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TECHNICAL REPORT NO 67-19
SEISMIC NOISE SURVEY, VOLUME 3
LONG-RANGE SEISMIC MEASUREMENTS PROGRAM

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TECHNICAL REPORT NO. 67-19

SEISMIC NOISE SURVEY, VOLUME 3
LONG-RANGE SEISMIC MEASUREMENTS PROGRAM

by

Carlos Pena

GEOTECH
A TELEDYNE COMPANY
3401 Shiloh Road
Garland, Texas

29 June 1967

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ABSTRACT

This report is the third in a series of studies which evaluate seismic noise levels at LRSM sites. Data from the short- and long-period vertical seismographs from 33 sites are reviewed, and standardized data compilation methods are discussed. Cumulative probability distribution of amplitude curves and noise spectrum curves are developed for each site studied.

SEISMIC NOISE SURVEY, VOLUME 3
LONG-RANGE SEISMIC MEASUREMENTS PROGRAM

1. INTRODUCTION

This report is volume 3 of a series of reports¹ which presents the results of seismic noise measurements taken from data recorded at the Long-Range Seismic Measurements (LRSM) Program field sites. Figure 1 shows the locations and designations of the sites evaluated in this report.

Measurements were taken from data recorded by the vertical seismographs at 33 sites during 1964 - 1966. Franklin, West Virginia (FN-WV) and Fort Stockton, Texas (FO-TX) did not have long-period seismographs, and the surveys of these sites are, therefore, limited to the short-period vertical seismographs. Surveys for both short- and long-period systems are included for 31 sites. The noise survey was conducted at each site after a sufficient time (2 weeks) had elapsed after initial setup to assure that all instruments had stabilized.

This work was done under Project VT/6703, Contracts F33657-67-C-1457 and AF 33(657)-16270. This project is under the technical direction of the Air Force Technical Applications Center (AFTAC) and the overall direction of the Advanced Research Projects Agency (ARPA).

2. DATA PRESENTATION

2.1 Table 1 gives general information about each site. It includes the noise occurrence at the 50 percent level for the short-period and long-period systems and the predominant periods of the noise. Sites are listed in alphabetical order.

2.2 The frequency response of the short-period systems are shown in figure 2. Figure 3 shows the frequency response of the long-period systems at all sites.

¹ Technical Report No. 65-25, Seismic Noise Survey, Volume 2, dated 6 April 1965 and Technical Report No. 63-45, Seismic Noise Survey, Volume 1, dated 30 April 1963. In addition, numerous standard noise surveys have been published as supporting or complementary data in special studies and letter reports.

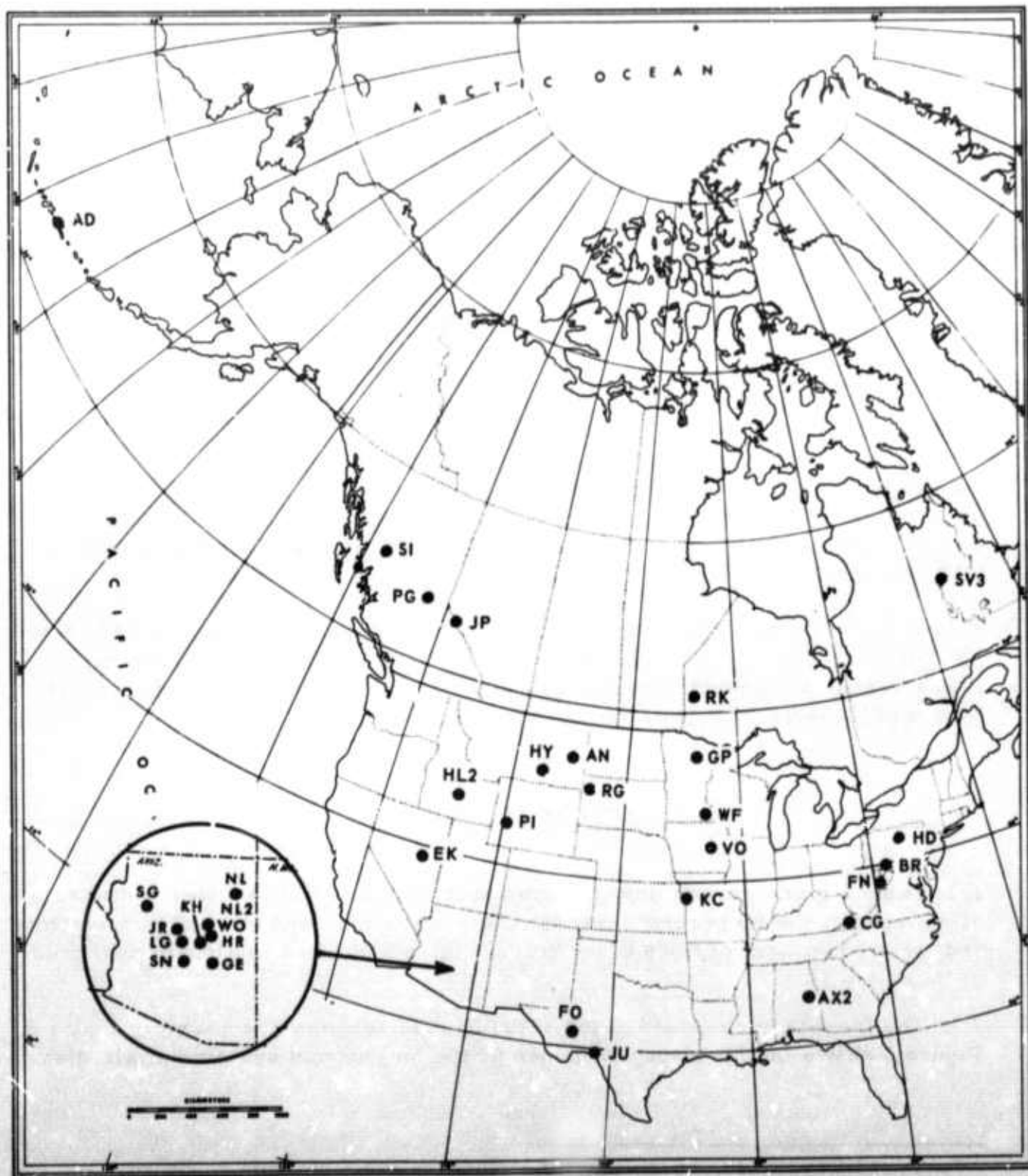


Figure 1. Location of LRSM sites, background NOISE SURVEY

Table 1. LRSM site information

Site designator	Elevation (km)	Type of installation	Large or small Benioff seismometer	50% Noise Level (mu)		Predominate per. of noise (sec)		Average magnitude (K)		Geology	Weathering
				SP	LP	SP	LP	SP	LP		
Adak Island, Alaska	0.06	Vault	Large	53.0	140	1.2	10, 15	42	25	Glacial drift	None
Angela, Montana	0.91	Vault	Large	6.9	150	0.5	15	210	22	Sandstone-shale	Moderate
Alexander City, Alabama	0.21	Vault	Large	9.7	301	0.4	15	183	40	Sandy clay	Moderate
Berlin, Pennsylvania	0.65	Vault	Large	11.0	460	0.3	25	140	9.7	Sandstone-shale	Moderate
Cumberland Gap, Virginia	0.40	Vault	Large	7.5	300	1.0	30	410	22	Dolomitic limestone	Deep
Eureka, Nevada	1.95	Vault	Large	2.5	210	1.0	15, 20	6.5	42	Sandstone	Shallow
Franklin, West Virginia	0.91	Vault	Small	6.6	--	1.0	--	170	--	Alluvium	None
Fort Stockton, Texas	0.88	Vault	Small	8.9	--	0.4	--	360	--	Alluvium	None
Globe, Arizona	1.48	Vault	Large	4.5	470	0.4	5	350	21	Altered shale	Shallow
Grand Rapids, Minnesota	0.43	Vault	Small	13.0	400	1.0	35	140	20	Glacial drift	None
Howard, Pennsylvania	0.37	Vault	Small	29.0	270	0.3	10, 15	100	8.3	Sandy clay	Moderate
Hailey, Idaho	1.83	Mine	Large	1.6	326	0.4	10	390	20	Basalt-limestone	None
Heber, Arizona	1.88	Vault	Large	3.0	170	0.7, 1.0	15	400	21	Limestone	Shallow
Hydham, Montana	0.98	Vault	Large	6.0	130	0.3	15	180	16	Loose sand	Moderate
Jasper, Alberta, Canada	1.12	Vault	Large	10.0	140	0.5, 0.6	10, 15	146	43	Sandstone-shale	Shallow
Jerome, Arizona	1.31	Vault	Large	12.0	230	0.3	15	250	22	Limestone	Shallow
June, Texas	0.53	Vault	Large	4.0	126	1.0	20	630	24	Alluvium	None
Kansas City, Missouri	0.27	Vault	Small	34.0	170	0.4	10	48	39	Limestone shale	Moderate
Kohle Ranch, Arizona	2.29	Vault	Large	19.9	460	0.6	15, 35	97	12	Residual soil	Deep
Long Valley, Arizona	1.77	Vault	Small	9.0	360	1.0, 1.2	15	250	52	Tuff-basalt	Shallow
Naslini, Arizona	1.77	Vault	Large	6.4	530	0.4	35	260	7.0	Claystone	Shallow
Naslini, Arizona	1.92	Vault	Large	3.4	240	0.4, 0.5	15	350	20	Alluvium	None
Pinedale, Wyoming	2.17	Vault	Small	3.7	600	1.0	10	260	5.4	Sandstone	Moderate
Prince George, British Columbia	0.91	Vault	Large	6.8	210	0.7	15	23	90	Gneiss	Moderate
Redig, South Dakota	0.92	Vault	Large	18.0	290	0.4	10	64.5	11	Granite	Shallow
Red Lake, Ontario, Canada	0.36	Vault	Small	5.2	480	0.6	45	204	22	Granite	Shallow
Seligman, Arizona	1.68	Vault	Large	3.0	150	0.5, 0.6	15	440	12	Sandy limestone	Shallow
Smithers, British Columbia	0.57	Vault	Large	14.0	470	1.4	35	154	25	Sandstone	Moderate
Sunflower, Arizona	0.88	Vault	Large	2.6	300	1.0, 1.2	5	370	18	Gneiss	Shallow
Schefferville, Quebec	0.57	Vault	Small	24.0	385	1.0	15, 30	75	32.6	Glacial	Moderate
Vinton, Iowa	0.27	Vault	Small	22.0	330	1.0	15	95	17	Limestone	Shallow
Winslow, Arizona	1.58	Vault	Large	7.5	250	0.4	15	310	50	Sandstone	Shallow
Wykoff, Minnesota	0.38	Vault	Small	20.0	350	1.2	15, 30	120	28	Dolomitic limestone	Shallow

-- No LP instruments

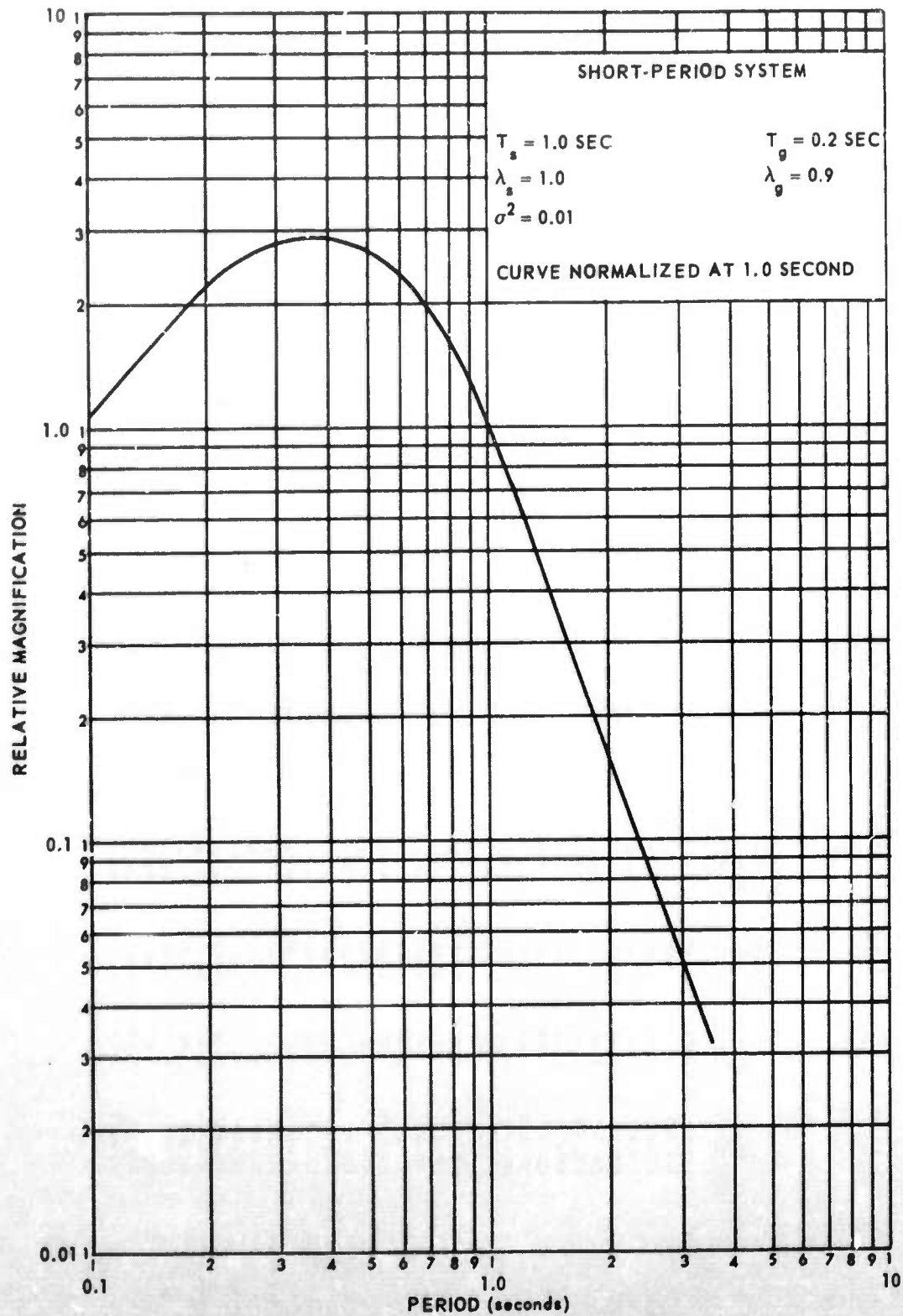


Figure 2. Frequency response of the short-period seismograph system

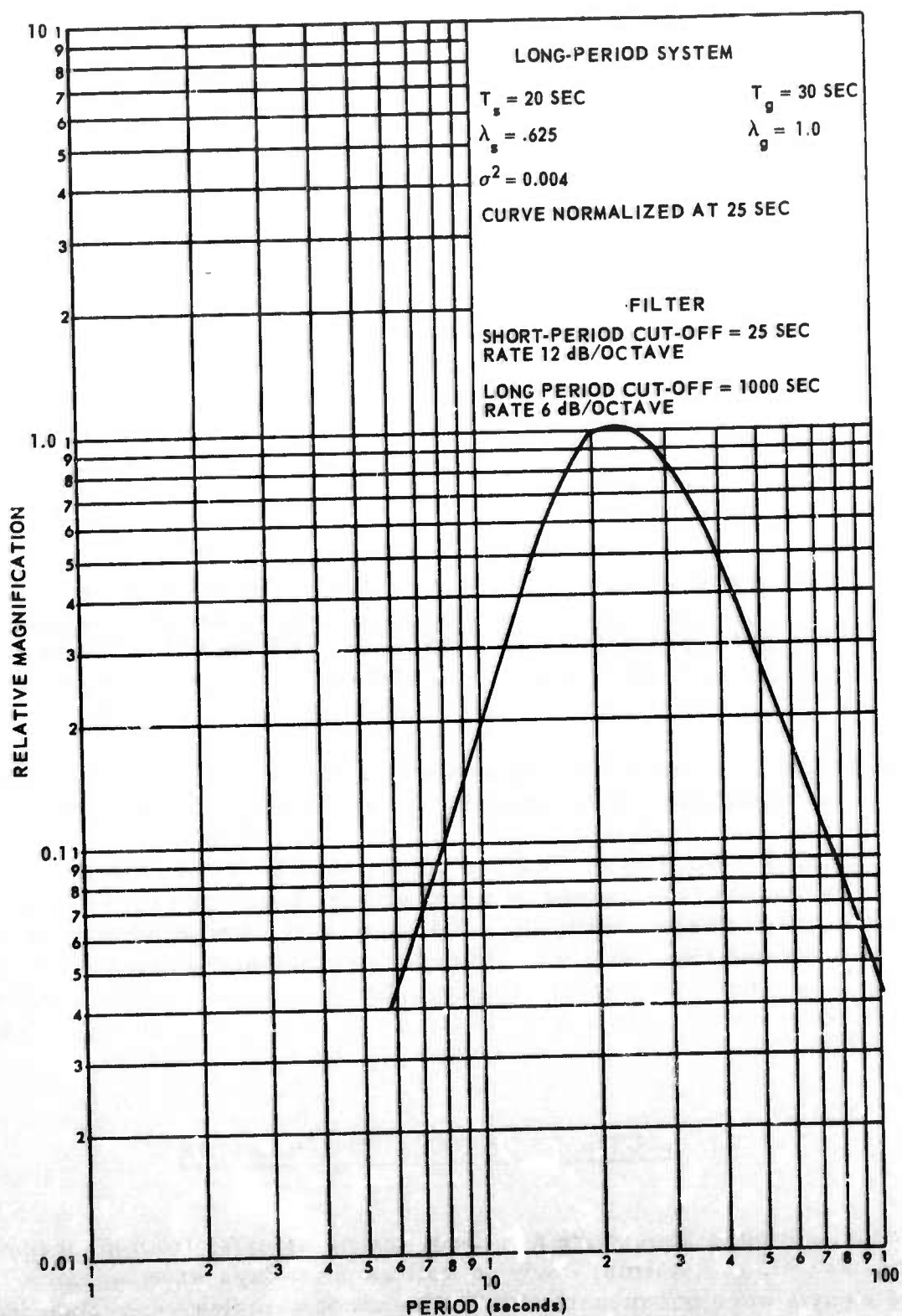


Figure 3. Frequency response of the long-period seismograph system

2.3 Appendix 1 contains curves which show the percentage of occurrence of short-period noise versus recorded amplitude in millimeters (peak-to-peak) divided by the magnification at 1 cps. Amplitude measurements were made in the period range of 0.3 to 1.4 seconds. The amplitudes taken from the 35 mm film recordings were divided by the magnification at 1 cps to reduce the data from all sites to a common reference. Thus, the noise occurrence curves give a measure of the normalized noise as seen on film and do not give a true measure of earth motion except at 1 cps. Appendix 2 contains curves which show the percentage of occurrence of long-period noise versus recorded amplitude in millimeters (peak-to-peak) divided by the magnification. Amplitude measurements were made in the period range of 6 to 100 seconds. The amplitudes from the film were divided by the magnification at 25 seconds to reduce the data to a common reference. Thus, the curves give a measure of normalized noise as seen on film and do not give a true measure of earth motion, except at 25 seconds.

2.4 Appendix 3 contains noise spectrum curves. The average amplitude in millimicrons, corrected for instrument response, is plotted as a function of period. The measurements cover a period range from 0.3 to 1.4 seconds for the short-period systems and from 6 to 100 seconds for the long-period systems.

2.5 Appendix 4 contains histograms showing the percentage of occurrence of noise at given periods for the short-period and long-period systems.

At X20 magnification 1 mm = 0.2 seconds on the short-period film seismograms. This can introduce bias caused by a tendency for analysts to read in even increments of period, for example, 0.2, 0.4, 0.6, etc. Recognizing this, efforts are made to avoid this tendency. The short-period histogram for EK-NV exhibits a saw-tooth appearance favoring the even periods. Additional data will be analyzed from this site and the results will be published in Noise Study No. 4.

3. METHODS OF DATA COMPILATION

A random sampling procedure was used, taking samples from night operating periods as well as daytime; windy as well as quiet days were sampled. Earthquake signals were not measured. Two hundred samples were taken from each team. The samples were read from 35 mm film at X20 magnification. The maximum trace amplitude present within the given period range was measured from peak-to-peak, to the nearest 0.5 millimeter; periods were measured to the nearest 0.1 second on the short-period records and to the nearest 1 second on the long-period records. Table 2 lists the period correction factors used to plot the noise spectrum curves.

Table 2. Period correction factors

<u>Period (seconds)</u> <u>SP</u>	<u>Correction factor</u>	<u>Period (seconds)</u> <u>LP</u>	<u>Correction factor</u>
0.3	0.357	6	22.727
0.4	0.344	7	14.925
0.5	0.377	8	10.000
0.6	0.418	9	7.246
0.7	0.497	10	5.319
0.8	0.591	15	1.724
0.9	0.769	20	1.042
1.0	1.000	25	1.000
1.1	1.234	30	1.176
1.2	1.538	35	1.515
1.3	1.923	40	2.000
1.4	2.380	45	2.778
		50	3.636
		55	4.651
		60	5.882
		65	7.143
		70	8.696
		75	10.638
		80	12.987
		85	15.152
		90	17.544
		95	20.000
		100	22.727

4. CONCLUSIONS

4.1 GENERAL

The geologic structure at each of the sites used for this report must be regarded as a variable which affects background noise.

There are several instances where sites, which are located on virtually the same type of geologic medium, have widely different noise levels. An explanation of this difference in levels does not readily present itself. However, many factors must naturally be considered in drawing conclusions from studies of the type dealt with in this report. Some of the most apparent factors are:

- a. The depth and extent of weathering of the geologic medium;
- b. The particular type of geology. In some cases, the composition of the medium may vary from point to point, which in turn causes variation of the noise level;
- c. The adequacy of seismometer vault protection procedures, that is, how well the vaults are sealed, how much covering they have, and the relative depth (with respect to ground level) of the seismometer emplacements;
- d. The environment (trees near the instruments, wind exposure and velocity, general climatic differences of various sites);
- e. Cultural noise; activity near the site (traffic, mining, or logging operations).

All of the above factors, separately and in combination, act on the sites' data. The extent of variation caused by these factors is, however, beyond the scope and purpose of this report.

4.2 OBSERVATIONS ON SHORT-PERIOD DATA

4.2.1 Four sites were located on limestone, and short-period noise (at the 50 percent occurrence level) at three of these (Heber, Arizona, Jerome, Arizona and Vinton, Iowa) measured less than 22 millimicrons. The fourth site, Kansas City, Missouri, measured 34 millimicrons.

4.2.2 There were three sites located on granite. Of these, the maximum noise level (at 50 percent occurrence) was 18 millimicrons, which occurred at Redig, South Dakota. The noise level at Red Lake, Ontario was computed to be 5.2 millimicrons and Sunflower, Arizona was 2.6 millimicrons.

4.2.3 Seven sites were located on sandstone; noise levels ranged from 2.5 millimicrons at Eureka, Nevada to 14 millimicrons at Smithers, British Columbia.

4.2.4 Twenty-one of the 33 sites included in this report exhibited noise levels (at the 50 percent occurrence level) of 10 millimicrons or less.

4.3 OBSERVATION ON LONG-PERIOD DATA

4.3.1 For the majority of the sites studied, noise from the long-period systems was predominantly in the 10-15 second period range.

4.3.2 It is impractical to correlate long-period noise level on the basis of geology alone.

4.3.3 Noise at the 50 percent occurrence level ranges from 120 millimicrons at Juno, Texas, to 600 millimicrons at Pinedale, Wyoming; noise at the remainder of the sites studied showed a random variation between these low and high levels. The average noise level from all sites is approximately 305 millimicrons.

4.4 OBSERVATIONS ON THE NAZLINI, ARIZONA SITES

The site which was designated NL-AZ was operated for the 10-month period April 1964 through January 1965. At this time the site was moved approximately 7 miles to take advantage of more stable soil in which to emplant the seismometer vaults. The new site, designated NL2AZ, became operational during mid-February 1965 and was closed early in October 1965.

In terms of background noise level, the move appears to have been propitious. The average noise levels (not corrected for period) of the vertical components at the two sites are summarized below:

	<u>Vertical SP</u>	<u>LP Vertical</u>
NL-AZ	6.4 mμ	530 mμ
NL2AZ	3.4 mμ	240 mμ

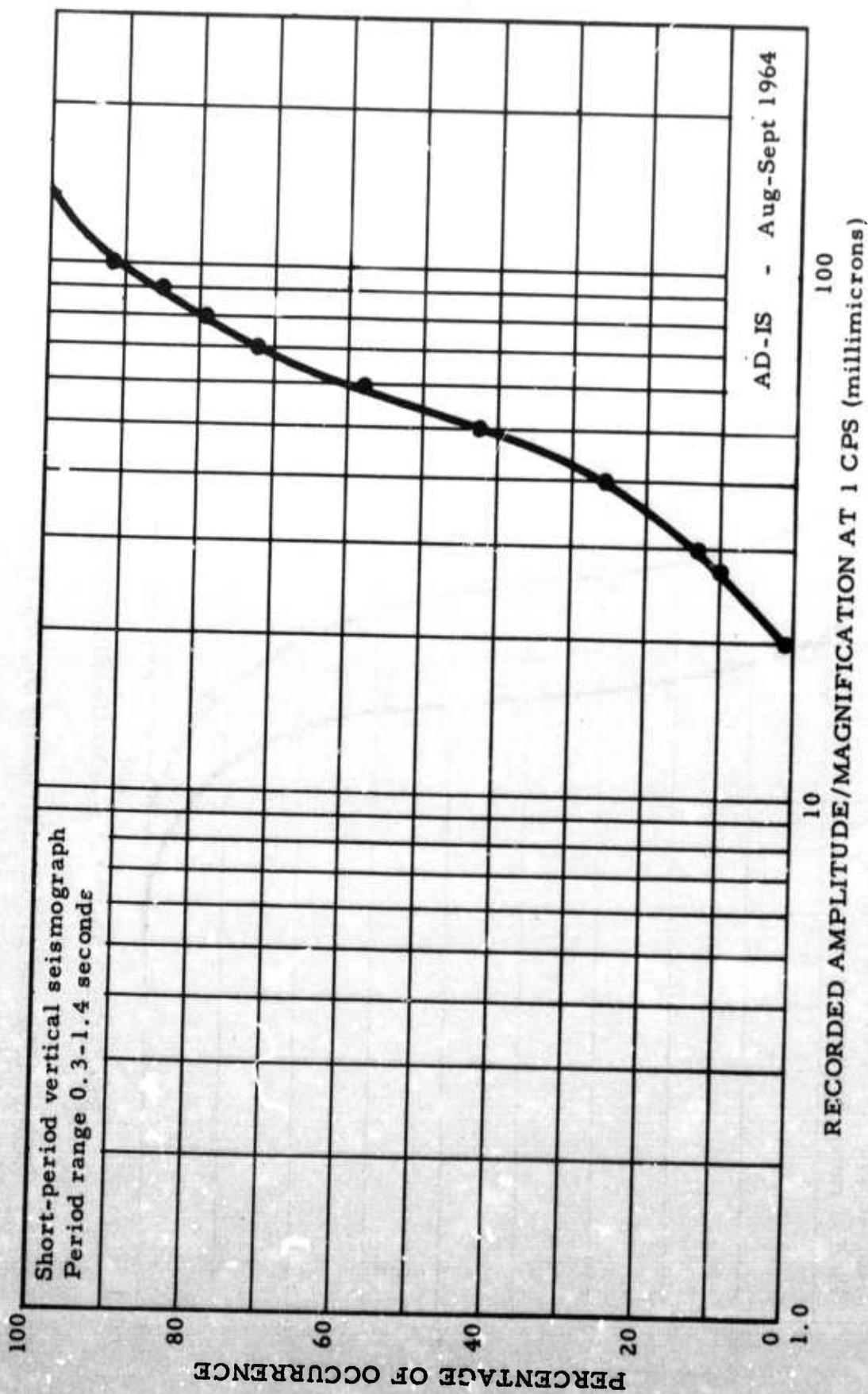
A comparison of the average operating magnifications of the two seismographs support the data shown above. The average magnification of the short-period vertical seismograph at NL-AZ was 260K; at NL2AZ it increased to 350K. The average long-period vertical magnification increased nearly 200 percent (from 7K to 20K) as a result of the site relocation.

5. ACKNOWLEDGMENTS

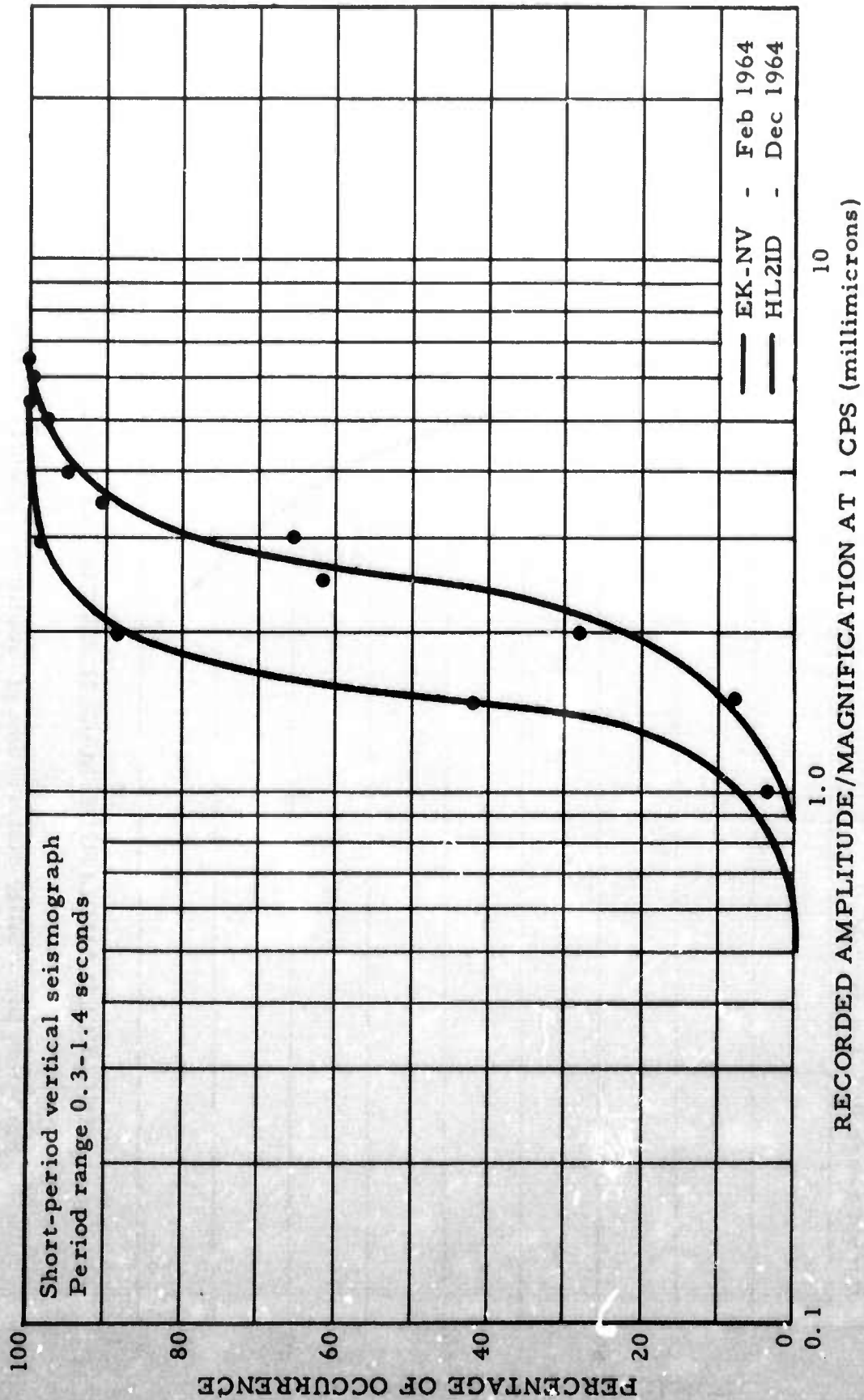
The author wishes to express his thanks to the members of the Data Reduction Section, LRSM, for their help in taking the noise samples and preparing drafts of the several curves included in this report.

