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HEBGEN LAKE EARTHQUAKE

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by

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Garland, Texas

under

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1 November 1962

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TABLES

ILLUSTRATIONS

ILLUSTRATIONS (continued)

UNITED STATES

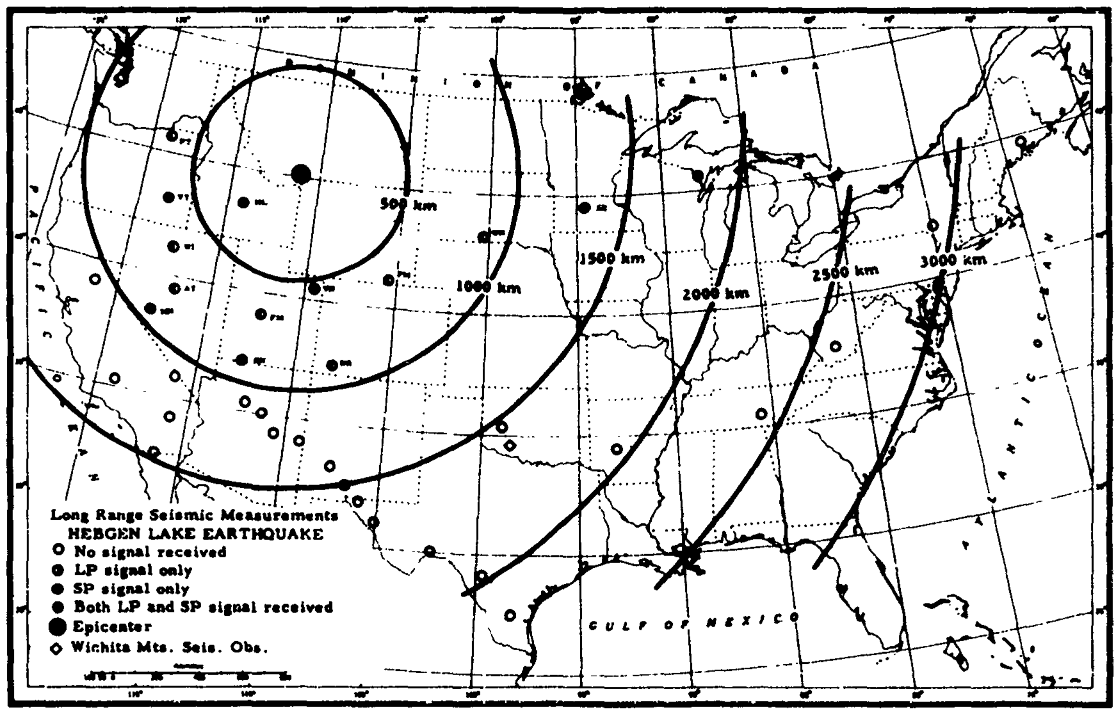

Figure 1. Approximate locations of stations receiving a signal from HEBGEN LAKE EARTHQUAKE.

INTRODUCTION

This report is concerned with the presentation of the basic seismic data from an earthquake that occurred near HEBGEN LAKE, Montana, on 25 February 1962. The data were recorded by the Long Range Seismic Measurements (LRSM) Program field teams established under VELA-UNIFORM Project 8.4. The United States Coast and Geodetic Survey (USC&GS) located the earthquake at 45.2° N., 111.2° W., approximately 25 km deep with an origin time of 17:17:38.9 GMT. The results of visual analysis are presented in both tabular and graphic form.

DATA AND RESULTS

The sources of data for this report were the 35-mm film and magnetic-tape recordings submitted by the 36 LRSM teams and the Wichita Mountains Seismological Observatory (WMSO). Magnifications and time corrections are listed in table 1. Distances were computed by the Southern Methodist University (SMU) Computer Laboratory, and the epicenter location given by USC&GS was checked using a computer at Geotech. Data reduction procedures, definitions, and analysis

techniques used in preparing this report are given in the appendix. LRSM site information is listed in table 2.

Each of the 37 stations reporting, except HL ID, produced usable recordings. The signal at HL ID overloaded both the high- and low-gain film and magnetic-tape channels. In some cases, it was necessary to analyze from the magnetic-tape playbacks in order to define the later phases. This was done because of poor light intensities or improper processing techniques on the 35-mm film recordings.

The approximate locations of the reporting field teams and the 13 stations recording one or more recognizable phases from the earthquake are shown in figure 1. Only one station, SE MN, recorded a recognizable signal beyond 950 km from the epicenter. Possible signals on the long-period seismograms were recognized at 3 stations.

Periods and amplitudes of the first half cycle ("A" measurement) and of the maximum half cycle ("D" measurement) of the P_n or P phase are listed in table 3. The "A" and "D" amplitudes divided by the period are plotted versus epicentral distance in figures 2 and 3, respectively. For this earthquake, the plots appear to show a higher attenuation rate with distance than for the explosions previously studied.

The grading system for first arrivals used in previous reports was utilized for this earthquake. It is explained in the appendix.

As for previous reports, the first arrivals at stations in the 200-1000-km distance range have been tentatively defined as waves traveling a critically refracted path beneath the Mohorovicic discontinuity and have been labeled as P_n. At HL ID, 299 km, this wave arrived as an impulsive signal and could easily be timed to within ±0.1 second; at greater distances from the epicenter the signal was emergent and may be mistimed by as much as 1-2 seconds. The travel times and residuals (reduced travel times) for this phase are listed in table 4; the residuals are plotted versus epicentral distance in figure 4. Because of the considerable scatter, no attempt was made to assign a velocity to the P_n phase. It is suggested that the apparent negative intercept for the P_n travel time versus distance plot may indicate that, due to insufficient data, an accurate origin time could not be determined.

The amplitudes and periods of P_g, L_g, and Rayleigh phases are listed in table 5. The maximum amplitudes divided by the periods for the P_g and L_g phases are plotted versus epicentral distance in figures 5 and 6, respectively. For the P_n or P phase, these amplitudes show a higher rate of signal attenuation with distance than the explosions previously studied.

The reduced travel times for P_g and L_g (listed in table 4) are plotted versus epicentral distance in figures 7 and 8, respectively. As for the P_n data, no attempt was made to assign velocities to these data for this report.

The travel time versus distance plots for all phases show an unusual amount of scattering. Listed below are possible reasons for this scattering:

a. Errors in the epicentral coordinates due to insufficient data;

b. Repeated motion at the earthquake source; i.e., at HL ID and VT OR the first arrival was followed by a large clear arrival 1-2 seconds later. This may indicate a double shock or the arrival of pP. At more distant stations, this may have been timed as a first arrival.

c. Regional variations in either the velocity of P_n in the upper mantle or the dip of the Mohorovicic discontinuity;

d. Variations in local geology beneath each station.

The epicenter calculated by a GEOTECH computer program was 45.32° N., 111.19° W., approximately 21 km deep with an origin time of 17:17:34.2 GMT. This location is in fair agreement with the USC&GS epicenter, but the lack of azimuthal control tends to make the results questionable.

