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TR 65-99

TECHNICAL REPORT NO. 65-99

OPERATION OF TWO OBSERVATORIES

Quarterly Report No. 1, Project VT/5054

1 May through 31 July 1965

GEOTECH

THE GEOTECHNICAL CORPORATION

3401 SHILOH ROAD GARLAND, TEXAS

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Sponsored by

Advanced Research Projects Agency

Nuclear Test Detection Office

ARPA Order No. 624

TELEDYNE INDUSTRIES, INCORPORATED

GEOTECH DIVISION

3401 Shiloh Road

Garland, Texas

IDENTIFICATION

AFTAC Project No:	VELA T/5054
Project Title:	Operation of Two Observatories
ARPA Order No:	624
ARPA Program Code No:	5810
Name of Contractor:	The Geotechnical Corporation
Date of Contract:	1 July 1963
Amount of Contract:	$1,677,304
Contract Number:	AF 33(657)-12373
Contract Expiration Date:	30 April 1966
Program Manager:	B. B. Leichliter, BR-8-8102

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ABSTRACT

This report describes the operation of the Blue Mountains Seismological Observatory and Unita Basin Seismological Observatory between the period of 1 May through 31 July 1965. Modifications and additions to the observatory instrumentation are described and tests to improve the operation of the observatories are reported.

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

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OPERATION OF TWO OBSERVATORIES

1. INTRODUCTION

1.1 AUTHORITY

This research was supported by the Advanced Research Projects Agency, Nuclear Test Detection Office, and was monitored by the Air Force Technical Applications Center under Contract AF 33(657)-12373.

1.2 HISTORY

The two seismological observatories operated under Project VT/5054 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 the observatory locations 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 began operation on the following dates:

BMSO	13 August 1962
UBSO	26 November 1962

2. OPERATION OF BMSO AND UBSO

2.1 GENERAL

Data are recorded at each of the observatories on a 24-hour basis. The observatories are normally manned between 8 and 10 hours a day, 5 days a week.

On week-ends and holidays, they are manned by a skeleton crew 8 hours a day; however, additional personnel are on call in case of an emergency.

2.2 STANDARD SEISMOGRAPH OPERATING PROCEDURES

The operating parameters and tolerances for allowable deviations from these parameters are shown in table 1. These parameters are checked and reset, as necessary, when the frequency response of a seismograph is found out of tolerance. The calibration norms and their respective tolerances for the frequency response checks are shown in table 2. The normal characteristics of the BMSO and UBSO seismographs are shown in figure 1.

2.3 OUTAGES CAUSED BY ELECTRICAL STORMS

2.3.1 Electrical Storms and Damage to Instrumentation at BMSO

BMSO experienced six electrical storms during this reporting period. During a storm on 17 June, the mirror of the galvanometer in the PTA of the Z7 seismograph was "flipped." On 24 June the same galvanometer was damaged by lightning and subsequently replaced. After these storms numerous carbon blocks required cleaning.

2.3.2 Electrical Storms and Damage to Instrumentation at UBSO

There were 23 electrical storms at UBSO during this reporting period. On two occasions major damage occurred as a result of these storms. A section of the power line cable for the shallow-hole siesmograph (SH) was damaged on 20 June. On 7 June at 21:32Z, the observatory was struck by lightning; however, there was no actual damage to the building. Damage to the instrumentation included a burned calibration coil in Z4 and partial damage to the long-period galvanometer in the vertical long-period seismograph. All fuses and carbon blocks were burned at the seismometer end of the spiral-four cables for the shallow-buried array. About 90 percent of the fuses and carbon blocks were burned at the CRB. Only a few fuses at the seismometers in the short-period surface array and at the intermediate-band and broad-band seismometers were blown. Fuses in the mass position control circuits and in the long-period vertical and north seismographs were destroyed. The wind direction and microbarograph systems also lost line fuses. The power

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

Seismograph				Operating parameters and tolerances					Filter settings	
System	Comp	Type	Model	T_s	λ_s	T_g	λ_g	σ^2	Bandpass at 3 dB cutoff (sec)	Cut off rate at SP side (dB/oct)
SP	Z and H	Johnson-Matheson	7515, 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	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	T_s	Seismometer free period (sec)
IB	Intermediate band	T_g	Galvanometer free period (sec)
BB	Broad band	λ_s	Seismometer damping constant
LP	Long period	λ_g	Galvanometer damping constant
UA	Unamplified (i.e., earth powered)	σ^2	Coupling coefficient

Table 2. Calibration norms and operating tolerances for frequency response of the standard seismographs at BMSO and UBSO

SP Johnson-Matheson Vertical and Horizontal

f (Hz)	T (sec)	R. M.	A. T. (±%)
0.2	5.0	0.0113	10
0.4	2.5	0.0950	7.5
0.8	1.25	0.685	5
1.0	1.0	1.0	-
1.5	0.67	1.52	5
2.0	0.5	1.90	5
3.0	0.33	2.12	7.5
4.0	0.25	1.87	12
6.0	0.167	1.15	20
8.0	0.125		
10.0	0.100		

LP Vertical and Horizontal

f (Hz)	T (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

IB Vertical and Horizontal

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

BB Vertical and Horizontal

f (Hz)	T (sec)	R. M.	A. T. (±%)
0.04	25.0	0.104	20
0.06	16.7	0.350	20
0.08	12.5	0.775	15
0.1	10.0	0.950	10
0.2	5.0	1.0	5
0.4	2.5	1.0	5
0.8	1.25	1.0	-
1.6	0.625	1.0	5
3.2	0.312	1.0	10
6.4	0.156	0.980	15

