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TECHNICAL REPORT NO. 65-43

INTERPRETATION AND USAGE OF SEISMIC DATA, LONG-RANGE SEISMIC MEASUREMENTS PROGRAM

GEOTECH

THE GEOTECHNICAL CORPORATION

3401 SHILOH ROAD

GARLAND, TEXAS

2

TECHNICAL REPORT NO. 65-43

INTERPRETATION AND USAGE OF SEISMIC DATA, LONG-RANGE SEISMIC MEASUREMENTS PROGRAM

by

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THE GEOTECHNICAL CORPORATION
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25 May 1965

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ABSTRACT

This report provides information for the interpretation of data compiled under the Long-Range Seismic Measurements Program.

The report outlines the operations schedule and operational tolerances, and presents information necessary for interpreting calibrations, routine recordings, and special event data.

Particular emphasis is placed on the interpretation of data contained in special event composite records, prepared by the LRSM magnetic-tape laboratory.

The final section provides interpretive information about data obtained from the Portable Seismograph System, Model 19282 currently being integrated into the LRSM Program.

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INTERPRETATION AND USAGE OF SEISMIC DATA, LONG-RANGE SEISMIC MEASUREMENTS PROGRAM

1. INTRODUCTION

This report has been prepared to provide information for the interpretation of seismograph data compiled by The Geotechnical Corporation (Geotech) under Project VT/4051.

The Long-Range Seismic Measurements (LRSM) teams operate various combinations of seismograph systems; however, two basic systems (long- and short-period), each containing one vertical and two horizontal seismometers, comprise the standard LRSM instrumentation. In addition to the basic six-seismometer configuration, several stations operate arrays of vertical seismometers, and some operate deep-hole systems.

All seismometer outputs are amplified by phototube amplifiers and all data channels are recorded on 35-mm film and magnetic tape. Teams operating arrays or deep-hole systems also record with 16-mm film Develocorders.

Also included in this report is a section (Composite Records, Section 7) of interpretive data on composite records, which are single tapes or films made by combining segments of selected data from each of the operative LRSM observatories. These composites also contain data from observatories operated under programs other than LRSM.

Figure 1 is a simplified block diagram of the standard LRSM seismograph system.

2. OPERATIONS

2.1 ROUTINE SCHEDULE

With the exception of occasional special assignments, all LRSM teams operate in compliance with a standard daily operations schedule. In interpreting and

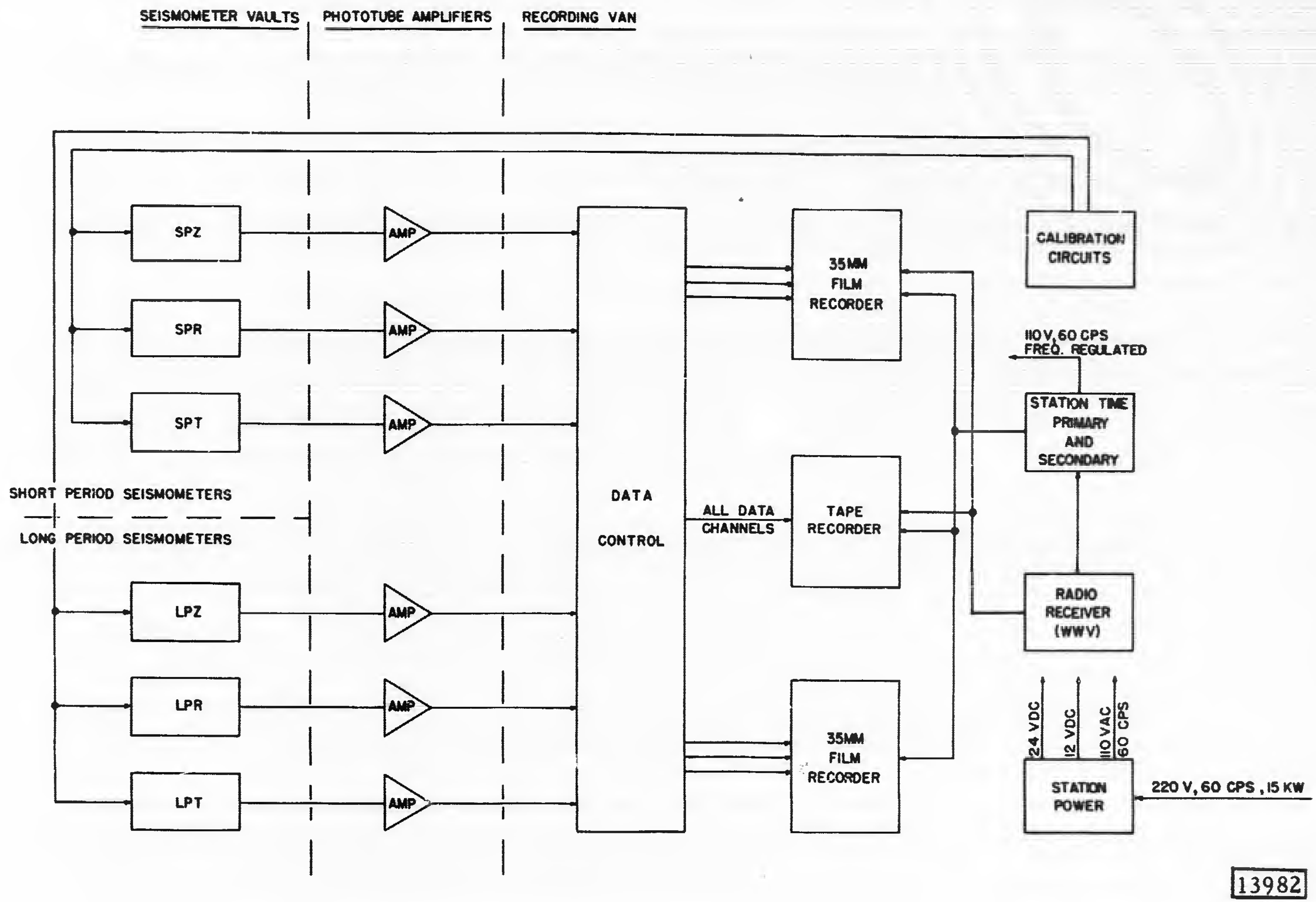


Figure 1. Simplified block diagram of the LRSM seismograph system

utilizing LRSM data, the user would benefit by having access to this daily operations schedule. Daily operational logs (discussed in section 2.3), which are provided with all data, are a useful adjunct to the operations schedule.

Table 1 is an abbreviated form of the LRSM teams' daily operational schedule. All routine operations which might affect the data are noted in the table. It should be noted that in some world time zones this schedule is modified for the convenience of team operators; additionally, during special recordings periods, the operations schedule may be superseded. In such cases, the user should rely on notations provided in the operational logs.

2.2 OPERATIONAL TOLERANCES

The LRSM teams maintain a strict tolerance limit on all equipment; thus, the user may, if he wishes, choose randomly any data from any LRSM team and be assured that the data are uniform and highly accurate.

Figure 2 is a reproduction of the operational tolerance chart which governs the setup and operation of equipment at LRSM teams.

2.3 OPERATIONAL LOGS

The daily operational logs are a necessity in the proper evaluation and interpretation of the seismograms and the magnetic tapes. All information pertinent to the data are recorded on the logs. The remarks section of each log is a particularly valuable aid, in that it gives information such as:

a. All outage times other than those established for record changes;

b. Special calibrations;

c. Special tests;

d. Any noticeable record anomaly;

e. Cultural and environmental noise;

f. System noise (60-cps pickup, air conditioner cycling, etc.,);

Table 1. Daily operational schedule

Time[1]	Operation	Notes
1700	All phototube amplifiers are balanced.	See section 6. 6.
1800	Short-period electromagnetic calibrations are accomplished.	See section 3. 4.
1805	Long-period electromagnetic calibrations are accomplished, followed by one long-period dc pulse (for phase response check).	See sections 3. 4 and 3. 2.
2200	Timing system adjustments are made.	See section 4.
2230	Tape system is aligned and calibrated with simultaneous voice comments.	Channels are aligned one at a time; see section 6. 8.
2330	End-of-run voice comments are recorded on tape.	
	Immediately after comments, tape is changed. Tape system is back in operation prior to 0000Z.	
0000	Time is coded on all recorders.	See section 4. 3.
	Immediately after coding, 35-mm film is removed and new film is loaded.	New film is positioned so that first hour marks (0100Z) will appear in the first six inches of the film.
0045	Short-period ball-lift calibrations are accomplished.	See section 3. 3.
	Immediately following short-period ball-lifts, long-period polarity checks are made.	See section 3. 1.
0100	Time is coded.	See section 4. 3.
	Voice comments are recorded on magnetic tape.	See section 6. 5.

[1]Times listed are Greenwich Mean Time.

	Item	Setup	Routine
1.	SP seis damping overshoot ratio	14:1 to 16:1	12:1 to 20:1
2.	SP seis free period	59.5 to 60.5 cpm	58 to 62 cpm; 46-50 JM
3.	SP average background noise level	2 mm (at X10) 60 mv (tape input)	same as setup same as setup
4.	SP calibration signal to background noise ratio	20:1 minimum	same as setup
5.	SP PTA linearity test	linear to 80% of clipping	same as setup
6.	SP PTA galvo balance	±.5 v	±.5v
7.	SP Mark II drum rate	.1 sec between any pair of 10 sec marks; .1 accumulative over 24 hrs	same as setup
8.	LP seis free period	19.5 to 20.5 sec/cycle	18.5 to 21.5 sec/cycle
9.	LP seis damping overshoot ratio	11.5:1 to 12.5:1	same as setup
10.	LP galvo free period	27 to 33 sec/cycle	same as setup
11.	LP galvo damping overshoot ratio	9.5:1 to 10.5:1	same as setup
12.	LP average background noise level	>5<10 mm (at X10) 60 mv (tape input)	same as setup same as setup
13.	LP-PTA galvo balance	±.5 volts	±2 volts
14.	LP seis mass position	centered	±2 mm (if remote centering)
15.	LP Mark II drum rate	0.2 sec between any pair of 10 sec marks; 0.2 accumulative over 24 hrs	same as setup
16.	PTA output balance SP & LP	±10 mv	±30 mv
17.	Timing error on 5400 or 5400A	50 milliseconds	same as setup
18.	Timing system rate	±50 milliseconds/day	same as setup
19.	Timing error on chronometer	±5 seconds	±30 seconds
20.	Chronometer rate	±2 seconds/day	same as setup
21.	Time mark amplitude (at X10)	2 to 3 mm	same as setup
22.	WWV trace shift	2 to 3 mm	same as setup
23.	Trace width (at X10)	less than 1 mm	
24.	Trace intensity on SP	complete resolution at .5 cps (at X10)	
25.	Trace intensity on LP	visible time marks	
26.	System noise test	completely quiet trace (less than 1/4 mm at X10)	
27.	Blocked-mass test	cross feed not to exceed 3-mm deflection (at X10)	
28.	Tape system noise	not to exceed 60 mv	

Figure 2. Operational tolerance chart

g. Instrument malfunction and repair;

h. Any pertinent data not specifically called for in other sections of the log (special magnification assignments, etc.,).

Figures 3a, 3b, 4a, and 4b are examples of properly completed short- and long-period operational logs. Figure 5 is an example of a magnetic-tape daily log. Figures 6 and 7 are copies of array systems logs and deep-well systems logs, respectively.

2.4 RUN NUMBERING

The run numbering system used by LRSM teams is illustrated by the following examples:

a. Run number 330-64. The number 330 represents the Greenwich Day of the year (November 25) that the film records are put on the recorder; 64 indicates the year.

b. Run number 005-65. The number 005 indicates the fifth Greenwich Day of the year (January 05); 65 is the year.

The run number is routinely recorded on the operational logs and scribed on the tab end of all film records. On magnetic tape, the run number is given in voice comments on channel 14 and is written on the beginning section of the tape reel.

NOTE

The magnetic-tape run number is dictated by the first hour mark to be recorded; i.e., on a routine day, the tape machine will be reloaded prior to the actual end of the Greenwich Day. The first hour mark on the new tape will be 0000Z of the following day; thus, the run number will correspond to the date of the 0000Z hour mark.

GVTX
Mar 20 1963
Stamp

OPERATIONAL LOG
SHORT PERIOD SYSTEM

Station Location: Grapevine, Texas
Run Number 079-63

TIME:
First hour mark 0100 Z (Hr) 20/3/63 Z (Day)
Last hour mark 0000 Z (Hr) 20/3/63 Z (Day)
Seismometer: Large Benioff ( ) Portable Benioff ( )

			SPZ	SPR	SPT
1. Calibration Data	1.1	COMPONENT	SPZ	SPR	SPT
	1.2	Direction earth motion for + deflection on film	UP	110 °	200 °
	1.3	Seis free period, cycles in 60 seconds	61.3	61.5	60.8
	1.4	WEIGHT LIFT CALIBRATION			
	1.4.1	PTA Attenuator	36 db	36 db	36 db
	1.4.2	DCM Attenuator	10 db	20 db	16 db
	1.4.3	Weight lift by: Manual – M Ball lift – BL	BL	BL	BL
	1.4.4	Weight used, actual (grams)	.2486	2.03	2.03
	1.4.5	X_1 Amplitude (weight OFF) in mm @ X10 view	13	9	11.5
	1.4.6	X_2 (mm @ X10 view)	1	.7	.9
	1.4.7	Damping overshoot ratio X_1/X_2	13/1	12.8/1	12.8/1
	1.4.8	Magnification @ X10 view in K	42.7	36.3	46.4
	1.4.9	Time of calibration	0045 Z	0046 Z	0047 Z
	1.5	ELECTROMAGNETIC CALIBRATION			
	1.5.1	EM calibration current (μamp peak-to-peak)	6000	6000	6000
	1.5.2	Amplitude on record (mm at X10 view) at 1 cps	67	53	68
	1.5.3	Magnification @ X10 view, in K	34.8	28.9	36.4
	1.5.4	Time of EM calibration	1803 Z	1803 Z	1803 Z
	1.6	DC PULSES			
	1.6.1	DC pulse current (μamps)	1820	1820	1820
	1.6.2	X_1 amplitude (current OFF) in mm @ X10 view	13	10	13
	1.6.3	Motor constant, G (check daily)	1.34	1.21	1.23

2. Time

2.1 First correction at hr 01 min 05 Z is (+ 0) (–0) seconds
2.2 Second correction at hr 12 min 05 Z is (+ 0) (–0) seconds
2.3 Third correction at hr 23 min 05 Z is (+ 0) (–0) seconds

3. Weather

3.1 Maximum Temperature 91 F°, Minimum Temperature 50 F°
3.2 Wind: Max 40 mph, Dir. NNW Time 0700*Z; Min. 2 mph; Dir. N, Time 2300 Z
3.3 Cloud Cover: Clear
3.4 Precipitation: Type None Amount 0 Source of Information Site instruments; radio

4. Remarks

*1. High gusty winds varying from 10-40 MPH prevailed between 0300 and 0800Z.
2. Station on secondary timing and F.R. power at the start of the run due to malfunction of the timing system.
3. WWV reception very poor 0300-1300 because the receiver was not reset from 5MC to 10 MC for this period.
4. Personnel in hut recentering PTA's 1700-1730Z.
5. Maintenance on timing system at 1700. Replaced 2N458A transistors in power unit. System on primary time and power at 1800Z.
6. Gain on SPR too low. This will be corrected.