APPENDIX 1 to TECHNICAL REPORT NO. 67-19

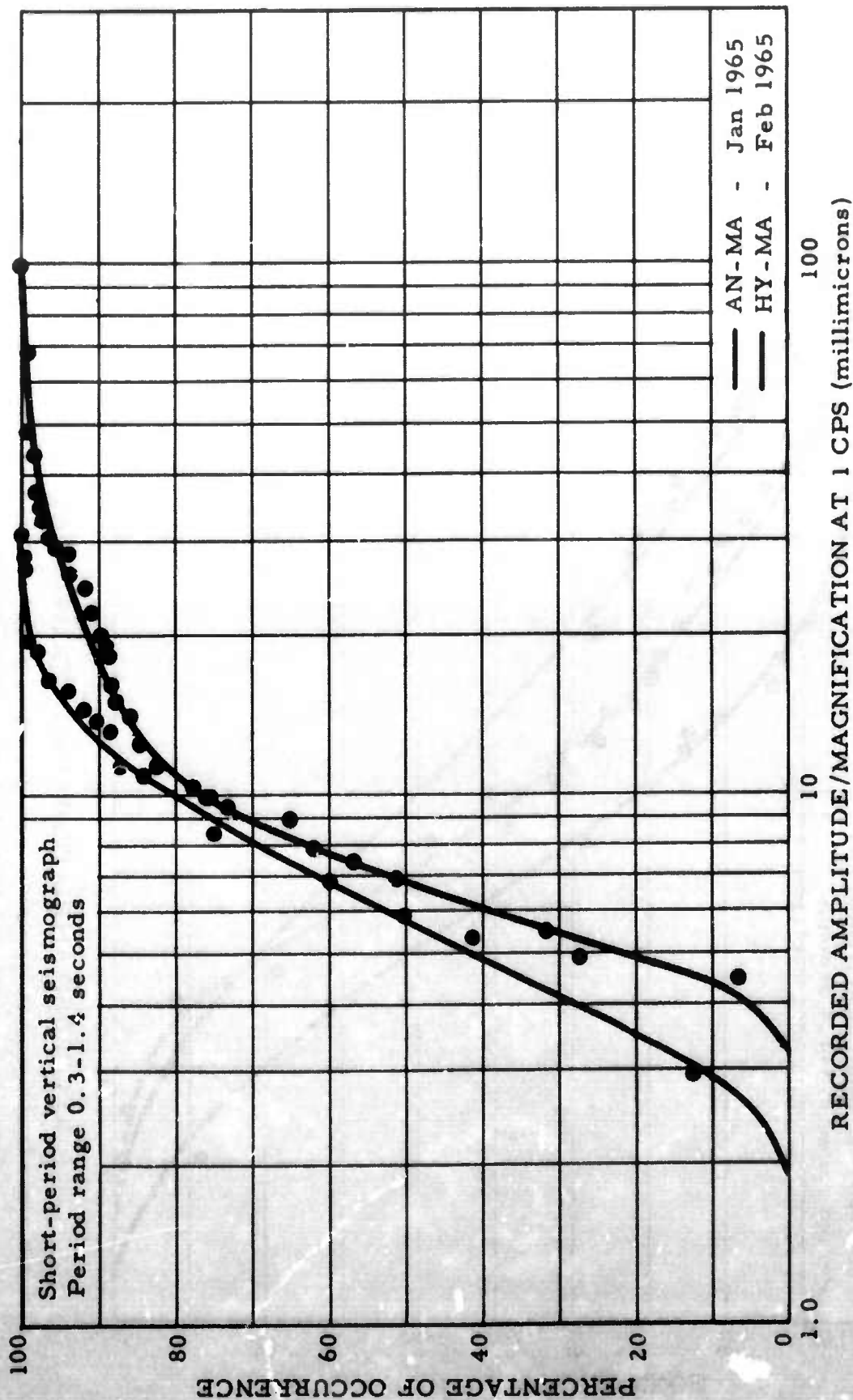
SHORT-PERIOD NOISE OCCURRENCE CURVES



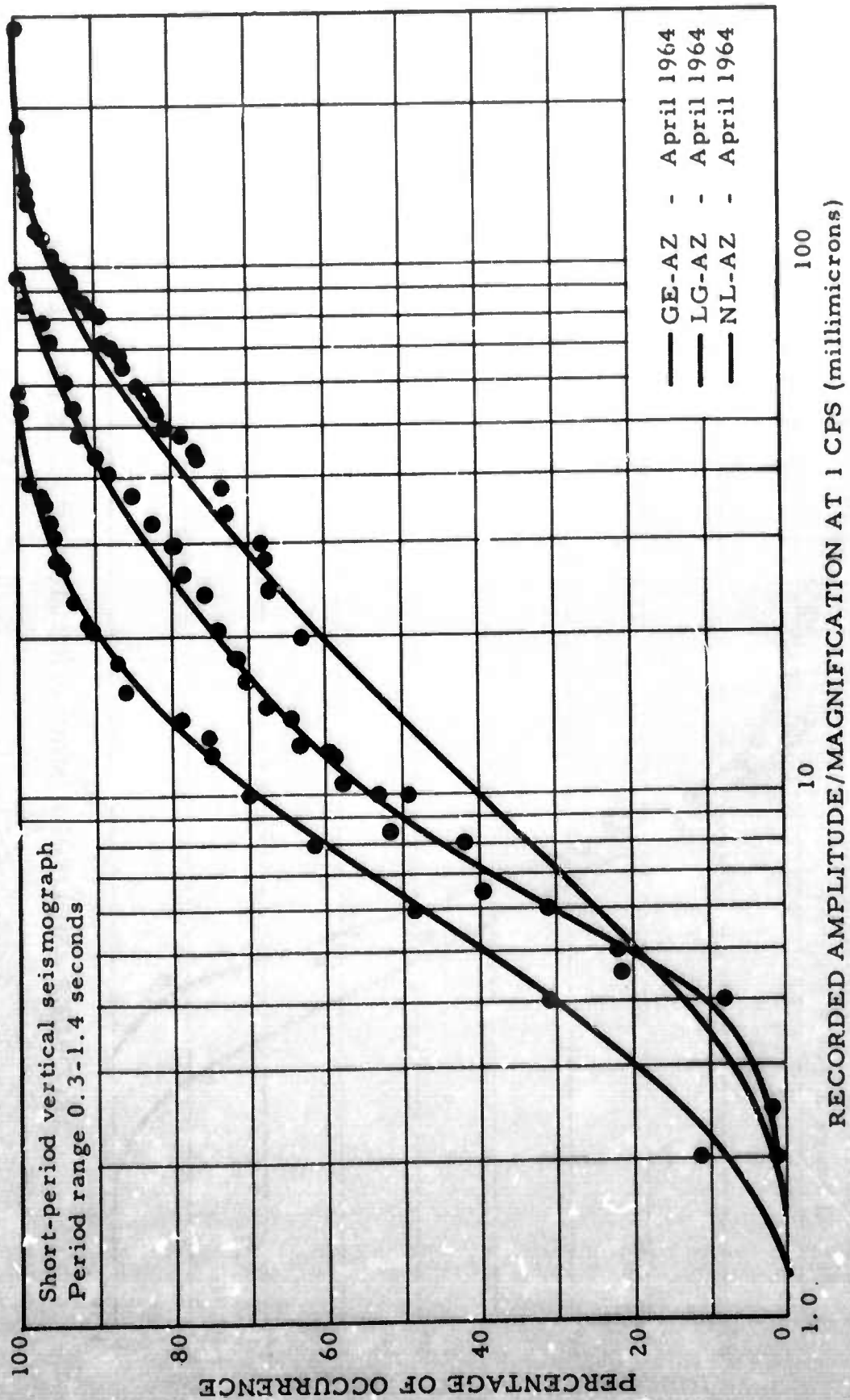
Cumulative probability distribution of amplitude, standard LRSM survey



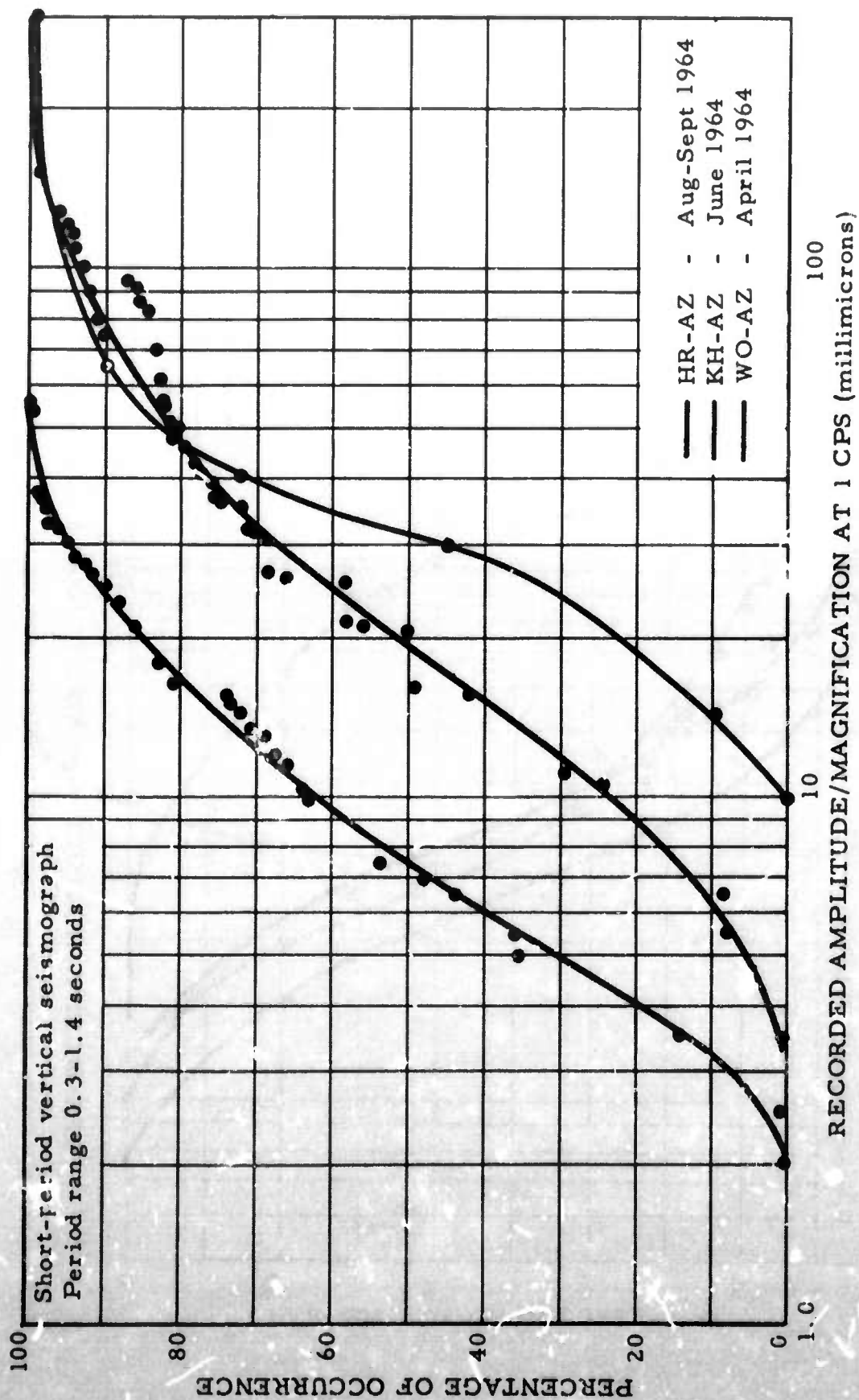
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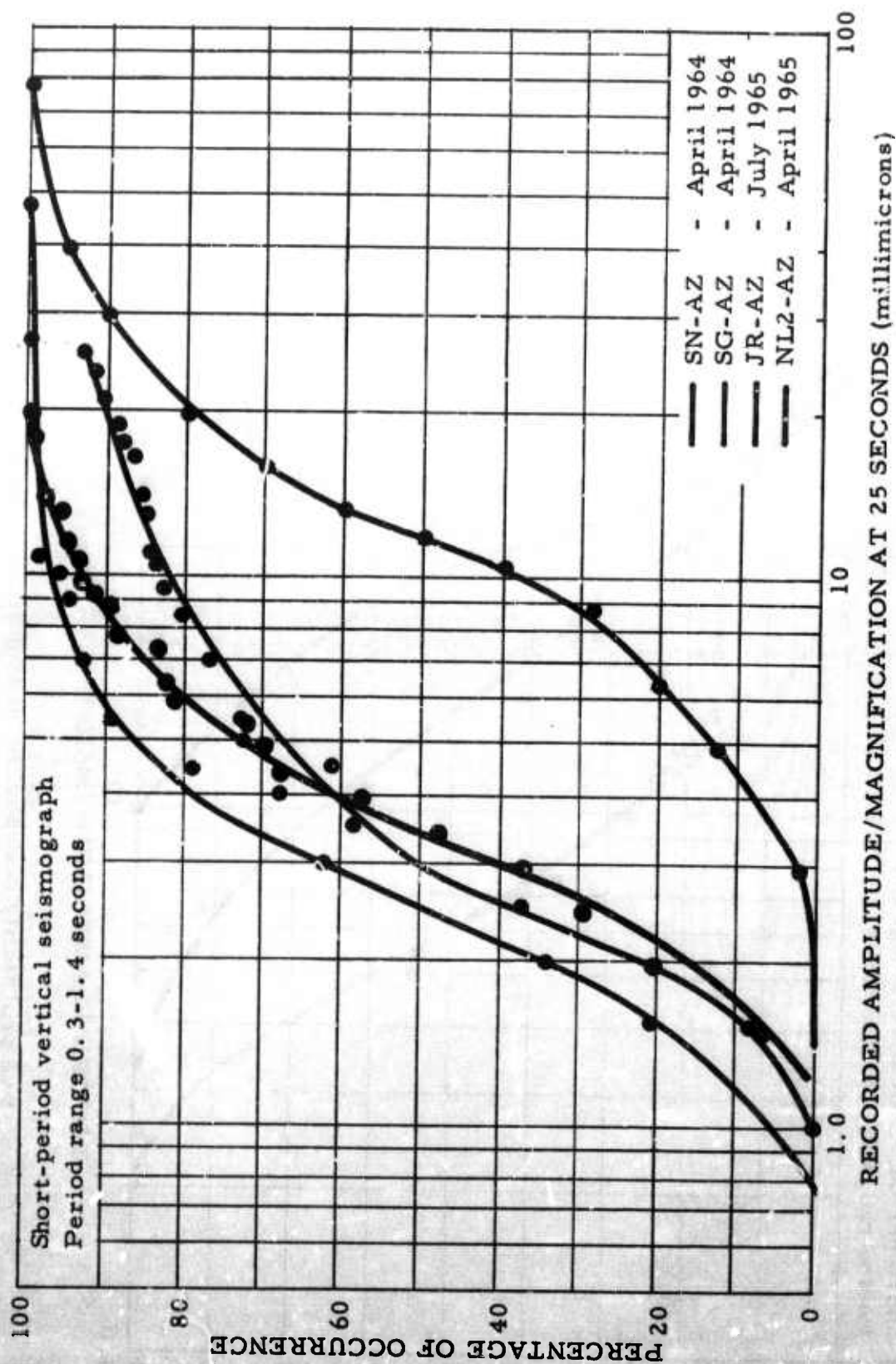
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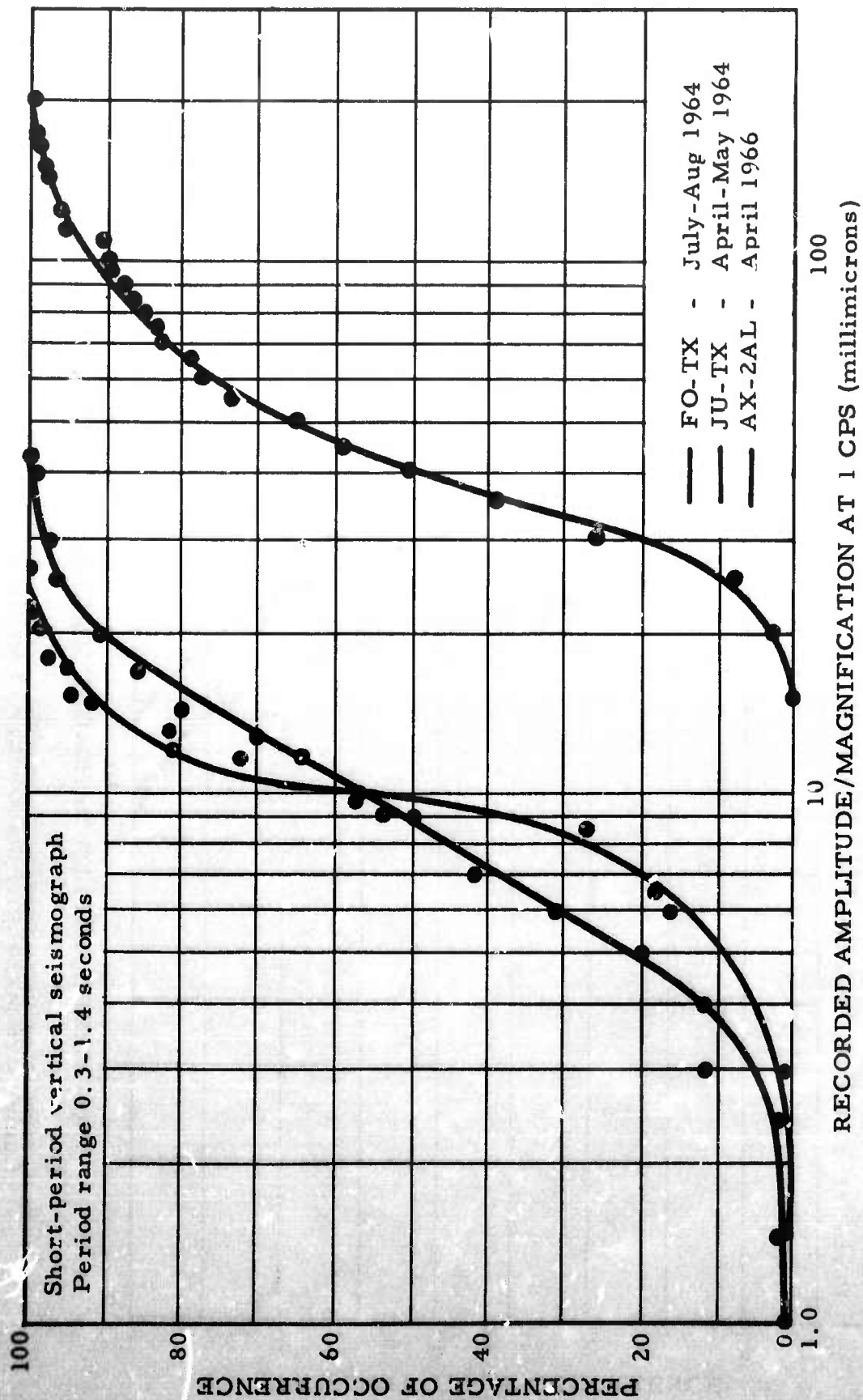
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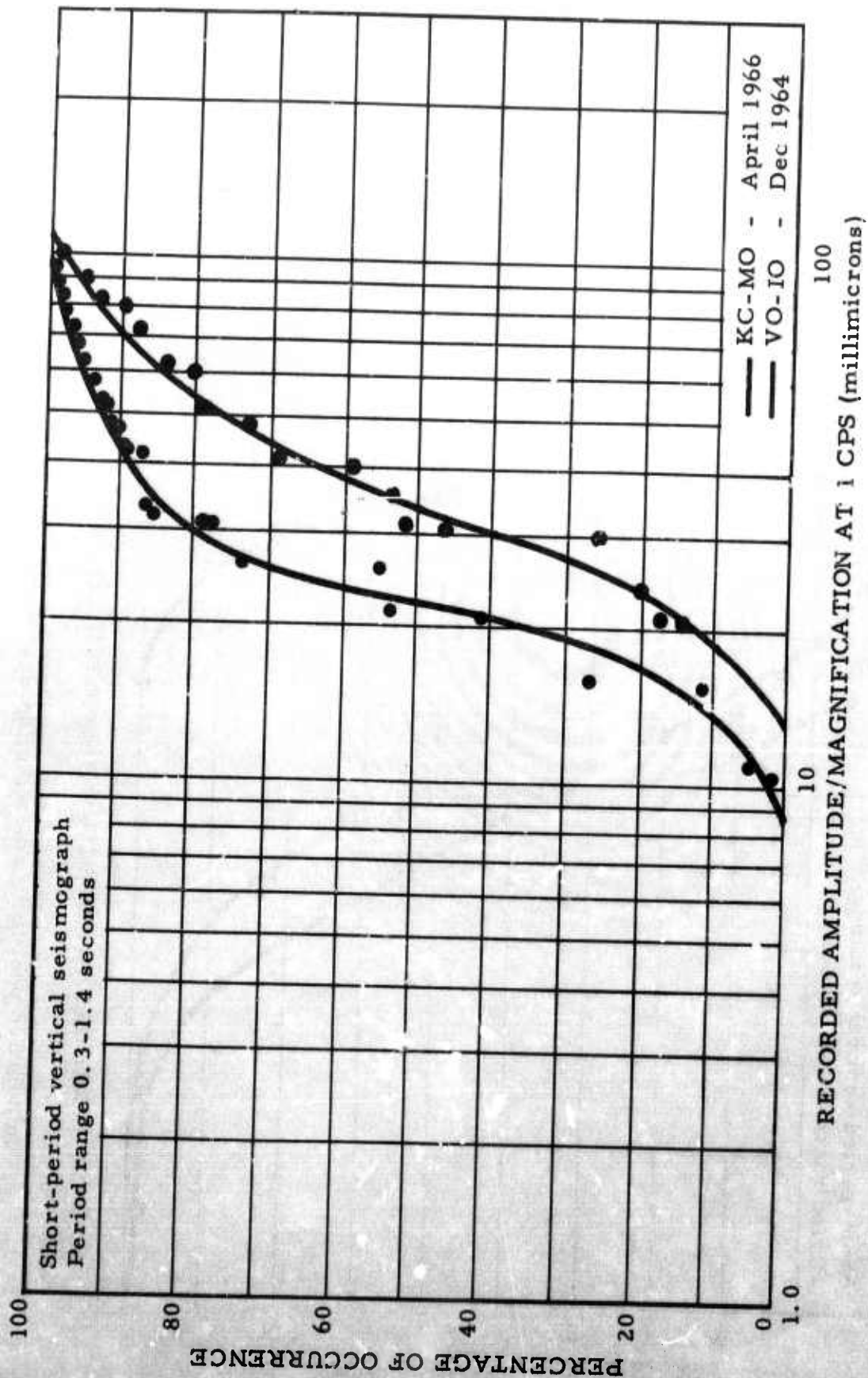
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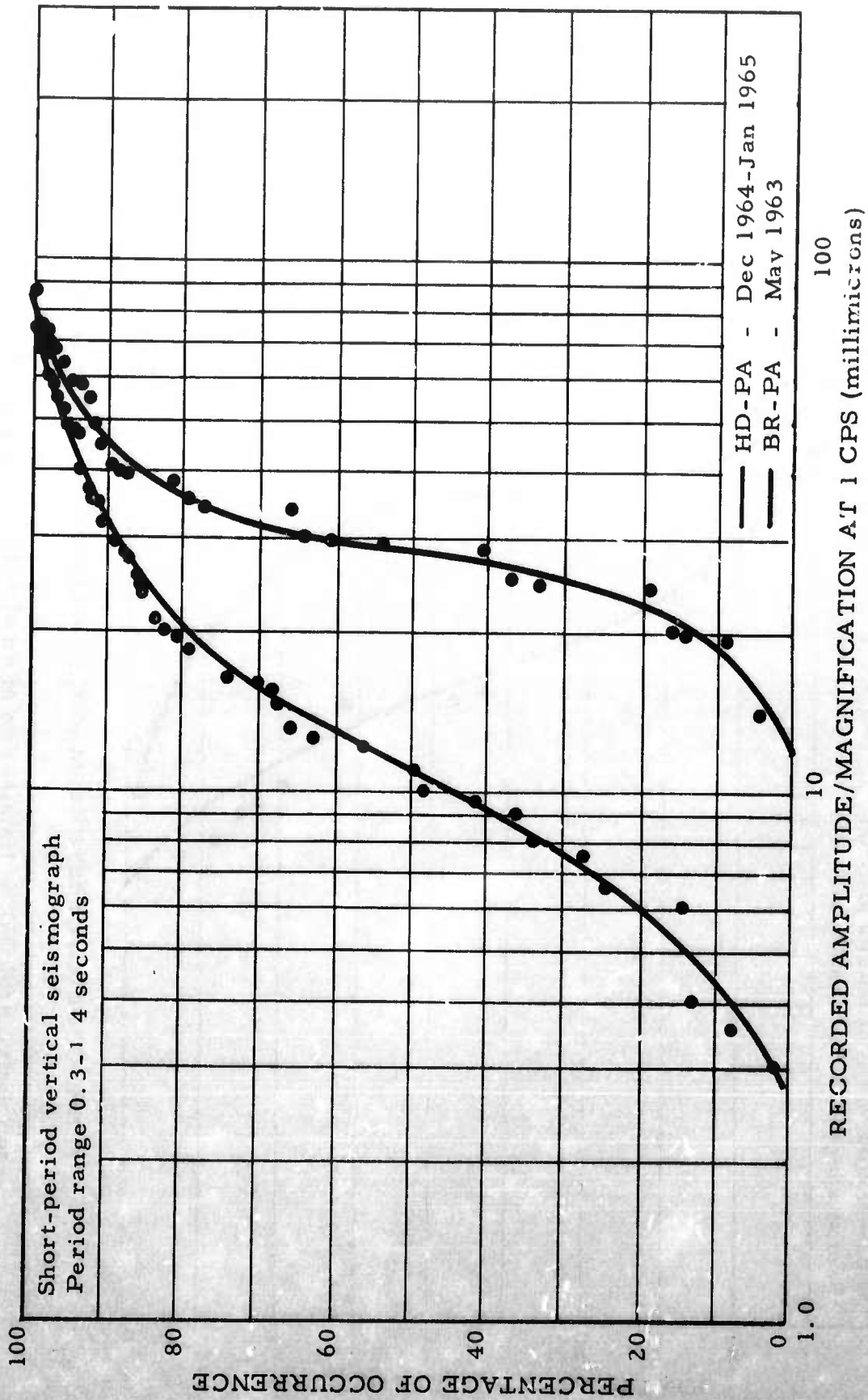
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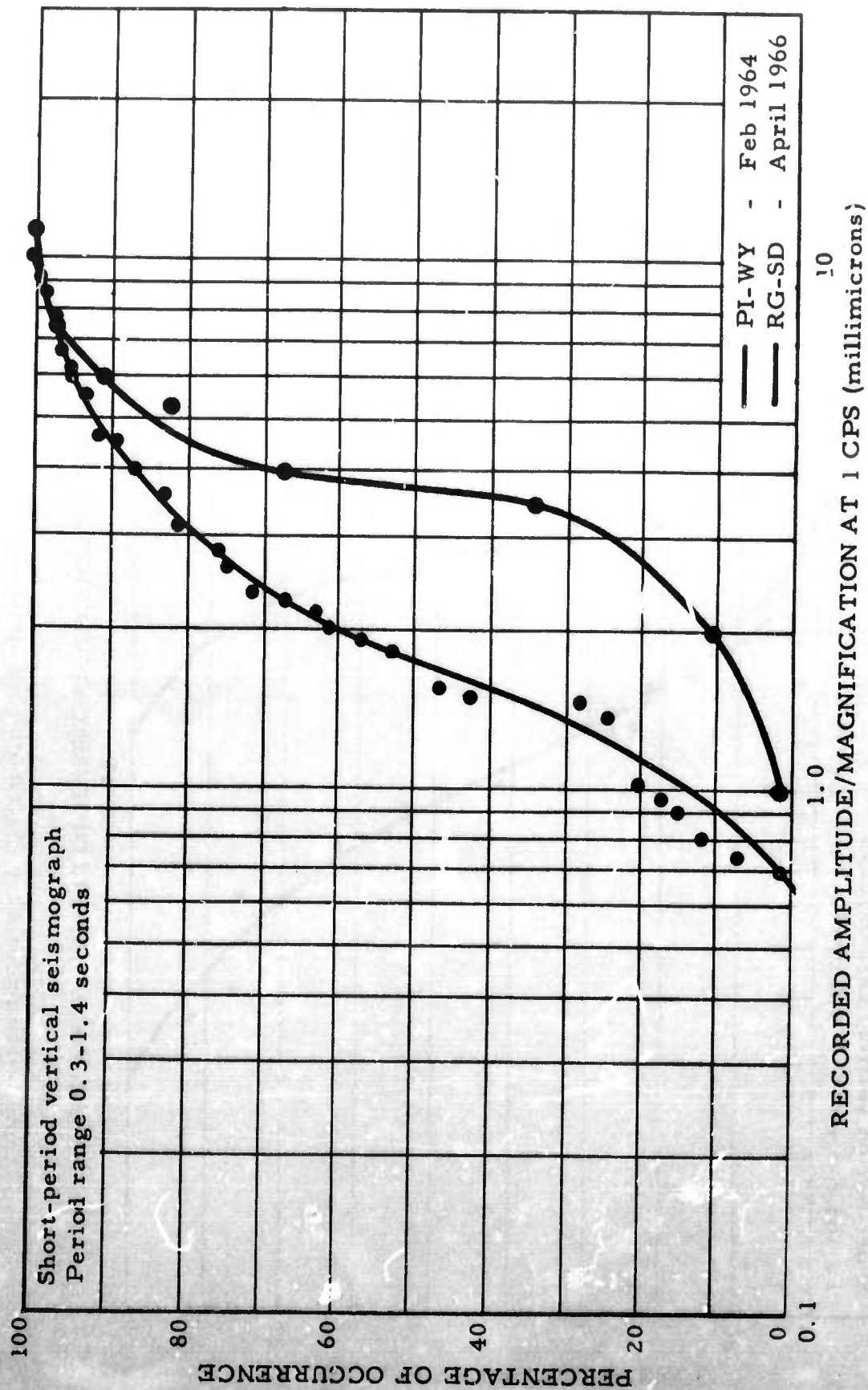
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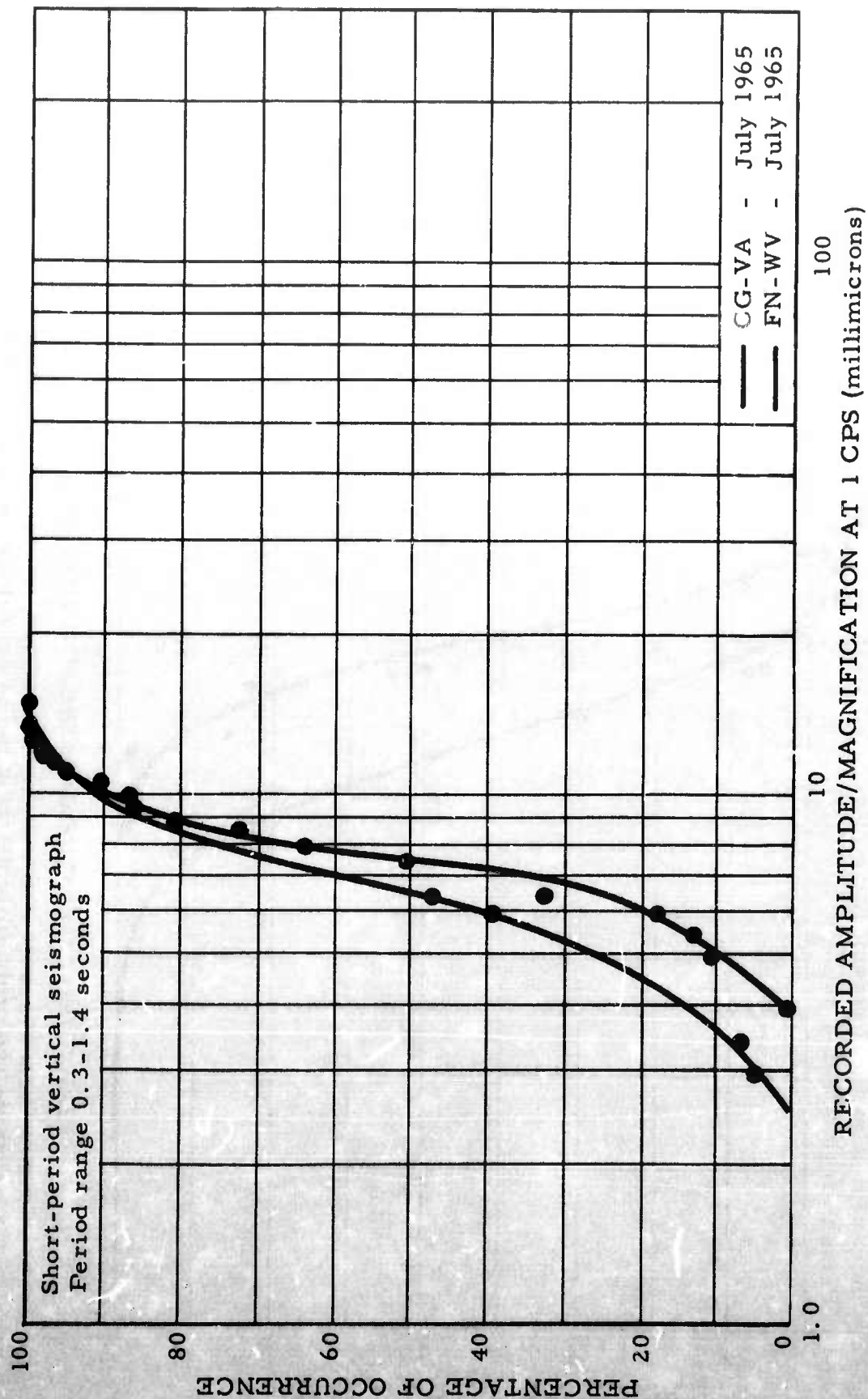
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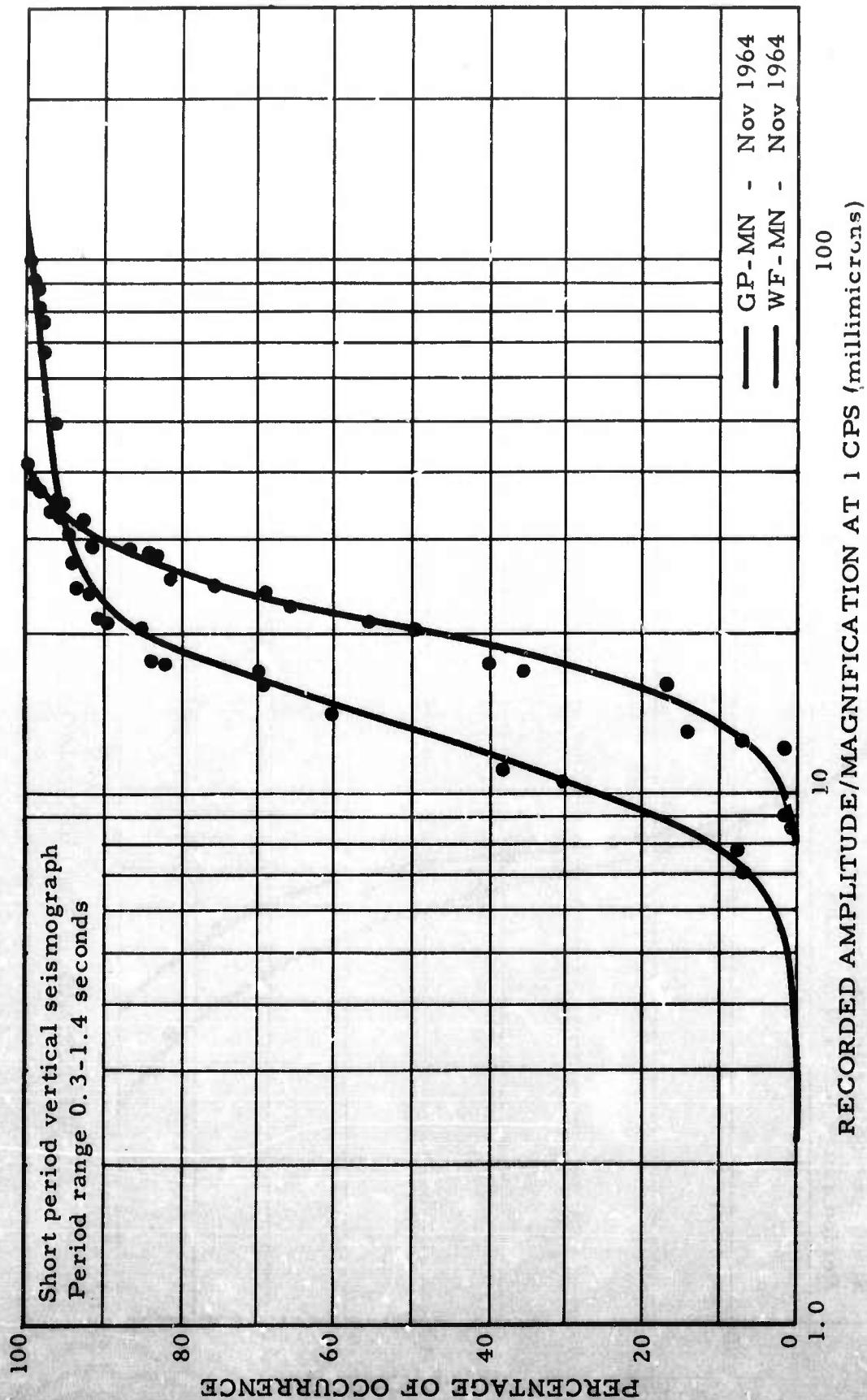
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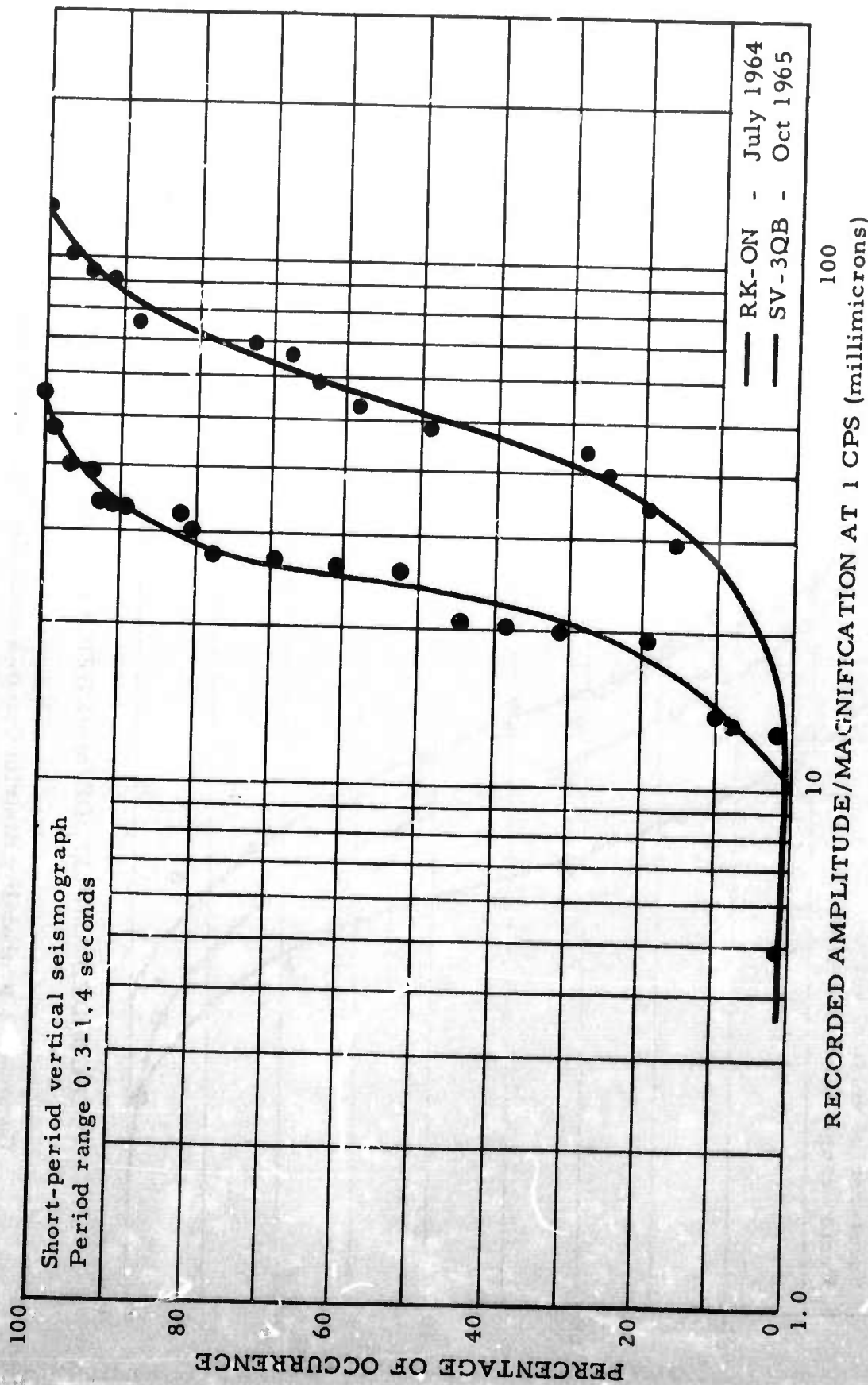
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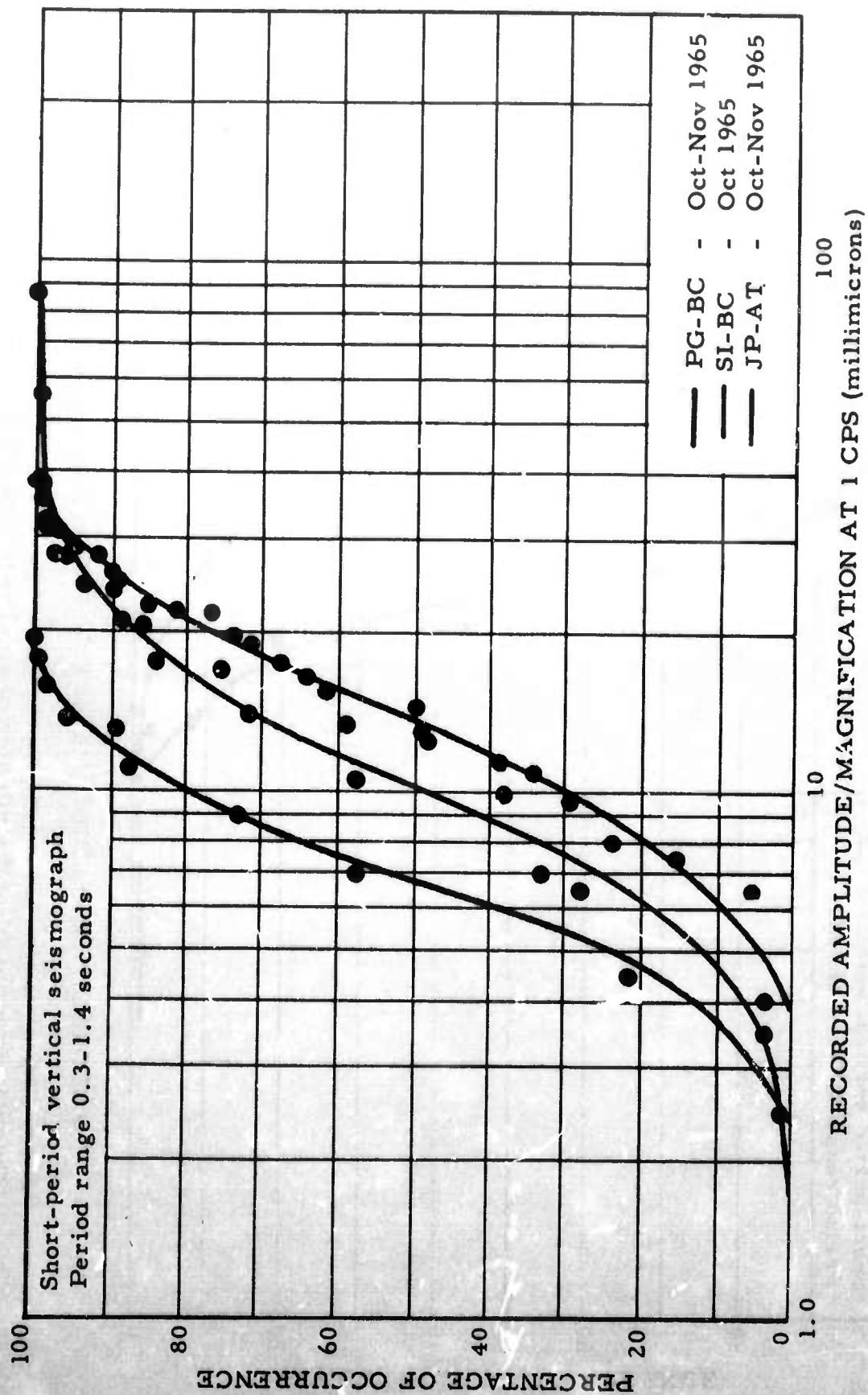
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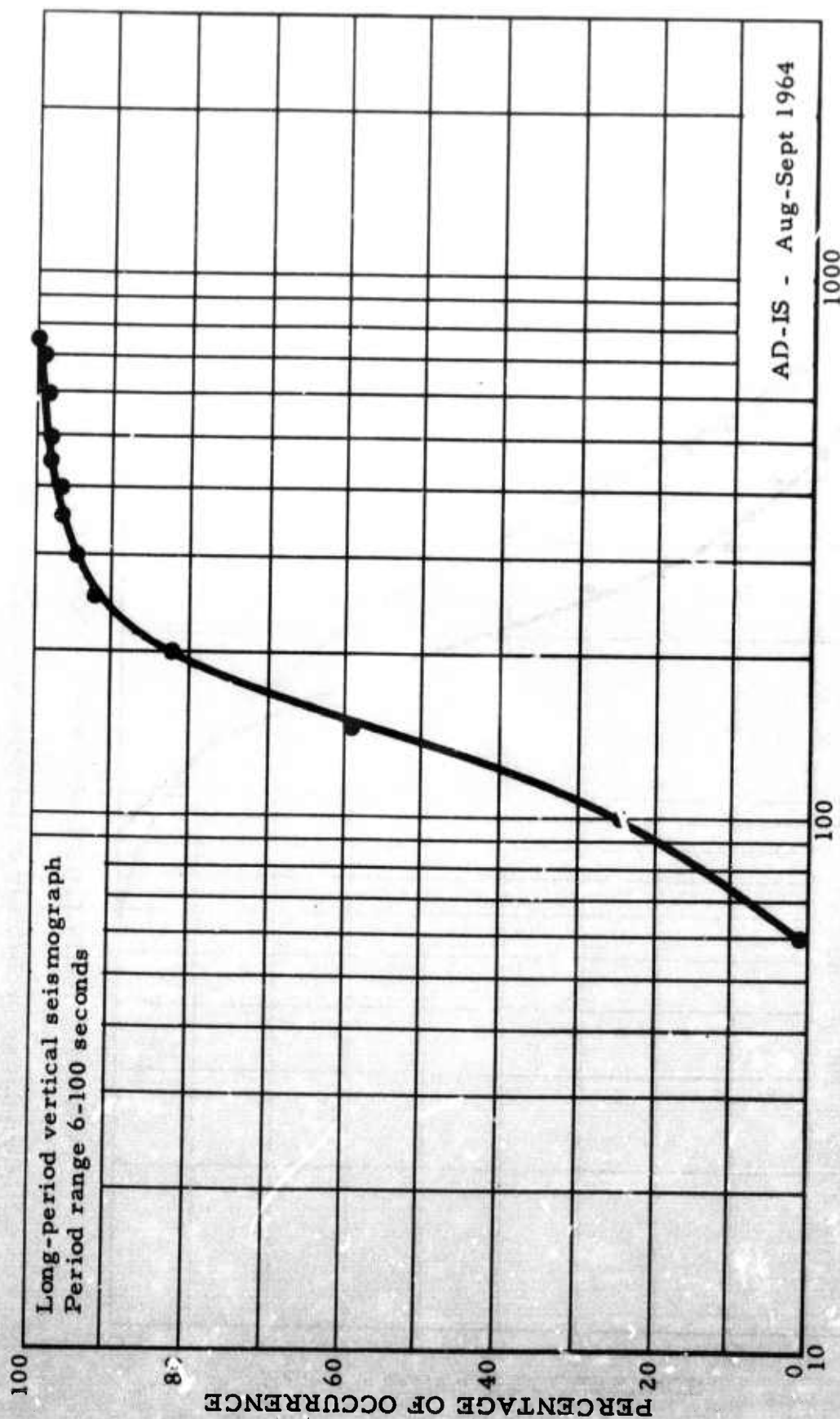
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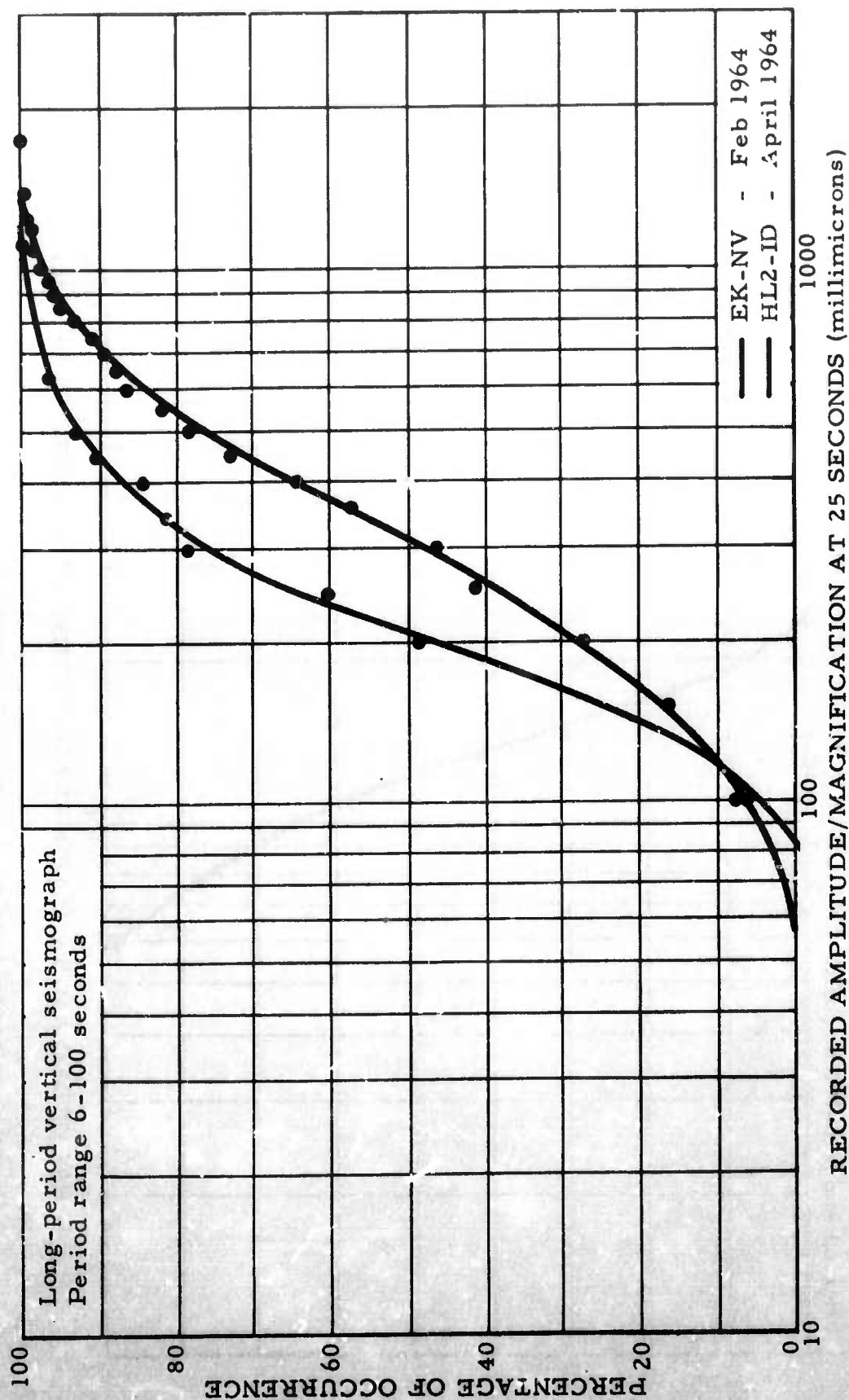
Cumulative probability distribution of amplitude, standard LRSM survey