The revised unified magnitude for each station that recorded a P_n or P phase (listed in table 3) was computed from the following equation:

$$m = \log_{10}(A/T) + B$$

where:

m = revised unified magnitude

A/T = the maximum peak-to-peak amplitude divided by the period

B = a correction factor that accounts for the attenuation of signal strength with distance

The magnitudes are plotted versus epicentral distance in figure 9. When all stations are considered, the average magnitude is 4.2 with a standard deviation of ±.68. As can be seen from figure 9, the magnitudes appear to be dependent on distance so that an average magnitude is probably deceiving.

SPECIAL PRESENTATIONS

Included in the envelope at the back of this report are reproductions of the signal from HEBGEN LAKE recorded at WI NV, VT OR, PT OR, PM WY, and VN UT. These records present the data from all three short-period instruments side by side with the data from all three long-period instruments.

The magnification of each trace, orientation of the instruments, and corrected time are noted on each record. The time base utilized is 2.0 centimeters per 10 seconds. Response curves for both the long-period and the short-period systems are included on each record, along with the distance in kilometers from NTS to the recording station.

RECOMMENDATIONS

Due to the relatively low magnitude of the HEBGEN LAKE earthquake, the data are not of sufficient quality to warrant further study. There appear to be no distinctive features of this earthquake that can be used to differentiate it from an underground explosion.

Table 1. HEBGEN LAKE EARTHQUAKE. Analysis Information

Station	Distance (km)	Time corr.	Magnification (k) Short period Z	Short period R	Short period T	Long period Z	Long period Z-lo	Long period R	Long period T	Remarks
HL ID	299	0.0	343.3	361	362.9	10.9	1.02	9.7	10.7	
VN UT	538	-7.0	154	160	191	22	2.49	13.3	7.75	
PT OR	603	-0.7	195	187	192.5	5.16	.51	2.17	2.62	
VT OR	621	0.0	282	288	296	16.29	1.63	18	11.54	
PM WY	650	-0.2	145	131	112	6.9	.72	7.07	6.6	
WI NV	664	-0.3	411	423	392	15	1.37	13.2	13	
FM UT	670	+0.1	290	296	320	11.8	1.18	5.4	5.06	
AT NV	798	+1.8	570	568	595	27.2	2.72	32.3	23.3	
WN SD	905	-0.9	54	49.4	45.6	8.04	.8	3.5	4.04	
DR CO	906	-0.2	368	380	380	10.6	1.14	24.5	25	
KN UT	919	-0.3	202	232	248	8.74	1.05	12.5	--	LP-T inoperative
MN NV	947	-0.3	596	588	552	34.7	2.04	19.8	21.1	
MV CL	1065	-1.3	227	379	255	8.0	.9	9.7	4.3	
WM AZ	1090	-8.5	206	194	221	14.5	1.44	14.22	14.78	
DV CL	1120	0.0	340	289	323	28.9	2.87	18.7	26.1	
FS AZ	1126	+0.2	177.5	184	240	27.1	3.44	25.5	25.8	
SF AZ	1197	+0.5	227	233	236	6.9	.69	13.5	11.6	
SV AZ	1237	0.0	85.9	86.9	91.1	15.1	1.48	18.8	16.1	
BF CL	1242	-8.4	510	510	620	13.9	1.59	13.0	14.6	SP-Z gain from EM Cal
TN CL	1287	+0.2	241	248	240	10.0	1	6.91	7.33	

Table 1. HEBGEN LAKE EARTHQUAKE. Analysis Information (continued)

Station	Distance (km)	Time corr.	Magnification (k) Short period Z	R	T	Long period Z	Z-lo	R	T	Remarks
SE MN	1309	0.0	222	229	225	16.2	1.62	16.2	14.8	
TC NM	1372	0.0	168	136	130	2.4	.24	12	12.5	SP-R and SP-T computed from 1 cps sinusoid
CP CL	1455	-0.7	215	227	214	5.22	.54	3.91	4.9	
LC NM	1475	+1.3	368	412	392	5.16	.82	5.3	4.81	
HB OK	1524	0.0	85.6	98	96	16.9	1.69	2.54	4.25	LP-Z change DB setting at 17:30
EP TX	1541	-0.9	275	256	280	8.9	.89	10.3	8.2	
WM SO	1583	0.0	780	(summation of ten short-period instruments)						
EF TX	1644	-1.8	388	392	172	2.69	.27	1.92	8.35	
NG WS	1798	-0.4	68.7	68	64.7	3.86	.39	3.99	3.60	
SS TX	1855	0.0	4.36	488	454	18	1.54	19	23.5	
MP AR	1934	-0.8	151	146.3	148	6	.6	8.3	10	
LP TX	2047	0.0	399	432	440	21.6	--	4.19	8.36	No sine wave for LP-Z lo
SJ TX	2262	-0.6	53.5	43.7	44.8	4.79	.4	4.63	4.35	
MM TN	2410	0.0	109	129	117	9.84	.98	8.88	10.6	SP-T gain from EM Cal
BL WV	2611	-0.9	65.6	56.7	59.9	6.97	.45	6.15	6.15	
DH NY	2921	+0.2	60.5	57.5	62	8.55	.86	7.55	7.92	SP-Z gain from EM Cal
BG ME	3279	-1.3	46.0	40.9	43	4.6	.46	--	5	SP-Z gain from EM Cal; unable to read LP-R

Table 2. HEBGEN LAKE EARTHQUAKE. Site Information

Site location	Site designation	Site location (geographic) North latitude deg	min	sec	West longitude deg	min	sec	Epicentral distance (km)	Bearing from epicenter (deg)	Horizontal seismometer orientation Radial (deg)	Transverse (deg)	Elevation (km)
Hailey, Idaho	HL ID	43	38	52	114	16	02	299	236	016	106	1.8
Vernal, Utah	VN UT	40	30	31	109	34	45	538	165	065	155	1.9
Pendleton, Oregon	PT OR	45	36	40	118	53	02	603	277	346	076	0.41
Venator, Oregon	VT OR	43	08	49	118	25	23	621	251	343	073	1.4
Laramie, Wyoming	PM WY	41	12	27	105	21	39	650	131	068	158	2.5
Winnemucca, Nevada	WI NV	41	21	02	117	27	30	664	232	346	076	1.5
Fillmore, Utah	FM UT	39	13	06	112	12	25	670	187	058	148	1.9
Austin, Nevada	AT NV	39	28	53	117	04	26	798	219	343	073	2.0
Winner, South Dakota	WN SD	43	15	08	100	11	46	905	100	069	159	0.79
Durango, Colorado	DR CO	37	27	53	107	47	00	906	160	090	180	2.2
Kanab, Utah	KN UT	37	01	22	112	49	39	919	189	095	185	1.7
Mina, Nevada	MN NV	38	26	10	118	08	53	947	220	308	038	1.5
Marysville, California	MV CL	39	13	36	121	18	05	1065	235	295	025	0.61
Williams, Arizona	WM AZ	35	25	04	112	[illegible]	54	1090	185	120	210	1.9
Death Valley, California	DV CL	35	50	00	116	06	06	1120	203	177	267	0.79

Table 2. HEBGEN LAKE EARTHQUAKE. Site Information (continued)

