 314.1 | 308.7 | 303.8 | 299.1 | 295.0 | 291.4 | 288.4 | 285.8 | 283.6 | 281.9 |
| 28.0 | 354.5 | 349.9 | 343.8 | 337.9 | 332.2 | 326.8 | 321.7 | 316.8 | 312.6 | 309.0 | 305.7 | 302.9 | 300.6 | 298.7 |
| 30.0 | 372.5 | 367.7 | 361.6 | 355.7 | 349.9 | 344.4 | 339.2 | 334.2 | 330.0 | 326.0 | 322.8 | 319.9 | 317.4 | 315.4 |
| 32.0 | 390.1 | 385.4 | 379.1 | 373.2 | 367.3 | 361.7 | 356.4 | 351.4 | 347.1 | 343.2 | 339.7 | 336.7 | 334.1 | 331.9 |
| 34.0 | 407.5 | 402.7 | 396.4 | 390.3 | 384.4 | 378.8 | 373.4 | 368.4 | 363.9 | 360.0 | 356.4 | 353.3 | 350.5 | 348.2 |
| 36.0 | 424.6 | 419.8 | 413.4 | 407.2 | 401.3 | 395.6 | 390.2 | 385.2 | 380.6 | 376.6 | 372.9 | 369.7 | 366.8 | 364.4 |
| 38.0 | 441.4 | 436.6 | 430.1 | 424.0 | 418.0 | 412.3 | 406.8 | 401.7 | 397.1 | 392.9 | 389.3 | 386.0 | 383.0 | 380.4 |
| 40.0 | 458.1 | 453.2 | 446.7 | 440.5 | 434.5 | 428.7 | 423.2 | 418.1 | 413.4 | 409.1 | 405.4 | 402.0 | 398.9 | 396.1 |
| 42.0 | 474.5 | 469.7 | 463.1 | 456.9 | 450.8 | 445.0 | 439.4 | 434.2 | 429.5 | 425.1 | 421.3 | 417.8 | 414.5 | 411.5 |
| 44.0 | 490.8 | 486.0 | 479.4 | 473.0 | 466.9 | 461.0 | 455.4 | 450.1 | 445.3 | 440.8 | 436.9 | 433.3 | 429.8 | 426.7 |
| 46.0 | 506.8 | 402.0 | 495.3 | 488.9 | 482.7 | 476.7 | 471.1 | 465.8 | 460.8 | 456.3 | 452.2 | 448.5 | 444.9 | 441.7 |
| 48.0 | 522.6 | 517.7 | 511.0 | 404.5 | 498.2 | 492.2 | 486.5 | 481.1 | 476.1 | 471.5 | 467.3 | 463.4 | 459.8 | 456.4 |
| 50.0 | 538.0 | 533.1 | 526.4 | 519.8 | 513.4 | 507.3 | 501.6 | 496.2 | 491.1 | 486.4 | 482.1 | 478.1 | 474.4 | 470.9 |
| 53.0 | 560.7 | 555.7 | 549.0 | 542.3 | 535.7 | 529.4 | 523.7 | 518.3 | 513.0 | 508.1 | 503.6 | 499.5 | 495.6 | 491.9 |
| 56.0 | 582.6 | 577.6 | 570.8 | 564.1 | 557.3 | 550.9 | 545.1 | 539.6 | 534.2 | 529.1 | 524.5 | 520.2 | 516.2 | 512.3 |
| 59.0 | 603.8 | 598.8 | 591.8 | 585.1 | 578.3 | 571.8 | 565.8 | 560.0 | 554.5 | 549.5 | 544.8 | 540.3 | 536.1 | 532.1 |
| 62.0 | 624.3 | 619.2 | 612.2 | 605.4 | 598.5 | 591.9 | 585.7 | 579.9 | 574.4 | 569.2 | 564.4 | 559.8 | 555.4 | 551.4 |
| 65.0 | 644.0 | 638.9 | 631.9 | 625.0 | 618.0 | 611.3 | 605.0 | 599.2 | 593.6 | 588.3 | 583.4 | 578.7 | 574.2 | 570.0 |
| 68.0 | 663.1 | 657.9 | 650.8 | 643.9 | 636.9 | 630.1 | 623.7 | 617.8 | 612.1 | 606.8 | 601.7 | 597.0 | 592.4 | 588.0 |
| 71.0 | 681.5 | 676.3 | 669.1 | 662.1 | 655.1 | 648.3 | 641.9 | 635.8 | 630.0 | 624.6 | 619.4 | 614.6 | 610.0 | 605.4 |
| 75.0 | 705.0 | 699.8 | 692.5 | 685.4 | 678.5 | 671.7 | 665.2 | 658.8 | 652.9 | 647.3 | 642.1 | 637.1 | 632.3 | 627.6 |
| 80.0 | 732.7 | 727.6 | 720.2 | 712.9 | 705.8 | 698.9 | 692.3 | 685.9 | 679.8 | 674.1 | 668.8 | 663.7 | 658.7 | 653.8 |
| 85.0 | 758.5 | 753.3 | 745.8 | 738.5 | 731.4 | 724.4 | 717.7 | 711.2 | 705.0 | 699.2 | 693.8 | 688.6 | 683.4 | 678.4 |
| 90.0 | 782.7 | 777.4 | 769.8 | 762.4 | 755.2 | 748.2 | 741.7 | 734.8 | 728.6 | 722.7 | 717.3 | 711.9 | 706.7 | 701.6 |
| 95.0 | 805.7 | 800.4 | 792.8 | 785.4 | 778.2 | 771.2 | 764.4 | 757.8 | 751.5 | 745.6 | 740.0 | 734.8 | 729.6 | 724.4 |
| 100.0 | 828.4 | 823.1 | 815.5 | 808.1 | 800.9 | 793.8 | 787.1 | 780.4 | 774.1 | 768.2 | 762.6 | 757.3 | 752.1 | 747.0 |
| 105.0 | 850.6 | 845.3 | 837.6 | 830.2 | 823.0 | 816.0 | 809.1 | 802.4 | 796.1 | 790.2 | 784.6 | 779.3 | 774.1 | 769.0 |
| 110.0 | 872.6 | 867.3 | 859.6 | 852.2 | 845.0 | 838.0 | 831.1 | 824.4 | 818.1 | 812.2 | 806.6 | 801.3 | 796.1 | 791.0 |
| 110.1 | 872.6 | 867.3 | 859.6 | 852.2 | 845.0 | 838.0 | 831.1 | 824.4 | 818.1 | 812.2 | 806.6 | 801.3 | 796.1 | 791.0 |

Table 2b. PKP$_2$ travel time versus distance and depth for use in the automated bulletin process program

| Distance (degrees) | Surface | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Travel times (seconds) | | | | | | | | | | | | | |
| | | Depth (kilometers) | | | | | | | | | | | | |
| 142.0 | 1170.2 | 1165.0 | 1157.4 | 1150.2 | 1143.1 | 1136.3 | 1129.7 | 1123.3 | 1117.1 | 1111.3 | 1105.9 | 1101.1 | 1096.3 | 1091.7 |
| 143.0 | 1173.5 | 1168.3 | 1160.7 | 1153.5 | 1146.4 | 1139.4 | 1132.8 | 1126.4 | 1120.1 | 1114.3 | 1108.8 | 1103.9 | 1099.1 | 1094.4 |
| 145.0 | 1180.4 | 1175.2 | 1167.6 | 1160.3 | 1153.2 | 1146.2 | 1139.4 | 1132.9 | 1126.7 | 1120.8 | 1115.3 | 1110.4 | 1105.5 | 1100.7 |
| 147.0 | 1188.1 | 1182.9 | 1175.3 | 1168.9 | 1160.7 | 1153.7 | 1146.9 | 1140.4 | 1134.0 | 1128.1 | 1122.6 | 1117.7 | 1112.6 | 1107.8 |
| 149.0 | 1196.1 | 1190.9 | 1183.3 | 1175.8 | 1168.6 | 1161.5 | 1154.6 | 1148.0 | 1141.4 | 1135.4 | 1129.9 | 1125.1 | 1120.0 | 1115.2 |
| 151.0 | 1204.4 | 1199.1 | 1191.5 | 1184.0 | 1176.8 | 1169.9 | 1162.8 | 1156.2 | 1149.8 | 1143.8 | 1138.3 | 1133.1 | 1128.0 | 1123.0 |
| 153.0 | 1212.8 | 1207.5 | 1199.9 | 1192.4 | 1185.2 | 1178.3 | 1171.4 | 1164.8 | 1158.4 | 1152.4 | 1146.9 | 1141.7 | 1136.6 | 1131.6 |
| 155.0 | 1221.2 | 1215.9 | 1208.3 | 1200.8 | 1193.6 | 1186.7 | 1179.8 | 1173.2 | 1166.8 | 1160.8 | 1155.3 | 1150.1 | 1145.0 | 1140.0 |
| 157.0 | 1229.8 | 1224.5 | 1216.9 | 1209.4 | 1202.2 | 1195.3 | 1188.4 | 1181.7 | 1175.3 | 1169.3 | 1163.8 | 1158.2 | 1153.1 | 1148.1 |
| 159.0 | 1238.4 | 1233.1 | 1225.5 | 1218.0 | 1210.8 | 1203.9 | 1197.0 | 1190.3 | 1183.9 | 1177.9 | 1172.4 | 1167.2 | 1162.1 | 1157.1 |
| 161.0 | 1247.0 | 1241.7 | 1234.1 | 1226.6 | 1219.3 | 1212.2 | 1205.3 | 1198.7 | 1192.2 | 1186.2 | 1180.7 | 1175.5 | 1170.4 | 1165.3 |
| 163.0 | 1255.7 | 1250.4 | 1242.8 | 1235.3 | 1228.0 | 1220.9 | 1214.0 | 1207.4 | 1200.9 | 1194.9 | 1189.4 | 1184.2 | 1179.1 | 1174.0 |
| 165.0 | 1264.4 | 1259.1 | 1251.5 | 1244.0 | 1236.7 | 1229.6 | 1222.7 | 1216.1 | 1209.6 | 1203.6 | 1198.1 | 1192.7 | 1187.6 | 1182.5 |
| 167.0 | 1273.1 | 1268.8 | 1260.2 | 1252.5 | 1245.4 | 1238.3 | 1231.4 | 1224.8 | 1218.3 | 1212.3 | 1206.8 | 1201.4 | 1196.3 | 1191.2 |
| 169.0 | 1281.9 | 1277.6 | 1269.0 | 1261.5 | 1254.2 | 1247.1 | 1240.2 | 1233.6 | 1227.1 | 1221.1 | 1215.6 | 1210.2 | 1205.1 | 1200.0 |
| 171.0 | 1290.8 | 1285.5 | 1277.8 | 1270.3 | 1263.0 | 1255.9 | 1249.0 | 1242.3 | 1235.8 | 1229.8 | 1224.2 | 1218.8 | 1213.7 | 1208.6 |
| 173.0 | 1299.6 | 1294.3 | 1286.6 | 1279.1 | 1272.8 | 1265.7 | 1258.8 | 1252.1 | 1245.6 | 1239.6 | 1234.0 | 1228.6 | 1223.5 | 1218.4 |
| 175.0 | 1308.5 | 1303.2 | 1295.5 | 1288.0 | 1280.7 | 1273.6 | 1266.7 | 1260.0 | 1253.5 | 1247.5 | 1241.9 | 1236.5 | 1231.4 | 1226.3 |
| 177.0 | 1317.4 | 1312.1 | 1304.4 | 1296.9 | 1289.6 | 1282.5 | 1275.6 | 1268.9 | 1262.4 | 1256.4 | 1250.8 | 1245.4 | 1240.3 | 1235.2 |
| 179.0 | 1326.2 | 1320.9 | 1313.2 | 1305.7 | 1298.4 | 1291.3 | 1284.4 | 1277.7 | 1271.2 | 1265.2 | 1259.6 | 1254.2 | 1249.1 | 1244.0 |
| 180.0 | 1330.6 | 1325.3 | 1317.6 | 1310.1 | 1302.8 | 1295.1 | 1288.2 | 1281.5 | 1275.0 | 1269.0 | 1263.4 | 1258.0 | 1252.9 | 1247.8 |
| 181.0 | 1335.0 | 1329.7 | 1322.0 | 1314.5 | 1307.2 | 1300.1 | 1293.2 | 1286.5 | 1280.0 | 1274.0 | 1268.4 | 1263.0 | 1257.9 | 1252.8 |

Table 2a. PKP1 travel time versus distance and depth for use in the automated bulletin process program

| Distance (degrees) | Surface | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Travel times (seconds) | | | | | | | | | | | | | |
| | | Depth (kilometers) | | | | | | | | | | | | |
| 109.0 | 1111.2 | 1105.8 | 1097.8 | 1090.0 | 1082.4 | 1075.0 | 1067.7 | 1060.7 | 1054.0 | 1047.5 | 1041.4 | 1035.5 | 1029.7 | 1023.9 |
| 110.0 | 1113.2 | 1107.8 | 1099.8 | 1092.0 | 1084.4 | 1077.0 | 1069.7 | 1062.7 | 1056.0 | 1049.5 | 1043.4 | 1037.5 | 1031.7 | 1025.9 |
| 112.0 | 1117.1 | 1111.7 | 1103.7 | 1095.9 | 1088.3 | 1080.9 | 1073.6 | 1066.6 | 1059.9 | 1053.4 | 1047.3 | 1041.4 | 1035.6 | 1029.8 |
| 115.0 | 1123.0 | 1117.6 | 1109.6 | 1101.8 | 1094.2 | 1086.8 | 1079.5 | 1072.5 | 1065.8 | 1059.3 | 1053.2 | 1047.3 | 1041.5 | 1035.7 |
| 120.0 | 1132.7 | 1127.3 | 1119.3 | 1111.5 | 1103.9 | 1096.5 | 1089.2 | 1082.2 | 1075.5 | 1069.0 | 1062.9 | 1057.0 | 1051.2 | 1045.4 |
| 125.0 | 1142.4 | 1137.0 | 1129.0 | 1121.2 | 1113.6 | 1106.2 | 1098.9 | 1091.9 | 1085.2 | 1078.7 | 1072.6 | 1066.7 | 1060.9 | 1055.1 |
| 130.0 | 1152.0 | 1146.6 | 1138.6 | 1130.8 | 1123.2 | 1115.8 | 1108.5 | 1101.5 | 1094.8 | 1088.3 | 1082.2 | 1076.3 | 1070.5 | 1064.7 |
| 135.0 | 1161.4 | 1156.0 | 1148.0 | 1140.2 | 1132.6 | 1125.2 | 1117.9 | 1110.9 | 1104.2 | 1097.7 | 1091.6 | 1085.7 | 1079.9 | 1074.1 |
| 140.0 | 1170.5 | 1165.1 | 1157.1 | 1149.3 | 1141.7 | 1134.3 | 1127.0 | 1120.0 | 1113.3 | 1106.8 | 1100.7 | 1094.8 | 1089.0 | 1083.2 |
| 145.0 | 1179.2 | 1173.9 | 1166.0 | 1158.2 | 1150.7 | 1143.3 | 1136.1 | 1129.1 | 1122.4 | 1116.0 | 1109.9 | 1104.0 | 1098.2 | 1092.5 |
| 150.0 | 1187.4 | 1182.0 | 1174.0 | 1166.1 | 1158.5 | 1151.0 | 1143.7 | 1136.6 | 1129.8 | 1123.3 | 1117.2 | 1111.2 | 1105.2 | 1099.3 |
| 155.0 | 1194.5 | 1189.1 | 1181.1 | 1173.2 | 1165.6 | 1158.1 | 1150.8 | 1143.7 | 1136.8 | 1130.3 | 1124.2 | 1118.2 | 1112.2 | 1106.3 |
| 160.0 | 1200.8 | 1195.4 | 1187.4 | 1179.5 | 1171.8 | 1164.3 | 1157.0 | 1149.9 | 1143.0 | 1136.5 | 1130.4 | 1124.4 | 1118.4 | 1112.4 |
| 165.0 | 1205.8 | 1200.4 | 1192.4 | 1184.5 | 1176.8 | 1169.3 | 1162.0 | 1154.8 | 1147.9 | 1141.4 | 1135.2 | 1129.2 | 1123.2 | 1117.2 |
| 170.0 | 1209.2 | 1203.8 | 1195.7 | 1187.8 | 1180.1 | 1172.6 | 1165.3 | 1158.1 | 1151.2 | 1144.7 | 1138.5 | 1132.5 | 1126.5 | 1120.5 |
| 175.0 | 1211.5 | 1206.1 | 1198.0 | 1190.1 | 1182.4 | 1174.9 | 1167.6 | 1160.4 | 1153.5 | 1147.0 | 1140.7 | 1134.8 | 1128.8 | 1122.8 |
| 177.0 | 1212.0 | 1206.6 | 1198.5 | 1190.6 | 1182.9 | 1175.4 | 1168.1 | 1160.9 | 1154.0 | 1147.5 | 1141.2 | 1135.2 | 1129.2 | 1123.2 |
| 179.0 | 1212.1 | 1206.7 | 1198.6 | 1190.7 | 1183.0 | 1175.5 | 1168.2 | 1161.0 | 1154.1 | 1147.6 | 1141.3 | 1135.3 | 1129.3 | 1123.3 |
| 180.0 | 1212.2 | 1206.8 | 1198.7 | 1190.8 | 1183.1 | 1175.6 | 1168.3 | 1161.1 | 1154.2 | 1147.7 | 1141.4 | 1135.4 | 1129.4 | 1123.4 |
| 181.0 | 1212.3 | 1206.9 | 1198.8 | 1190.9 | 1183.2 | 1175.7 | 1168.4 | 1161.2 | 1154.3 | 1147.8 | 1141.5 | 1135.5 | 1129.5 | 1123.5 |

Table 3a. PKKP1 travel times versus distance and depth for use in the automated bulletin process program

| Distance (degrees) | Travel times (seconds) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Depth (kilometers) | | | | | | | | | | | | |
| | Surface | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
| 0 | 1910.0 | 1904.6 | 1896.5 | 1888.6 | 1880.9 | 1873.4 | 1866.1 | 1858.9 | 1852.0 | 1845.0 | 1839.2 | 1833.2 | 1827.2 | 1821.2 |
| 1.0 | 1910.1 | 1904.7 | 1896.6 | 1888.7 | 1881.0 | 1873.5 | 1866.2 | 1859.0 | 1852.1 | 1845.1 | 1839.3 | 1833.3 | 1827.3 | 1821.3 |
| 40.0 | 1892.0 | 1886.6 | 1878.6 | 1870.7 | 1863.0 | 1855.5 | 1848.2 | 1841.0 | 1834.1 | 1827.6 | 1821.4 | 1815.4 | 1809.4 | 1803.4 |
| 65.0 | 1864.0 | 1858.5 | 1850.4 | 1842.5 | 1834.8 | 1827.3 | 1820.1 | 1812.9 | 1806.1 | 1799.5 | 1793.5 | 1787.5 | 1781.4 | 1775.4 |
| 90.0 | 1825.0 | 1819.7 | 1811.7 | 1803.9 | 1796.3 | 1788.8 | 1781.5 | 1774.4 | 1767.6 | 1761.1 | 1755.0 | 1748.9 | 1743.0 | 1737.2 |
| 115.0 | 1780.0 | 1774.6 | 1766.6 | 1758.8 | 1751.2 | 1743.8 | 1736.5 | 1729.5 | 1722.8 | 1716.3 | 1710.2 | 1705.3 | 1698.5 | 1692.7 |
| 135.0 | 1742.0 | 1736.6 | 1728.6 | 1720.8 | 1713.2 | 1705.8 | 1698.5 | 1691.5 | 1684.8 | 1678.3 | 1672.2 | 1666.3 | 1660.3 | 1654.7 |
| 150.0 | 1713.0 | 1707.6 | 1699.6 | 1691.9 | 1684.3 | 1676.9 | 1669.7 | 1662.7 | 1656.0 | 1649.5 | 1643.4 | 1637.6 | 1631.8 | 1626.0 |
| 162.0 | 1690.0 | 1684.6 | 1676.6 | 1668.8 | 1661.2 | 1653.8 | 1646.4 | 1639.4 | 1632.7 | 1626.2 | 1620.1 | 1614.2 | 1608.4 | 1602.5 |
| 165.0 | 1684.0 | 1678.6 | 1670.6 | 1662.8 | 1655.2 | 1647.8 | 1640.4 | 1633.0 | 1626.7 | 1620.2 | 1614.1 | 1608.2 | 1602.4 | 1596.5 |

Table 3b. PKKP2 travel times versus distance and depth for use in the automated bulletin process program

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 104.0 | 1815.1 | 1809.7 | 1801.6 | 1793.7 | 1786.0 | 1778.5 | 1771.2 | 1764.0 | 1757.1 | 1750.6 | 1744.3 | 1738.3 | 1732.3 | 1726.3 |
| 105.0 | 1810.7 | 1805.3 | 1797.2 | 1789.3 | 1781.6 | 1774.1 | 1766.8 | 1759.6 | 1752.7 | 1746.2 | 1739.9 | 1733.9 | 1727.9 | 1721.9 |
| 110.0 | 1788.5 | 1783.1 | 1775.0 | 1767.1 | 1759.4 | 1751.9 | 1744.6 | 1737.4 | 1730.5 | 1724.0 | 1717.8 | 1711.8 | 1705.7 | 1699.8 |
| 120.0 | 1744.8 | 1739.4 | 1731.4 | 1723.5 | 1715.8 | 1708.3 | 1701.0 | 1693.8 | 1686.9 | 1680.4 | 1674.3 | 1668.3 | 1662.3 | 1656.3 |
| 126.0 | 1719.4 | 1714.0 | 1705.9 | 1698.9 | 1690.3 | 1684.8 | 1675.6 | 1668.4 | 1661.6 | 1655.1 | 1649.0 | 1643.1 | 1637.0 | 1631.0 |
| 128.0 | 1711.0 | 1705.6 | 1697.5 | 1790.5 | 1681.9 | 1674.4 | 1667.2 | 1660.0 | 1653.2 | 1646.7 | 1640.6 | 1634.7 | 1628.6 | 1622.6 |

Table 3c. PKKP3 travel times versus distance and depth for use in the automated bulletin process program

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 93.0 | 1820.7 | 1815.3 | 1807.3 | 1799.5 | 1791.9 | 1784.5 | 1777.2 | 1770.2 | 1763.5 | 1757.0 | 1750.9 | 1745.0 | 1739.2 | 1733.4 |
| 94.0 | 1818.4 | 1813.0 | 1805.0 | 1797.2 | 1789.6 | 1782.2 | 1774.9 | 1767.9 | 1761.2 | 1754.7 | 1748.6 | 1742.7 | 1736.9 | 1731.1 |
| 100.0 | 1803.7 | 1798.4 | 1790.4 | 1782.6 | 1775.1 | 1767.7 | 1760.4 | 1753.4 | 1746.7 | 1740.3 | 1734.2 | 1728.3 | 1722.5 | 1716.7 |
| 110.0 | 1775.7 | 1770.2 | 1762.3 | 1754.6 | 1747.1 | 1739.7 | 1732.6 | 1725.7 | 1719.0 | 1712.6 | 1706.6 | 1700.7 | 1695.0 | 1689.4 |
| 120.0 | 1742.5 | 1737.2 | 1729.3 | 1721.5 | 1714.0 | 1706.6 | 1699.4 | 1692.5 | 1685.8 | 1679.4 | 1673.3 | 1667.4 | 1661.6 | 1655.9 |
| 126.0 | 1719.4 | 1714.1 | 1706.1 | 1698.2 | 1690.6 | 1683.1 | 1675.7 | 1668.6 | 1661.8 | 1655.2 | 1649.1 | 1643.0 | 1637.0 | 1631.1 |
| 128.0 | 1711.4 | 1706.1 | 1698.1 | 1690.2 | 1682.6 | 1675.1 | 1667.0 | 1660.6 | 1653.8 | 1647.2 | 1641.1 | 1635.0 | 1629.0 | 1623.1 |

Table 4 PP travel times versus distance and depth for use in the automated bulletin process program

| | Travel times (seconds) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Depth (kilometers) | | | | | | | | | | | | |
| Distance (degrees) | Surface | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
| 0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 |
| 0.5 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 |
| 1.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 |
| 5.0 | 85.0 | 85.0 | 85.0 | 85.0 | 85.0 | 85.0 | 85.0 | 85.0 | 85.0 | 85.0 | 85.0 | 85.0 | 85.0 | 85.0 |
| 10.0 | 156.0 | 156.0 | 156.0 | 156.0 | 156.0 | 156.0 | 156.0 | 156.0 | 156.0 | 156.0 | 156.0 | 156.0 | 156.0 | 156.0 |
| 15.0 | 227.0 | 227.0 | 227.0 | 227.0 | 227.0 | 227.0 | 227.0 | 227.0 | 227.0 | 227.0 | 227.0 | 227.0 | 227.0 | 227.0 |
| 20.0 | 296.0 | 292.0 | 291.0 | 290.0 | 289.0 | 289.0 | 289.0 | 289.0 | 289.0 | 289.0 | 289.0 | 289.0 | 289.0 | 289.0 |
| 25.0 | 364.0 | 360.0 | 358.0 | 356.0 | 355.0 | 354 | 354.0 | 354.0 | 354.0 | 354.0 | 354.0 | 354.0 | 354.0 | 354.0 |
| 30.0 | 430.0 | 426.0 | 423.0 | 420.0 | 418.0 | 417.0 | 417.0 | 417.0 | 417.0 | 417.0 | 417.0 | 417.0 | 417.0 | 417.0 |
| 35.0 | 494.0 | 490.0 | 486.0 | 483.0 | 480.0 | 477.0 | 474.0 | 471.0 | 468.0 | 468.0 | 468.0 | 468.0 | 468.0 | 468.0 |
| 40.0 | 554.0 | 550.0 | 546.0 | 541.0 | 536.0 | 532.0 | 528.0 | 524.0 | 521.0 | 518.0 | 517.0 | 516.0 | 516.0 | 516.0 |
| 45.0 | 605.0 | 600.0 | 595.0 | 589.0 | 584.0 | 579.0 | 575.0 | 571.0 | 567.0 | 564.0 | 562.0 | 560.0 | 559.0 | 559.0 |
| 50.0 | 654.0 | 649.0 | 644.0 | 638.0 | 632.0 | 627.0 | 622.0 | 618.0 | 614.0 | 611.0 | 608.0 | 606.0 | 604.0 | 503.0 |
| 55.0 | 700.0 | 695.0 | 690.0 | 684.0 | 678.0 | 673.0 | 668.0 | 663.0 | 659.0 | 656.0 | 653.0 | 651.0 | 649.0 | 648.0 |
| 60.0 | 745.0 | 740.0 | 734.0 | 728.0 | 722.0 | 717.0 | 712.0 | 707.0 | 703.0 | 699.0 | 696.0 | 693.0 | 691.0 | 690.0 |
| 65.0 | 789.0 | 781.0 | 776.0 | 770.0 | 764.0 | 759.0 | 754.0 | 749.0 | 745.0 | 741.0 | 730.0 | 735.0 | 733.0 | 732.0 |
| 70.0 | 832.0 | 827.0 | 821.0 | 815.0 | 809.0 | 803.0 | 798.0 | 793.0 | 788.0 | 784.0 | 781.0 | 778.0 | 775.0 | 773.0 |
| 80.0 | 916.0 | 911.0 | 905.0 | 898.0 | 892.0 | 887.0 | 881.0 | 876.0 | 871.0 | 867.0 | 863.0 | 860.0 | 863.0 | 861.0 |
| 90.0 | 998.0 | 993.0 | 986.0 | 980.0 | 974.0 | 968.0 | 962.0 | 957.0 | 952.0 | 948.0 | 944.0 | 941.0 | 937.0 | 934.0 |
| 100.0 | 1076.0 | 1071.0 | 1064.0 | 1058.0 | 1051.0 | 1045.0 | 1040.0 | 1034.0 | 1029.0 | 1025.0 | 1021.0 | 1017.0 | 1013.0 | 1010.0 |
| 110.0 | 1151.0 | 1146.0 | 1139.0 | 1132.0 | 1126.0 | 1119.0 | 1114.0 | 1108.0 | 1103.0 | 1098.0 | 1094.0 | 1090.0 | 1086.0 | 1082.0 |
| 120.0 | 1221.0 | 1216.0 | 1209.0 | 1202.0 | 1195.0 | 1189.0 | 1183.0 | 1177.0 | 1172.0 | 1167.0 | 1162.0 | 1158.0 | 1154.0 | 1150.0 |
| 130.0 | 1288.0 | 1283.0 | 1276.0 | 1269.0 | 1262.0 | 1255.0 | 1249.0 | 1243.0 | 1238.0 | 1232.0 | 1228.0 | 1223.0 | 1219.0 | 1214.0 |
| 140.0 | 1351.0 | 1346.0 | 1339.0 | 1332.0 | 1325.0 | 1318.0 | 1311.0 | 1305.0 | 1300.0 | 1294.0 | 1289.0 | 1285.0 | 1280.0 | 1276.0 |
| 150.0 | 1410.0 | 1405.0 | 1397.0 | 1390.0 | 1383.0 | 1377.0 | 1370.0 | 1364.0 | 1358.0 | 1352.0 | 1347.0 | 1342.0 | 1338.0 | 1333.0 |
| 160.0 | 1465.0 | 1460.0 | 1452.0 | 1445.0 | 1438.0 | 1431.0 | 1425.0 | 1418.0 | 1412.0 | 1406.0 | 1401.0 | 1396.0 | 1391.0 | 1386.0 |
| 170.0 | 1517.0 | 1512.0 | 1504.0 | 1497.0 | 1490.0 | 1483.0 | 1467.0 | 1461.0 | 1454.0 | 1449.0 | 1443.0 | 1438.0 | 1433.0 | 1428.0 |
| 180.0 | 1565.0 | 1560.0 | 1552.0 | 1545.0 | 1537.0 | 1530.0 | 1524.0 | 1517.0 | 1511.0 | 1505.0 | 1500.0 | 1494.0 | 1489.0 | 1484.0 |
| 190.0 | 1611.0 | 1606.0 | 1598.0 | 1591.0 | 1583.0 | 1576.0 | 1570.0 | 1563.0 | 1557.0 | 1551.0 | 1546.0 | 1540.0 | 1535.0 | 1530.0 |
| 38.0 | 794.3 | 786.2 | 774.7 | 763.8 | 753.1 | 742.8 | 733.2 | 723.9 | 715.6 | 708.0 | 701.1 | 695.1 | 689.8 | 685.2 |
| 43.0 | 868.9 | 860.7 | 849.0 | 837.7 | 826.8 | 816.4 | 806.3 | 796.7 | 788.0 | 780.0 | 772.7 | 765.3 | 760.6 | 755.4 |
| 48.0 | 940.6 | 932.4 | 920.4 | 908.9 | 897.9 | 887.2 | 876.9 | 866.9 | 857.9 | 849.6 | 842.1 | 835.2 | 829.0 | 823.4 |
| 50.0 | 978.6 | 960.3 | 948.3 | 936.7 | 925.6 | 914.8 | 904.4 | 894.3 | 885.2 | 876.8 | 869.2 | 862.2 | 855.8 | 850.0 |
| 52.0 | 996.2 | 987.9 | 975.8 | 964.1 | 952.9 | 942.0 | 931.5 | 921.4 | 912.2 | 903.7 | 895.9 | 888.7 | 882.2 | 676.2 |
| 57.0 | 1063.4 | 1055.1 | 1042.8 | 1030.9 | 1019.5 | 1008.4 | 997.7 | 987.4 | 977.9 | 969.0 | 960.9 | 953.4 | 946.4 | 940.0 |
| 62.0 | 1128.1 | 1119.7 | 1107.2 | 1095.1 | 1083.5 | 1072.2 | 1061.3 | 1050.7 | 1040.9 | 1031.7 | 1023.3 | 1015.5 | 1008.0 | 1001.1 |
| 64.0 | 1153.2 | 1144.7 | 1132.2 | 1120.0 | 1108.3 | 1096.9 | 1085.9 | 1075.2 | 1065.3 | 1056.0 | 1047.5 | 1039.5 | 1031.9 | 1024.3 |
| 66.0 | 1177.8 | 1169.2 | 1156.7 | 1144.5 | 1132.6 | 1121.2 | 1110.1 | 1099.3 | 1089.2 | 1079.9 | 1071.2 | 1063.0 | 1055.3 | 1048.1 |
| 68.0 | 1201.9 | 1193.3 | 1180.8 | 1168.4 | 1156.6 | 1145.0 | 1133.8 | 1122.9 | 1112.8 | 1103.3 | 1094.4 | 1086.1 | 1078.3 | 1070.9 |
| 70.0 | 1225.6 | 1217.0 | 1204.4 | 1191.9 | 1180.0 | 1168.4 | 1157.1 | 1146.1 | 1135.8 | 1126.2 | 1117.2 | 1108.8 | 1100.8 | 1093.2 |
| 72.0 | 1248.8 | 1240.2 | 1227.4 | 1214.8 | 1202.9 | 1191.2 | 1179.8 | 1157.5 | 1147.1 | 1148.6 | 1139.5 | 1131.1 | 1122.9 | 1115.1 |
| 74.0 | 1271.4 | 1262.8 | 1249.8 | 1237.3 | 1225.2 | 1213.4 | 1202.0 | 1190.8 | 1180.4 | 1170.5 | 1161.4 | 1152.9 | 1144.5 | 1136.5 |
| 76.0 | 1293.6 | 1285.0 | 1271.9 | 1259.3 | 1247.1 | 1235.3 | 1223.7 | 1212.5 | 1201.9 | 1192.0 | 1182.9 | 1174.2 | 1165.6 | 1157.6 |
| 79.0 | 1326.0 | 1317.3 | 1304.2 | 1291.4 | 1279.1 | 1267.1 | 1255.5 | 1244.1 | 1233.4 | 1223.4 | 1214.1 | 1205.1 | 1196.6 | 1188.3 |
| 82.0 | 1357.2 | 1348.5 | 1335.3 | 1322.4 | 1309.9 | 1297.8 | 1286.0 | 1274.6 | 1263.8 | 1253.6 | 1244.0 | 1235.0 | 1226.2 | 1217.9 |
| 85.0 | 1387.3 | 1378.4 | 1365.2 | 1352.2 | 1339.6 | 1327.3 | 1315.4 | 1304.0 | 1293.0 | 1282.6 | 1272.8 | 1263.6 | 1254.7 | 1246.2 |
| 88.0 | 1416.0 | 1407.2 | 1393.8 | 1380.7 | 1368.0 | 1355.5 | 1343.5 | 1332.0 | 1320.9 | 1310.3 | 1300.4 | 1290.9 | 1281.9 | 1273.3 |
| 91.0 | 1443.4 | 1434.6 | 1421.1 | 1407.9 | 1395.1 | 1382.5 | 1370.4 | 1358.8 | 1347.6 | 1336.9 | 1326.9 | 1317.3 | 1308.1 | 1299.4 |
| 94.0 | 1469.7 | 1460.8 | 1447.2 | 1434.0 | 1421.1 | 1408.5 | 1396.3 | 1384.6 | 1373.3 | 1362.7 | 1352.6 | 1342.9 | 1333.6 | 1324.8 |
| 97.0 | 1495.2 | 1486.3 | 1472.7 | 1459.5 | 1446.6 | 1433.9 | 1421.7 | 1410.0 | 1398.7 | 1387.9 | 1377.8 | 1368.1 | 1358.7 | 1349.9 |
| 100.0 | 1520.4 | 1511.5 | 1497.9 | 1484.6 | 1471.7 | 1459.1 | 1446.9 | 1435.1 | 1423.9 | 1413.0 | 1402.9 | 1393.2 | 1383.9 | 1375.1 |
| 105.0 | 1562.1 | 1549.2 | 1539.6 | 1526.3 | 1513.3 | 1500.7 | 1483.5 | 1476.7 | 1465.4 | 1454.6 | 1444.4 | 1434.7 | 1425.4 | 1416.6 |
| 110.0 | 1603.6 | 1594.7 | 1581.1 | 1567.8 | 1554.9 | 1542.2 | 1530.0 | 1518.2 | 1506.9 | 1496.1 | 1485.3 | 1475.6 | 1466.9 | 1458.1 |
| 112.0 | 1620.2 | 1712.3 | 1597.7 | 1584.4 | 1571.5 | 1558.8 | 1546.6 | 1534.8 | 1523.5 | 1512.7 | 1501.9 | 1492.2 | 1483.5 | 1474.7 |