Signed [signature]

Figure 3a. Operational log, short-period system

OPERATIONAL LOG
SHORT PERIOD SYSTEM
PAGE No. 2

GVTX
Mar 20 1963

Stamp

TYPE OF CALIBRATIONS
(x) Weekly
(   ) Monthly
(   ) Special

5. FREQUENCY RESPONSE

5.1 Electromagnetic calibration current 6000 μamp peak-to-peak.

5.2 COMPONENT

Attenuator Settings PTA 36 db Data Control module 10 db

Motor constant, G = 1.34 newton/ampere

Frequency (cps)	0.3	0.5	0.7	1.0	1.5	2.0	3.0	5.0	7.0
Amplitude on record (mm @ X10 view)		38	67			49	23	5.5	
Magnification @ X10 view in K		4.9	34.8			102.3	108.5	72.0	

5.3 COMPONENT

Attenuator Settings PTA 36 db Data control module 20 db

Motor constant, G = 1.21 newton/ampere

Frequency (cps)	0.3	0.5	0.7	1.0	1.5	2.0	3.0	5.0	7.0
Amplitude on record (mm @ X10 view)		29		53		38	18	3	
Magnification @ X10 view in K		3.6		28.9		82.5	88.1	40.7	

5.4 COMPONENT

Attenuator Settings PTA, 36 db Data control module, 16 db

Motor constant, G = 1.23 newton/ampere

Frequency (cps)	0.3	0.5	0.7	1.0	1.5	2.0	3.0	5.0	7.0
Amplitude on record (mm @ X10 view)		37		68		49	23	6	
Magnification @ X10 view in K		5.0		36.5		104.9	110.8	80.4	

5.5 Results of the EOM dummy load noise test:

Satisfactory (   ) Unsatisfactory (   )

5.6 Comments or additional remarks:

1. The radial gain is too low. It will be corrected for the next run.
2. SPR & SPT G's out of spec's will adjust at E.O.M. cal.

Signed James J. [illegible] Jr.

Figure 3b. Operational log, short-period system, page 2

GVTX
Mar 20 1963
Stamp

OPERATIONAL LOG
LONG PERIOD SYSTEM

Station Location: Grapevine, Texas
Run Number 079-63

TIME:
First hour mark 0100 Z (Hr) 20/3/63 Z (Day)
Last hour mark 0000 Z (Hr) 20/3/63 Z (Day)
Seismometer: Sprengnether Long Period

				LPZ	LPR	LPT
1. Calibration Data	1.1	COMPONENT		LPZ	LPR	LPT
	1.2	Direction earth motion for + deflection on film		UP	110 °	200 °
	1.3	Voltage applied to polarity checker gives negative deflection.	Yes	X	X	X
			No			
	1.4	Time of polarity checks		0054 Z	0054 Z	0054 Z
	1.5	Seis free period, seconds		21.0	20.0	20.0
	1.6	PTA galvo free period, seconds		29.8	31.0	31.0
	1.7	PTA Attenuator		18 db	12 db	6 db
	1.8	DCM Attenuator		18 db	18 db	18 db
	1.9	ELECTROMAGNETIC CALIBRATION				
	1.9.1	EM calibration current (μamp, peak-to-peak)		40	40	40
	1.9.2	Amplitude on record @ 25 seconds (mm @ X10)		105	70	82
	1.9.3	Motor constant, G		.076	.087	.112
	1.9.4	Magnification (@ X10 view) in K		21.9	12.7	11.6
	1.9.5	Time of EM calibration		1810 Z	1810 Z	1810 Z
	1.9.6	Magnification on LPZ – lo at 25 sec. period (@ X10)		2.19		

2. Time

2.1 First correction at hr 01 min 05 Z is (+0) (–0) seconds
2.2 Second correction at hr 12 min 05 Z is (+0) (–0) seconds
2.3 Third correction at hr 23 min 05 Z is (+0) (–0) seconds

3. Weather

3.1 Maximum Temperature 91 F°, Minimum Temperature 50 F°
3.2 Wind: Max 40 mph, Dir. NNW, Time 0700* Z; Min. 2 mph, Dir. N, Time 2300 Z
3.3 Cloud Cover: Clear
3.4 Precipitation: Type None Amount 0 Source of Information Site instruments; radio

4. Remarks

*1. High, gusty winds varying from 10 to 40 MPH prevailed between 0300-0800Z.
2. Station on secondary time and F. R. power at the start of the run due to malfunction of the timing system.
3. Personnel in hut recentering PTA's 1700-1730Z.
4. Maintenance on timing system at 1700. Replaced 2N458A transistors in power unit. System on primary time and power at 1800Z.

Signed [signature]

Figure 4a. Operational log, long-period system

OPERATIONAL LOG
LONG PERIOD SYSTEM
PAGE 2

GVTX
Mar 20 1963

Stamp

TYPE OF CALIBRATIONS
(x) Weekly
( ) Monthly
( ) Special

5. FREQUENCY RESPONSE

5.1 Electromagnetic calibration current 40 μamp peak-to-peak.

5.2 LPZ

Attenuator Settings PTA, 18 db Data control module, 18 db

Motor constant, G = .076 newton/ampere

Frequency (cps)	.100	.083	.067	.050	.040	.033	.025	.016	.011
Period (seconds)	10	12	15	20	25	30	40	62.5	91
Amplitude on record (mm @ X10 view)	-		28	60	105	125		123	
Magnification @ X10 view in K	-		15.5	19.8	21.8	18.2		4.74	

5.3 LPN

Attenuator Settings PTA 18 db Data control module 12 db

Motor constant, G = .087 newton/ampere

Frequency (cps)	.100	.083	.067	.050	.040	.033	.025	.016	.011
Period (seconds)	10	12	15	20	25	30	40	62.5	91
Amplitude on record (mm @ X10 view)	-		21	45	70	80		78	
Magnification @ X10 view in K	-		10.3	13.1	12.7	10.1		2.46	

5.4 LPT

Attenuator Settings PTA, 18 db Data control module, 6 db

Motor constant, G = .112 newton/ampere

Frequency (cps)	.100	.083	.067	.050	.040	.033	.025	.016	.011
Period (seconds)	10	12	15	20	25	30	40	62.5	91
Amplitude on record (mm @ X10 view)	-		22	50	82	90		84	
Magnification @ X10 view in K	-		8.6	11.0	11.5	8.82		2.06	

5.5 Results of the EOM dummy load noise test:
Satisfactory ( ) Unsatisfactory ( )

5.6 Comments or additional remarks:

1. The calibration at .100 cps was not measurable because of high microseismic activity. A higher current from the EM calibrator would clip the tape system at .033 cps.

Signed [signature]

Figure 4b. Operational log, long-period system, page 2

GVTX

Mar 20 1963

Stamp

MAGNETIC TAPE DAILY LOG

Station Location: Grapevine, Texas
Run Number 079-63

TIME:
First hour mark 0000 Z (Hr) 20/3/63 Z (Day)
Last hour mark 2300 Z (Hr) 20/3/63 Z (Day)

Seismometer: Sprengnether Long Period
Large Benioff (x) Portable Benioff ( )

1 Tape System Data

CHANNEL	DATA	"Y" (CAL. LEVEL IN μ) ROUTINE (✓) PRE-RUN ( )	SYSTEM NOISE MV, P-P, UNCOMP. 0030Z	SYSTEM NOISE MV, P-P, UNCOMP. 2230Z	D. C. OFFSET AT D. C. M. MONITOR IN M. V.	SPECIAL CHANNEL ASSIGNMENTS
1						
2	S. P. T. Low	At 1.0 C. P. S.	40	55		
3	S. P. R. High	1.839 At 1.0 C. P. S.	60	65	0	
4	S. P. R. Low	At 1.0 C. P. S.	60	55		
5	S. P. Z. High	1.894 At 1.0 C. P. S.	60	60	0	
6	S. P. Z. Low	At 1.0 C. P. S.	55	60		
7	Wow and Flutter	N.A.	60	60		
8	S. P. T. High	1.869 At 1.0 C. P. S.	60	60	0	
9	L. P. Z. High	4.810 At .040 C. P. S.	55	50	-20	
10	L. P. Z. Low	At .040 C. P. S.	50	60		
11	L. P. R. High	5.539 At .040 C. P. S.	65	60	+40	
12	L. P. R. Low	At .040 C. P. S.	60	65		
13	L. P. T. High	7.089 At .040 C. P. S.	55	50	-150	
14	Time and Voice	N.A.				

2 Direction of Ground Motion For Positive Voltage into VCO:
R 110 ° Azimuth
T 200 ° Azimuth

3 Calibration Wts: S. P. (Actual Weight in Grams)

Z	R	T
.2486	2.03	2.03

4 Calibration Methods: S. P.
(x) Ball-Lift ( ) Manual

5 Motor constant, G
SPZ 1.34 SPR 1.21 SPT 1.23 LPZ .076 LPR .087 LPT .112

6 Times of Calibrations, Other Than Routine

Tape	Z	L. P.	Z
S. P.	Z	Other Systems	
S. P.	Z		Z
S. P.	Z		Z
L. P.	Z		Z
L. P.	Z		Z

7 Calibration Current:

	Routine		Other
S. P.	6000	μA	μA
L. P.	40	μA	μA
	Pre-Run		μA
S. P.		μA	
L. P.		μA	

8 REMARKS:

1. Station on secondary time and F. R. power at the start of this run due to malfunction of the timing system.
2. WWV reception very poor from 0300-1300 because the receiver was not reset from 5MC to 10 MC for this period.

Signed *James J. [signature]*

Figure 5. Magnetic tape daily log

00 NW
Mar 30 1965
Stamp

OPERATIONAL LOG
ARRAY SYSTEM

Station Location: Oslo, Norway
Run Number 089-65

TIME:
First hour mark 1300 Z (Hr) 30 Mar 65 Z (Day)
Last hour mark 1200 Z (Hr) 31 Mar 65 Z (Day)
Seismometer Type Large Benioff

1. Calibration Data

1.1	COMPONENT	Z_1	Z_2	Z_3	Z_4	Z_5	Z_6	Z_7	SPR	SPT
1.2	Dir. earth mo for + film def.	UP	UP	UP	UP	UP	UP	UP	138	228
1.3	Seis free period (cpm)	60.3	59.3	59.4	59.5	59.5	60.6	59.7	60.8*	59.3 *
1.4	PTA Attenuator -operate (db)	30	30	18	24	30	24	24	18	18
1.5	DCM Attenuator -operate (db)	6	6	6	6	6	6	6	6	6
1.6	WEIGHT LIFT CAL									
1.6.1	PTA Attenuator -calibrate (db)	30	30	18	24	30	24	24	18	18
1.6.2	DCM Attenuator -calibrate (db)	12	12	12	12	12	12	12	12	12
1.6.3	Weight lift by: (Man - BL)	BL	BL	BL	BL	BL	BL	BL	BL	BL
1.6.4	Weight used, actual (grams)	.2463	.2464	.2468	.2469	.2473	.2473	.2473	2.03	2.03
1.6.5	X_1(wt OFF) in mmX10 view	16.0	16.0	17.0	17.0	17.0	17.0	16.0	13.0	14.0
1.6.6	X_2(mm @ X10 view)	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.0
1.6.7	Damping overshoot ratio X_1/X_2	1510/1	15.0/1	15.5/1	15.5/1	15.5/1	15.5/1	15.0/1	13.0/1	14.0/1
1.6.8	Mag. (@ X10 in K) -calibrate	45.9	45.9	48.8	48.8	48.8	48.8	45.9	46.9	49.0
1.6.9	Mag. (@ X10 in K) -operate	91.8	91.8	97.6	97.6	97.6	97.6	91.8	93.8	98.0
1.6.10	Time of calibration (Z)	1315	1317	1319	1321	1323	1325	1327	1329	1331
1.7	EM CALIBRATION									
1.7.1	PTA Attenuator -calibrate (db)	30	30	18	24	30	24	24	18	18
1.7.2	DCM Attenuator -calibrate (db)	12	12	12	12	12	12	12	12	12
1.7.3	EM cal current (μamp p-to-p)	800	800	800	800	800	800	800	800	800
1.7.4	1 cps Ampl. (mm at X10 view)	33.0	34.0	33.0	34.0	35.0	35.0	34.0	33.0	34.0
1.7.5	Mag. (@ X10 in K) -calibrate	41.3	42.5	42.5	42.5	43.7	43.7	42.5	38.3	42.5
1.7.6	Mag. (@ X10 in K) -operate	82.6	85.0	85.0	85.0	87.4	87.4	85.0	76.6	85.0
1.7.7	Time of EM calibration (Z)	0925	0925	0925	0925	0925	0925	0925	0925	0925
1.8	DC PULSES									
1.8.1	DC pulse current (μamps)	570	570	570	570	570	570	570	500	500
1.8.2	X_1 (current OFF) mm X10 view	16.0	16.0	16.5	17.0	17.0	17.0	16.0	14.0	14.0
1.8.3	Motor constant, G(check daily)	4.24	4.24	4.12	4.24	4.24	4.24	4.24	4.27	3.97

2. Time

2.1 First correction at hr 13 min 00 Z is (+ 0) (− 0) seconds
2.2 Second correction at hr 00 min 00 Z is (+ 0) (− 0) seconds
2.3 Third correction at hr 11 min 00 Z is (+ 06) (−) seconds

3. Weather

3.1 Maximum Temperature 50 F°, Minimum Temperature 22 F°
3.2 Wind: Max 0 mph, Dir. , Time Z; Min. 0 mph; Dir. , Time Z
3.3 Cloud Cover: Partly cloudy
3.4 Precipitation: Type None Amount Source of Information Observation

4. D-corder Trace Identification

Film Top	6. SPZ#5	12.
1. Time: Potsdam, Germany	7. SPZ#6	13.
2. SPZ#1	8. SPZ#7	14.
3. SPZ#2	9. SPZ Summation	15.
4. SPZ#3	10. SPR	16
5. SPZ#4	11. SPT	Film Bottom

Signed F. Jegg

Figure 6. Array system operational log

FOTX

Apr 10 1965

Stamp

OPERATIONAL LOG
DEEP WELL SYSTEM

Station Location: Ft. Stockton, Texas
Run Number 100-65

TIME:
First hour mark 2300 Z (Hr) 9 Apr Z (Day)
Last hour mark 2100 Z (Hr) 10 Apr Z (Day)

1. Calibration Data	1.1	Instrument No. and motor constants	1. 0.627	2. 0.610	3. 0.738	4.
	1.2	Model No.	11167	11167	11167	
	1.3	Depth of seismometer in feet	15,000	7,030	191	
	1.4	Direction earth motion for + deflection on film	UP	UP	UP	
	1.5	Seis free period, cycles in 60 seconds	60.2	61.4	59.6	0112Z
	1.6	PTA Attenuator —operate	06 db	06 db	00 db	db
	1.7	DCM Attenuator —operate	06 db	04 db	00 db	db
	1.8	WEIGHT LIFT CALIBRATION				
	1.8.1	PTA Attenuator —calibrate	06 db	06 db	00 db	db
	1.8.2	DCM Attenuator —calibrate	16 db	08 db	00 db	db
	1.8.3	Weight used, actual (grams)	0.032	0.024	0.0248	
	1.8.4	X_1 Amplitude (weight OFF) in mm @ X10 view	30.5	35.0	33.0	
	1.8.5	Magnification @ X10 view in K —calibrate	-	-	-	
	1.8.6	Magnification @ X10 view, in K —operate	-	-	-	
	1.8.7	Time of calibration	0527 Z	0532 Z	0537 Z	Z
	1.9	ELECTRODYNAMIC CALIBRATION				
	1.9.1	PTA Attenuator —calibrate	06 db	06 db	00 db	db
	1.9.2	DCM Attenuator —calibrate	20 db	16 db	16 db	db
	1.9.3	ED calibration current (MA peak-to-peak)	0.76	0.88	2.0	
	1.9.4	Amplitude on record (mm at X10 view) at 1 cps	43.0	45.5	46.5	
	1.9.5	Magnification @ X10 view, in K —calibrate	366.0	337.0	128.0	
	1.9.6	Magnification @ X10 view in K —operate	1890	1440	825	
	1.9.7	Time of ED calibration	1244 Z	1248 Z	1249 Z	Z
	1.10	DC PULSES Times	0547Z	0548Z	0549Z	
	1.10.1	X_1 amplitude (current OFF) in mm @ X10 view	32.0	39.0	32.0	
	1.10.2	X_2 (mm @ X10 view)	2.0	2.0	2.0	
	1.10.3	Damping overshoot ratio X_1/X_2	16.1/1	19.5/1	16.0/1	

2. Time

2.1 First correction at hr 05 min 05 Z is (+) (-0.0) seconds
2.2 Second correction at hr 13 min 15 Z is (+) (-0.10) seconds
2.3 Third correction at hr 21 min 05 Z is (+) (-0.15) seconds

3. Weather

3.1 Maximum Temperature 89 F°, Minimum Temperature 52 F°
3.2 Wind: Max 30 mph, Dir. SW, Time 2100 Z; Min. 5 mph; Dir. SW, Time 1300 Z
3.3 Cloud Cover: 10% average
3.4 Precipitation: Type None Amount Source of Information Observation

4. D-corder Trace Identification

Film Top		
1. WWV TIME	6. SPZ VT 5051	12. ANEMOMETER (5mph/mm)
2. SPZ VT 4051	7. DW#3 "	13.
3. DW#3 "	8. DW#2 "	14.
4. DW#2 "	9. DW#1 "	15.
5. DW#1 "	10 SPR VT 4051	16.
	11 SPT "	Film Bottom

Signed [signature]

Figure 7. Deep-well system operational log

3. CALIBRATION

3.1 POLARITY

3.1.1 General

The vertical and horizontal seismometers of both the long- and short-period systems are set up to conform to the following criteria:

a. The vertical seismometer is connected so that an upward movement of the earth will produce an upward deflection on film and a positive voltage to the magnetic-tape system.

b. The radial horizontal seismometer is connected so that earth motion away from the Nevada Test Site will give an upward deflection on film and a positive voltage to the magnetic-tape system.

c. The transverse horizontal seismometer is connected so that earth motion to the right, as seen from the Nevada Test Site (i.e., if one were standing with his back toward the Nevada Test Site, facing the seismometer), will cause an upward deflection on film and a positive voltage to the magnetic-tape system.