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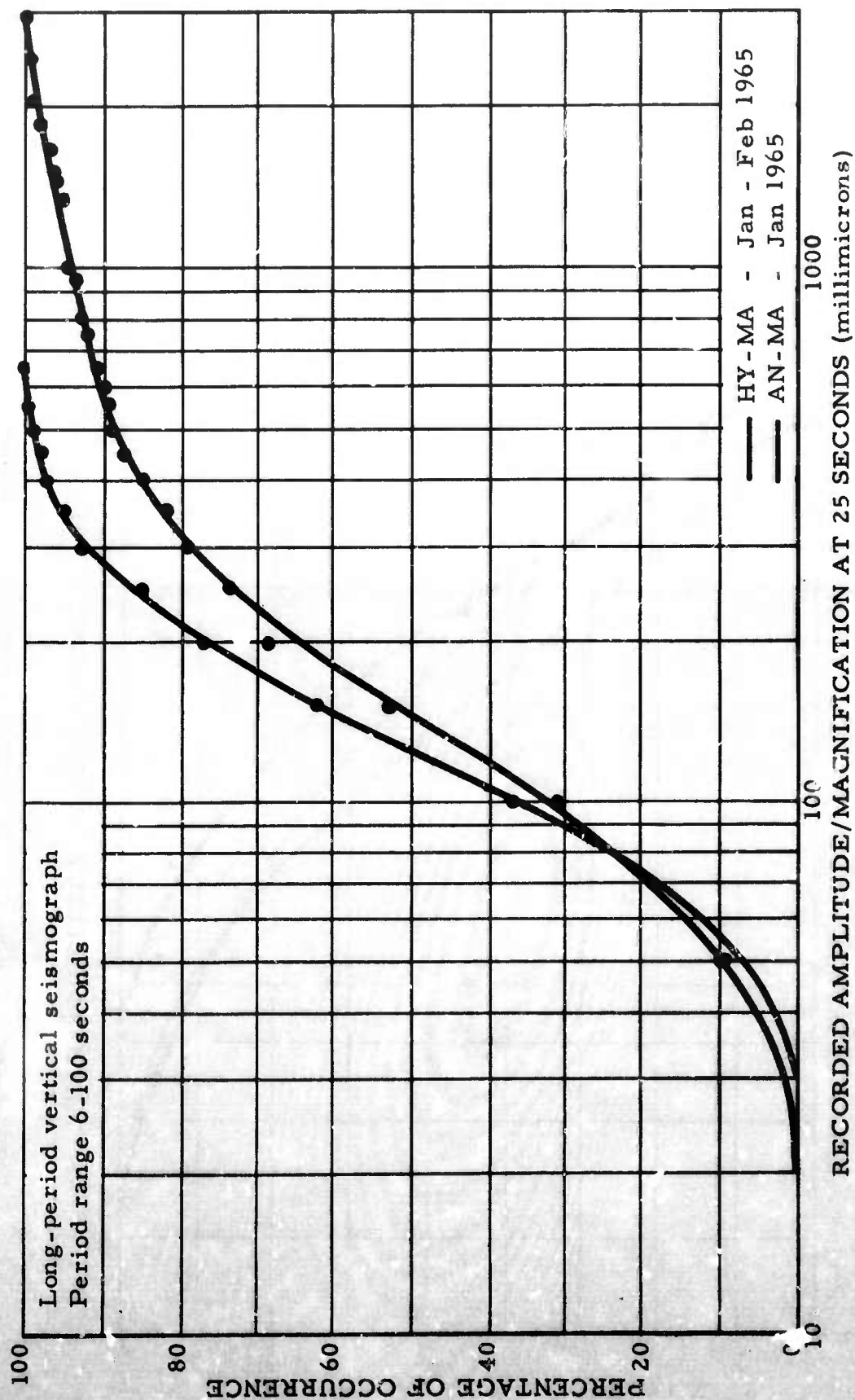
LONG-PERIOD NOISE OCCURRENCE CURVES



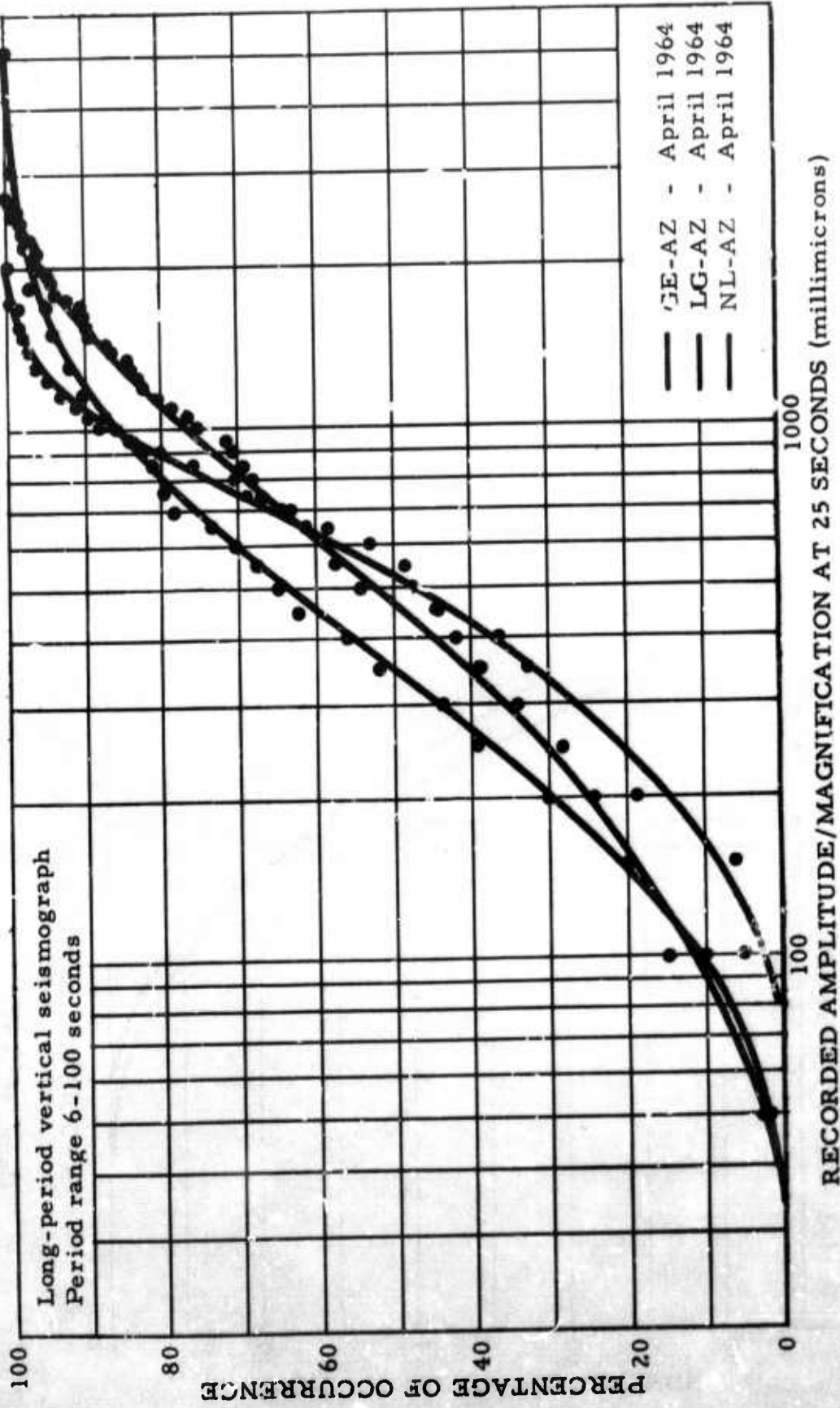
Cumulative probability distribution of amplitude, standard LRSM survey