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

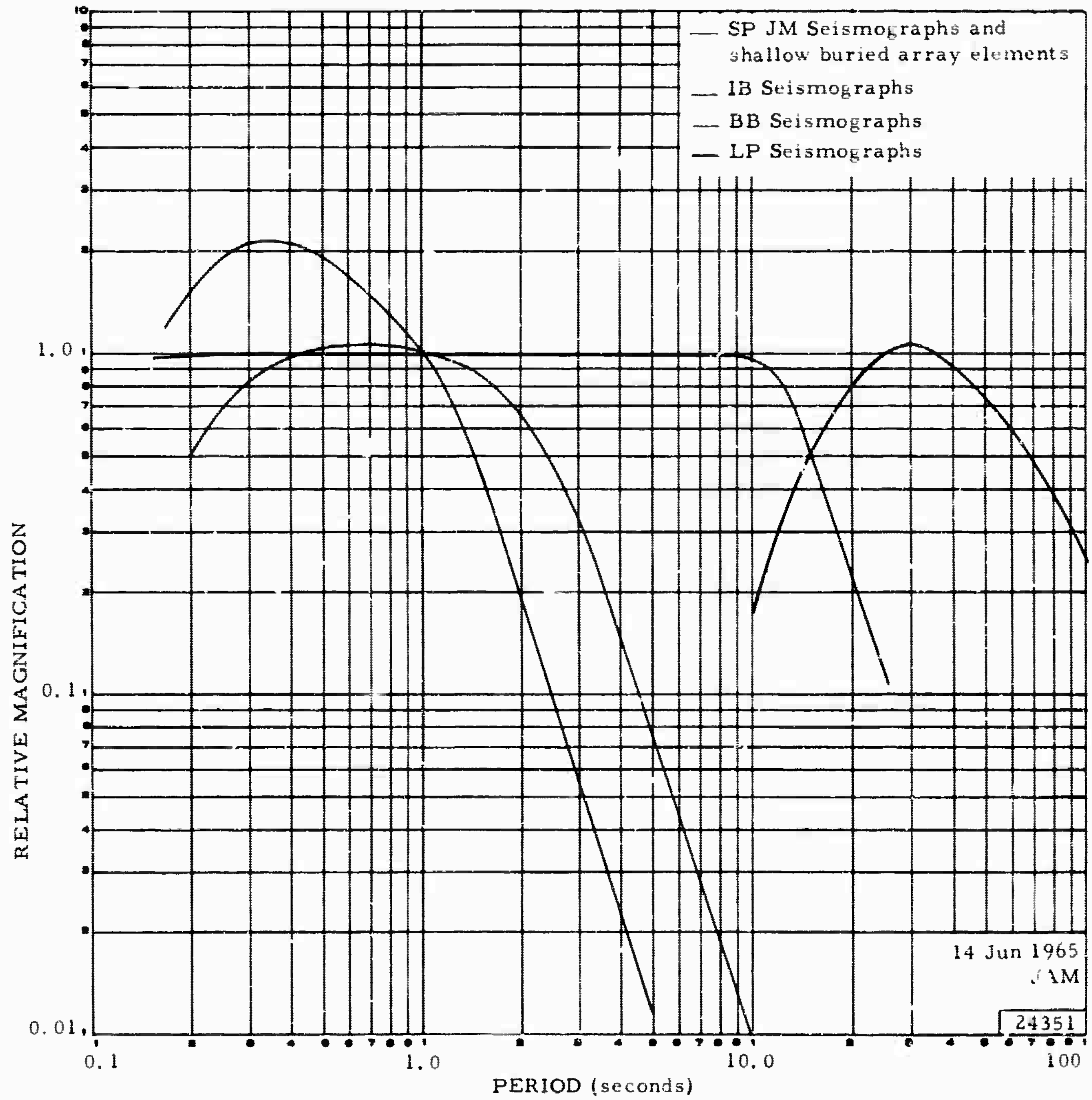

Figure 1. Normalized response characteristics of the routine seismographs at BMSO and UBSO during the reporting period

rheostat in the remote power control unit at the CRB was damaged. The telephone termination box in the CRB, the termination unit on the pole outside the CRB, and the line from the pole to the CRB were all severely damaged by the strike.

After the storm on 7 June, we decided to modify the lightning protectors at the seismometer-PTA end of the spiral-four cables in the shallow-buried array. The lightning protection circuit at the PTA consists of a fuse in series with each of the lines, and carbon blocks to ground on either side of the fuse. To reduce the number of fuses lost during severe storms, a carbon block with a smaller gap was installed on the line side of the fuse. Lightning-induced voltage surges on the data line near the PTA will now tend to discharge through the smaller gap, possibly decreasing the number of fuses destroyed.

2.4 DATA CHANNEL ASSIGNMENTS AND STANDARD OPERATING MAGNIFICATION OF SEISMOGRAPHS

In compliance with AFTAC specifications, each data format recorded at each observatory is assigned a data group number. When a data format is changed, a new data group number is assigned to the new format. All of the data formats and their group numbers, recorded during the reporting period at BMSO, are listed in table 3; data formats and data group numbers recorded at UBSO during this reporting period are listed in table 4.

2.5 EQUIPMENT MALFUNCTIONS

Component failure information is routinely punched onto IBM cards. A program, PROGRAM MISERABLE, has been written to tabulate some of these data. A printout of the tabulated data for BMSO and UBSO for the reporting period is shown in tables 5 and 6. The interpretation of the codes used is given in appendix 2 of this report.

2.6 CALIBRATION OF TEST EQUIPMENT

Routine calibration of test equipment was accomplished at each observatory during the reporting period. The 1-percent standard meter used at BMSO to calibrate test equipment was returned to the Garland laboratory for inspection.

Table 3. Data channel assignments and normal operating magnifications of seismographs at BMSO

DEVELOCORDERS

Fast speed, [illegible] mm/minute

Primary data Channel	Primary data Data group 4002 1 May to 31 July	Primary data Mag	Secondary data Channel	Secondary data Data group 4009 1 May to 31 July	Secondary data Mag
1	V	19K	1	V	1K
2	Z1	750K	2	Z3	1500K
3	Z4	750K	3	Z3L	70K
4	Z7	750K	4	NSL	70K
5	Z2	750K	5	ESL	70K
6	Z5	750K	6	ΣQ	1000K
7	Z6	750K	7	ΣA	1000K
8	Z8	750K	8	ΣB	1000K
9	Z9	750K	9	ΣC	1000K
10	Z10	750K	10	MS	—
11	ΣSF	5000K	11	WI	—
12	ΣS	2500K	12	ΣS	4000K
13	Z3	750K	13	ZIB	60K
14	NSP	750K	14	NIB	60K
15	ESP	750K	15	EIB	60K
16	WWV	—	16	WWV	—

Slow speed, 3 mm/minute

Channel	Data group 4005 1 May to 31 July	Mag
1	WI	—
2	MS	—
3	ZLL	1K
4	NLL	1K
5	ELL	1K
6	ZLP	15K
7	NLP	10K
8	ELP	10K
9	ML	—
10	ZBB	5K
11	NBB	5K
12	EBB	5K
13	Z8	600K
14	WWV	—

MAGNETIC-TAPE RECORDERS

Primary data Channel	Primary data Data group 4007 1 May to 31 July	Secondary data Channel	Secondary data Data group 4001 1 May to 31 July
1	TCDMG	1	TCDMG
2	Z1	2	ZLP
3	Z2	3	NLP
4	Z3	4	ELP
5	Z4	5	NSP
6	Z5	6	ESP
7	Comp	7	Comp
8	Z6	8	ZIB
9	Z7	9	NIB
10	Z8	10	EIB
11	Z9	11	ZBB
12	Z10	12	NBB
13	ΣSF	13	EBB
14	WWV	14	WWV