Figure 8 shows, by illustration, these polarity orientations. Each data channel is checked routinely to ensure that the circuit polarity is correct with reference to the orientation of the seismometer.

Under certain circumstances (special noise study programs, etc.,) an LRSM team may operate at a site without the requirement to orient towards the Nevada Test Site. In such case, the horizontal seismometers will ordinarily be oriented North-South and East-West. The operational logs will always designate such an orientation.

3.1.2 Short-Period Polarity Check

Circuit polarity of a short-period instrument is checked using a small weight lifted from the mass of the instrument. There are two methods by which this can be accomplished. The first, the ball lift method, is done remotely. Using this method, a "weight off" deflection is the first in a series of paired deflections. The last deflection (which should be in an upward direction if the circuit polarity is correct) will be a "weight on" deflection. Figure 9 shows a set of ball-lift calibrations.

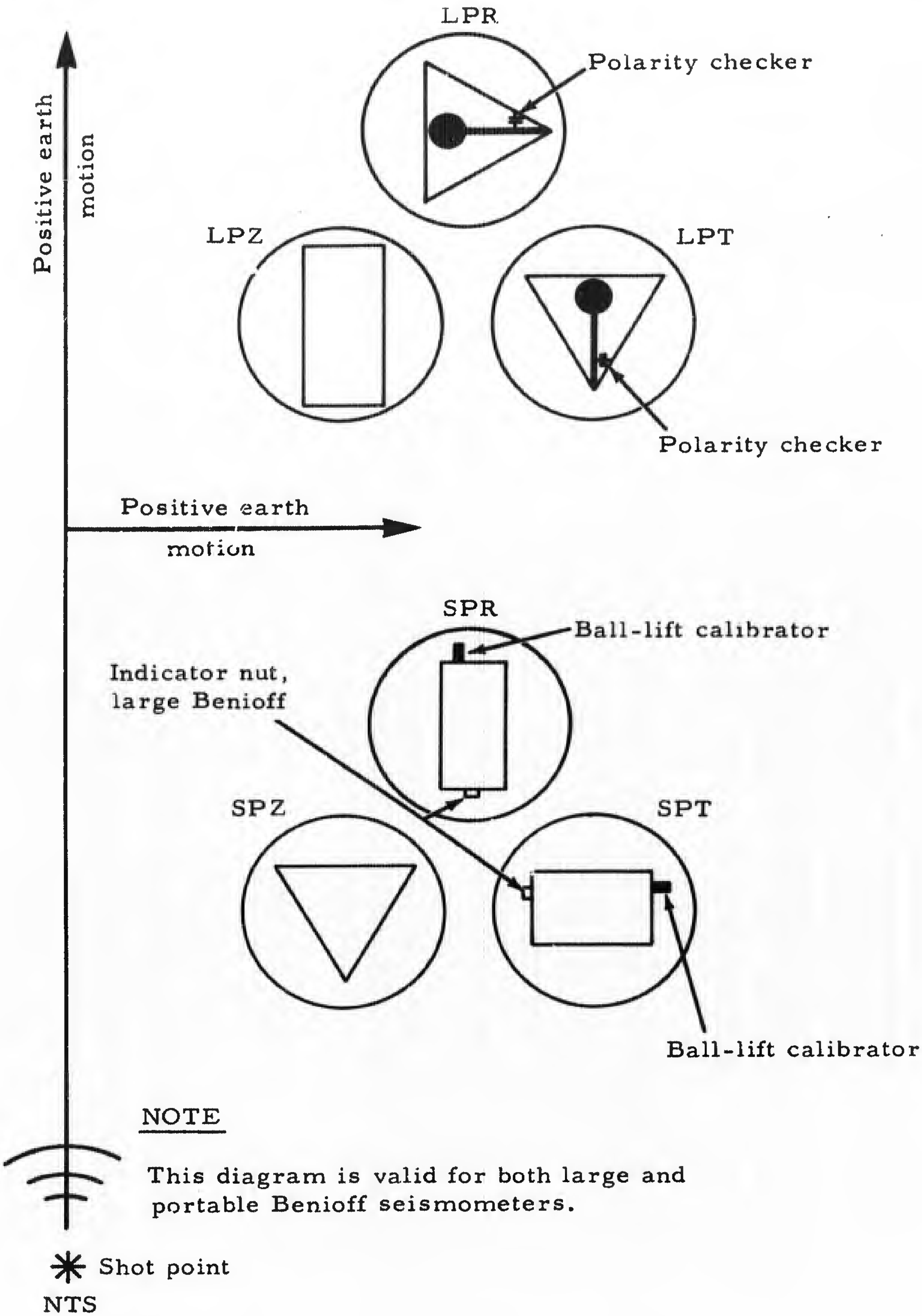
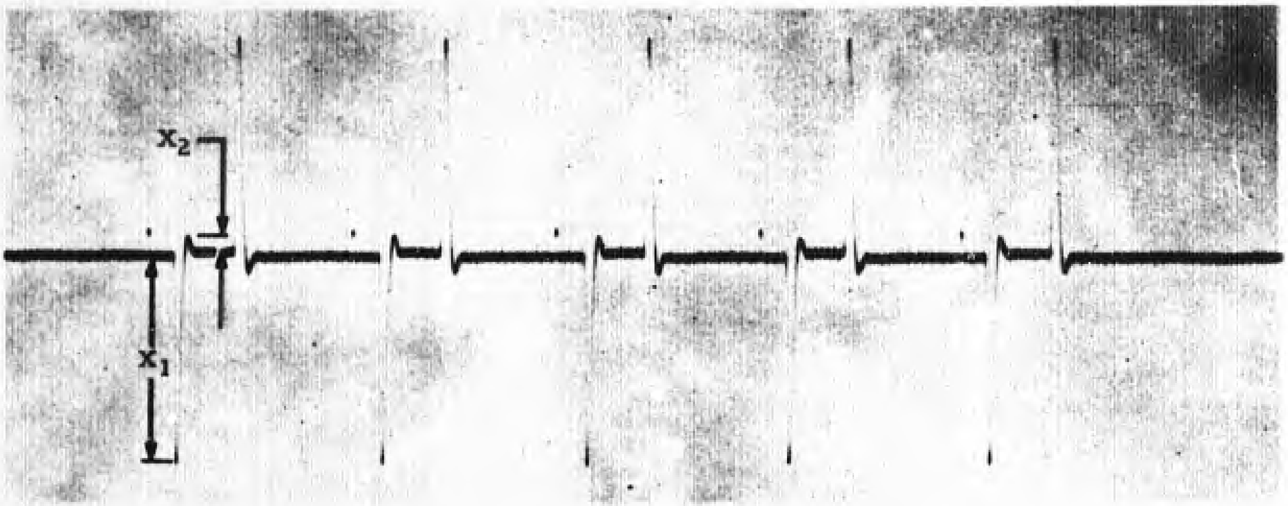


Figure 8. Polarity orientation diagram

WEIGHT ON - 7 SECONDS



WEIGHT OFF - 3 SECONDS

Figure 9. Example of ball-lift calibration showing proper polarity, damping and spacing

The second short-period polarity check method (manual weight lift) is accomplished by lifting a weight manually from any of the short-period instruments. In using the manual weight lift, "weight off" is the first deflection in the series, and the last deflection is a "weight on." Manual weight lifts are always preceded by two cue marks, signifying that the deflections are to be produced by the manual weight-lift method, and that the first deflection will be "weight off."

The manual weight-lift method is not normally used during routine operation. It is employed during the initial setup of the seismographs and in some cases during special calibrations. The short-period operational logs will reflect this information when it is required.

Ball lifts and manual weight lifts, in addition to serving as polarity checks, also provide a means for determining magnification (see section 3.3 for a discussion).

3.1.3 Long-Period Polarity Check

The circuit polarity on a long-period instrument is correct when actuation of the polarity checker (voltage ON) results in a downward deflection on film and a negative voltage to the magnetic-tape system. Voltage is held on electrostatic plates (mounted on the seismometer) for 1 minute. This allows time for the trace to return to zero. When the voltage is switched off, the seismometer produces an upward deflection on film and a positive voltage to the magnetic-tape system.

3.2 LONG-PERIOD PHASE RESPONSE CHECK

To determine phase variations which are present between one long-period field system and another, a dc pulse is periodically applied to each long-period seismometer calibration coil. At the instant the dc pulse is sensed by the calibration coil, a small offset is simultaneously recorded on the 35-mm film and magnetic tape. From this offset and the impulse response wavelet from the seismometer, determinations of phase response can be made. This phase check is performed on a routine basis and appears on film and magnetic-tape records immediately after the daily sine-wave calibrations.

3.3 CALCULATION OF MAGNIFICATION FROM WEIGHT-LIFT CALIBRATIONS

The weight-lift calibration can be performed remotely (ball-lift calibration) or manually (manual calibration) by lifting a test weight from the mass of the seismometer. In either case, the magnification at 1 cps is determined from the amplitude of trace displacement per gram of the test weight lifted, multiplied by a calibration constant. The equation used for computing magnification is:

$$\text{Magnification} = \frac{KC\ X_1}{m}$$

where:

K = Calibration constant, determined by shake-table test of equivalent ground motion, in grams per millimeter.

= 710[a] for large Benioff Seismometers, Geotech Model 1051 and and 1101.

[a]Previously quoted as 800; however, recent shake-table tests have shown that 710 is a better calibration constant for the large Benioff seismometers. On 10 October 1963, the LRSM field teams began using the constant 710 to compute magnification.

= 95 for portable Benioff Seismometers, Geotech Model 4681A and 6102A.

= 108 for vertical Johnson-Matheson Seismometers, Geotech Model 6480.

C = Correction factor to account for magnification changes when the seismometer damping deviates from critical (15:1 overshoot ratio, X_1/X_2). See figure 10.

X_1 = Initial trace deflection (in millimeters) caused by lifting the weight "m." See figure 9.

X_2 = Overshoot of trace as it returns to the zero reference line, in millimeters. See figure 9.

m = Effective mass of the weight lifted in grams. Use one-half actual weight when lifted by the manual weight-lift method on the horizontals. Use one-tenth actual weight when lifted by ball-lift method on the horizontals. Use actual values for weights lifted from vertical seismometers.

3.4 CALCULATION OF MAGNIFICATION FROM ELECTROMAGNETIC (EM) CALIBRATIONS

The equation used for computing magnification (M) from an electromagnetic (sine-wave) calibration is:

$$M = \frac{4\pi^2 f^2 \ mA}{i_2 \ G(10)^3}$$

where:

f = Frequency of i_2, in cycles per second

m = Seismometer mass, in kilograms

= 107.5 for large vertical Benioff (SP) seismometer

= 100.0 for large horizontal Benioff (SP) seismometer

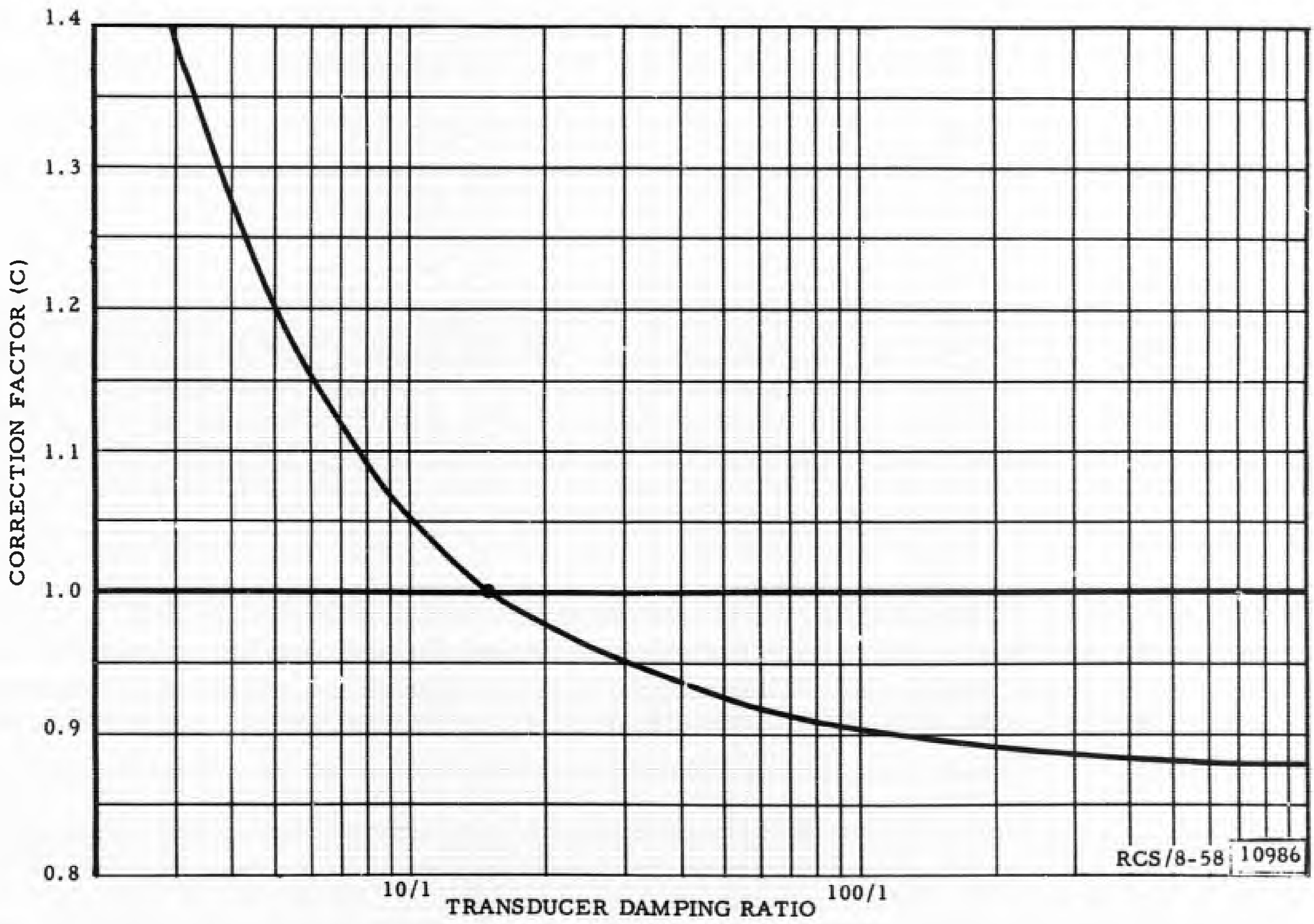


Figure 10. Correction factor (C) as a function of transducer damping ratio for correcting system magnification computed from a weight-lift calibration, for large and portable Benioff seismometers

= 14.4 for portable vertical Benioff (SP) seismometer.