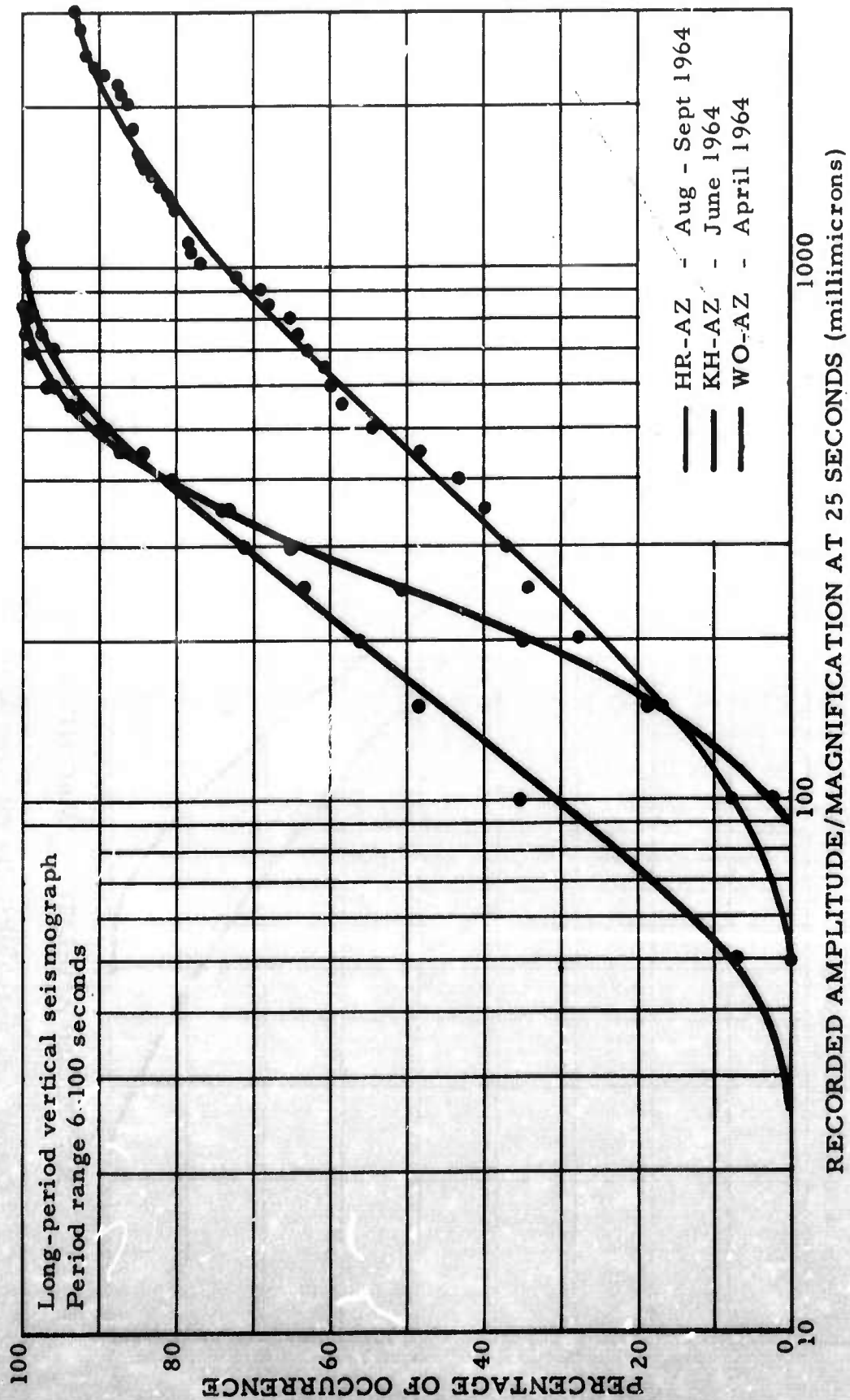
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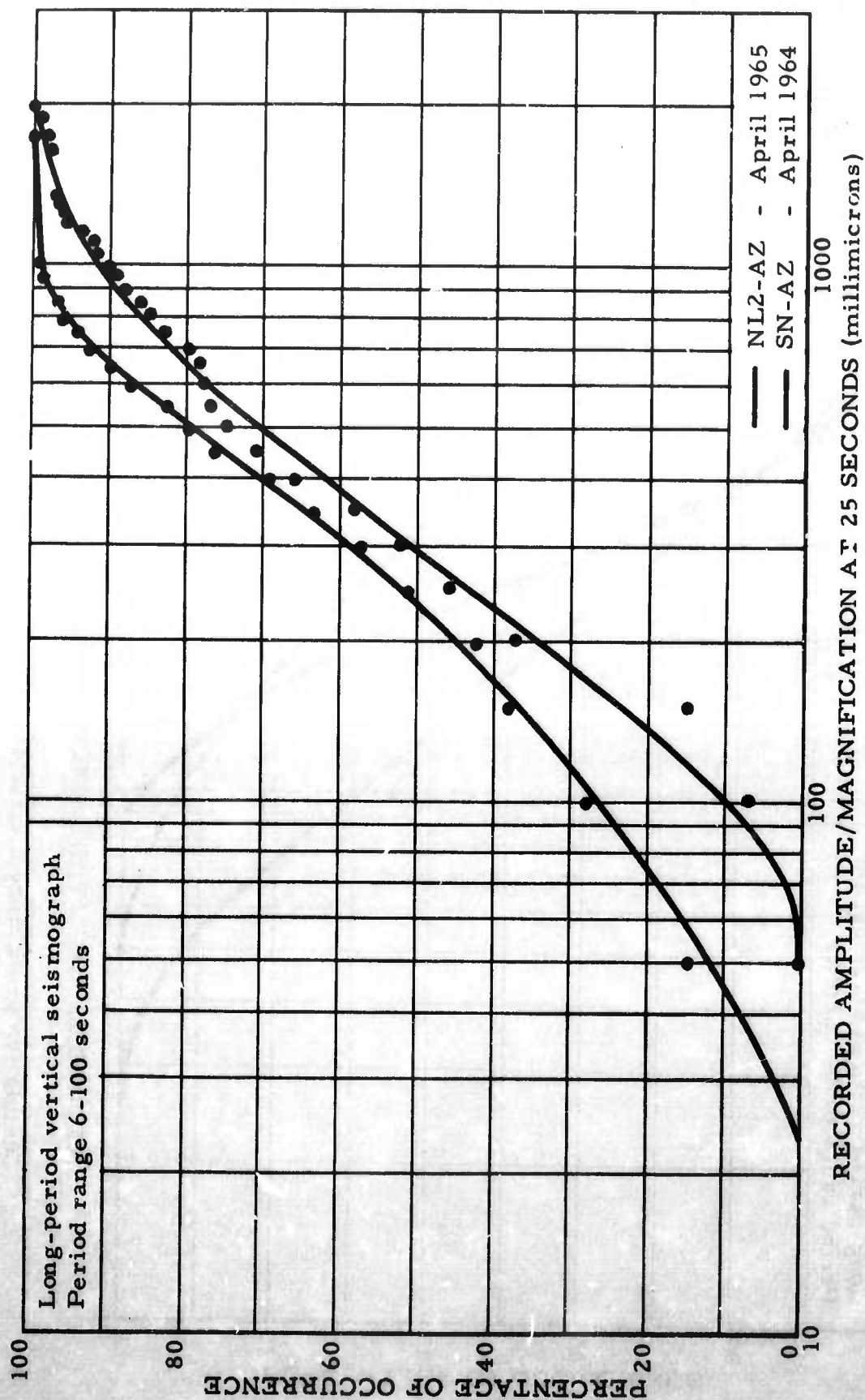
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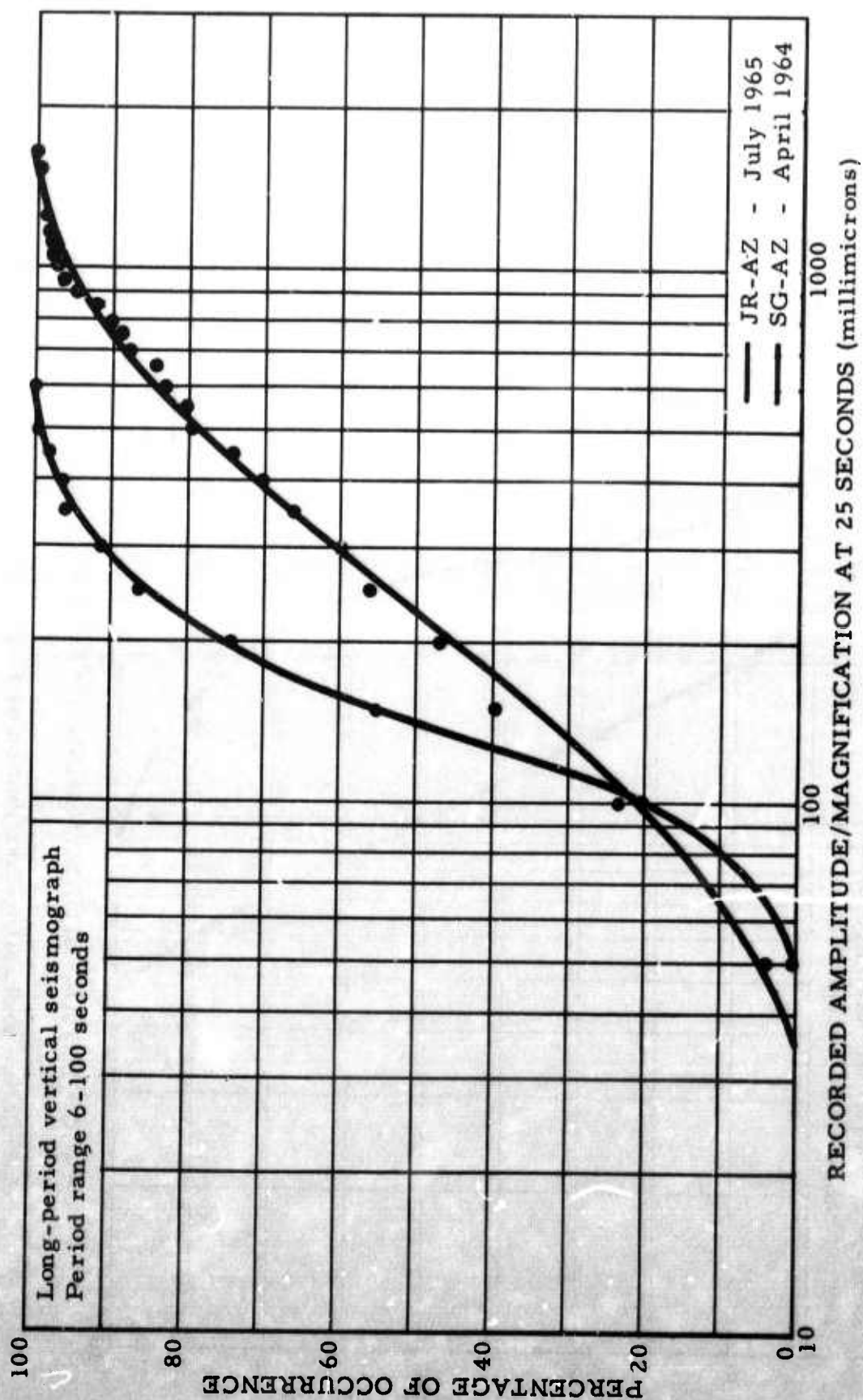
Cumulative probability distribution of amplitude, standard LRSM survey



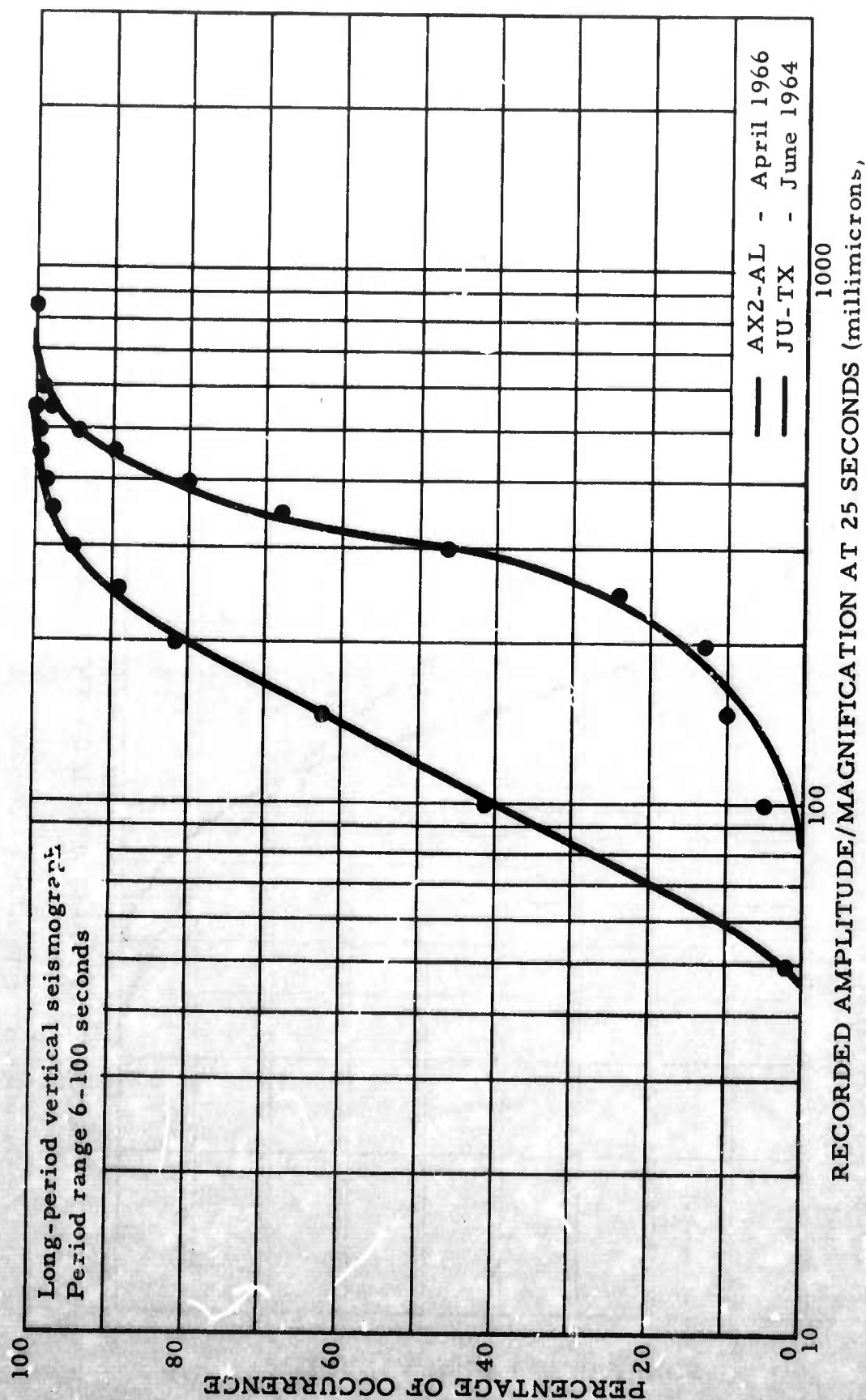
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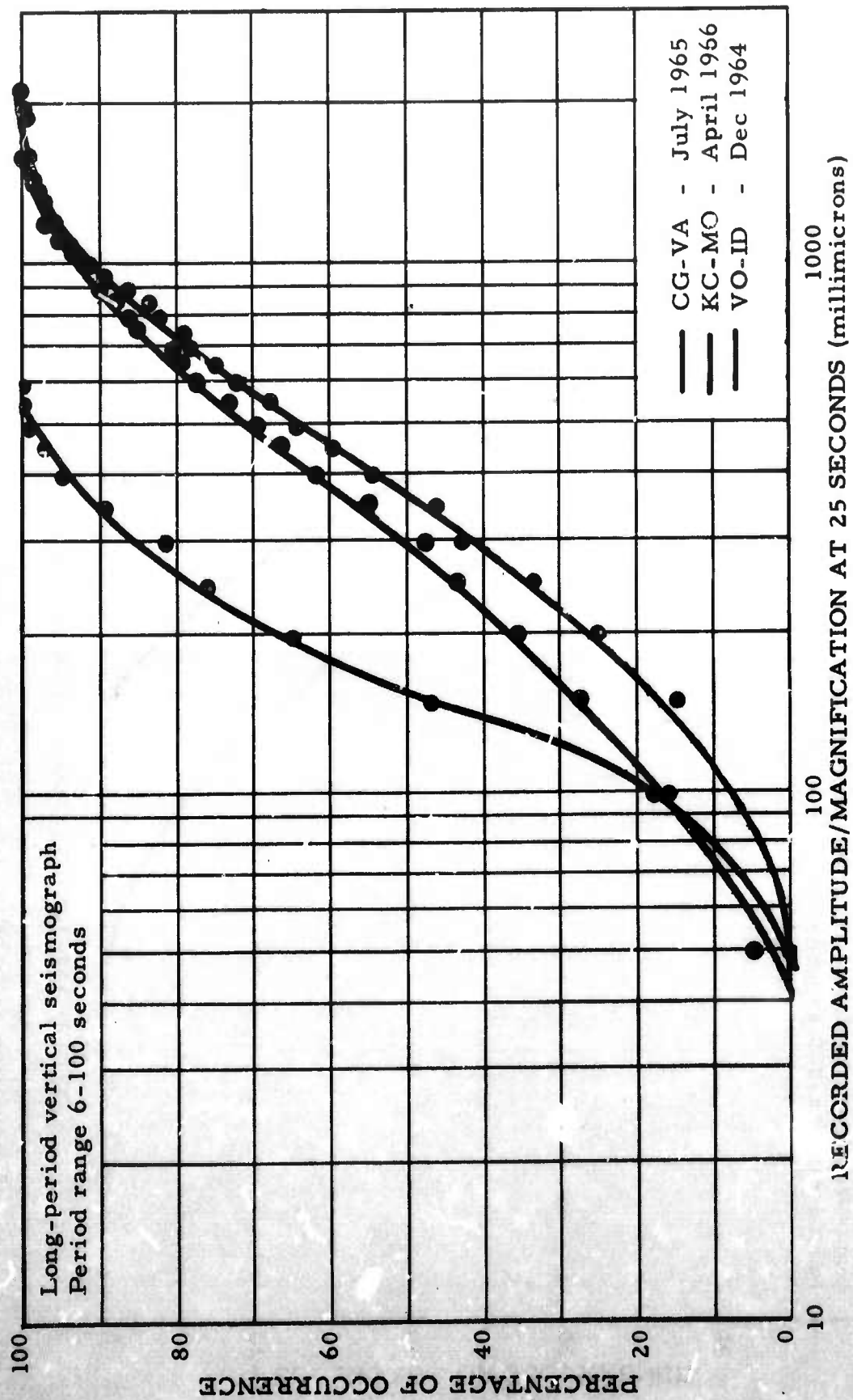
Cumulative probability distribution of amplitude, standard LRSM survey



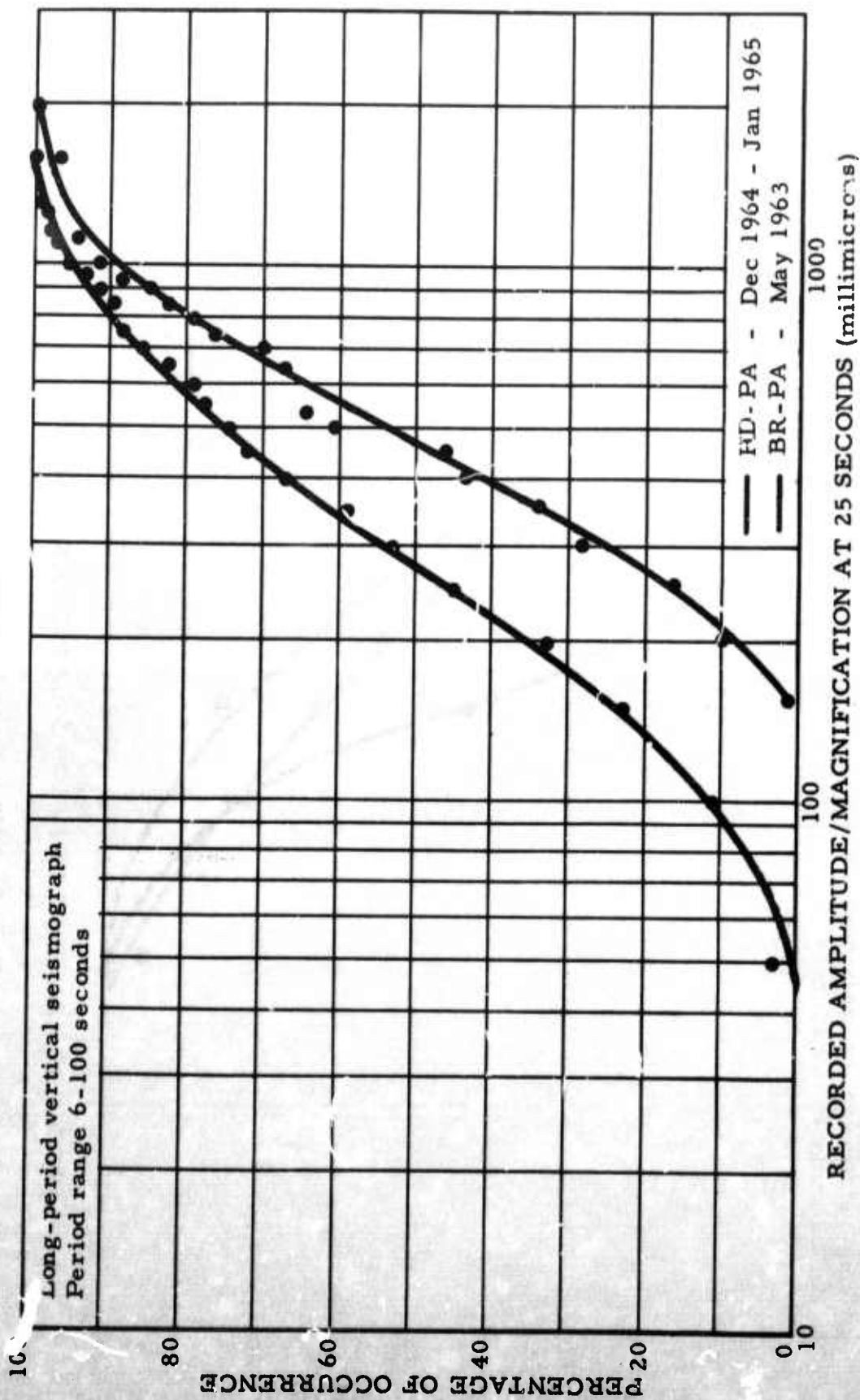
Cumulative probability distribution of amplitude, standard LRSM survey



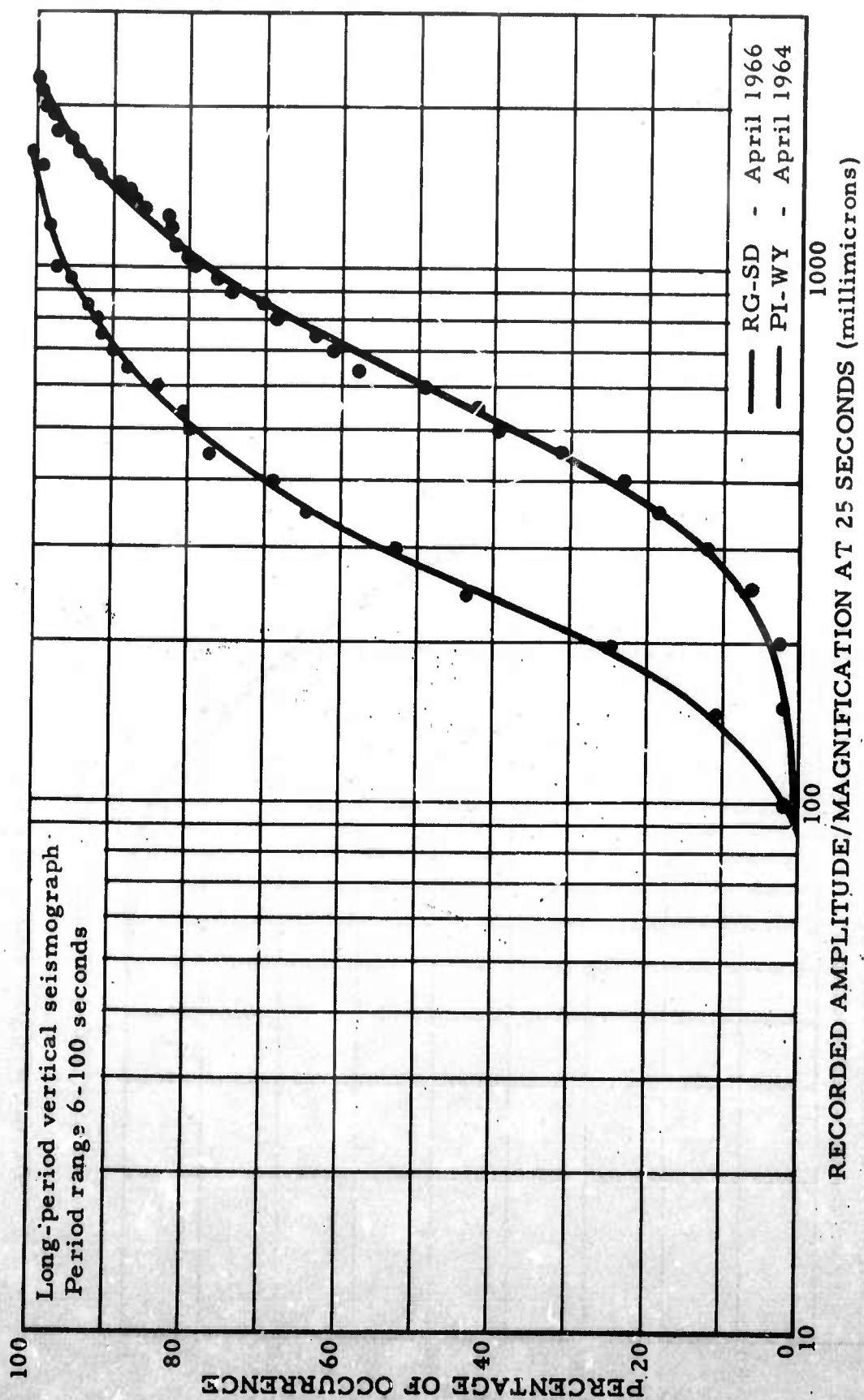
Cumulative probability distribution of amplitude, standard LRSM survey



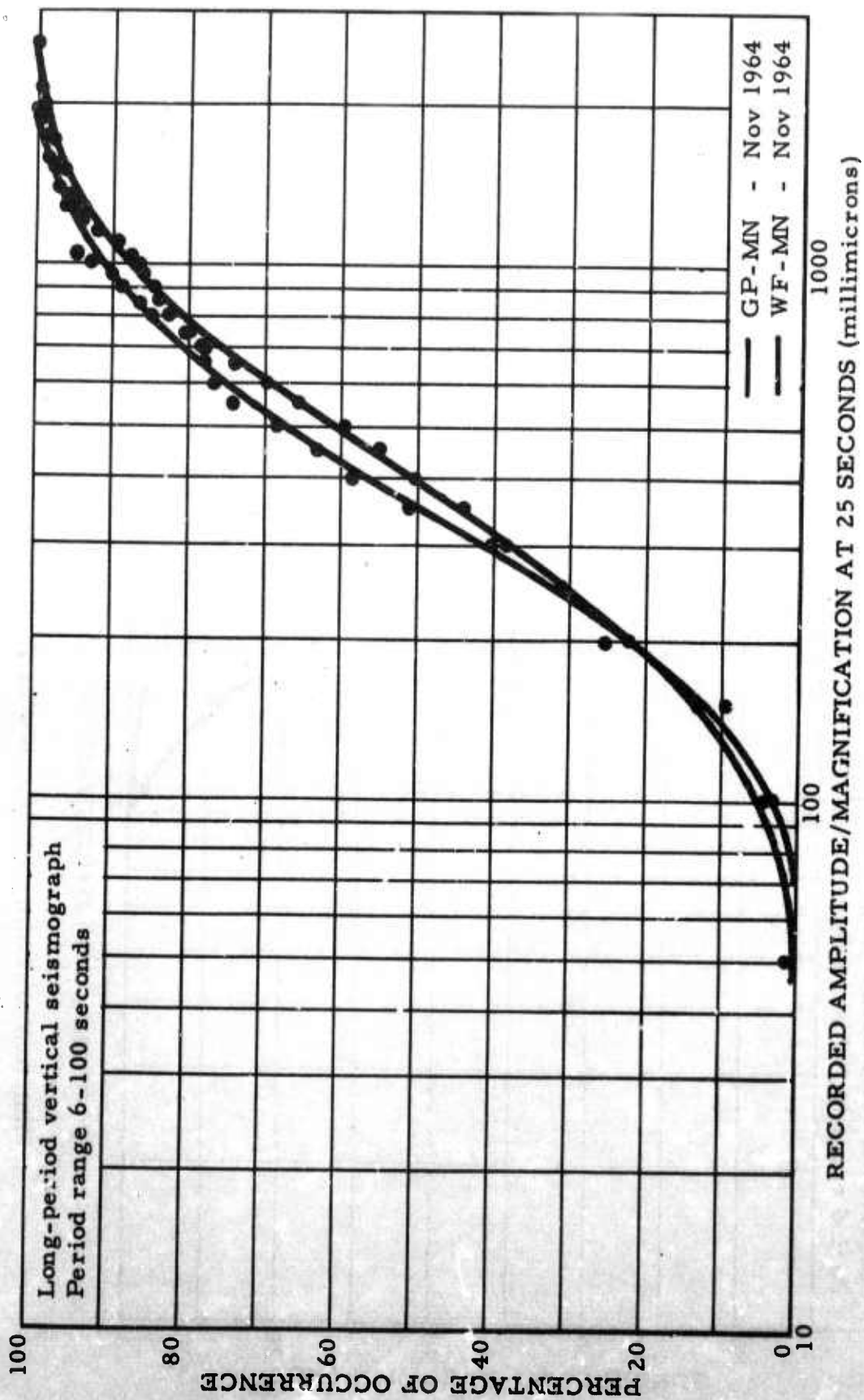
Cumulative probability distribution of amplitude, standard LRSM survey



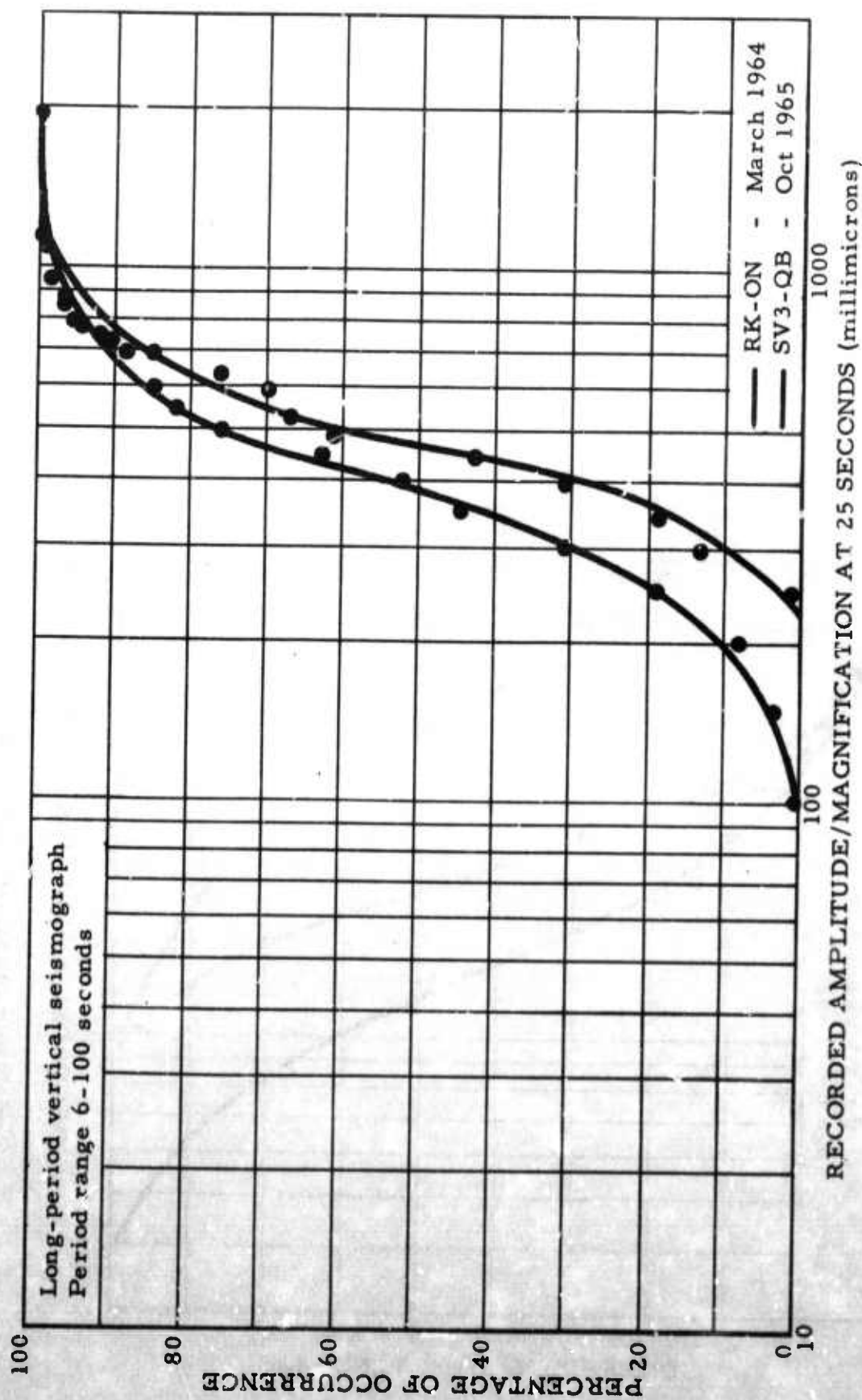
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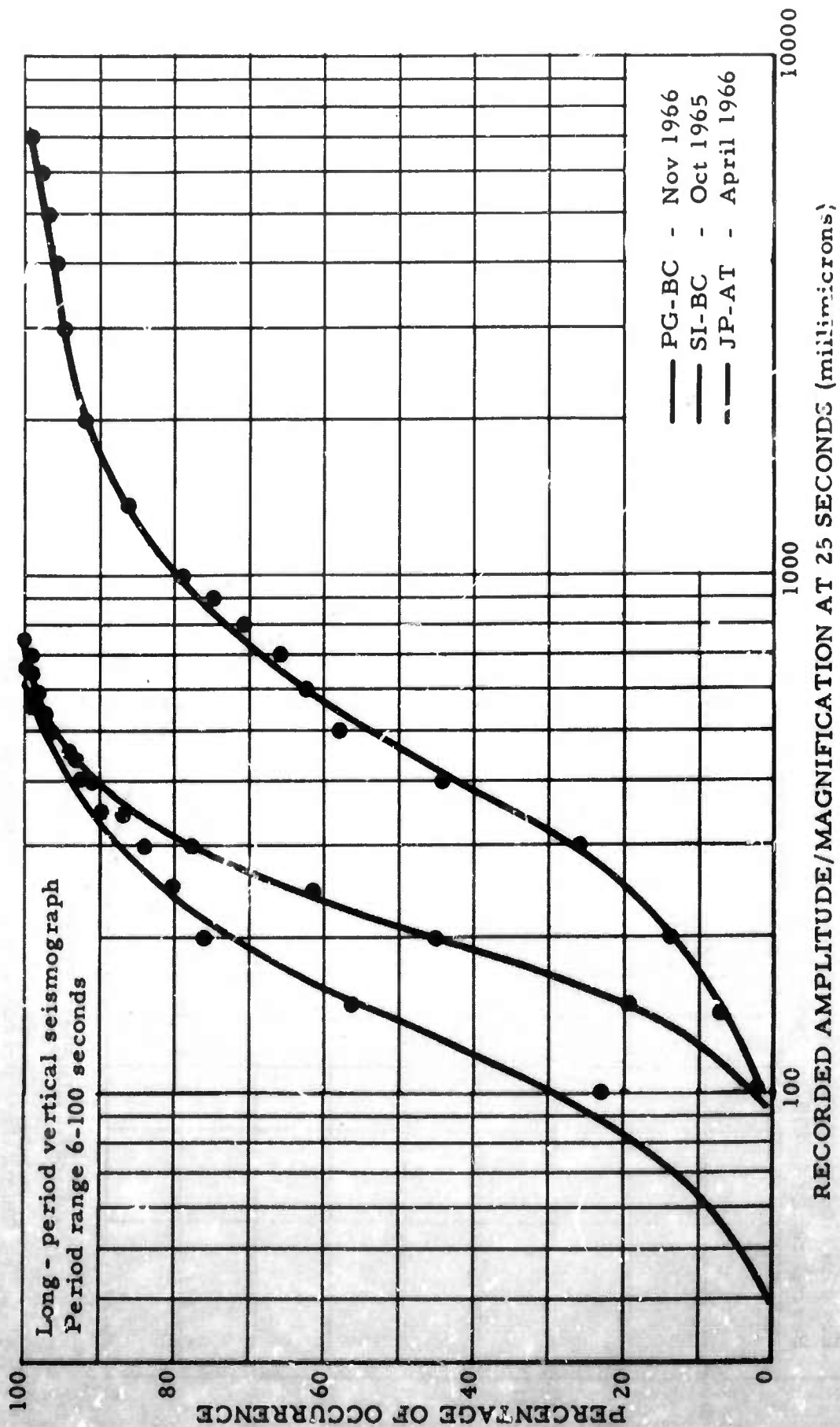
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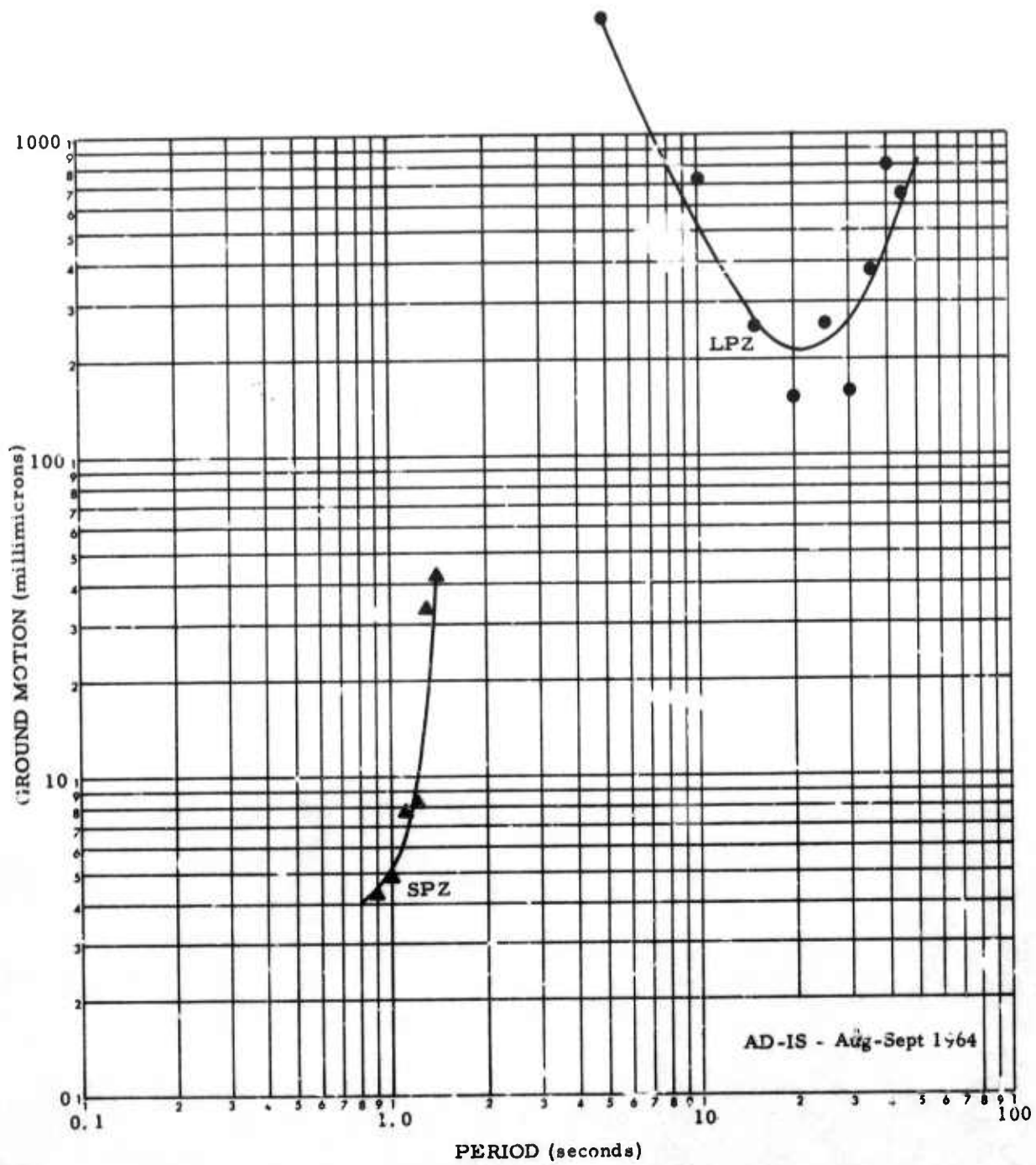
Cumulative probability distribution of amplitude, standard LRSM survey