KEY

Z	Amplified vertical short-period seismograph from a site identified by a suffix number
Z3L	Amplified vertical short-period low-gain seismograph - number denotes seismometer site
ZIB	Vertical intermediate band seismometer
ZLL	Vertical long-period low-gain seismograph
ZLP	Vertical long-period seismograph
ZBB	Vertical broad-band seismograph
V	Unamplified vertical short-period seismograph
ΣSF	ΣS filtered
ΣS	Summation of Z1 through Z10
ΣQ	Summation of Z4, Z5, & Z8
ΣA	Summation of Z1, Z3, & Z5
ΣB	Summation of Z2, Z4, & Z6
ΣC	Summation of Z7, Z8, Z9, & Z10
NSP	Amplified north-south short-period seismograph
NSL	North-south short-period low-gain seismograph
NIB	North-south intermediate-band seismograph
NLL	North-south long-period low-gain seismograph
NLP	North-south long-period seismograph
NBB	North-south broad-band seismograph
ESP	Amplified east-west seismograph
ESL	East-west short-period low-gain seismograph
EIB	East-west intermediate-band seismograph
ELL	East-west long-period low-gain seismograph
ELP	East-west long-period seismograph
EBB	East-west broad-band seismograph
MS	Microbarograph - short-period
WI	Anemometer - wind speed & direction
ML	Microbargraph - long-period
WWV	Radio time
Comp	Compensation
TCDMG	Time code management data group
Mag	Magnification (see note)
Note:	Magnification of: Short-period measured at 1 Hz; Intermediate-band measured at 1 Hz; Broad-band measured at 0.8 Hz; Long-period measured at 0.04 Hz

Table 4. Data channel assignments and normal operating magnifications at UBSO

DEVELOCORDERS

Fast speed, 30 mm/minute

SP Primary			SP Secondary				
Channel	Data group 5000 1 May to 31 July	Mag	Channel	Data group 5018 1 May to 13 June	Mag	Data group 5020 14 June to 31 July	Mag
1	V	24K	1	V	1K	V	1K
2	Z1	600K	2	Z10	1200K	NEP	1.5K
3	Z3	600K	3	ΣQ	1200K	EEP	1.8K
4	Z5	600K	4	Z1	600K	ΣQ	750K
5	Z2	600K	5	SH1	2400K	Z1	650K
6	Z4	600K	6	SH1L	500K	SH1	2000K
7	Z6	600K	7	ΣSF	6000K	SH1L	600K
8	Z7	600K	8	DH1	2000K	ΣSF	6000K
9	Z8	600K	9	DH1L	600K	DH1	2000K
10	Z9	600K	10	ΣS	3000K	DH1L	600K
11	ΣSF	6000K	11	ZIB	50K	ZIB	50K
12	ΣS	1550K	12	NIB	50K	NIB	50K
13	Z10	600K	13	EIB	50K	EIB	50K
14	NSP	600K	14	MS	—	MS	—
15	ESP	600K	15	WI	—	WI	—
16	WWV	—	16	WWV	—	WWV	—

Slow speed, 3 mm/minute			Shallow-buried array		
Channel	Data group 5004 1 May to 31 July	Mag	Channel	Data group 5016 1 May to 31 July	Mag
1	WI	—	1	SZ10L	100K
2	MS	—	2	SZ1	600K
3	ZLL	2K	3	SZ3	600K
4	NLL	2K	4	SZ5	600K
5	ELL	2K	5	SZ2	600K
6	ZLP	40K	6	SZ4	600K
7	NLP	20K	7	SZ6	600K
8	ELP	20K	8	Test	—
9	Test	—	9	ΣSSF	6700K
10	ML	—	10	ΣSS	1600K
11	ZBB	2.5K	11	SZ7	600K
12	NBB	2.5K	12	SZ8	600K
13	EBB	2.5K	13	SZ9	600K
14	SZ	350K	14	SZ10	600K
15	Test	—	15	WI	—
16	WWV	—	16	WWV	—

MAGNETIC-TAPE RECORDERS

No. 1		No. 2		No. 3	
Channel	Data group 5007 1 May to 31 July	Channel	Data group 5011 1 May to 31 July	Channel	Data group 5013 1 May to 31 July
1	TCMDG	1	TCMDG	1	TCMDG
2	Z1	2	ZLP	2	SZ1
3	Z2	3	NLP	3	SZ2
4	Z3	4	ELP	4	SZ3
5	Z4	5	NSP	5	SZ4
6	Z5	6	ESP	6	SZ5
7	Comp	7	Comp	7	Comp
8	Z6	8	ZIB	8	SZ6
9	Z7	9	Test	9	SZ7
10	Z8	10	Z1	10	SZ[illegible]
11	Z9	11	ZBB	11	SZ9
12	Z10	12	SH1	12	SZ10
13	ΣSF	13	DH1	13	ΣSSF
14	WWV	14	WWV	14	WWV

KEY

Z	Amplified vertical short-period seismograph from a site identified by a suffix number
ZIB	Vertical intermediate-band seismograph
ZLL	Vertical long-period low-gain seismograph
ZLP	Vertical long-period seismograph
ZBB	Vertical broad-band seismograph
V	Unamplified vertical short-period seismograph
ΣSF	ΣS filtered
ΣQ	Summation of Z4, Z5, & Z8
ΣS	Summation of Z1 through Z10
ΣSSF	ΣSS filtered
ΣSS	Summation of SZ1 through SZ10
NSP	Amplified north-south short-period seismograph
NIB	North-south intermediate-band seismograph
NEP	Unamplified north short-period seismograph
NLL	North-south long-period low-gain seismograph
NLP	North-south long-period seismograph
NBB	North-south broad-band seismograph
ESP	Amplified east-west seismograph
EIB	East-west intermediate-band seismograph
EEP	Unamplified east short-period seismograph
ELL	East-west long-period low-gain seismograph
ELP	East-west long-period seismograph
EBB	East-west broad-band seismograph
SH	Seismometer in 500 ft hole
	Number with SH or DH indicates 1st or 2nd seismometer in hole
DH	Seismometer in 10,000 ft hole
SZ10L	Amplified vertical short-period low-gain seismometer in a hole
SZ	Amplified vertical short-period seismometer in a hole at a depth of 200 ft
WWV	Radio time
MS	Microbarograph - short-period
WI	Anemometer - wind speed & direction
Test	Test instrumentation
Comp	Compensation
Mag	Magnification (see note)
TCMDG	Time code management data group
Note:	Magnification of:
	Short-period measured at 1 Hz
	Intermediate-band measured at 1 Hz
	Broad-band measured at 0.8 Hz
	Long-period measured at 0.04 Hz

Table 5. Component failure report for BMSO

Specific function	Model No.	Sub assembly	No. serviced	Repair time	Time inop	Prevent.	Catas.	Component	No.
PS	(4304)		1	.1	.1	1	0	V102	1
VR	(760R)		2	7.0	4.0	0	2	Q33 Q32	1 1
DEV	(4000)		1	.5	.5	1	0	B306	1
HE	(2484-1)		2	2.1	15.2	1	1	STYLUS BXXX	1 1
TR	(7360)	OSC	8	2.9	2.9	8	0	V103 V101 V102	1 5 2
PR	(11395)		1	.4	.4	0	1	F101	1
DSC	(10821)		2	.2	.2	2	0	V302 V303	1 1
MPD	(12322)		1	.1	17.6	0	1	F104	1

Table 6. Component failure report for UBSO

Specific function	Model No.	Sub assembly	No. serviced	Repair time	Time inop	Prevent.	Catas.	Component	No.
PTA	(4300)		4	.8	.8	2	2	V101 V102 V103 GALVO	1 1 1 1
PTA	(12613-1)		3	1.1	6.1	2	1	DS101 V102 V101	1 1 1
PS	(LH124FM)		1	3.0	6.0	0	1	Q10	1
PS	(4304)		1	.1	.1	0	1	V201	1
RPC	(11901)		1	.1	12.0	0	1	DSXXX	1
	(4000)		1	.1	.1	0	1	DS601	1
SP	(7515)		1	1.0	144.0	0	1	CALBN COIL	1
MOC	(10380)		3	1.2	18.0	0	3	V401 V402 V403	1 1 1
FV	(6585)		2	.4	.1	0	2	DS201 F102	1 1

The meter did not require recalibration and was returned to BMSO. The standard meter used at UBSO will be sent to Garland for laboratory tests soon. A dual equipment calibration record/log for each item of test equipment has been kept up to date by the observatories and the Garland laboratory during the reporting period.