= 14.2 for portable horizontal Benioff (SP) seismometer.

= 10.0 for vertical Sprengnether (LP) seismometer.

= 10.0 for horizontal Sprengnether (LP) seismometer.

= 18.0 for vertical Johnson-Matheson Seismometer, Geotech Model 6480.

= 103.0 for Deep-Hole Seismometer, Geotech Model 11167.

A = Recorded trace amplitude, peak-to-peak millimeters (at X10 view) due to i_2.

i_2 = Sinusoidal current through calibrator coil, in amperes peak-to-peak (see team operational logs).

G = Motor constant of remote calibrator actuator, in newtons/ampere (see team operational logs).

3.5 CALCULATION OF MAGNIFICATION FROM ELECTRODYNAMIC (ED) CALIBRATIONS

In the past, deep-hole instruments were calibrated with a sinusoidal motion induced by an electrodynamic calibrator. By October 1964, all LRSM deep-hole teams had abandoned the use of this calibrator. The station logs should be consulted for information regarding the type of calibration (ED or EM) that was applied to a deep-hole instrument. The equation for computing magnification (M) from an electrodynamic calibration is:

$$M = \frac{4\pi^2 f_o^2 mA}{\left(\frac{i_2}{2}\right)^2 G (10)^3}$$

where:

m, A, and i_z are as quoted above (section 3.4)

f_o = Frequency of recorded sine-wave, in cps. For the ED calibrator, the output frequency is twice the input frequency ($f_o = 2f_{in}$).

G = Motor constant of remote calibrator actuator, in newtons/(ampere)^2 (see team operational logs).

3.6 CALCULATION OF GROUND MOTION

Ground motion can be estimated at any frequency on the short- or long-period systems when the magnification is known at that frequency. The following relationship is used:

$$Y = \frac{A(10)^3}{M_1 G_t} = \frac{\text{amplitude of recorded deflection (mm) x } (10)^3}{\text{magnification at frequency of deflection}}$$

where:

Y = Equivalent ground motion, in microns. Y is given in the magnetic-tape daily logs for the calibration levels at 1.0 second on the short-period system and 25 seconds on the long-period system.

A = Recorded amplitude in millimeters of the oscillation for which true ground motion is to be determined. This amplitude should be measured at the same viewer magnification for which M is given. The data in the film logs are given for X10 viewer magnification.

M_1 = System magnification at 1.0 second for the short-period system and 25 seconds for the long-period system, determined from the calibration data on visual recordings or from the data given in the operational logs.

G_t = Correction factor by which M is multiplied to determine magnifications at periods other than 1.0 or 25 seconds. These factors can be taken from table 2 or can be determined from the response curves in figures 11, 12, 13, 14, and 15.

The above relationship is used to determine ground motion of seismic data; however, these determinations are approximate because sinusoidal motion is assumed. The accuracy of the results depends on how nearly sinusoidal the seismic oscillations are and how accurately the period of oscillation is determined. After the value of Y has been determined, it can be applied to the calibration data on magnetic tape to derive a system sensitivity factor in units of volts per unit displacement. The correction factors (G_t) in table 2 can be applied to the sensitivity factor to determine sensitivities at any period. Additional information on the subject of this sensitivity factor can be found in paragraph 6.9.

4. TIMING

4.1 GENERAL

Station time is kept in near-synchronization with the WWV radio broadcast from the National Bureau of Standards. Time from the LRSM seismic stations is reported in Greenwich Mean Time.

The LRSM stations use two types of timing systems. Primary timing is provided by a frequency-regulated power source employing a crystal oscillator. Secondary time, used as standby in the event of failure of the primary time, is supplied by a chronometer. The station time recorded on film is superimposed on the data traces and on the WWV standard time trace. Station time can then be compared with WWV standard time during any portion of the film trace.

4.2 TIME PROGRAMS

The primary timing program is composed of a 125-millisecond pulse every 10 seconds, which is omitted every 60 seconds; a 500-millisecond pulse

Table 2. Period correction factors for computing actual ground motion

Short period			Long period		
Period (sec)	G_t Benioff	G_t Johnson-Matheson	Period (sec)	G_t w/Filter 6824-2	G_t w/Filter 6824-13
0.3	2.80	2.48	5	0.040	0.178
0.4	2.90	2.48	10	0.240	0.629
0.5	2.65	2.10	15	0.694	1.082
0.6	2.39	1.77	20	0.994	1.152
0.7	2.01	1.52	25	1.000	1.000
0.8	1.69	1.33	30	0.845	0.799
0.9	1.30	1.12	35	0.646	0.608
1.0	1.00	1.00	40	0.491	0.468
1.1	0.81	0.85	45	0.380	0.368
1.2	0.65	0.73	50	0.299	0.290
1.3	0.52	0.62	55	0.239	0.236
1.4	0.42	0.54	60	0.194	0.181
1.5	0.34	0.45	65	0.159	0.146
2.0	0.16	0.21	70	0.133	0.123
2.5	0.08	0.10	75	0.112	0.102
3.0	0.048	0.058	80	0.095	0.088
3.5	0.030	0.036	85	0.081	0.074
4.0	0.021	0.025	90	0.070	0.064
4.5	0.015	0.017	95	0.061	0.057
5.0	0.011	0.012	100	0.054	0.050

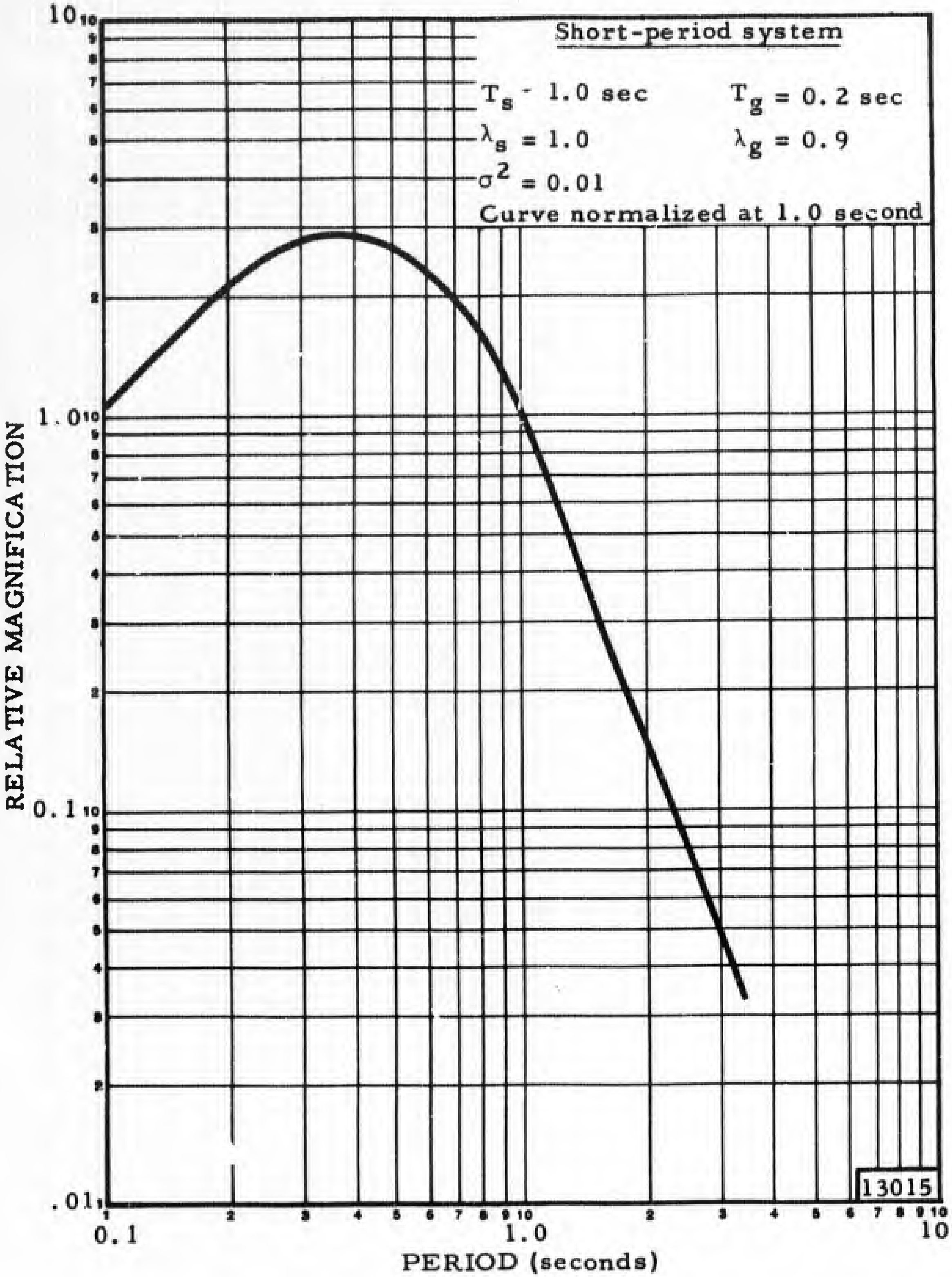


Figure 11. Frequency response of the short-period seismograph system

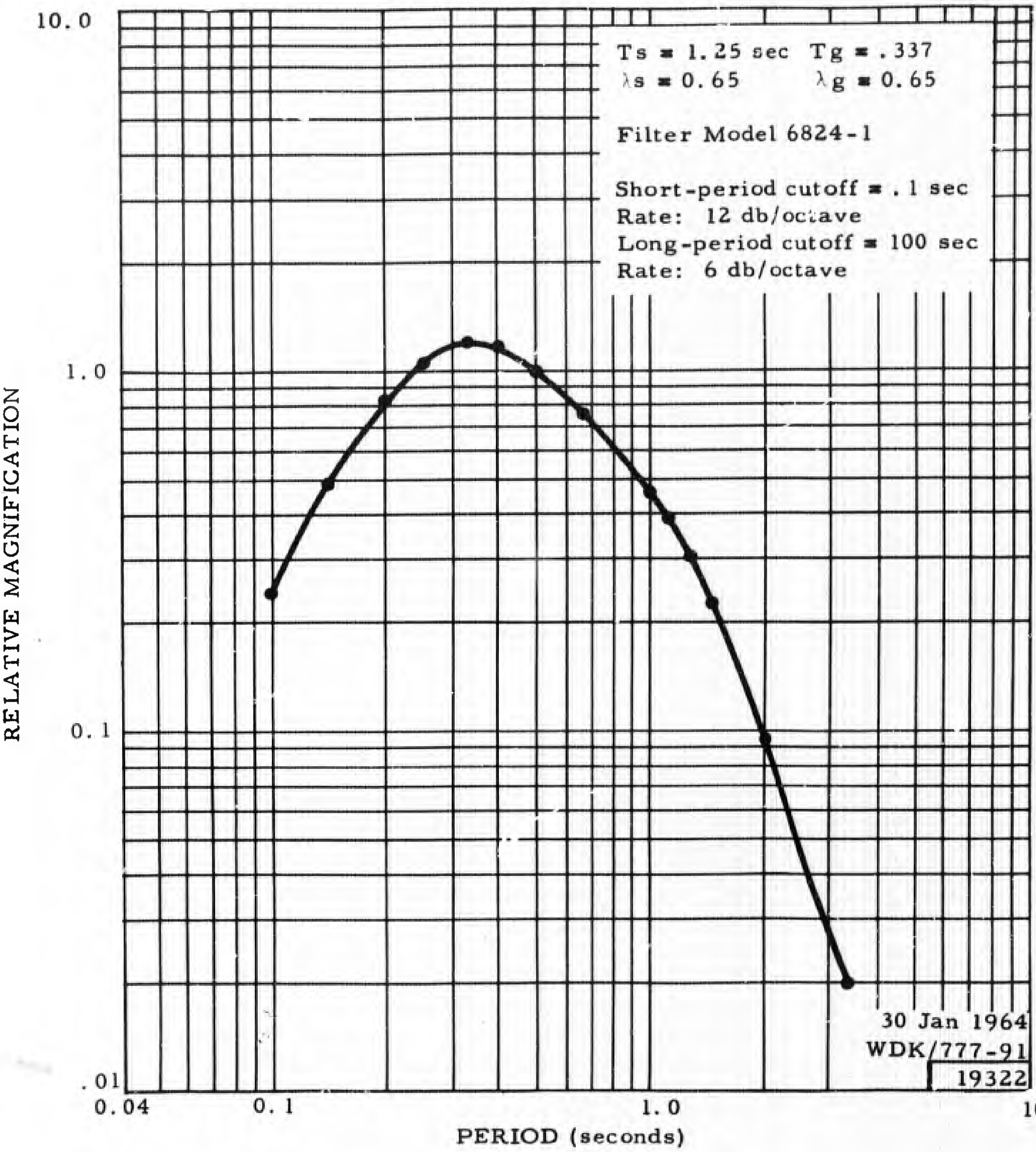


Figure 12. Frequency response of the Johnson-Matheson short-period seismograph system

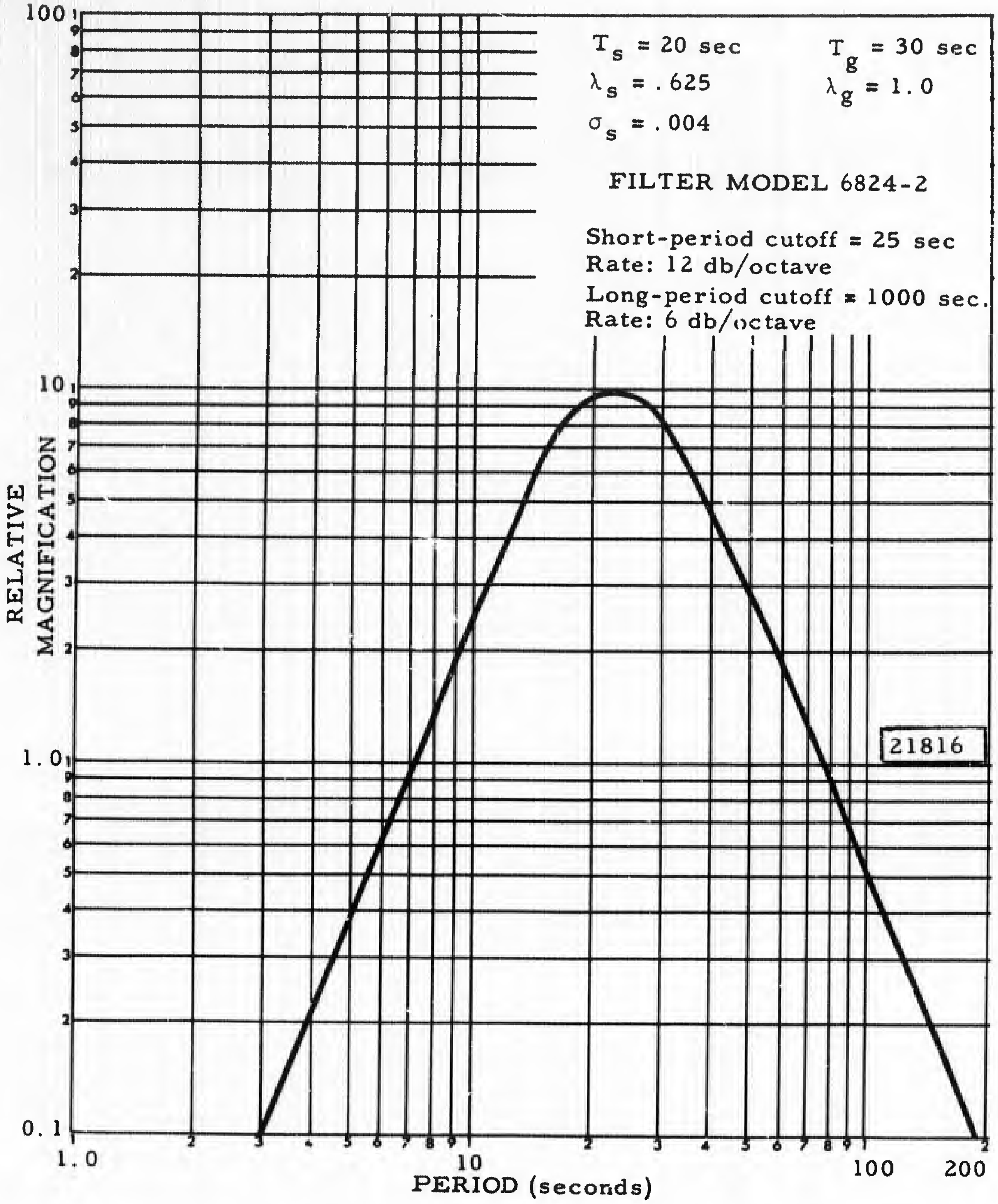


Figure 13. Frequency response of the long-period seismograph system, filter No. 6824-2