Table 5. S travel times versus distance and depth for use in the automated bulletin process program

| Distance (degrees) | Travel times (seconds) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Depth (kilometers) | | | | | | | | | | | | |
| | Surface | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
| 0 | 10.7 | 9.2 | 23.6 | 37.7 | 51.5 | 65.1 | 78.3 | 91.2 | 103.6 | 115.5 | 126.9 | 137.9 | 148.9 | 159.0 |
| 0.01 | 10.7 | 9.2 | 23.6 | 37.7 | 51.5 | 65.1 | 78.3 | 91.2 | 103.6 | 115.5 | 126.9 | 137.9 | 148.9 | 159.0 |
| 1.0 | 36.1 | 30.8 | 35.8 | 45.7 | 57.4 | 69.7 | 81.9 | 94.2 | 106.3 | 117.6 | 128.9 | 139.6 | 150.2 | 160.4 |
| 2.5 | 47.2 | 68.8 | 69.5 | 74.4 | 81.1 | 89.5 | 98.7 | 108.7 | 118.8 | 128.7 | 138.4 | 148.2 | 157.8 | 167.3 |
| 4.0 | 112.2 | 106.9 | 106.4 | 108.5 | 112.2 | 117.5 | 123.9 | 131.1 | 138.8 | 146.6 | 154.6 | 162.6 | 170.9 | 179.1 |
| 6.0 | 162.6 | 157.2 | 155.7 | 155.7 | 157.1 | 159.7 | 163.2 | 168.4 | 172.4 | 177.4 | 182.7 | 188.3 | 194.6 | 200.9 |
| 8.0 | 212.6 | 207.0 | 204.7 | 203.5 | 203.2 | 203.9 | 205.4 | 207.7 | 210.0 | 121.5 | 215.6 | 218.8 | 222.8 | 226.9 |
| 10.0 | 262.2 | 256.6 | 253.2 | 250.8 | 249.2 | 248.6 | 248.6 | 249.1 | 249.0 | 249.4 | 250.5 | 251.9 | 253.8 | 256.5 |
| 12.0 | 311.1 | 305.3 | 301.1 | 297.7 | 295.2 | 293.3 | 291.8 | 290.9 | 288.3 | 286.8 | 286.0 | 285.9 | 286.4 | 287.5 |
| 14.0 | 359.2 | 353.3 | 348.3 | 344.0 | 340.3 | 337.3 | 335.0 | 330.8 | 326.7 | 323.6 | 321.5 | 320.1 | 319.3 | 319.2 |
| 16.0 | 406.4 | 400.2 | 394.6 | 389.4 | 384.8 | 380.6 | 374.5 | 369.0 | 304.0 | 359.8 | 356.4 | 353.7 | 351.9 | 351.0 |
| 17.0 | 429.5 | 423.3 | 417.3 | 411.7 | 406.5 | 400.2 | 393.5 | 387.6 | 382.1 | 377.4 | 373.4 | 370.4 | 368.2 | 366.9 |
| 18.0 | 452.3 | 446.0 | 439.4 | 433.6 | 426.7 | 419.3 | 412.3 | 405.8 | 399.7 | 394.5 | 390.3 | 386.9 | 384.4 | 382.7 |
| 19.0 | 474.9 | 468.5 | 461.5 | 454.0 | 445.8 | 438.0 | 430.6 | 423.5 | 417.0 | 411.5 | 407.0 | 403.2 | 400.4 | 398.5 |
| 20.0 | 497.1 | 490.6 | 481.6 | 472.7 | 464.3 | 456.1 | 448.3 | 440.8 | 434.0 | 428.2 | 423.5 | 419.4 | 416.3 | 414.1 |
| 21.0 | 517.4 | 510.0 | 500.5 | 491.3 | 482.3 | 473.7 | 465.5 | 457.8 | 450.8 | 444.8 | 439.7 | 435.6 | 432.2 | 429.7 |
| 22.0 | 536.2 | 528.7 | 518.7 | 509.1 | 599.8 | 490.9 | 482.5 | 474.5 | 467.3 | 461.1 | 455.9 | 451.5 | 448.0 | 445.3 |
| 23.0 | 554.4 | 546.8 | 536.3 | 526.3 | 516.8 | 507.8 | 499.1 | 491.0 | 483.6 | 477.2 | 471.8 | 467.2 | 463.6 | 460.8 |
| 24.0 | 571.9 | 564.3 | 553.5 | 543.2 | 533.6 | 524.4 | 515.6 | 507.2 | 499.7 | 593.2 | 487.6 | 482.9 | 479.1 | 476.3 |
| 25.0 | 588.9 | 581.3 | 570.3 | 560.0 | 550.1 | 540.7 | 531.8 | 523.3 | 515.7 | 509.0 | 503.3 | 498.5 | 494.7 | 491.8 |
| 27.0 | 622.1 | 614.2 | 603.2 | 592.7 | 582.5 | 572.8 | 563.7 | 555.1 | 547.3 | 540.4 | 534.5 | 529.6 | 525.6 | 522.5 |
| 29.0 | 654.3 | 646.3 | 635.3 | 624.7 | 614.4 | 604.5 | 595.2 | 486.4 | 578.5 | 571.5 | 565.5 | 560.5 | 556.3 | 552.9 |
| 31.0 | 686.0 | 677.9 | 666.8 | 656.1 | 645.8 | 635.8 | 626.5 | 617.5 | 609.5 | 602.5 | 596.4 | 591.1 | 586.7 | 583.0 |
| 33.0 | 717.2 | 709.2 | 698.0 | 687.3 | 676.8 | 666.8 | 657.4 | 648.4 | 640.3 | 633.2 | 626.8 | 621.4 | 616.7 | 612.7 |
| 35.0 | 748.2 | 740.2 | 728.9 | 718.1 | 707.6 | 697.5 | 688.0 | 678.9 | 670.8 | 663.5 | 656.9 | 651.2 | 646.2 | 642.0 |

Table 6. pP travel time versus distance and depth for use in the automated bulletin process program

| Distance (degrees) | Travel time (seconds) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth (kilometers) | | | | | | | | | | | | |
| | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
| 19.0 | 270.5 | 276.5 | 276.6 | 285.7 | 292.3 | 299.1 | 304.1 | 311.8 | 317.9 | 325.6 | 330.8 | 341.5 | 345.6 |
| 20.0 | 281.5 | 287.1 | 288.9 | 295.9 | 302.2 | 208.9 | 313.8 | 321.3 | 327.3 | 334.8 | 339.8 | 350.3 | 354.3 |
| 26.0 | 340.6 | 346.5 | 351.7 | 357.1 | 361.7 | 365.8 | 370.1 | 376.0 | 381.4 | 388.4 | 392.8 | 402.6 | 405.9 |
| 30.0 | 377.7 | 383.6 | 389.7 | 394.9 | 400.4 | 405.2 | 405.2 | 413.0 | 416.0 | 422.8 | 426.9 | 436.4 | 439.4 |
| 36.0 | 429.8 | 435.4 | 442.2 | 447.3 | 453.6 | 458.2 | 463.2 | 466.7 | 470.6 | 473.9 | 476.7 | 485.8 | 488.4 |
| 40.0 | 463.2 | 469.7 | 475.5 | 481.5 | 486.7 | 492.2 | 498.1 | 502.4 | 506.1 | 509.4 | 512.0 | 517.9 | 520.1 |
| 46.0 | 512.0 | 518.3 | 524.9 | 530.7 | 536.7 | 542.1 | 546.8 | 551.8 | 556.3 | 560.2 | 563.5 | 569.9 | 572.7 |
| 50.0 | 543.1 | 549.4 | 555.8 | 562.4 | 568.3 | 573.6 | 579.2 | 584.1 | 588.4 | 592.1 | 596.1 | 598.4 | 600.9 |
| 56.0 | 587.6 | 594.8 | 601.1 | 607.3 | 613.9 | 620.1 | 625.6 | 630.0 | 635.1 | 639.5 | 643.2 | 646.2 | 649.3 |
| 62.0 | 629.2 | 636.2 | 643.4 | 649.5 | 655.9 | 661.7 | 667.9 | 672.4 | 678.2 | 682.4 | 686.8 | 690.4 | 693.4 |
| 65.0 | 648.9 | 655.9 | 663.0 | 670.0 | 676.3 | 683.0 | 688.2 | 693.6 | 699.3 | 703.4 | 707.7 | 712.2 | 716.0 |
| 71.0 | 686.3 | 694.1 | 701.1 | 708.1 | 714.3 | 720.9 | 724.8 | 732.0 | 737.6 | 742.4 | 746.6 | 752.0 | 756.4 |
| 75.0 | 709.8 | 717.5 | 724.4 | 731.5 | 737.7 | 745.2 | 750.8 | 756.9 | 762.3 | 767.1 | 772.1 | 776.3 | 780.6 |
| 80.0 | 737.6 | 745.2 | 752.9 | 759.8 | 765.9 | 773.3 | 779.9 | 784.8 | 791.1 | 795.8 | 800.7 | 805.7 | 809.8 |
| 85.0 | 763.3 | 771.8 | 778.5 | 785.4 | 792.4 | 799.7 | 806.2 | 812.0 | 817.2 | 822.8 | 827.6 | 832.4 | 837.4 |
| 90.0 | 787.4 | 795.8 | 803.4 | 810.2 | 817.2 | 823.7 | 830.8 | 836.6 | 842.7 | 848.3 | 852.9 | 858.7 | 863.6 |
| 95.0 | 811.4 | 818.8 | 826.4 | 833.2 | 840.2 | 847.4 | 853.8 | 859.5 | 865.6 | 871.0 | 876.8 | 881.6 | 886.4 |
| 100.0 | 834.1 | 841.5 | 849.8 | 855.9 | 862.9 | 870.1 | 876.4 | 882.1 | 888.2 | 893.6 | 899.3 | 905.1 | 910.0 |
| 105.0 | 856.3 | 863.6 | 871.2 | 878.0 | 885.0 | 892.1 | 898.4 | 904.1 | 910.2 | 915.6 | 921.3 | 927.1 | 932.0 |
| 110.0 | 878.3 | 885.6 | 893.2 | 900.0 | 907.0 | 914.1 | 920.4 | 926.1 | 932.2 | 937.6 | 943.3 | 948.1 | 954.0 |

## Table 7. PCP travel time versus distance and depth for use in the automated bulletin process program

| Distance (degrees) | Travel time (seconds) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Depth (kilometers) | | | | | | | | | | | | |
| | Surface | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
| 0 | 514.3 | 508.9 | 500.8 | 492.9 | 485.2 | 477.4 | 470.4 | 463.2 | 456.3 | 449.8 | 443.5 | 437.5 | 431.5 | 425.5 |
| 1.0 | 514.3 | 508.9 | 500.8 | 492.9 | 485.2 | 477.4 | 470.4 | 463.2 | 456.3 | 449.8 | 443.5 | 437.5 | 431.5 | 425.5 |
| 3.0 | 514.7 | 509.3 | 501.2 | 493.3 | 485.6 | 478.1 | 470.8 | 463.6 | 456.7 | 450.2 | 443.9 | 437.9 | 431.9 | 425.9 |
| 5.0 | 515.4 | 510.0 | 501.9 | 494.0 | 486.3 | 478.8 | 471.5 | 464.3 | 457.4 | 450.9 | 444.6 | 438.6 | 432.6 | 426.6 |
| 10.0 | 519.0 | 513.6 | 505.6 | 497.7 | 490.0 | 482.5 | 475.2 | 468.1 | 461.2 | 454.7 | 448.5 | 442.5 | 436.5 | 430.5 |
| 15.0 | 524.9 | 419.5 | 511.5 | 503.6 | 495.9 | 488.4 | 481.1 | 474.0 | 467.1 | 460.6 | 454.4 | 448.4 | 442.4 | 436.4 |
| 20.0 | 533.0 | 527.6 | 519.6 | 511.8 | 504.2 | 496.8 | 489.5 | 482.4 | 475.6 | 469.2 | 463.1 | 457.2 | 451.4 | 445.6 |
| 25.0 | 543.0 | 537.6 | 529.6 | 521.8 | 514.2 | 506.8 | 499.5 | 492.4 | 485.6 | 479.2 | 473.1 | 467.2 | 461.4 | 455.6 |
| 30.0 | 554.9 | 549.6 | 541.6 | 533.9 | 526.3 | 519.0 | 511.9 | 504.9 | 498.2 | 491.8 | 485.8 | 480.1 | 474.4 | 468.7 |
| 35.0 | 568.6 | 563.3 | 555.3 | 547.6 | 540.0 | 532.7 | 525.6 | 518.6 | 511.9 | 505.5 | 499.5 | 493.8 | 488.1 | 482.4 |
| 40.0 | 583.9 | 578.6 | 570.7 | 563.0 | 555.5 | 548.3 | 541.3 | 534.4 | 527.8 | 521.5 | 515.6 | 510.0 | 504.4 | 499.0 |
| 45.0 | 600.5 | 595.2 | 587.3 | 579.6 | 572.1 | 564.9 | 557.9 | 551.0 | 544.4 | 538.1 | 532.2 | 526.6 | 521.0 | 515.6 |
| 50.0 | 618.3 | 613.0 | 605.2 | 597.6 | 590.2 | 583.1 | 576.1 | 569.3 | 562.8 | 556.6 | 550.9 | 545.4 | 540.1 | 535.0 |
| 60.0 | 656.6 | 651.3 | 643.5 | 636.0 | 628.7 | 621.6 | 614.7 | 608.0 | 601.6 | 595.5 | 589.8 | 584.3 | 579.0 | 573.8 |
| 70.0 | 697.8 | 692.5 | 685.3 | 677.8 | 670.6 | 663.5 | 656.7 | 650.0 | 643.6 | 637.6 | 632.0 | 626.6 | 621.3 | 616.1 |
| 80.0 | 740.6 | 735.3 | 727.6 | 720.1 | 712.9 | 705.8 | 699.0 | 692.3 | 686.0 | 680.1 | 674.5 | 669.1 | 663.8 | 658.7 |
| 90.0 | 784.2 | 778.9 | 771.2 | 763.7 | 756.5 | 749.4 | 742.6 | 735.9 | 729.6 | 723.7 | 718.1 | 712.7 | 707.4 | 702.3 |
| 95.0 | 806.3 | 801.0 | 793.3 | 785.8 | 778.6 | 771.5 | 764.7 | 758.0 | 751.7 | 745.8 | 740.2 | 734.8 | 729.5 | 724.4 |
| 100.0 | 828.5 | 823.2 | 815.5 | 808.0 | 800.8 | 793.7 | 786.9 | 780.2 | 773.9 | 768.0 | 762.4 | 757.0 | 751.7 | 746.6 |
| 105.0 | 872.5 | 867.2 | 859.5 | 852.0 | 844.8 | 837.1 | 830.3 | 823.6 | 817.3 | 811.4 | 805.8 | 800.4 | 795.1 | 790.0 |

Table 8a. SKP1 travel time versus distance and depth for use in the automated bulletin process program

| Distance (degrees) | Travel times (seconds) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Surface | Depth (kilometers) | | | | | | | | | | | | |
| | | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
| 103.0 | 1315.0 | 1305.8 | 1291.5 | 1277.5 | 1263.7 | 1250.2 | 1237.0 | 1224.3 | 1211.9 | 1200.1 | 1188.8 | 1177.9 | 1167.2 | 1157.0 |
| 104.0 | 1317.0 | 1307.8 | 1293.5 | 1279.5 | 1265.7 | 1252.2 | 1239.0 | 1226.3 | 1213.9 | 1202.1 | 1190.8 | 1179.9 | 1169.2 | 1159.0 |
| 105.0 | 1319.0 | 1309.8 | 1295.5 | 1281.5 | 1267.7 | 1254.2 | 1241.0 | 1228.3 | 1215.9 | 1204.1 | 1192.8 | 1181.9 | 1171.2 | 1161.0 |
| 115.0 | 1338.4 | 1329.2 | 1314.9 | 1300.8 | 1287.1 | 1273.6 | 1260.4 | 1247.6 | 1235.3 | 1223.4 | 1212.2 | 1201.2 | 1190.5 | 1180.2 |
| 125.0 | 1357.7 | 1348.5 | 1334.2 | 1320.1 | 1306.3 | 1292.8 | 1279.6 | 1266.9 | 1254.6 | 1242.7 | 1231.4 | 1220.4 | 1209.7 | 1199.4 |
| 140.0 | 1385.0 | 1375.8 | 1361.5 | 1347.4 | 1333.6 | 1320.1 | 1306.9 | 1294.1 | 1281.8 | 1269.9 | 1258.6 | 1247.6 | 1236.9 | 1226.6 |
| 155.0 | 1407.4 | 1398.2 | 1383.9 | 1369.8 | 1356.0 | 1342.4 | 1329.2 | 1316.4 | 1304.1 | 1292.2 | 1280.8 | 1269.8 | 1259.1 | 1248.8 |
| 170.0 | 1420.4 | 1411.2 | 1396.8 | 1382.7 | 1368.9 | 1355.4 | 1342.2 | 1329.3 | 1217.0 | 1305.0 | 1293.6 | 1282.6 | 1271.9 | 1261.5 |
| 180.0 | 1422.9 | 1413.7 | 1399.3 | 1385.2 | 1371.4 | 1357.8 | 1344.6 | 1331.7 | 1319.3 | 1307.4 | 1296.0 | 1285.0 | 1274.3 | 1263.9 |
| 185.0 | 1423.5 | 1414.3 | 1399.9 | 1385.8 | 1372.0 | 1358.4 | 1345.2 | 1332.3 | 1319.9 | 1308.0 | 1296.6 | 1285.6 | 1274.9 | 1264.5 |

Table 8b. SKP2 travel time versus distance and depth for use in the automated bulletin process program

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 129.0 | 1352.0 | 1342.9 | 1328.7 | 1314.8 | 1301.2 | 1287.9 | 1275.0 | 1262.3 | 1250.4 | 1238.8 | 1227.8 | 1217.0 | 1206.7 | 1196.7 |
| 130.0 | 1356.2 | 1347.1 | 1332.9 | 1319.0 | 1305.4 | 1292.1 | 1279.2 | 1266.5 | 1254.6 | 1243.0 | 1232.0 | 1221.2 | 1210.9 | 1200.9 |
| 135.0 | 1377.6 | 1368.5 | 1354.3 | 1340.4 | 1326.8 | 1313.5 | 1300.6 | 1287.9 | 1276.0 | 1264.4 | 1253.4 | 1242.6 | 1232.3 | 1222.3 |
| 140.0 | 1399.5 | 1390.4 | 1376.2 | 1362.3 | 1348.7 | 1335.4 | 1322.5 | 1309.8 | 1297.9 | 1286.3 | 1275.3 | 1264.5 | 1254.2 | 1244.2 |
| 145.0 | 1421.8 | 1412.7 | 1398.5 | 1384.6 | 1371.0 | 1357.8 | 1344.8 | 1332.2 | 1320.7 | 1308.8 | 1297.7 | 1267.0 | 1276.7 | 1266.7 |
| 148.0 | 1435.0 | 1425.9 | 1411.7 | 1397.9 | 1384.3 | 1371.0 | 1358.1 | 1345.5 | 1333.7 | 1322.1 | 1311.1 | 1300.4 | 1290.1 | 1280.2 |
| 151.0 | 1438.2 | 1429.1 | 1414.9 | 1401.1 | 1387.5 | 1374.2 | 1361.3 | 1348.7 | 1336.9 | 1325.3 | 1314.3 | 1303.6 | 1293.3 | 1283.5 |

Table 9a. SKS1 travel time versus distance and depth for use in the automated bulletin process program

| Distance (degrees) | Travel times (seconds) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Depth (kilometers) | | | | | | | | | | | | |
| | Surface | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
| 60.5 | 1203.9 | 1194.9 | 1191.2 | 1167.8 | 1154.6 | 1141.7 | 1129.2 | 1117.2 | 1105.8 | 1094.8 | 1084.3 | 1074.2 | 1064.5 | 1055.3 |
| 61.9 | 1213.6 | 1204.6 | 1190.9 | 1177.5 | 1164.3 | 1151.4 | 1138.9 | 1126.9 | 1115.5 | 1104.5 | 1094.0 | 1083.9 | 1074.2 | 1065.0 |
| 63.0 | 1221.2 | 1212.2 | 1198.5 | 1185.1 | 1171.9 | 1159.0 | 1146.5 | 1134.5 | 1123.1 | 1112.1 | 1101.6 | 1091.5 | 1081.8 | 1072.6 |
| 65.0 | 1236.2 | 1227.2 | 1213.5 | 1200.1 | 1186.9 | 1174.0 | 1161.5 | 1149.5 | 1138.1 | 1127.1 | 1116.6 | 1106.5 | 1096.8 | 1087.6 |
| 70.0 | 1273.4 | 1264.4 | 1250.7 | 1236.3 | 1223.1 | 1210.2 | 1197.7 | 1185.7 | 1174.3 | 1163.3 | 1152.8 | 1142.7 | 1133.0 | 1124.8 |
| 75.0 | 1310.2 | 1301.2 | 1287.5 | 1274.1 | 1260.9 | 1248.0 | 1235.5 | 1223.5 | 1212.1 | 1201.1 | 1190.6 | 1180.5 | 1170.8 | 1161.6 |
| 80.0 | 1346.3 | 1337.3 | 1323.5 | 1310.0 | 1296.7 | 1283.8 | 1271.3 | 1259.2 | 1247.6 | 1236.4 | 1225.8 | 1215.6 | 1205.8 | 1196.3 |
| 85.0 | 1380.8 | 1371.8 | 1357.9 | 1344.3 | 1331.0 | 1318.1 | 1305.5 | 1293.3 | 1281.7 | 1270.5 | 1259.8 | 1249.5 | 1239.6 | 1230.1 |
| 90.0 | 1412.8 | 1403.7 | 1389.8 | 1376.1 | 1362.7 | 1349.6 | 1336.9 | 1324.7 | 1312.9 | 1301.5 | 1290.8 | 1280.2 | 1270.2 | 1260.6 |
| 95.0 | 1441.1 | 1432.0 | 1418.0 | 1404.3 | 1390.7 | 1377.5 | 1364.7 | 1352.3 | 1340.4 | 1329.0 | 1318.1 | 1307.4 | 1297.2 | 1287.4 |
| 100.0 | 1467.0 | 1457.9 | 1443.9 | 1430.0 | 1416.5 | 1403.2 | 1390.3 | 1377.7 | 1365.8 | 1354.4 | 1343.3 | 1332.5 | 1322.1 | 1312.2 |
| 105.0 | 1490.5 | 1481.4 | 1467.3 | 1453.4 | 1439.8 | 1426.5 | 1413.5 | 1400.9 | 1388.9 | 1377.4 | 1366.3 | 1355.5 | 1345.1 | 1335.1 |
| 110.0 | 1512.2 | 1503.1 | 1488.9 | 1475.0 | 1461.3 | 1448.0 | 1435.0 | 1422.4 | 1410.3 | 1398.7 | 1387.5 | 1376.7 | 1366.3 | 1356.2 |
| 115.0 | 1532.0 | 1522.8 | 1508.6 | 1494.6 | 1480.9 | 1467.5 | 1454.5 | 1441.9 | 1429.8 | 1418.1 | 1406.8 | 1396.0 | 1385.5 | 1375.4 |
| 120.0 | 1550.0 | 1540.8 | 1526.5 | 1512.5 | 1498.8 | 1485.4 | 1472.4 | 1459.7 | 1447.5 | 1435.8 | 1424.5 | 1413.6 | 1403.1 | 1392.9 |
| 125.0 | 1565.9 | 1556.7 | 1542.4 | 1528.4 | 1514.7 | 1501.3 | 1488.2 | 1475.4 | 1463.2 | 1451.5 | 1440.2 | 1429.3 | 1418.7 | 1408.4 |
| 130.0 | 1579.9 | 1570.7 | 1556.4 | 1542.3 | 1528.6 | 1515.2 | 1502.0 | 1489.2 | 1477.0 | 1465.2 | 1453.9 | 1443.0 | 1432.4 | 1422.1 |
| 131.0 | 1582.4 | 1573.2 | 1558.9 | 1544.8 | 1531.1 | 1517.7 | 1504.5 | 1491.7 | 1479.5 | 1467.7 | 1456.4 | 1445.5 | 1434.9 | 1424.6 |
| 133.0 | 1587.3 | 1478.1 | 1563.8 | 1549.7 | 1536.0 | 1522.6 | 1509.4 | 1496.6 | 1484.4 | 1472.6 | 1461.3 | 1450.4 | 1439.8 | 1429.5 |
| 135.0 | 1591.1 | 1581.9 | 1567.6 | 1553.5 | 1539.7 | 1526.2 | 1513.0 | 1500.2 | 1488.0 | 1476.1 | 1464.8 | 1453.9 | 1443.2 | 1432.8 |

Table 9b. SKS2 travel time versus distance and depth for use in the automated bulletin process program

| Distance (degrees) | Travel times (seconds) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Depth (kilometers) | | | | | | | | | | | | |
| | Surface | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
| 97.0 | 1518.9 | 1509.8 | 1495.8 | 1482.1 | 1468.5 | 1455.2 | 1442.4 | 1429.9 | 1418.0 | 1406.6 | 1395.5 | 1384.8 | 1374.5 | 1364.6 |
| 99.0 | 1522.9 | 1513.8 | 1499.8 | 1486.1 | 1472.5 | 1459.2 | 1446.3 | 1433.7 | 1421.8 | 1410.4 | 1399.3 | 1388.5 | 1378.1 | 1368.2 |
| 105.0 | 1534.6 | 1525.5 | 1511.4 | 1497.5 | 1483.9 | 1470.6 | 1457.6 | 1445.0 | 1433.0 | 1421.5 | 1410.4 | 1399.6 | 1389.2 | 1379.2 |
| 115.0 | 1554.0 | 1544.8 | 1530.6 | 1516.6 | 1502.9 | 1489.5 | 1476.5 | 1463.9 | 1451.8 | 1440.1 | 1428.8 | 1418.0 | 1407.5 | 1397.4 |
| 125.0 | 1573.0 | 1563.8 | 1549.5 | 1535.5 | 1521.8 | 1508.4 | 1495.3 | 1482.5 | 1470.3 | 1458.6 | 1447.3 | 1436.4 | 1425.8 | 1415.5 |
| 135.0 | 1590.8 | 1581.6 | 1567.3 | 1553.2 | 1539.4 | 1525.9 | 1512.7 | 1499.9 | 1487.7 | 1475.8 | 1464.5 | 1453.6 | 1442.9 | 1432.5 |
| 150.0 | 1613.8 | 1604.6 | 1590.3 | 1476.2 | 1562.3 | 1548.7 | 1535.5 | 1522.6 | 1510.3 | 1498.4 | 1487.1 | 1476.1 | 1465.4 | 1454.9 |
| 165.0 | 1628.5 | 1619.3 | 1605.0 | 1590.9 | 1577.0 | 1563.4 | 1550.3 | 1537.4 | 1525.0 | 1513.1 | 1501.8 | 1490.8 | 1480.1 | 1469.5 |
| 180.0 | 1633.5 | 1624.3 | 1609.9 | 1595.8 | 1581.9 | 1568.3 | 1455.2 | 1542.3 | 1529.9 | 1518.0 | 1506.7 | 1495.7 | 1485.0 | 1474.5 |
| 185.0 | 1633.7 | 1624.5 | 1610.1 | 1596.0 | 1582.1 | 1568.5 | 1555.4 | 1542.5 | 1530.1 | 1518.2 | 1506.9 | 1495.9 | 1485.2 | 1474.7 |

Table 10. SS travel time versus distance and depth for use in the automated bulletin process program

| Distance (degrees) | Surface | Travel times (seconds) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Depth (kilometers) | | | | | | | | | | | | |
| | | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
| 0 | 21.0 | 16.0 | 15.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 |
| 0.5 | 24.0 | 29.0 | 28.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 |
| 1.0 | 47.0 | 42.0 | 41.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 |
| 3.0 | 98.0 | 93.0 | 92.0 | 88.0 | 88.0 | 88.0 | 88.0 | 88.0 | 88.0 | 88.0 | 88.0 | 83.0 | 88.0 | 88.0 |
| 5.0 | 148.0 | 143.0 | 142.0 | 138.0 | 138.0 | 138.0 | 138.0 | 138.0 | 138.0 | 138.0 | 138.0 | 138.0 | 138.0 | 138.0 |
| 7.0 | 199.0 | 194.0 | 193.0 | 189.0 | 189.0 | 189.0 | 189.0 | 189.0 | 189.0 | 189.0 | 189.0 | 189.0 | 189.0 | 189.0 |
| 9.0 | 250.0 | 245.0 | 244.0 | 240.0 | 240.0 | 240.0 | 240.0 | 240.0 | 240.0 | 240.0 | 240.0 | 240.0 | 240.0 | 240.0 |
| 11.0 | 300.0 | 295.0 | 294.0 | 290.0 | 290.0 | 290.0 | 290.0 | 290.0 | 290.0 | 290.0 | 290.0 | 290.0 | 290.0 | 290.0 |
| 13.0 | 350.0 | 345.0 | 344.0 | 340.0 | 340.0 | 340.0 | 340.0 | 340.0 | 340.0 | 340.0 | 340.0 | 340.0 | 340.0 | 340.0 |
| 15.0 | 400.0 | 395.0 | 394.0 | 390.0 | 390.0 | 390.0 | 390.0 | 390.0 | 390.0 | 390.0 | 390.0 | 390.0 | 390.0 | 390.0 |
| 18.0 | 475.0 | 469.0 | 467.0 | 463.0 | 463.0 | 463.0 | 463.0 | 463.0 | 463.0 | 463.0 | 463.0 | 463.0 | 463.0 | 463.0 |
| 21.0 | 549.0 | 543.0 | 540.0 | 539.0 | 539.0 | 539.0 | 539.0 | 539.0 | 539.0 | 539.0 | 539.0 | 539.0 | 539.0 | 539.0 |
| 24.0 | 622.0 | 616.0 | 613.0 | 611.0 | 610.0 | 610.0 | 610.0 | 610.0 | 610.0 | 610.0 | 610.0 | 610.0 | 610.0 | 610.0 |
| 27.0 | 695.0 | 689.0 | 686.0 | 683.0 | 681.0 | 681.0 | 681.0 | 681.0 | 681.0 | 681.0 | 681.0 | 681.0 | 681.0 | 681.0 |
| 30.0 | 766.0 | 760.0 | 755.0 | 751.0 | 748.0 | 746.0 | 746.0 | 744.0 | 743.0 | 743.0 | 743.0 | 743.0 | 743.0 | 743.0 |
| 33.0 | 836.0 | 830.0 | 824.0 | 820.0 | 816.0 | 813.0 | 811.0 | 810.0 | 807.0 | 805.0 | 805.0 | 805.0 | 805.0 | 805.0 |
| 36.0 | 905.0 | 899.0 | 892.0 | 887.0 | 882.0 | 878.0 | 873.0 | 868.0 | 863.0 | 860.0 | 859.0 | 858.0 | 858.0 | 858.0 |
| 39.0 | 972.0 | 966.0 | 958.0 | 950.0 | 943.0 | 936.0 | 929.0 | 923.0 | 917.0 | 913.0 | 909.0 | 907.0 | 907.0 | 907.0 |
| 42.0 | 1035.0 | 1029.0 | 1019.0 | 1010.0 | 1002.0 | 993.0 | 986.0 | 979.0 | 972.0 | 967.0 | 963.0 | 960.0 | 958.0 | 958.0 |
| 45.0 | 1091.0 | 1085.0 | 1075.0 | 1067.0 | 1058.0 | 1048.0 | 1040.0 | 1032.0 | 1025.0 | 1019.0 | 1015.0 | 1010.0 | 1009.0 | 1008.0 |
| 48.0 | 1144.0 | 1136.0 | 1125.0 | 1114.0 | 1105.0 | 1095.0 | 1087.0 | 1078.0 | 1071.0 | 1066.0 | 1060.0 | 1056.0 | 1054.0 | 1053.0 |
| 51.0 | 1195.0 | 1187.0 | 1176.0 | 1166.0 | 1156.0 | 1146.0 | 1138.0 | 1129.0 | 1122.0 | 1116.0 | 1110.0 | 1106.0 | 1103.0 | 1101.0 |
| 54.0 | 1244.0 | 1236.0 | 1125.0 | 1215.0 | 1205.0 | 1195.0 | 1187.0 | 1178.0 | 1171.0 | 1165.0 | 1159.0 | 1155.0 | 1152.0 | 1150.0 |
| 57.0 | 1293.0 | 1285.0 | 1274.0 | 1265.0 | 1254.0 | 1244.0 | 1236.0 | 1227.0 | 1219.0 | 1213.0 | 1207.0 | 1202.0 | 1199.0 | 1196.0 |
| 60.0 | 1340.0 | 1332.0 | 1321.0 | 1310.0 | 1300.0 | 1290.0 | 1281.0 | 1272.0 | 1264.0 | 1257.0 | 1251.0 | 1246.0 | 1243.0 | 1240.0 |
| 65.0 | 1419.0 | 1411.0 | 1400.0 | 1389.0 | 1379.0 | 1369.0 | 1360.0 | 1351.0 | 1343.0 | 1336.0 | 1330.0 | 1325.0 | 1322.0 | 1319.0 |
| 70.0 | 1496.0 | 1488.0 | 1477.0 | 1466.0 | 1456.0 | 1445.0 | 1436.0 | 1427.0 | 1419.0 | 1412.0 | 1405.0 | 1400.0 | 1396.0 | 1392.0 |
| 75.0 | 1573.0 | 1565.0 | 1553.0 | 1542.0 | 1532.0 | 1521.0 | 1512.0 | 1503.0 | 1495.0 | 1488.0 | 1481.0 | 1476.0 | 1471.0 | 1467.0 |
| 80.0 | 1649.0 | 1641.0 | 1629.0 | 1618.0 | 1608.0 | 1597.0 | 1588.0 | 1578.0 | 1570.0 | 1562.0 | 1556.0 | 1550.0 | 1544.0 | 1540.0 |
| 85.0 | 1723.0 | 1715.0 | 1703.0 | 1692.0 | 1682.0 | 1671.0 | 1662.0 | 1652.0 | 1644.0 | 1636.0 | 1630.0 | 1624.0 | 1618.0 | 1614.0 |
| 90.0 | 1796.0 | 1788.0 | 1776.0 | 1765.0 | 1754.0 | 1743.0 | 1733.0 | 1724.0 | 1715.0 | 1707.0 | 1700.0 | 1693.0 | 1688.0 | 1683.0 |
| 95.0 | 1867.0 | 1859.0 | 1847.0 | 1836.0 | 1825.0 | 1814.0 | 1804.0 | 1795.0 | 1786.0 | 1778.0 | 1771.0 | 1764.0 | 1759.0 | 1754.0 |
| 100.0 | 1937.0 | 1929.0 | 1917.0 | 1905.0 | 1894.0 | 1883.0 | 1873.0 | 1863.0 | 1854.0 | 1846.0 | 1838.0 | 1831.0 | 1825.0 | 1820.0 |
| 105.0 | 2006.0 | 1998.0 | 1986.0 | 1974.0 | 1963.0 | 1952.0 | 1942.0 | 1932.0 | 1923.0 | 1915.0 | 1907.0 | 1900.0 | 1894.0 | 1889.0 |
| 110.0 | 2074.0 | 2066.0 | 2054.0 | 2042.0 | 2030.0 | 2019.0 | 2009.0 | 1999.0 | 1989.0 | 1981.0 | 1973.0 | 1966.0 | 1959.0 | 1953.0 |
| 115.0 | 2140.0 | 2132.0 | 2120.0 | 2108.0 | 2096.0 | 2085.0 | 2075.0 | 2065.0 | 2055.0 | 2047.0 | 2039.0 | 2032.0 | 2025.0 | 2019.0 |
| 120.0 | 2205.0 | 2197.0 | 2184.0 | 2172.0 | 2161.0 | 2150.0 | 2139.0 | 2128.0 | 2118.0 | 2109.0 | 2101.0 | 2093.0 | 2086.0 | 2080.0 |
| 125.0 | 2269.0 | 2261.0 | 2248.0 | 2236.0 | 2225.0 | 2214.0 | 2203.0 | 2192.0 | 2182.0 | 2173.0 | 2165.0 | 2157.0 | 2150.0 | 2144.0 |
| 130.0 | 2331.0 | 2323.0 | 2310.0 | 2298.0 | 2286.0 | 2275.0 | 2264.0 | 2253.0 | 2243.0 | 2234.0 | 2225.0 | 2217.0 | 2210.0 | 2203.0 |
| 135.0 | 2392.0 | 2384.0 | 2371.0 | 2359.0 | 2347.0 | 2336.0 | 2325.0 | 2314.0 | 2304.0 | 2295.0 | 2286.0 | 2278.0 | 2271.0 | 2264.0 |
| 140.0 | 2451.0 | 2442.0 | 2430.0 | 2417.0 | 2405.0 | 2394.0 | 2383.0 | 2372.0 | 2362.0 | 2353.0 | 2344.0 | 2336.0 | 2328.0 | 2321.0 |
| 145.0 | 2509.0 | 2500.0 | 2488.0 | 2475.0 | 2463.0 | 2452.0 | 2441.0 | 2430.0 | 2420.0 | 2411.0 | 2402.0 | 2394.0 | 2386.0 | 2379.0 |
| 150.0 | 2565.0 | 2556.0 | 2544.0 | 2531.0 | 2518.0 | 2507.0 | 2496.0 | 2484.0 | 2474.0 | 2464.0 | 2455.0 | 2446.0 | 2438.0 | 2430.0 |
| 155.0 | 2620.0 | 2611.0 | 2599.0 | 2586.0 | 2573.0 | 2561.0 | 2550.0 | 2538.0 | 2528.0 | 2518.0 | 2509.0 | 2500.0 | 2492.0 | 2484.0 |
| 160.0 | 2673.0 | 2664.0 | 2651.0 | 2638.0 | 2626.0 | 2614.0 | 2602.0 | 2591.0 | 2580.0 | 2570.0 | 2561.0 | 2552.0 | 2544.0 | 2535.0 |
| 165.0 | 2725.0 | 2716.0 | 2703.0 | 2690.0 | 2678.0 | 2666.0 | 2654.0 | 2643.0 | 2632.0 | 2622.0 | 2613.0 | 2604.0 | 2596.0 | 2507.0 |
| 170.0 | 2775.0 | 2766.0 | 2753.0 | 2740.0 | 2727.0 | 2715.0 | 2703.0 | 2692.0 | 2681.0 | 2671.0 | 2661.0 | 2652.0 | 2643.0 | 2635.0 |
| 175.0 | 2823.0 | 2814.0 | 2801.0 | 2788.0 | 2775.0 | 2763.0 | 2751.0 | 2740.0 | 2729.0 | 2719.0 | 2709.0 | 2700.0 | 2691.0 | 2783.0 |
| 180.0 | 2869.0 | 2860.0 | 2847.0 | 2834.0 | 2821.0 | 2508.0 | 2796.0 | 2785.0 | 2773.0 | 2763.0 | 2753.0 | 2743.0 | 2734.0 | 2726.0 |
| 185.0 | 2913.0 | 2904.0 | 2891.0 | 2878.0 | 2865.0 | 2852.0 | 2840.0 | 2829.0 | 2817.0 | 2807.0 | 2797.0 | 2787.0 | 2778.0 | 2770.0 |