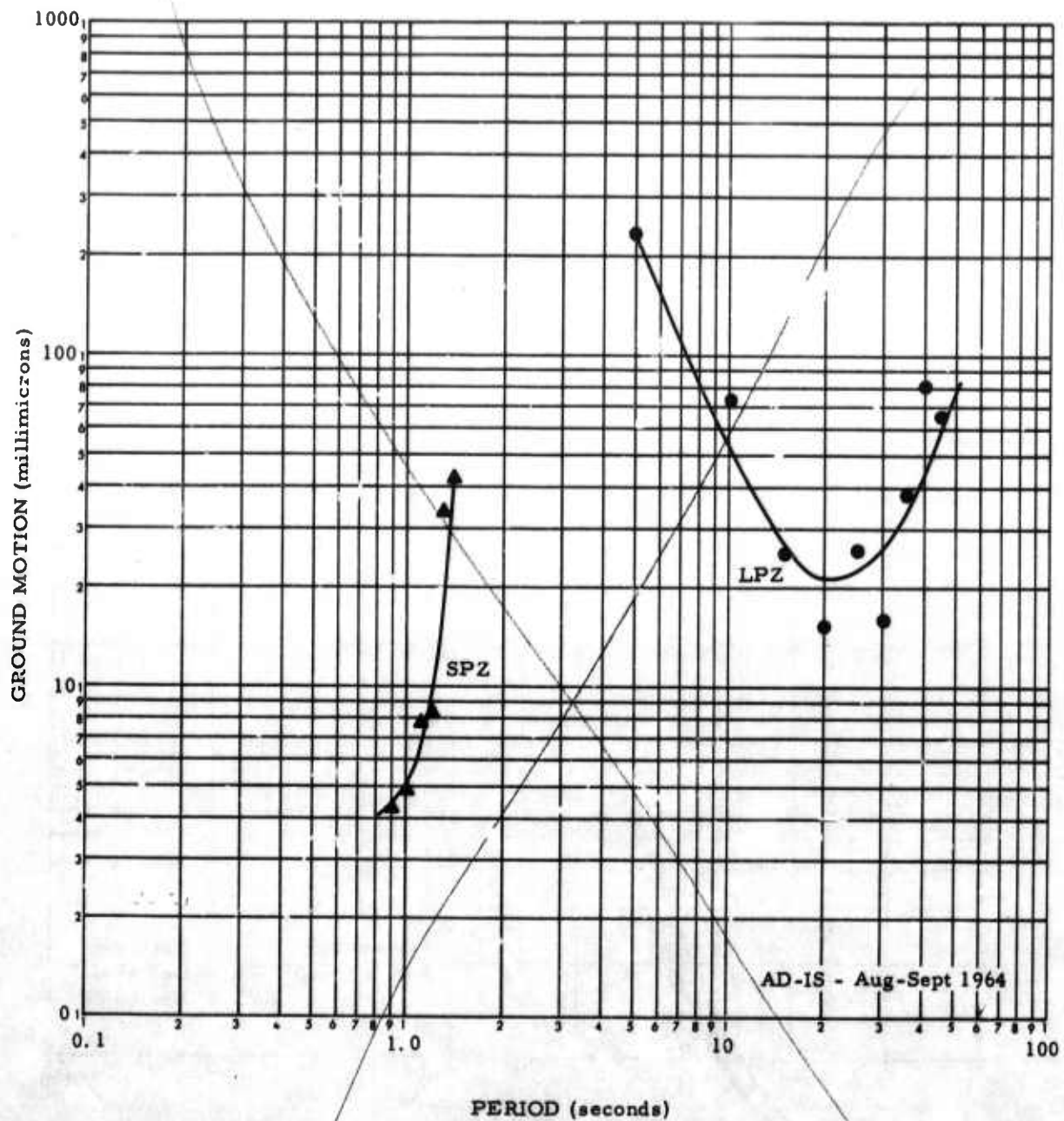
Cumulative probability distribution of amplitude, standard LRSM survey