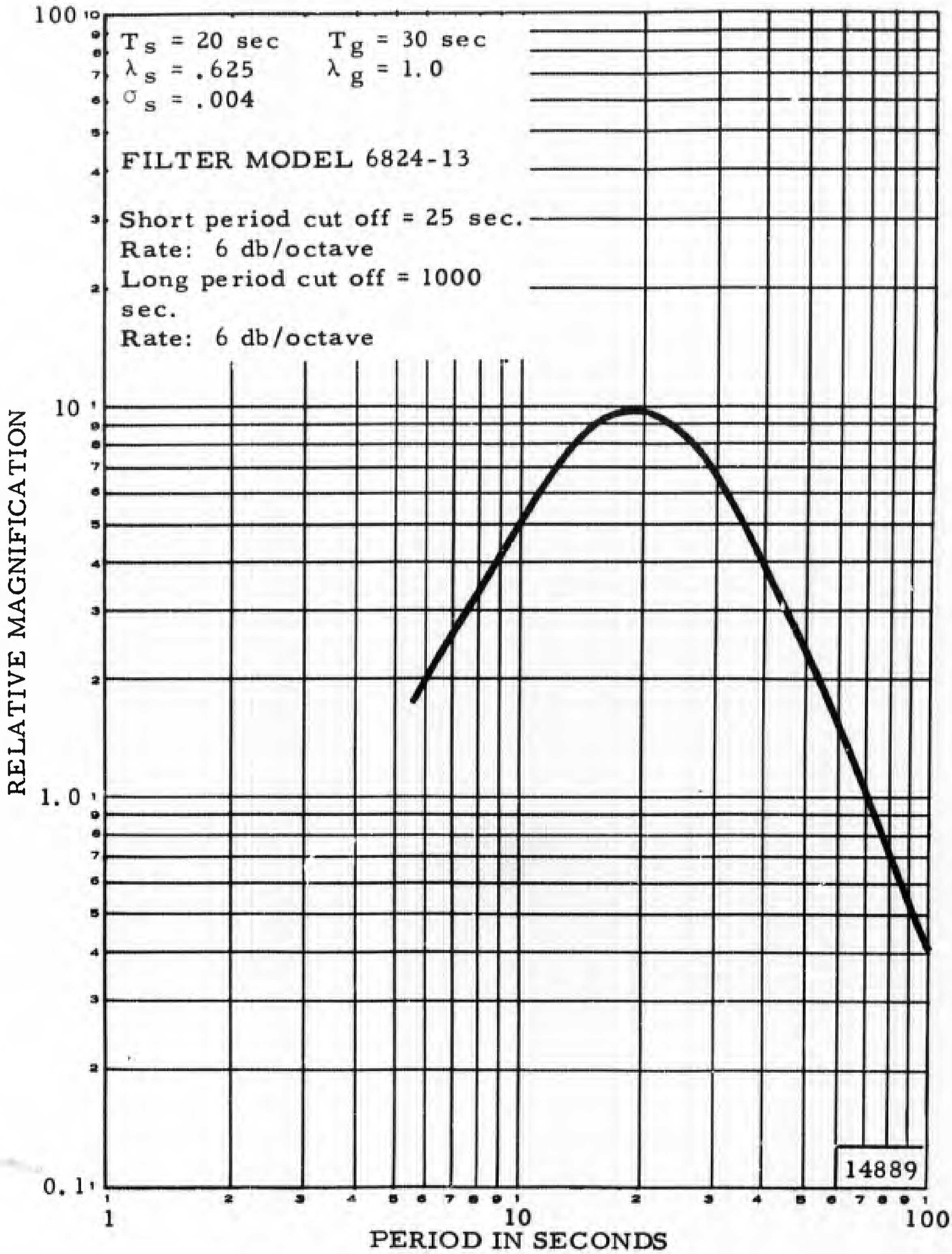


Figure 14. Frequency response of the long-period seismograph system, filter No. 6824-13

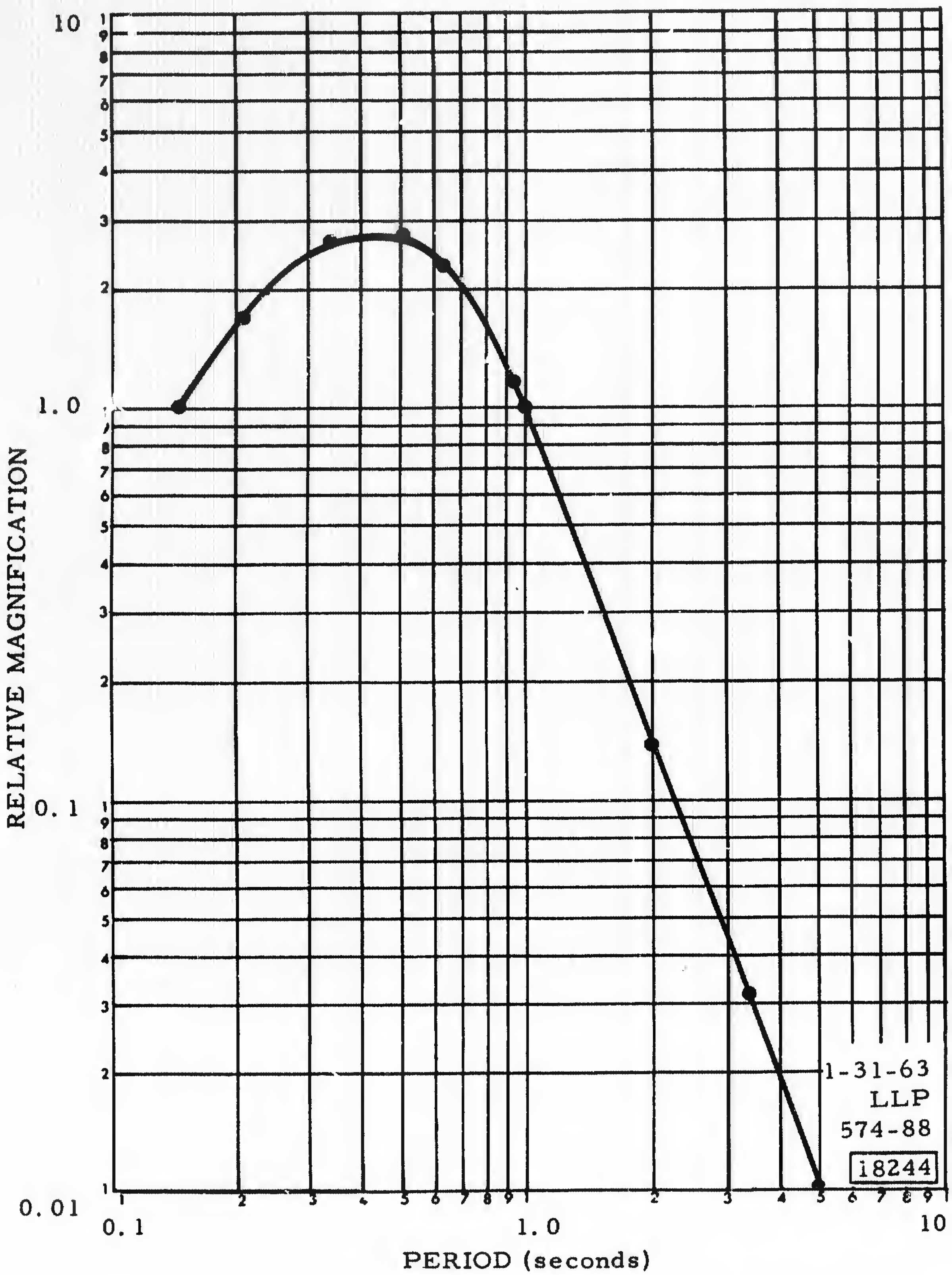


Figure 15. Frequency response of the deep-hole seismograph system

every 5 minutes; a single 1-second pulse each half-hour; and two 1-second pulses (separated by 1 second) each hour.

The secondary (chronometer) program format consists of a 500-millisecond time pulse every 10 seconds for five consecutive 10-second periods, followed by a single 10-second period with no pulse; thus, the format is tantamount to having a time pulse on the 10th, 20th, 30th, 40th, and 50th seconds of each minute, and an absence of any pulse on the 60th second.

Time corrections are normally taken from the WWV film trace at three points on each film run (0100Z, 1300Z, and 0000Z) and are noted in the operational logs. The procedure for determining time corrections is simply to measure the difference between a known WWV time fiducial and a corresponding station timing system fiducial. If station time is fast, the time correction is minus; if slow, the time correction is plus. Figure 16 shows examples of corrections taken from a 35-mm film WWV radio trace.

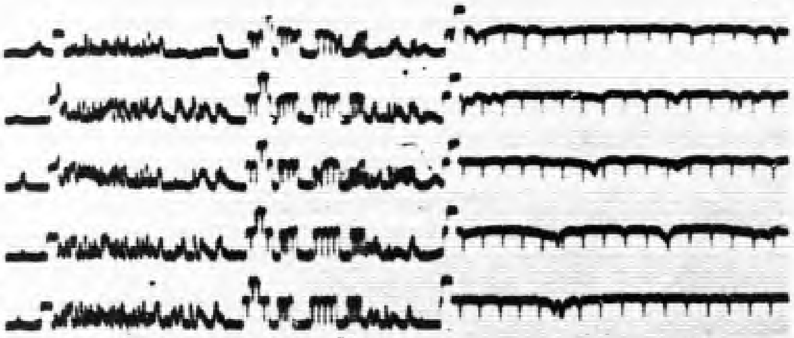
4.3 WWV PROGRAM

The National Bureau of Standards' Radio Station WWV, located at Beltsville, Maryland, broadcasts time signals at 2.5, 5, 10, 15, 20, and 25 megacycles. These time signals are broadcast continually, day and night, except for a 4-minute period of silence beginning 45 minutes (±15 seconds) after each hour. Two standard frequencies, 440 and 600 cycles, are broadcast on all carriers. These tones are given alternately, starting with the 600-cycle tone on the hour for a duration of 3 minutes, interrupted for 2 minutes, followed by the 440-cycle tone for 2 minutes and a 3-minute interruption. Except for the 600-cycle tone after the hour, the tones last 2 minutes.

At approximately 30 seconds prior to each 5-minute mark, WWV gives station identification, Greenwich Mean Time, and a propagation notice - all in International Morse Code utilizing the 440-cycle tone. Just prior to the tone return at the 5-minute mark, a voice announcement is made of Eastern Standard Time.

A pulse, or tick, consisting of 5 cycles of a 1000-cycle tone occurs at precise 1-second intervals, providing a continuous source for accurate time corrections.

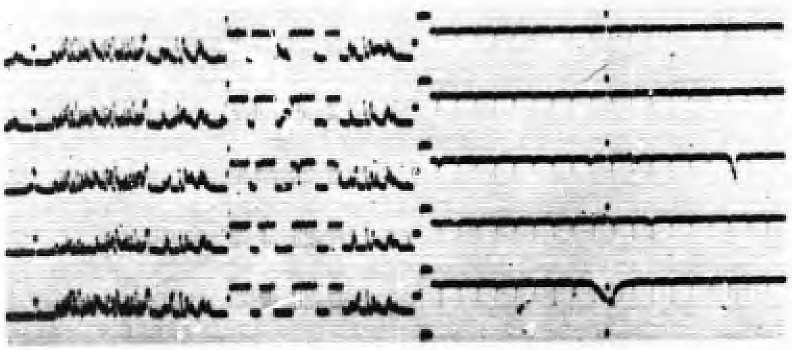
All WWV voice announcements, codes, and tones are recorded on channel 14 of the LRSM magnetic tapes and can be recovered upon playout.



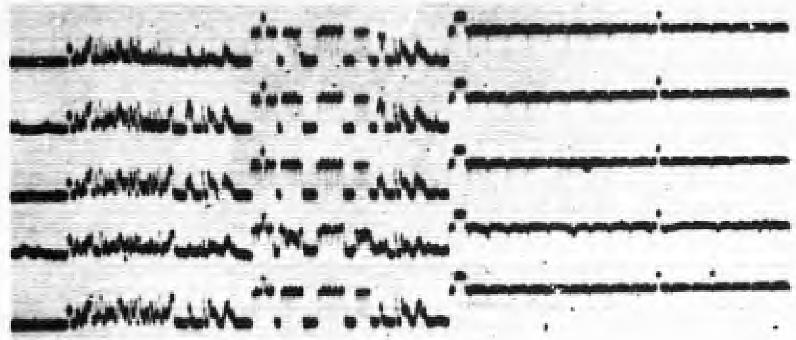
Time Correction:
+10.4 sec top trace
+10.1 sec bottom trace

Time Correction:
+ 0.1 sec top trace
- 0.1 sec bottom trace

CHRONOMETER
TIMING



Time Correction:
-0.3 sec top trace
-0.4 sec bottom trace



Time Correction:
+ 0.3 sec top trace
+ 0.3 sec bottom trace

PRIMARY
TIMING

Figure 16. Examples of time corrections

WWVH, located on Maui, Hawaii, broadcasts on frequencies of 5, 10, and 15 megacycles, and uses basically the same program materials as WWV.

The accuracy of the time programs from WWV and WWVH agree with the U. S. Naval Observatory time standard.

4.4 CODING

The time is coded on film and tape immediately after the first and last hour marks of the film recording period (after the WWV offset and the timing system double fiducials). When the secondary timing system is in use, the time is coded approximately 10 seconds after the hour.

Coding is accomplished manually by the station operator by means of a pulse keying device. If an error is made in coding, the International Morse Code error correction procedure is used (a series of eight dots signifying an error has been made, followed by the correct coding). The International Morse Code for numerals is listed below:

one	. - - - -
two	. . - - -
three	. . . - -
four	. . . . -
five	. . . . .
six	- . . . .
seven	- - . . .
eight	- - - . .
nine	- - - - .
ten	- - - - -

5. FILM RECORDINGS

5.1 THIRTY-FIVE-MILLIMETER FILM RECORDINGS

5.1.1 Description of Recorders

Seismic data, station time, and WWV data are recorded on two Film Recorders, Geotech Model 1301A. Each recorder provides four channels. The short-period film recorder is designed to record 24 hours (at a rate of one drum revolution per hour) on a 36-1/2 inch film strip, at a speed of 0.25 millimeters per second. The long-period film recorder is of the same design, but with a speed of 0.05 millimeters per second and a corresponding drum rate of one revolution every 5 hours.

5.1.2 Operation

The magnification level of each channel of the film recorders is adjusted by an attenuator housed in a data control module mounted in an equipment rack external to the film recorders. For normal field team operation, the short-period system is adjusted for 2 millimeters of seismic background at X10 view. The long-period level is adjusted for 5- to 10-mm of seismic background at X10 view. The maximum amplitude of the recorded seismic signal is limited only by the width of the film. The film recorders are operated continuously, with record changes at 0000 GMT daily. The drums are set so that the first hour mark will occur within 6 inches of the beginning of the film strip.