Table 11. Corrected P'P' travel time tables (seconds for use in the automated bulletin process program

| Distance Degrees | Surface | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 2424.0 | 2418.6 | 2410.5 | 2402.6 | 2394.9 | 2387.4 | 2380.1 | 2372.9 | 2366.0 | 2359.5 | 2353.2 | 2347.2 | 2341.2 | 2335.2 |
| .01 | 2423.9 | 2418.5 | 2410.4 | 2402.5 | 2394.8 | 2387.3 | 2380.0 | 2372.8 | 2365.9 | 2359.4 | 2353.1 | 2347.1 | 2341.1 | 2335.1 |
| 10.0 | 2423.0 | 2417.6 | 2409.5 | 2401.6 | 2393.9 | 2386.4 | 2379.1 | 2371.9 | 2365.0 | 2358.5 | 2352.2 | 2346.2 | 2340.2 | 2334.2 |
| 30.0 | 2412.0 | 2406.6 | 2398.5 | 2390.6 | 2382.9 | 2375.4 | 2368.1 | 2360.9 | 2354.0 | 2347.5 | 2341.2 | 2335.2 | 2329.2 | 2323.2 |
| 60.0 | 2375.0 | 2369.6 | 2361.6 | 2353.7 | 2346.1 | 2338.6 | 2331.3 | 2324.2 | 2317.4 | 2310.9 | 2304.8 | 2298.8 | 2292.8 | 2286.9 |
| 90.0 | 2323.0 | 2317.6 | 2309.6 | 2301.8 | 2294.2 | 2286.8 | 2279.5 | 2272.5 | 2265.8 | 2259.3 | 2253.2 | 2247.3 | 2241.5 | 2235.7 |
| 110.0 | 2285.0 | 2279.6 | 2271.6 | 2263.8 | 2256.2 | 2248.8 | 2241.5 | 2234.5 | 2227.8 | 2221.3 | 2215.2 | 2209.3 | 2203.5 | 2197.7 |
| 130.0 | 2246.0 | 2240.6 | 2232.6 | 2224.8 | 2217.2 | 2209.8 | 2202.5 | 2195.5 | 2188.8 | 2182.3 | 2176.2 | 2170.3 | 2164.5 | 2158.7 |
| 140.0 | 2226.0 | 2220.6 | 2212.6 | 2204.8 | 2197.2 | 2189.8 | 2182.5 | 2175.5 | 2168.8 | 2162.3 | 2156.2 | 2150.3 | 2144.5 | 2138.7 |
| 150.0 | 2206.0 | 2200.6 | 2192.6 | 2184.8 | 2177.2 | 2169.8 | 2162.5 | 2155.5 | 2148.8 | 2142.3 | 2136.2 | 2130.3 | 2124.5 | 2118.7 |

Table 12. PS travel time versus distance and depth for use in the automated bulletin process program

| Distance (degrees) | Travel times (seconds) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Depth (kilometers) | | | | | | | | | | | | |
| | Surface | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
| 40.0 | 833.0 | 830.0 | 830.0 | 830.0 | 830.0 | 830.0 | 830.0 | 830.0 | 830.0 | 830.0 | 830.0 | 830.0 | 830.0 | 830.0 |
| 44.9 | 904.9 | 901.9 | 901.9 | 901.9 | 901.9 | 901.9 | 901.9 | 901.9 | 901.9 | 901.9 | 901.9 | 901.9 | 901.9 | 901.9 |
| 50.0 | 976.0 | 973.0 | 973.0 | 973.0 | 973.0 | 973.0 | 973.0 | 973.0 | 973.0 | 973.0 | 973.0 | 973.0 | 973.0 | 973.0 |
| 55.0 | 1047.0 | 1040.0 | 1043.0 | 1042.0 | 1042.0 | 1042.0 | 1042.0 | 1042.0 | 1042.0 | 1042.0 | 1042.0 | 1042.0 | 1042.0 | 1042.0 |
| 60.0 | 1117.0 | 1114.0 | 1112.0 | 1109.0 | 1109.0 | 1109.0 | 1109.0 | 1109.0 | 1109.0 | 110910 | 1109.0 | 1109.0 | 1109.0 | 1109.0 |
| 70.0 | 1252.0 | 1248.0 | 1245.0 | 1243.0 | 1242.0 | 1242.0 | 1242.0 | 1242.0 | 1242.0 | 1242.0 | 1242.0 | 1242.0 | 1242.0 | 1242.0 |
| 80.0 | 1381.0 | 1377.0 | 1373.0 | 1370.0 | 1367.0 | 1366.0 | 1365.0 | 1364.0 | 1364.0 | 1364.0 | 1364.0 | 1364.0 | 1364.0 | 1364.0 |
| 90.0 | 1503.0 | 1499.0 | 1494.0 | 1491.0 | 1487.0 | 1482.0 | 1480.0 | 1477.0 | 1475.0 | 1473.0 | 1473.0 | 1473.0 | 1473.0 | 1473.0 |
| 95.0 | 1560.0 | 1556.0 | 1551.0 | 1546.0 | 1541.0 | 1537.0 | 1534.0 | 1530.0 | 1528.0 | 1526.0 | 1526.0 | 1526.0 | 1526.0 | 1526.0 |
| 100.0 | 1613.0 | 1608.0 | 1603.0 | 1598.0 | 1594.0 | 1590.0 | 1586.0 | 1583.0 | 1580.0 | 1578.0 | 1577.0 | 1576.0 | 1576.0 | 1575.0 |
| 105.0 | 1665.0 | 1660.0 | 1655.0 | 1649.0 | 1644.0 | 1640.0 | 1635.0 | 1631.0 | 1628.0 | 1626.0 | 1625.0 | 1624.0 | 1624.0 | 1624.0 |
| 115.0 | 1762.0 | 1757.0 | 1751.0 | 1745.0 | 1740.0 | 1734.0 | 1729.0 | 1724.0 | 1721.0 | 1718.0 | 1715.0 | 1713.0 | 1711.0 | 1710.0 |
| 125.0 | 1851.0 | 1846.0 | 1840.0 | 1834.0 | 1828.0 | 1822.0 | 1817.0 | 1812.0 | 1808.0 | 1805.0 | 1802.0 | 1800.0 | 1797.0 | 1796.0 |
| 130.0 | 1894.0 | 1889.0 | 1883.0 | 1877.0 | 1871.0 | 1865.0 | 1860.0 | 1855.0 | 1850.0 | 1847.0 | 1843.0 | 1840.0 | 1837.0 | 1836.0 |
| 135.0 | 1937.0 | 1932.0 | 1926.0 | 1920.0 | 1914.0 | 1908.0 | 1903.0 | 1898.0 | 1894.0 | 1890.0 | 1886.0 | 1883.0 | 1880.0 | 1879.0 |
| 140.0 | 1979.0 | 1974.0 | 1966.0 | 1952.0 | 1956.0 | 1950.0 | 1945.0 | 1940.0 | 1936.0 | 1932.0 | 1928.0 | 1925.0 | 1922.0 | 1921.0 |
| 145.0 | 2020.0 | 2015.0 | 2009.0 | 2003.0 | 1997.0 | 1991.0 | 1985.0 | 1980.0 | 1976.0 | 1972.0 | 1968.0 | 1965.0 | 1962.0 | 1961.0 |
| 150.0 | 2062.0 | 2057.0 | 2051.0 | 2045.0 | 2039.0 | 2033.0 | 2027.0 | 2022.0 | 2018.0 | 2014.0 | 2010.0 | 2007.0 | 2004.0 | 2003.0 |
| 65.0 | 1590.0 | 1583.0 | 1574.0 | 1564.0 | 1556.0 | 1548.0 | 1540.0 | 1533.0 | 1527.0 | 1522.0 | 1518.0 | 1516.0 | 1515.0 | 1514.0 |
| 70.0 | 1681.0 | 1673.0 | 1663.0 | 1653.0 | 1644.0 | 1635.0 | 1627.0 | 1619.0 | 1612.0 | 1606.0 | 1600.0 | 1598.0 | 1596.0 | 1595.0 |
| 75.0 | 1767.0 | 1759.0 | 1749.0 | 1739.0 | 1730.0 | 1721.0 | 1713.0 | 1705.0 | 1698.0 | 1692.0 | 1686.0 | 1683.0 | 1681.0 | 1679.0 |
| 80.0 | 1850.0 | 1842.0 | 1831.0 | 1821.0 | 1811.0 | 1801.0 | 1792.0 | 1784.0 | 1768.0 | 1762.0 | 1757.0 | 1752.0 | 1749.0 | 1747.0 |
| 95.0 | 1931.0 | 1923.0 | 1912.0 | 1902.0 | 1892.0 | 1882.0 | 1873.0 | 1865.0 | 1857.0 | 1851.0 | 1846.0 | 1841.0 | 1838.0 | 1836.0 |
| 90.0 | 2011.0 | 2003.0 | 1992.0 | 1981.0 | 1971.0 | 1961.0 | 1952.0 | 1943.0 | 1935.0 | 1928.0 | 1923.0 | 1918.0 | 1914.0 | 1911.0 |
| 95.0 | 2089.0 | 2081.0 | 2070.0 | 2059.0 | 2049.0 | 2039.0 | 2030.0 | 2021.0 | 2013.0 | 2006.0 | 2001.0 | 1996.0 | 1992.0 | 1989.0 |
| 100.0 | 2167.0 | 2159.0 | 2148.0 | 2137.0 | 2127.0 | 2117.0 | 2107.0 | 2098.0 | 2090.0 | 2083.0 | 2077.0 | 2072.0 | 2068.0 | 2065.0 |
| 105.0 | 2245.0 | 2237.0 | 2226.0 | 2215.0 | 2205.0 | 2195.0 | 2185.0 | 2176.0 | 2168.0 | 2161.0 | 2155.0 | 2150.0 | 2146.0 | 2143.0 |
| 110.0 | 2322.0 | 2314.0 | 2303.0 | 2292.0 | 2282.0 | 2272.0 | 2262.0 | 2253.0 | 2245.0 | 2238.0 | 2232.0 | 2227.0 | 2223.0 | 2220.0 |
| 115.0 | 2398.0 | 2390.0 | 2379.0 | 2368.0 | 2358.0 | 2348.0 | 2338.0 | 2329.0 | 2321.0 | 2314.0 | 2307.0 | 2302.0 | 2298.0 | 2295.0 |
| 120.0 | 2473.0 | 2465.0 | 2452.0 | 2441.0 | 2431.0 | 2421.0 | 2412.0 | 2402.0 | 2394.0 | 2387.0 | 2380.0 | 2374.0 | 2369.0 | 2365.0 |
| 125.0 | 2548.0 | 2540.0 | 2526.0 | 2517.0 | 2507.0 | 2497.0 | 2488.0 | 2478.0 | 2470.0 | 2463.0 | 2456.0 | 2450.0 | 2445.0 | 2441.0 |
| 130.0 | 2621.0 | 2613.0 | 2601.0 | 2590.0 | 2580.0 | 2570.0 | 2560.0 | 2550.0 | 2542.0 | 2535.0 | 2528.0 | 2522.0 | 2517.0 | 2513.0 |
| 135.0 | 2694.0 | 2686.0 | 2674.0 | 2663.0 | 2653.0 | 2643.0 | 2633.0 | 2623.0 | 2615.0 | 2608.0 | 2601.0 | 2595.0 | 2590.0 | 2585.0 |
| 140.0 | 2765.0 | 2757.0 | 2745.0 | 2733.0 | 2722.0 | 2712.0 | 2702.0 | 2692.0 | 2683.0 | 2675.0 | 2668.0 | 2661.0 | 2656.0 | 2651.0 |
| 145.0 | 2836.0 | 2828.0 | 2816.0 | 2804.0 | 2793.0 | 2783.0 | 2773.0 | 2763.0 | 2754.0 | 2746.0 | 2739.0 | 2732.0 | 2727.0 | 2722.0 |
| 150.0 | 2906.0 | 2898.0 | 2866.0 | 2874.0 | 2863.0 | 2853.0 | 2843.0 | 2833.0 | 2824.0 | 2816.0 | 2809.0 | 2802.0 | 2797.0 | 2792.0 |
| 155.0 | 2975.0 | 2967.0 | 2955.0 | 2943.0 | 2932.0 | 2921.0 | 2910.0 | 2900.0 | 2891.0 | 2883.0 | 2875.0 | 2868.0 | 2863.0 | 2857.0 |
| 160.0 | 3043.0 | 3035.0 | 3023.0 | 3011.0 | 3000.0 | 2989.0 | 2978.0 | 2968.0 | 2959.0 | 2951.0 | 2943.0 | 2936.0 | 2930.0 | 2924.0 |
| 165.0 | 3110.0 | 3102.0 | 3090.0 | 3078.0 | 3067.0 | 3056.0 | 3045.0 | 3035.0 | 3026.0 | 3018.0 | 3010.0 | 3003.0 | 2997.0 | 2991.0 |
| 170.0 | 3177.0 | 3169.0 | 3157.0 | 3145.0 | 3134.0 | 3123.0 | 3112.0 | 3102.0 | 3093.0 | 3085.0 | 3077.0 | 3069.0 | 3063.0 | 3057.0 |
| 175.0 | 3243.0 | 3235.0 | 3222.0 | 3210.0 | 3199.0 | 3188.0 | 3177.0 | 3167.0 | 3158.0 | 3149.0 | 3141.0 | 3133.0 | 3126.0 | 3120.0 |
| 180.0 | 3308.0 | 3300.0 | 3288.0 | 3276.0 | 3265.0 | 3254.0 | 3242.0 | 3232.0 | 3223.0 | 3214.0 | 3206.0 | 3198.0 | 3191.0 | 3185.0 |
| 185.0 | 3372.0 | 3365.0 | 3352.0 | 3340.0 | 3329.0 | 3318.0 | 3307.0 | 3296.0 | 3287.0 | 3278.0 | 3270.0 | 3262.0 | 3255.0 | 3219.0 |

Table 13. SSS travel time versus distance and depth for use in the automated bulletin process program

| Distance (degrees) | Travel times (seconds) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Surface | Depth (kilometers) | | | | | | | | | | | | |
| | | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 79[illegible] |
| 0 | 32.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 |
| 0.5 | 45.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 |
| 1.0 | 58.0 | 53.0 | 53.0 | 53.0 | 53.0 | 53.0 | 53.0 | 53.0 | 53.0 | 53.0 | 53.0 | 53.0 | 53.0 | 53.0 |
| 3.0 | 108.0 | 103.0 | 103.0 | 103.0 | 103.0 | 103.0 | 103.0 | 103.0 | 103.0 | 103.0 | 103.0 | 103.0 | 103.0 | 103.0 |
| 5.0 | 159.0 | 154.0 | 154.0 | 154.0 | 154.0 | 154.0 | 154.0 | 154.0 | 154.0 | 154.0 | 154.0 | 154.0 | 154.0 | 154.0 |
| 7.0 | 210.0 | 205.0 | 205.0 | 205.0 | 205.0 | 205.0 | 205.0 | 205.0 | 205.0 | 205.0 | 205.0 | 205.0 | 205.0 | 205.0 |
| 9.0 | 261.0 | 256.0 | 256.0 | 256.0 | 256.0 | 256.0 | 256.0 | 256.0 | 256.0 | 256.0 | 256.0 | 256.0 | 256.0 | 256.0 |
| 11.0 | 311.0 | 306.0 | 306.0 | 306.0 | 306.0 | 306.0 | 306.0 | 306.0 | 306.0 | 306.0 | 306.0 | 306.0 | 306.0 | 306.0 |
| 13.0 | 362.0 | 357.0 | 357.0 | 357.0 | 357.0 | 357.0 | 357.0 | 357.0 | 357.0 | 357.0 | 357.0 | 357.0 | 357.0 | 357.0 |
| 15.0 | 413.0 | 408.0 | 408.0 | 408.0 | 408.0 | 408.0 | 408.0 | 408.0 | 408.0 | 408.0 | 408.0 | 408.0 | 408.0 | 408.0 |
| 18.0 | 488.0 | 483.0 | 483.0 | 483.0 | 483.0 | 483.0 | 483.0 | 483.0 | 483.0 | 483.0 | 483.0 | 483.0 | 483.0 | 483.0 |
| 21.0 | 563.0 | 558.0 | 557.0 | 557.0 | 557.0 | 557.0 | 557.0 | 557.0 | 557.0 | 557.0 | 557.0 | 557.0 | 557.0 | 557.0 |
| 24.0 | 638.0 | 633.0 | 632.0 | 632.0 | 632.0 | 632.0 | 632.0 | 632.0 | 632.0 | 632.0 | 632.0 | 632.0 | 632.0 | 632.0 |
| 27.0 | 713.0 | 708.0 | 707.0 | 707.0 | 707.0 | 707.0 | 707.0 | 707.0 | 707.0 | 707.0 | 707.0 | 707.0 | 707.0 | 707.0 |
| 30.0 | 787.0 | 781.0 | 779.0 | 778.0 | 778.0 | 778.0 | 778.0 | 778.0 | 778.0 | 778.0 | 778.0 | 778.0 | 778.0 | 778.0 |
| 33.0 | 860.0 | 854.0 | 852.0 | 850.0 | 850.0 | 850.0 | 850.0 | 850.0 | 850.0 | 850.0 | 850.0 | 850.0 | 850.0 | 850.0 |
| 36.0 | 933.0 | 927.0 | 925.0 | 923.0 | 923.0 | 923.0 | 923.0 | 923.0 | 923.0 | 923.0 | 923.0 | 923.0 | 923.0 | 923.0 |
| 39.0 | 1006.0 | 1000.0 | 998.0 | 995.0 | 995.0 | 995.0 | 995.0 | 995.0 | 995.0 | 995.0 | 995.0 | 995.0 | 995.0 | 995.0 |
| 42.0 | 1078.0 | 1072.0 | 1068.0 | 1065.0 | 1064.0 | 1064.0 | 1064.0 | 1064.0 | 1064.0 | 1064.0 | 1064.0 | 1064.0 | 1064.0 | 1064.0 |
| 45.0 | 1149.0 | 1143.0 | 1138.0 | 1134.0 | 1132.0 | 1132.0 | 1132.0 | 1132.0 | 1132.0 | 1132.0 | 1132.0 | 1132.0 | 1132.0 | 1132.0 |
| 48.0 | 1219.0 | 1213.0 | 1207.0 | 1202.0 | 1198.0 | 1197.0 | 1197.0 | 1197.0 | 1195.0 | 1195.0 | 1195.0 | 1195.0 | 1195.0 | 1195.0 |
| 51.0 | 1289.0 | 1283.0 | 1277.0 | 1272.0 | 1269.0 | 1266.0 | 1265.0 | 1263.0 | 1263.0 | 1263.0 | 1263.0 | 1263.0 | 1263.0 | 1263.0 |
| 54.0 | 1357.0 | 1351.0 | 1345.0 | 1339.0 | 1335.0 | 1331.0 | 1328.0 | 1326.0 | 1322.0 | 1321.0 | 1321.0 | 1321.0 | 1321.0 | 1321.0 |
| 57.0 | 1425.0 | 1419.0 | 1412.0 | 1406.0 | 1401.0 | 1395.0 | 1389.0 | 1384.0 | 1379.0 | 1377.0 | 1376.0 | 1376.0 | 1376.0 | 1376.0 |
| 60.0 | 1491.0 | 1485.0 | 1477.0 | 1470.0 | 1462.0 | 1454.0 | 1447.0 | 1441.0 | 1436.0 | 1432.0 | 1430.0 | 429.0 | 1429.0 | 1429.0 |

Table 14. SPP travel time tables (seconds) for use in the automated bulletin process program

| Distance (degrees) | Surface | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40.0 | 840.0 | 832.0 | 820.0 | 809.0 | 798.0 | 787.0 | 777.0 | 767.0 | 759.0 | 751.0 | 744.0 | 738.0 | 732.0 | 727.0 |
| 44.99 | 912.0 | 904.0 | 892.0 | 881.0 | 870.0 | 859.0 | 849.0 | 839.0 | 831.0 | 823.0 | 816.0 | 810.0 | 804.0 | 799.0 |
| 50.0 | 983.0 | 975.0 | 963.0 | 952.0 | 941.0 | 930.0 | 920.0 | 910.0 | 902.0 | 894.0 | 886.0 | 880.0 | 874.0 | 870.0 |
| 55.0 | 1054.0 | 1046.0 | 1034.0 | 1023.0 | 1012.0 | 1001.0 | 991.0 | 981.0 | 973.0 | 965.0 | 957.0 | 951.0 | 945.0 | 941.0 |
| 60.0 | 1125.0 | 1117.0 | 1105.0 | 1093.0 | 1082.0 | 1072.0 | 1062.0 | 1052.0 | 1043.0 | 1035.0 | 1027.0 | 1021.0 | 1015.0 | 1010.0 |
| 65.0 | 1195.0 | 1187.0 | 1175.0 | 1163.0 | 1152.0 | 1142.0 | 1132.0 | 1122.0 | 1113.0 | 1105.0 | 1097.0 | 1091.0 | 1085.0 | 1080.0 |
| 70.0 | 1285.0 | 1277.0 | 1265.0 | 1253.0 | 1242.0 | 1231.0 | 1221.0 | 1211.0 | 1202.0 | 1193.0 | 1186.0 | 1179.0 | 1173.0 | 1168.0 |
| 75.0 | 1333.0 | 1325.0 | 1313.0 | 1301.0 | 1290.0 | 1279.0 | 1269.0 | 1259.0 | 1250.0 | 1241.0 | 1234.0 | 1227.0 | 1221.0 | 1216.0 |
| 80.0 | 1401.0 | 1393.0 | 1380.0 | 1369.0 | 1358.0 | 1347.0 | 1336.0 | 1326.0 | 1317.0 | 1308.0 | 1300.0 | 1293.0 | 1286.0 | 1281.0 |
| 85.0 | 1467.0 | 1459.0 | 1446.0 | 1435.0 | 1424.0 | 1413.0 | 1402.0 | 1392.0 | 1383.0 | 1374.0 | 1366.0 | 1359.0 | 1352.0 | 1347.0 |
| 90.0 | 1533.0 | 1525.0 | 1512.0 | 1501.0 | 1489.0 | 1478.0 | 1467.0 | 1456.0 | 1447.0 | 1438.0 | 1430.0 | 1422.0 | 1415.0 | 1409.0 |
| 95.0 | 1597.0 | 1589.0 | 1576.0 | 1565.0 | 1553.0 | 1542.0 | 1531.0 | 1520.0 | 1511.0 | 1502.0 | 1494.0 | 1486.0 | 1479.0 | 1473.0 |
| 100.0 | 1660.0 | 1652.0 | 1639.0 | 1627.0 | 1615.0 | 1604.0 | 1593.0 | 1582.0 | 1572.0 | 1563.0 | 1555.0 | 1547.0 | 1539.0 | 1533.0 |
| 105.0 | 1721.0 | 1713.0 | 1700.0 | 1688.0 | 1676.0 | 1665.0 | 1654.0 | 1643.0 | 1633.0 | 1624.9 | 1616.0 | 1608.0 | 1600.0 | 1594.0 |
| 110.0 | 1781.0 | 1772.0 | 1759.0 | 1747.0 | 1735.0 | 1723.0 | 1712.0 | 1701.0 | 1690.0 | 1680.0 | 1671.0 | 1663.0 | 1655.0 | 1647.0 |
| 115.0 | 1837.0 | 1828.0 | 1815.0 | 1803.0 | 1791.0 | 1779.0 | 1768.0 | 1757.0 | 1746.0 | 1736.0 | 1727.0 | 1719.0 | 1711.0 | 1703.0 |
| 120.0 | 1890.0 | 1881.0 | 1868.0 | 1859.0 | 1843.0 | 1831.0 | 1821.0 | 1808.0 | 1798.0 | 1787.0 | 1778.0 | 1769.0 | 1761.0 | 1753.0 |
| 125.0 | 1942.0 | 1933.0 | 1920.0 | 1908.0 | 1895.0 | 1883.0 | 1873.0 | 1860.0 | 1850.0 | 1839.0 | 1830.0 | 1821.0 | 1813.0 | 1805.0 |
| 130.0 | 1992.0 | 1983.0 | 1970.0 | 1957.0 | 1944.0 | 1932.0 | 1920.0 | 1908.0 | 1897.0 | 1887.0 | 1877.0 | 1868.0 | 1859.0 | 1850.0 |
| 135.0 | 2041.0 | 2032.0 | 2019.0 | 2006.0 | 1993.0 | 1981.0 | 1969.0 | 1957.0 | 1946.0 | 1936.0 | 1926.0 | 1917.0 | 1908.0 | 1899.0 |
| 140.0 | 2088.0 | 2079.0 | 2066.0 | 2053.0 | 2040.0 | 2028.0 | 2016.0 | 2004.0 | 1993.0 | 1983.0 | 1973.0 | 1964.0 | 1955.0 | 1946.0 |
| 145.0 | 2134.0 | 2125.0 | 2112.0 | 2099.0 | 2086.0 | 2074.0 | 2062.0 | 2050.0 | 2039.0 | 2029.0 | 2019.0 | 2010.0 | 2001.0 | 1992.0 |
| 150.0 | 2180.0 | 2171.0 | 2158.0 | 2144.0 | 2131.0 | 2119.0 | 2107.0 | 2095.0 | 2084.0 | 2073.0 | 2063.0 | 2054.0 | 2045.0 | 2036.0 |
| 155.0 | 2224.0 | 2215.0 | 2202.0 | 2188.0 | 2175.0 | 2163.0 | 2151.0 | 2139.0 | 2128.0 | 2117.0 | 2107.0 | 2098.0 | 2089.0 | 2080.0 |
| 160.0 | 2267.0 | 2258.0 | 2245.0 | 2231.0 | 2218.0 | 2206.0 | 2194.0 | 2182.0 | 2171.0 | 2160.0 | 2150.0 | 2141.0 | 2132.0 | 2123.0 |
| 165.0 | 2310.0 | 2301.0 | 2288.0 | 2274.0 | 2261.0 | 2249.0 | 2237.0 | 2225.0 | 2214.0 | 2203.0 | 2193.0 | 2184.0 | 2175.0 | 2166.0 |
| 170.0 | 2353.0 | 2344.0 | 2331.0 | 2317.0 | 2304.0 | 2292.0 | 2280.0 | 2268.0 | 2256.0 | 2246.0 | 2235.0 | 2226.0 | 2216.0 | 2208.0 |
| 175.0 | 2395.0 | 2386.0 | 2373.0 | 2359.0 | 2346.0 | 2334.0 | 2322.0 | 2310.0 | 2298.0 | 2288.0 | 2277.0 | 2268.0 | 2258.0 | 2250.0 |
| 180.01 | 2437.0 | 2428.0 | 2415.0 | 2401.0 | 2388.0 | 2376.0 | 2364.0 | 2352.0 | 2340.0 | 2330.0 | 2319.0 | 2310.0 | 2300.0 | 2292.0 |
| 185.0 | 2478.0 | 2469.0 | 2456.0 | 2442.0 | 2429.0 | 2417.0 | 2405.0 | 2393.0 | 2381.0 | 2371.0 | 2360.0 | 2351.0 | 2341.0 | 2333.0 |

Table 15. PPP travel time tables (seconds) for use in the automated bulletin process program

| Distance (degrees) | Surface | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.0 | 92.0 | 89.0 | 88.0 | 86.0 | 83.0 | 83.0 | 77.0 | 77.0 | 75.0 | 71.0 | 61.0 | 53.0 | 45.0 | 40.0 |
| 10.0 | 163.0 | 160.0 | 159.0 | 157.0 | 154.0 | 154.0 | 148.0 | 148.0 | 146.0 | 142.0 | 132.0 | 124.0 | 118.0 | 113.0 |
| 15.0 | 234.0 | 230.0 | 229.0 | 227.0 | 224.0 | 224.0 | 218.0 | 218.0 | 216.0 | 212.0 | 202.0 | 194.0 | 186.0 | 181.0 |
| 20.0 | 305.0 | 301.0 | 301.0 | 299.0 | 296.0 | 296.0 | 290.0 | 290.0 | 288.0 | 234.0 | 274.0 | 266.0 | 258.0 | 253.0 |
| 25.0 | 375.0 | 371.0 | 371.0 | 369.0 | 366.0 | 366.0 | 360.0 | 360.0 | 358.0 | 354.0 | 344.0 | 336.0 | 328.0 | 323.0 |
| 30.0 | 444.0 | 440.0 | 439.0 | 438.0 | 435.0 | 435.0 | 429.0 | 429.0 | 427.0 | 423.0 | 413.0 | 405.0 | 397.0 | 392.0 |
| 35.0 | 512.0 | 508.0 | 506.0 | 505.0 | 502.0 | 502.0 | 496.0 | 496.0 | 494.0 | 490.0 | 480.0 | 472.0 | 464.0 | 459.0 |
| 40.0 | 579.0 | 575.0 | 572.0 | 570.0 | 570.0 | 570.0 | 564.0 | 564.0 | 562.0 | 555.0 | 548.0 | 540.0 | 532.0 | 527.0 |
| 45.0 | 645.0 | 641.0 | 638.0 | 636.0 | 636.0 | 636.0 | 630.0 | 630.0 | 628.0 | 624.0 | 614.0 | 606.0 | 598.0 | 593.0 |
| 50.0 | 709.0 | 705.0 | 701.0 | 698.0 | 696.0 | 694.0 | 694.0 | 694.0 | 692.0 | 688.0 | 678.0 | 670.0 | 662.0 | 657.0 |
| 55.0 | 772.0 | 768.0 | 764.0 | 760.0 | 757.0 | 754.0 | 751.0 | 748.0 | 745.0 | 744.0 | 740.0 | 732.0 | 724.0 | 719.0 |
| 60.0 | 831.0 | 827.0 | 821.0 | 816.0 | 811.0 | 807.0 | 803.0 | 799.0 | 796.0 | 794.0 | 793.0 | 792.0 | 784.0 | 779.0 |
| 65.0 | 883.0 | 879.0 | 874.0 | 869.0 | 864.0 | 870.0 | 856.0 | 852.0 | 849.0 | 847.0 | 846.0 | 845.0 | 837.0 | 832.0 |
| 70.0 | 932.0 | 827.0 | 922.0 | 916.0 | 911.0 | 906.0 | 902.0 | 897.0 | 894.0 | 891.0 | 889.0 | 887.0 | 885.0 | 880.0 |
| 75.0 | 980.0 | 975.0 | 970.0 | 964.0 | 959.0 | 954.0 | 950.0 | 945.0 | 942.0 | 939.0 | 937.0 | 935.0 | 933.0 | 928.0 |
| 80.0 | 1027.0 | 1022.0 | 1016.0 | 1010.0 | 1005.0 | 999.0 | 995.0 | 990.0 | 986.0 | 983.0 | 980.0 | 978.0 | 976.0 | 975.0 |
| 85.0 | 1073.0 | 1068.0 | 1062.0 | 1056.0 | 1051.0 | 1045.0 | 1041.0 | 1036.0 | 1032.0 | 1029.0 | 1026.0 | 1024.0 | 1022.0 | 1021.0 |
| 90.0 | 1117.0 | 1112.0 | 1106.0 | 1100.0 | 1094.0 | 1089.0 | 1084.0 | 1079.0 | 1075.0 | 1071.0 | 1068.0 | 1066.0 | 1064.0 | 1062.0 |
| 95.0 | 1162.0 | 1157.0 | 1151.0 | 1145.0 | 1139.0 | 1134.0 | 1129.0 | 1124.0 | 1120.0 | 1116.0 | 1113.0 | 1111.0 | 1109.0 | 1107.0 |
| 100.0 | 1205.0 | 1200.0 | 1194.0 | 1188.0 | 1182.0 | 1176.0 | 1171.0 | 1165.0 | 1162.0 | 1158.0 | 1155.0 | 1152.0 | 1150.0 | 1148.0 |
| 105.0 | 1248.0 | 1243.0 | 1237.0 | 1231.0 | 1725.0 | 1219.0 | 1214.0 | 1209.0 | 1205.0 | 1201.0 | 1198.0 | 1195.0 | 1193.0 | 1191.0 |
| 110.0 | 1291.0 | 1286.0 | 1280.0 | 1274.0 | 1268.0 | 1262.0 | 1257.0 | 1252.0 | 1248.0 | 1244.0 | 1241.0 | 1238.0 | 1236.0 | 1234.0 |
| 115.0 | 1333.0 | 1328.0 | 1322.0 | 1316.0 | 1310.0 | 1304.0 | 1299.0 | 1294.0 | 1290.0 | 1286.0 | 1283.0 | 1280.0 | 1278.0 | 1276.0 |
| 120.0 | 1374.0 | 1369.0 | 1363.0 | 1357.0 | 1350.0 | 1345.0 | 1339.0 | 1334.0 | 1330.0 | 1325.0 | 1322.0 | 1319.0 | 1316.0 | 1313.0 |
| 125.0 | 1415.0 | 1410.0 | 1404.0 | 1398.0 | 1391.0 | 1386.0 | 1380.0 | 1375.0 | 1371.0 | 1366.0 | 1363.0 | 1360.0 | 1357.0 | 1354.0 |
| 130.0 | 1456.0 | 1451.0 | 1445.0 | 1439.0 | 1432.0 | 1427.0 | 1421.0 | 1416.0 | 1412.0 | 1407.0 | 1404.0 | 1401.0 | 1398.0 | 1395.0 |
| 135.0 | 1497.0 | 1492.0 | 1486.0 | 1480.0 | 1473.0 | 1468.0 | 1462.0 | 1457.0 | 1453.0 | 1448.0 | 1445.0 | 1442.0 | 1439.0 | 1436.0 |
| 140.0 | 1536.0 | 1531.0 | 1525.0 | 1518.0 | 1512.0 | 1506.0 | 1500.0 | 1495.0 | 1490.0 | 1486.0 | 1482.0 | 1478.0 | 1475.0 | 1472.0 |
| 145.0 | 1576.0 | 1571.0 | 1565.0 | 1558.0 | 1552.0 | 1546.0 | 1540.0 | 1535.0 | 1530.0 | 1526.0 | 1522.0 | 1518.0 | 1515.0 | 1512.0 |
| 150.0 | 1614.0 | 1609.0 | 1603.0 | 1596.0 | 1590.0 | 1584.0 | 1578.0 | 1573.0 | 1568.0 | 1564.0 | 1560.0 | 1556.0 | 1553.0 | 1550.0 |
| 155.0 | 1652.0 | 1647.0 | 1641.0 | 1634.0 | 1628.0 | 1622.0 | 1616.0 | 1611.0 | 1606.0 | 1602.0 | 1598.0 | 1594.0 | 1591.0 | 1588.0 |
| 160.0 | 1689.0 | 1684.0 | 1677.0 | 1671.0 | 1664.0 | 1658.0 | 1652.0 | 1647.0 | 1642.0 | 1637.0 | 1633.0 | 1629.0 | 1625.0 | 1621.0 |
| 165.0 | 1726.0 | 1721.0 | 1714.0 | 1708.0 | 1701.0 | 1695.0 | 1689.0 | 1684.0 | 1679.0 | 1674.0 | 1670.0 | 1666.0 | 1662.0 | 1658.0 |
| 170.0 | 1762.0 | 1757.0 | 1750.0 | 1744.0 | 1737.0 | 1731.0 | 1725.0 | 1720.0 | 1715.0 | 1710.0 | 1706.0 | 1702.0 | 1698.0 | 1694.0 |
| 175.0 | 1797.0 | 1792.0 | 1785.0 | 1778.0 | 1771.0 | 1765.0 | 1759.0 | 1754.0 | 1749.0 | 1744.0 | 1740.0 | 1736.0 | 1732.0 | 1728.0 |
| 180.01 | 1832.0 | 1827.0 | 1820.0 | 1813.0 | 1806.0 | 1800.0 | 1794.0 | 1789.0 | 1784.0 | 1779.0 | 1774.0 | 1770.0 | 1766.0 | 1762.0 |
| 185.0 | 1866.0 | 1861.0 | 1854.0 | 1847.0 | 1840.0 | 1834.0 | 1828.0 | 1823.0 | 1818.0 | 1813.0 | 1808.0 | 1804.0 | 1800.0 | 1796.0 |