APPENDIX 3 to TECHNICAL REPORT NO. 67-19

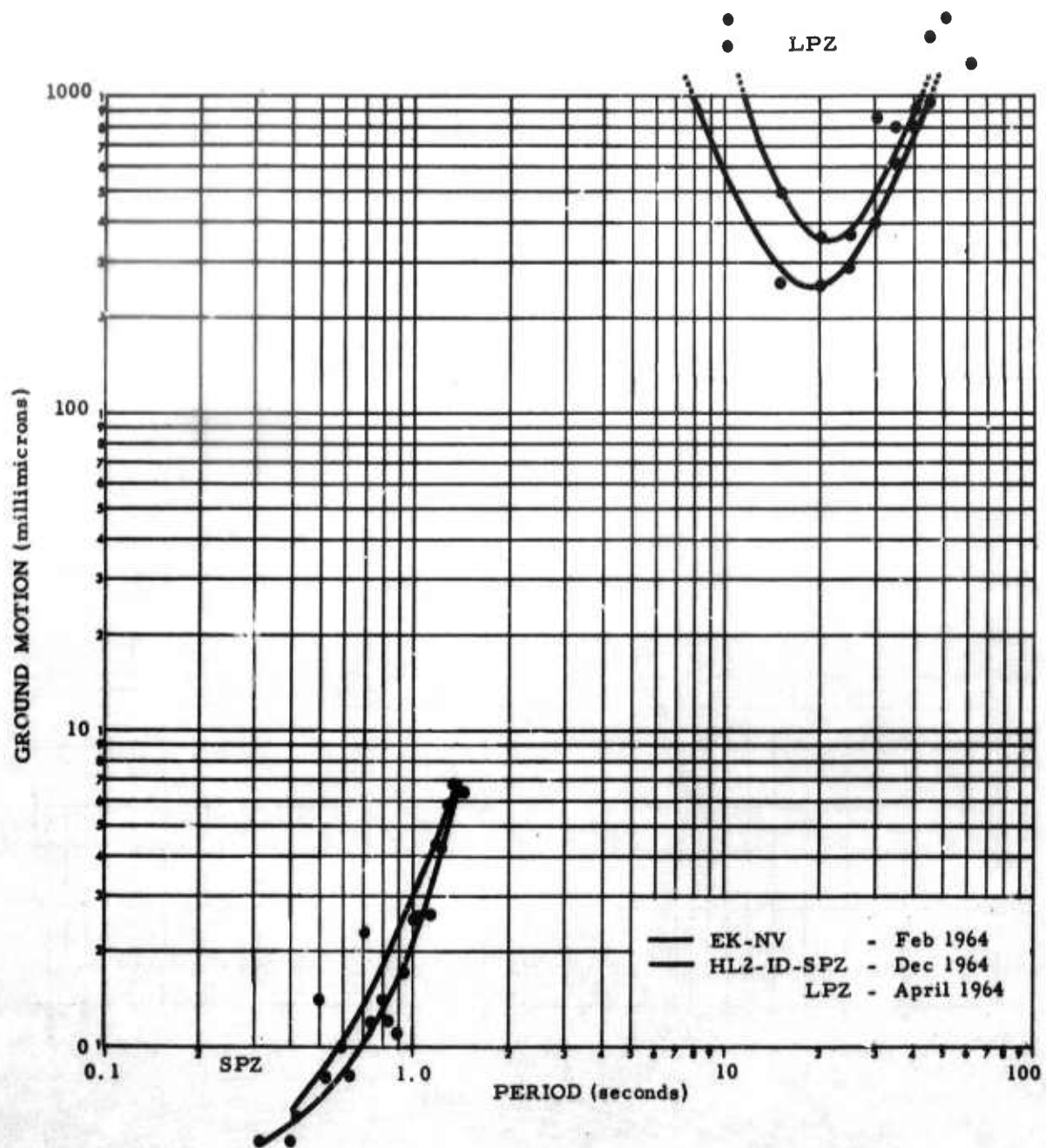
NOISE SPECTRUM CURVES



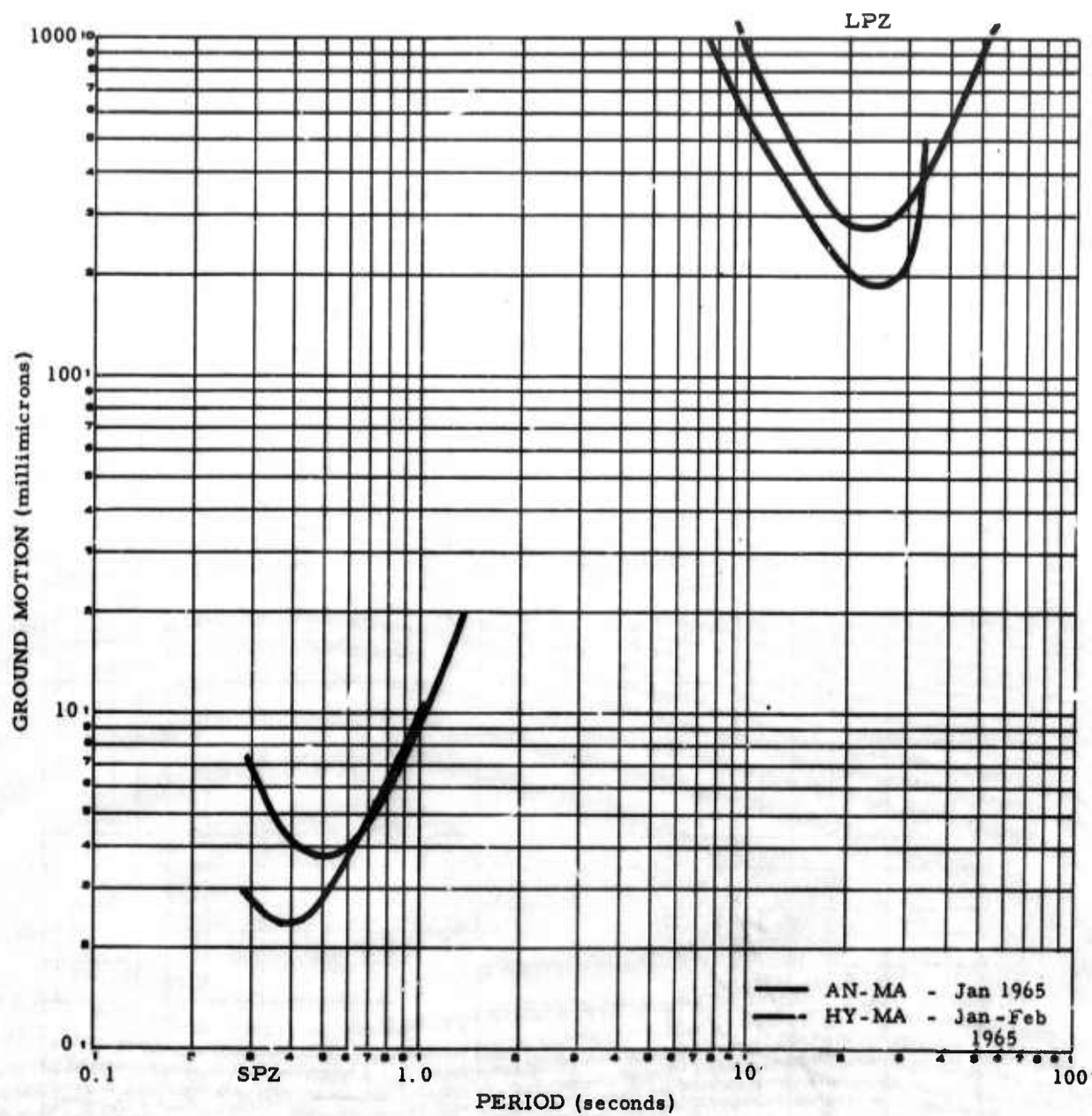
Noise spectrum curve, LRSM



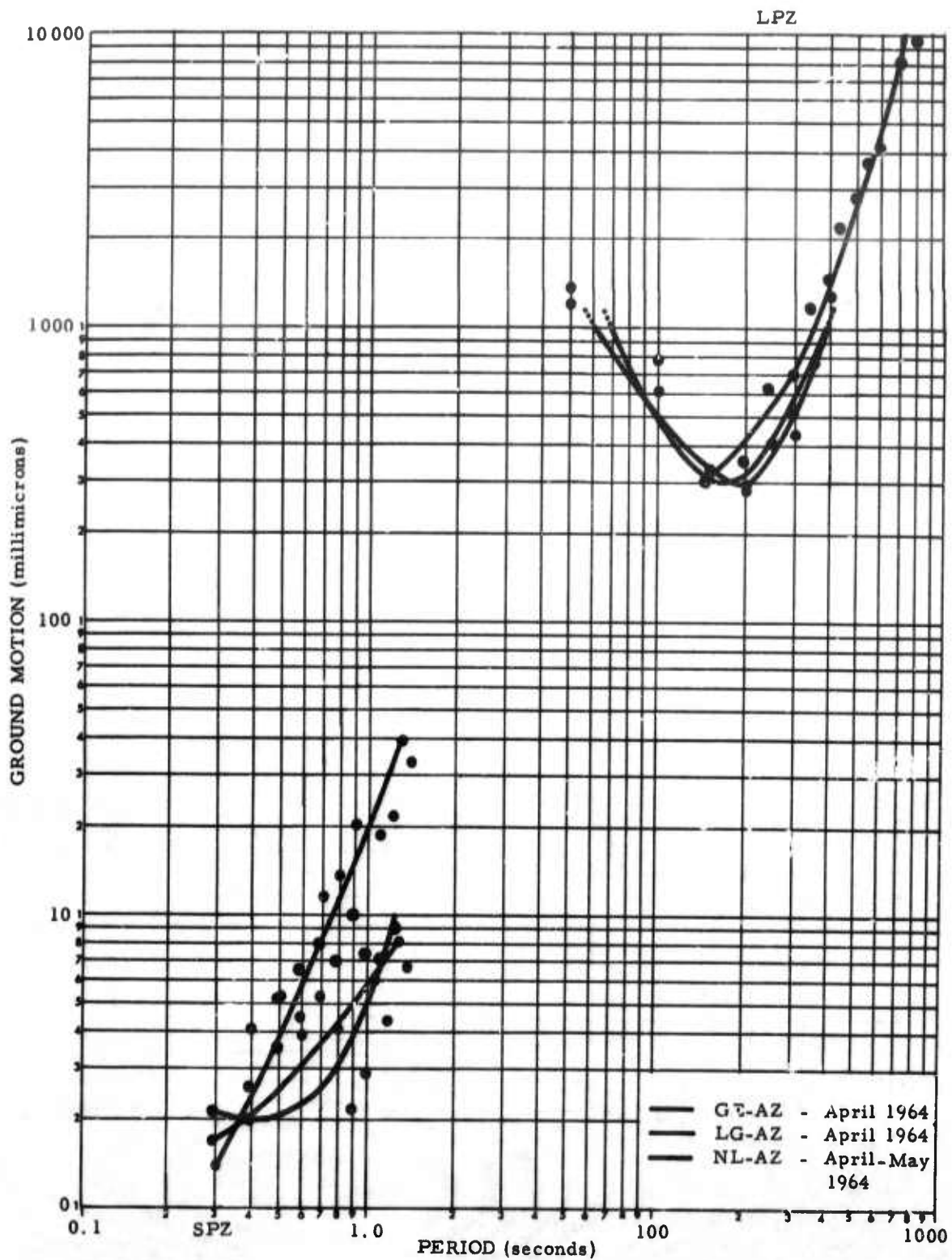
Noise spectrum curve, LRSM



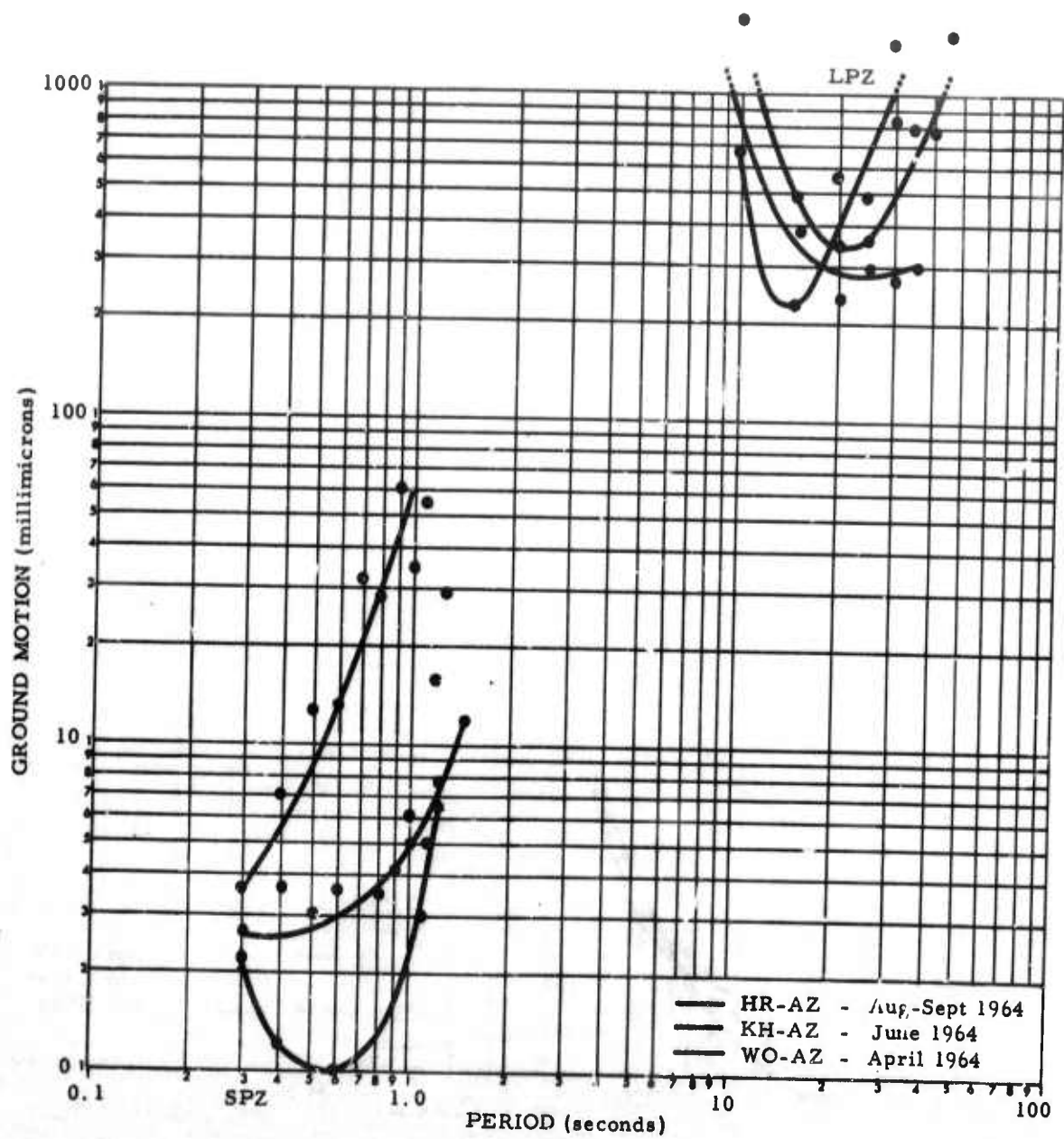
Noise spectrum curve, LRSM



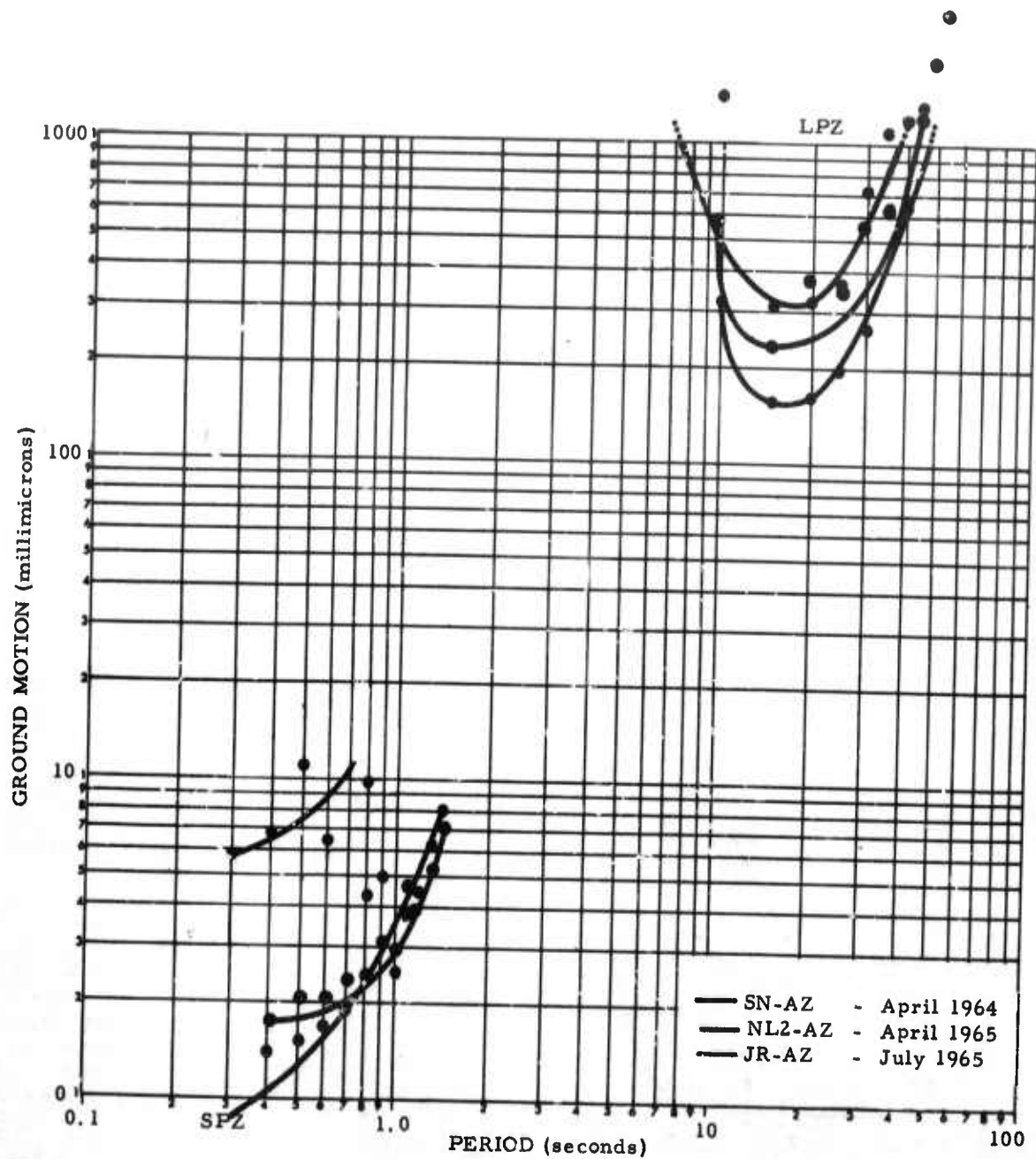
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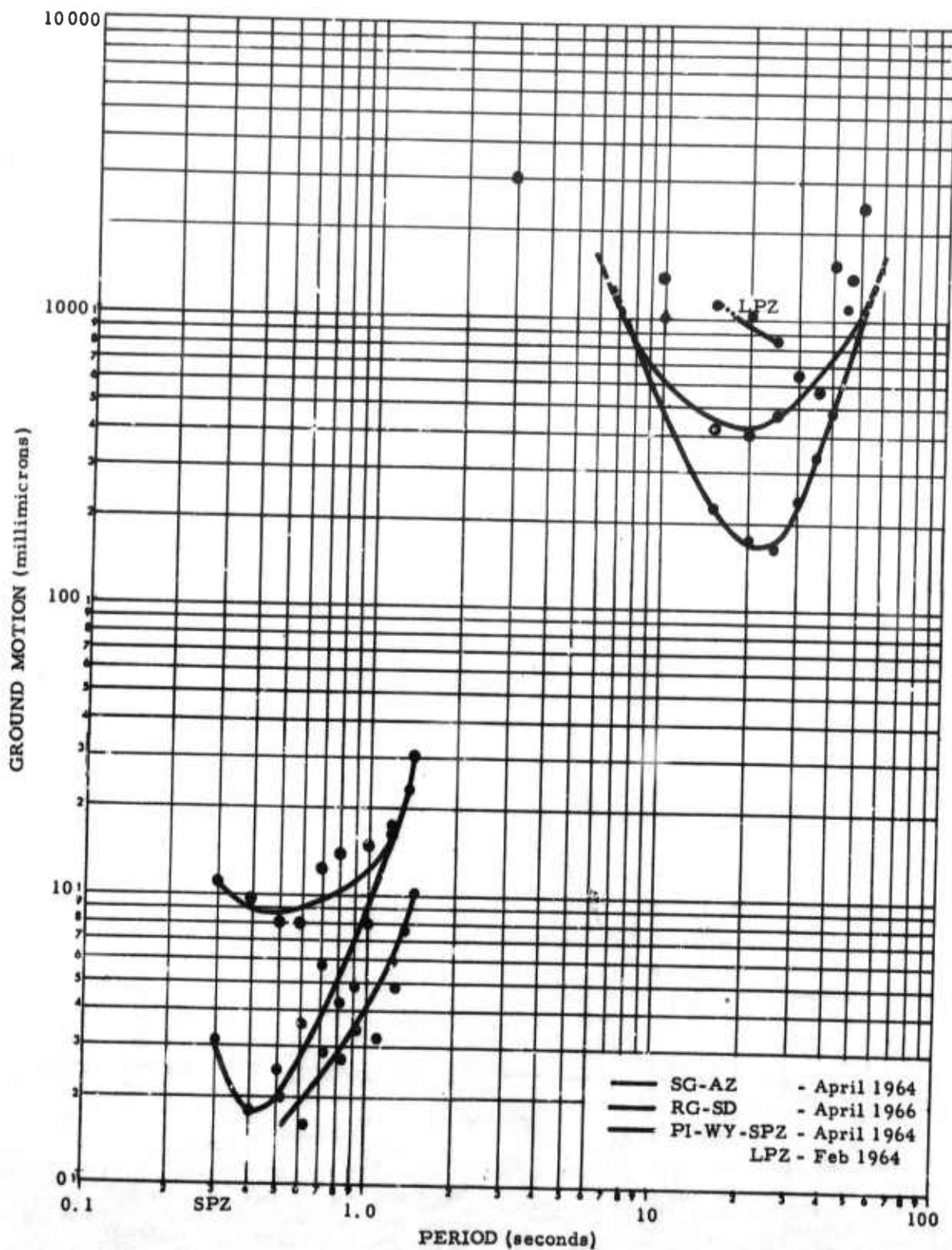
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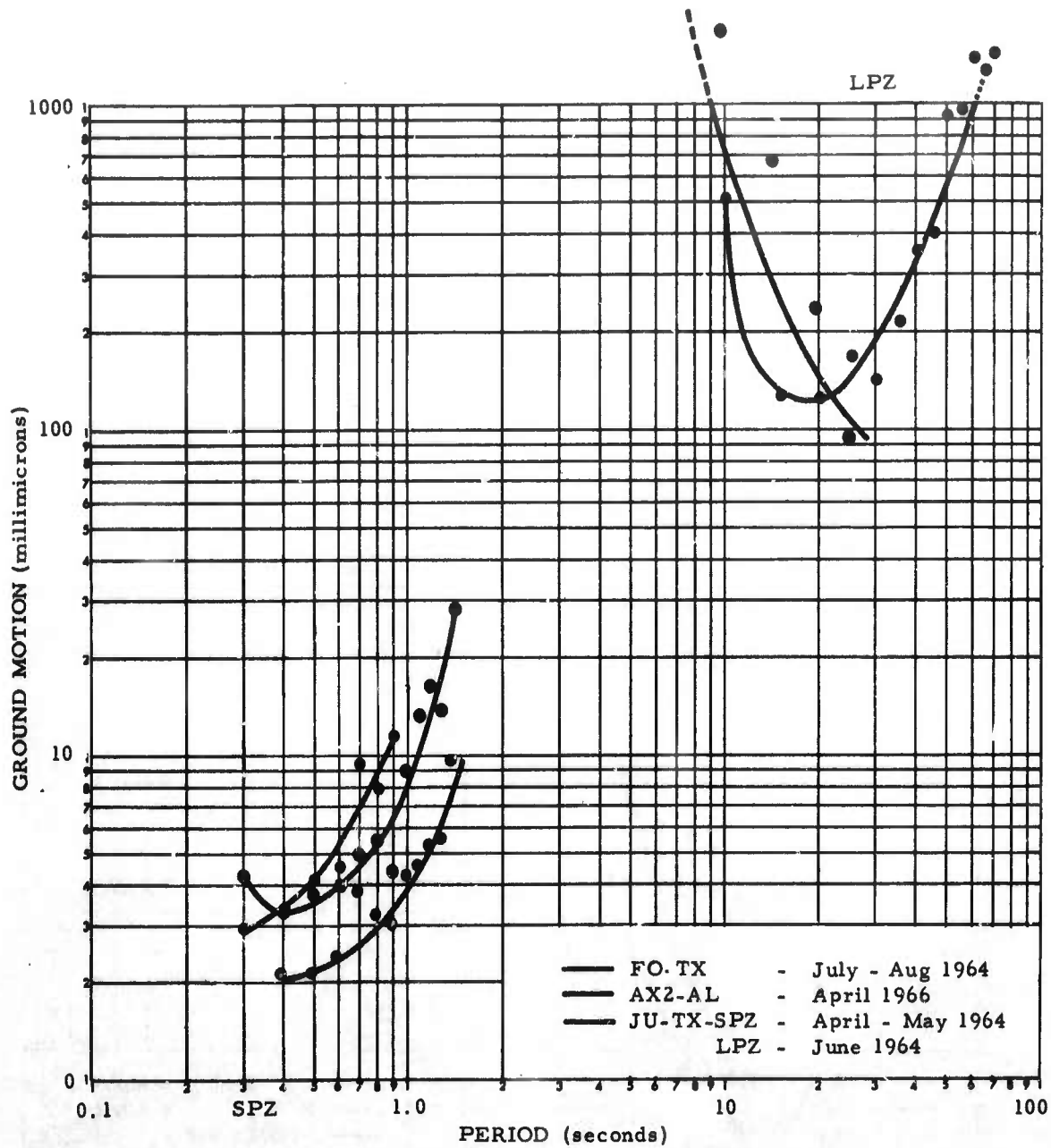
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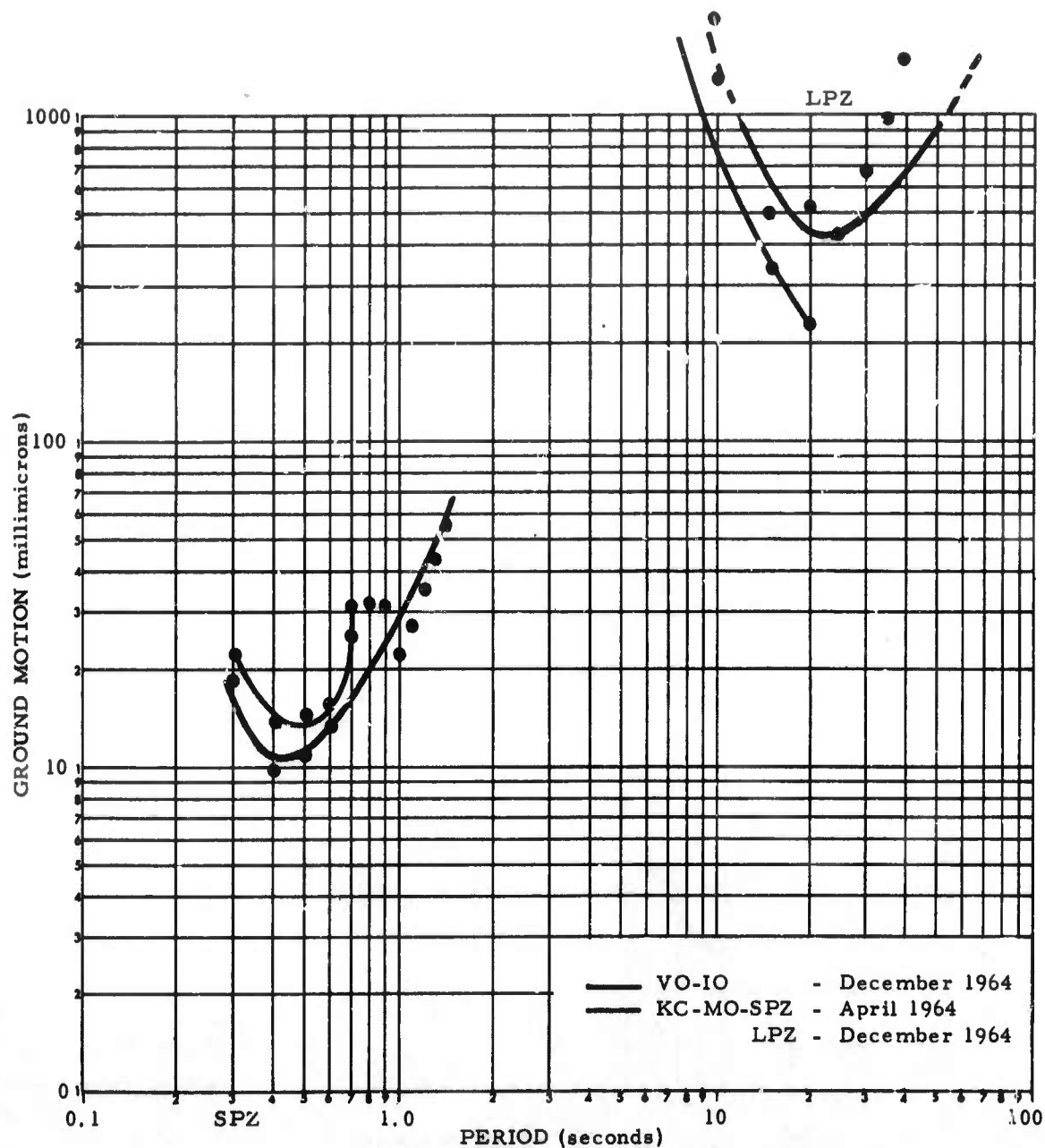
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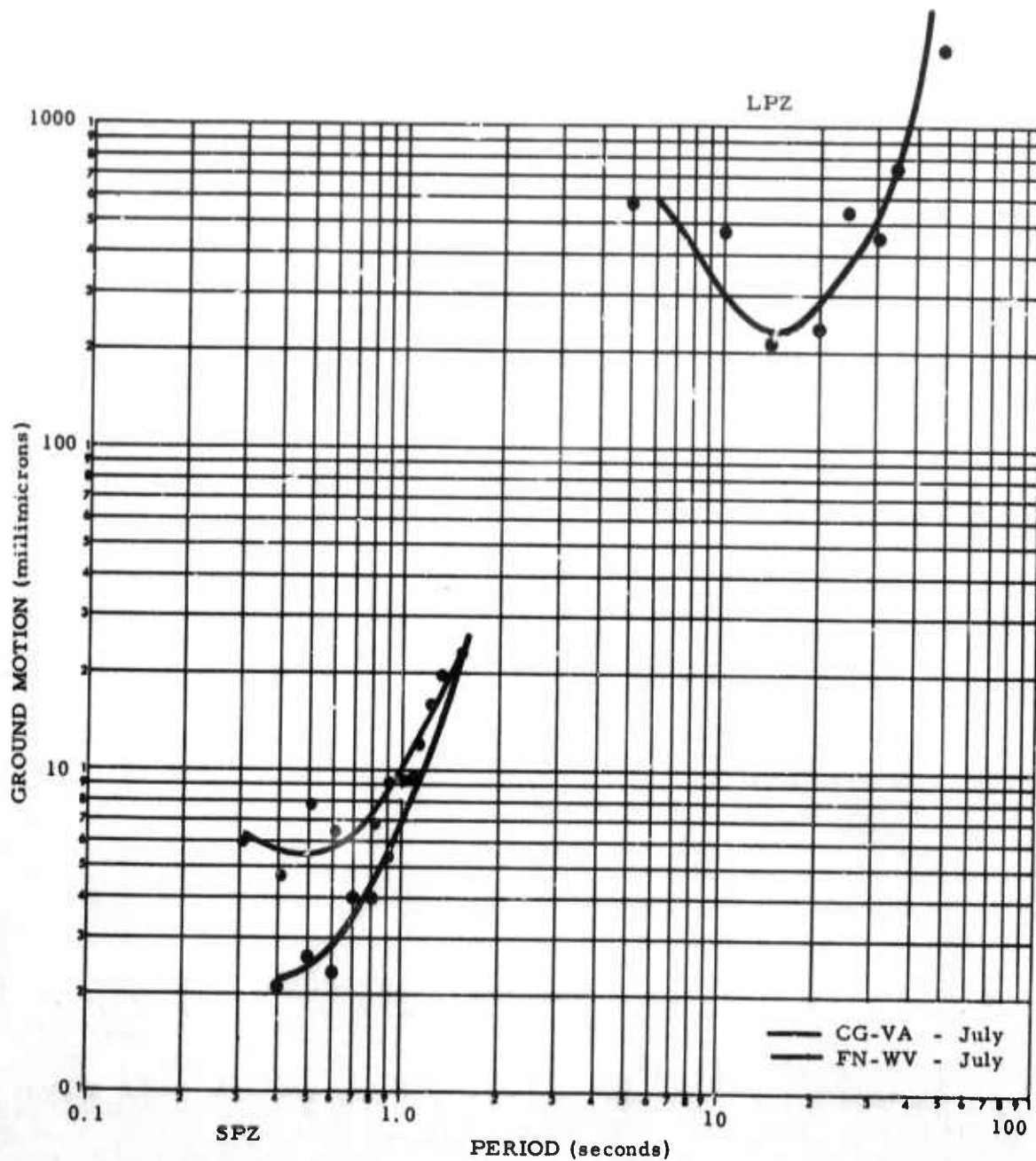
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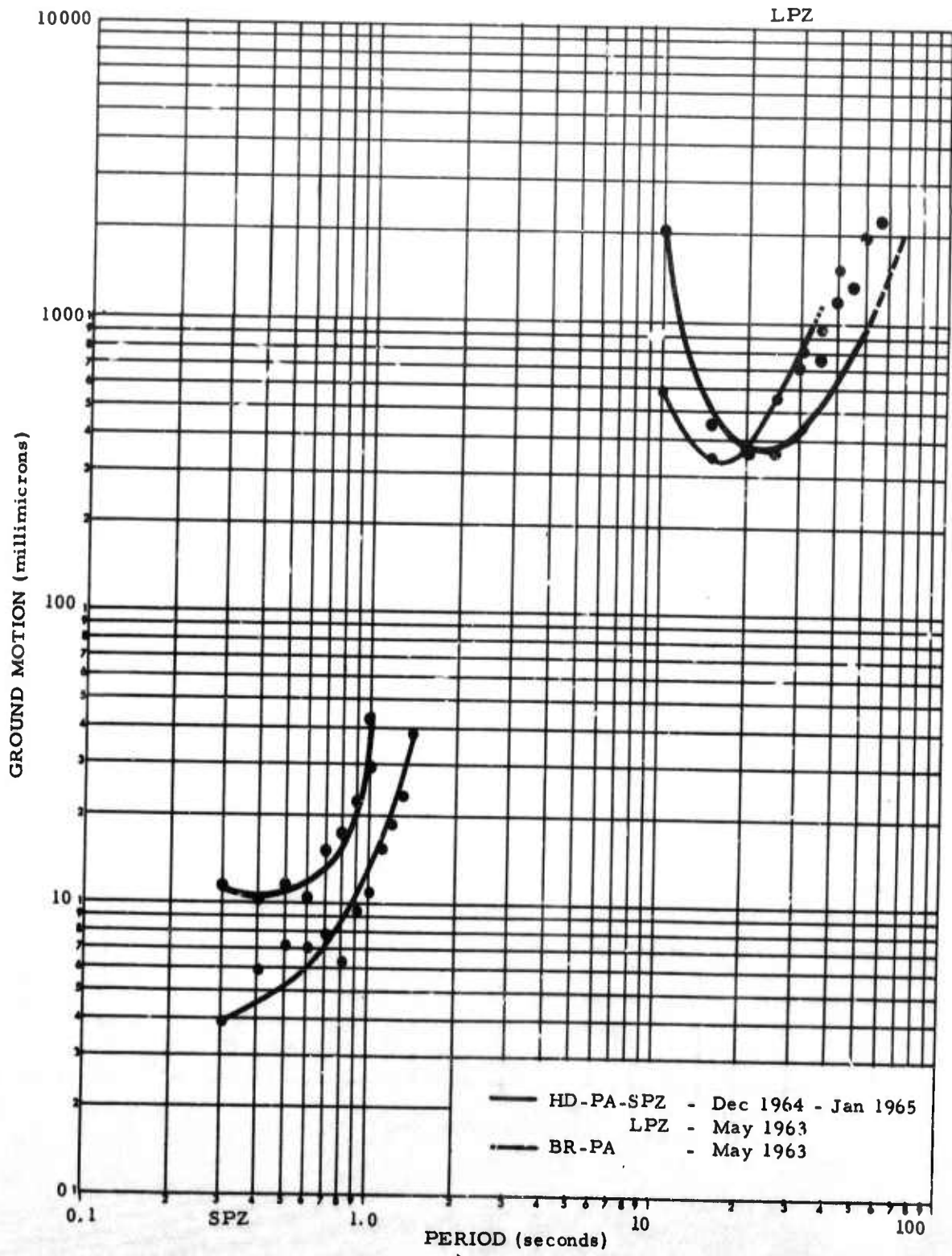
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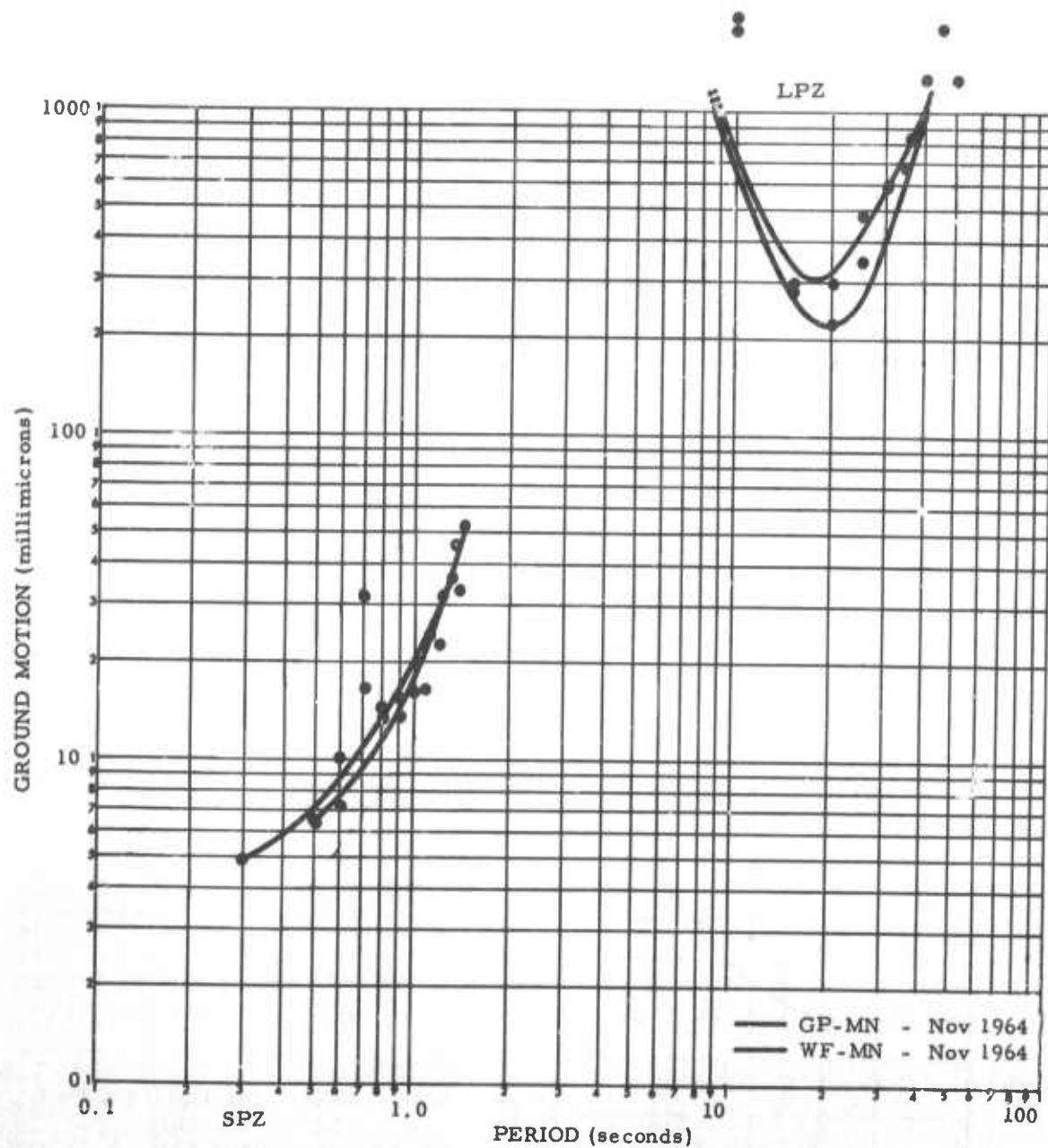
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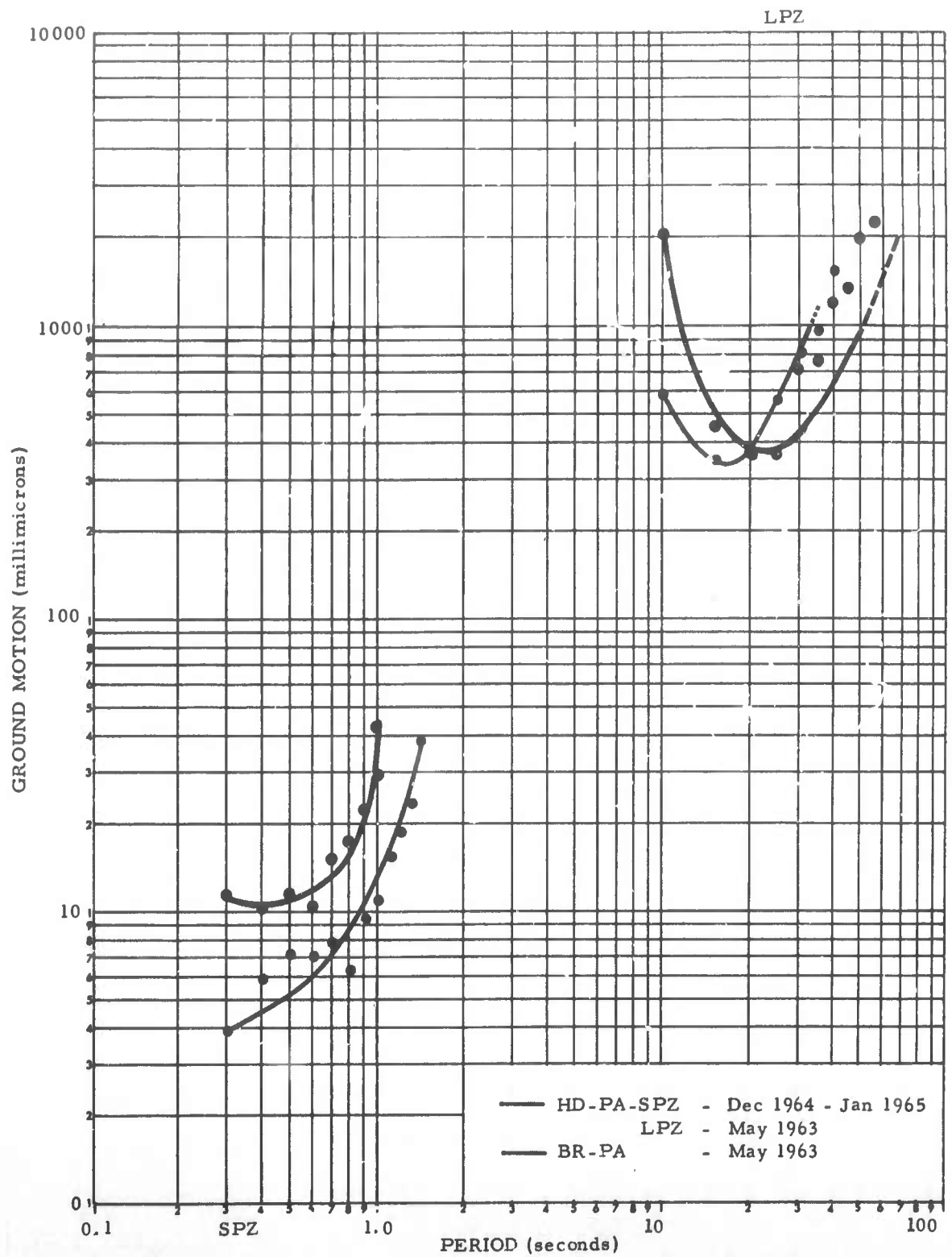
Noise spectrum curve, LRSM



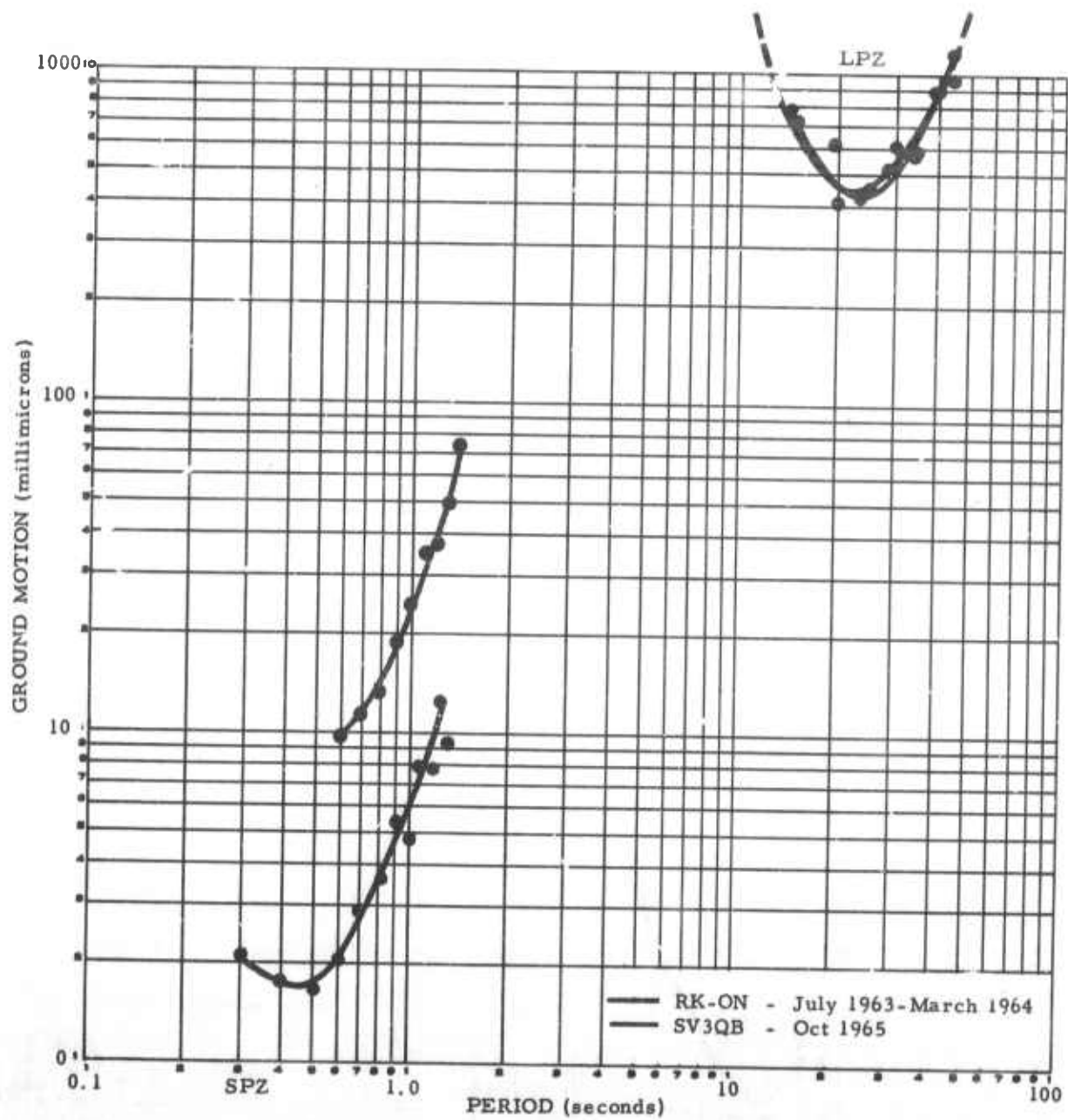
Noise spectrum curve, LRSM



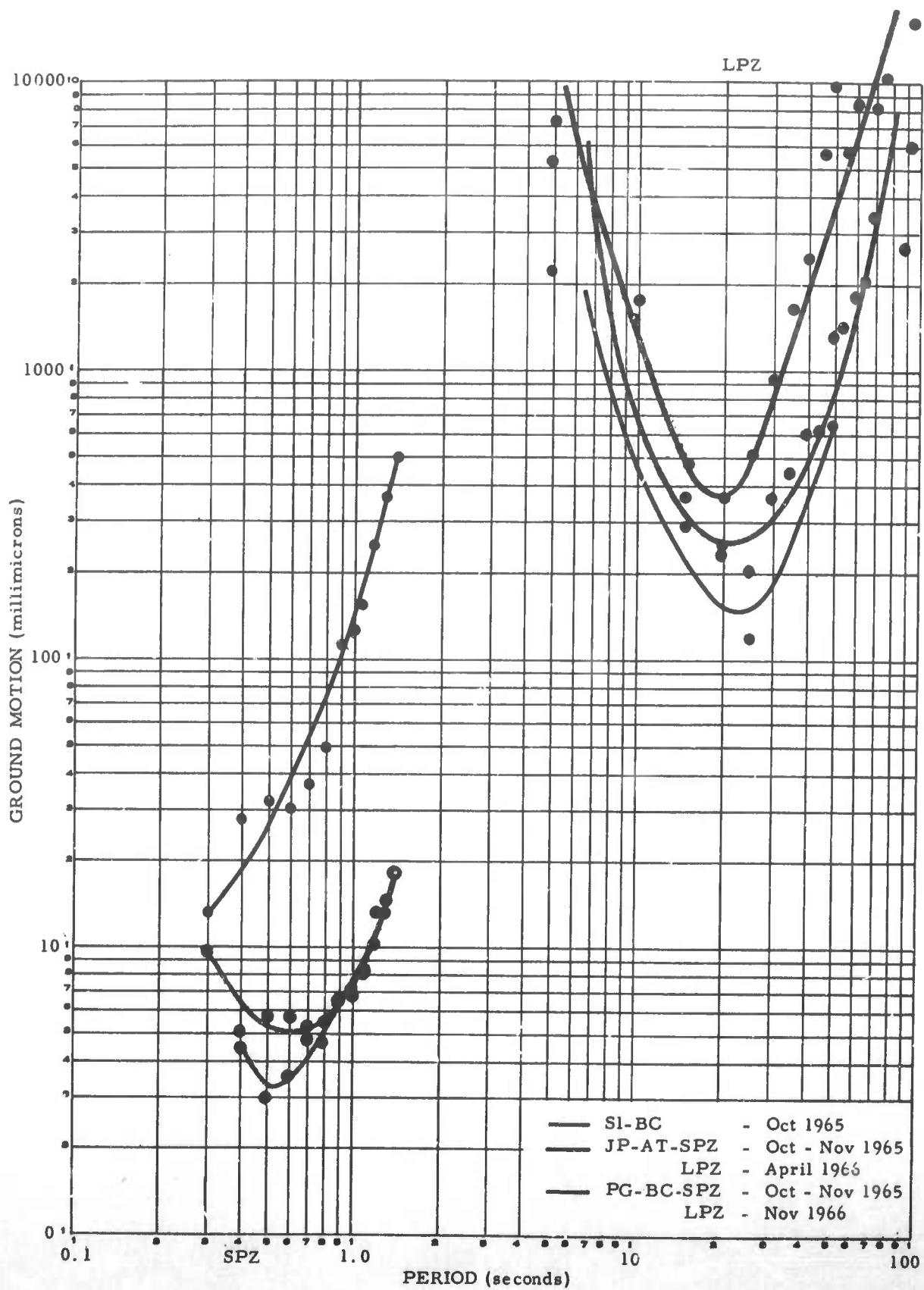
Noise spectrum curve, LRSM



Noise spectrum curve, LRS



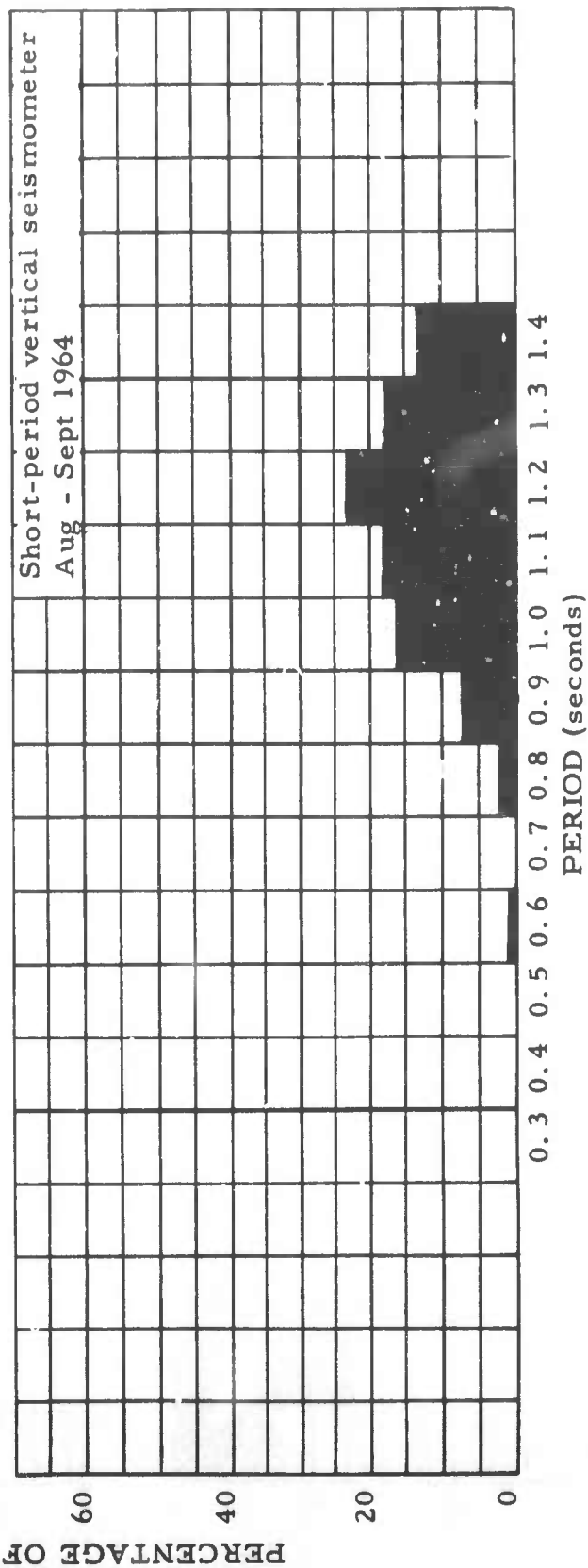
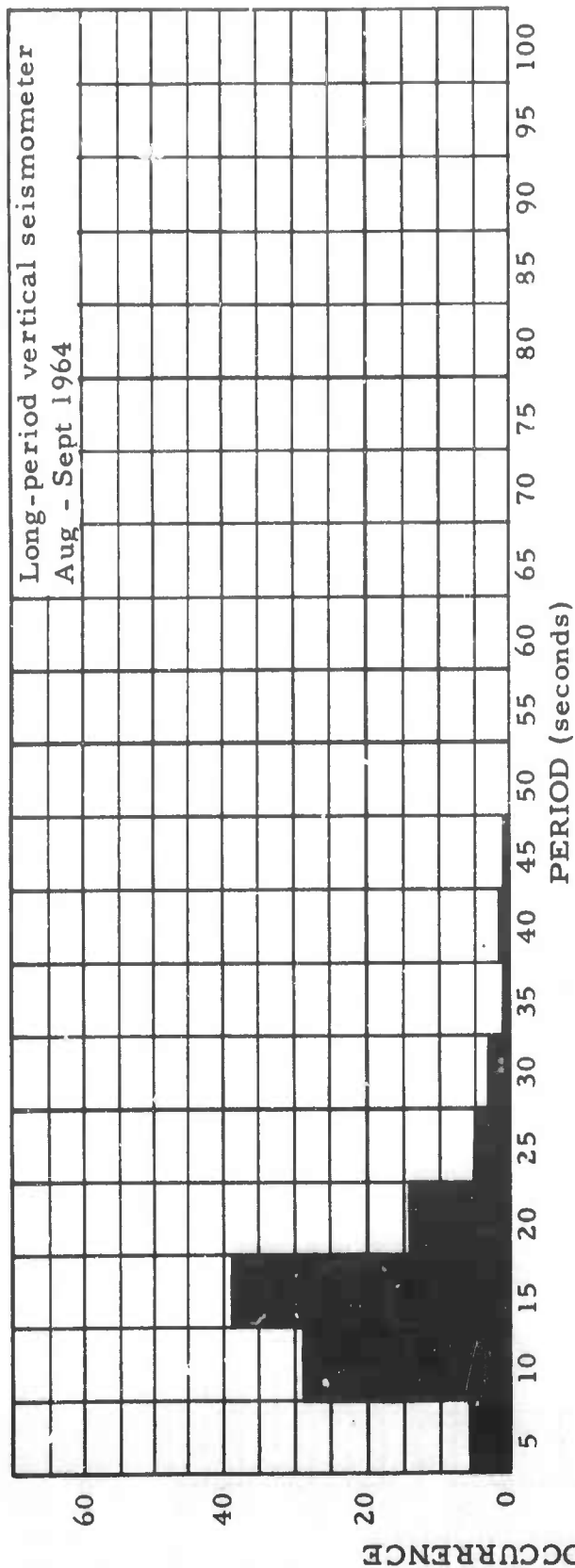
Noise spectrum curve, LRSM