5.1.3 Film Marking

Each 35-mm film recording is scribed (on the emulsion side of the leading edge of the film) with the following information:

a. Run number;

b. First and last hour marks appearing on the film;

c. Operating magnification of the channel, computed from ball-lift calibration (short-period) or electromagnetic calibration (long-period);

d. G (motor constant) G_l is the notation for large short-period Benioff seismometers; G_p for portable Benioff seismometers; and G for long-period seismometers;

e. i (calibration current) in microamperes, peak-to-peak.

5.1.4 Film Trace Assignments

The film trace assignments on each recorder are as follows:

Short-Period Recorder:

Channel	Data	Designation
1	Short-period vertical	SPZ
2	Short-period radial	SPR
3	Short-period transverse	SPT
4	Radio trace of WWV standard time	RADIO

Long-Period Recorder:

Channel	Data	Designation
1	Long-period vertical	LPZ
2	Long-period radial	LPR
3	Long-period transverse	LPT
4	Long-period vertical-low gain (1/10 LPZ)	LPZ-LO

Station time is superimposed on all data traces and the WWV trace.

5.2 SIXTEEN-MILLIMETER FILM RECORDINGS

5.2.1 General

Several of the LRSM teams are equipped with Develocorders, multichannel 16-mm film recorder/processors.

5.2.2 Description of Recorders

Depending on which of two models are in use, the Develocorder is a 16-channel (Model 4000) or a 20-channel (Model 4000C) photographic recorder which records analog data traces on 16-mm film. The exposed film is automatically developed, fixed, washed, and dried within the Develocorder. Data trace images are projected to a view screen (magnification X10) by an optical system. Recording speed is 3 centimeters/minute (142 feet/24 hours).

5.2.3 Operation

Short-period seismic background is normally adjusted to 2-3 millimeters at X10 view. The Develocorders are normally operated on a 24-hour recording period.

5.2.4 Film Trace Assignments

Data trace assignments on Develocorder film vary from one station to another, depending on the type of site configuration. The trace assignments are always listed, however, in the operational logs.

5.2.5 Identifications

Film identification markings are printed on the top portion of the film. These markings are printed by means of a flasher assembly internal to the Develocorder. Every minute, from 0001 to 2400, is printed. This time is not precisely synchronized with WWV, but is generally printed near the referenced minute mark. Also printed on the film, but at 5-minute intervals, is the day of the year.

6. MAGNETIC-TAPE RECORDINGS

6.1 GENERAL

Data are recorded in the field on 14-channel Ampex magnetic-tape systems, Model 314. Field recordings are made at a speed of 0.3 ips (inches per second). A 2500-foot (10-inch) reel of magnetic tape normally contains 24 hours of data.

6.2 TAPE MARKING

On the beginning of each reel, immediately following the green leader, the tape is stamped with the team designator and the run number. Approximately 2 inches further down the tape, the time of the first WWV 5-minute mark (which is to appear on the tape data) is written on the oxide side of the tape. Still further down the tape, a black line is marked across the back (the slick side) to indicate the approximate location of the noted 5-minute mark.

6.3 OPERATION

The routine recording period for the magnetic-tape system is 24 hours, beginning at 0000 GMT. Data from the seismometers are recorded on 11 channels of the tape. The output of the seismic instruments is adjusted to 60 millivolts average seismic background noise for short period and 100 millivolts for long period at the input to the tape system.

Traces with one-tenth the magnification of the normal high-gain traces are recorded on magnetic tape for all of the seismic data channels except the long-period transverse. This practice extends the effective dynamic range of the tape recordings by approximately 17 dB.

Amplified channels are sometimes used for background studies. They are commonly designated "Operational Amplifier," "Amplified," or "Super-High" channels. The increase in sensitivity over corresponding normal high-gain channels is specified in the magnetic-tape daily log.

6.4 SPECIFICATIONS

6.4.1 System Specifications

Type	Ampex Model 314
Tape speed	Field recordings made at 0.3 ips
Center frequency	270 cps for 0.3 ips tape speed
Dynamic range	The following can be achieved when reproducing with systems comparable to Ampex 100B or Minneapolis-Honeywell LAR 7400 systems: With flutter compensation, 45 to 50 dB. Without flutter compensation, 34 to 40 dB (based on noise measurements made with an RMS meter).
Tape speed deviation	±0.50% maximum from nominal
Heads	14-channel - per IRIG specifications

Frequency response	Flat within 1/2 dB from dc to 50 cps at 0.3 ips
Input level	± 1.41 volts zero-to-peak to produce ±40% deviation on high-gain channels
Polarity	Positive voltage at the input to an FM record amplifier results in an increase in carrier frequency.
Maximum harmonic distortion	2.0%
FM linearity	Dc and ac linearity ±2% of full bandwidth
Center frequency drift	No more than 2% of full scale in 24 hours after 1-hour warmup
Sensitivity drift	No more than 1% of full scale in 24 hours after 1-hour warmup

6.4.2 Magnetic-Tape Specifications

The magnetic-tape data are recorded on Reeves Soundcraft or Ampex instrumentation-grade tape, 1.5 mil thick by 1-inch wide; it conforms to MIL-T-210 29A specifications. The tape is wound on NAB standard reels.

6.5 SYSTEM IDENTIFICATIONS

6.5.1 Channel Assignments

Standard channel assignments on the LRSM magnetic tapes are as follows:

Channel 1	Not in use (reserved for BCD time)
Channel 2	SPT-LO
Channel 3	SPR-HI
Channel 4	SPR-LO
Channel 5	SPZ-HI
Channel 6	SPZ-LO
Channel 7	Wow and flutter compensation at 270-cps center carrier frequency

Channel 8	SPT-HI
Channel 9	LPZ-HI
Channel 10	LPZ-LO
Channel 11	LPR-HI
Channel 12	LPR-LO
Channel 13	LPT-HI
Channel 14	WWV, voice comments and station time

As previously mentioned, the data user is cautioned not to assume that any given LRSM team utilizes these standard assignments at all times. Channel assignments must always be determined from the operations logs.

6.5.2 Voice Comments

At 0105Z, the following voice comments are recorded on channel No. 14 of the magnetic-tape system:

a. Team number and station designator;

b. Station location;

c. Run number and date;

d. Channel identification;

e. Seismometer orientation and polarity.

Voice comments are also made before and after any maintenance which affects the data and prior to any instrument calibrations. Calibration comments include all information pertinent to the calibration, such as:

a. Size of calibration weight used;

b. Current used;

c. G (motor constant) of the calibrator actuators;

d. Each frequency of all sine wave calibrations,

End-of-run comments include:

a. Team number and designator;

b. Station location;

c. Run number and date;

d. Remarks (weather conditions, equipment malfunctions, maintenance, etc.,).

6.6 USEFUL RANGES OF THE TAPE SYSTEM AND THE PHOTOTUBE AMPLIFIER (PTA)

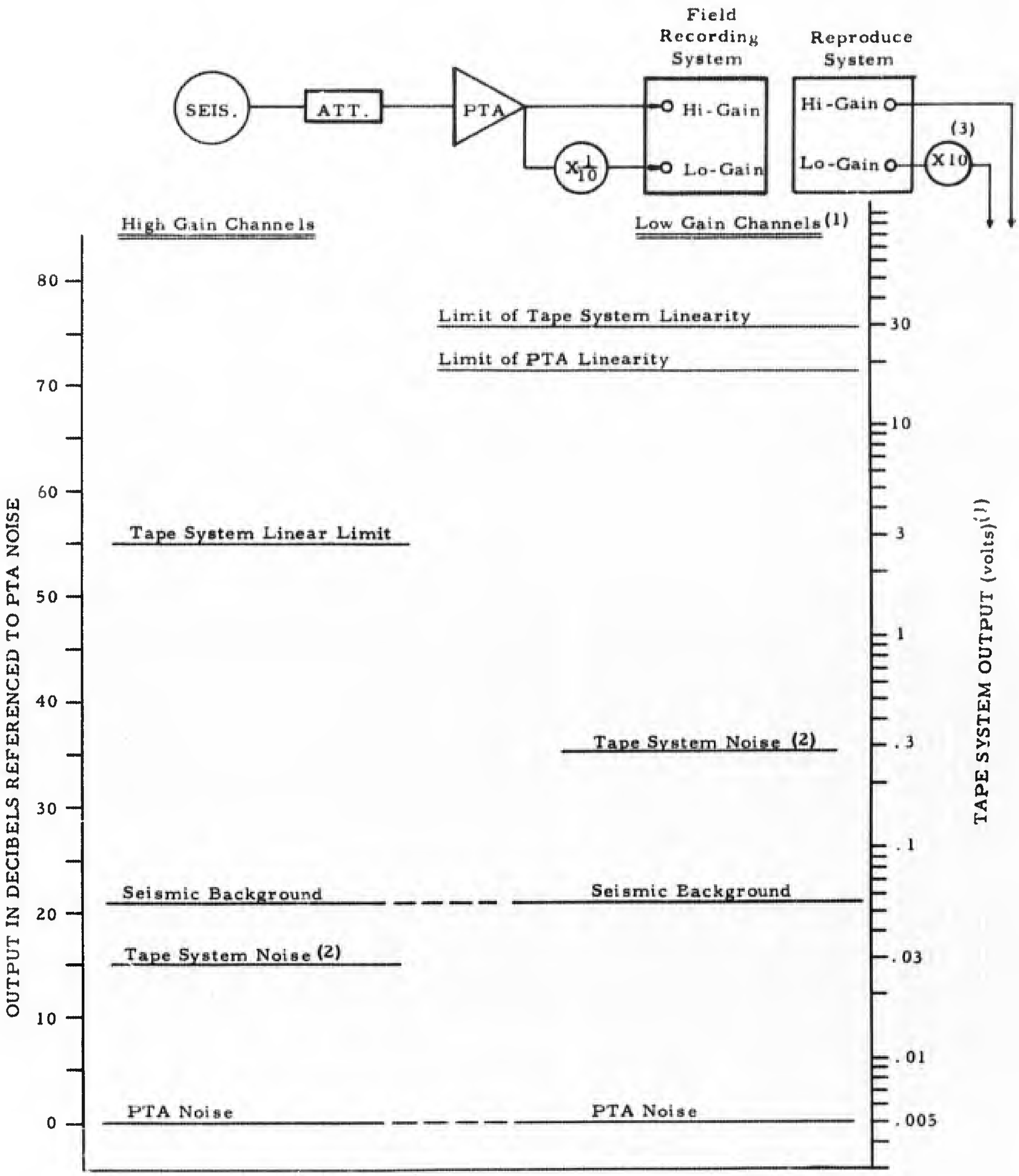
The useful range (±2% linearity) of the PTA output is 16 volts peak-to-peak. The linear range of the magnetic-tape system record and reproduce electronics is 2.8 volts peak-to-peak (input) for high-gain channels and 28 volts peak-to-peak (input) for low-gain channels. A 2.8 volt peak-to-peak signal input will produce a ±40% deviation of the center carrier (e.g., a ±40% deviation of the 270 cps carrier corresponds to a minimum frequency of 162 cps and a maximum of 378 cps).

The linear range of the PTA will be exceeded on a low-gain tape channel before the range of the tape system is exceeded. On the high-gain channels, however, the magnetic-tape system electronics will become nonlinear before the nonlinear region of the PTA is reached. These relationships are illustrated in figure 17 along with the relative levels of seismic background, tape noise, and PTA noise.

PTA clipping occurs at approximately 20 volts peak-to-peak output, which is somewhat beyond the linear range of the PTA. This PTA clipping limits the maximum signal recorded on the low (one-tenth) gain channel to 2 volts peak-to-peak, which is within the linear range of the tape channels.

6.7 RECORDING TIME ON MAGNETIC TAPE

At the beginning of the LRSM Program, station time was recorded on channel 1 (an FM channel) of the magnetic-tape system. In May 1962, station time was moved from channel 1 to the direct record channel (channel 14). Station time is now recorded in the form of a low-level, precision-frequency, 60-cps tone. The time-mark pulses from the station timing system are used to raise the level of the 60-cps tone by a factor of 3 or more; thus, the time code is changed from a series of dc pulses to a series of 60-cps pulses.



(1) Voltage levels given are those that would be reproduced if levels were set for 5 mv of PTA noise from both channels

(2) Tape system noise levels are for compensated playback

(3) This amplifier is shown for comparison purposes only

Figure 17. Relative levels of data and noise on LRSM magnetic tapes

This 60-cps station time is recorded simultaneously with WWV and voice on channel 14. Bandpass filters are used to separate the two for playout purposes and a converter puts station time back into the conventional dc pulse mode.

Channel 1 is left blank to accommodate a digital code that will eventually be placed on the tapes for high-speed machine searching.

6.8 TAPE SYSTEM CALIBRATION

The magnetic-tape system is calibrated daily to ensure that the 2.8-volt peak-to-peak linear range of the tape system is kept within tolerance. The system's center carrier frequency of 270 cps, the maximum low-frequency deviation, and the maximum high-frequency deviation are each aligned at the end of each recording period. Following the alignment of all channels, the center carrier and both upper and lower deviations are recorded for quality control verification. The tape system noise level (in millivolts) near the beginning and the end of each run for each data channel of the tape system is measured and entered in the daily tape log.

6.9 CALCULATION OF SENSITIVITY FROM EM CALIBRATIONS

To find the sensitivity of a channel in the tape system, it is necessary to first compute earth motion equivalent to a given sine-wave calibration by using the following formula:

$$Y = \frac{G i_2 10^6}{4\pi^2 f^2 m}$$

where:

Y = Equivalent earth motion in microns, due to i_2;

G = Motor constant of remote calibrator actuator, in newtons/ampere (see team operational log);

i_2 = Sinusoidal current through calibrator coil, in amperes peak-to-peak (see team operational log);

f = Frequency of i_2, in cycles per second;

m = Seismometer mass, in kilograms;

= 107.5 for large vertical Benioff (SP) seismometer

= 100.0 for large horizontal Benioff (SP) seismometer

= 14.4 for portable vertical Benioff (SP) seismometer

= 14.2 for portable horizontal Benioff (SP) seismometer

= 10.0 for vertical Sprengnether (LP) seismometer

= 10.0 for horizontal Sprengnether (LP) seismometer

= 18.0 for vertical Johnson-Matheson Seismometer, Geotech Model 6480

= 103.0 for Deep-Hole Seismometer, Geotech Model 11167

= 5.0 for Geotech Portable Short-Period Seismometer, Model 18300

= 10.0 for Geotech Vertical Long-Period Seismometer, Model 7505A

= 10.0 for Geotech Horizontal Long-Period Seismometer, Model 8700C

When the equivalent earth motion for a 1-cps (short-period) and .04 cps (long-period) calibration is known, the sensitivity of a magnetic-tape channel at that frequency can be determined by measuring the peak-to-peak voltage of the calibration signal from playback and substituting into the following formula:

Sensitivity at 1 cps (volts/micron)

$$= \frac{\text{peak-to-peak volts from playback of cal signal}}{\text{equivalent earth motion at 1 cps in microns (Y)}}$$

The sensitivity at any other frequency can be obtained by multiplying the sensitivity 1 cps (short period) and .04 (long period) by the correction factor G_t for that particular frequency and seismograph system (see table 2).

The equivalent earth motion in microns for the 1.0 cps sine-wave calibration and the .04 cps sine-wave calibration are given on the tape logs under column "Y" (cal level in microns).

For some applications, it is not necessary to determine the playback sensitivity. For instance, if an oscillograph record is made when the tape is played back, the magnification of the visual record can be found by using the magnification formula already discussed for film records in paragraph 3.4 or by the relationship:

$$\text{Magnification (in K)} = \frac{A}{Y}$$

where:

A = Calibration amplitude in millimeters peak-to-peak

Y = Equivalent earth motion in microns (given in daily tape log)

The magnification at any frequency other than the calibration frequency can be found by using the correction factors (G_t) given in table 2.