Table 16. SP travel time tables (seconds) for use in the automated bulletin process program

| Distance (degrees) | Surface | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40.0 | 833.0 | 825.0 | 813.0 | 802.0 | 791.0 | 780.0 | 770.0 | 760.0 | 752.0 | 744.0 | 737.0 | 731.0 | 725.0 | 720.0 |
| 45.1 | 905.0 | 897.0 | 885.0 | 874.0 | 863.0 | 852.0 | 842.0 | 832.0 | 824.0 | 816.0 | 809.0 | 803.0 | 797.0 | 792.0 |
| 50.0 | 976.0 | 968.0 | 956.0 | 945.0 | 934.0 | 923.0 | 913.0 | 903.0 | 894.0 | 886.0 | 879.0 | 873.0 | 867.0 | 862.0 |
| 55.0 | 1047.0 | 1039.0 | 1027.0 | 1016.0 | 1005.0 | 994.0 | 984.0 | 974.0 | 965.0 | 957.0 | 950.0 | 944.0 | 938.0 | 933.0 |
| 60.0 | 1117.0 | 1109.0 | 1097.0 | 1085.0 | 1074.0 | 1063.0 | 1053.0 | 1043.0 | 1034.0 | 1025.0 | 1018.0 | 1011.0 | 1005.0 | 999.0 |
| 65.0 | 1185.0 | 1177.0 | 1165.0 | 1153.0 | 1142.0 | 1131.0 | 1121.0 | 1111.0 | 1102.0 | 1093.0 | 1086.0 | 1079.0 | 1073.0 | 1067.0 |
| 70.0 | 1252.0 | 1244.0 | 1231.0 | 1220.0 | 1208.0 | 1197.0 | 1186.0 | 1176.0 | 1167.0 | 1158.0 | 1150.0 | 1143.0 | 1136.0 | 1130.0 |
| 75.0 | 1318.0 | 1310.0 | 1297.0 | 1286.0 | 1274.0 | 1263.0 | 1252.0 | 1242.0 | 1233.0 | 1224.0 | 1216.0 | 1209.0 | 1202.0 | 1196.0 |
| 80.0 | 1381.0 | 1373.0 | 1360.0 | 1348.0 | 1336.0 | 1325.0 | 1314.0 | 1304.0 | 1294.0 | 1285.0 | 1276.0 | 1269.0 | 1261.0 | 1254.0 |
| 85.0 | 1443.0 | 1434.0 | 1422.0 | 1410.0 | 1398.0 | 1386.0 | 1375.0 | 1365.0 | 1355.0 | 1345.0 | 1337.0 | 1329.0 | 1321.0 | 1314.0 |
| 90.0 | 1503.0 | 1494.0 | 1482.0 | 1469.0 | 1457.0 | 1446.0 | 1435.0 | 1424.0 | 1414.0 | 1404.0 | 1395.0 | 1387.0 | 1379.0 | 1370.0 |
| 95.0 | 1560.0 | 1551.0 | 1538.0 | 1526.0 | 1513.0 | 1502.0 | 1490.0 | 1479.0 | 1468.0 | 1458.0 | 1449.0 | 1441.0 | 1432.0 | 1424.0 |
| 100.0 | 1613.0 | 1604.0 | 1591.0 | 1579.0 | 1566.0 | 1554.0 | 1543.0 | 1531.0 | 1520.0 | 1510.0 | 1501.0 | 1492.0 | 1484.0 | 1474.0 |
| 105.0 | 1665.0 | 1656.0 | 1643.0 | 1630.0 | 1618.0 | 1605.0 | 1594.0 | 1582.0 | 1571.0 | 1561.0 | 1552.0 | 1543.0 | 1534.0 | 1525.0 |
| 110.0 | 1714.0 | 1705.0 | 1692.0 | 1679.0 | 1666.0 | 1654.0 | 1642.0 | 1631.0 | 1620.0 | 1609.0 | 1600.0 | 1590.0 | 1581.0 | 1573.0 |
| 115.0 | 1762.0 | 1753.0 | 1740.0 | 1727.0 | 1714.0 | 1702.0 | 1690.0 | 1679.0 | 1668.0 | 1657.0 | 1648.0 | 1638.0 | 1629.0 | 1621.0 |
| 120.0 | 1807.0 | 1798.0 | 1785.0 | 1772.0 | 1759.0 | 1746.0 | 1734.0 | 1723.0 | 1712.0 | 1701.0 | 1691.0 | 1681.0 | 1672.0 | 1663.0 |
| 125.0 | 1851.0 | 1842.0 | 1829.0 | 1816.0 | 1803.0 | 1790.0 | 1778.0 | 1767.0 | 1756.0 | 1745.0 | 1735.0 | 1725.0 | 1716.0 | 1708.0 |
| 130.0 | 1894.0 | 1885.0 | 1872.0 | 1859.0 | 1846.0 | 1834.0 | 1822.0 | 1810.0 | 1799.0 | 1788.0 | 1778.0 | 1768.0 | 1759.0 | 1750.0 |
| 135.0 | 1937.0 | 1928.0 | 1915.0 | 1902.0 | 1889.0 | 1877.0 | 1865.0 | 1853.0 | 1842.0 | 1831.0 | 1821.0 | 1811.0 | 1802.0 | 1793.0 |
| 140.0 | 1979.0 | 1970.0 | 1956.0 | 1943.0 | 1930.0 | 1918.0 | 1906.0 | 1894.0 | 1882.0 | 1872.0 | 1861.0 | 1852.0 | 1842.0 | 1834.0 |
| 145.01 | 2020.0 | 2011.0 | 1997.0 | 1984.0 | 1971.0 | 1959.0 | 1947.0 | 1935.0 | 1923.0 | 1913.0 | 1902.0 | 1893.0 | 1883.0 | 1875.0 |
| 150.0 | 2061.0 | 2052.0 | 2038.0 | 2025.0 | 2012.0 | 2000.0 | 1988.0 | 1976.0 | 1964.0 | 1954.0 | 1943.0 | 1934.0 | 1924.0 | 1916.0 |

Table 17. PPS travel time tables (seconds) for use in the automated bulletin process program

| Distance Degrees | Surface | 33 | 97 | 160 | 224 | 286 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40.0 | 840.0 | 837.0 | 837.0 | 832.0 | 832.0 | 829.0 | 823.0 | 817.0 | 817.0 | 807.0 | 798.0 | 791.0 | 791.0 | 784.0 |
| 44.99 | 912.0 | 909.0 | 909.0 | 904.0 | 904.0 | 900.0 | 895.0 | 889.0 | 889.0 | 879.0 | 870.0 | 863.0 | 863.0 | 856.0 |
| 50.0 | 983.0 | 980.0 | 980.0 | 975.0 | 975.0 | 971.0 | 966.0 | 960.0 | 960.0 | 950.0 | 941.0 | 934.0 | 934.0 | 927.0 |
| 55.0 | 1054.0 | 1051.0 | 1051.0 | 1046.0 | 1046.0 | 1042.0 | 1037.0 | 1031.0 | 1031.0 | 1021.0 | 1012.0 | 1005.0 | 1005.0 | 998.0 |
| 60.0 | 1125.0 | 1122.0 | 1122.0 | 1117.0 | 1117.0 | 1113.0 | 1108.0 | 1102.0 | 1102.0 | 1092.0 | 1083.0 | 1076.0 | 1076.0 | 1069.0 |
| 65.0 | 1195.0 | 1192.0 | 1192.0 | 1187.0 | 1187.0 | 1183.0 | 1178.0 | 1172.0 | 1172.0 | 1162.0 | 1153.0 | 1146.0 | 1146.0 | 1139.0 |
| 70.0 | 1285.0 | 1281.0 | 1280.0 | 1277.0 | 1277.0 | 1273.0 | 1268.0 | 1262.0 | 1262.0 | 1252.0 | 1243.0 | 1236.0 | 1236.0 | 1229.0 |
| 75.0 | 1333.0 | 1329.0 | 1328.0 | 1325.0 | 1325.0 | 1321.0 | 1316.0 | 1310.0 | 1310.0 | 1300.0 | 1291.0 | 1284.0 | 1284.0 | 1277.0 |
| 80.0 | 1401.0 | 1397.0 | 1395.0 | 1393.0 | 1393.0 | 1389.0 | 1384.0 | 1378.0 | 1378.0 | 1368.0 | 1359.0 | 1352.0 | 1352.0 | 1345.0 |
| 85.0 | 1467.0 | 1463.0 | 1461.0 | 1459.0 | 1459.0 | 1455.0 | 1450.0 | 1444.0 | 1444.0 | 1434.0 | 1425.0 | 1418.0 | 1418.0 | 1411.0 |
| 90.0 | 1533.0 | 1529.0 | 1526.0 | 1523.0 | 1522.0 | 1521.0 | 1516.0 | 1510.0 | 1510.0 | 1500.0 | 1491.0 | 1484.0 | 1484.0 | 1477.0 |
| 95.0 | 1597.0 | 1593.0 | 1590.0 | 1587.0 | 1586.0 | 1585.0 | 1580.0 | 1574.0 | 1574.0 | 1564.0 | 1555.0 | 1548.0 | 1548.0 | 1541.0 |
| 100.0 | 1660.0 | 1656.0 | 1652.0 | 1649.0 | 1646.0 | 1644.0 | 1643.0 | 1642.0 | 1642.0 | 1632.0 | 1623.0 | 1616.0 | 1616.0 | 1609.0 |
| 105.0 | 1721.0 | 1717.0 | 1713.0 | 1710.0 | 1707.0 | 1705.0 | 1704.0 | 1703.0 | 1703.0 | 1693.0 | 1684.0 | 1677.0 | 1677.0 | 1670.0 |
| 110.0 | 1781.0 | 1777.0 | 1772.0 | 1769.0 | 1763.0 | 1760.0 | 1757.0 | 1754.0 | 1752.0 | 1752.0 | 1743.0 | 1736.0 | 1736.0 | 1729.0 |
| 115.0 | 1837.0 | 1833.0 | 1828.0 | 1825.0 | 1819.0 | 1816.0 | 1813.0 | 1810.0 | 1808.0 | 1808.0 | 1799.0 | 1792.0 | 1792.0 | 1785.0 |
| 120 0 | 1890.0 | 1886.0 | 1880.0 | 1875.0 | 1870.0 | 1866.0 | 1862.0 | 1859.0 | 1856.0 | 1854.0 | 1853.0 | 1846.0 | 1846.0 | 1839.0 |
| 125.0 | 1942.0 | 1937.0 | 1931.0 | 1926.0 | 1921.0 | 1917.0 | 1913.0 | 1910.0 | 1907.0 | 1905.0 | 1904.0 | 1897.0 | 1897.0 | 1890.0 |
| 130.0 | 1992.0 | 1987.0 | 1982.0 | 1976.0 | 1971.0 | 1966.0 | 1962.0 | 1958.0 | 1954.0 | 1952.0 | 1950.0 | 1948.0 | 1948.0 | 1941.0 |
| 135.0 | 2041.0 | 2036.0 | 2031.0 | 2025.0 | 2020.0 | 2015.0 | 2011.0 | 2007.0 | 2003.0 | 2001 0 | 1999.0 | 1997.0 | 1997.0 | 1990.0 |
| 140.0 | 2088.0 | 2083.0 | 2077.0 | 2072.0 | 2066.0 | 2061.0 | 2056.0 | 2052.0 | 2048.0 | 2045.0 | 2042.0 | 2039.0 | 2038.0 | 2037.0 |
| 145.0 | 2134.0 | 2129.0 | 2123.0 | 2118.0 | 2112.0 | 2107.0 | 2102.0 | 2098.0 | 2094.0 | 2091.0 | 2088.0 | 2085.0 | 2084.0 | 2083.0 |
| 150.0 | 2180.0 | 2175.0 | 2169.0 | 2164.0 | 2158.0 | 2153.0 | 2148.0 | 2144.0 | 2140.0 | 2137.0 | 2134.0 | 2131.0 | 2129.0 | 2127.0 |
| 155.0 | 2224.0 | 2219.0 | 2213.0 | 2207.0 | 2201.0 | 2196.0 | 2190.0 | 2186.0 | 2181.0 | 2177.0 | 2174.0 | 2171.0 | 2169.0 | 2167.0 |
| 160.0 | 2267.0 | 2262.0 | 2256.0 | 2250.0 | 2244.0 | 2239.0 | 2233.0 | 2229.0 | 2224.0 | 2220.0 | 2217.0 | 2214.0 | 2212.0 | 2210.0 |
| 165.0 | 2310.0 | 2305.0 | 2299.0 | 2293.0 | 2287.0 | 2282.0 | 2276.0 | 2272.0 | 2267.0 | 2263.0 | 2260.0 | 2257.0 | 2255.0 | 2253.0 |
| 170.0 | 2353.0 | 2348.0 | 2342.0 | 2336.0 | 2330.0 | 2325.0 | 2319.0 | 2314.0 | 2309.0 | 2305.0 | 2301.0 | 2298.0 | 2296.0 | 2294.0 |
| 175.0 | 2395.0 | 2390.0 | 2384.0 | 2378.0 | 2372.0 | 2366.0 | 2360.0 | 2355.0 | 2351.0 | 2347.0 | 2343.0 | 2340.0 | 2338.0 | 2336.0 |
| 180.01 | 2437.0 | 2432.0 | 2426.0 | 2420.0 | 2414.0 | 2408.0 | 2402.0 | 2397.0 | 2393.0 | 2389.0 | 2385.0 | 2382.0 | 2380.0 | 2378.0 |
| 185.0 | 2478.0 | 2473.0 | 2467.0 | 2461.0 | 2455.0 | 2449.0 | 2443.0 | 2438.0 | 2434.0 | 2430.0 | 2426.0 | 2423.0 | 2421.0 | 2419.0 |

## Table 18. ScS travel time tables (seconds) for use in the automated bulletin process program

| Distance Degrees | Surface | 33 | 97 | 160 | 224 | 288 | 351 | 415 | 479 | 542 | 606 | 673 | 733 | 797 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .0 | 935.7 | 926.5 | 912.1 | 898.0 | 884.2 | 870.6 | 857.8 | 844.9 | 832.5 | 820.6 | 809.2 | 798.2 | 787.5 | 777.1 |
| 1.0 | 935.8 | 926.6 | 912.2 | 898.1 | 884.3 | 870.7 | 857.9 | 845.0 | 832.6 | 820.7 | 809.3 | 798.3 | 787.6 | 777.2 |
| 5.0 | 937.9 | 928.7 | 914.3 | 900.2 | 886.4 | 872.8 | 859.6 | 846.7 | 834.3 | 822.4 | 811.0 | 800.0 | 789.3 | 778.9 |
| 15.0 | 955.5 | 946.3 | 932.0 | 918.1 | 904.3 | 890.8 | 877.6 | 864.8 | 852.5 | 840.6 | 829.3 | 818.3 | 807.6 | 796.3 |
| 25.0 | 988.9 | 979.7 | 965.5 | 951.5 | 937.8 | 924.4 | 911.3 | 898.6 | 886.3 | 874.6 | 863.5 | 852.7 | 852.2 | 842.0 |
| 35.0 | 1036.4 | 1027.3 | 1013.1 | 999.3 | 985.7 | 972.5 | 959.6 | 947.0 | 935.2 | 923.7 | 912.7 | 902.0 | 891.7 | 881.8 |
| 45.0 | 1095.1 | 1086.0 | 1072.0 | 1058.3 | 1044.9 | 1031.8 | 1019.1 | 1006.8 | 995.0 | 983.7 | 972.8 | 962.4 | 952.3 | 942.7 |
| 55.0 | 1162.5 | 1153.4 | 1139.5 | 1126.0 | 1112.8 | 1099.9 | 1087.4 | 1075.2 | 1064.5 | 1053.4 | 1042.8 | 1032.6 | 1022.8 | 1013.4 |
| 65.0 | 1236.4 | 1227.4 | 1213.6 | 1200.1 | 1187.0 | 1174.2 | 1161.8 | 1149.7 | 1138.2 | 1127.3 | 1116.9 | 1106.9 | 1097.3 | 1088.1 |
| 75.0 | 1315.0 | 1306.0 | 1292.4 | 1279.0 | 1265.9 | 1253.2 | 1240.9 | 1229.1 | 1217.6 | 1206.7 | 1196.4 | 1186.6 | 1177.2 | 1168.2 |
| 85.0 | 1396.5 | 1387.5 | 1373.9 | 1360.6 | 1347.6 | 1335.0 | 1322.8 | 1311.0 | 1299.6 | 1288.8 | 1278.7 | 1269.0 | 1259.7 | 1250.8 |
| 90.0 | 1437.8 | 1428.8 | 1415.2 | 1401.9 | 1388.9 | 1376.3 | 1364.1 | 1352.3 | 1340.9 | 1330.1 | 1320.0 | 1310.3 | 1301.0 | 1292.1 |

# APPENDIX 7 to TECHNICAL REPORT NO. 65-58

# TABLES SHOWING DISTRIBUTION OF MAGNITUDES OF EVENTS LOCATED BY THE USC&GS 1 FEBRUARY 1963 THROUGH 30 SEPTEMBER 1964

Table 1a. Number of earthquakes located by the USC&GS from which P phase was recorded at BMSO, as function of BMSO magnitude and epicentral distance, February 1963 through September 1964

DELTA FROM BMO IS ABSCISSA     STATION MAGNITUDE IS ORDINATE

| | 16.25 | 18.75 | 21.25 | 23.75 | 26.25 | 28.75 | 31.25 | 33.75 | 36.25 | 38.75 | 41.25 | 43.75 | 46.25 | 48.75 | 51.25 | 53.75 | 56.25 | 58.75 | 61.25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 6.4 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 6.2 | 0 | 0 | 0 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 1 |
| 5.8 | 0 | 0 | 0 | 8 | 2 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 5 |
| 5.6 | 0 | 0 | 2 | 10 | 3 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 6 | 5 |
| 5.4 | 1 | 1 | 3 | 22 | 4 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 5 | 3 | 12 |
| 5.2 | 1 | 0 | 3 | 19 | 6 | 0 | 0 | 2 | 1 | 3 | 0 | 0 | 3 | 3 | 1 | 1 | 2 | 6 | 15 |
| 5.0 | 0 | 0 | 6 | 37 | 14 | 1 | 2 | 1 | 3 | 9 | 3 | 2 | 0 | 3 | 6 | 8 | 5 | 12 | 35 |
| 4.8 | 1 | 0 | 9 | 37 | 16 | 1 | 2 | 2 | 1 | 5 | 6 | 0 | 2 | 6 | 8 | 10 | 3 | 18 | 40 |
| 4.6 | 0 | 3 | 11 | 64 | 19 | 8 | 9 | 5 | 8 | 6 | 6 | 2 | 3 | 3 | 12 | 15 | 18 | 24 | 51 |
| 4.4 | 2 | 2 | 12 | 73 | 29 | 4 | 9 | 7 | 9 | 6 | 10 | 9 | 2 | 6 | 24 | 15 | 17 | 36 | 99 |
| 4.2 | 1 | 3 | 13 | 83 | 35 | 7 | 11 | 14 | 19 | 17 | 11 | 8 | 11 | 14 | 20 | 27 | 12 | 49 | 93 |
| 4.0 | 0 | 6 | 12 | 104 | 40 | 19 | 15 | 8 | 13 | 15 | 33 | 8 | 12 | 21 | 21 | 35 | 10 | 39 | 85 |
| 3.8 | 2 | 5 | 6 | 92 | 43 | 6 | 6 | 15 | 21 | 14 | 25 | 7 | 9 | 6 | 15 | 14 | 9 | 14 | 43 |
| 3.6 | 5 | 5 | 13 | 69 | 25 | 6 | 4 | 6 | 8 | 16 | 14 | 4 | 1 | 2 | 3 | 9 | 2 | 9 | 12 |
| 3.4 | 3 | 4 | 4 | 23 | 4 | 3 | 1 | 2 | 2 | 2 | 3 | 0 | 0 | 0 | 1 | 7 | 1 | 1 | 1 |
| 3.2 | 2 | 4 | 0 | 6 | 3 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 3 | 1 |
| 3.0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 18 | 34 | 94 | 659 | 246 | 55 | 60 | 62 | 91 | 93 | 115 | 41 | 44 | 67 | 114 | 145 | 86 | 226 | 498 |

| | 63.75 | 66.25 | 68.75 | 71.25 | 73.75 | 76.25 | 78.75 | 81.25 | 83.75 | 86.25 | 88.75 | 91.25 | 93.75 | 96.25 | 98.75 | 101.25 | 103.75 | 106.25 | 108.75 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 5 |
| 6.4 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 10 |
| 6.2 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 15 |
| 6.0 | 1 | 0 | 0 | 2 | 1 | 1 | 3 | 1 | 1 | 0 | 3 | 1 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 30 |
| 5.8 | 3 | 0 | 0 | 3 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 4 | 6 | 1 | 2 | 1 | 0 | 0 | 0 | 43 |
| 5.6 | 1 | 0 | 1 | 4 | 2 | 1 | 2 | 2 | 4 | 4 | 2 | 5 | 5 | 3 | 0 | 0 | 1 | 0 | 1 | 68 |
| 5.4 | 4 | 3 | 2 | 1 | 0 | 4 | 7 | 5 | 6 | 7 | 6 | 16 | 10 | 3 | 2 | 3 | 1 | 2 | 4 | 146 |
| 5.2 | 5 | 2 | 1 | 3 | 2 | 6 | 13 | 6 | 10 | 12 | 8 | 23 | 18 | 5 | 3 | 2 | 4 | 4 | 3 | 196 |
| 5.0 | 2 | 2 | 5 | 10 | 5 | 6 | 11 | 19 | 13 | 12 | 16 | 24 | 27 | 14 | 7 | 13 | 10 | 9 | 5 | 356 |
| 4.8 | 9 | 4 | 4 | 13 | 6 | 7 | 23 | 16 | 19 | 19 | 18 | 28 | 31 | 20 | 11 | 11 | 6 | 5 | 2 | 422 |
| 4.6 | 12 | 2 | 7 | 14 | 11 | 9 | 37 | 29 | 22 | 26 | 42 | 54 | 65 | 18 | 10 | 9 | 2 | 4 | 0 | 640 |
| 4.4 | 38 | 9 | 15 | 17 | 19 | 24 | 47 | 30 | 31 | 30 | 50 | 62 | 54 | 19 | 14 | 4 | 0 | 1 | 0 | 835 |
| 4.2 | 42 | 6 | 16 | 9 | 9 | 20 | 44 | 40 | 42 | 26 | 51 | 37 | 33 | 7 | 5 | 3 | 0 | 1 | 0 | 839 |
| 4.0 | 32 | 5 | 10 | 12 | 14 | 23 | 31 | 30 | 38 | 31 | 51 | 32 | 11 | 4 | 3 | 0 | 0 | 0 | 0 | 823 |
| 3.8 | 11 | 3 | 7 | 13 | 17 | 7 | 13 | 17 | 30 | 18 | 18 | 11 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 520 |
| 3.6 | 5 | 3 | 2 | 3 | 7 | 6 | 4 | 7 | 27 | 8 | [illegible] | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 293 |
| 3.4 | 3 | 1 | 2 | 0 | 2 | 0 | 1 | 2 | 11 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 86 |
| 3.2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32 |
| 3.0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 172 | 41 | 72 | 108 | 95 | 115 | 238 | 207 | 258 | 193 | 280 | 304 | 268 | 95 | 60 | 46 | 24 | 28 | 16 | 5308 |

Table 1b. Number of earthquakes located by the USC&GS from which P phase was recorded at BMSO and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and epicentral distance, February 1963 through September 1964

DELTA FROM [illegible] IS ABSCISSA CGS MAGNITUDE IS ORDINATE

| | 16.25 | 18.75 | 21.25 | 23.75 | 26.25 | 28.75 | 31.25 | 33.75 | 36.25 | 38.75 | 41.25 | 43.75 | 46.25 | 48.75 | 51.25 | 53.75 | 56.25 | 58.75 | 61.25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.8 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.6 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.4 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 5.2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4.8 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 3 |
| 4.6 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 2 | 0 | 0 | 1 | 0 | 2 | 0 | 3 | 1 | 2 | 11 |
| 4.4 | 0 | 0 | 2 | 3 | 4 | 1 | 1 | 2 | 2 | 0 | 2 | 1 | 1 | 0 | 0 | 6 | 4 | 3 | 9 |
| 4.2 | 0 | 0 | 2 | 3 | 4 | 0 | 3 | 3 | 3 | 1 | 6 | 0 | 0 | 4 | 6 | 5 | 2 | 5 | 15 |
| 4.0 | 0 | 1 | 0 | 3 | 4 | 2 | 2 | 3 | 6 | 1 | 4 | 0 | 1 | 0 | 4 | 5 | 2 | 5 | 8 |
| 3.8 | 0 | 1 | 0 | 1 | 5 | 5 | 1 | 4 | 7 | 4 | 1 | 1 | 0 | 0 | 1 | 6 | 0 | 1 | 1 |
| 3.6 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 4 | 5 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 1 | 3 | 6 | 13 | 24 | 10 | 8 | 20 | 27 | 10 | 14 | 4 | 3 | 6 | 12 | 27 | 9 | 18 | 49 |

| | 63.75 | 66.25 | 68.75 | 71.25 | 73.75 | 76.25 | 78.75 | 81.25 | 83.75 | 86.25 | 88.75 | 91.25 | 93.75 | 96.25 | 98.75 | 101.25 | 103.75 | 106.25 | 108.75 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 6.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 2 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 3 |
| 5.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 1 | 1 | 6 | 3 | 4 | 3 | 24 |
| 5.6 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 1 | 1 | 2 | 3 | 6 | 1 | 6 | 5 | 4 | 35 |
| 5.4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 2 | 0 | 4 | 3 | 11 | 4 | 2 | 34 |
| 5.2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 1 | 7 | 6 | 8 | 6 | 4 | 7 | 7 | 54 |
| 5.0 | 3 | 0 | 2 | 0 | 1 | 1 | 2 | 0 | 0 | 5 | 4 | 4 | 3 | 3 | 14 | 13 | 6 | 11 | 9 | 84 |
| 4.8 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 3 | 2 | 2 | 6 | 6 | 12 | 8 | 19 | 8 | 6 | 13 | 14 | 115 |
| 4.6 | 6 | 0 | 1 | 0 | 1 | 0 | 3 | 1 | 4 | 10 | 13 | 19 | 22 | 7 | 7 | 8 | 6 | 6 | 15 | 155 |
| 4.4 | 11 | 0 | 0 | 2 | 1 | 2 | 2 | 2 | 1 | 5 | 9 | 12 | 8 | 0 | 11 | 4 | 4 | 5 | 14 | 142 |
| 4.2 | 9 | 1 | 2 | 4 | 1 | 2 | 1 | 1 | 5 | 5 | 11 | 10 | 5 | 4 | 5 | 3 | 3 | 1 | 4 | 139 |
| 4.0 | 3 | 1 | 1 | 1 | 1 | 0 | 0 | 2 | 1 | 2 | 4 | 6 | 4 | 6 | 2 | 2 | 1 | 1 | 1 | 90 |
| 3.8 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 48 |
| 3.6 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 21 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | | 0 | 0 | 0 | 0 | 0 | 2 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 37 | 4 | 8 | 8 | 5 | 5 | 10 | 9 | 21 | 29 | 56 | 64 | 70 | 40 | 80 | 56 | 51 | 57 | 75 | 957 |

Table 1c. Number of earthquakes located by the USC&GS from which P phase was not recorded at BMSO and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and epicentral distance, February 1963 through September 1964

DELTA FROM BMO IS ABSCISSA    CGS MAGNITUDE IS ORDINATE

| | 16.25 | 10.75 | 21.25 | 23.75 | 26.25 | 20.75 | 31.25 | 33.75 | 36.25 | 38.75 | 41.25 | 43.75 | 46.25 | 48.75 | 51.25 | 53.75 | 56.25 | 58.75 | 61.25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 6.2 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 |
| 6.8 | 0 | 1 | 0 | 1 | 3 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 3 | 5 |
| 5.0 | 0 | 0 | 0 | 11 | 3 | 1 | 0 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 2 | 1 | 0 | 2 | 2 |
| 5.6 | 0 | 0 | 0 | 23 | 6 | 1 | 2 | 1 | 3 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 2 | 8 | 17 |
| 5.4 | 1 | 2 | 3 | 27 | 10 | 1 | 0 | 0 | 2 | 1 | 2 | 3 | 1 | 2 | 3 | 6 | 7 | 8 | 14 |
| 5.2 | 2 | 2 | 10 | 30 | 13 | 2 | 2 | 4 | 3 | 4 | 2 | 2 | 3 | 2 | 5 | 5 | 5 | 17 | 32 |
| 5.0 | 0 | 1 | 8 | 48 | 23 | 4 | 2 | 5 | 2 | 11 | 6 | 3 | 2 | 3 | 14 | 14 | 9 | 22 | 50 |
| 4.8 | 2 | 5 | 9 | 73 | 31 | 4 | 7 | 4 | 5 | 0 | 14 | 6 | 1 | 6 | 15 | 20 | 14 | 34 | 66 |
| 4.6 | 4 | 4 | 22 | 93 | 25 | 6 | 0 | 6 | 9 | 9 | 16 | 9 | 4 | 15 | 19 | 20 | 17 | 33 | 96 |
| 4.4 | 3 | 4 | 11 | 107 | 41 | 11 | 11 | 15 | 21 | 13 | 25 | 4 | 11 | 14 | 10 | 32 | 10 | 40 | 108 |
| 4.2 | 2 | 8 | 17 | 85 | 45 | 11 | 9 | 16 | 17 | 10 | 28 | 11 | 13 | 16 | 19 | 19 | 11 | 38 | 81 |
| 4.0 | 3 | 4 | 6 | 07 | 22 | 7 | 9 | 7 | 12 | 20 | 13 | 0 | 2 | 2 | 6 | 10 | 5 | 11 | 16 |
| 3.0 | 2 | 2 | 7 | 45 | 12 | 4 | 2 | 3 | 10 | 11 | 2 | 1 | 3 | 0 | 1 | 8 | 1 | 3 | 1 |
| 3.6 | 0 | 0 | 0 | 10 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 |
| 3.4 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 17 | 33 | 93 | 652 | 239 | 53 | 54 | 62 | 87 | 90 | 111 | 41 | 42 | 64 | 104 | 138 | 02 | 222 | 490 |

| | 63.75 | 66.25 | 68.75 | 71.25 | 73.75 | 76.25 | 78.75 | 01.25 | 03.75 | 86.25 | 08.75 | 91.25 | 93.75 | 96.25 | 98.75 | 101.25 | 103.75 | 106.25 | 100.75 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 6 |
| 6.4 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 3 | 0 | 2 | 1 | 1 | 2 | 1 | 18 |
| 6.2 | 0 | 1 | 0 | 2 | 2 | 0 | 1 | 1 | 2 | 0 | 0 | 2 | 5 | 0 | 1 | 0 | 2 | 1 | 1 | 30 |
| 6.0 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 0 | 0 | 1 | 2 | 2 | 6 | 3 | 3 | 0 | 1 | 0 | 2 | 46 |
| 5.8 | 2 | 1 | 0 | 4 | 0 | 1 | 1 | 1 | 3 | 2 | 5 | 4 | 7 | 6 | 3 | 6 | 2 | 2 | 1 | 77 |
| 5.6 | 8 | 2 | 2 | 4 | 1 | 3 | 7 | 1 | 10 | 6 | 4 | 13 | 11 | 4 | 1 | 6 | 5 | 7 | 1 | 171 |
| 5.4 | 4 | 3 | 4 | 4 | 4 | 6 | 7 | 7 | 13 | 14 | 7 | 23 | 12 | 7 | 4 | 9 | 4 | 1 | 3 | 231 |
| 5.2 | 3 | 2 | 2 | 8 | 5 | 4 | 17 | 16 | 19 | 16 | 20 | 28 | 33 | 11 | 7 | 6 | 3 | 5 | 2 | 360 |
| 5.0 | 11 | 4 | 5 | 12 | 9 | 4 | 23 | 25 | 22 | 16 | 22 | 39 | 51 | 16 | 9 | 2 | 2 | 4 | 3 | 506 |
| 4.0 | 26 | 7 | 10 | 15 | 14 | 12 | 29 | 34 | 21 | 26 | 52 | 47 | 52 | 12 | 13 | 3 | 0 | 2 | 1 | 710 |
| 4.6 | 43 | 6 | 15 | 14 | 9 | 17 | 54 | 40 | 43 | 34 | 69 | 54 | 46 | 17 | 6 | 3 | 1 | 1 | 0 | 885 |
| 4.4 | 40 | 6 | 19 | 10 | 12 | 15 | 27 | 29 | 50 | 36 | 40 | 32 | 19 | 5 | 4 | 2 | 1 | 0 | 0 | 846 |
| 4.2 | 22 | 5 | 0 | 14 | 15 | 27 | 41 | 26 | 26 | 21 | 29 | 15 | 5 | 3 | 0 | 0 | 0 | 0 | 0 | 713 |
| 4.0 | 7 | 2 | 4 | 7 | 13 | 9 | 13 | 10 | 22 | 4 | 12 | 7 | 3 | 1 | 0 | 1 | 0 | 0 | 0 | 357 |
| 3.8 | 0 | 1 | 0 | 3 | 7 | 5 | 5 | 5 | 6 | 6 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 159 |
| 3.6 | 0 | 0 | 1 | 3 | 0 | 2 | 1 | 0 | 11 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35 |
| 3.4 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| 3.2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 169 | 41 | 71 | 105 | 92 | 106 | 228 | 196 | 250 | 103 | 267 | 280 | 253 | 05 | 54 | 39 | 22 | 26 | 15 | 5156 |

Table 2a. Number of earthquakes located by the USC&GS from which P phase was recorded at UBSO, as a function of UBSO magnitude and epicentral distance, February 1963 through September 1964