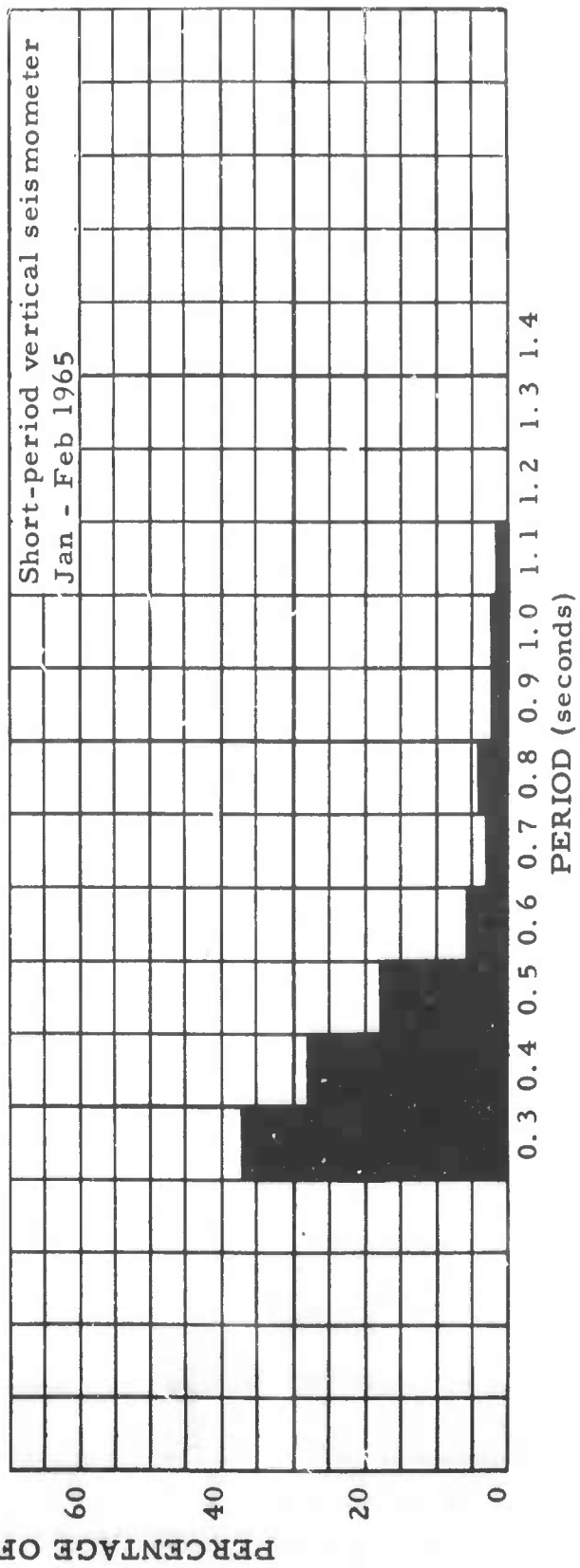
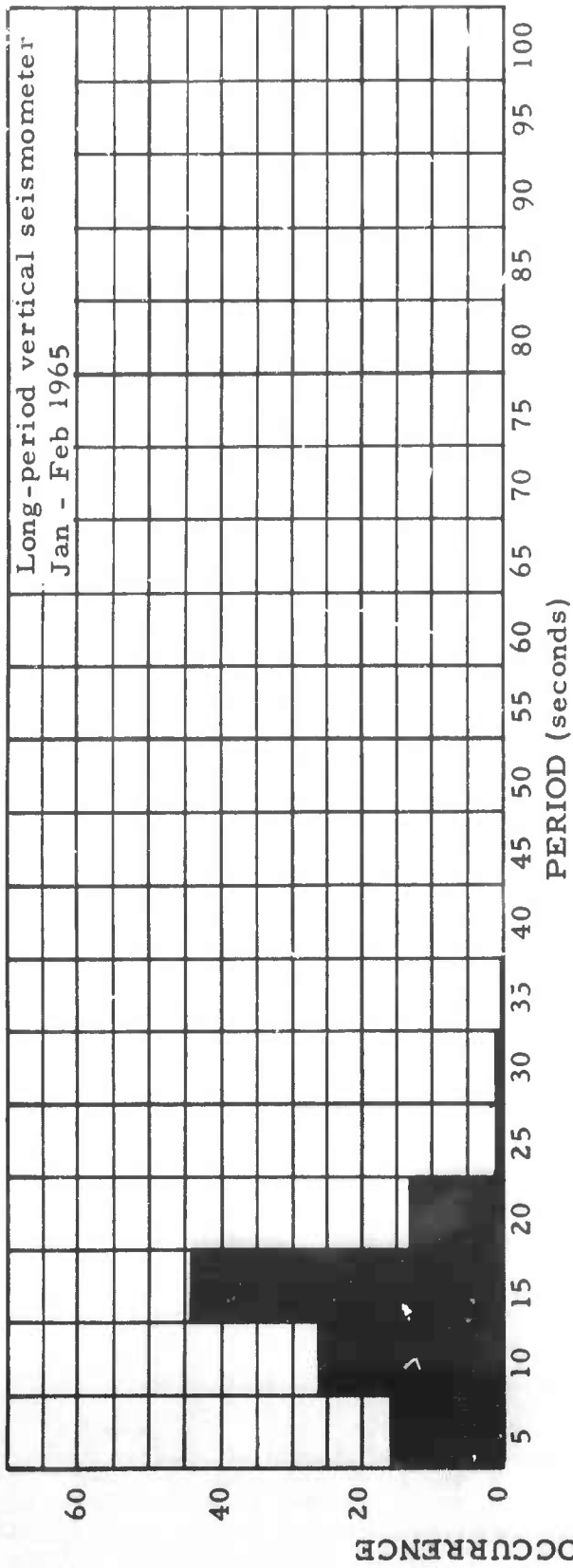
Noise spectrum curve, LRSM

APPENDIX 4 to TECHNICAL REPORT NC. 67-19

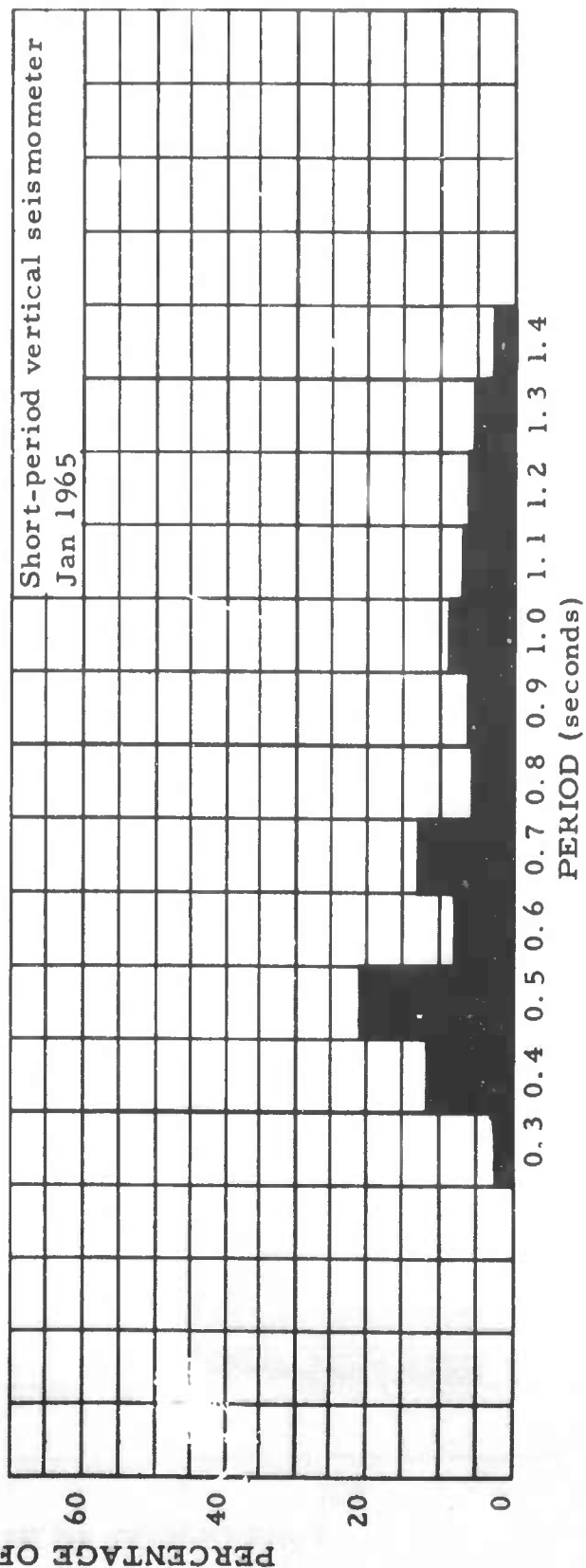
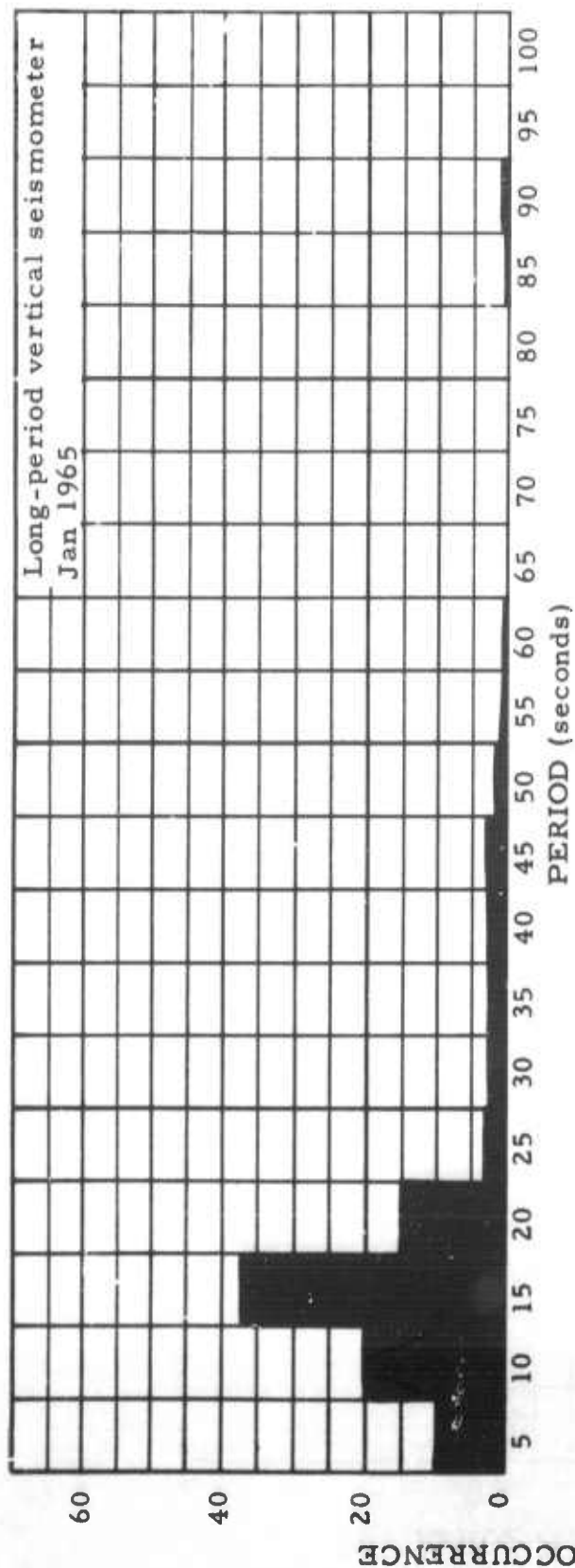
SHORT-PERIOD AND LONG-PERIOD SPECTRUM HISTOGRAMS



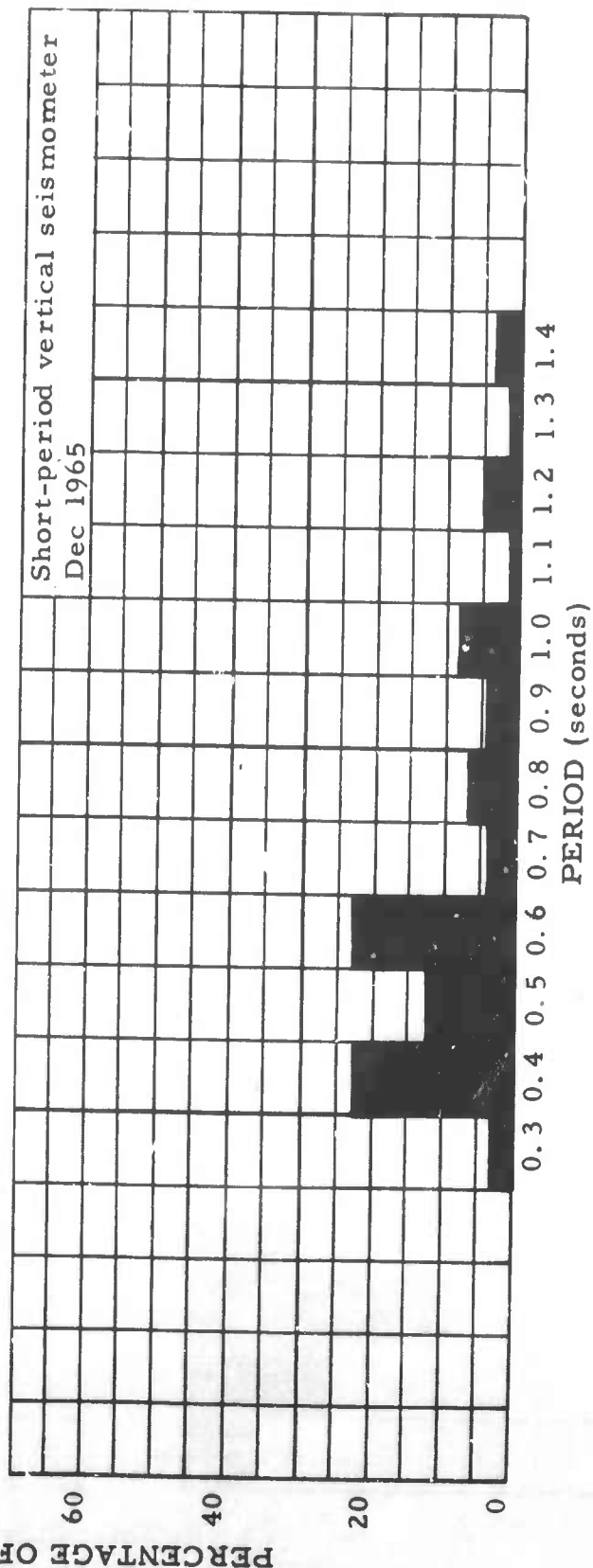
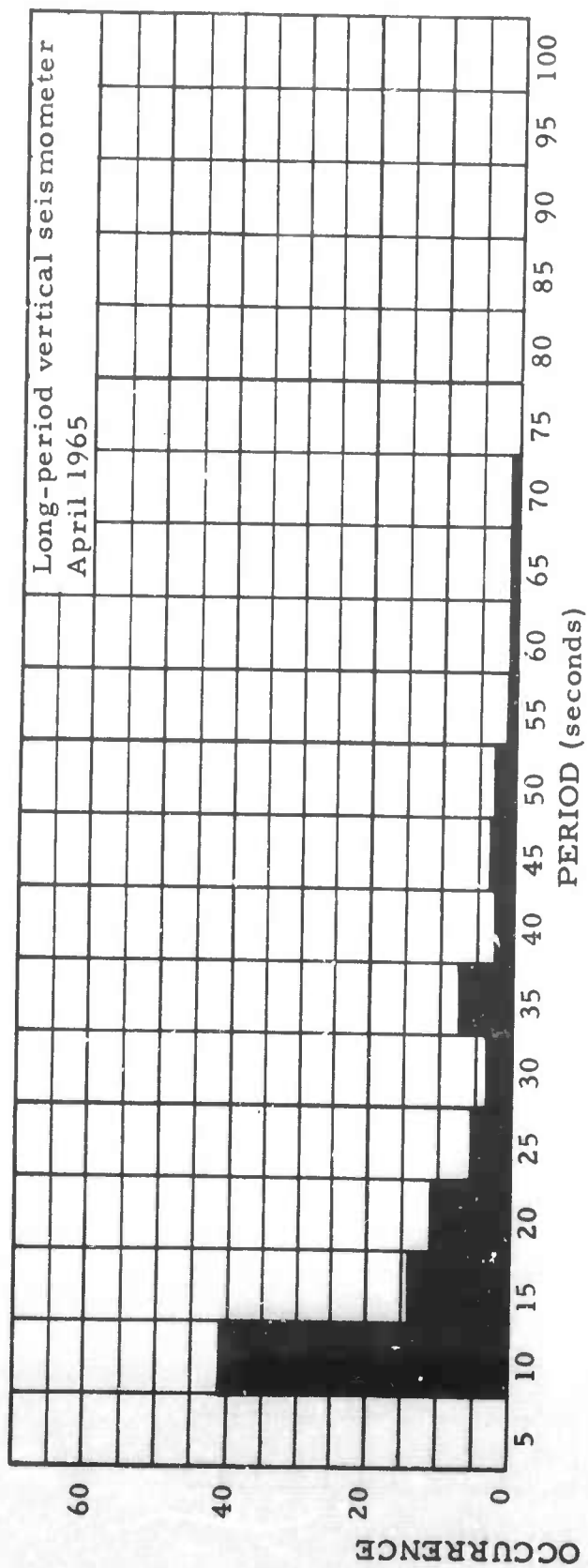
Percentage of occurrence for indicated periods for AD-IS



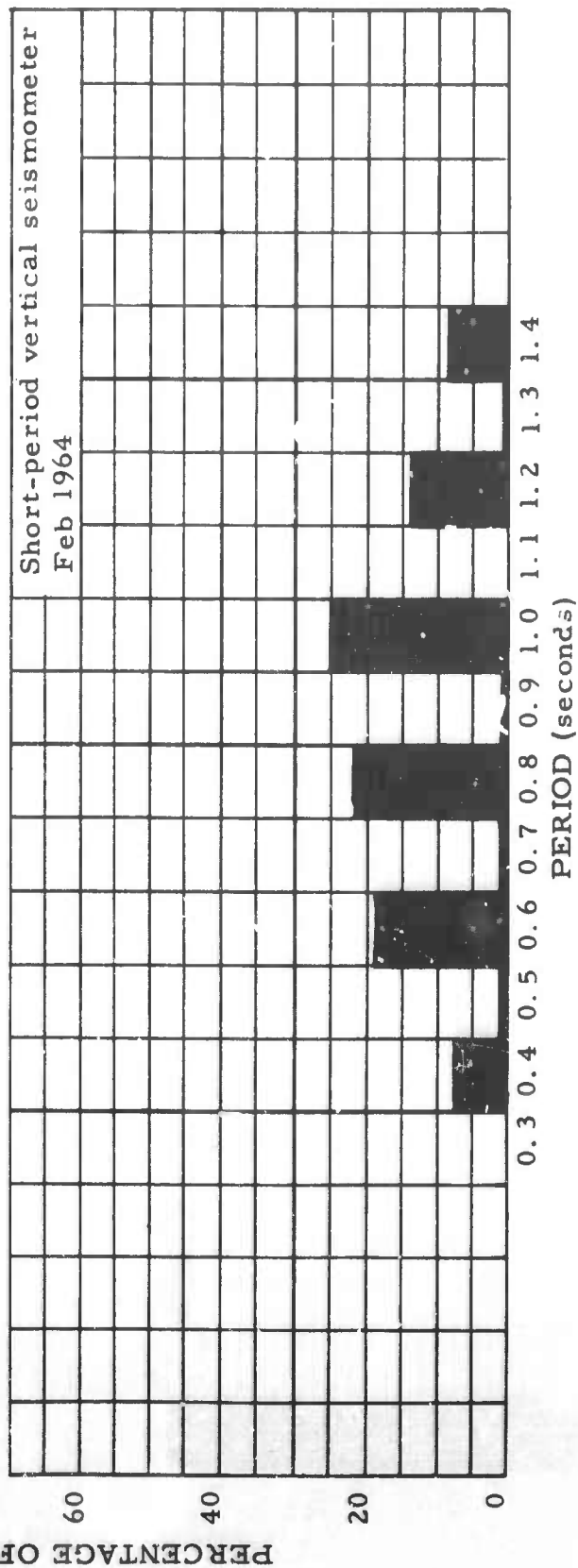
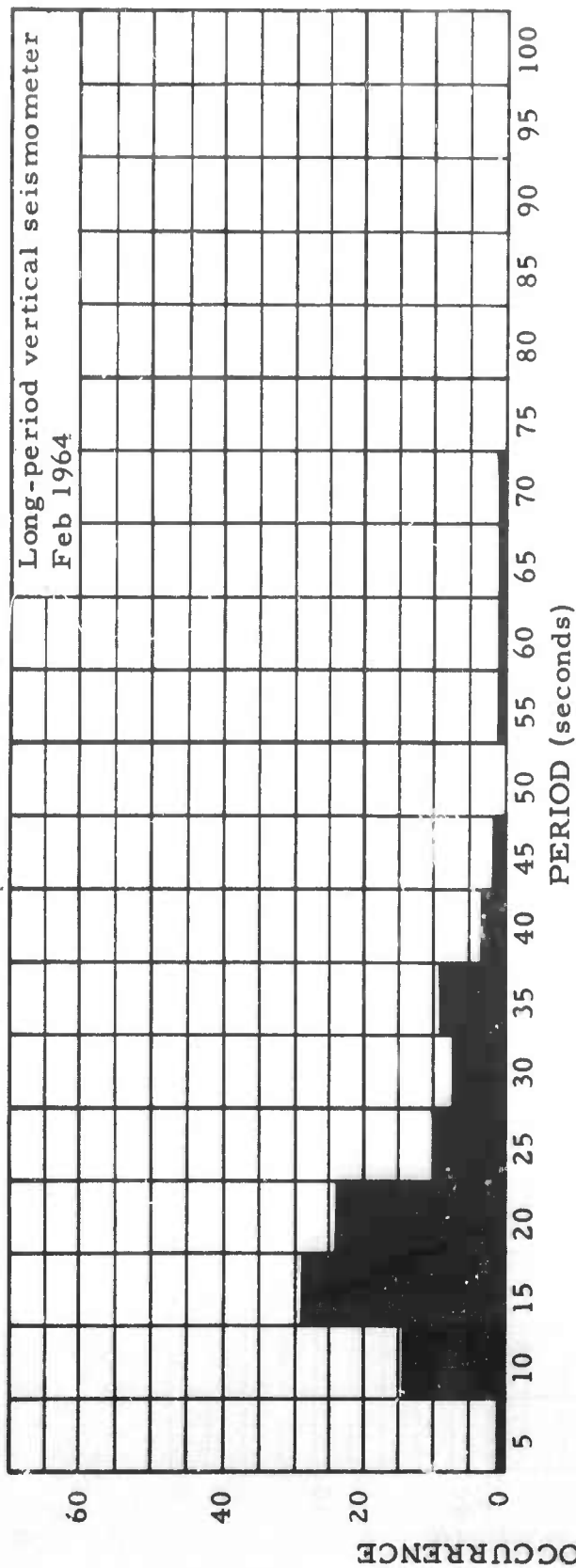
Percentage of occurrence for indicated periods for HY-MA



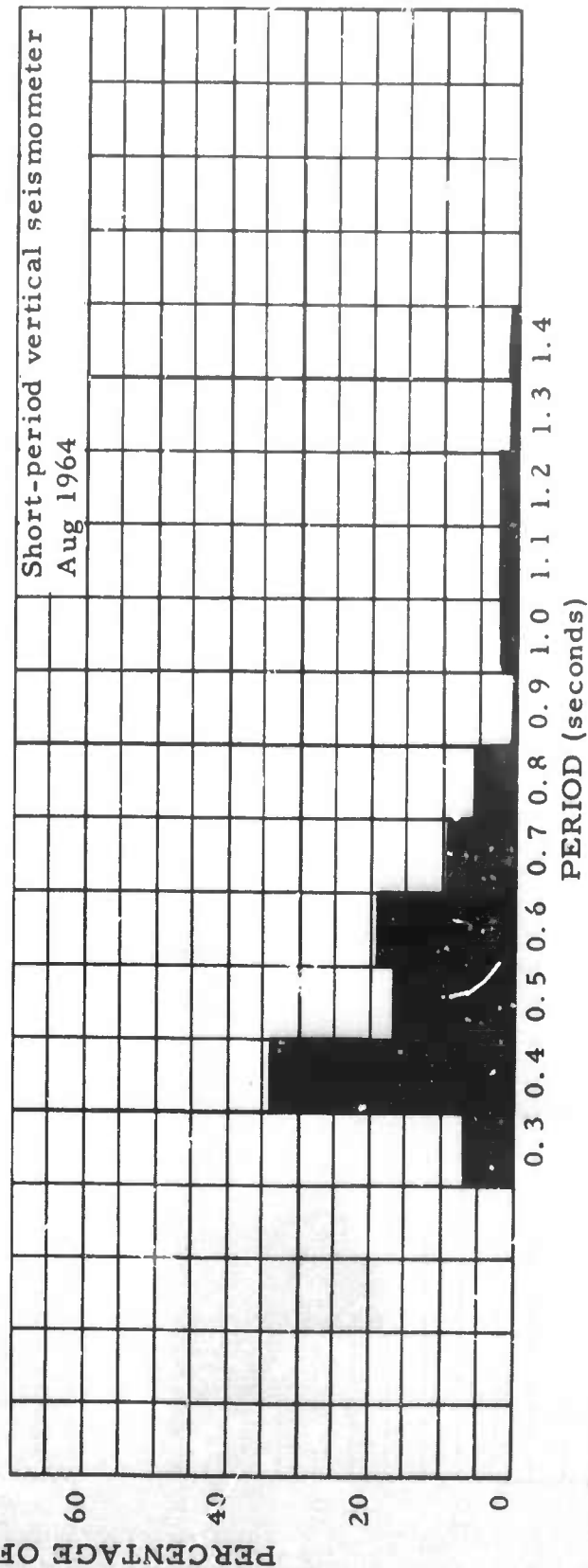
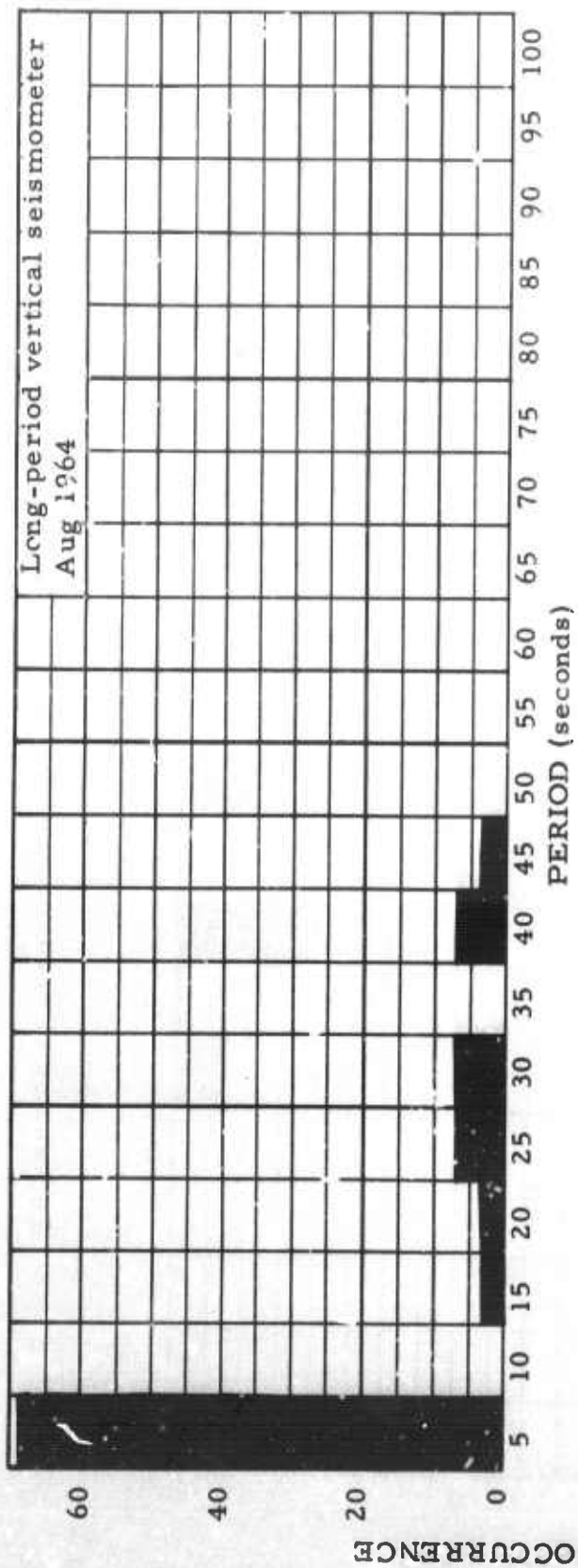
Percentage of occurrence for indicated periods for AN-MA