7. COMPOSITE RECORDS

7.1 GENERAL

A composite record is a single tape or film, containing the calibration data and signals from a specific seismic event recorded at each of the operative observatories. The composites are prepared by recording onto a single reel of magnetic tape, the signals from the original magnetic-tape records. Composite film records are direct playbacks of the composite tape. Microfilmed copies of the station logs are attached to the end of the film composites.

Detailed information on a particular composite is provided in the "Composite Record Discussion" report prepared for that event.

7.2 MAGNETIC-TAPE COMPOSITE

The magnetic-tape composite record contains calibration data, seismic background data, signals, station-time data, and WWV time-reference data. Insofar as possible, the data are arranged in order of increasing distance from the epicenter.

As was mentioned in section 1 of this report, data from observatories other than LRSM stations are included in composites. The frequency response characteristics for systems in operation at these observatories are given in figures 18, 19, and 20. Response characteristics of LRSM short- and long-period systems are shown in figures 11, 12, 13, 14, and 15.

In preparing a magnetic-tape composite, selected segments of data from approximately 40 reels of tape are rerecorded onto a single reel. The advantages are that access to specific signals is greatly simplified and the cost of providing copies is reduced. A composite record for a scheduled event will have calibration data for each station recorded 5 to 10 minutes before the event, followed by about 20 minutes of seismic data, including the signal. Thus, approximately 30 minutes of data are recorded from each station; i.e., the composite presents sequentially a segment of data from an observatory, followed by a "tape break" (short segment of random noise), followed by data from another observatory, etc. Unscheduled arrivals, such as earthquakes or delayed shots, will not have calibration data so conveniently arranged.

Station-time data are recorded on channel 14 in the form of a 60-cps carrier that is amplitude-modulated by the time pulses from the standard LRSM timing system. At the time of a 10-second, 5-minute, half-hour, or hour mark, the amplitude of the 60-cps carrier rises to a level approximately three times that of the background "tone." The 60-cps power from the station timing system is used for the carrier. This 60-cps time program is direct-recorded on channel 14 concurrently with WWV and the team's voice comments. A system of filters is required to separate these timing signals. Timing is discussed in more detail in paragraph 4.

Field recordings are made at a tape speed of 0.3 inch per second (ips). Recording onto the composite tape is done in the laboratory with two instrumentation-grade magnetic-tape systems operated at 30 ips. Direct-recording is used in this process, so demodulation of the original carriers is not necessary.

A continuous binary reference code which can be used for computer searching is recorded on channel 1 of the composite tape. The code utilized is that recommended by the Time Code Standards Committee of the Working Group for Systems Development, VELA-UNIFORM, Task III. It is recorded FM with a 270-cps center carrier after the composite is made. The binary time code bears no relationship to actual station times and can be used only for reference purposes. See figure 21 for an explanation of the VELA Standard Time Code.

The seismological observatories and a few LRSM mobile observatories record either binary time code or other data on channel 1 of the field tapes. Data from

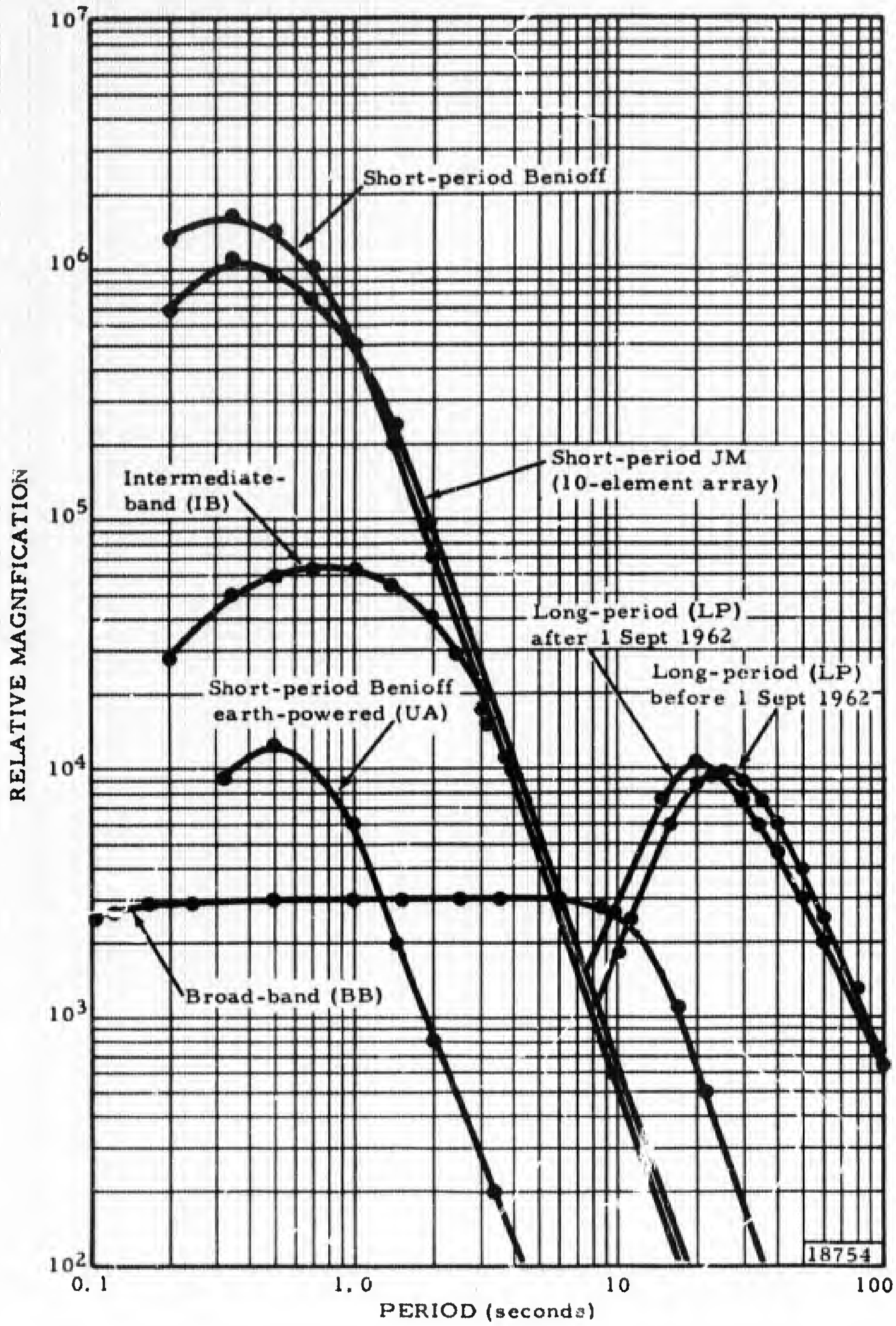


Figure 18. Response characteristics of seismographs at Wichita Mountains Seismological Observatory

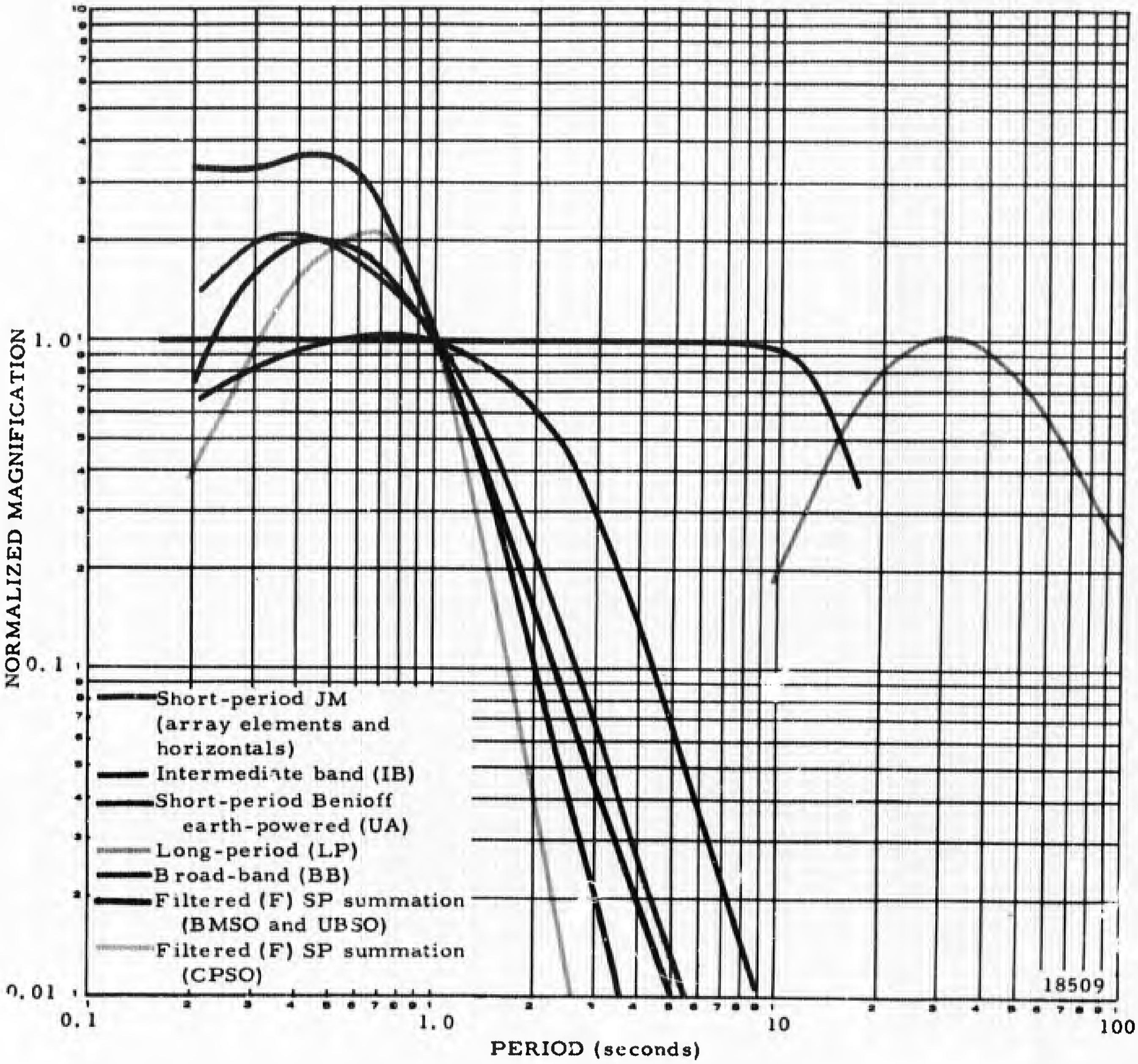


Figure 19. Normalized response characteristics of seismographs at Blue Mountains Observatory, Cumberland Plateau Observatory, and Uinta Basin Observatory

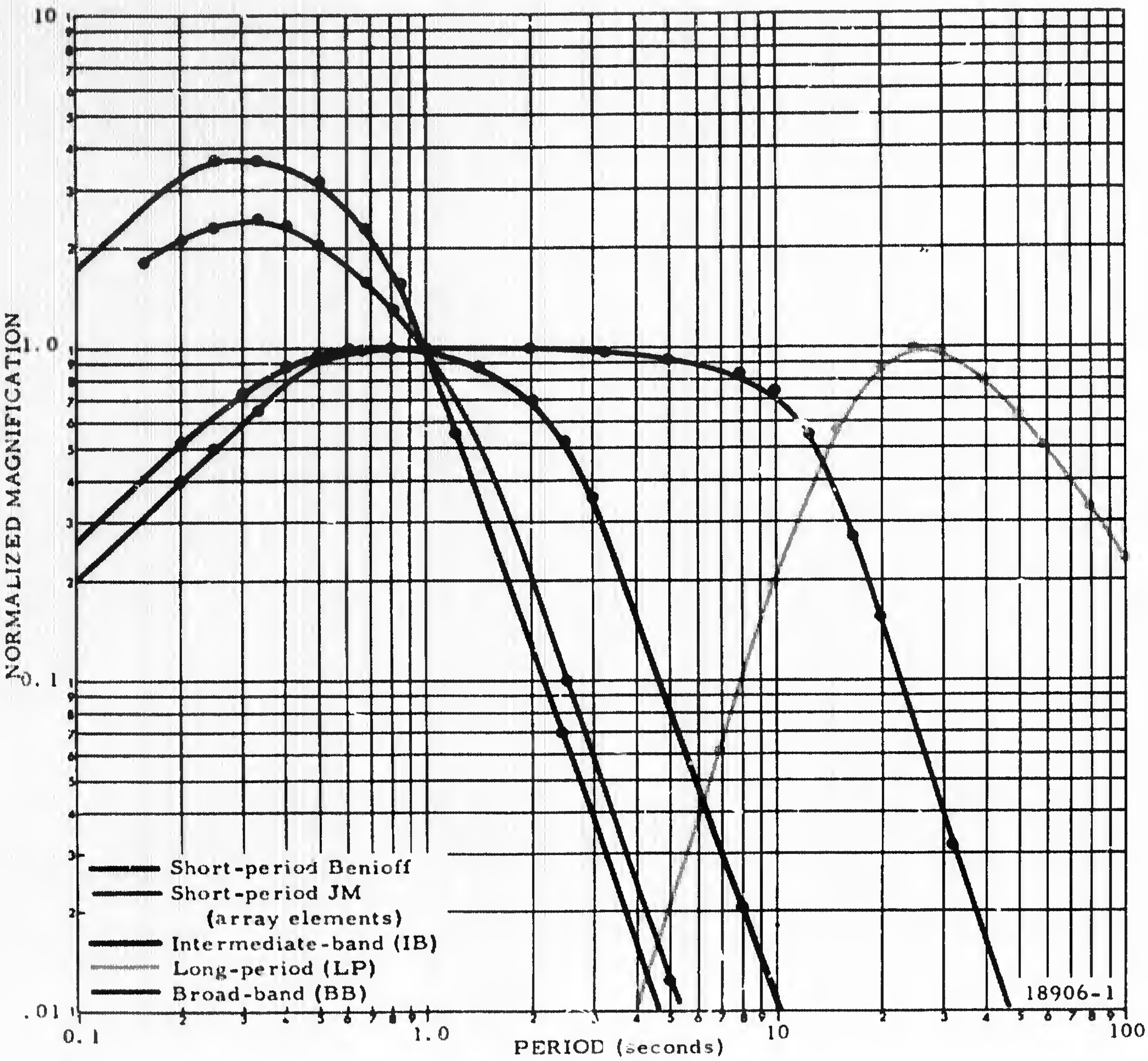
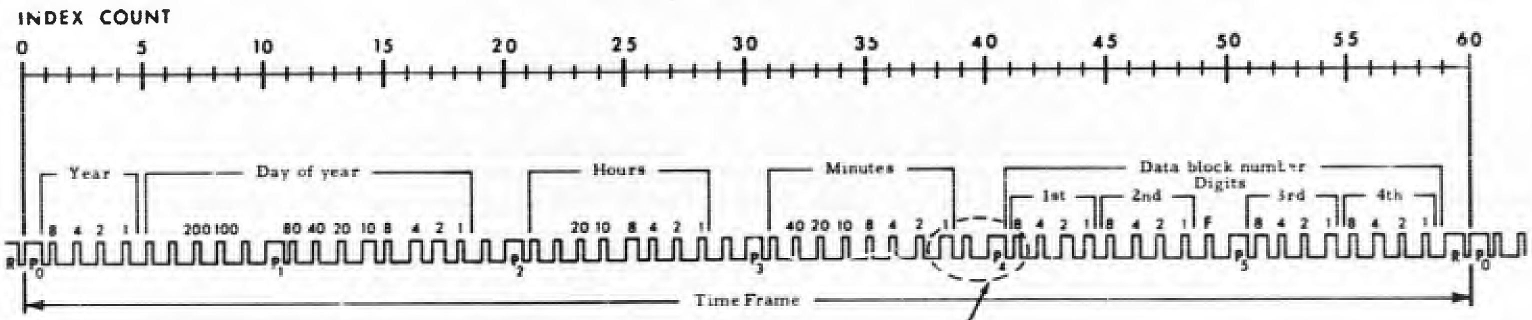
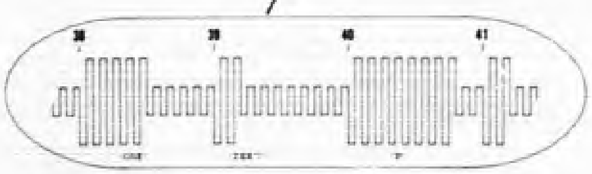


Figure 20. Normalized response characteristics of seismographs at Tonto Forest Observatory





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

Figure 21. VELA standard time code

such sites are placed at the end of the composite and the channel 1 reference code is terminated before it can record over these segments, thus leaving the original field data intact.