2.7 SHIPMENT OF DATA TO SEISMIC DATA LABORATORY (SDL)

BMSO and UBSO magnetic-tape seismograms from 1 April through 31 May were shipped to SDL. Magnetic-tape seismograms are shipped to SDL with the regular LRSM shipment of data about 15 days after the end of the month during which they were recorded.

All 16-millimeter film seismograms recorded at BMSO and UBSO through 31 May were sent to SDL. The primary and secondary short-period and the long-period 16-millimeter film seismograms and their corresponding operating logs were shipped to SDL as soon as the data for the monthly five-station earthquake bulletin were compiled.

2.8 SECURITY INSPECTION

Security procedures and facilities at UBSO were reviewed by Mr. Calvin C. Gorham, USAF-WCWR, on 21 July. Mr. Gorham discussed the procedures required for handling classified documents that might be received at the observatory. Current security procedures at UBSO were satisfactory.

3. EVALUATE DATA AND PROVIDE MOST EFFECTIVE OBSERVATORY POSSIBLE

3.1 MODIFICATIONS AND ADDITIONS TO INSTRUMENTATION AT BMSO AND UBSO

During this reporting period Helicorder modifications were completed at both observatories. The objective of these modifications is to flatten the frequency response of the Helicorder so that it will be a more suitable monitoring device.

Installation of the peristaltic pumps and one date timer at UBSO was completed in July. These modifications are expected to improve the quality of the film seismograms and reduce the maintenance time required by the Develocorders.

Engineering plans for other modifications and additions to the instrumentation at the observatories are in various stages of completion. Equipment required for the remaining changes and additions is being assembled and delivered to the observatories as it becomes available.

3.2 PHASE-SHIFT MEASUREMENTS AT UBSO

During this reporting period, phase-shift measurements were made on the 10-vertical short-period seismographs at UBSO under another program. Additional phase-shift measurements were made on 10-element shallow-buried array seismographs under Project VT/5054. These measurements were taken late in June 1965 midway between the June and July frequency response calibrations. The July frequency responses indicated that all seismographs were within the allowable tolerance; thus we assumed that the frequency response of each seismograph was in tolerance at the time the phase-response measurements were made. The phase-response was measured in all cases by comparing the phase of the input calibration current to that of the PTA output voltage using a Variable-Phase-Function Generator, Hewlett-Packard, Model 203A. The mean phase response and the maximum and average deviations from the mean are shown in figures 2 through 4. The actual phase-measurement data for each seismograph are shown in tables 7 and 8. All seismographs were within the $\pm 4.5^{\circ}$ tolerance at 1 Hz against which the seismographs are checked on a monthly basis. The buried array generally shows less deviation from the mean than does the surface array. These reduced deviations, especially at 3-5 Hz, are primarily attributed to improved features in the Model 12613 PTA used in the buried array compared to the features in the Model 4300 PTA used in the surface array. The use of adjustable galvanometer damping controls and the absence of long data lines are also believed to contribute to the decreased deviations in the buried-array data.

3.3 STABILITY OF CALIBRATORS IN THE UBSO SHALLOW-BURIED ARRAY

In January 1965, when the shallow-buried array at UBSO was initially installed the equivalent weights of the weight-lift calibrators in the seismometers were

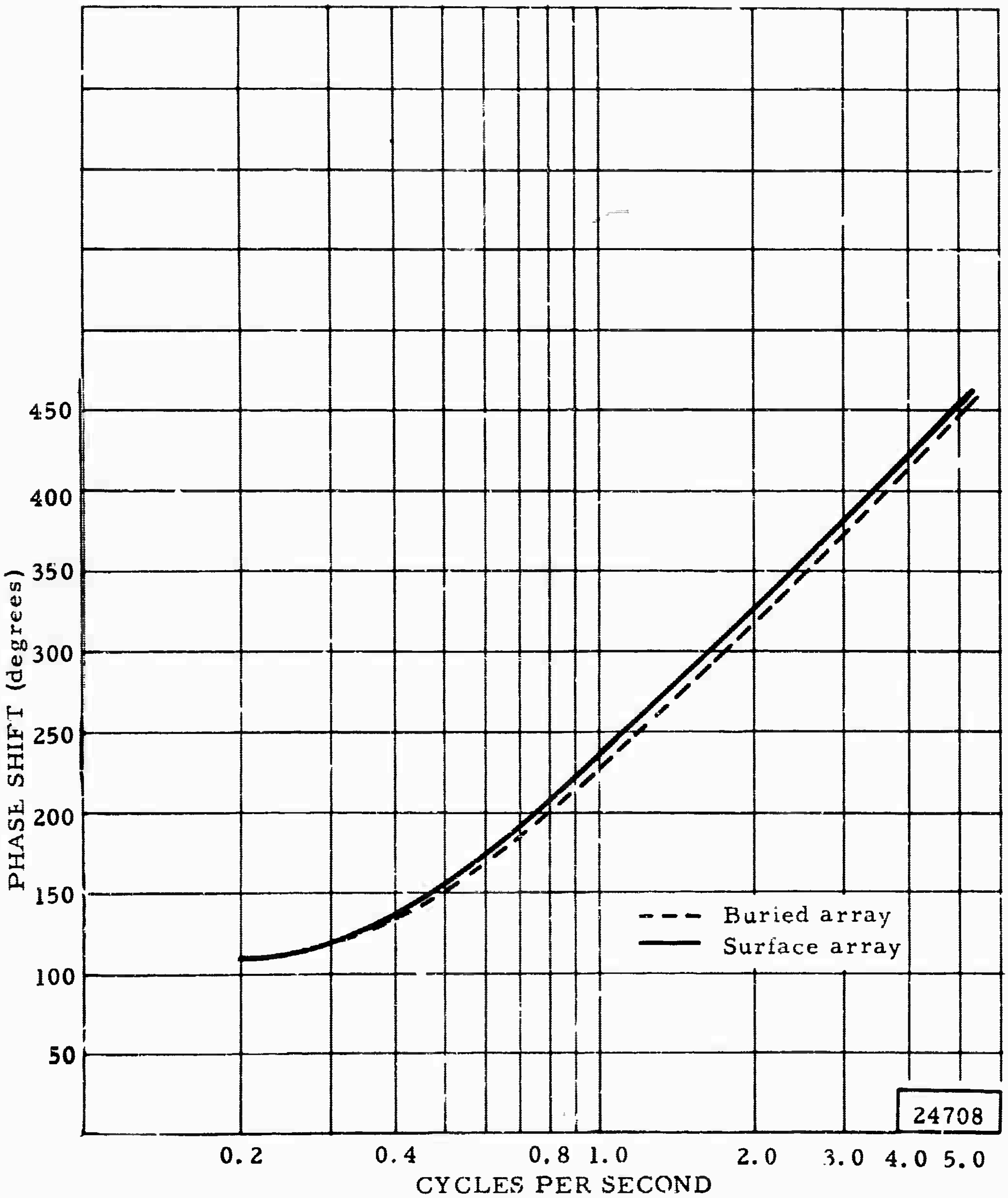

Figure 2. Mean phase response of the surface array seismographs and the shallow-buried array seismographs at UBSO