DELTA FROM UBO IS ABSCISSA  STATION MAGNITUDE IS ORDINATE

| | 16.25 | 18.75 | 21.25 | 23.75 | 26.25 | 28.75 | 31.25 | 33.75 | 36.25 | 38.75 | 41.25 | 43.75 | 46.25 | 48.75 | 51.25 | 53.75 | 56.25 | 58.75 | 61.25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 2 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 2 | 1 |
| 5.8 | 0 | 0 | 0 | 0 | 0 | 2 | 9 | 5 | 1 | 0 | 0 | 0 | 1 | 2 | 1 | 2 | 3 | 3 | 0 |
| 5.6 | 0 | 0 | 1 | 0 | 0 | 0 | 22 | 4 | 0 | 2 | 1 | 2 | 2 | 2 | 3 | 5 | 3 | 3 | 3 |
| 5.4 | 0 | 0 | 1 | 1 | 0 | 11 | 50 | 9 | 1 | 1 | 1 | 6 | 2 | 3 | 3 | 2 | 3 | 1 | 3 |
| 5.2 | 2 | 0 | 0 | 0 | 0 | 11 | 42 | 12 | 4 | 3 | 6 | 8 | 8 | 7 | 4 | 7 | 6 | 10 | 6 |
| 5.0 | 4 | 0 | 3 | 2 | 2 | 22 | 58 | 14 | 0 | 5 | 6 | 10 | 10 | 8 | 8 | 5 | 3 | 12 | 9 |
| 4.8 | 3 | 1 | 2 | 5 | 6 | 28 | 73 | 24 | 4 | 6 | 12 | 19 | 17 | 14 | 11 | 15 | 9 | 21 | 9 |
| 4.6 | 9 | 1 | 4 | 4 | 18 | 21 | 114 | 38 | 7 | 5 | 14 | 7 | 11 | 17 | 14 | 11 | 9 | 12 | 15 |
| 4.4 | 6 | 0 | 13 | 10 | 7 | 35 | 112 | 32 | 0 | 4 | 11 | 12 | 23 | 24 | 10 | 13 | 7 | 20 | 7 |
| 4.2 | 7 | 4 | 0 | 6 | [illegible] | 26 | 104 | 29 | 10 | 7 | 13 | 13 | 23 | 8 | 10 | 11 | 7 | 10 | 6 |
| 4.0 | 6 | 5 | 7 | 6 | 9 | 22 | 79 | 29 | 4 | 11 | 7 | 10 | 18 | 7 | 19 | 6 | 2 | 6 | 3 |
| 3.8 | 8 | 4 | 8 | 5 | 6 | 13 | 31 | 21 | 5 | 3 | 4 | 1 | 11 | 4 | 5 | 5 | 1 | 2 | 1 |
| 3.6 | 4 | 1 | 5 | 4 | 5 | 6 | 11 | 2 | 1 | 2 | 1 | 0 | 1 | 1 | 2 | 0 | 0 | 2 | 2 |
| 3.4 | 5 | 1 | 3 | 0 | 1 | 0 | [illegible] | [illegible] | 1 | 5 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| 3.2 | 1 | 0 | 0 | 0 | 1 | 0 | [illegible] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 55 | 18 | 55 | 43 | 56 | 198 | 711 | 224 | 47 | 54 | 77 | 90 | 131 | 98 | [illegible] | 83 | 55 | 104 | 66 |

| | 63.75 | 66.25 | 68.75 | 71.25 | 73.75 | 76.25 | 78.75 | 81.25 | 83.75 | 86.25 | 88.75 | 91.25 | 93.75 | 96.25 | 98.75 | 101.25 | 103.75 | 106.25 | 108.75 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 6.8 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 4 |
| 6.4 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 3 | 0 | 0 | 1 | 1 | 0 | 15 |
| 6.2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 2 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 25 |
| 6.0 | 0 | 1 | 4 | 1 | 0 | 0 | 2 | 1 | 2 | 0 | 3 | 5 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 38 |
| 5.8 | 1 | 3 | 8 | 1 | 0 | 1 | 5 | 1 | 4 | 2 | 2 | 2 | 1 | 1 | 2 | 0 | 1 | 1 | 0 | 65 |
| 5.6 | 2 | 6 | 11 | 3 | [illegible] | 0 | 6 | 3 | 4 | 9 | 7 | 9 | 5 | 0 | 1 | 0 | 2 | 2 | 2 | 135 |
| 5.4 | 4 | 0 | 16 | 4 | 1 | 1 | 3 | 4 | 7 | 12 | 9 | 6 | 12 | 6 | 9 | 3 | 5 | 1 | 7 | 208 |
| 5.2 | 11 | 16 | 46 | 6 | 4 | 2 | 9 | 9 | 9 | 19 | 13 | 12 | 20 | 8 | 12 | 2 | 7 | 2 | 6 | 349 |
| 5.0 | 9 | 19 | 51 | 11 | 6 | 12 | 8 | 15 | 17 | 21 | 27 | 18 | 16 | 13 | 17 | 4 | 6 | 5 | 4 | 460 |
| 4.8 | 12 | 24 | 76 | 29 | 7 | 15 | 15 | 25 | 21 | 19 | 23 | 31 | 31 | 25 | 17 | 9 | 5 | 0 | 0 | 657 |
| 4.6 | 6 | 23 | 107 | 31 | 10 | 23 | 18 | 32 | 40 | 27 | 24 | 27 | 53 | 35 | 15 | 9 | 2 | 1 | 0 | 798 |
| 4.4 | 5 | 34 | 103 | 21 | 14 | 25 | 20 | 37 | 31 | 37 | 38 | 22 | [illegible] | 27 | 8 | 4 | 0 | 1 | 0 | 844 |
| 4.2 | 9 | 32 | 79 | 22 | 15 | 10 | 20 | 42 | 22 | 39 | 24 | 16 | 19 | 10 | 6 | 1 | 0 | 0 | 0 | 701 |
| 4.0 | 3 | 9 | 45 | 11 | 14 | 7 | 18 | 29 | 15 | 43 | 19 | 8 | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 489 |
| 3.8 | 2 | 9 | 17 | 4 | 7 | 3 | 9 | 9 | 5 | 22 | 9 | 1 | [illegible] | 0 | 1 | 0 | 0 | 0 | 0 | 237 |
| 3.6 | 1 | 1 | 5 | 1 | 2 | 2 | 3 | 1 | 1 | 9 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 77 |
| 3.4 | 0 | 0 | 1 | [illegible] | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26 |
| 3.2 | 0 | 0 | 1 | [illegible] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 67 | 188 | 571 | 140 | 84 | 112 | 145 | 209 | 178 | 262 | 201 | 159 | 225 | 136 | 91 | 34 | 29 | 15 | 19 | 5138 |

Table 2b. Number of earthquakes located by the USC&GS from which P phase was recorded at UBSO and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and epicentral distance, February 1963 through September 1964

DELTA FROM UBO IS ABSCISSA     CGS MAGNITUDE IS ORDINATE

| | 16.25 | 18.75 | 21.25 | 23.75 | 26.25 | 28.75 | 31.25 | 33.75 | 36.25 | 38.75 | 41.25 | 43.75 | 46.25 | 48.75 | 51.25 | 53.75 | 56.25 | 58.75 | 61.25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 |
| 5.8 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 4 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 1 |
| 5.6 | 1 | 1 | 1 | 0 | 0 | 3 | 21 | 8 | 1 | 3 | 1 | 2 | 3 | 2 | 5 | 2 | 3 | 3 | 2 |
| 5.4 | 2 | 0 | 1 | 0 | 0 | 5 | 28 | 8 | 1 | 0 | 2 | 2 | 1 | 4 | 4 | 3 | 2 | 4 | 7 |
| 5.2 | 0 | 0 | 1 | 0 | 1 | 11 | 44 | 7 | 3 | 5 | 3 | 5 | 4 | 3 | 4 | 7 | 3 | 4 | 1 |
| 5.0 | 3 | 0 | 2 | 2 | 1 | 14 | 62 | 14 | 2 | 3 | 5 | 4 | 12 | 8 | 5 | 8 | 3 | 15 | 4 |
| 4.8 | 3 | 0 | 3 | 4 | 2 | 17 | 78 | 23 | 5 | 5 | 6 | 12 | 11 | 13 | 7 | 11 | 11 | 13 | 10 |
| 4.6 | 11 | 0 | 5 | 4 | 5 | 31 | 95 | 17 | 8 | 5 | 11 | 17 | 14 | 19 | 21 | 14 | 10 | 15 | 14 |
| 4.4 | 6 | 1 | 10 | 7 | 8 | 36 | 116 | 36 | 7 | 10 | 20 | 16 | 21 | 16 | 19 | 14 | 11 | 14 | 12 |
| 4.2 | 10 | 6 | 9 | 4 | 12 | 30 | 97 | 53 | 17 | 8 | 21 | 14 | 23 | 22 | 16 | 14 | 8 | 19 | 8 |
| 4.0 | 6 | 8 | 8 | 11 | 12 | 23 | 89 | 29 | 2 | 4 | 4 | 10 | 21 | 7 | 7 | 3 | 0 | 4 | 2 |
| 3.8 | 7 | 1 | 10 | 5 | 8 | 21 | 45 | 11 | 0 | 6 | 0 | 2 | 13 | 1 | 3 | 1 | 0 | 2 | 0 |
| 3.6 | 1 | 1 | 3 | 3 | 4 | 1 | 9 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 3.4 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 3.2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 53 | 18 | 54 | 40 | 53 | 192 | 704 | 214 | 47 | 49 | 75 | 87 | 123 | 96 | 93 | 77 | 53 | 97 | 63 |

| | 63.75 | 66.25 | 68.75 | 71.25 | 73.75 | 76.25 | 78.75 | 81.25 | 83.75 | 86.25 | 88.75 | 91.25 | 93.75 | 96.25 | 98.75 | 101.25 | 103.75 | 106.25 | 108.75 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| 6.4 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 3 | 0 | 0 | 2 | 1 | 11 |
| 6.2 | 0 | 1 | 1 | 0 | 1 | 1 | 3 | 0 | 0 | 1 | 0 | 0 | 1 | 4 | 1 | 1 | 1 | 0 | 1 | 23 |
| 6.0 | 0 | 2 | 4 | 2 | 0 | 0 | 3 | 0 | 1 | 0 | 1 | 1 | 3 | 1 | 5 | 4 | 1 | 3 | 0 | 42 |
| 5.8 | 0 | 3 | 1 | 2 | 0 | | 4 | 0 | 1 | 3 | 3 | 3 | 5 | 4 | 5 | 0 | 4 | 2 | 3 | 67 |
| 5.6 | 2 | 4 | 17 | 4 | 1 | 1 | 7 | 5 | 4 | 9 | 5 | 8 | 5 | 6 | 6 | 4 | 0 | 2 | 5 | 157 |
| 5.4 | 5 | 8 | 17 | 6 | 3 | 4 | 5 | 8 | 9 | 13 | 11 | 8 | 15 | 7 | 11 | 5 | 5 | 2 | 2 | 218 |
| 5.2 | 4 | 14 | 34 | 2 | 5 | 6 | 10 | 13 | 12 | 22 | 16 | 9 | 25 | 15 | 14 | 4 | 9 | 2 | 4 | 326 |
| 5.0 | 8 | 20 | 53 | 8 | 5 | 10 | 9 | 23 | 17 | 20 | 23 | 20 | 27 | 24 | 20 | 9 | 6 | 0 | 1 | 470 |
| 4.8 | 13 | 26 | 75 | 21 | 12 | 20 | 19 | 26 | 28 | 27 | 26 | 29 | 40 | 29 | 10 | 3 | 0 | 0 | 0 | 638 |
| 4.6 | 14 | 24 | 113 | 32 | 16 | 20 | 22 | 44 | 34 | 44 | 37 | 38 | 45 | 31 | 8 | 0 | 0 | 0 | 0 | 838 |
| 4.4 | 7 | 31 | 118 | 34 | 15 | 23 | 17 | 34 | 28 | 52 | 32 | 16 | 26 | 5 | 2 | 0 | 1 | 0 | 0 | 821 |
| 4.2 | 6 | 31 | 96 | 25 | 13 | 15 | 24 | 32 | 26 | 29 | 25 | 10 | 14 | 2 | 1 | 0 | 0 | 0 | 0 | 740 |
| 4.0 | 1 | 13 | 29 | 5 | 5 | 6 | 9 | 13 | 8 | 18 | 7 | 6 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 324 |
| 3.8 | 2 | 6 | 4 | 2 | 4 | 0 | 3 | 4 | 0 | 8 | 5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 175 |
| 3.6 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 7 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 40 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| 3.2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 65 | 184 | 563 | 145 | 80 | 107 | 137 | 203 | 168 | 256 | 193 | 150 | 212 | 130 | 87 | 30 | 27 | 14 | 17 | 4956 |

Table 2c. Number of earthquakes located by the USC&GS from which P phase was not recorded at UBSO and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and epicentral distance, February 1963 through September 1964

DELTA FROM UBO IS ABSCISSA    CGS MAGNITUDE IS ORDINATE

| | 16.25 | 18.75 | 21.25 | 23.75 | 26.25 | 28.75 | 31.25 | 33.75 | 36.25 | 38.75 | 41.25 | 43.75 | 46.25 | 48.75 | 51.25 | 53.75 | 56.25 | 58.75 | 61.25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 5.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.6 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 4.8 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| 4.6 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 4.4 | 2 | 0 | 1 | 0 | 0 | 1 | 7 | 2 | 2 | 4 | 1 | 1 | 2 | 0 | 0 | 2 | 2 | 1 | 3 |
| 4.2 | 3 | 0 | 0 | 2 | 0 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 1 | 0 | 1 | 0 | 3 | 3 | 2 |
| 4.0 | 0 | 0 | 0 | 0 | 1 | 2 | 11 | 3 | 0 | 2 | 1 | 0 | 1 | 0 | 3 | 0 | 1 | 0 | 0 |
| 3.8 | 1 | 0 | 1 | 0 | 1 | 5 | 8 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 3.6 | 0 | 0 | 0 | 0 | 0 | 3 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 6 | 1 | 2 | 3 | 4 | 13 | 41 | 12 | 7 | 10 | 5 | 4 | 4 | 2 | 5 | 5 | 9 | 4 | 8 |

| | 63.75 | 66.25 | 68.75 | 71.25 | 73.75 | 76.25 | 78.75 | 81.25 | 83.75 | 86.25 | 88.75 | 91.25 | 93.75 | 96.25 | 98.75 | 101.25 | 103.75 | 106.25 | 108.75 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 6.2 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| 6.0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 5 |
| 5.8 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 2 | 0 | 2 | 5 | 6 | 20 |
| 5.6 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 3 | 1 | 3 | 3 | 5 | 3 | 4 | 28 |
| 5.4 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 3 | 3 | 1 | 2 | 3 | 8 | 23 |
| 5.2 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 2 | 4 | 15 | 14 | 9 | 8 | 7 | 68 |
| 5.0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 9 | 17 | 8 | 10 | 19 | 7 | 17 | 97 |
| 4.8 | 1 | 1 | 1 | 0 | 2 | 1 | 0 | 2 | 2 | 3 | 2 | 2 | 18 | 30 | 23 | 14 | 25 | 7 | 12 | 152 |
| 4.6 | 0 | 4 | 8 | 1 | 1 | 1 | 2 | 5 | 2 | 4 | 4 | 8 | 34 | 34 | 20 | 7 | 16 | 4 | 10 | 176 |
| 4.4 | 1 | 2 | 7 | 2 | 0 | 2 | 1 | 4 | 1 | 4 | 1 | 5 | 31 | 16 | 7 | 9 | 13 | 5 | 2 | 144 |
| 4.2 | 0 | 1 | 7 | 4 | 2 | 2 | 1 | 6 | 4 | 2 | 5 | 1 | 21 | 8 | 5 | 1 | 8 | 0 | 5 | 113 |
| 4.0 | 2 | 4 | 3 | 0 | 1 | 0 | 0 | 1 | 0 | 7 | 3 | 2 | 11 | 8 | 1 | 3 | 4 | 0 | 2 | 77 |
| 3.8 | 0 | 1 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 3 | 1 | 0 | 1 | 1 | 0 | 0 | 35 |
| 3.6 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 5 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 18 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 4 | 20 | 35 | 10 | 8 | 6 | 5 | 21 | 10 | 33 | 19 | 21 | 136 | 123 | 88 | 64 | 104 | 44 | 73 | 969 |

Table 3a. Number of earthquakes located by the USC&GS from which P phase was recorded at WMSO, as a function of WMSO magnitude and epicentral distance, February 1963 through September 1964

DELTA FROM WMO IS ABSCISSA   STATION MAGNITUDE IS ORDINATE

|  | 16.25 | 18.75 | 21.25 | 23.75 | 26.25 | 28.75 | 31.25 | 33.75 | 36.25 | 38.75 | 41.25 | 43.75 | 46.25 | 48.75 | 51.25 | 53.75 | 56.25 | 58.75 | 61.25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 5.8 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 1 | 2 | 2 | 2 | 0 | 1 |
| 5.6 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 10 | 1 | 1 | 1 | 0 | 2 | 2 | 1 | 1 |
| 5.4 | 0 | 0 | 1 | 4 | 0 | 1 | 3 | 2 | 0 | 1 | 17 | 9 | 0 | 3 | 1 | 1 | 0 | 2 | 2 |
| 5.2 | 1 | 0 | 2 | 3 | 4 | 1 | 0 | 0 | 1 | 2 | 15 | 11 | 3 | 4 | 5 | 7 | 3 | 9 | 5 |
| 5.0 | 0 | 0 | 5 | 10 | 5 | 0 | 1 | 4 | 11 | 15 | 41 | 11 | 2 | 8 | 6 | 4 | 5 | 7 | 4 |
| 4.8 | 2 | 5 | 6 | 14 | 8 | 2 | 4 | 3 | 7 | 21 | 54 | 16 | 3 | 12 | 9 | 8 | 12 | 9 | 3 |
| 4.6 | 9 | 6 | 12 | 13 | 11 | 12 | 8 | 5 | 9 | 35 | 73 | 22 | 10 | 14 | 9 | 14 | 10 | 19 | 12 |
| 4.4 | 11 | 12 | 18 | 18 | 9 | 5 | 10 | 6 | 23 | 46 | 96 | 34 | 12 | 12 | 10 | 18 | 12 | 18 | 16 |
| 4.2 | 11 | 15 | 24 | 19 | 12 | 7 | 4 | 12 | 21 | 66 | 124 | 43 | 11 | 14 | 14 | 11 | 15 | 14 | 12 |
| 4.0 | 17 | 17 | 24 | 16 | 11 | 10 | 5 | 5 | 21 | 33 | 101 | 14 | 3 | 9 | 7 | 5 | 7 | 5 | 4 |
| 3.8 | 13 | 27 | 14 | 8 | 7 | 9 | 1 | 3 | 9 | 12 | 33 | 4 | 1 | 2 | 4 | 1 | 3 | 5 | 1 |
| 3.6 | 12 | 18 | 13 | 2 | 1 | 2 | 1 | 1 | 3 | 3 | 4 | 2 | 0 | 1 | 2 | 1 | 1 | 0 | 2 |
| 3.4 | 6 | 3 | 4 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 84 | 104 | 124 | 112 | 70 | 50 | 39 | 41 | 106 | 236 | 572 | 173 | 47 | 81 | 70 | 74 | 72 | 91 | 63 |

|  | 63.75 | 66.25 | 68.75 | 71.25 | 73.75 | 76.25 | 78.75 | 81.25 | 83.75 | 86.25 | 88.75 | 91.25 | 93.75 | 96.25 | 98.75 | 101.25 | 103.75 | 106.25 | 108.75 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 |
| 6.4 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 9 |
| 6.2 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 9 |
| 6.0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 21 |
| 5.8 | 0 | 1 | 1 | 0 | 0 | 2 | 3 | 0 | 1 | 0 | 2 | 1 | 4 | 3 | 2 | 0 | 1 | 3 | 4 | 43 |
| 5.6 | 2 | 0 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 2 | 7 | 5 | 2 | 3 | 1 | 0 | 2 | 2 | 5 | 62 |
| 5.4 | 2 | 2 | 4 | 4 | 1 | 3 | 8 | 1 | 0 | 4 | 8 | 6 | 7 | 7 | 4 | 3 | 0 | 6 | 4 | 121 |
| 5.2 | 4 | 1 | 5 | 0 | 4 | 7 | 14 | 12 | 1 | 8 | 8 | 10 | 13 | 7 | 9 | 8 | 6 | 5 | 3 | 201 |
| 5.0 | 6 | 6 | 12 | 8 | 2 | 14 | 24 | 4 | 4 | 15 | 20 | 13 | 18 | 13 | 8 | 9 | 5 | 1 | 1 | 322 |
| 4.8 | 10 | 3 | 8 | 9 | 10 | 15 | 31 | 8 | 5 | 23 | 17 | 33 | 31 | 18 | 23 | 10 | 3 | 2 | 0 | 457 |
| 4.6 | 6 | 10 | 20 | 19 | 8 | 31 | 51 | 12 | 4 | 22 | 35 | 46 | 39 | 19 | 14 | 3 | 0 | 0 | 0 | 642 |
| 4.4 | 18 | 12 | 22 | 15 | 14 | 22 | 97 | 28 | 4 | 34 | 26 | 44 | 26 | 14 | 3 | 3 | 0 | 0 | 0 | 768 |
| 4.2 | 15 | 13 | 10 | 18 | 10 | 34 | 118 | 46 | 7 | 21 | 14 | 30 | 13 | 9 | 3 | 0 | 0 | 0 | 0 | 807 |
| 4.0 | 11 | 6 | 2 | 6 | 7 | 18 | 47 | 21 | 2 | 9 | 7 | 9 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 462 |
| 3.8 | 1 | 2 | 2 | 4 | 2 | 6 | 6 | 4 | 1 | 0 | 0 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 191 |
| 3.6 | 1 | 1 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 75 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 79 | 54 | 88 | 86 | 50 | 156 | 404 | 141 | 31 | 138 | 146 | 202 | 159 | 95 | 69 | 38 | 20 | 19 | 21 | 4217 |

Table 3b. Number of earthquakes located by the USC&GS from which P phase was recorded at WMSO and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and epicentral distance, February 1963 through September 1964

DELTA FROM WMO IS ABSCISSA    CGS MAGNITUDE IS ORDINATE

| | 16.25 | 18.75 | 21.25 | 23.75 | 26.25 | 28.75 | 31.25 | 33.75 | 36.25 | 38.75 | 41.25 | 43.75 | 46.25 | 48.75 | 51.25 | 53.75 | 56.25 | 58.75 | 61.25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 6.0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 0 | 1 | 2 | 0 | 1 | 0 | 1 |
| 5.8 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 7 | 2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 5.6 | 1 | 0 | 1 | 2 | 1 | 2 | 1 | 0 | 0 | 5 | 19 | 7 | 1 | 3 | 3 | 4 | 2 | 4 | 1 |
| 5.4 | 0 | 3 | 0 | 4 | 1 | 0 | 2 | 1 | 0 | 8 | 23 | 7 | 1 | 3 | 2 | 2 | 4 | 4 | 5 |
| 5.2 | 2 | 2 | 2 | 1 | 0 | 4 | 0 | 2 | 4 | 12 | 34 | 8 | 2 | 5 | 4 | 6 | 2 | 7 | 4 |
| 5.0 | 5 | 2 | 7 | 4 | 6 | 0 | 2 | 0 | 9 | 27 | 40 | 12 | 2 | 8 | 10 | 4 | 10 | 8 | 5 |
| 4.8 | 7 | 6 | 9 | 8 | 8 | 0 | 2 | 4 | 10 | 24 | 65 | 23 | 4 | 11 | 7 | 12 | 9 | 16 | 8 |
| 4.6 | 3 | 12 | 12 | 7 | 10 | 2 | 9 | 9 | 15 | 42 | 89 | 22 | 7 | 16 | 7 | 14 | 12 | 14 | 16 |
| 4.4 | 16 | 14 | 22 | 22 | 10 | 11 | 7 | 6 | 19 | 44 | 104 | 29 | 12 | 11 | 15 | 13 | 5 | 16 | 8 |
| 4.2 | 13 | 14 | 15 | 27 | 19 | 15 | 9 | 9 | 20 | 34 | 92 | 37 | 12 | 6 | 12 | 9 | 10 | 11 | 9 |
| 4.0 | 19 | 16 | 23 | 20 | 8 | 8 | 4 | 6 | 14 | 29 | 67 | 10 | 3 | 4 | 4 | 3 | 9 | 6 | 2 |
| 3.8 | 10 | 20 | 19 | 7 | 5 | 4 | 0 | 1 | 10 | 9 | 15 | 5 | 0 | 4 | 0 | 2 | 2 | 3 | 0 |
| 3.6 | 4 | 9 | 3 | 2 | 0 | 1 | 1 | 1 | 0 | 0 | 5 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 3.4 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 82 | 90 | 114 | 107 | 68 | 48 | 38 | 39 | 101 | 234 | 562 | 165 | 45 | 72 | 68 | 71 | 67 | 89 | 59 |

| | 63.75 | 66.25 | 68.75 | 71.25 | 73.75 | 76.25 | 78.75 | 81.25 | 83.75 | 86.25 | 88.75 | 91.25 | 93.75 | 96.25 | 98.75 | 101.25 | 103.75 | 106.25 | 108.75 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 5 |
| 6.4 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 9 |
| 6.2 | 3 | 0 | 1 | 0 | 0 | 2 | 2 | 0 | 1 | 0 | 3 | 1 | 0 | 0 | 1 | 1 | 3 | 1 | 2 | 24 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 1 | 0 | 0 | 3 | 0 | 2 | 1 | 1 | 2 | 1 | 2 | 5 | 33 |
| 5.8 | 1 | 0 | 2 | 1 | 0 | 2 | 2 | 2 | 0 | 1 | 0 | 2 | 6 | 4 | 4 | 3 | 2 | 3 | 2 | 52 |
| 5.6 | 2 | 1 | 2 | 1 | 2 | 4 | 18 | 6 | 1 | 5 | 7 | 7 | 4 | 5 | 3 | 3 | 3 | 4 | 3 | 138 |
| 5.4 | 2 | 2 | 5 | 4 | 4 | 10 | 14 | 7 | 2 | 8 | 9 | 9 | 10 | 8 | 7 | 7 | 3 | 3 | 4 | 188 |
| 5.2 | 5 | 6 | 3 | 4 | 3 | 18 | 28 | 5 | 2 | 10 | 17 | 16 | 10 | 17 | 17 | 2 | 2 | 3 | 0 | 269 |
| 5.0 | 7 | 4 | 11 | 2 | 6 | 21 | 50 | 13 | 1 | 16 | 19 | 26 | 13 | 16 | 10 | 8 | 2 | 1 | 1 | 388 |
| 4.8 | 12 | 5 | 12 | 17 | 13 | 27 | 68 | 22 | 7 | 21 | 25 | 22 | 32 | 20 | 14 | 7 | 0 | 0 | 0 | 557 |
| 4.6 | 18 | 12 | 18 | 13 | 12 | 29 | 87 | 29 | 2 | 34 | 25 | 39 | 39 | 11 | 7 | 1 | 1 | 0 | 0 | 695 |
| 4.4 | 12 | 10 | 13 | 23 | 14 | 26 | 67 | 34 | 6 | 21 | 17 | 40 | 21 | 6 | 1 | 1 | 1 | 0 | 0 | 697 |
| 4.2 | 11 | 11 | 15 | 8 | 2 | 8 | 48 | 16 | 3 | 16 | 17 | 17 | 14 | 1 | 2 | 0 | 1 | 0 | 0 | 563 |
| 4.0 | 2 | 2 | 0 | 2 | 3 | 3 | 11 | 1 | 2 | 5 | 3 | 12 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 302 |
| 3.8 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 123 |
| 3.6 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 76 | 54 | 83 | 77 | 59 | 153 | 398 | 138 | 29 | 137 | 145 | 196 | 154 | 92 | 67 | 37 | 19 | 17 | 20 | 4078 |

Table 3c. Number of earthquakes located by the USC&GS from which P phase was not recorded at WMSO and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and epicentral distance, February 1963 through September 1964

DELTA FROM WMO IS ABSCISSA    CGS MAGNITUDE IS ORDINATE

| | 16.25 | 18.75 | 21.25 | 23.75 | 26.25 | 28.75 | 31.25 | 33.75 | 36.25 | 38.75 | 41.25 | 43.75 | 46.25 | 48.75 | 51.25 | 53.75 | 56.25 | 58.75 | 61.25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 5.4 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 5.0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 4.8 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 7 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 1 |
| 4.6 | 8 | 4 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 1 | 1 | 1 | 5 | 1 |
| 4.4 | 14 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 9 | 4 | 1 | 1 | 1 | 3 | 3 | 4 | 4 |
| 4.2 | 22 | 2 | 0 | 0 | 1 | 0 | 1 | 2 | 0 | 3 | 9 | 3 | 1 | 2 | 4 | 2 | 4 | 14 | 6 |
| 4.0 | 18 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 6 | 5 | 12 | 6 | 1 | 0 | 1 | 1 | 5 | 4 | 1 |
| 3.8 | 18 | 1 | 2 | 1 | 0 | 1 | 0 | 0 | 6 | 13 | 16 | 3 | 0 | 0 | 0 | 0 | 4 | 4 | 1 |
| 3.6 | 15 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 |
| 3.4 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 100 | 15 | 5 | 2 | 2 | 1 | 1 | 5 | 14 | 26 | 96 | 22 | 4 | 3 | 9 | 8 | 20 | 36 | 14 |

| | 63.75 | 66.25 | 68.75 | 71.25 | 73.75 | 76.25 | 78.75 | 81.25 | 83.75 | 86.25 | 88.75 | 91.25 | 93.75 | 96.25 | 98.75 | 101.25 | 103.75 | 106.25 | 108.75 | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| 6.0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 10 |
| 5.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 7 | 21 |
| 5.6 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 2 | 2 | 1 | 4 | 12 | 34 |
| 5.4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 2 | 2 | 0 | 3 | 5 | 3 | 4 | 16 | 44 |
| 5.2 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 2 | 3 | 0 | 1 | 12 | 16 | 13 | 30 | 93 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 2 | 3 | 2 | 6 | 13 | 26 | 22 | 12 | 39 | 140 |
| 4.8 | 1 | 0 | 0 | 2 | 0 | 3 | 4 | 0 | 0 | 3 | 5 | 2 | 7 | 17 | 11 | 39 | 39 | 16 | 30 | 195 |
| 4.6 | 3 | 2 | 0 | 0 | 3 | 4 | 24 | 8 | 1 | 5 | 8 | 9 | 11 | 25 | 34 | 58 | 33 | 22 | 13 | 26[illegible] |
| 4.4 | 1 | 2 | 0 | 0 | 0 | 7 | 51 | 7 | 0 | 1 | 9 | 19 | 13 | 18 | 29 | 39 | 13 | 5 | 14 | 277 |
| 4.2 | 4 | 4 | 6 | 2 | 2 | 22 | 45 | 8 | 0 | 4 | 19 | 14 | 23 | 14 | 15 | 27 | 7 | 2 | 7 | 301 |
| 4.0 | 2 | 1 | 2 | 1 | 0 | 4 | 14 | 5 | 1 | 3 | 9 | 13 | 10 | 10 | 6 | 10 | 3 | 4 | 2 | 164 |
| 3.8 | 1 | 1 | 0 | 0 | 2 | 2 | 2 | 1 | 0 | 0 | 5 | 3 | 6 | 3 | 2 | 2 | 0 | 2 | 1 | 103 |
| 3.6 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 9 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 39 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | [illegible] |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 12 | 10 | 8 | 6 | 9 | 43 | 145 | 31 | 2 | 20 | 63 | 80 | 80 | 96 | 118 | 222 | 137 | 86 | 176 | 1725 |

Table 4a. Number of earthquakes located by the USC&GS from which P phase was recorded at CPSO, as a function of CPSO magnitude and epicentral distance, February 1963 through September 1964

DELTA FROM CPO IS ABSCISSA     STATION MAGNITUDE IS ORDINATE

| | 16.25 | 18.75 | 21.25 | 23.75 | 26.25 | 28.75 | 31.25 | 33.75 | 36.25 | 38.75 | 41.25 | 43.75 | 46.25 | 48.75 | 51.25 | 53.75 | 56.25 | 58.75 | 61.25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 |
| 6.2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 2 | 1 | 0 | 0 | 0 | 0 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 4 | 4 | 0 | 1 | 1 | 0 | 0 |
| 5.8 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 5 | 7 | 2 | 0 | 2 | 3 | 1 |
| 5.6 | 0 | 1 | 0 | 2 | 1 | 1 | 3 | 6 | 1 | 1 | 0 | 1 | 9 | 13 | 0 | 1 | 1 | 2 | 3 |
| 5.4 | 0 | 2 | 0 | 3 | 0 | 0 | 3 | 0 | 2 | 0 | 2 | 3 | 10 | 25 | 3 | 3 | 4 | 6 | 8 |
| 5.2 | 0 | 0 | 3 | 6 | 3 | 2 | 2 | 3 | 1 | 3 | 2 | 4 | 19 | 32 | 5 | 7 | 7 | 7 | 11 |
| 5.0 | 0 | 0 | 8 | 4 | 3 | 2 | 8 | 3 | 3 | 4 | 6 | 10 | 27 | 40 | 6 | 7 | 13 | 12 | 12 |
| 4.8 | 0 | 1 | 13 | 20 | 8 | 2 | 15 | 6 | 1 | 3 | 4 | 8 | 26 | 52 | 7 | 7 | 19 | 17 | 22 |
| 4.6 | 0 | 1 | 14 | 33 | 12 | 6 | 21 | 10 | 10 | 7 | 7 | 23 | 84 | 54 | 14 | 9 | 15 | 20 | 17 |
| 4.4 | 0 | 5 | 19 | 37 | 16 | 16 | 26 | 10 | 8 | 9 | 12 | 22 | 78 | 51 | 10 | 10 | 13 | 21 | 13 |
| 4.2 | 0 | 5 | 29 | 38 | 15 | 10 | 19 | 10 | 8 | 12 | 13 | 16 | 58 | 36 | 11 | 8 | 6 | 8 | 7 |
| 4.0 | 3 | 6 | 33 | 41 | 17 | 6 | 11 | 8 | 6 | 4 | 5 | 7 | 24 | 14 | 1 | 5 | 0 | 0 | 5 |
| 3.8 | 3 | 5 | 34 | 16 | 2 | 1 | 3 | 1 | 0 | 4 | 1 | 3 | 7 | 4 | 1 | 0 | 2 | 0 | 0 |
| 3.6 | 2 | 0 | 16 | 10 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 0 | 0 | 1 | 0 |
| 3.4 | 0 | 1 | 4 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| 3.2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 8 | 28 | 174 | 218 | 82 | 49 | 111 | 58 | 41 | 48 | 54 | 101 | 359 | 340 | 62 | 59 | 84 | 98 | 99 |

| | 63.75 | 66.25 | 68.75 | 71.25 | 73.75 | 76.25 | 78.75 | 81.25 | 83.75 | 86.25 | 88.75 | 91.25 | 93.75 | 96.25 | 98.75 | 101.25 | 103.75 | 106.25 | 108.75 | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 6.6 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| 6.4 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 15 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 14 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 18 |
| 5.8 | 0 | 2 | 1 | 4 | 0 | 1 | 1 | 1 | 5 | 6 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 49 |
| 5.6 | 1 | 5 | 3 | 2 | 2 | 1 | 4 | 3 | 8 | 11 | 2 | 0 | 1 | 1 | 3 | 1 | 4 | 1 | 3 | 96 |
| 5.4 | 3 | 3 | 7 | 2 | 3 | 3 | 0 | 9 | 12 | 17 | 0 | 3 | 0 | 6 | 1 | 2 | 1 | 2 | 1 | 149 |
| 5.2 | 6 | 9 | 2 | 5 | 4 | 1 | 3 | 3 | 18 | 21 | 2 | 1 | 2 | 5 | 6 | 2 | 1 | 1 | 0 | 209 |
| 5.0 | 12 | 9 | 11 | 6 | 12 | 5 | 4 | 9 | 36 | 44 | 4 | 3 | 3 | 9 | 5 | 2 | 2 | 1 | 0 | 345 |
| 4.8 | 14 | 26 | 14 | 6 | 7 | 8 | 10 | 13 | 51 | 80 | 6 | 6 | 6 | 15 | 3 | 3 | 0 | 0 | 0 | 401 |
| 4.6 | 12 | 19 | 18 | 7 | 16 | 12 | 5 | 20 | 63 | 82 | 5 | 7 | 1 | 6 | 1 | 0 | 1 | 0 | 0 | 632 |
| 4.4 | 5 | 8 | 6 | 4 | 8 | 9 | 9 | 24 | 47 | 68 | 6 | 3 | 3 | 4 | 3 | 0 | 1 | 0 | 0 | 590 |
| 4.2 | 1 | 5 | 3 | 2 | 3 | 8 | 4 | 8 | 12 | 19 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 377 |
| 4.0 | 0 | 1 | 1 | 2 | 3 | 3 | 1 | 4 | 4 | 10 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 229 |
| 3.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 95 |
| 3.6 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 41 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 58 | 67 | 67 | 40 | 60 | 53 | 41 | 99 | 263 | 365 | 31 | 25 | 20 | 48 | 22 | 11 | 13 | 7 | 6 | 3389 |

Table 4b. Number of earthquakes located by the USC&GS from which P phase was recorded at CPSO and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and epicentral distance, February 1963 through September 1964