Site location	Site designation	Site location (geographic) North latitude deg	min	sec	West longitude deg	min	sec	Epicentral distance (km)	Bearing from epicenter (deg)	Horizontal seismometer orientation Radial (deg)	Transverse (deg)	Elevation (km)
Flagstaff, Arizona	FS AZ	35	04	09	111	18	34	1126	181	120	210	1.9
Snowflake, Arizona	SF AZ	34	26	19	110	30	52	1197	177	123	213	2.0
Springerville, Arizona	SV AZ	34	10	32	109	08	49	1237	171	120	210	2.1
Bakersfield, California	BF CL	35	39	12	118	51	06	1242	214	233	323	0.56
Twentynine Palms, California	TN CL	34	11	54	115	57	00	1287	200	176	266	0.53
Sleepy Eye, Minnesota	SE MN	44	24	51	94	39	55	1309	88	073	163	0.24
Truth or Consequences, New Mexico	TC NM	33	11	03	107	27	42	1372	165	122	212	1.5
Campo, California	CP CL	32	43	44	116	22	16	1455	200	182	272	1.2
Las Cruces, New Mexico	LC NM	32	24	08	106	35	58	1475	163	124	214	1.6
Hobart, Oklahoma	HB OK	35	10	35	98	54	37	1524	133	103	193	0.49

Table 2. HEBGEN LAKE EARTHQUAKE. Site Information (continued)

Site location	Site designation	Site location (geographic) North latitude deg	min	sec	West longitude deg	min	sec	Epicentral distance (km)	Bearing from epicenter (deg)	Horizontal seismometer orientation Radial (deg)	Transverse (deg)	Elevation (km)
El Paso, Texas	EP TX	31	55	58	105	58	00	1541	161	125	215	1.6
Wichita Mtns. Seis. Obs.	WM SO	34	43	05	98	35	21	1583	133	090	000	0.51
Eagle Flat, Texas	EF TX	31	10	35	105	07	48	1644	159	126	216	1.4
Niagara, Wisconsin	NG WS	45	45	34	88	09	15	1798	80	078	168	0.40
Sanderson, Texas	SS TX	30	01	17	102	19	41	1855	152	126	216	0.73
Mountain Pine, Arkansas	MP AR	34	36	06	93	08	45	1934	121	105	195	0.33
La Pryor, Texas	LP TX	29	10	47	99	40	35	2047	146	124	214	0.27
San Jose, Texas	SJ TX	27	36	43	98	18	46	2262	145	127	217	0.11
McMinnville, Tennessee	MM TN	35	33	52	85	35	20	2410	107	103	193	0.38
Beckley, West Virginia	BL WV	37	47	56	81	18	36	2611	98	100	190	0.61
Delhi, New York	DH NY	42	14	39	74	53	18	2921	83	095	185	0.65
Bangor, Maine	BG ME	44	38	04	69	13	17	3279	76	095	[illegible]	0.18

Table 3. HEBGEN LAKE EARTHQUAKE.
Periods and Amplitudes of P_n or P Arrivals

Station	Distance (km)	Grade	Period (sec) A	Period (sec) D	Amplitude (mμ) A	Amplitude (mμ) D	Particle velocity (mμ/sec) A	Particle velocity (mμ/sec) D	Magnitude (m)
HL ID	299	1	(.4)	(.4)	(13)*	(80)*	(32)	(200)	(4.9)
VN UT	538	3	.5	.4	1.2	2.6	2.4	6.5	4.1
PT OR	603	2	.5	(.4)	7	(80)	14	(200)	(5.8)
VT OR	621	2	.4	.4	.59	3.9	1.5	8.5	4.5
PM WY	650	3	.5	1.1	1.3	11	2.5	10	4.6
WI NV	664	3	.4	.4	.81	1	2	2.5	4.0
FM UT	670	3	.4	.4	2.1	2.1	5.2	5.2	4.2
AT NV	798	3	.6	.6	.74	.74	1.2	1.2	3.6
WN SD	905	3	-	-	--	--	--	--	--
DR CO	906	3	.5	.5	.2	.5	.4	1	4
KN UT	919	3	.5	.5	.91	.91	1.8	1.8	4
MN NV	947	3	.5	.5	.31	.31	.6	.6	3.9
MV CL	1065	-	-	-	--	--	--	--	--
WM AZ	1090	-	-	-	--	--	--	--	--
DV CL	1120	-	-	-	--	--	--	--	--
FS AZ	1126	-	-	-	--	--	--	--	--
SF AZ	1197	-	-	-	--	--	--	--	--
SV AZ	1237	-	-	-	--	--	--	--	--
BF CL	1242	-	-	-	--	--	--	--	--
TN CL	1287	-	-	-	--	--	--	--	--
SE MN	1309	4	-	-	--	--	--	--	--
TC NM	1372	-	-	-	--	--	--	--	--
CP CL	1455	-	-	-	--	--	--	--	--
LC NM	1475	-	-	-	--	--	--	--	--
HB OK	1524	-	-	-	--	--	--	--	--

Table 3. HEBGEN LAKE EARTHQUAKE.
Periods and Amplitudes of P_n or P Arrivals (continued

Station	Distance (km)	Grade	Period (sec) A	Period (sec) D	Amplitude (mμ) A	Amplitude (mμ) D	Particle velocity (mμ/sec) A	Particle velocity (mμ/sec) D	Magnitude (m)
EP TX	1541	-	-	-	--	--	--	--	--
WM SO	1583	-	-	-	--	--	--	--	--
EF TX	1644	-	-	-	--	--	--	--	--
NG WS	1798	-	-	-	--	--	--	--	--
SS TX	1855	-	-	-	--	--	--	--	--
MP AR	1934	-	-	-	--	--	--	--	--
LP TX	2047	-	-	-	--	--	--	--	--
SJ TX	2262	-	-	-	--	--	--	--	--
MM TN	2410	-	-	-	--	--	--	--	--
BL WV	2611	-	-	-	--	--	--	--	--
DH NY	2921	-	-	-	--	--	--	--	--
BG ME	3279	-	-	-	--	--	--	--	--

Average magnitude 4.2
Standard deviation ±.68

Explanation of grades:

1 = good first break
2 = poor first break
3 = no recognizable first break
4 = no P_n or P recognized

() measured from magnetic-tape playbacks in rear pocket
()*HL ID playback magnification: SPZ 12.7k

Table 4. HEBGEN LAKE EARTHQUAKE. Travel Times of Principal Phases

Station	Distance	(1) P_n T	[1]Reduced T	Grade	(2) P_g T	[2]Reduced T	(3) L_g T	[3]Reduced T	Remarks
HL ID	299	34.3	-2.6	1	--	--	65.1	-20.3	P_g not recognized; L_g clipped
VN UT	538	65.4	-1.0	3	75.1	-14.6	129.7	-24.0	
PT OR	603	75.2	+0.8	2	--	--	163.9	- 8.4	P_g not recognized
VT OR	621	75.3	-1.4	2	88.8	-14.7	163.1	-14.3	
PM WY	650	83.9	+3.7	3	98.5	- 9.8	170.1	-15.6	
WI NV	664	86.8	+4.8	3	96.4	-14.3	163.2	-26.5	
FM UT	670	88.0	+5.3	3	103.3	- 8.4	--	--	L_g not recognized
AT NV	798	100.5	+2.0	3	126.5	- 6.5	200.6	-27.4	
WN SD	905	--	--	4	140.1	-10.7	260.9	+ 2.3	P_n not recognized
DR CO	906	110.9	-1.0	3	142.4	- 8.6	233.5	-25.4	
KN UT	919	115.8	+2.3	3	--	--	262.0	- 0.6	P_g not recognized
MN NV	947	120.6	+3.7	3	135.0	-22.8	248.0	-22.6	
MV CL	1065	--	--	-	--	--	--	--	
WM AZ	1050	--	--	-	--	--	--	--	
DV CL	1120	--	--	-	--	--	--	--	
FS AZ	1126	--	--	-	--	--	--	--	
SF AZ	1197	--	--	-	--	--	--	--	
SV AZ	1237	--	--	-	--	--	--	--	
BF CL	1242	--	--	-	--	--	--	--	
TN CL	1287	--	--	-	--	--	--	--	