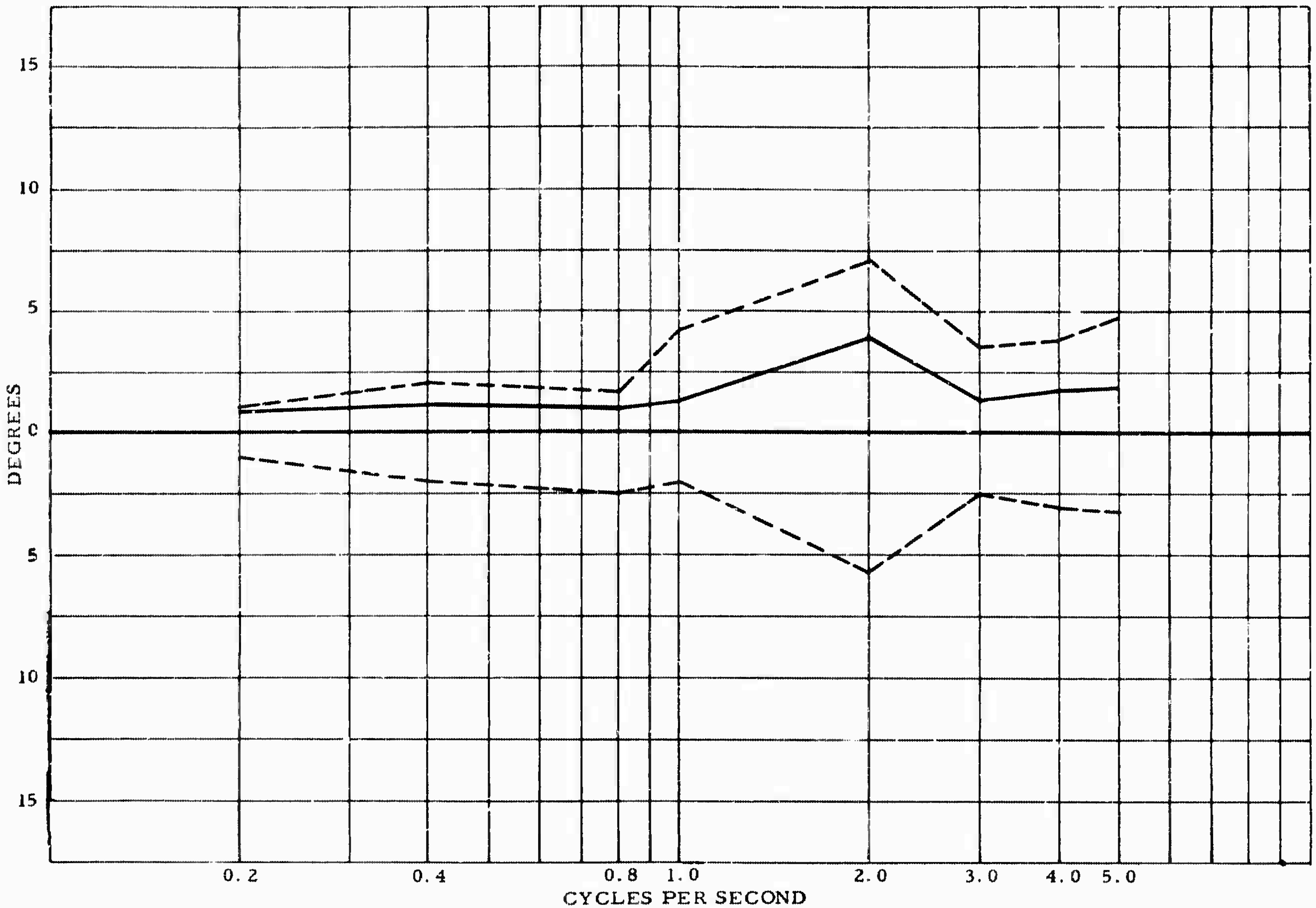

Figure 3. Maximum positive, maximum negative, and average deviation from the mean phase response for the surface array seismographs at UBSO