Copies of the master composite tapes are rerecorded by the same direct-recording method used in preparing the original (master) composite. The master composite and all copies are carefully checked to ensure that the correct data were recorded and are of the required quality.

The beginning of each station segment is marked in ink on the back of the tape with the five-letter site code. The beginning of data from each station is announced on channel 14 with a voice comment, followed by an index number and the five-letter site code in International Morse Code. The stations are numbered sequentially as they appear in the composite.

7.3 SIXTEEN-MILLIMETER DEVELOCORDER FILM COMPOSITE RECORD

The record is a film playout of the composite tape, with the channels individually attenuated to optimize the readability of the film. The one-tenth gain channels on tape are attenuated 6 dB less than the high-gain channels during playout to derive a high-to-low amplitude ratio on film of 5 to 1. In addition to the high-gain and low-gain information, WWV is also provided. During playout, a filtering system is used to pass only the 440-cycle WWV tone. This action inhibits all timing fiducials except at the odd 5 minutes (5, 15, 25, etc.,). Station time is superimposed on all data traces and the WWV trace. The timebase is 5 cm/10 sec at X10 view.

In making the short-period 16-mm film playout, a "zero-return" card is used in the reproduce discriminators to keep uselessly high amplitudes from interfering with the rest of the data. This card detects any signal which causes the carrier deviation to exceed ± 45% and reads it out as a "dead" trace. The maximum linear range of the systems corresponds to a carrier deviation of ±40%. (See sections 6.3 and 6.4).

Time-reference numerals, which appear at the top of the film every minute, are useful for gauging time intervals along the record, but bear no relationship to actual event time.

Every minute, a two-letter station designator, followed by a three-digit run number, appears between the time reference numerals. The station designator, which identifies the source of each data segment, is the first two letters of the five-letter code for each station (e.g., LC, VN, NG). The run number is the day the event took place, numerically expressed (e.g., April 12 = run No. 102, or the 102d day of the year).

The stations generally appear in order of increasing distance from the event epicenter. Normal trace assignments, from top to bottom, are:

Trace	Tape channel No.	Data (assuming standard tape channel assignments)
1	1	Binary code
2	5	SP-Z Hi gain
3	6	SP-Z Lo gain
4	3	SP-R Hi gain
5	4	SP-R Lo gain
6	8	SP-T Hi gain
7	2	SP-T Lo gain
8	14	WWV

Irregular channel assignments or other deviations from this procedure are given in the Composite Record Discussion report for the particular event.

7.3.1 Restrictions on Amplitude Measurement on Film

When attempting amplitude measurements on film, it should be remembered that the high-gain magnetic-tape channels become nonlinear before the zero return circuit is actuated.

The Develocorder input circuits are adjusted so that the useful range of the tape channels (2.8 volts peak-to-peak) corresponds to a known amplitude on the film. The liminting amplitudes on the high-gain channels for any particular composite film are listed in the Composite Discussion Reports. The amplitude of any signal exceeding this limit should be measured from the corresponding low-gain trace.

The limit of accurate measurement on a low-gain trace is determined by the limit of the PTA linearity. The limiting amplitudes on the low-gain channels for any particular composite are listed in the Composite Discussion Reports. The amplitude of any signal which exceeds this limit on a low-gain channel cannot be accurately determined from these records.

7.3.2 Operational Logs

Microfilm reproductions of the operational logs are attached to the end of each 16-mm composite film. Logs pertaining to the 35-mm film records are included with the magnetic-tape logs. The logs are microfilmed in the order in which the data are recorded on the composite tape. They are reviewed for completeness and accuracy, and changes are made when necessary. Logs not available for a particular composite are listed in the discussion booklet.

8. PORTABLE SYSTEM

8.1 GENERAL

In the spring of 1964, a portable seismograph system was constructed and subsequently phased into the LRSM Program. This system answers a need for greater mobility and has the capability for unattended operation in remote locations under all environmental extremes.

In anticipation of increased usage of the portable system, this section is included to aid in interpretation of portable system data.

Figure 22 is a simplified block diagram of the basic portable seismograph system.

8.2 INSTRUMENTATION

8.2.1 Short-Period Seismographs

Three Portable Seismometers, Geotech Model 18300, comprise the short-period instrumentation. This model seismometer can be used as a vertical or horizontal instrument by a simple suspension conversion.

8.2.2 Long-Period Seismographs

One Vertical Seismometer, Geotech Model 7505A, and two Horizontal Seismometers, Geotech Model 8700C, make up the long-period complement of instruments.

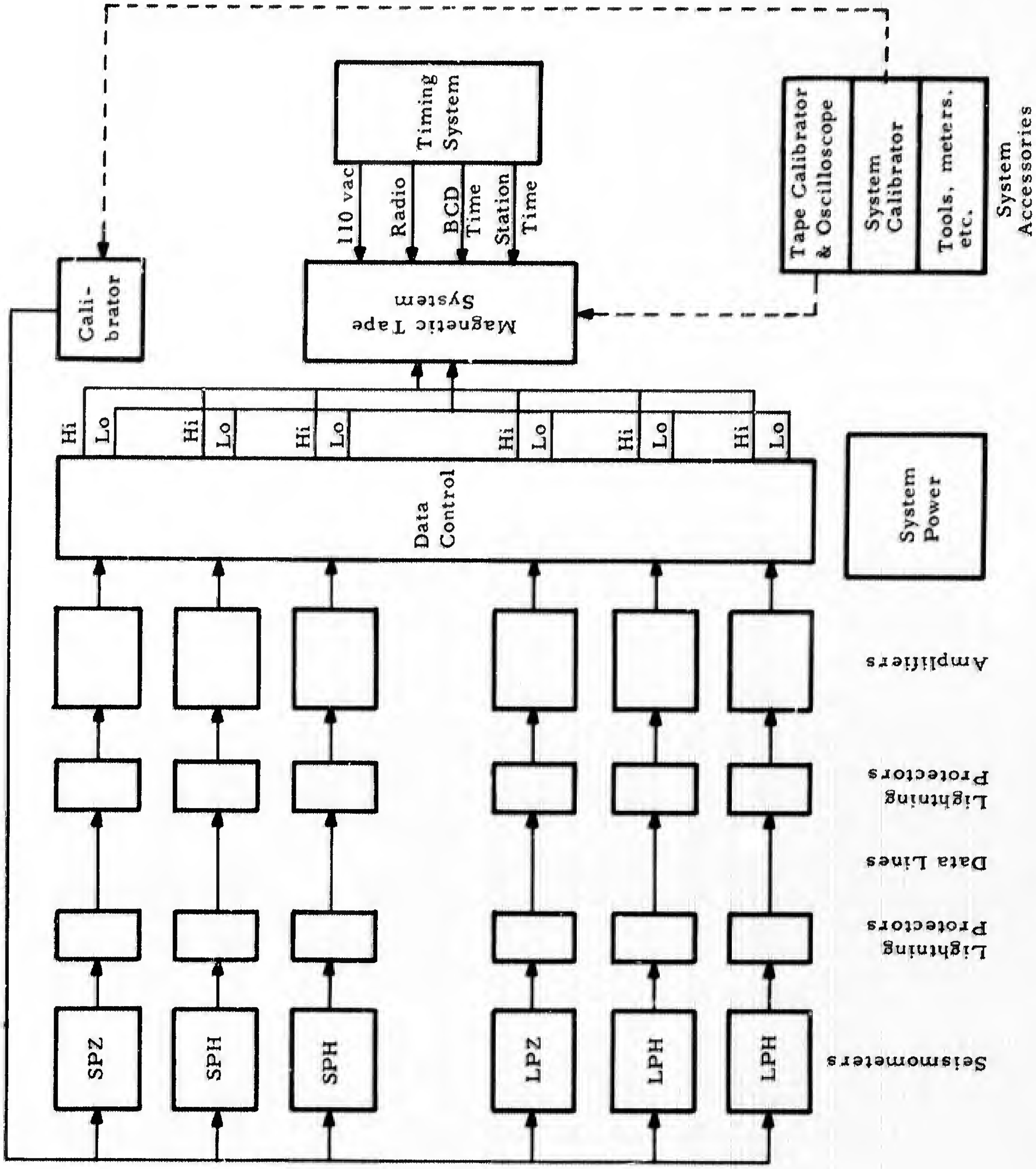


Figure 22. Basic Portable Seismograph System, Model 19282

8.2.3 Recorder

Data are recorded on a 14-channel slow-speed Magnetic-Tape Recorder, Geotech Model 19429. This system records frequency-modulated (FM) data with a tape speed of 0.03 ips and will operate unattended for a period of 7 days. The FM center frequency (27 cps) conforms to the VELA UNIFORM magnetic-tape format.

8.3 CALIBRATION

The short-period seismographs can be calibrated by both electromagnetic and weight-lift methods. The long-period seismographs are calibrated by electromagnetic calibration methods only. Previous chapters in this report discuss these calibration methods.

Figure 23 is a curve showing correction factor (C) to be used when magnification is computed from the short-period weight-lift method (see section 3.3).

The frequency responses of both long- and short-period portable systems are within the tolerance limits prescribed for LRSM data (see figures 11 through 14).

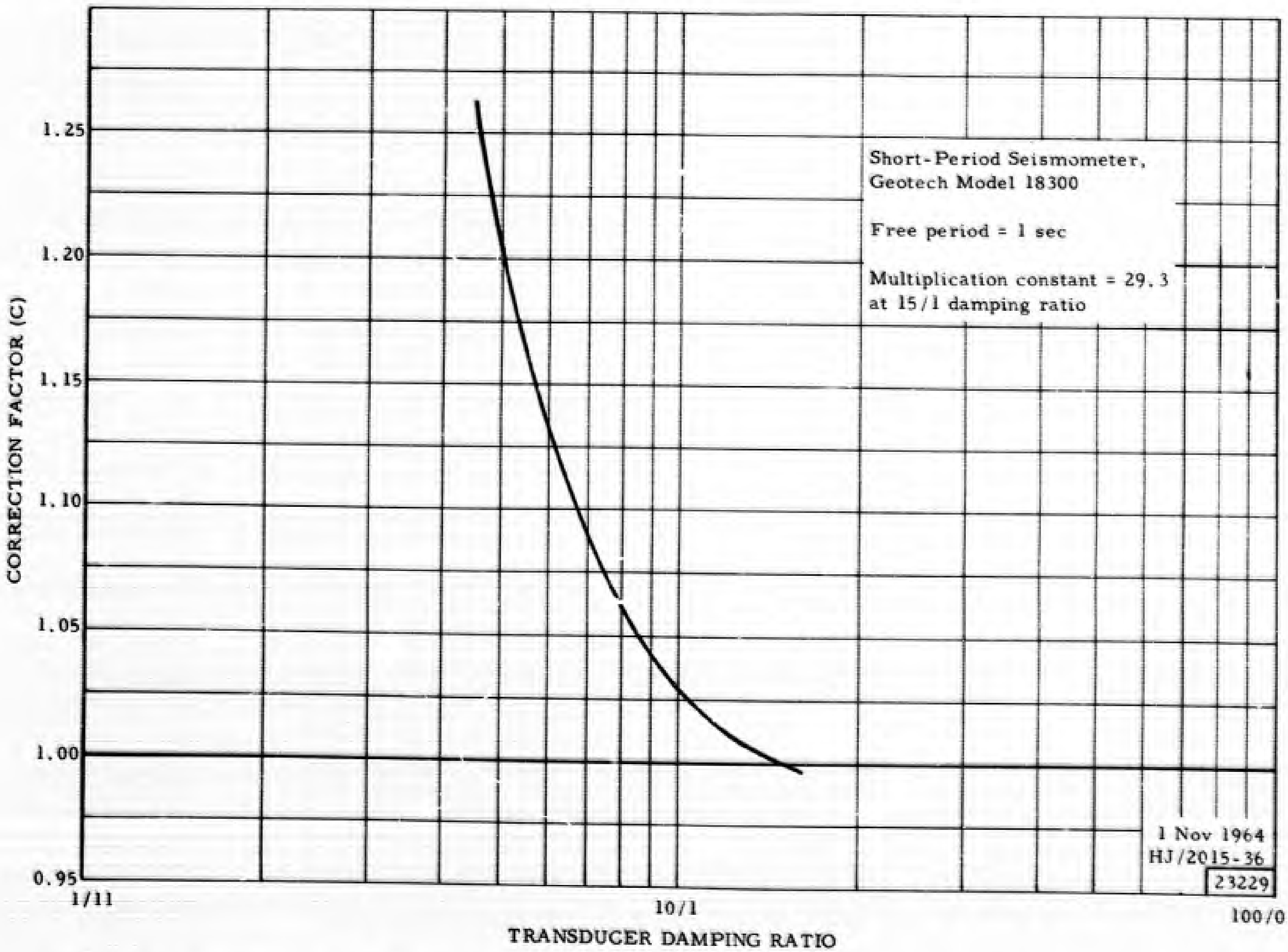


Figure 23. Correction factor (C) for correcting system magnification computed from a weight-lift calibration

9. GLOSSARY OF ABBREVIATIONS

Abbreviations[1]	Meaning	Reference(s)
ATT	Attenuator	Figure 16
BB	Broad-band seismograph	Figure 17
BL	Ball-lift (calibration)	Figure 6, section 3.1
BMO	Blue Mountains Observatory	Sections 1, 7
Cal.	Calibration(s)	Section 3
Ch.	Tape channel(s)	Section 6.5
Chrono.	Chronometer (timing system)	Sections 4.1, 4.2
CPO	Cumberland Plateau Observatory	Sections 1, 7
cps	Cycles per second	Section 3
DH	Deep-hole seismograph	Section 1
ED	Electrodynamic (calibration)	Section 3.5
EM	Electromagnetic (calibration)	Section 3.4
Hi	High-gain data channel	Section 6.5, figure 16
IB	Intermediate-band seismograph	Figure 17
ips	Inches per second	Section 6.1
JM	Johnson-Matheson seismometer	Figures 17, 18
Lo	Low-gain data channel	Section 6.5, figure 16
LP	Long-period seismograph	Figures 12, 13
LRSM	Long-Range Seismic Measurements (Program)	Section 1
mV	Millivolts	Section 6.3
Oper. Amp.	Operation amplifier	Section 6.4.1
PTA	Phototube amplifier	Section 6.6
R	Radially oriented horizontal seismometers	Section 3.1
SP	Short-period seismograph	Figure 10, 11, 14, 17, 18, 19
Sta.	Station (or site)	Section 1
T	Transversely oriented horizontal seismometer	Section 3.1

[1]These are the most common abbreviations used by personnel in the program. They are frequently used by the LRSM team members when completing their operational logs.

Abbreviations	Meaning	Reference(s)
TFO	Tonto Forest Observatory	Sections 1, 7
UBO	Uinta Basin Observatory	Sections 1, 7
WMO	Wichita Mountains Observatory	Sections 1, 7
Z	Vertically oriented seismometer	Section 3.1

10. SUPPLEMENTAL INFORMATION

All phases of the LRSM Program are oriented toward continual development and refinement of equipment and methods resulting in new systems, such as the portable system described in section 8. As new equipment and methods are developed in the future, addenda will be published for inclusion in this manual.