Table 4. HEBGEN LAKE EARTHQUAKE. Travel Times of Principal Phases (continued)

		(1) P_n			(2) P_g		(3) L_g		
Station	Distance	T	[1]Reduced T	Grade	T	[2]Reduced T	T	[3]Reduced T	Remarks
SE MN	1309	--	--	4	195.7	-22.5	362.1	-11.9	P not recognized
TC NM	1372	--	--	-	--	--	--	--	
CP CL	1455	--	--	-	--	--	--	--	
LC NM	1475	--	--	-	--	--	--	--	
HB OK	1524	--	--	--	--	--	--	--	
EP TX	1541	--	--	-	--	--	--	--	
WM SO	1583	--	--	-	--	--	--	--	
EF TX	1644	--	--	-	--	--	--	--	
NG WS	1798	--	--	-	--	--	--	--	
SS TX	1855	--	--	-	--	--	--	--	
MP AR	1934	--	--	-	--	--	--	--	
LP TX	2047	--	--	-	--	--	--	--	
SJ TX	2262	--	--	-	--	--	--	--	
MM TN	2410	--	--	-	--	--	--	--	
BL WV	2611	--	--	-	--	--	--	--	
DH NY	2921	--	--	-	--	--	--	--	
BG ME	3279	--	--	-	--	--	--	--	

[1]Reduced T = T - $\Delta/8.1$
[2]Reduced T = T - $\Delta/6.0$
[3]Reduced T = T - $\Delta/3.5$

Table 5. HEBGEN LAKE EARTHQUAKE. Periods and Amplitudes of P_g, L_g and Rayleigh Phases

		P_g			L_g			Rayleigh	
Station	Distance (km)	Period (sec)	Amplitude (mμ)	Particle velocity (mμ/sec)	Period (sec)	Amplitude (mμ)	Particle velocity (mμ/sec)	Period (sec)	Amplitude (mμ)
HL ID	299	--	--	--	--	--	--	14.5	400
VN UT	538	.7	4.1	6	.7	95	135	--	--
PT OR	603	--	--	--	(.5)	(75)	(155)	--	--
VT OR	621	.5	34	70	(.8)	(245)	(310)	14	260
PM WY	650	.6	10	17	.5	11	23	--	--
WI NV	664	(.6)	(22)	(37)	(.7)	(40)	(55)	--	--
FM UT	670	.6	2.8	4.6	--	--	--	--	--
AT NV	798	.7	5.5	8	.7	5.5	7.5	--	--
WN SD	905	.5	10.5	21	.7	77	110	--	--
DR CO	906	.6	2.2	3.4	.7	2.7	3.8	--	--
KN UT	919	--	--	--	.6	1.4	1.5	--	--
MN NV	947	.7	1.9	2.7	1.0	7	7	14	200
MV CL	1065	--	--	--	--	--	--	--	--
WM AZ	1090	--	--	--	--	--	--	--	--
DV CL	1120	--	--	--	--	--	--	--	--
FS AZ	1126	--	--	--	--	--	--	--	--
SF AZ	1197	--	--	--	--	--	--	--	--
SV AZ	1237	--	--	--	--	--	--	--	--
BF CL	1242	--	--	--	--	--	--	--	--
TN CL	1287	--	--	--	--	--	--	--	--

Table 5. HEBGEN LAKE EARTHQUAKE. Periods and Amplitudes of P_g, L_g and Rayleigh Phases (continued)

		P_g			L_g			Rayleigh	
Station	Distance (km)	Period (sec)	Amplitude (mμ)	Particle velocity (mμ/sec)	Period (sec)	Amplitude (mμ)	Particle velocity (mμ/sec)	Period (sec)	Amplitude (mμ)
SE MN	1309	.5	1.7	3.3	.6	10	16	--	--
TC NM	1372	--	--	--	--	--	--	--	--
CP CL	1455	--	--	--	--	--	--	--	--
LC NM	1475	--	--	--	--	--	--	--	--
HB OK	1524	--	--	--	--	--	--	--	--
EP TX	1541	--	--	--	--	--	--	--	--
WM SO	1583	--	--	--	--	--	--	--	--
EF TX	1644	--	--	--	--	--	--	--	--
NG WS	1798	--	--	--	--	-	--	--	--
SS TX	1855	--	--	--	--	--	--	--	--
MP AR	1934	--	--	--	--	--	--	--	--
LP TX	2047	--	--	--	--	--	--	--	--
SJ TX	2262	--	--	--	--	--	--	--	--
MM TN	2410	--	--	--	--	--	--	--	--
BL WV	2611	--	--	--	--	--	--	--	--
DH NY	2921	--	--	--	--	--	--	--	--
BG ME	3279	--	--	--	--	--	--	--	--