DELTA FROM CPO IS ABSCISSA CGS MAGNITUDE IS ORDINATE

| | 16.25 | 18.75 | 21.25 | 23.75 | 26.25 | 28.75 | 31.25 | 33.75 | 36.25 | 38.75 | 41.25 | 43.75 | 46.25 | 48.75 | 51.25 | 53.75 | 56.25 | 58.75 | 61.25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 2 | 0 | 2 | 0 | 1 | 0 |
| 6.0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 4 | 1 | 0 | 0 | 1 | 0 |
| 5.8 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 8 | 8 | 1 | 0 | 0 | 0 | 1 |
| 5.6 | 0 | 0 | 2 | 2 | 0 | 0 | 3 | 2 | 2 | 1 | 3 | 1 | 17 | 17 | 1 | 1 | 4 | 0 | 2 |
| 5.4 | 0 | 0 | 2 | 9 | 1 | 2 | 4 | 0 | 2 | 1 | 3 | 3 | 20 | 19 | 5 | 1 | 5 | 3 | 3 |
| 5.2 | 0 | 1 | 5 | 4 | 4 | 1 | 2 | 2 | 0 | 2 | 5 | 10 | 12 | 35 | 3 | 6 | 5 | 7 | 8 |
| 5.0 | 0 | 2 | 8 | 10 | 2 | 2 | 11 | 3 | 4 | 2 | 3 | 11 | 40 | 35 | 5 | 7 | 5 | 7 | 7 |
| 4.8 | 0 | 1 | 7 | 24 | 8 | 6 | 11 | 7 | 4 | 4 | 5 | 17 | 46 | 50 | 6 | 4 | 11 | 12 | 9 |
| 4.6 | 2 | 1 | 16 | 27 | 10 | 6 | 19 | 12 | 6 | 11 | 11 | 24 | 68 | 42 | 9 | 5 | 17 | 15 | 17 |
| 4.4 | 1 | 4 | 31 | 35 | 19 | 9 | 11 | 12 | 7 | 5 | 8 | 13 | 69 | 54 | 8 | 7 | 10 | 22 | 18 |
| 4.2 | 2 | 6 | 27 | 45 | 15 | 12 | 19 | 9 | 9 | 9 | 11 | 15 | 41 | 45 | 12 | 11 | 14 | 21 | 17 |
| 4.0 | 0 | 4 | 36 | 30 | 8 | 7 | 15 | 5 | 5 | 8 | 2 | 3 | 22 | 22 | 4 | 10 | 4 | 2 | 7 |
| 3.8 | 0 | 7 | 23 | 11 | 10 | 1 | 6 | 0 | 0 | 1 | 0 | 2 | 5 | 3 | 3 | 3 | 3 | 2 | 3 |
| 3.6 | 0 | 2 | 10 | 5 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| 3.4 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTA | 5 | 28 | 168 | 207 | 77 | 47 | 102 | 53 | 40 | 47 | 52 | 100 | 353 | 336 | 59 | 57 | 79 | 94 | 93 |

| | 63.75 | 66.25 | 68.75 | 71.25 | 73.75 | 76.25 | 78.75 | 81.25 | 83.75 | 86.25 | 88.75 | 91.25 | 93.75 | 96.25 | 98.75 | 101.25 | 103.75 | 106.25 | 108.75 | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 4 |
| 6.4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 6 |
| 6.2 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 3 | 1 | 1 | 22 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 2 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 1 | 2 | 26 |
| 5.8 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 0 | 1 | 2 | 0 | 2 | 3 | 1 | 0 | 42 |
| 5.6 | 3 | 2 | 5 | 2 | 1 | 2 | 2 | 3 | 10 | 13 | 2 | 1 | 0 | 8 | 2 | 1 | 3 | 3 | 1 | 122 |
| 5.4 | 1 | 3 | 4 | 2 | 3 | 6 | 4 | 8 | 8 | 13 | 3 | 3 | 1 | 4 | 6 | 3 | 0 | 0 | 1 | 156 |
| 5.2 | 1 | 6 | 4 | 5 | 3 | 0 | 1 | 14 | 16 | 20 | 0 | 2 | 4 | 8 | 7 | 1 | 1 | 0 | 0 | 205 |
| 5.0 | 4 | 5 | 3 | 3 | 9 | 5 | 4 | 10 | 37 | 36 | 3 | 3 | 3 | 7 | 1 | 2 | 1 | 0 | 0 | 300 |
| 4.8 | 8 | 18 | 8 | 3 | 17 | 10 | 14 | 18 | 44 | 56 | 7 | 6 | 2 | 9 | 1 | 0 | 0 | 0 | 0 | 453 |
| 4.6 | 13 | 17 | 11 | 14 | 10 | 10 | 5 | 18 | 59 | 70 | 5 | 4 | 4 | 4 | 3 | 0 | 0 | 0 | 0 | 565 |
| 4.4 | 10 | 13 | 16 | 6 | 4 | 12 | 8 | 7 | 53 | 86 | 4 | 4 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 569 |
| 4.2 | 10 | 15 | 7 | 1 | 6 | 4 | 1 | 8 | 24 | 46 | 2 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 467 |
| 4.0 | 2 | 2 | 3 | 0 | 0 | 1 | 0 | 2 | 3 | 10 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 219 |
| 3.8 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 89 |
| 3.6 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 56 | 82 | 63 | 37 | 55 | 52 | 40 | 95 | 261 | 356 | 31 | 24 | 20 | 47 | 21 | 11 | 12 | 7 | 5 | 3272 |

Table 4c. Number of earthquakes located by the USC&GS from which P phase was not recorded at CPSO and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and epicentral distance, February 1963 through September 1964

DELTA FROM CPO IS ABSCISSA CGS MAGNITUDE IS ORDINATE

| | 16.25 | 18.75 | 21.25 | 23.75 | 26.25 | 28.75 | 31.25 | 33.75 | 36.25 | 38.75 | 41.25 | 43.75 | 46.25 | 48.75 | 51.25 | 53.75 | 56.25 | 58.75 | 61.25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 5.8 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 5.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.2 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 3 | 4 | 0 | 0 | 1 | 0 | 1 |
| 5.0 | 0 | 0 | 0 | 1 | 2 | 0 | 2 | 1 | 0 | 0 | 0 | 1 | 3 | 2 | 0 | 0 | 1 | 0 | 0 |
| 4.8 | 0 | 0 | 1 | 5 | 0 | 2 | 4 | 1 | 0 | 1 | 0 | 4 | 6 | 2 | 1 | 1 | 1 | 1 | 1 |
| 4.6 | 0 | 2 | 1 | 0 | 9 | 3 | 4 | 2 | 2 | 0 | 3 | 5 | 10 | 5 | 0 | 1 | 1 | 1 | 1 |
| 4.4 | 1 | 1 | 6 | 22 | 12 | 4 | 7 | 8 | 3 | 5 | 3 | 11 | 21 | 11 | 4 | 1 | 5 | 0 | 4 |
| 4.2 | 0 | 4 | 13 | 24 | 11 | 5 | 6 | 10 | 6 | 2 | 3 | 12 | 31 | 15 | 2 | 3 | 2 | 4 | 2 |
| 4.0 | 1 | 1 | 17 | 25 | 12 | 4 | 2 | 6 | 7 | 1 | 3 | 11 | 45 | 14 | 3 | 2 | 2 | 3 | 2 |
| 3.8 | 1 | 2 | 19 | 23 | 4 | 2 | 5 | 6 | 1 | 4 | 3 | 7 | 33 | 9 | 0 | 6 | 2 | 1 | 1 |
| 3.6 | 0 | 0 | 7 | 22 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 9 | 0 | 2 | 0 | 1 | 0 | 0 |
| 3.4 | 0 | 0 | 7 | 7 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.2 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 3 | 10 | 77 | 130 | 54 | 21 | 31 | 36 | 22 | 13 | 15 | 52 | 162 | [illegible] | 13 | 14 | 17 | 10 | 12 |

| | 63.75 | 66.25 | 68.75 | 71.25 | 73.75 | 76.25 | 78.75 | 81.25 | 83.75 | 86.25 | 88.75 | 91.25 | 93.75 | 96.25 | 98.75 | 101.25 | 103.75 | 106.25 | 108.75 | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 3 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 1 | 9 |
| 5.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 6 | 4 | 4 | 21 |
| 5.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 3 | 0 | 0 | 6 | 9 | 11 | 4 | 37 |
| 5.4 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 0 | 1 | 0 | 2 | 3 | 9 | 20 | 9 | 11 | 60 |
| 5.2 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 3 | 3 | 1 | 0 | 1 | 5 | 6 | 13 | 24 | 10 | 22 | 113 |
| 5.0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 4 | 2 | 3 | 3 | 11 | 10 | 15 | 32 | 27 | 24 | 159 |
| 4.8 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 1 | 4 | 3 | 4 | 5 | 4 | 20 | 21 | 27 | 34 | 42 | 20 | 228 |
| 4.6 | 3 | 3 | 0 | 3 | 5 | 2 | 1 | 6 | 14 | 16 | 7 | 10 | 4 | 26 | 27 | 39 | 48 | 35 | 38 | 345 |
| 4.4 | 4 | 2 | 2 | 3 | 5 | 4 | 2 | 3 | 23 | 10 | 2 | 7 | 8 | 14 | 25 | 42 | 44 | 25 | 30 | 392 |
| 4.2 | 4 | 4 | 4 | 5 | 6 | 4 | 6 | 10 | 31 | 24 | 2 | 8 | 6 | 26 | 30 | 26 | 30 | 21 | 12 | 414 |
| 4.0 | 3 | 2 | 0 | 2 | 1 | 1 | 0 | 6 | 11 | 9 | 2 | 5 | 4 | 8 | 10 | 14 | 21 | 9 | 8 | 277 |
| 3.8 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 2 | 0 | 1 | 0 | 0 | 2 | 1 | 2 | 1 | 14 | 1 | 2 | 158 |
| 3.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 5 | 8 | 0 | 1 | 62 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 20 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 6 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 15 | 11 | 7 | 14 | 22 | 16 | 13 | 32 | 91 | 80 | 20 | 39 | 36 | 118 | 143 | 200 | 298 | 204 | 186 | 2307 |

Table 5a. Number of earthquakes located by the USC&GS from which P phase was recorded by at least one observatory, as a function of net magnitude and maximum epicentral distance at which P or P' phase was recorded, February 1963 through September 1964

DELTA FROM NET IS ABSCISSA     STATION MAGNITUDE IS ORDINATE

| | 16.25 | 18.75 | 21.25 | 23.75 | 26.25 | 28.75 | 31.25 | 33.75 | 36.25 | 38.75 | 41.25 | 43.75 | 46.25 | 48.75 | 51.25 | 53.75 | 56.25 | 58.75 | 61.25 | 63.75 | 66.25 | 68.75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 |
| 6.0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 5.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 6 | 5 | 0 | 1 | 0 | 1 | 2 | 0 | 0 | 1 |
| 5.6 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 11 | 8 | 2 | 0 | 0 | 2 | 2 | 1 | 2 | 2 |
| 5.4 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 1 | 3 | 1 | 0 | 2 | 10 | 20 | 0 | 2 | 3 | 1 | 5 | 2 | 0 | 4 |
| 5.2 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 1 | 0 | 3 | 1 | 5 | 21 | 23 | 3 | 4 | 3 | 6 | 5 | 2 | 6 | 2 |
| 5.0 | 2 | 0 | 1 | 3 | 2 | 2 | 1 | 4 | 1 | 5 | 4 | 4 | 24 | 30 | 5 | 11 | 4 | 8 | 8 | 4 | 3 | 3 |
| 4.8 | 0 | 0 | 2 | 5 | 3 | 3 | 6 | 2 | 3 | 9 | 4 | 13 | 37 | 42 | 6 | 11 | 9 | 12 | 11 | 15 | 9 | 7 |
| 4.6 | 2 | 2 | 3 | 6 | 7 | 9 | 10 | 15 | 9 | 11 | 15 | 14 | 62 | 53 | 12 | 13 | 13 | 24 | 15 | 5 | 16 | 15 |
| 4.4 | 5 | 2 | 3 | 19 | 11 | 10 | 19 | 8 | 6 | 14 | 30 | 22 | 79 | 53 | 25 | 26 | 15 | 34 | 17 | 19 | 22 | 32 |
| 4.2 | 2 | 2 | 7 | 22 | 19 | 13 | 24 | 9 | 12 | 33 | 56 | 21 | 83 | 71 | 26 | 26 | 18 | 29 | 17 | 10 | 32 | 33 |
| 4.0 | 4 | 0 | 11 | 29 | 22 | 15 | 14 | 19 | 20 | 43 | 57 | 14 | 47 | 46 | 16 | 18 | 10 | 18 | 6 | 6 | 18 | 17 |
| 3.8 | 9 | 1 | 9 | 16 | 13 | 19 | 20 | 7 | 10 | 24 | 20 | 8 | 10 | 15 | 3 | 8 | 1 | 5 | 3 | 2 | 1 | 3 |
| 3.6 | 2 | 3 | 10 | 9 | 6 | 3 | 6 | 1 | 5 | 5 | 6 | 1 | 2 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 3 |
| 3.4 | 3 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 29 | 11 | 46 | 115 | 84 | 76 | 104 | 67 | 72 | 149 | 194 | 105 | 397 | 372 | 98 | 121 | 78 | 142 | 92 | 70 | 105 | 122 |

| | 71.25 | 73.75 | 76.25 | 78.75 | 81.25 | 83.75 | 86.25 | 88.75 | 91.25 | 93.75 | 96.25 | 98.75 | 101.25 | 103.75 | 106.25 | 108.75 | 111.25 | 113.75 | 116.25 | 118.75 | 121.25 | 123.75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 6.2 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 2 | 1 | 2 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 6.0 | 1 | 1 | 0 | 1 | 0 | 4 | 2 | 1 | 2 | 2 | 1 | 0 | 0 | 1 | 1 | 2 | 0 | 4 | 0 | 2 | 0 | 1 |
| 5.8 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 |
| 5.6 | 1 | 1 | 2 | 2 | 4 | 9 | 5 | 0 | 5 | 3 | 0 | 2 | 2 | 3 | 4 | 5 | 1 | 0 | 1 | 4 | 0 | 0 |
| 5.4 | 0 | 0 | 4 | 4 | 3 | 9 | 10 | 4 | 13 | 8 | 13 | 7 | 4 | 2 | 1 | 0 | 2 | 2 | 4 | 7 | 2 | 3 |
| 5.2 | 3 | 4 | 5 | 5 | 6 | 14 | 20 | 10 | 14 | 16 | 10 | 19 | 7 | 5 | 4 | 8 | 3 | 4 | 2 | 3 | 4 | 3 |
| 5.0 | 6 | 2 | 7 | 18 | 17 | 16 | 33 | 15 | 24 | 36 | 29 | 23 | 13 | 8 | 2 | 2 | 4 | 2 | 2 | 13 | 3 | 2 |
| 4.8 | 6 | 11 | 12 | 8 | 18 | 41 | 51 | 32 | 42 | 54 | 57 | 27 | 15 | 5 | 2 | 1 | 2 | 5 | 4 | 9 | 8 | 5 |
| 4.6 | 15 | 7 | 9 | 37 | 28 | 64 | 103 | 52 | 90 | 99 | 71 | 40 | 15 | 3 | 1 | 1 | 1 | 0 | 1 | 5 | 2 | 2 |
| 4.4 | 4 | 6 | 19 | 33 | 47 | 99 | 145 | 68 | 94 | 96 | 39 | 20 | 4 | 3 | 0 | 1 | 0 | 2 | 2 | 1 | 3 | 4 |
| 4.2 | 17 | 13 | 29 | 52 | 46 | 65 | 109 | 69 | 73 | 61 | 19 | 5 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 |
| 4.0 | 6 | 16 | 8 | 23 | 28 | 31 | 42 | 26 | 43 | 21 | 6 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.8 | 5 | 6 | 8 | 0 | 7 | 4 | 17 | 19 | 16 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.6 | 2 | 2 | 3 | 2 | 2 | 8 | 7 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.2 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 67 | 70 | 108 | 189 | 209 | 367 | 551 | 305 | 419 | 401 | 262 | 148 | 66 | 32 | 16 | 21 | 14 | 23 | 18 | 47 | 22 | 21 |

Table 5a, Continued

DELTA FROM NET IS ABSCISSA     STATION MAGNITUDE IS ORDINATE

| | 126.25 | 128.75 | 131.25 | 133.75 | 136.25 | 138.75 | 141.25 | 143.75 | 146.25 | 148.75 | 151.25 | 153.75 | 156.25 | 158.75 | 161.25 | 163.75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.8 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.6 | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.4 | 6 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.2 | 5 | 3 | 2 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.0 | 9 | 5 | 8 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4.8 | 7 | 1 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4.6 | 2 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4.4 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4.2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 36 | 14 | 16 | 14 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | 166.25 | 168.75 | 171.25 | 173.75 | 176.25 | 178.75 | TOTAL |
|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 6.4 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 19 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 0 | 36 |
| 5.8 | 0 | 0 | 0 | 0 | 0 | 0 | 34 |
| 5.6 | 0 | 0 | 0 | 0 | 0 | 0 | 98 |
| 5.4 | 0 | 0 | 0 | 0 | 0 | 0 | 166 |
| 5.2 | 0 | 0 | 0 | 0 | 0 | 0 | 279 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 424 |
| 4.8 | 0 | 0 | 0 | 0 | 0 | 0 | 637 |
| 4.6 | 0 | 0 | 0 | 0 | 0 | 0 | 985 |
| 4.4 | 0 | 0 | 0 | 0 | 0 | 0 | 1167 |
| 4.2 | 0 | 0 | 0 | 0 | 0 | 0 | 1130 |
| 4.0 | 0 | 0 | 0 | 0 | 0 | 0 | 696 |
| 3.8 | 0 | 0 | 0 | 0 | 0 | 0 | 301 |
| 3.6 | 0 | 0 | 0 | 0 | 0 | 0 | 101 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 6108 |

Table 5b. Number of earthquakes located by the USC&GS from which either P or P' phase was recorded by at least one observatory and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and maximum epicentral distance at which either P or P' phase was recorded.
February 1963 through September 1964

DELTA FROM NET IS ABSCISSA     CGS MAGNITUDE IS ORDINATE

| | 16.25 | 18.75 | 21.25 | 23.75 | 26.25 | 28.75 | 31.25 | 33.75 | 36.25 | 38.75 | 41.25 | 43.75 | 46.25 | 48.75 | 51.25 | 53.75 | 56.25 | 58.75 | 61.25 | 63.75 | 66.25 | 68.75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 6.0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 2 | 2 | 0 | 1 | 1 |
| 5.8 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 8 | 7 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 5.6 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 2 | 1 | 0 | 0 | 16 | 17 | 1 | 2 | 3 | 5 | 4 | 3 | 2 | 3 |
| 5.4 | 0 | 0 | 0 | 6 | 2 | 1 | 4 | 0 | 1 | 0 | 1 | 2 | 19 | 19 | 2 | 2 | 3 | 2 | 4 | 2 | 4 | 4 |
| 5.2 | 1 | 0 | 1 | 3 | 3 | 0 | 1 | 1 | 1 | 4 | 5 | 10 | 13 | 33 | 4 | 7 | 2 | 7 | 7 | 4 | 4 | 3 |
| 5.0 | 1 | 0 | 2 | 6 | 1 | 4 | 1 | 4 | 2 | 11 | 2 | 10 | 34 | 34 | 5 | 13 | 8 | 8 | 6 | 6 | 7 | 7 |
| 4.8 | 1 | 2 | 2 | 12 | 9 | 5 | 8 | 6 | 1 | 9 | 7 | 15 | 44 | 50 | 10 | 11 | 9 | 15 | 13 | 10 | 12 | 8 |
| 4.6 | 3 | 0 | 7 | 15 | 4 | 6 | 13 | 7 | 6 | 11 | 19 | 15 | 68 | 50 | 14 | 15 | 14 | 24 | 4 | 15 | 16 | 20 |
| 4.4 | 7 | 1 | 7 | 15 | 13 | 9 | 11 | 10 | 14 | 28 | 35 | 9 | 80 | 57 | 21 | 23 | 8 | 37 | 18 | 8 | 14 | 30 |
| 4.2 | 2 | 3 | 11 | 15 | 13 | 10 | 13 | 17 | 13 | 22 | 55 | 28 | 56 | 57 | 16 | 22 | 16 | 22 | 10 | 14 | 33 | 30 |
| 4.0 | 6 | 2 | 2 | 10 | 13 | 17 | 22 | 10 | 16 | 39 | 45 | 6 | 34 | 27 | 11 | 12 | 7 | 10 | 4 | 2 | 5 | 11 |
| 3.8 | 3 | 1 | 6 | 13 | 15 | 17 | 15 | 7 | 12 | 19 | 14 | 4 | 13 | 4 | 4 | 9 | 1 | 3 | 2 | 2 | 2 | 0 |
| 3.6 | 1 | 1 | 6 | 4 | 4 | 3 | 7 | 0 | 0 | 1 | 4 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 3.4 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 25 | 10 | 44 | 104 | 78 | 73 | 98 | 64 | 69 | 146 | 188 | 100 | 388 | 364 | 89 | 116 | 71 | 136 | 87 | 68 | 102 | 118 |

| | 71.25 | 73.75 | 76.25 | 78.75 | 81.25 | 83.75 | 86.25 | 88.75 | 91.25 | 93.75 | 96.25 | 98.75 | 101.25 | 103.75 | 106.25 | 108.75 | 111.25 | 113.75 | 116.25 | 118.75 | 121.25 | 123.75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 6.4 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 2 |
| 6.2 | 0 | 1 | 1 | 1 | 1 | 3 | 0 | 2 | 0 | 2 | 1 | 0 | 2 | 1 | 0 | 2 | 0 | 3 | 2 | 0 | 1 | 0 |
| 6.0 | 0 | 1 | 0 | 1 | 2 | 3 | 2 | 0 | 0 | 2 | 3 | 2 | 1 | 0 | 2 | 4 | 0 | 2 | 1 | 4 | 1 | 1 |
| 5.8 | 1 | 1 | 1 | 3 | 2 | 2 | 2 | 0 | 1 | 4 | 4 | 6 | 4 | 3 | 4 | 1 | 5 | 1 | 2 | 6 | 4 | 3 |
| 5.6 | 3 | 0 | 3 | 5 | 1 | 10 | 12 | 2 | 15 | 5 | 15 | 6 | 3 | 3 | 3 | 1 | 4 | 3 | 3 | 11 | 3 | 4 |
| 5.4 | 3 | 3 | 5 | 5 | 8 | 11 | 17 | 9 | 17 | 13 | 13 | 12 | 9 | 6 | 2 | 4 | 4 | 5 | 4 | 6 | 3 | 9 |
| 5.2 | 3 | 2 | 4 | 6 | 14 | 22 | 27 | 14 | 24 | 38 | 33 | 29 | 7 | 7 | 2 | 1 | 1 | 6 | 3 | 12 | 5 | 3 |
| 5.0 | 6 | 8 | 7 | 10 | 16 | 36 | 48 | 28 | 47 | 42 | 46 | 27 | 16 | 5 | 1 | 3 | 2 | 6 | 3 | 6 | 8 | 4 |
| 4.8 | 7 | 9 | 11 | 20 | 30 | 57 | 75 | 42 | 69 | 75 | 54 | 30 | 12 | 0 | 0 | 0 | 0 | 3 | 3 | 5 | 2 | 4 |
| 4.6 | 12 | 7 | 18 | 35 | 39 | 76 | 106 | 60 | 96 | 93 | 57 | 19 | 2 | 1 | 0 | 1 | 0 | 1 | 2 | 2 | 2 | 3 |
| 4.4 | 7 | 3 | 19 | 29 | 29 | 72 | 124 | 58 | 66 | 61 | 15 | 6 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 3 |
| 4.2 | 12 | 15 | 16 | 42 | 33 | 48 | 77 | 51 | 33 | 31 | 5 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 4.0 | 2 | 11 | 9 | 18 | 12 | 12 | 27 | 18 | 19 | 7 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 3.8 | 3 | 6 | 5 | 3 | 8 | 0 | 8 | 7 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.6 | 2 | 0 | 2 | 2 | 1 | 4 | 5 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.4 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 62 | 67 | 101 | 181 | 198 | 357 | 532 | 294 | 394 | 375 | 249 | 140 | 61 | 29 | 15 | 19 | 18 | 31 | 27 | 57 | 32 | 36 |

Table 5b. Continued

DELTA FROM NET IS ABSCISSA CGS MAGNITUDE IS ORDINATE

| | 126.25 | 128.75 | 131.25 | 133.75 | 136.25 | 138.75 | 141.25 | 143.75 | 146.25 | 148.75 | 151.25 | 153.75 | 156.25 | 158.75 | 161.25 | 163.75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 2 | 0 | 3 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.2 | 3 | 1 | 1 | 2 | 0 | 1 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.0 | 6 | 0 | 3 | 2 | 1 | 2 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 5.8 | 9 | 6 | 2 | 4 | 2 | 1 | 3 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.6 | 10 | 8 | 9 | 2 | 5 | 7 | 0 | 3 | 3 | 6 | 1 | 0 | 0 | 0 | 0 | 0 |
| 5.4 | 13 | 6 | 4 | 2 | 14 | 1 | 3 | 4 | 4 | 7 | 1 | 0 | 0 | 0 | 0 | 0 |
| 5.2 | 11 | 6 | 4 | 4 | 10 | 3 | 5 | 5 | 0 | 8 | 2 | 0 | 0 | 0 | 0 | 0 |
| 5.0 | 6 | 5 | 5 | 8 | 13 | 4 | 3 | 3 | 4 | 6 | 1 | 1 | 0 | 0 | 0 | 0 |
| 4.8 | 1 | 4 | 5 | 6 | 4 | 1 | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4.6 | 3 | 2 | 3 | 2 | 3 | 2 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4.4 | 4 | 2 | 3 | 7 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4.2 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4.0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 71 | 40 | 42 | 41 | 59 | 25 | 18 | 18 | 12 | 36 | 6 | 2 | 0 | 0 | 0 | 0 |

| | 166.25 | 168.75 | 171.25 | 173.75 | 176.25 | 178.75 | TOTAL |
|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| 6.4 | 0 | 0 | 0 | 0 | 0 | 0 | 23 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 41 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 0 | 63 |
| 5.8 | 0 | 0 | 0 | 0 | 0 | 0 | 113 |
| 5.6 | 0 | 0 | 0 | 0 | 0 | 0 | 232 |
| 5.4 | 0 | 0 | 0 | 1 | 0 | 0 | 308 |
| 5.2 | 0 | 0 | 0 | 0 | 0 | 0 | 435 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 606 |
| 4.8 | 0 | 0 | 0 | 0 | 0 | 0 | 792 |
| 4.6 | 0 | 0 | 0 | 0 | 0 | 0 | 1006 |
| 4.4 | 0 | 0 | 0 | 0 | 0 | 0 | 976 |
| 4.2 | 0 | 0 | 0 | 0 | 0 | 0 | 849 |
| 4.0 | 0 | 0 | 0 | 0 | 0 | 0 | 451 |
| 3.8 | 0 | 0 | 0 | 0 | 0 | 0 | 211 |
| 3.6 | 0 | 0 | 0 | 0 | 0 | 0 | 56 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 0 | 0 | 0 | 1 | 0 | 0 | 6186 |

Table 5c. Number of earthquakes located by the USC&GS from which no observatory recorded a P or P' phase and for which the USC&GS computed a magnitude, as a function of USC&GS magnitude and minimum epicentral distance, February 1963 through September 1964

DELTA FROM NET IS ABSCISSA CGS MAGNITUDE IS ORDINATE

|  | 16.25 | 18.75 | 21.25 | 23.75 | 26.25 | 28.75 | 31.25 | 33.75 | 36.25 | 38.75 | 41.25 | 43.75 | 46.25 | 48.75 | 51.25 | 53.75 | 56.25 | 58.75 | 61.25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 5.2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 4.6 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 4.4 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 4.2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 0 | 1 | 1 | 2 | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 6 |

|  | 63.75 | 66.25 | 68.75 | 71.25 | 73.75 | 76.25 | 78.75 | 81.25 | 83.75 | 86.25 | 88.75 | 91.25 | 93.75 | 96.25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 5.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 1 |
| 5.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 3 |
| 5.4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 1 | 2 | 0 |
| 5.2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 6 | 5 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 3 | 3 | 2 |
| 4.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 6 | 4 | 8 | 5 |
| 4.6 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 3 | 11 | 12 | 6 |
| 4.4 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 6 | 7 | 6 | 8 |
| 4.2 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 7 | 6 | 2 | 4 |
| 4.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 6 | 2 | 6 |
| 3.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| 3.6 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 4 | 0 | 0 | 1 | 2 | 2 | 3 | 2 | 11 | 2 | 29 | 40 | 47 | 41 |

Table 5c, Continued

DELTA FROM NET IS ABSCISSA CGS MAGNITUDE IS ORDINATE

| | 98.75 | 101.25 | 103.75 | 106.25 | 108.75 | 111.25 | 113.75 | 116.25 | 118.75 | 121.25 | 123.75 | 126.25 | 128.75 | 131.25 | 133.75 | 136.25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.8 | 1 | 4 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.6 | 5 | 0 | 3 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 5.4 | 0 | 2 | 7 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 5.2 | 5 | 5 | 2 | 3 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.0 | 13 | 8 | 3 | 6 | 2 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4.8 | 17 | 4 | 7 | 7 | 7 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 4.6 | 5 | 6 | 5 | 3 | 7 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4.4 | 10 | 2 | 2 | 2 | 6 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4.2 | 5 | 3 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4.0 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.8 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.6 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 64 | 37 | 35 | 28 | 28 | 10 | 2 | 3 | 2 | 2 | 1 | 0 | 1 | 1 | 0 | 0 |

| | 138.75 | 141.25 | 143.75 | 146.25 | 148.75 | 151.25 | 153.75 | 156.25 | 158.75 | 161.25 | 163.75 | 166.25 | 168.75 | 171.25 | 173.75 | 176.25 | 178.75 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.6 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 6.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 5.8 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 |
| 5.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 |
| 5.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 |
| 5.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 |
| 5.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 47 |
| 4.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 71 |
| 4.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 71 |
| 4.4 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 60 |
| 4.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 39 |
| 4.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22 |
| 3.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| 3.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 3.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 3.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | | 418 |

# APPENDIX 8 to TECHNICAL REPORT NO. 65-58

## SUMMARY OF ROUTINE MICROSEISMIC NOISE DATA

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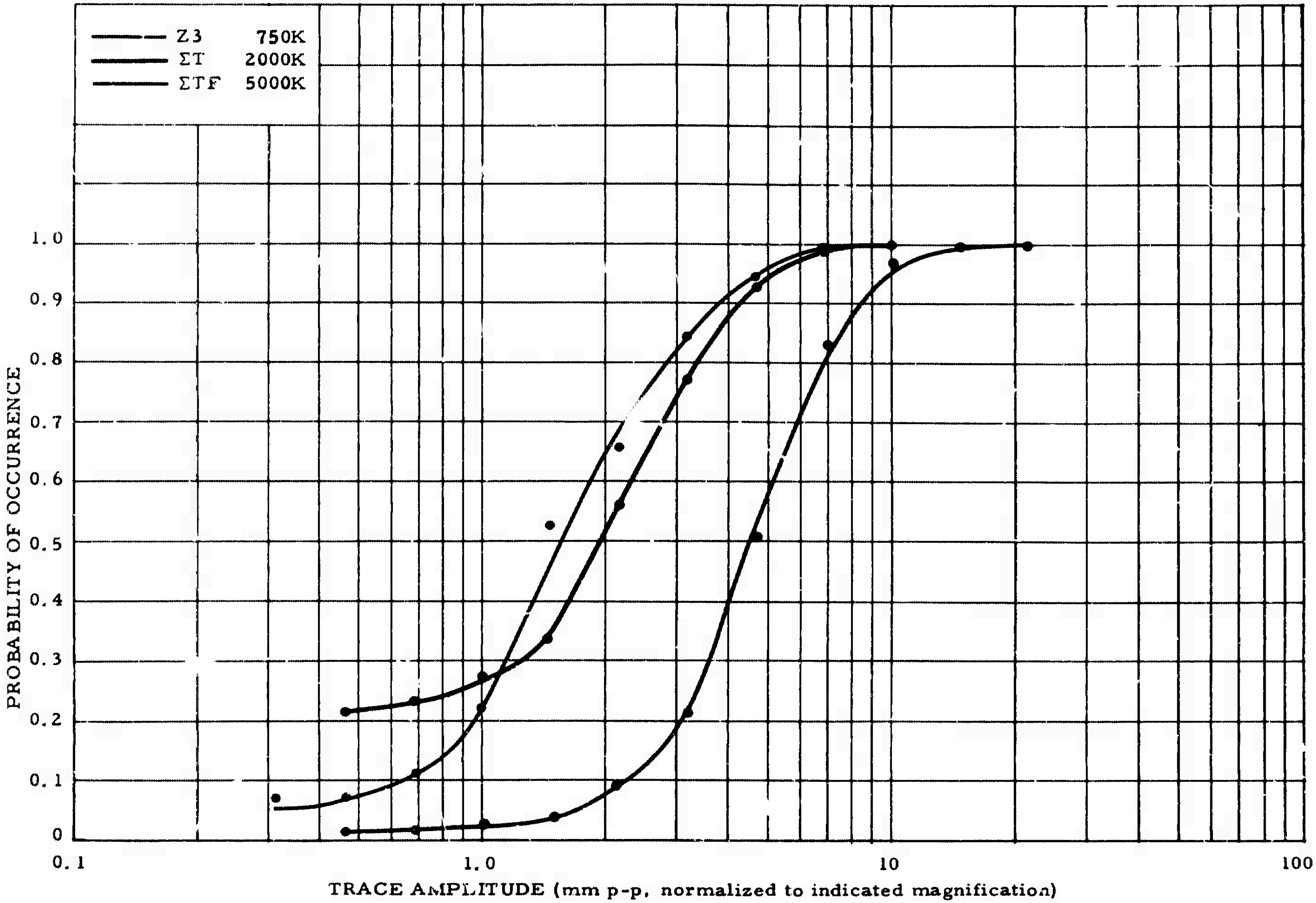


Figure 1a. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given trace amplitude (X10 view) at BMSO during March 1964-February 1965

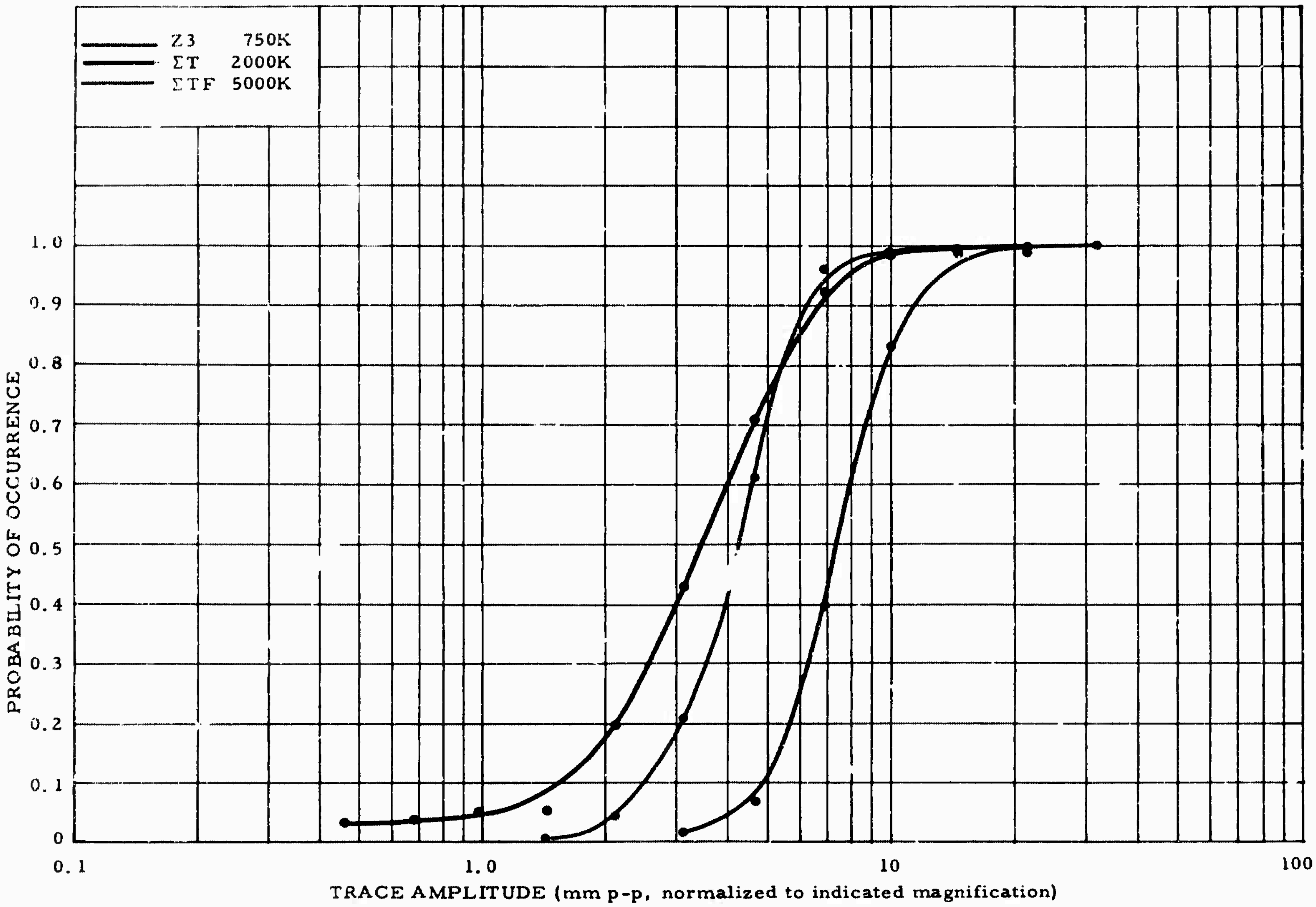


Figure 1b. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given trace amplitude (X10 view) at BMSO during February 1965