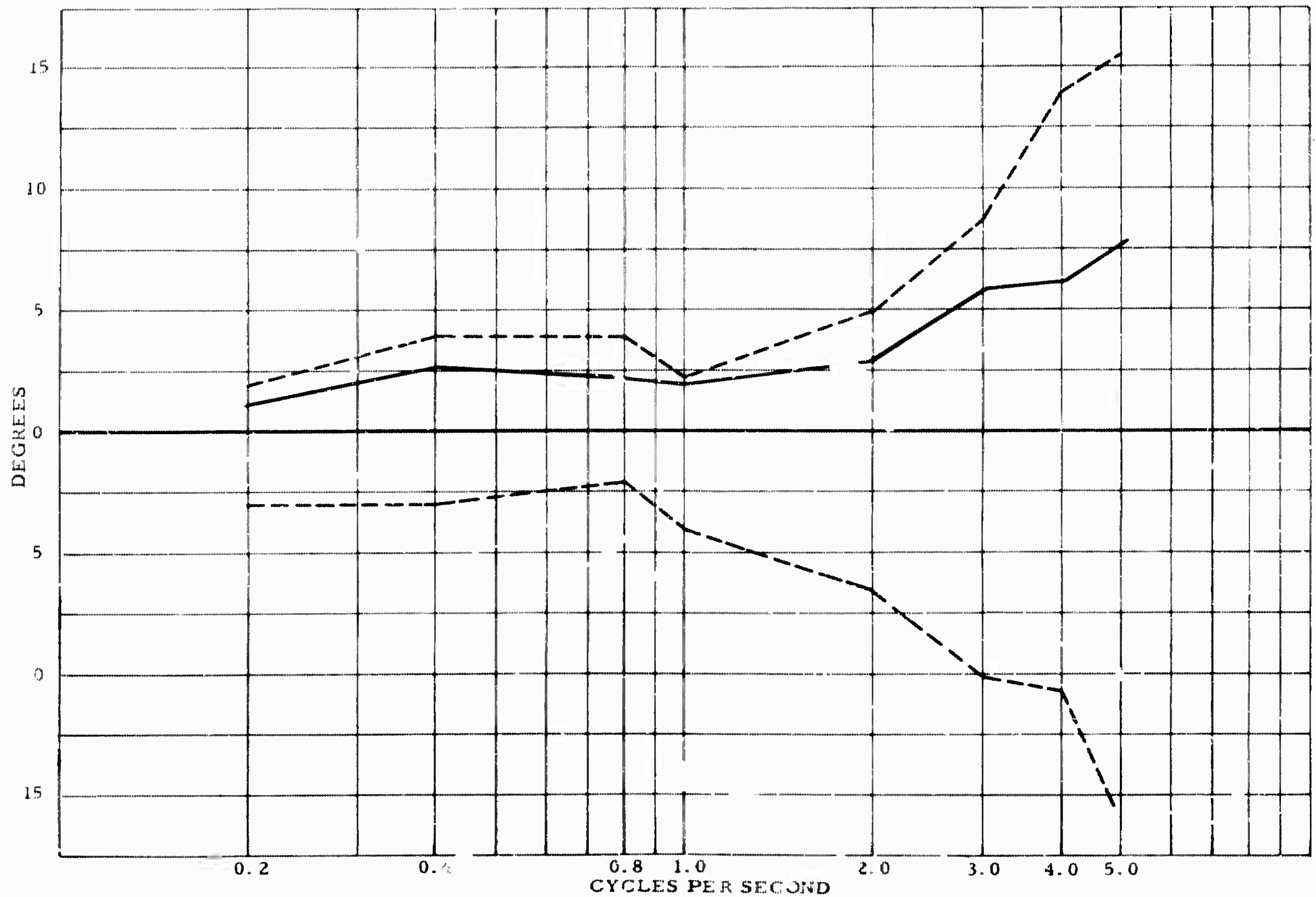

Figure 4. Maximum positive, maximum negative, and average deviation from the mean phase response for the shallow-buried array seismograph at UBSO

Table 7 Phase response measurement data for Johnson-Matheson vertical ten-element surface array at UBSO

Seismograph	1	2	3	4	5	6	7	8	9	10
Frequency in cps	Degrees shift									
0.2	110	113	108	113	112	111	111	112	110	111
0.4	140	139	136	142	138	138	135	139	137	138
0.8	210	210	206	212	210	210	206	207	206	206
1.0	244	244	243	243	242	242	240	238	240	239
2.0	329	328	330	324	323	323	321	328	323	320
3.0	390	389	390	382	380	380	374	371	380	376
4.0	438	424	437	427	423	423	415	412	422	419
5.0	463	465	470	458	454	454	443	438	452	450

Table 8 Phase response measurement data for ten-element shallow-buried array at UBSO

Seismograph	1	2	3	4	5	6	7	8	9	10
Frequency in cps	Degrees shift									
0.2	110	109	111	110	109	109	111	109	111	109
0.4	136	136	137	137	135	134	138	135	138	134
0.8	203	205	203	203	204	202	205	203	205	201
1.0	234	240	235	236	236	235	237	234	236	235
2.0	316	322	319	329	329	318	317	327	321	320
3.0	372	374	373	323	376	375	374	374	378	375
4.0	416	415	415	414	420	417	417	418	421	418
5.0	446	444	444	445	448	447	447	449	452	448

determined before they were placed in the shallow holes. This was done by comparing deflections produced by 200-mg weight lifts. The equivalent weights of the weight-lift calibrators were again tested late in January 1965 after the seismometers were installed in the holes. In the later tests, the deflections caused by remote actuation of the weight-lift calibrator were compared with deflections caused by current step functions in the electromagnetic (EM) calibrator coils.

The average difference in equivalent weights determined by the two mehtods was 2.8 percent and all differences were less than 6 percent. An agreement of less than 6 percent was considered satisfactory. Several factors contributed to the observed discrepancies. These include reading inaccuracies and minor calibration control unit which monitors the current through the EM calibrator.

The equivalent weight of the weight-lift calibrator is slightly dependent on the position of the seismometer mass. A ± 25 percent displacement of the mass from its center position will result in a 3 percent change in equivalent weight. The mass position changed slightly after the instrument had been lowered into the hole; but tests indicated that the mass was still within the established tolerance of ± 1.6 mm (25 percent of total travel). If the mass moved from center position at the surface to ± 1.6 mm of center when lowered into a hole a change of 3 percent would be observed in the equivalent weight.

In addition, tests conducted at WMSO have proved that the best reading accuracy that can be expected when the measurements are taken from Helicorder records is 0.5 percent. To make the comparison, outlined in the first part of this section, four measurements were necessary; thus the possible reading error was ± 2 percent.

During the early part of May, remote weight-lift tests were again conducted at UBSO to determine the combined stability of the weight-lift calibrators and the EM calibrators in the seismometers for the buried-array seismographs. A comparison was made between the equivalent weight measured immediately after the seismometer was installed and the present equivalent weight as computed from the recent test data. Table 9 shows the percentage change that has occurred since the initial installation.

Table 9 Equivalent weight test data

Instrument	Serial No.	Equivalent weight after installation (mg)	Equivalent weight measured 4 May (mg)	Change percentage
SZ1	574	42.0	41.6	-0.95
SZ2	576	41.2	42.3	+2.9
SZ3	473	43.5	Weight-lift calibrator inoperative	
SZ4	577	44.0	42.4	-3.6
SZ5	477	44.5	45.0	+0.11
SZ6	573	45.0	44.5	-0.12
SZ7	479	46.0	45.1	-1.9
SZ8	478	44.3	43.9	-0.95
SZ9	578	46 6	47.7	+0.22
SZ10	480	42.3	43.7	+3.3

The percentage of change in the calculated equivalent weights from late in January until May 1965 is considerably less than that observed for the interval in January during which the seismometers were lowered into the holes. This should be expected because the first two measurements were influenced by the environmental changes which occur in lowering the instruments into the hole. The latter two measurements lapse a period of time when the instruments environment was stable.

The weight-lift calibrator was originally intended for checking the motor constant (G) of the EM calibrator and the polarity of a seismograph. Operational requirements for an observatory stipulate that G be checked periodically and adjusted to within ± 3 percent of a mean value for an array. Because changes of up to 6 percent have been observed in the calculated equivalent weight since a manual weight-life was actually made, the weight-lift calibrator in its present state is not satisfactory for detecting minor changes in G. It may be possible to determine the deviations in equivalent weight caused by the mass position deviations. If this can be reliably determined, the usefulness of the weight-lift calibrators would be increased. An investigation will be made to determine if such a procedure can be established and if improvements should be made to the weight-lift calibrators.

4. TRANSMIT DAILY MESSAGES TO THE USC&GS

In August 1964, we were requested to furnish data to the USC&GS on possible depth phases in addition to those which are readily identifiable. On 28 June 1965, we were requested to terminate this procedure and report only those pP phases which can be identified.

Arrival times, periods, and amplitude measurements recorded at each observatory are reported daily to the Director of the USC&GS in Washington, D.C. A list of the number of events of all types reported to the USC&GS by BMSO and UBSO during this reporting period is included in table 10.