() Measured from magnetic-tape playouts in rear pocket

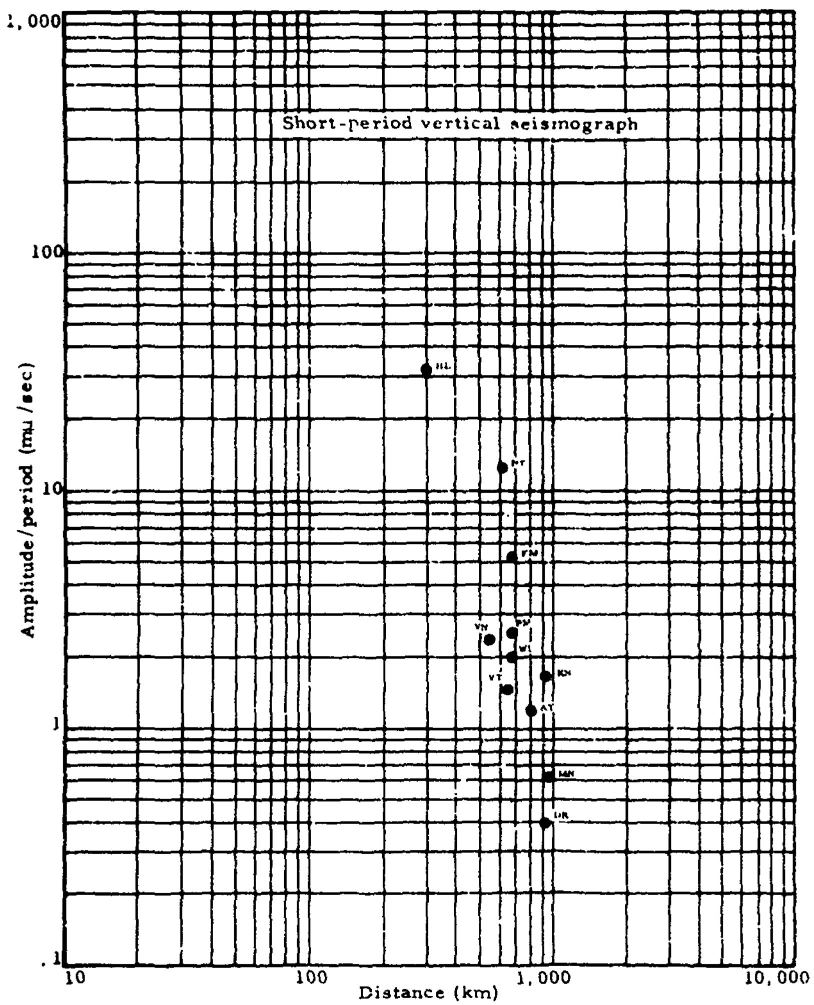

Figure 2. HEBGEN LAKE EARTHQUAKE. First motion amplitude of P_n or P

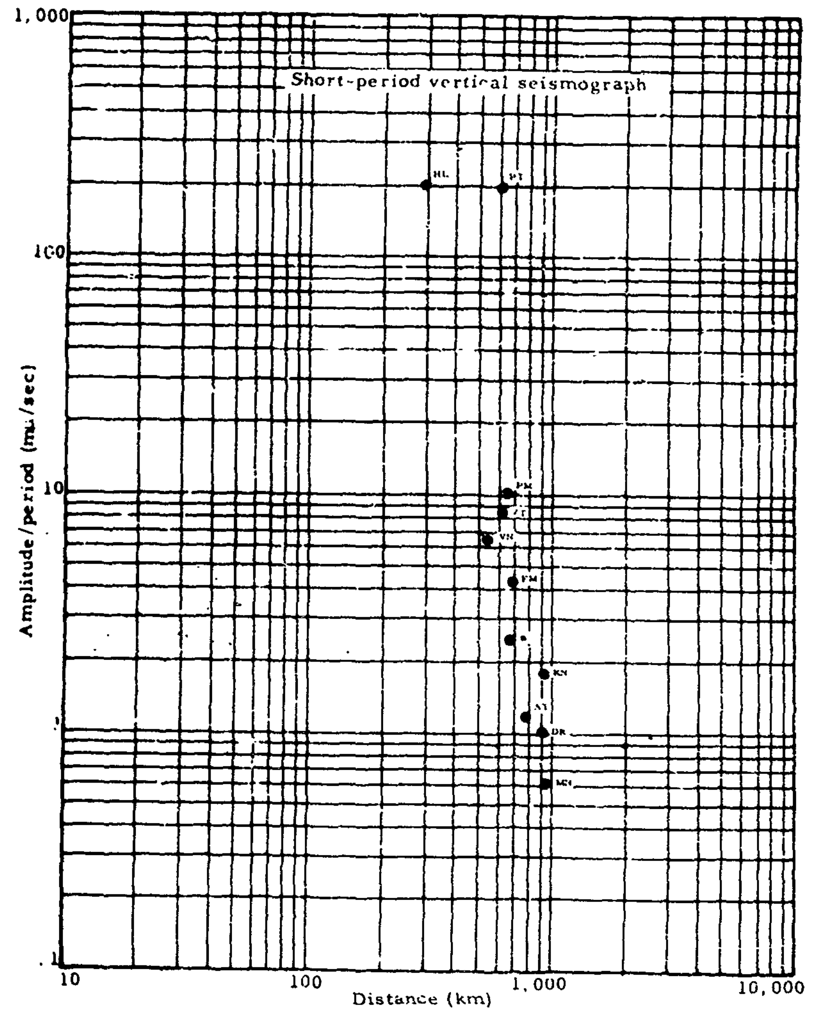

Figure 3. HEBGEN LAKE EARTHQUAKE. Maximum amplitudes of P_n or P

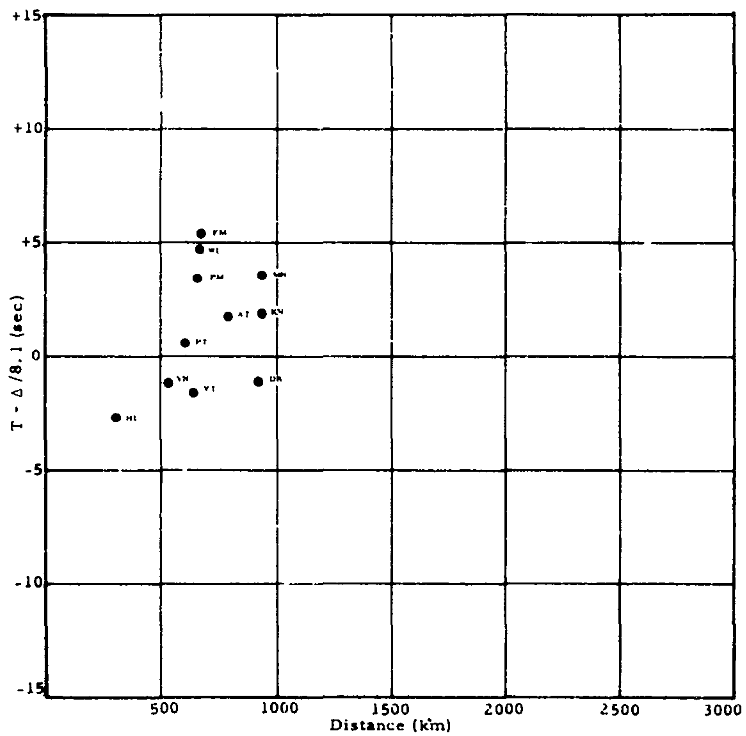

Figure 4. HEBGEN LAKE EARTHQUAKE. Travel times of P_n or P

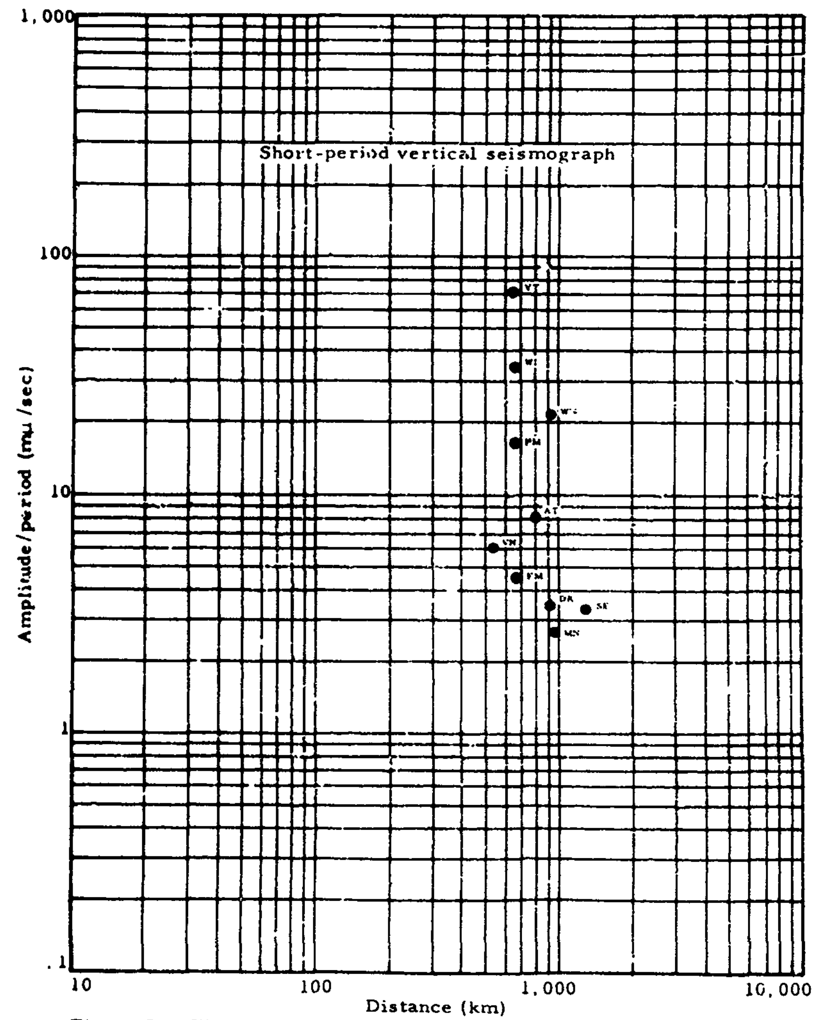

Figure 5. HEBGEN LAKE EARTHQUAKE. Maximum amplitudes of P_g

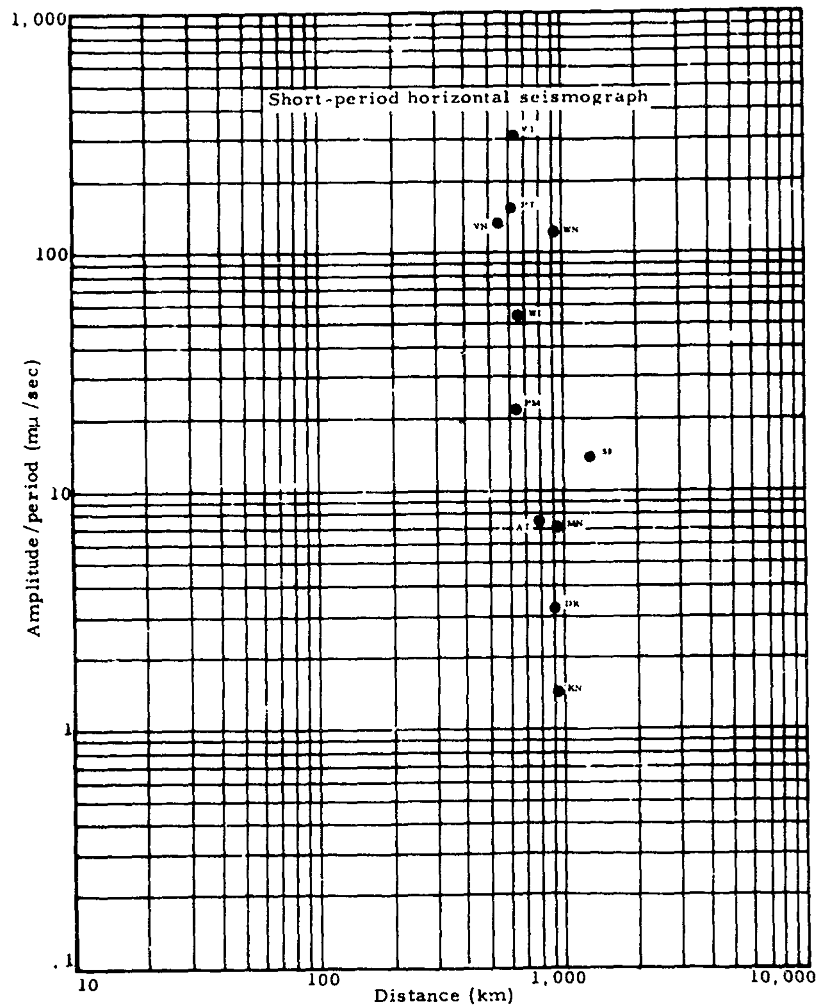

Figure 6. HEBGEN LAKE EARTHQUAKE. Maximum amplitudes of L_g

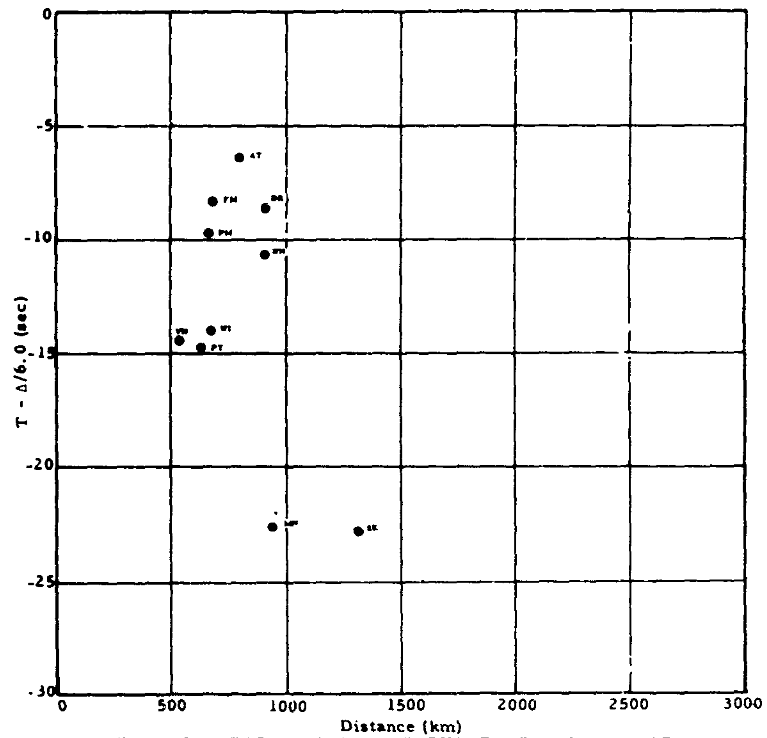

Figure 7. HEBGEN LAKE EARTHQUAKE. Travel times of P_g

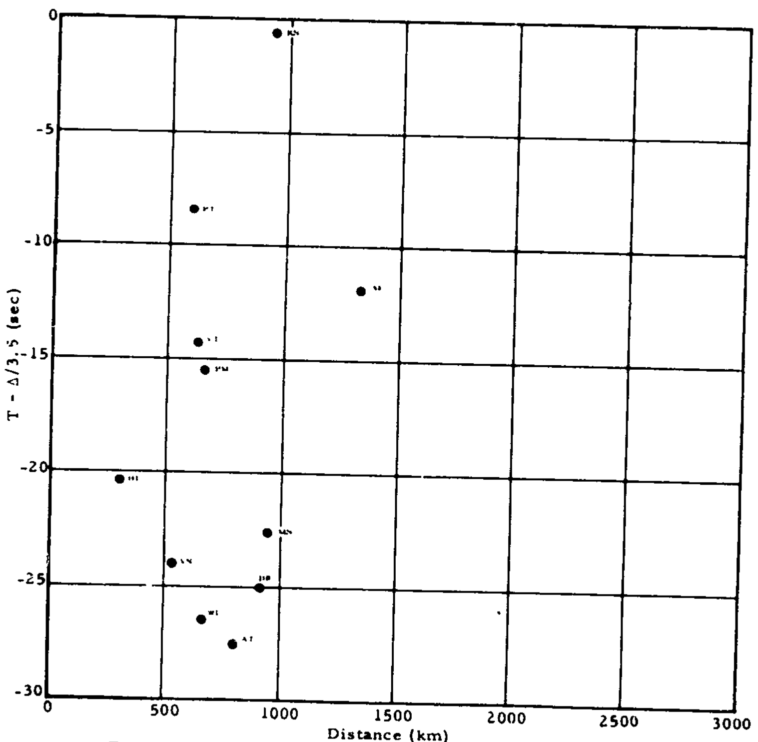

Figure 8. HEBGEN LAKE EARTHQUAKE. Travel times of L_g

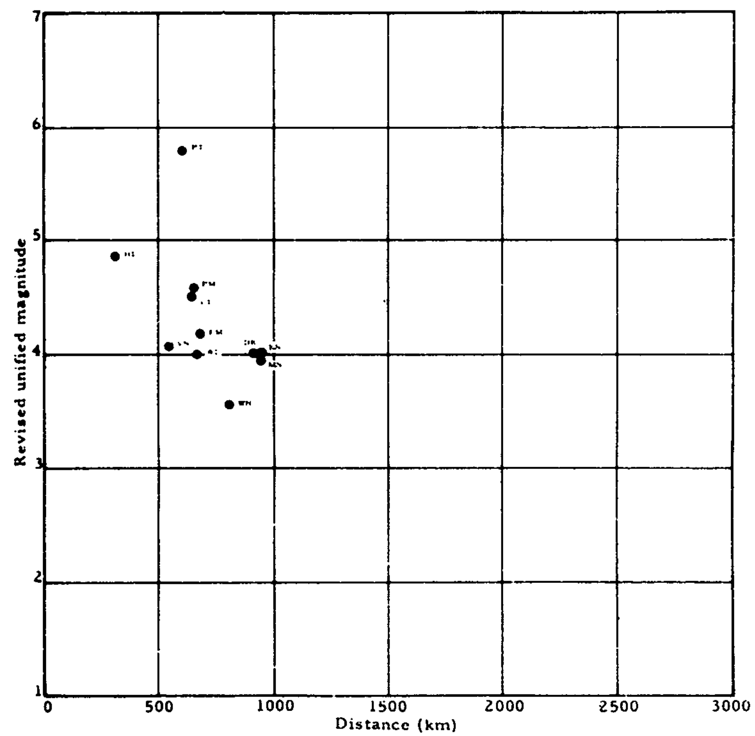

Figure 9. HEBGEN LAKE EARTHQUAKE.
Revised unified magnitude versus epicentral distance

APPENDIX

SITE INSTRUMENTATION

AND

DATA REDUCTION TECHNIQUES