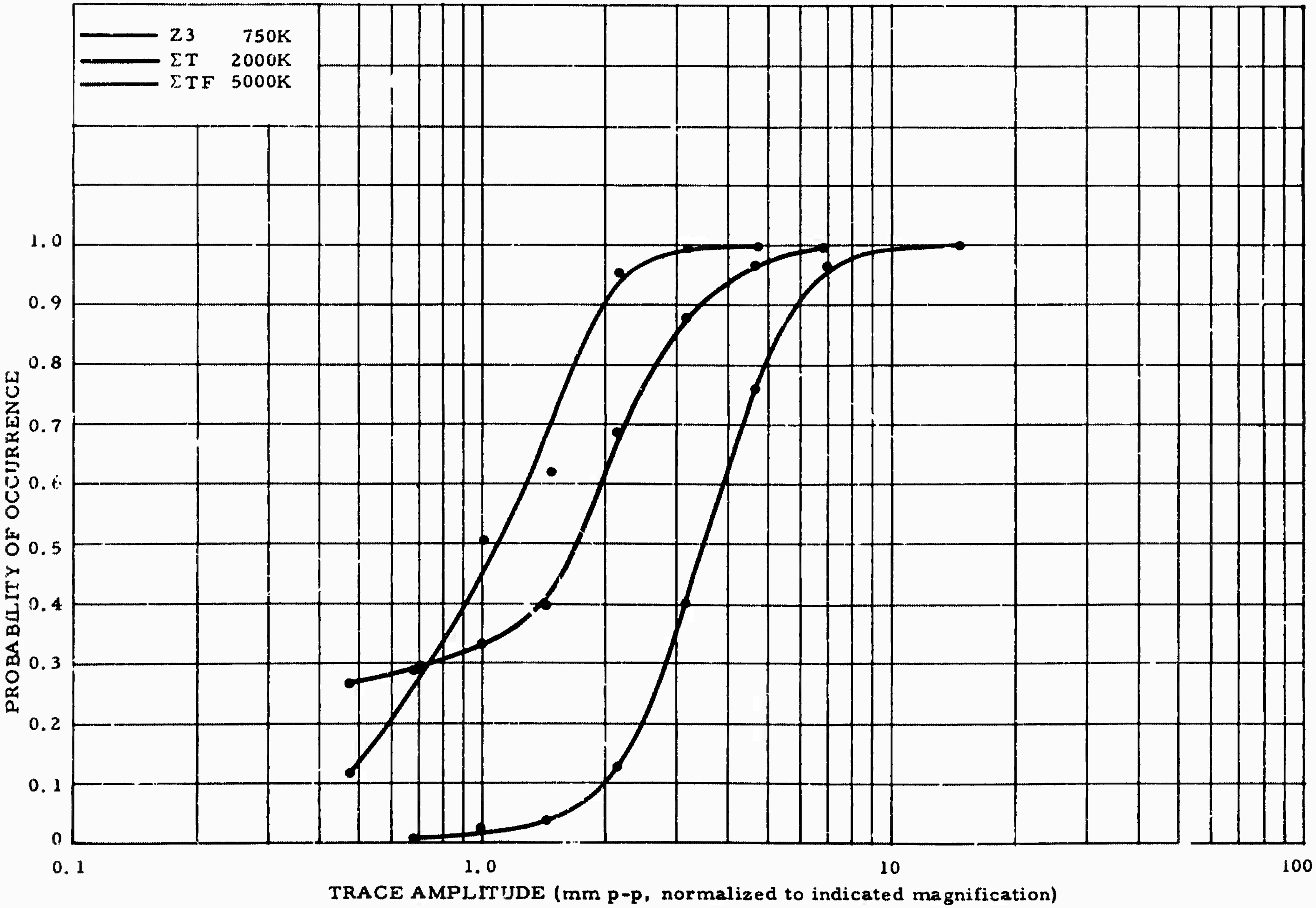


Figure 1c. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given trace amplitude (X10 view) at BMSO during August 1964

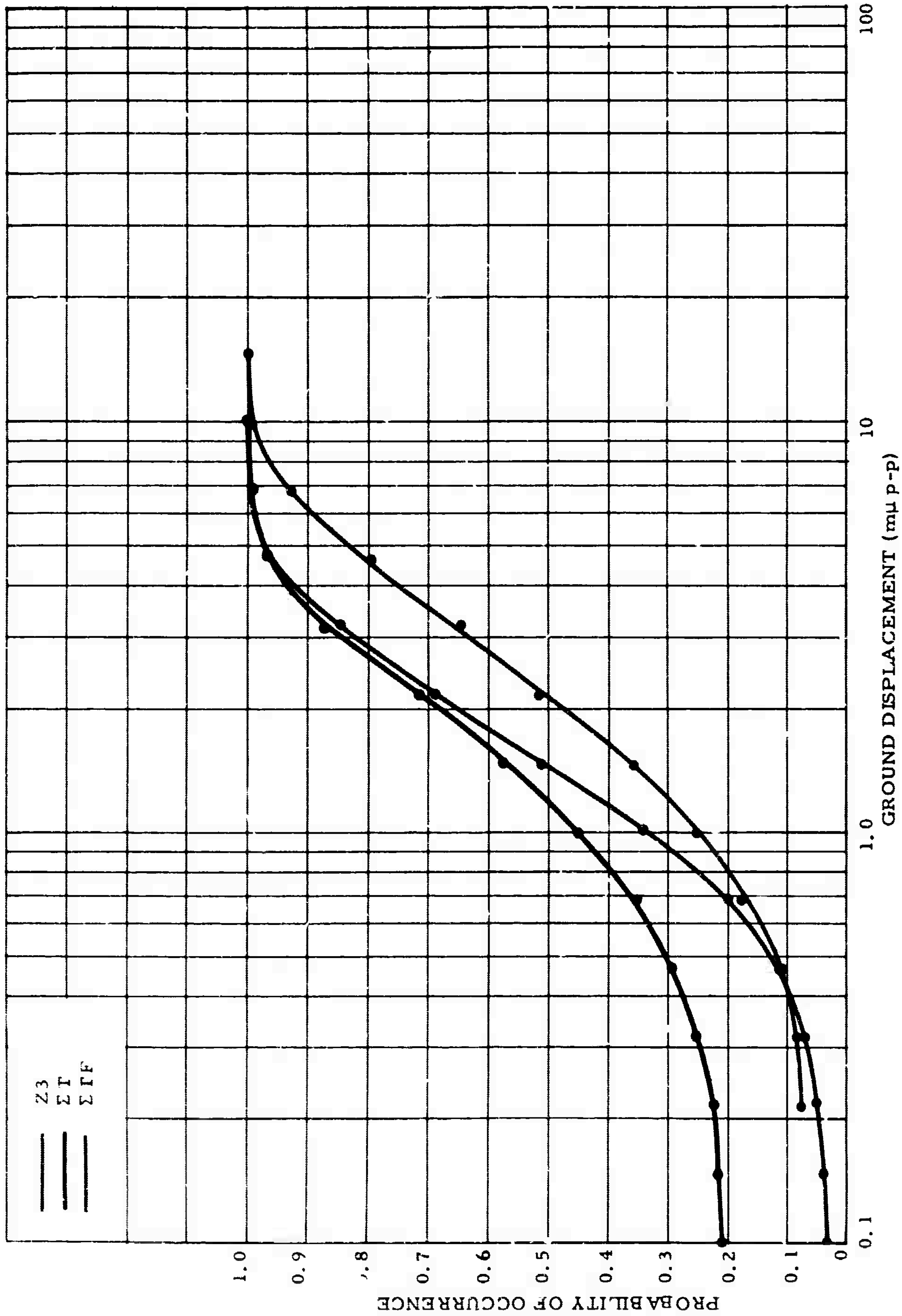


Figure 2a. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given ground displacement at BMSO during March 1964-February 1965

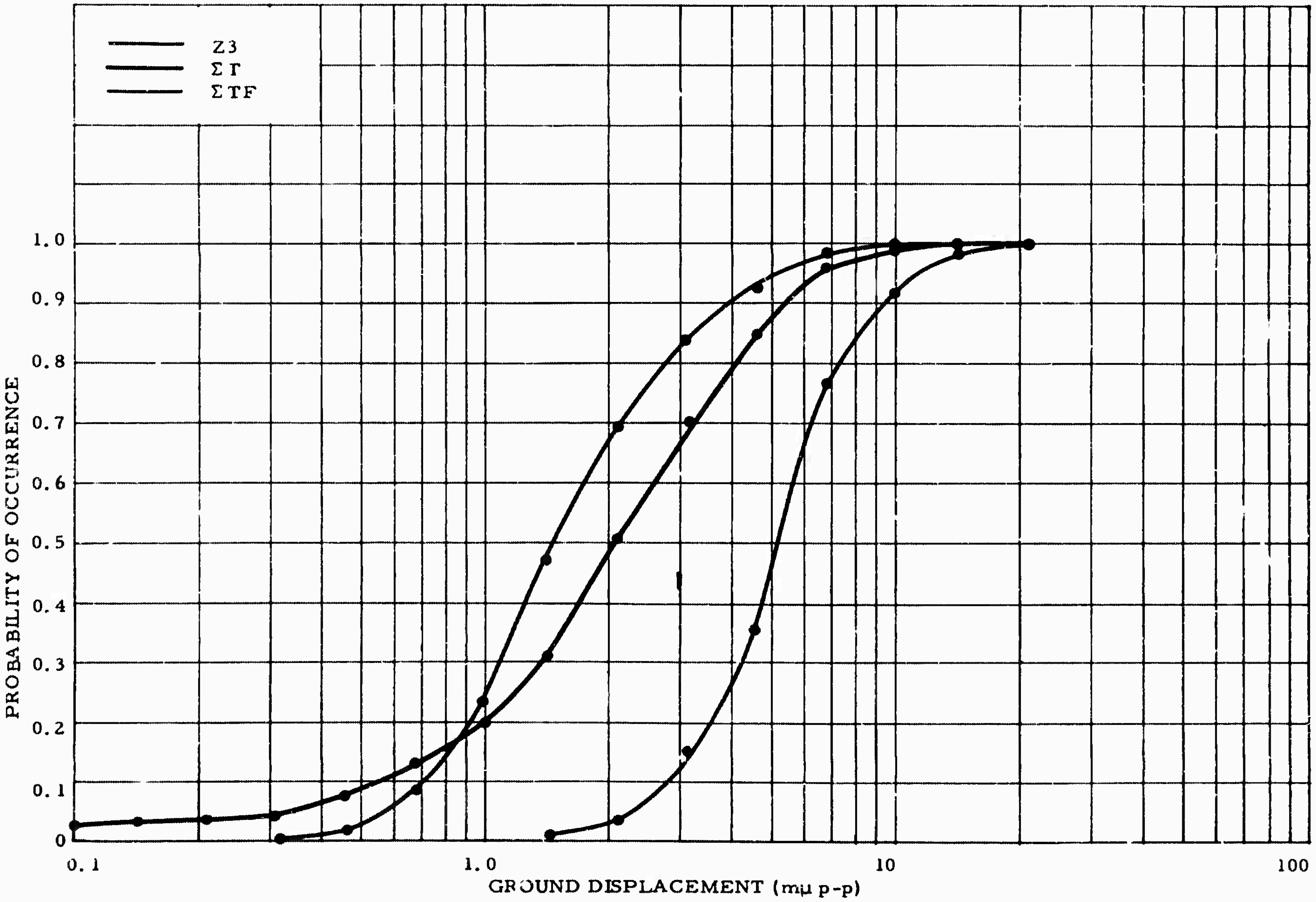


Figure 2b. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given ground displacement at BMSO during February 1965

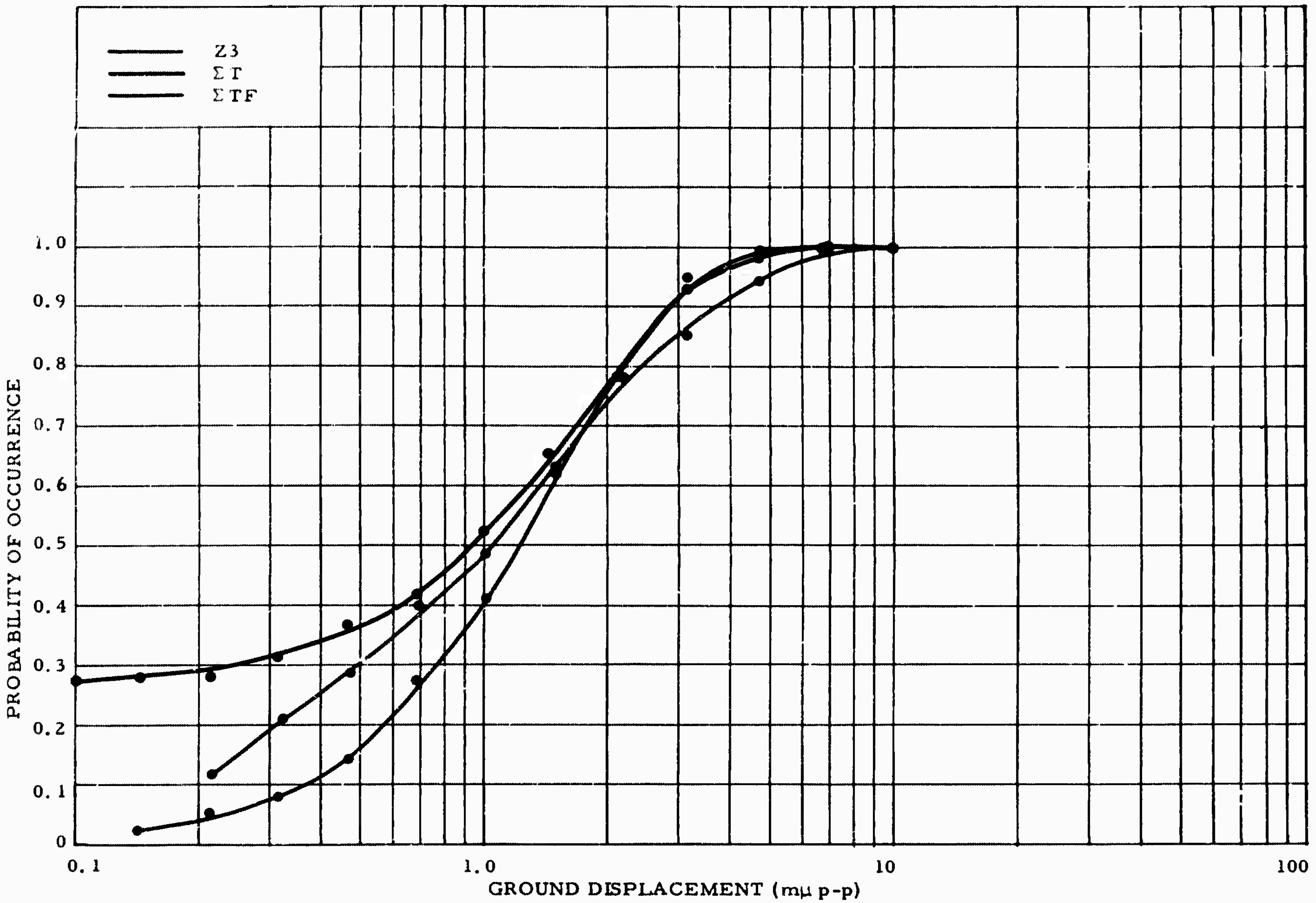


Figure 2c. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given ground displacement at BMSO during August 1964

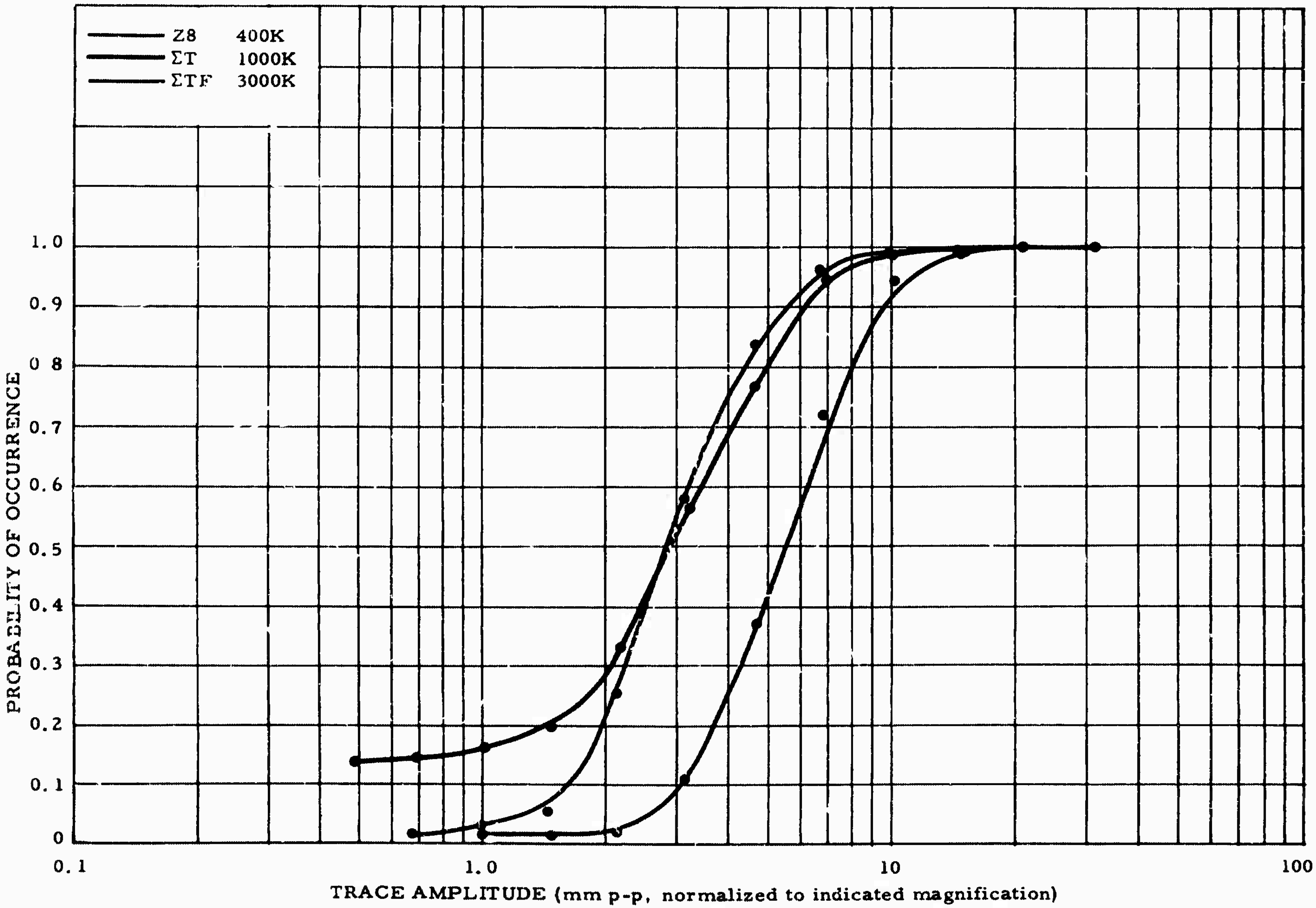


Figure 3a. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given trace amplitude (X10 view) at CPSO during March 1964-February 1965

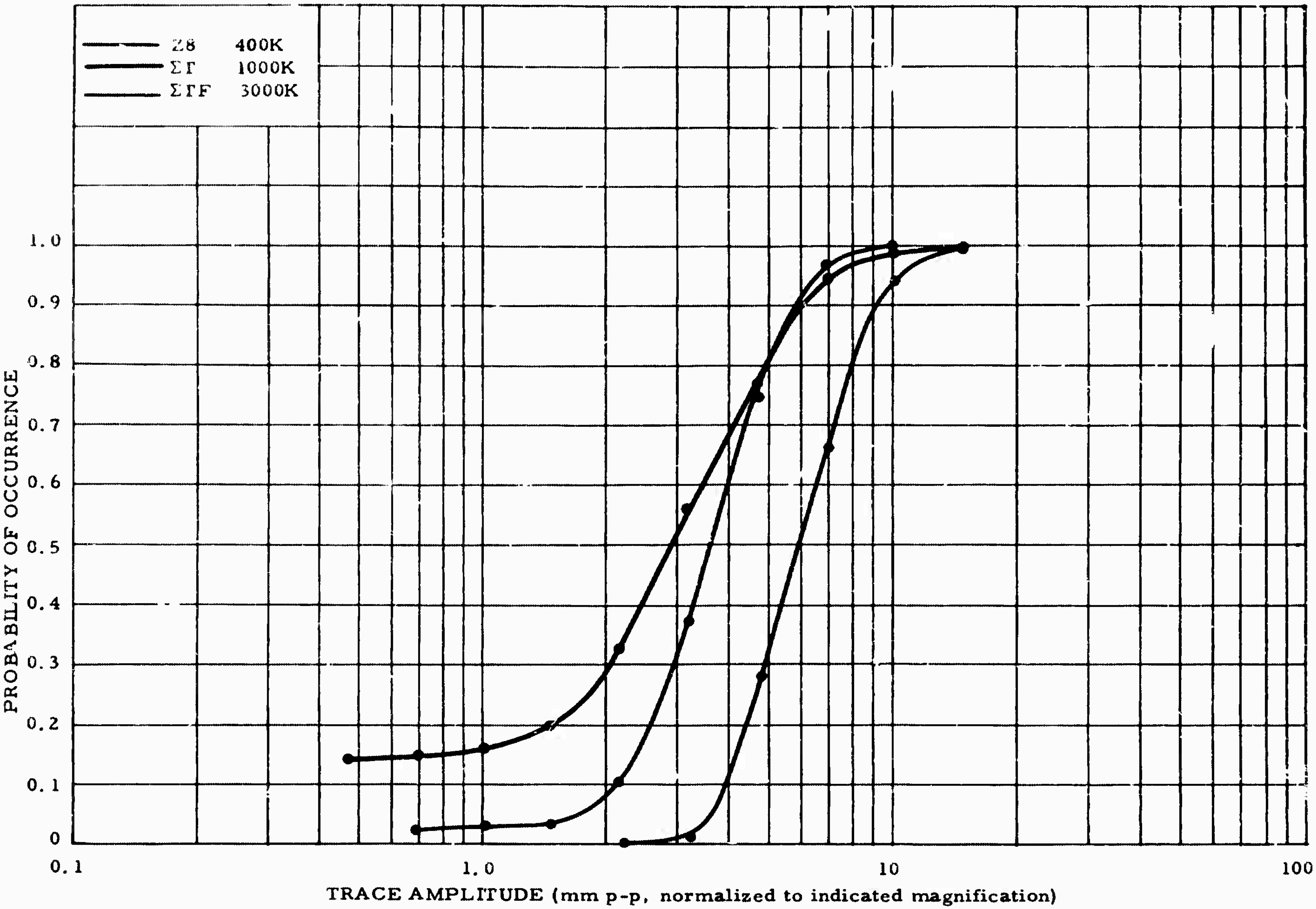


Figure 3b. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given trace amplitude (X10 view) at CPSO during March 1964

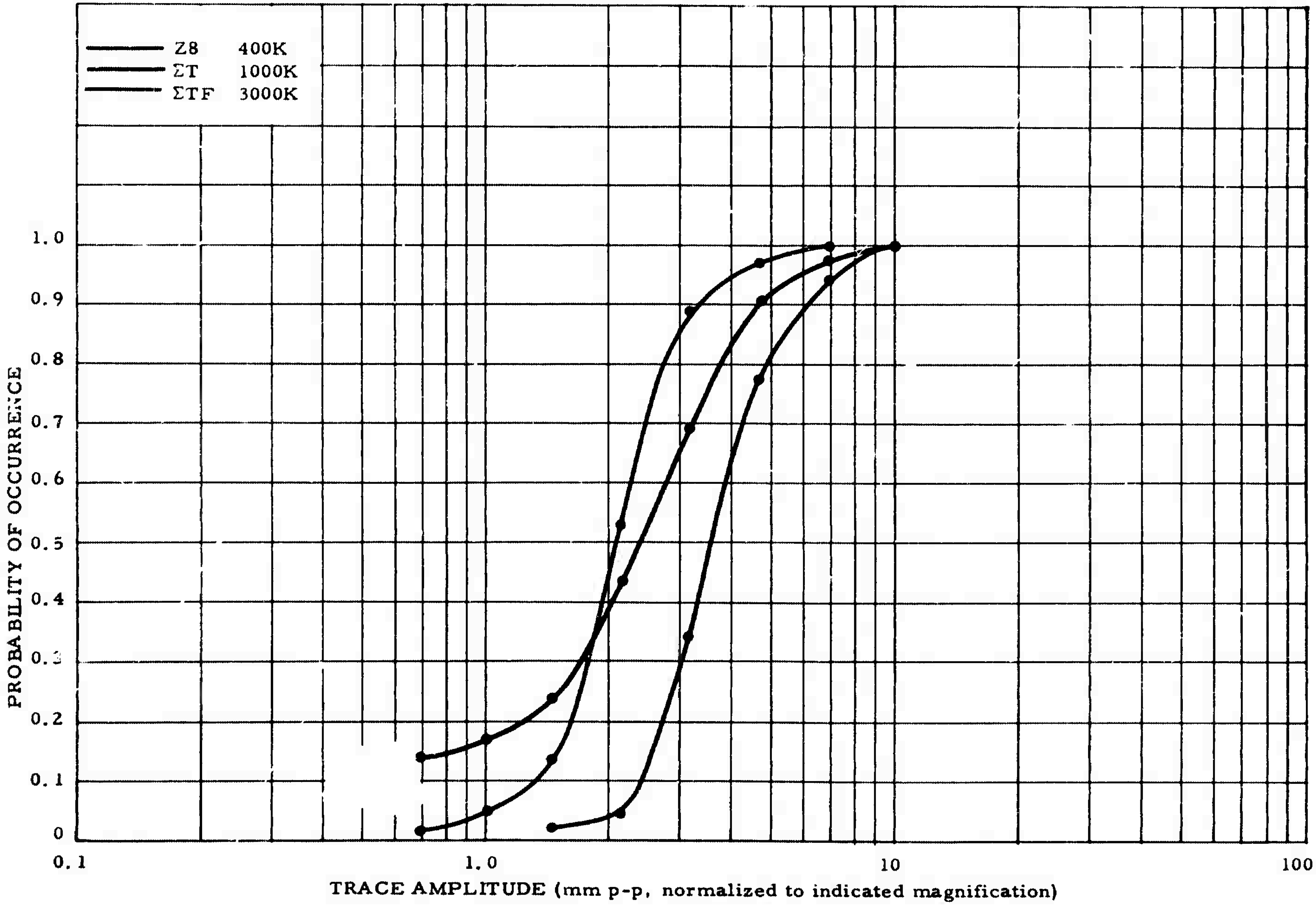


Figure 3c. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given trace amplitude (X10 view) at CPSO during June 1964

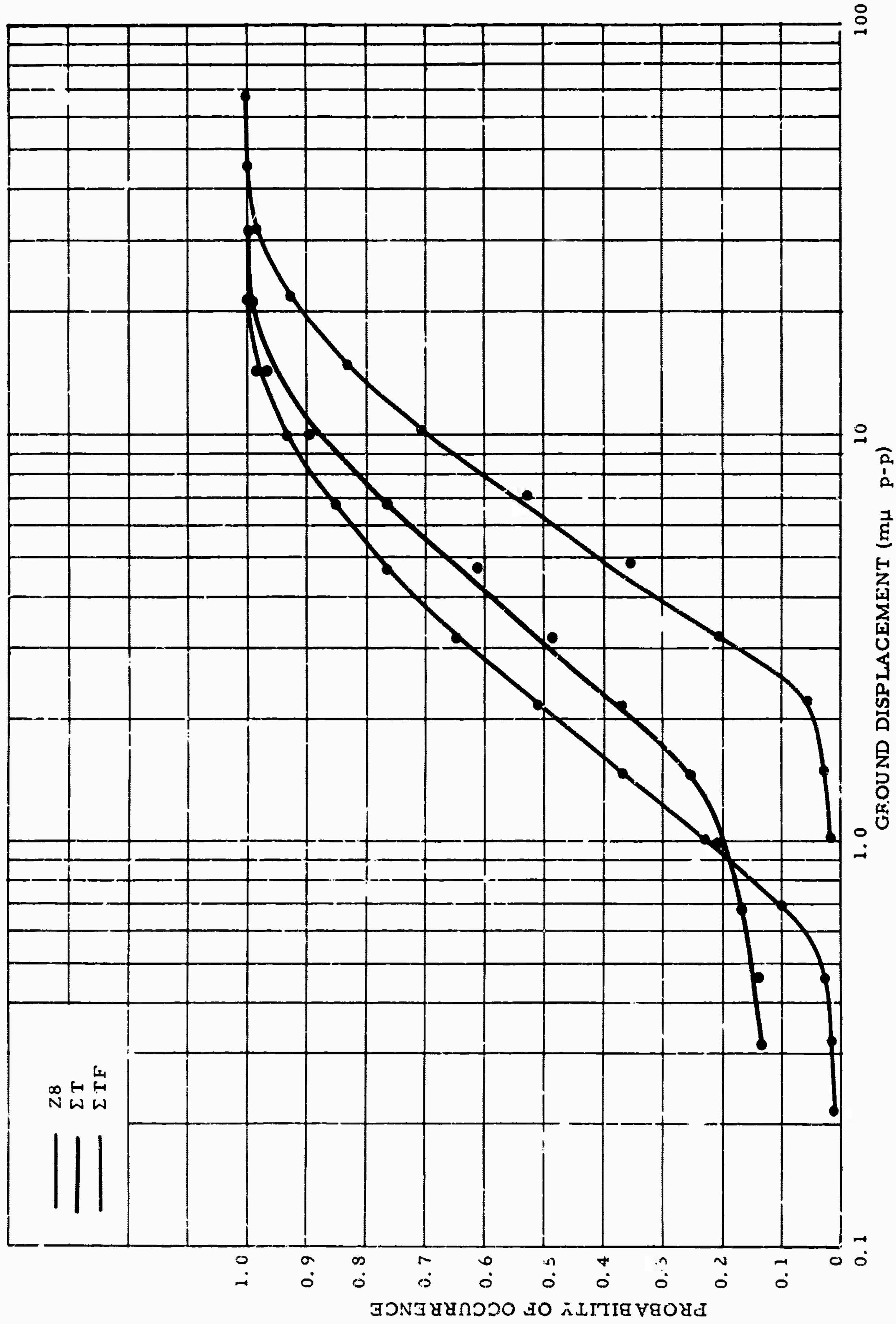


Figure 4a. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given ground displacement at CPSO during March 1964-February 1965

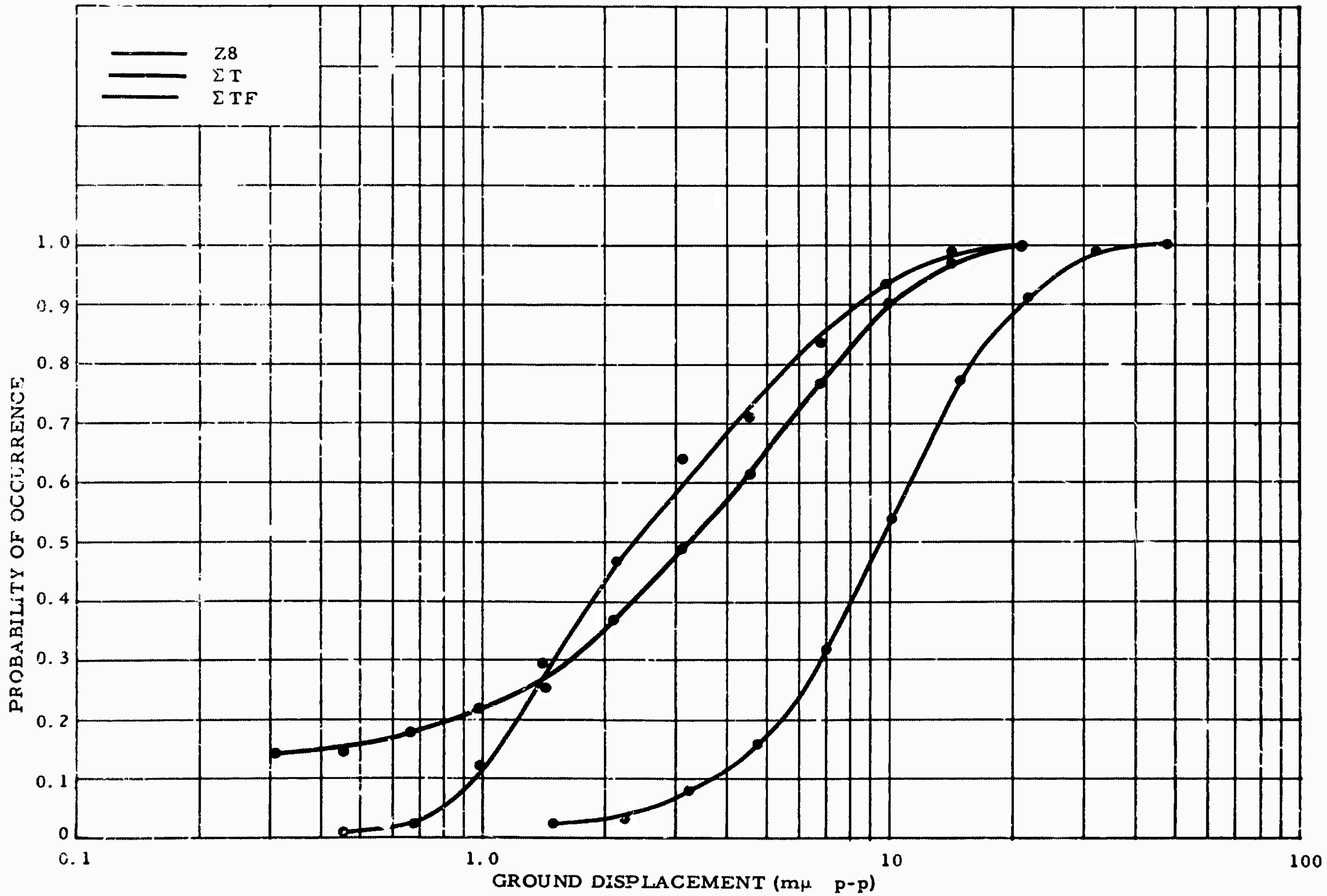


Figure 4b. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given ground displacement at CPSO during March 1964

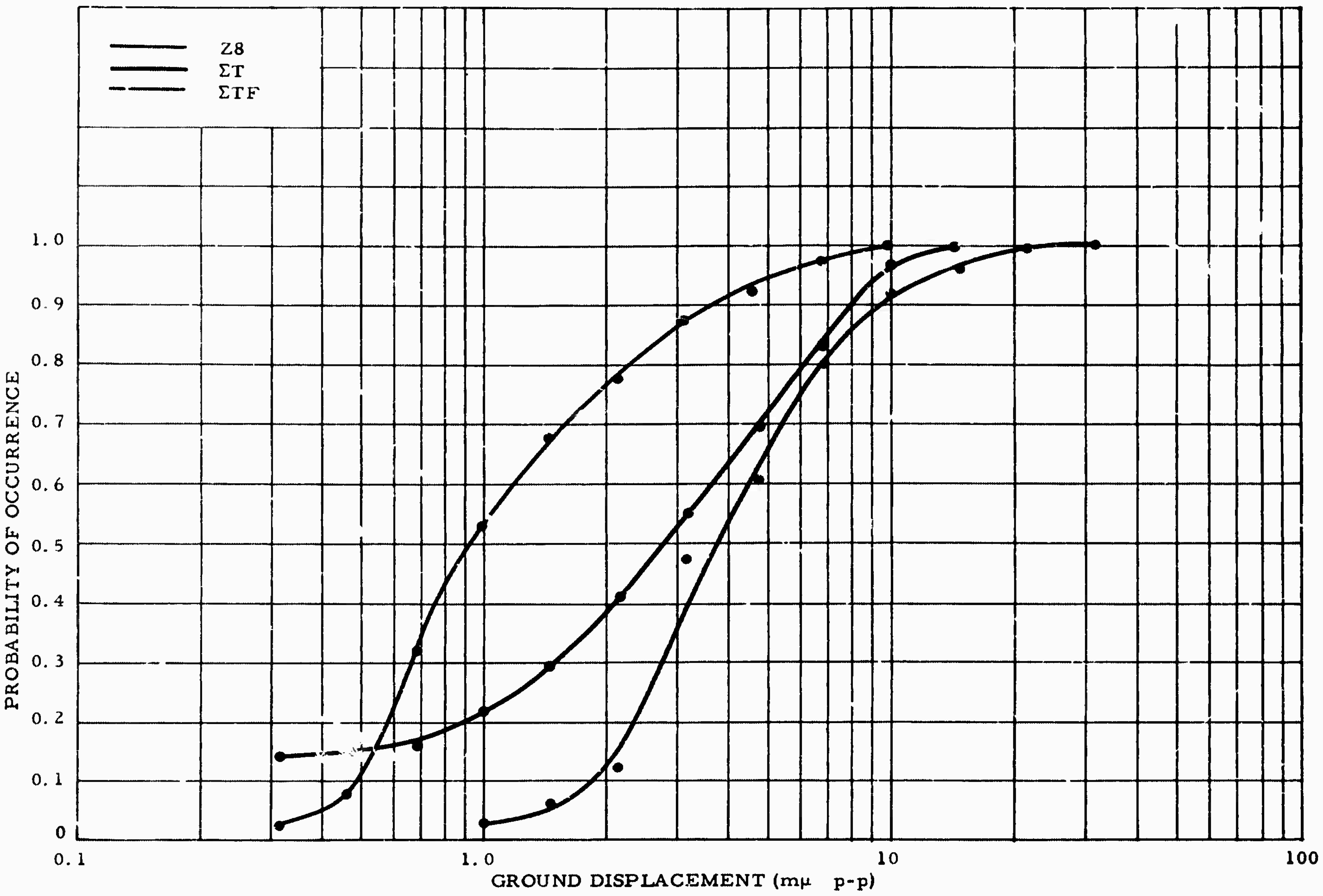


Figure 4c. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given ground displacement at CPSO during June 1964