Table 10. Locals (L), Near-regionals (N), Regionals (R), and Teleseisms (T) reported to the USC&GS by BMSO, from 1 May through 31 July

	Month	L	N	R	T
BMSO	May	70	69	4	433
	June	65	68	15	602
	July	93	97	15	670
UBSO	May	13	307	18	861
	June	10	301	31	1145
	July	24	388	41	883

5. PUBLISH MONTHLY EARTHQUAKE BULLETIN

Data from BMSO and UBSO were combined with data from CPSO, TFSO, and WMSO and published in a multistation earthquake bulletin. The bulletins for December 1964 and January 1965 were published during this reporting period. Data for May have been keypunched, transcribed onto magnetic tape, and sent to SDL for processing.

In March 1965 a questionnaire was mailed with each earthquake bulletin. The questionnaire was intended to establish the usefulness of the earthquake bulletin to those who receive it. The questionnaire asked and the replies received during during this reporting period follow:

	Yes	No
1. Do you consider the data useable for research studies?	36	0
2. Have you used the information in previous work?	29	7
3. Are you using the information in present work?	30	6
4. Do you plan to use the information in future work?	32	4
5. Do you want to continue receiving these reports?	31	5
6. Is your copy being properly addressed? If not, please give the proper address.	32	4
7. Any comments, suggestions, or criticisms you have about the publication will be appreciated.		

6. PROVIDE OBSERVATORY FACILITIES TO OTHER ORGANIZATIONS

6.1 GENERAL

Both observatories continued to cooperate with Stanford Research Institute (SRI) in their study of aftershocks of continental earthquakes. They reported to SRI by telephone all earthquakes detected that occurred within the Continental United States throughout this reporting period. On July 27, we were notified by SRI that our earthquake reports to them were no longer necessary as they had finished their current earthquake study.

Data have been furnished to the USC&GS by all observatories on several occasions when the USC&GS requested information about specific arrivals This is in addition to the routine daily report to the USC&GS.

6.2 VISITORS

Mr. Edward Cooper of Bell Telephone Laboratory was at BMSO from 14 June to 16 June to install the classified spectrum analyzer.

The deep hole facilities at UBSO were made available to Dr. Gene Simmons of SMU. Dr. Simmons ran a temperature profile of the deep hole. This information will be sueful for the vertical array work scheduled for early fall.

Captain Clent Houston, Captain Fred Munzlinger, and B. B. Leichliter visited UBSO on 24 and 25 June and BMSO on 26 June 1965. The purpose of this visit was to familiarize the newly assigned Project Officer, Captain Munzlinger, with the operation of the two observatories.

7. INSTRUMENT EVALUATION

7.1 INSTALLATION OF MULTIPLE ARRAY PROCESSOR AT UBSO

Installation requirements for the multiple array processors (MAP) to be installed at UBSO were coordinated with Texas Instruments personnel during June. Present facilities at UBSO are adequate to accommodate the MAP system power and space requirements. TI personnel will provide approximately 40 hours of operation, interpretation, and maintenance instructions for station personnel.

7.2 INSTALLATION OF THE CLASSIFIED BELL TELEPHONE LABORATORY (BTL) SPECTRUM ANALYZER

Installation of the classified BTL spectrum analyzer at BMSO was completed in mid-June. A representative of BTL was at BMSO from 14 June to 16 June to assist in the installation of the analyzer and the instruction of station personnel in its operations.

Data from the vertical short-period seismograph Z8 and the vertical long-period seismograph are being monitored by the spectrum analyzer. Data records made from 17 June to 28 June were sent to SDL; data commencing with 28 June records were sent weekly.

W. S. Mitcham of our Garland laboratory spent 15 and 16 June at BMSO with Mr. Cooper. Mr. Mitcham's report on the system was sent to the Project Officer.

7.3 EVALUATION OF SHORT-PERIOD FM PHOTOTUBE AMPLIFIER, MODEL 12613, AS A LONG-PERIOD AMPLIFIER

In conjunction with work on the proposed long-period array at UBSO, (Section 9.3), tests were conducted on a FM Phototube Amplifier (PTA), Model 12613, to determine the feasibility of its use as a long-period amplifier.

The FM PTA was modified to have a flat response to periods under 200 sec (3-dB down at 300 sec). A passive filter with the same frequency response as a 110-sec critically damped galvanometer was used in conjunction with a Hewlett-Packard, Model 425A Amplifier to provide the same response normally acquired from a long-period PTA. A standard long-period seismometer (Model 8700C) with a 50-ohm data coil was directly coupled to a standard 5-Hz galvanometer in the PTA. The clipping level was 15 μ at 5 sec periods; the measured noise level in the approximate period range of 25 to 50 seconds was 62.5 mμ. The noise amplitudes increased slowly with period up to approximately 120 seconds. At periods greater than 120 sec the noise increased approximately proportional to period. The unfiltered 1/f noise had the appearance of discrete pulses, caused by random changes in the emitter firing voltage of the unijunction transistor used as a relaxation oscillator. The pulses could be observed as changes of 0.2 Hz in the carrier frequency with random durations at random intervals. Substitution of other transistors in the same circuit eliminated the discrete pulses and the rapid onset of 1/f noise, but all transistors that were on hand at the time had higher noise levels in the 25 sec region than the original transistor so that no improvement in the band of interest could be obtained.

Other tests indicated that a 1.0 mfd capacitor shunted across each phototube causes the voltage at the phototube junction to vary exactly as the output of a simple RC low-pass filter section with a cut-off period of 100 sec. Therefore, half of the filtering necessary to simulate the galvanometer can be done at the phototubes. The phototubes and optical system have a dynamic range approximately 30 dB greater than the remainder of the PTA, therefore, filtering at the phototubes can be used to effectively provide a 14 dB increase in the clipping level at 25-sec period. To accomplish this, more voltage amplification is needed than is available in the low-level amplifier section in the PTA. Either an additional stage of amplification or the adaptation of the amplifier section used in the analog version of the PTA would provide the necessary amplification.

In our opinion, a long-period system using the modified PTA would provide better overall performance under average field conditions than other available amplifiers at magnifications of approximately 25 to 50K. The input noise level would be somewhat higher than that which could be obtained from the use of a long-period galvanometer under ideal conditions, but lower than that which can be obtained using other flat amplifiers such as the RA5 for which to our knowledge there is no effective method of filtering at the input. Under remote conditions as an unattended system (except for periodic calibration and maintenance), the higher noise level would be more than compensated for by increased stability and reliability. In addition, the use of FM transmission would result in decreased spurious noise reception and would require less effort for line installation and maintenance.

8. RESEARCH INVESTIGATIONS

8.1 STUDIES TO DETERMINE P-PHASE TRAVEL TIME CORRECTIONS FOR BMSO, CPSO, TFSO, UBSO, AND WMSO

Preliminary P arrival residual data for BMSO, CPSO, TFSO, UBSO, and WMSO were gathered under Project VT/1124 and were used to determine the P phase association time-window widths for the ABP. The travel-time residuals, grouped by observatory, were further classified by epicentral distance (10-degree increments), USC&GS reported magnitude, and station-to-epicenter azimuth.

Utilizing the data already processed, we are determining "unbiased" travel-time corrections for each of the five observatories. In addition, the variation of station travel-time corrections as a function of station-to-epicenter azimuth is being studied.