SITE INSTRUMENTATION AND DATA REDUCTION TECHNIQUES

Introduction

This appendix contains a brief description of the instrumentation operation and data reduction techniques employed in recording and compiling the data included in this report.

Instrumentation

The standard LRSM Seismological Observatory is composed of a three-component long-period and a three-component short-period seismograph system. Figure 1 is a simplified block diagram of the systems, and figures 2 and 3 shows the response curves for these systems. Data are recorded on magnetic tape with a 14-channel magnetic tape system at a tape speed of 0.3 ips. FM recording is used with 270 cps center frequencies. Data are also recorded on 35-millimeter film. All recordings are 24-hours in duration. Accurate timing is provided by comparing the output of a crystal controlled timing system with the time transmitted by WWV or WWVH. System calibration is performed daily, monthly and just preceeding all scheduled explosions. The two basic parameters that are determined from the system calibration are system polarity and system magnification as a function of frequency. The systems are operated 24 hours per day and 7 days per week. When the systems are in a routine operational status they are staffed by two men.

Data Reduction Techniques

Measurements. The data reported by the Long Range Seismic Measurements Program routinely consist of information pertaining to the amplitudes, periods, and travel times of the P_n or P, P_g, L_g, Love and Rayleigh phases. The information is normally obtained from the 35-mm film seismograms. Arrival times and periods are read to within ± 0.1 second on the short-period seismograms and to within ± 1 second on long-period seismograms. Amplitudes are read to the nearest half millimeter.

The arrival time, period, and amplitude of the P_n or P phase is read on the short-period vertical seismogram. *Where possible,* the amplitudes A, B, C, and D as shown in figure 4, are taken from each arrival.