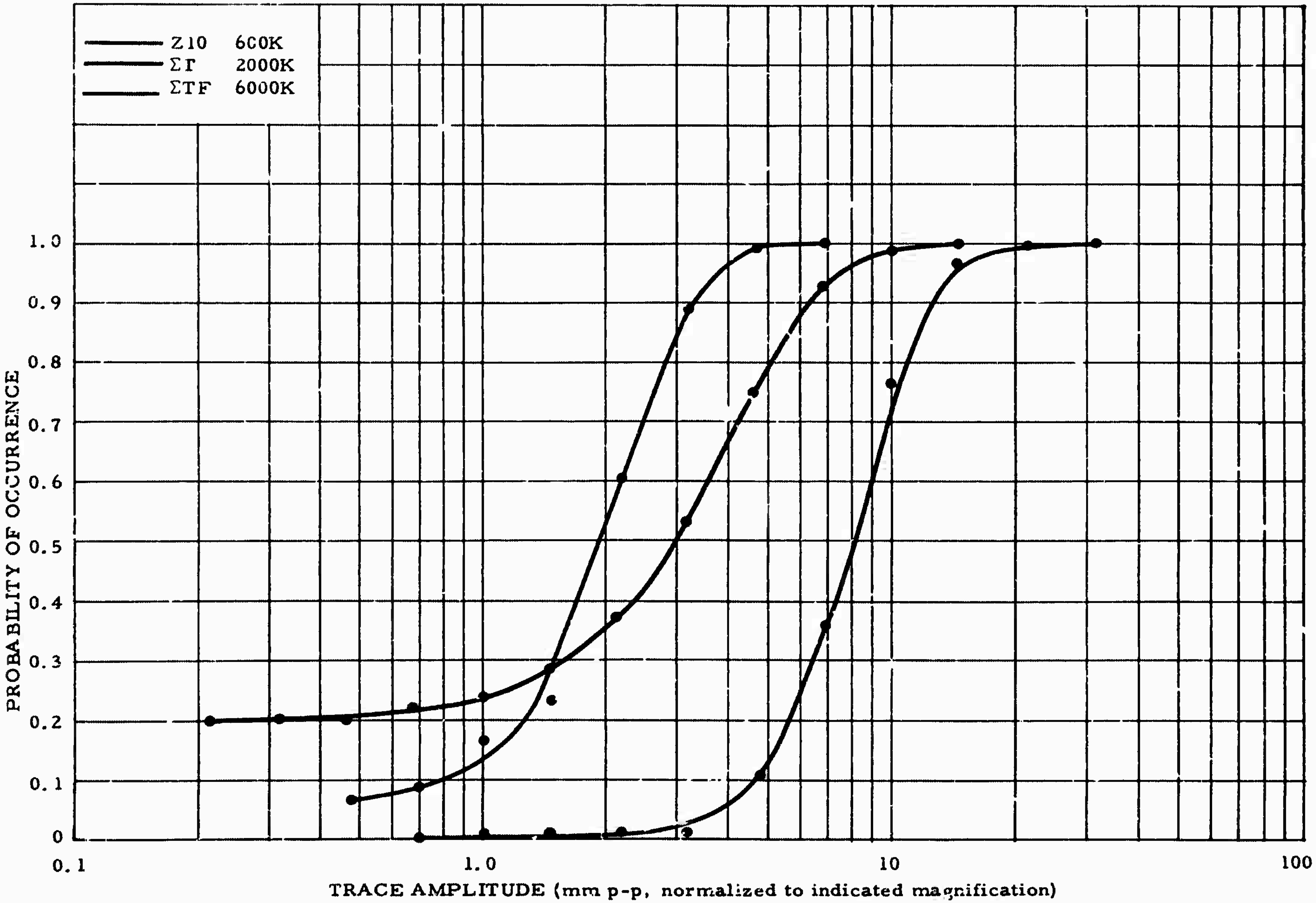


Figure 5a. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given trace amplitude (X10 view) at UBSO during March 1964-February 1965

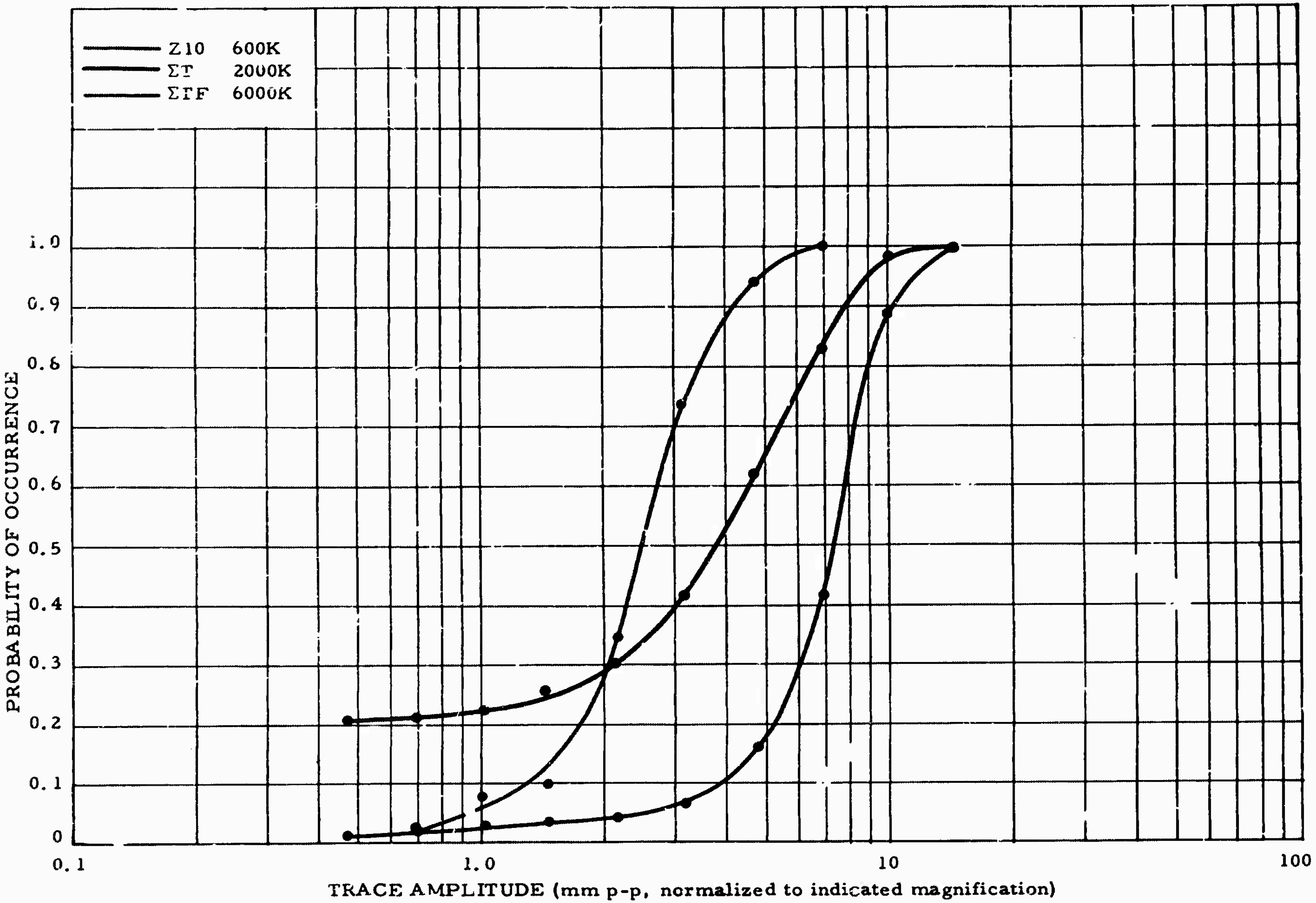


Figure 5b. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given trace amplitude (X10 view) at UBSO during March 1964

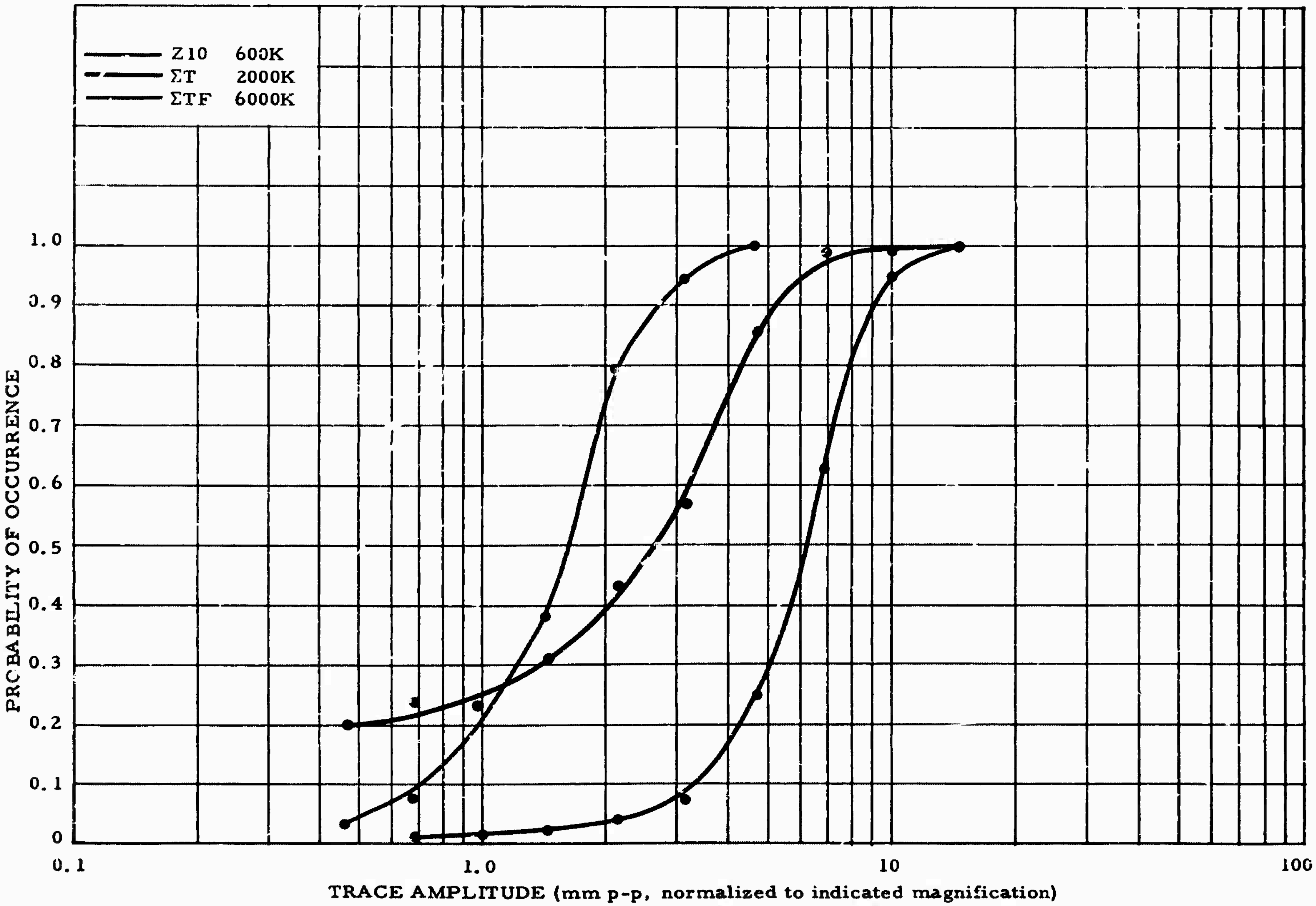


Figure 5c. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given trace amplitude (X10 view) at UBSO during May 1964

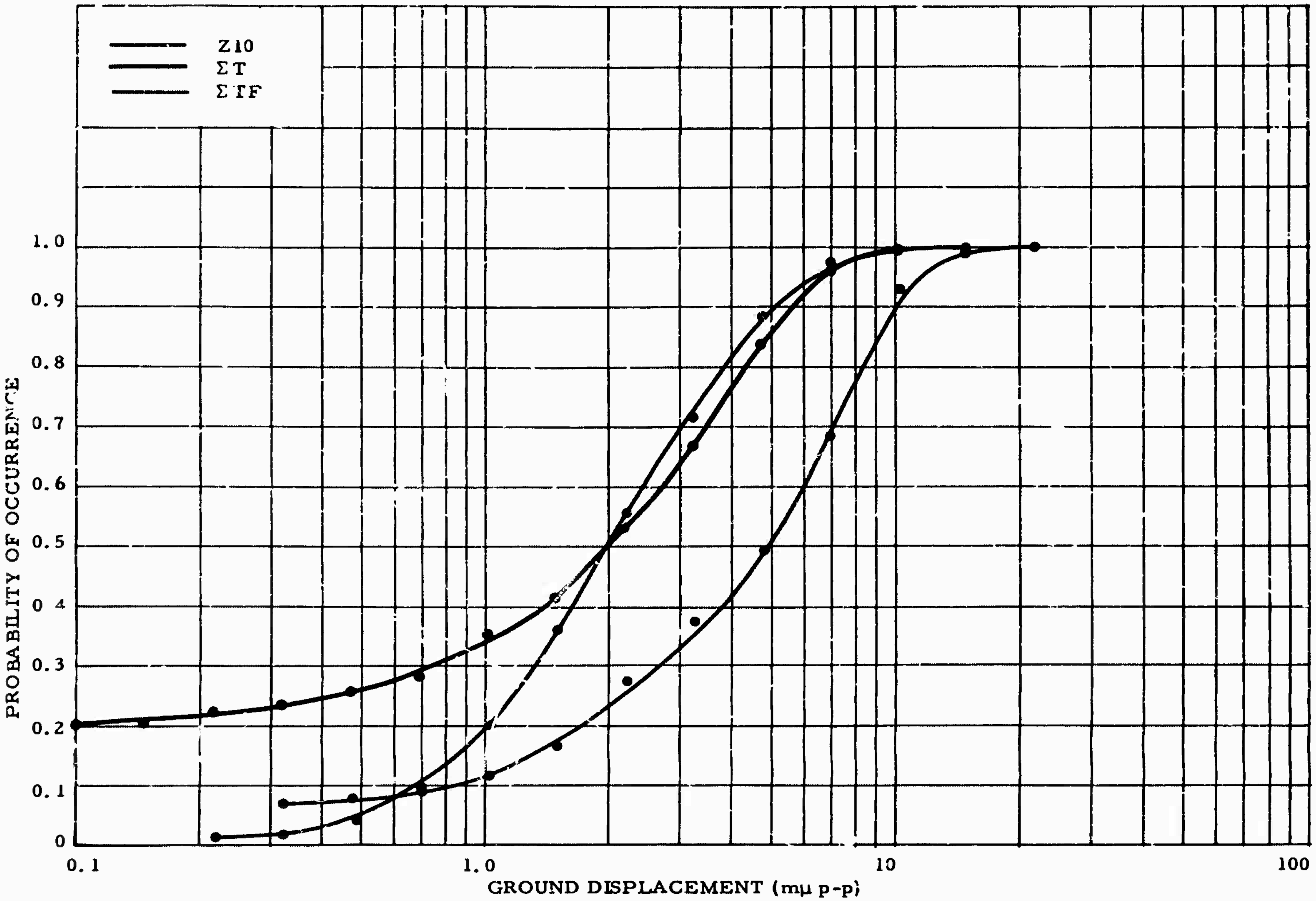


Figure 6a. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given ground displacement at UBSO during March 1964-February 1965

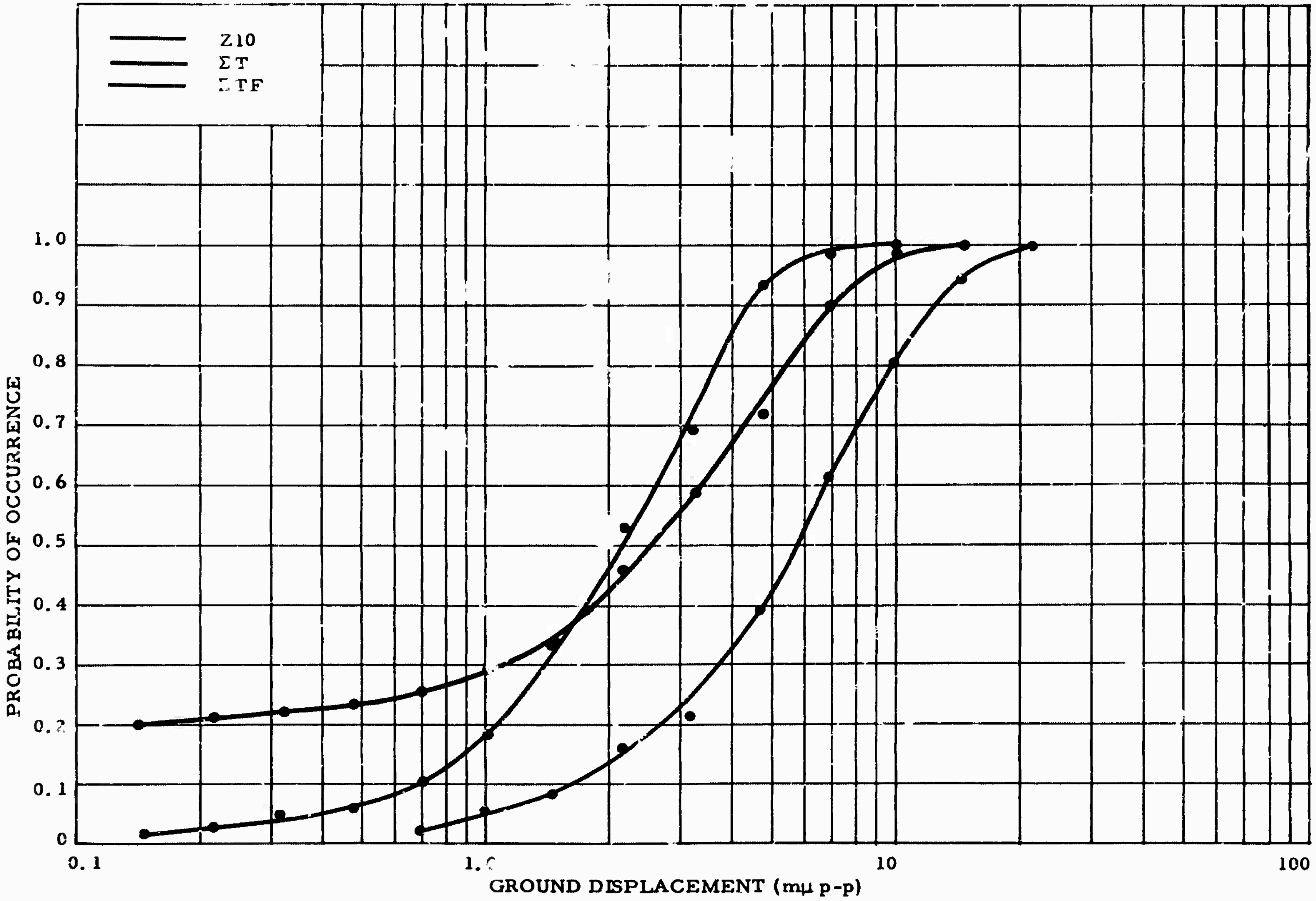


Figure 6b. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given ground displacement at UBSO during March 1964

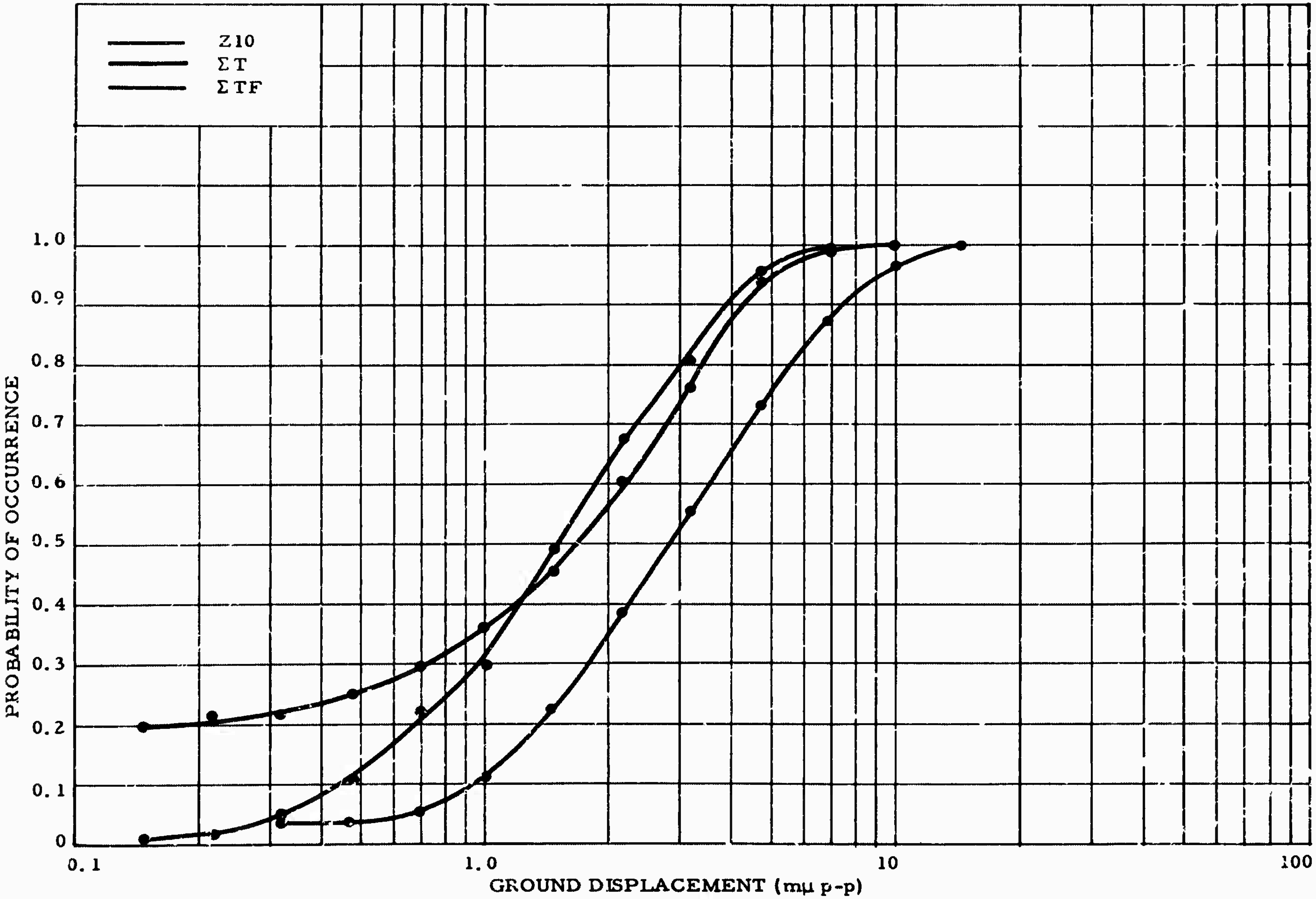
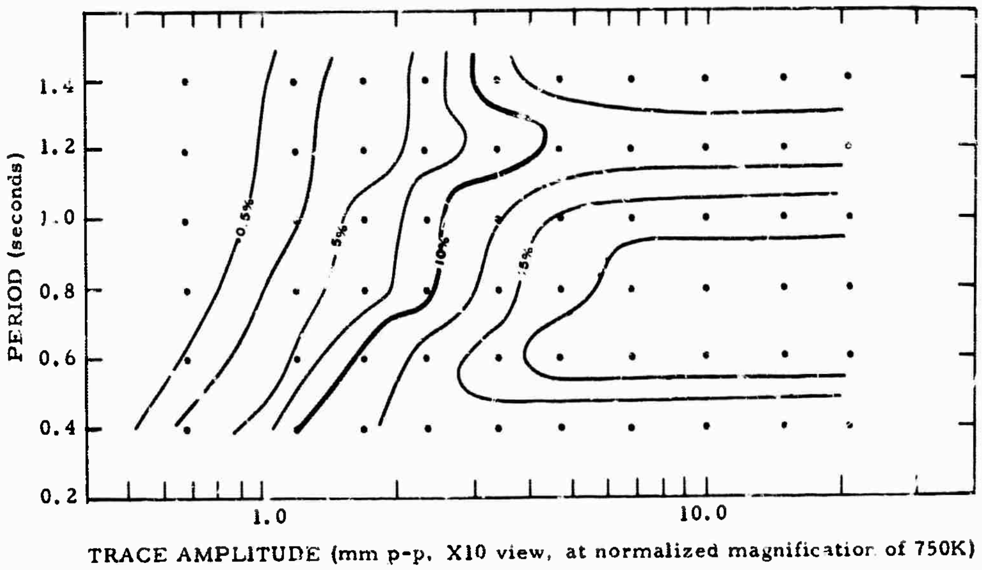


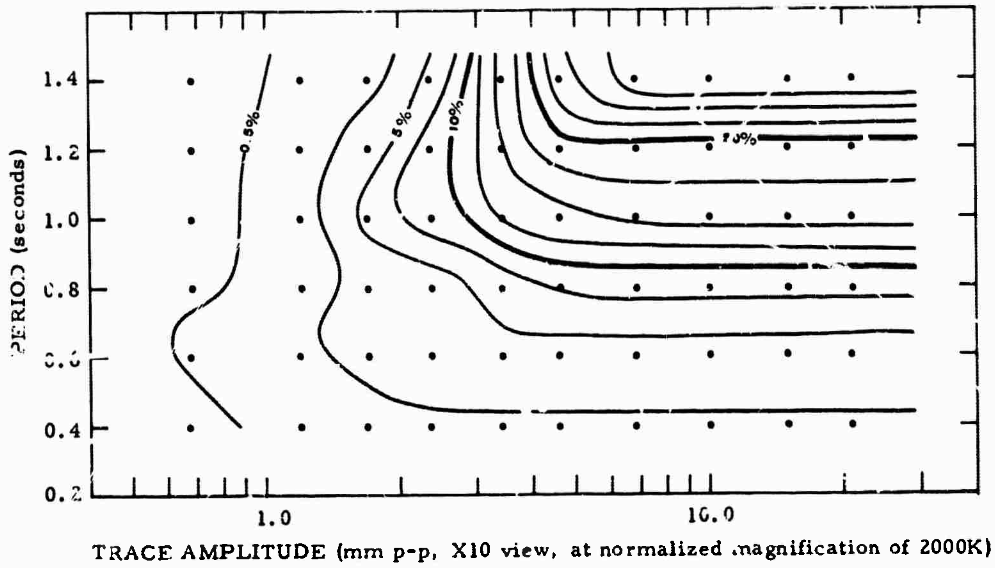
Figure 6c. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than a given ground displacement at UBSO during May 1964



(a)

ΣZ

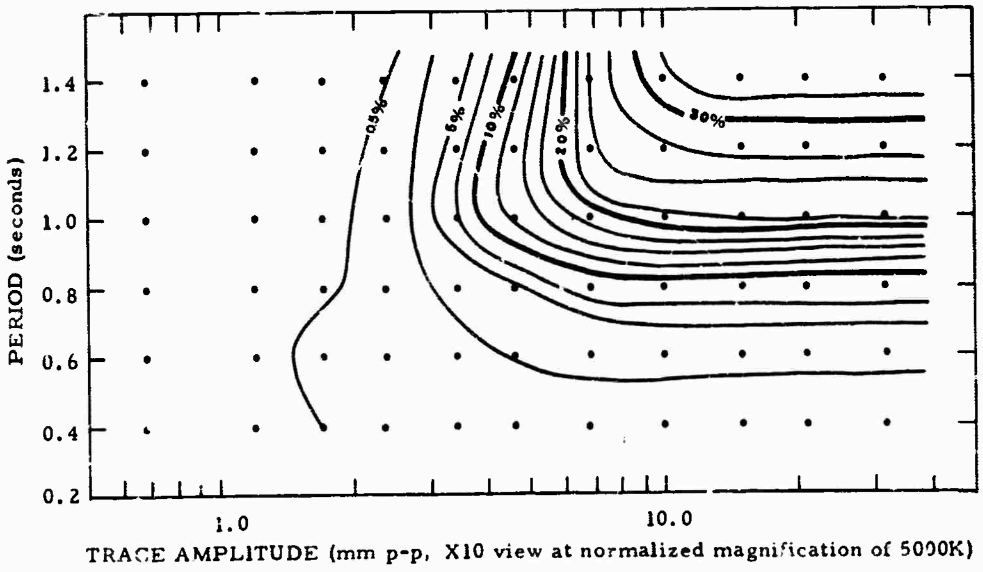
Amplitude of
6.58 percent
of occurrence
is 0.4 mm or less



(b)

ΣT

Amplitude of
20.98 percent
of occurrence
is 0.4 mm or less

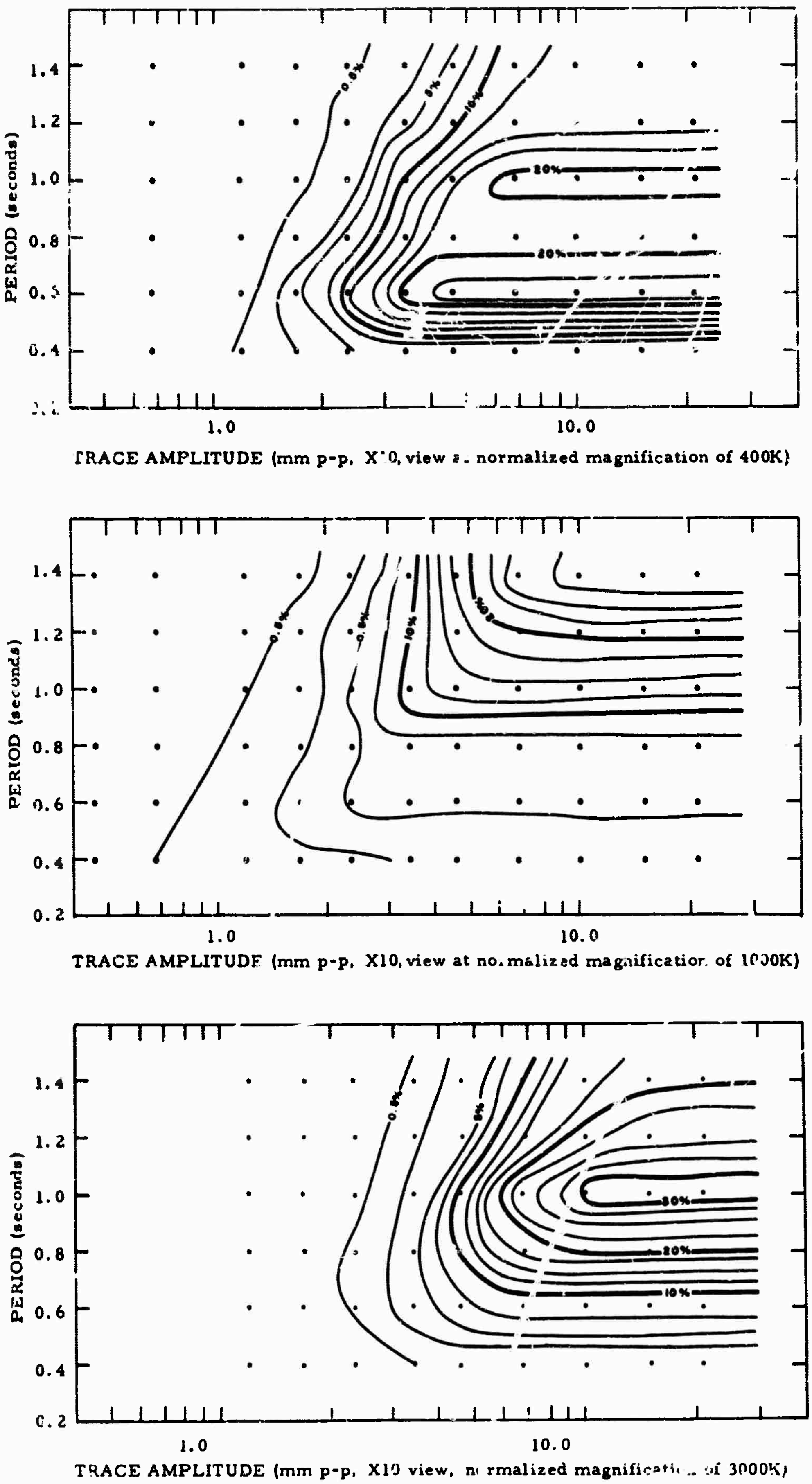


(c)

ΣTF

Amplitude of
1.72 percent
of occurrence
is 0.4 mm or less

Figure 7. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than the indicated amplitude and at the indicated period; BMSO, March 1964 through February 1965
(Contour interval = 2.5 percent)



(a)

Z8

Amplitude of
1.41 percent
of occurrence
is 0.4 mm or less

(b)

ΣT

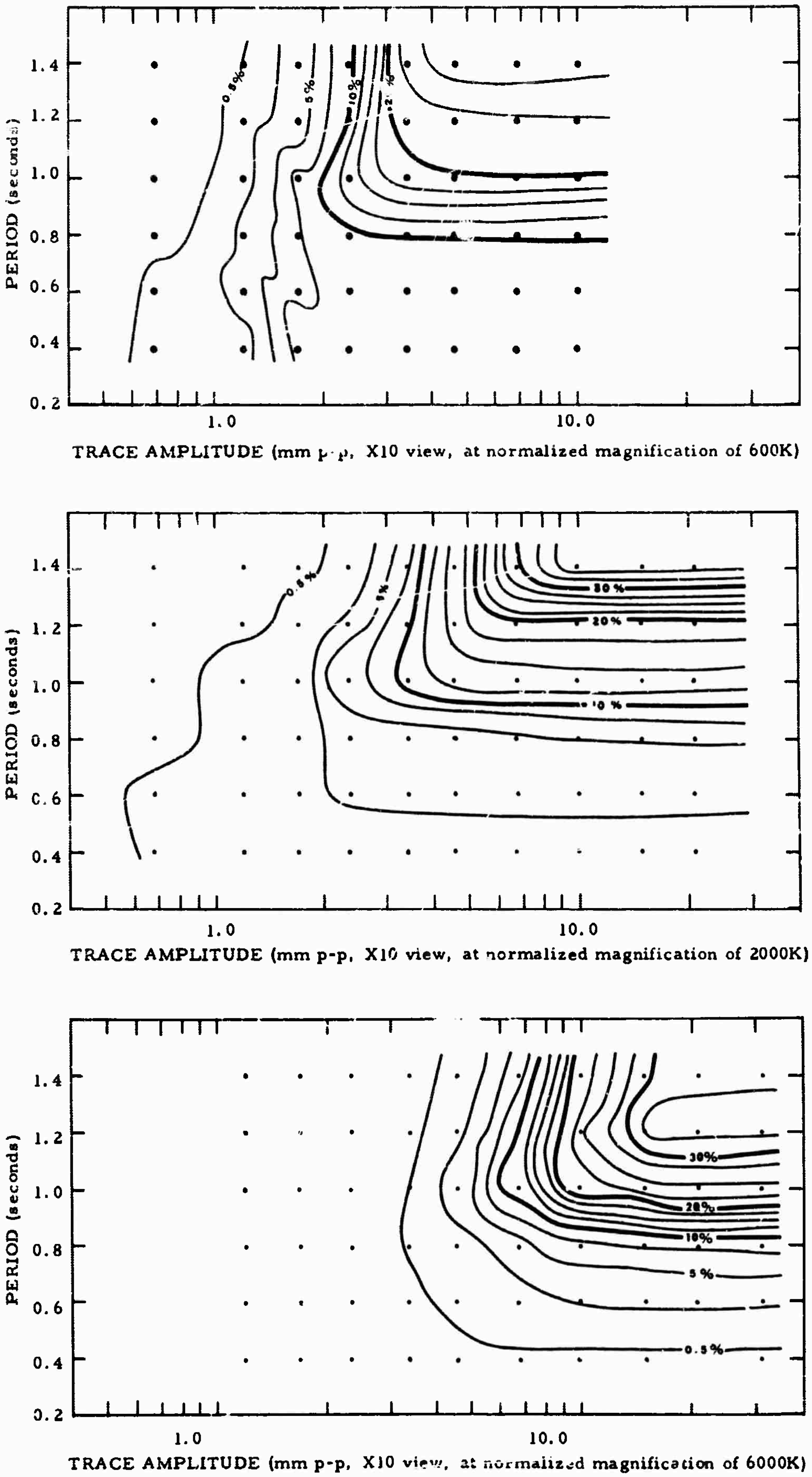
Amplitude of
20.92 percent
of occurrence
is 0.4 mm or less

(c)

ΣTF

Amplitude of
0.663 percent
of occurence
is 0.4 mm or less

Figure 8. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than the indicated amplitude and at the indicated period, CPSO, March 1964 through February 1965 (Contour interval = 2.5 percent)



(a)

**Z10**

Amplitude of
6.32 percent
of occurrence
is 0.4 mm or less

(b)

**ΣT**

Amplitude of
19.70 percent
of occurrence
is 0.4 mm or less

(c)

**ΣTF**

Amplitude of
0.4 percent
of occurrence
is 0.4 mm or less

Figure 9. Probability of microseisms in the 0.4-1.4 second period range occurring at or less than the indicated amplitude and at the indicated period; UBSO, March 1964 through February 1965 (Contour interval = 2.5 percent)