The effectivness of each of the correction factors developed will be determined using data from each observatory recorded since August 1964. We anticipate that this study, including a report of the results, will require approximately 12 months.

8.2 MAGNITUDE CORRECTION FACTORS

On 23 July, we submitted an outline and requested approval of a planned study designed to refine the estimates of station magnitude correction factors developed under Project VT/036 and reported in TR 64-123, and to refine the distance-depth magnitude correction factors developed by Gutenberg and Richter. We plan to conduct this study jointly under Projects VT/5054 and VT/5055 using teleseismic P phase data recorded at the five VELA-UNIFORM seismological observatories.

8.3 UBSO ATLAS OF SIGNALS AND NOISE

During July we submitted an outline of our plans to compile an atlas of signals and noise recorded at UBSO. In general, the atlas would include sections on the following:

- Introduction;
- Earthquake phases recorded at UBSO;
- P and PKP phases from various distances and azimuth from UBSO;
- Representative noise samples.

We estimate that the atlas, if approved, will be ready for distribution in March 1966.

8.4 AUTOMATED BULLETIN PROCESS

The Automated Bulletin Process (ABP) outputs of January, February, and March 1965 data, were received from SDL during this reporting period. These data were reviewed and based on these reviews, we made recommendations for refining the ABP.

At the present time, we plan to publish the five-station bulletin data through June 1965 using data processed by the existing ABP program, and to rewrite the ABP jointly with SDL in order to more efficiently integrate the original ABP program and subsequent refinements of the program. We are coordinating with AFTAC and SDL so that, if possible, the new ABP program will be available for processing the July 1965 bulletin data.

9. REPORTS AND DOCUMENTS

9.1 Forty copies of Geotech Technical Report No. 65-28, - Installation of a 10-Element Shallow-Buried Array at the Unita Basin Seismological Observatory Vernal Utah, were distributed on 5 May.

9.2 Three copies of the routine monthly microseismic noise data for BMSO, CPSO, and WMSO were sent to the Project Officer on 10 May.

9.3 On 20 May, we were requested to reconsider our initial recommendations for the installation of a four-element array of long-period seismographs at UBSO. We reviewed our recommendations in light of both the long-period array data that will be available from the LASA seismographs and the long-period data that will be available from the TFSO extended array. These considerations were summarized and presented in a letter to the Project Officer dated 4 June 1965.

9.4 A schedule for the transmittal of routine microseismic noise data to AFTAC was submitted to the Project Officer 8 June.

9.5 Three sets of cumulative probability-of-occurrence curves for miscroseismic noise recorded by the surface and shallow-buried array elements and summation seismographs at UBSO were sent to the Project Office on 25 June. Comparisons of microseismic noise data measured from surface array element Z10 operating at normal magnifications of 2000K and 4000K were also included.

9.6 Copies of TFSO special microseismic noise data for May 1965 were sent to the Project Officer on 24 July.

9.7 The final report for Project VT/1124 (TR 65-58) was being compiled for distribution at the close of this reporting period. Distribution was scheduled for the first part of August.

APPENDIX 1 to TECHNICAL REPORT NO. 65-99

STATEMENT OF WORK TO BE DONE

AFTAC PROJECT AUTHORIZATION NO. VELA T/5054

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STATEMENT OF WORK TO BE DONE

AFTAC Project Authorization No. VELA T/5054

1. Tasks.

a. Operation:

(1) Continue operation of the Blue Mountains Seismological Observatory (BMSO), ———————————————— ——— and Unita Basin Seismological Observatory (UBSO), normally recording data continuously.

(2) Evaluate the seismic data to determine optimum operational characteristics and make changes in the operating parameters as may be required to provide the most effective observatories possible. Addition and modification of instrumentation are within the scope of work. However, such instrument modifications and additions, data evaluation, and major parameter changes are subject to the prior approval of the AFTAC Project Officer.

(3) Conduct routine daily analysis of seismic data at each observatory and transmit daily seismic reports to the US Coast and Geodetic Survey, Washington D.C. 20230, using the established report format and detailed instructions.

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

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

(a) Completeness and accuracy of operation logs.

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

(c) Quality and completeness of voice comments.

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

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

(f) Measurement of DC unbalance.

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

(h) Check of uncompensated noise on each channel.

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

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

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

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

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

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

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

c. Special Investigations: Conduct research investigations as approved or requested by the AFTAC Project Officer to obtain fundamental information which will lead to improvements in the detection capability of each seismological observatory. In recommended multiobservatory research programs and those designed for the individual observatories, environmental and equipment differences that will exist among the observatories during the operational period should be considered.

These programs should take advantage of geological, meteorological, and seismological conditions unique to each observatory. Furthermore, the following expected and existing equipment differences could bear on the research programs:

(1) BMSO——— and UBSO - Surface array designs.

(2) BMSO - Digital spectrum analyzer with dual channel output of short-period and long-period spectrograms developed by Bell Telephone Laboratories, Incorporated (installation expected in fall of 1964).

(3) UBSO - Deep-well seismograph; 10-element array of shallow-borehole seismographs; multiple array processor (installation programmed summer 1965 under Project VELA T/5052; includes training in operation, maintenance, and calibration of the processor and in analysis techniques for appropriate UBSO personnel).

Research might pursue investigations in, but is not necessarily limited to, the following areas of interest: microseismic noise, signal characteristics, data presentation, detection threshold, and array design (surface and shallow borehole). Prior to commencing any research investigation, AFTAC approval of the proposed investigation and of a comprehensive program outline of the intended research must be obtained. Furthermore, research should be planned for completion during the contract period.

APPENDIX 2 to TECHNICAL REPORT NO. 65-99

COMPONENT FAILURE CARD KEYPUNCH FORMAT

COMPONENT FAILURE CARD KEYPUNCH FORMAT

1. Observatory or LRSM Team Code (columns 1-3)
   1.1 Observatory Codes
      a. BMØ
      b. CPØ
      c. TFØ
      d. UBØ
      e. WMØ

2. Date
   Date of failure in years and day of the year (columns 4-8) - i.e.,
   31 March 1964 - 64091

3. General Equipment Code 1-4 alphabetic characters (columns 9-12)
   3.1 General Function Code (column 9)
      a. S - Sensor
      b. P - 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. A - 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 21-24)

6. Subassembly Code - 1-4 alphabetic characters left justified (columns 25-28)

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. TSP - Transport

p. OSC - Oscillator

q. CSL - Channel selector

r. DISC - Discriminator

s. FDV - Frequency divider

t. SSCP - Stroboscope

u. CMOD - Control module

v. DT - Date timer

w. PASY - Pump assembly

x. MONT - Monitor

y. RCU - Remote centering unit

z. NKRG - Numerik 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 Alphabetic Characters, left justified (columns 43-53)
      a. Electrical or electronic component - use symbols designated in Military Standard 16B "Electrical and Electronic Reference Designations"
      b. Mechanical components - use abbreviated description for component

10. Component Part Number - Manufacturers Part Number
    1-10 alphanumeric characters right justified (columns 54-63)

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" parts 1 and 2
    Cataloging Handbook H4-1 and H4-2

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)

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