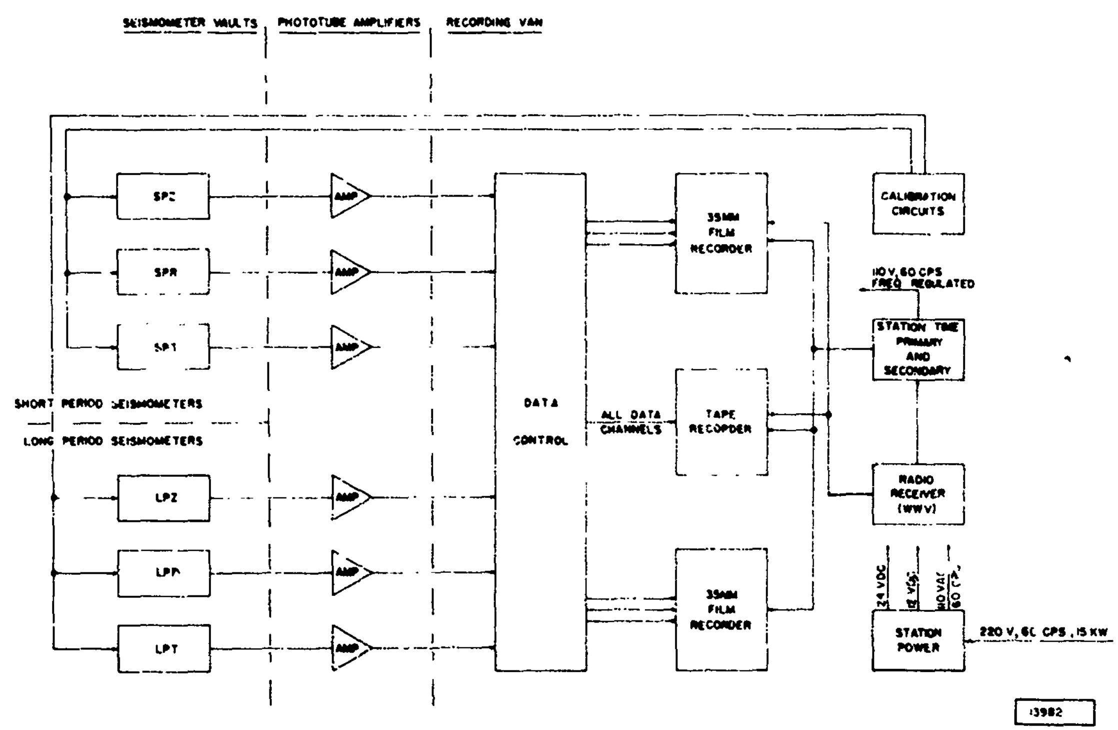

Figure A1. Simplified block diagram of the LRSM seismograph system

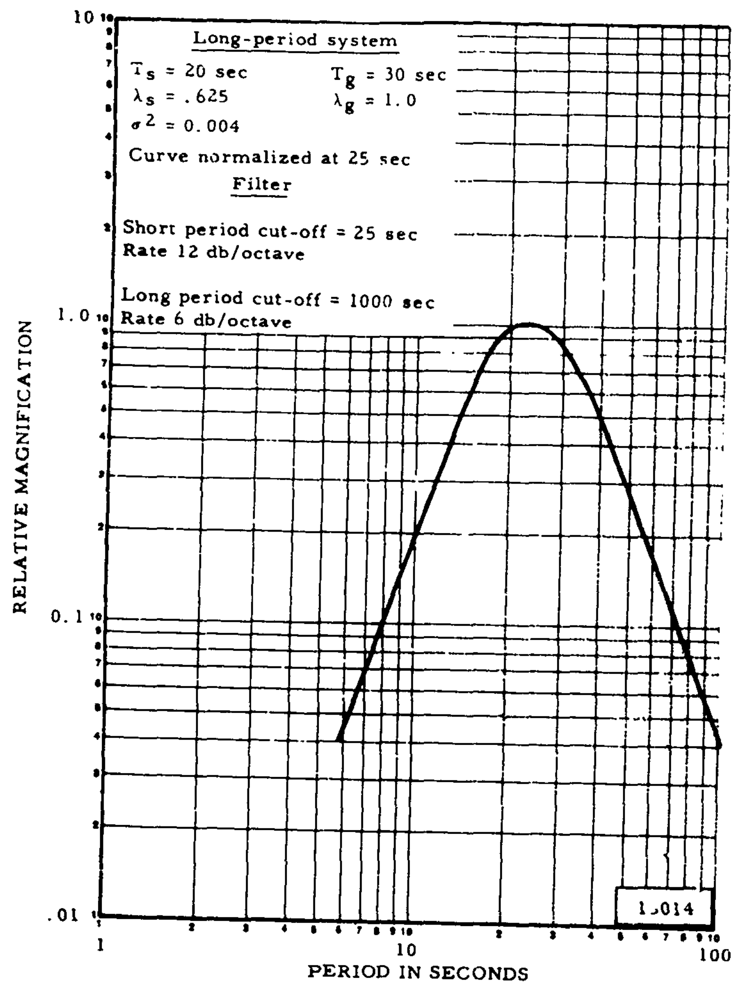

Figure A2. Frequency response of the long-period seismograph system

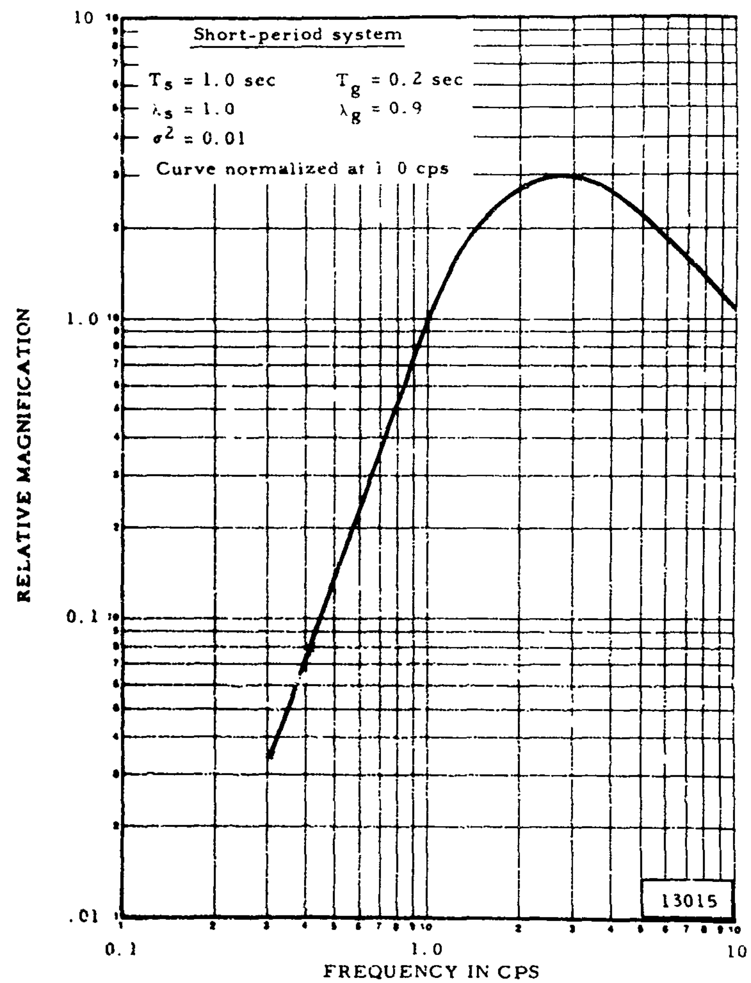

Figure A3. Frequency response of the short-period seismograph system

Note: d is the maximum peak-to-peak amplitude within the first three or four cycles.

Figure A4. Example of amplitude measurements

The quality of the first motion is assigned a grade which is based upon the criteria listed below:

Grade 1. The first half cycle is easily recognized and can be timed to within 0.1 second. The signal-to-noise ratio for the first half cycle exceeds 3:1.

Grade 2. The first half cycle is recognizable but emergent, and the actual arrival time may be as much as 0.3 second in error. The signal-to-noise ratio for the first half cycle is less than 3:1.

Grade 3. The first half cycle is totally obscured by background noise. Uncertainty in timing may be as much as 1-2 second.

Grade 4. No P_n or P phase is recognized.

Furthermore, the type of first motion is assigned as outlined in the appendices to Hearings of the Joint Committee on Atomic Energy,

Technical Working Group - II titled "Technical Aspects of Detection and Inspection Control of a Nuclear Weapons Test Ban". For the later phases (P_g, L_g, Love and Rayleigh) normally only the maximum amplitude and its period is read. For the P_g phase this information is obtained from the short-period vertical seismogram; for L_g from the short-period transverse seismogram; for Rayleigh from the long-period vertical seismogram and for Love from the long-period transverse seismogram. In addition to the seismic information obtained above, the deflection of the ball lifts and/or sine wave calibrations are read in order to compute the magnification, also the difference between station time and WWV time is read as close to the event as possible.

Data Reduction

The measurements listed above are reduced to standard quantities using the following procedures:

To obtain observed travel times, the origin time is subtracted from the observed arrival time and the appropriate time correction is applied. To increase the accuracy of the graphical presentations the difference between the observed and the theoretical travel times (reduced travel times) are plotted, rather than the observed travel times. Reduced travel times are obtained as follows:

$$T_R = T_O - \Delta/V_o .$$

where T_R = reduced travel time, T_O = observed travel time, and Δ = distance.

The values of velocity (V_o) used in this report are 8.1 km/sec for P_n or P; 6.0 km/sec for P_g and 3.5 km/sec for L_g.

Amplitudes read for this report are calculated and reported in terms of 1/2 peak-to-peak, except P_n or P "A" measurements (see figure 4), which are zero-to-peak measurements. It will be noted that most measurements are reported as millimicrons per second (mμ/sec). This is a velocity measurement found by dividing the amplitude in millimicrons by its period in seconds.

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END