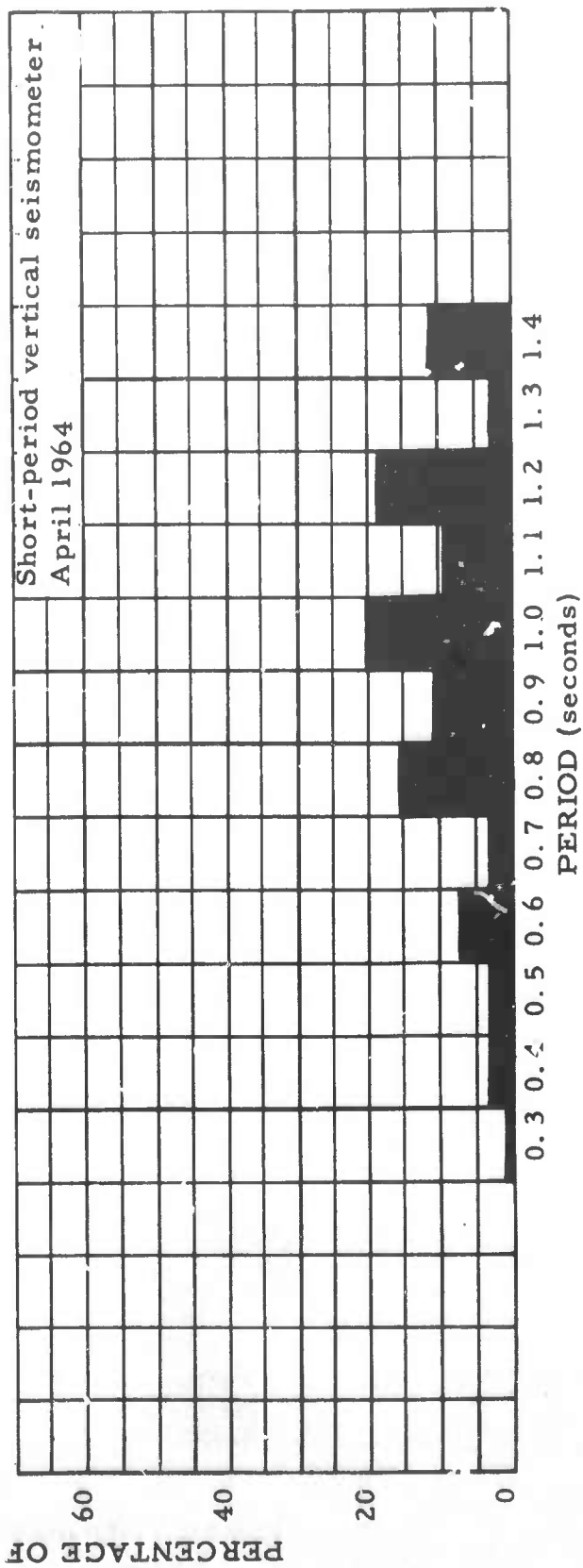
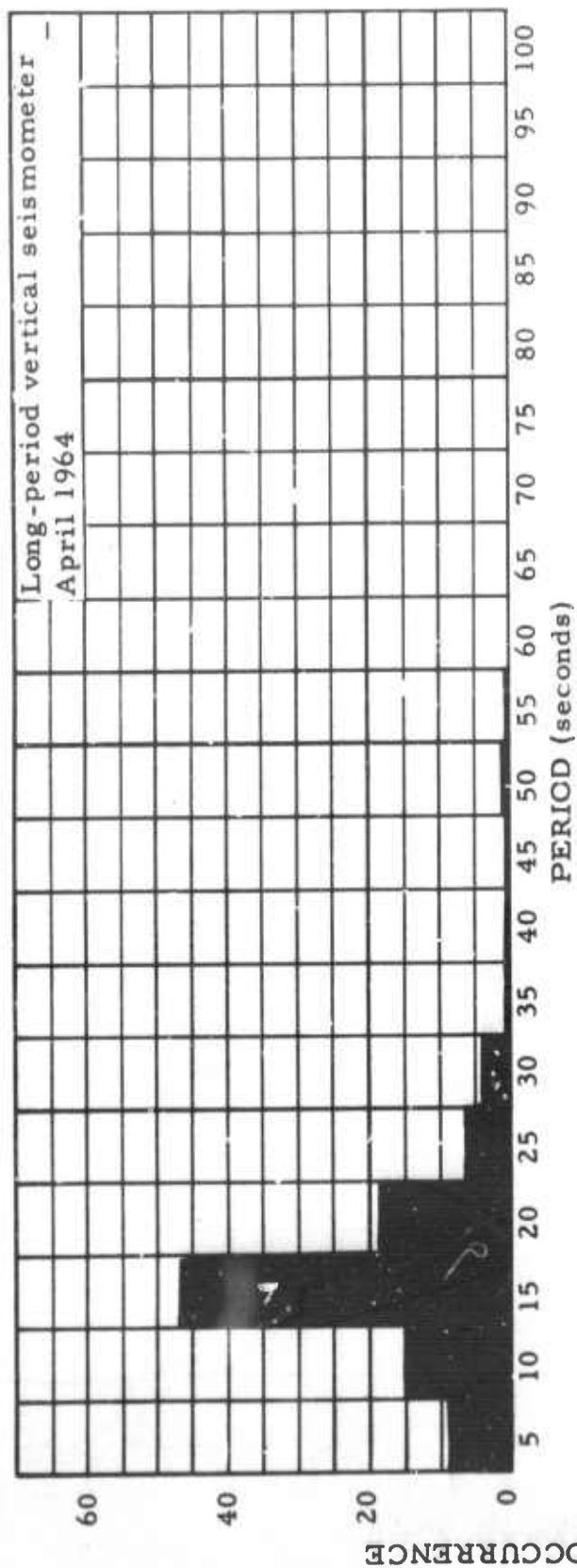
Percentage of occurrence for indicated periods for HL2ID



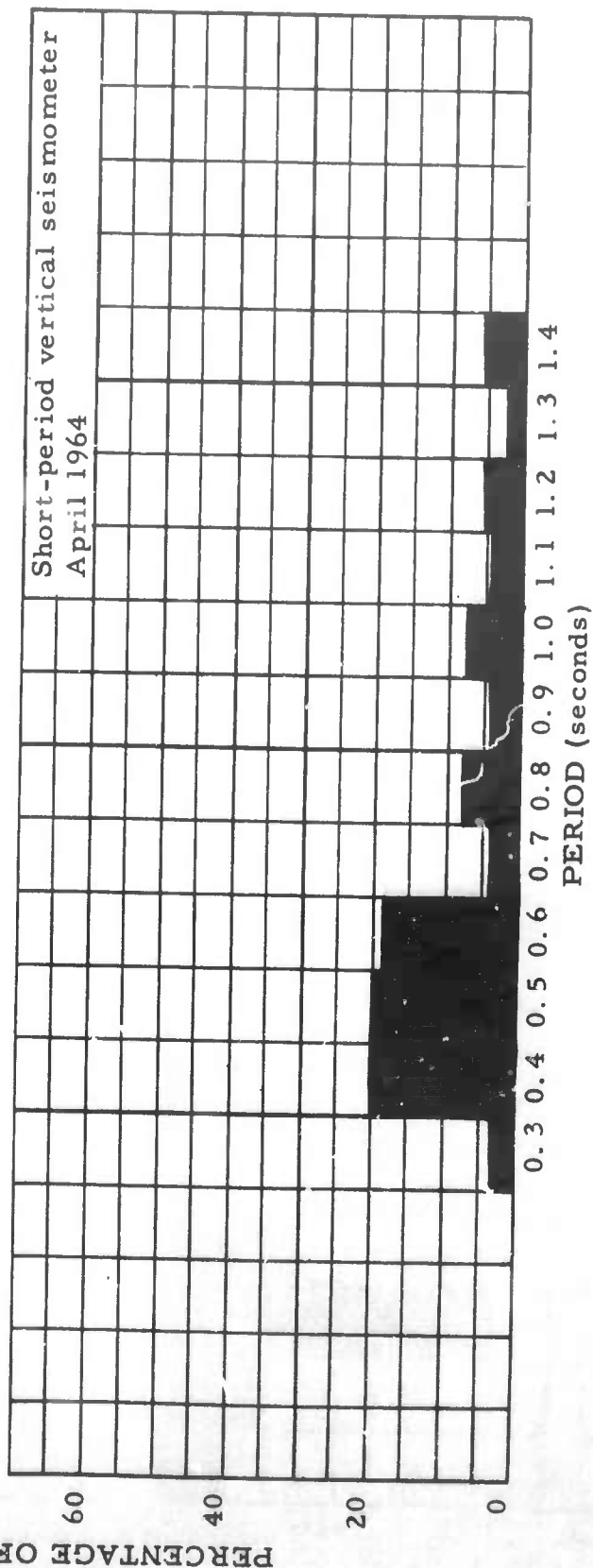
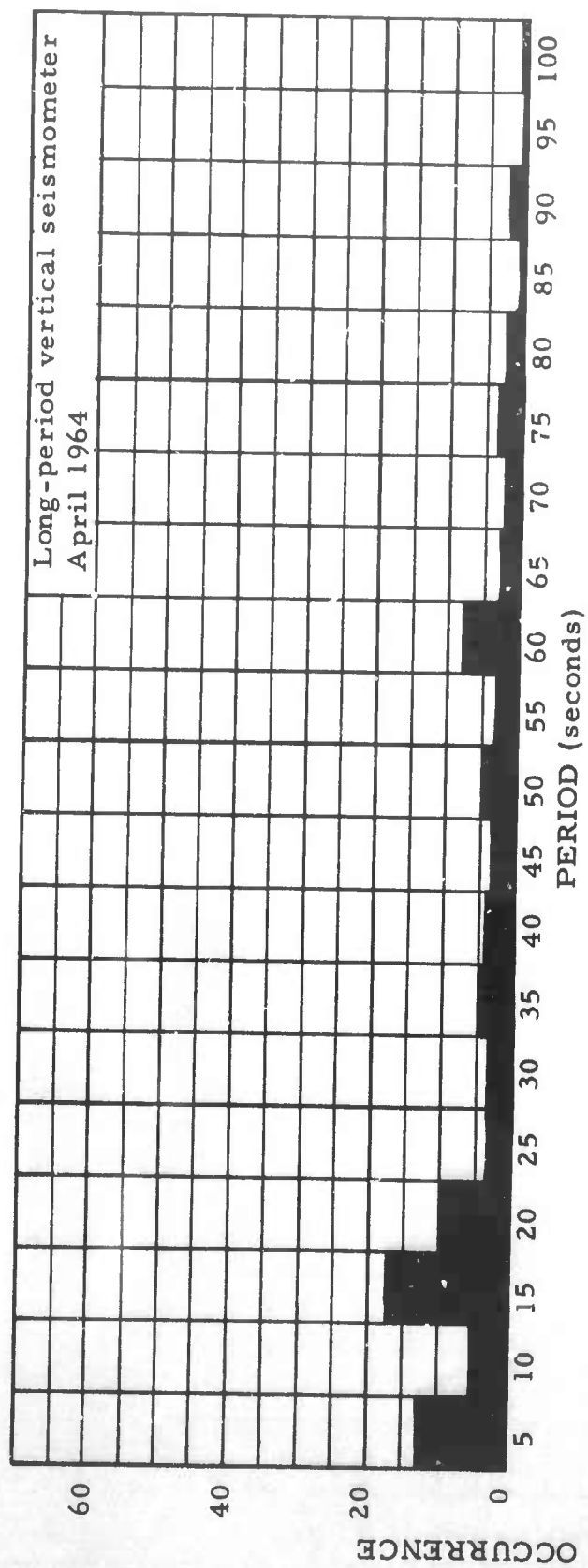
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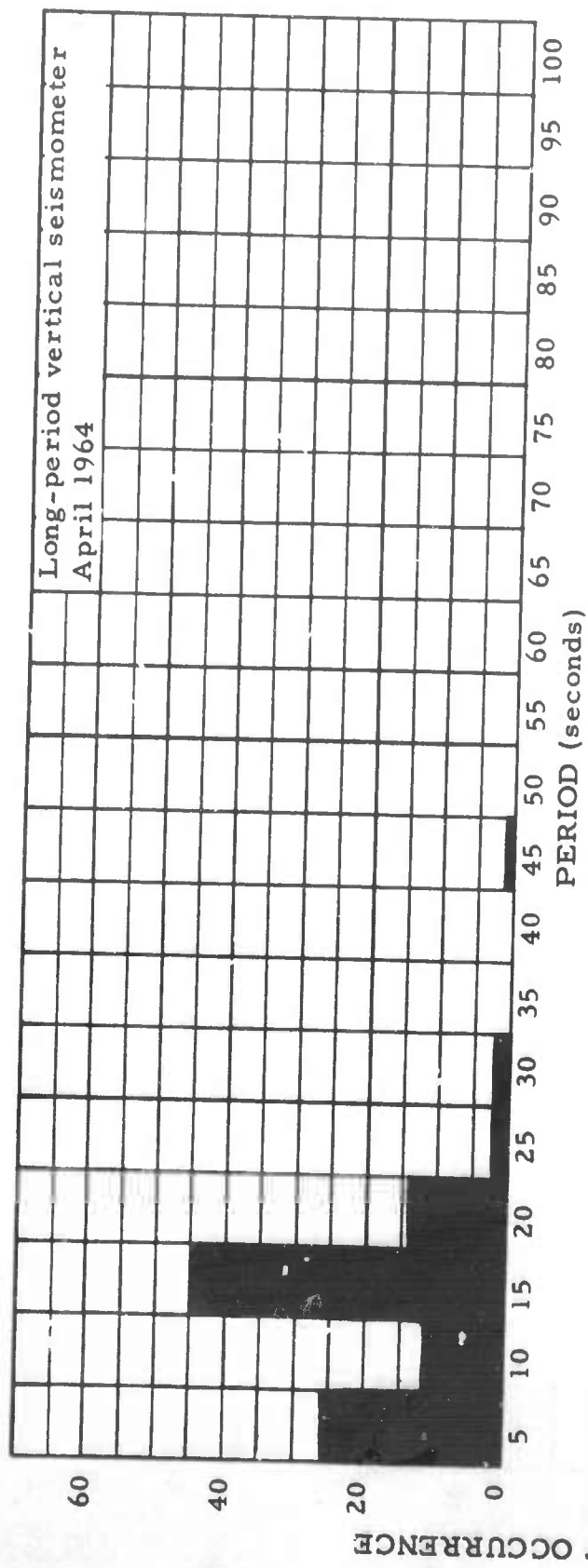
Percentage of occurrence for indicated periods for GE-AZ



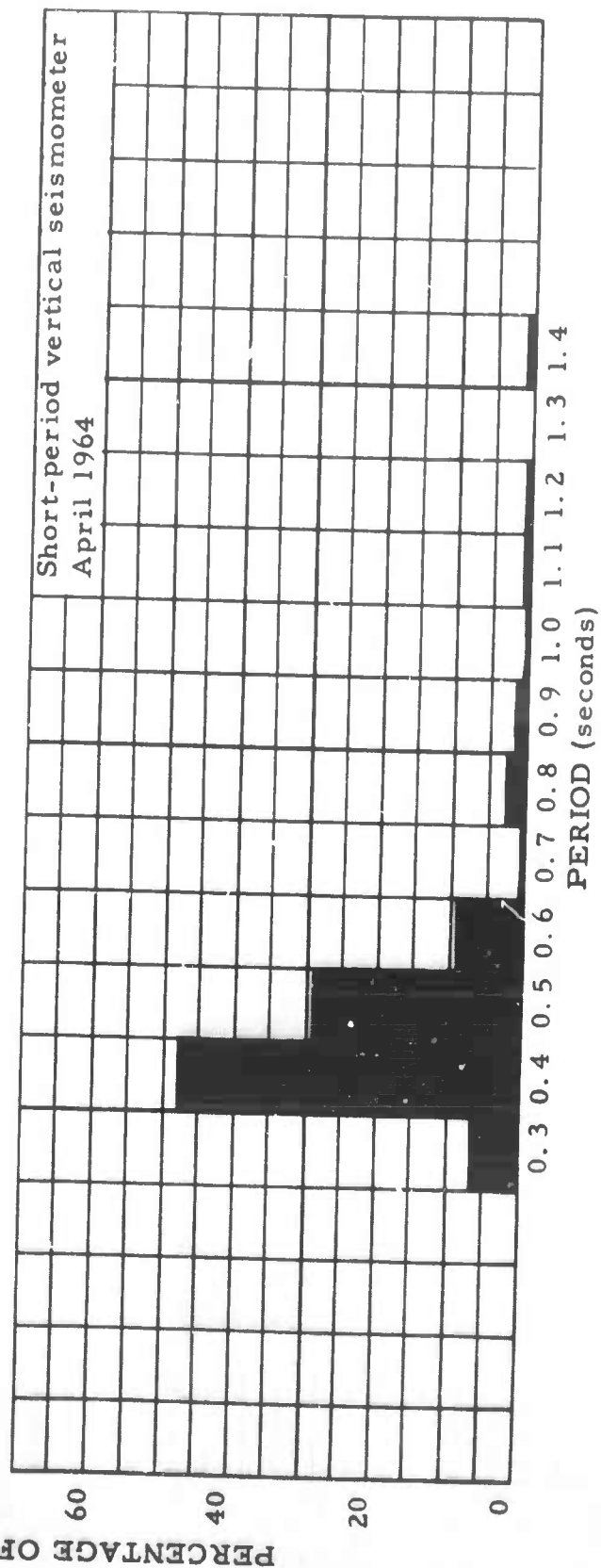
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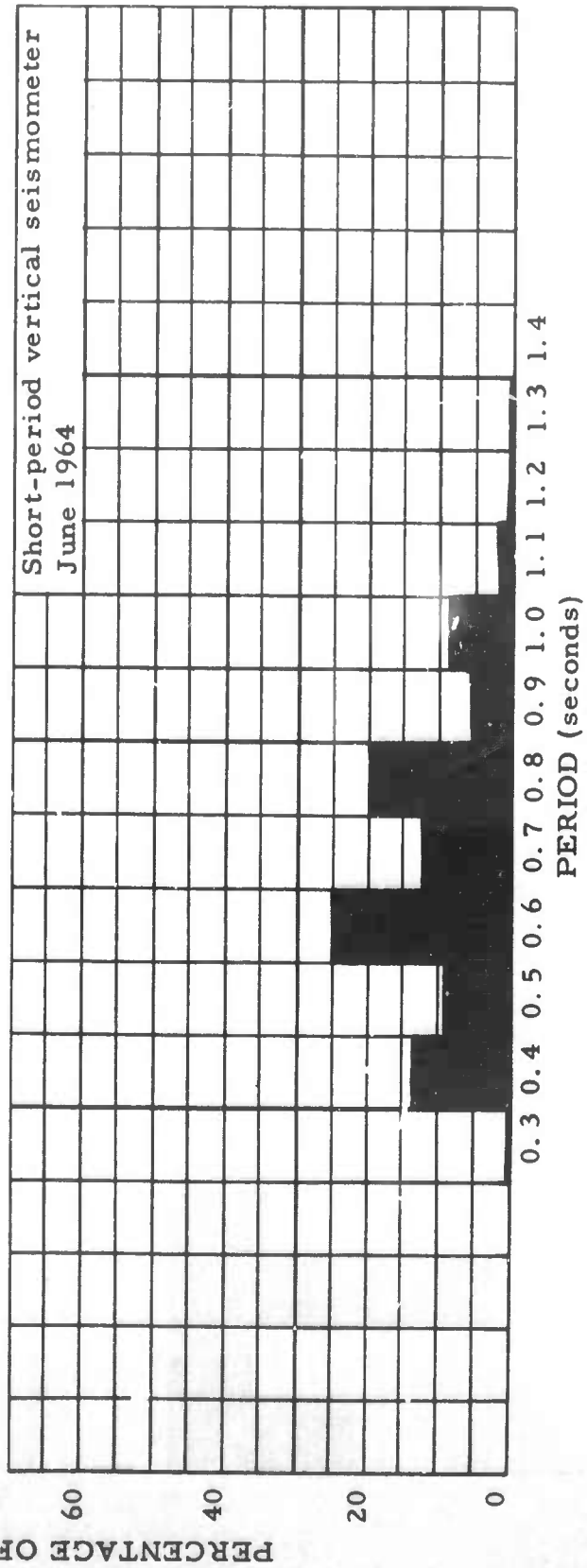
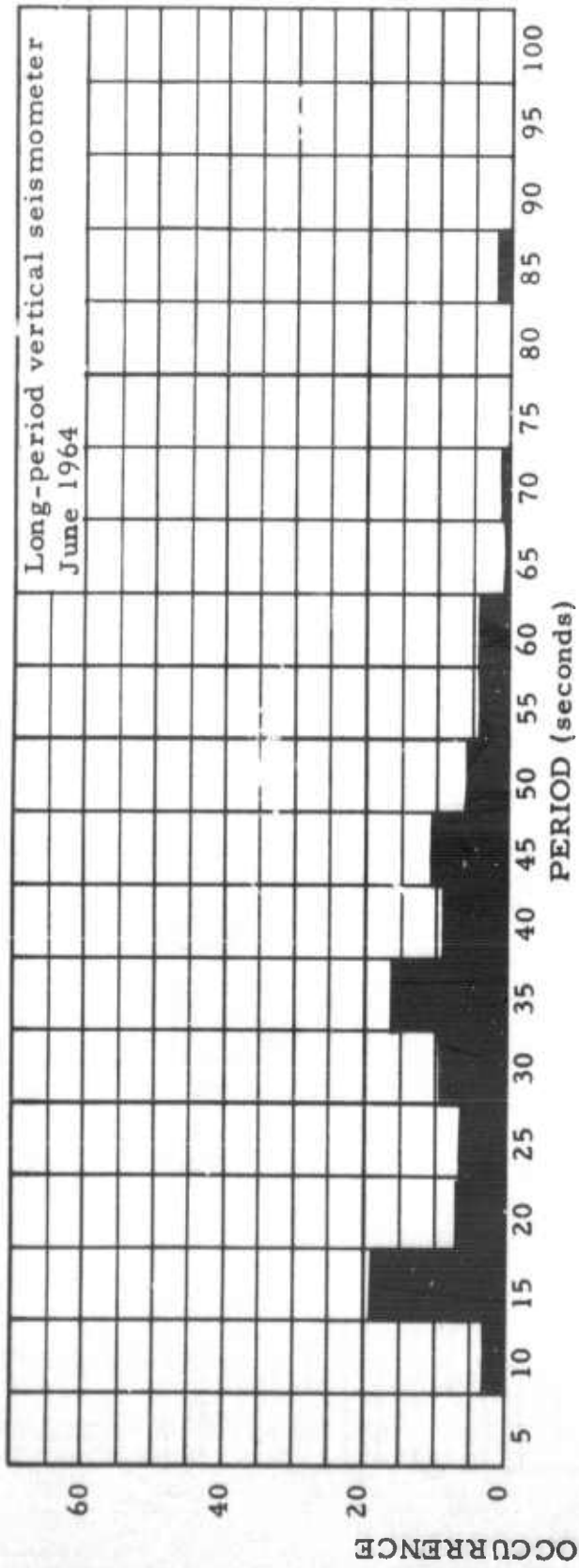
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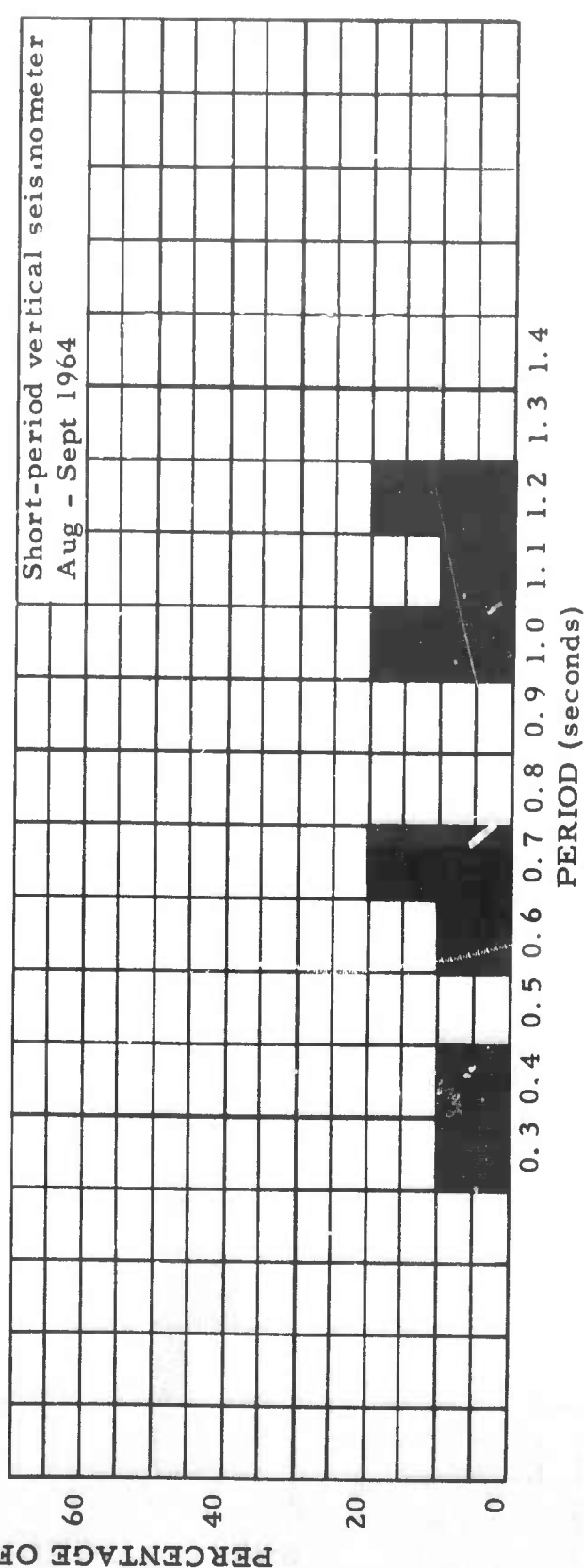
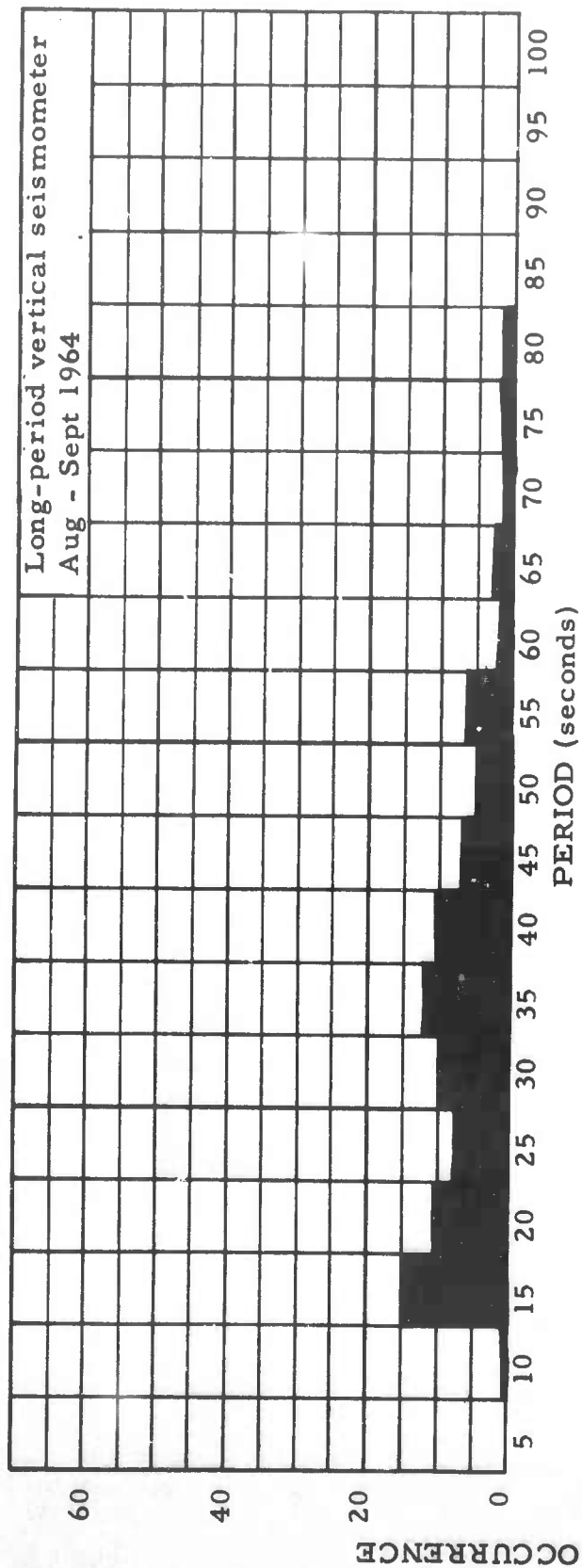
-9-



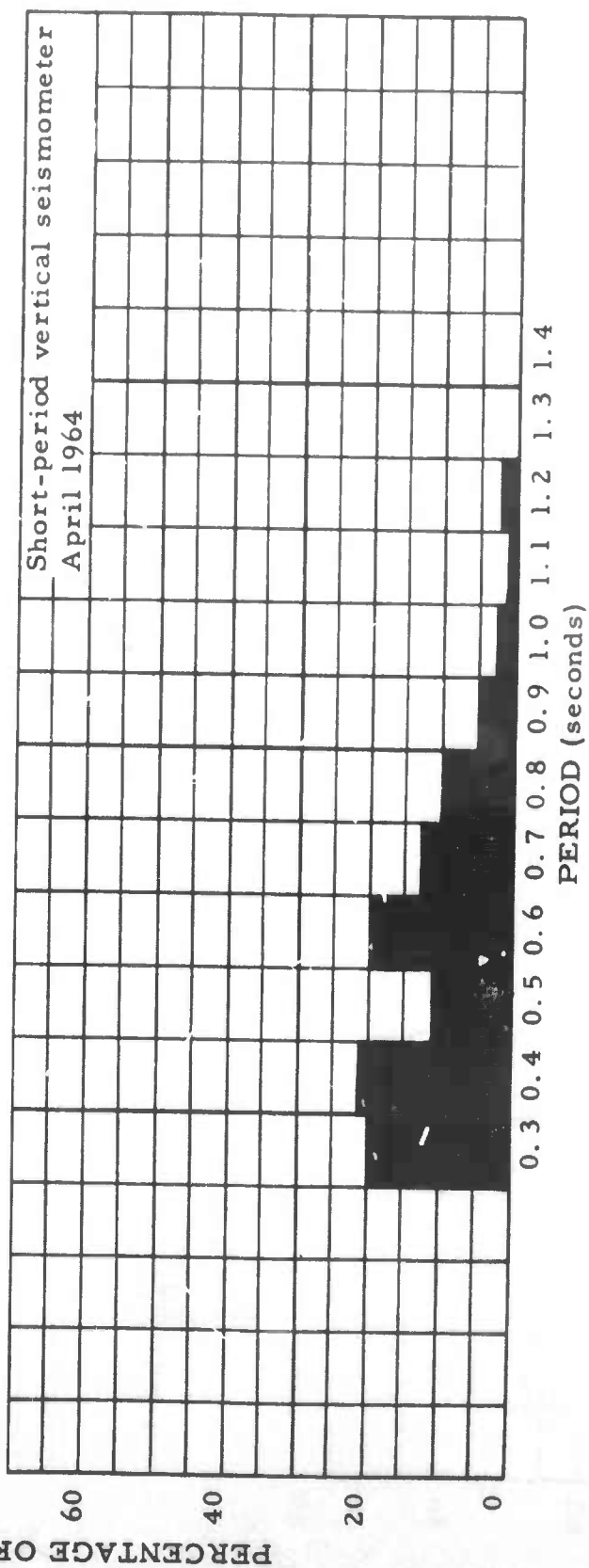
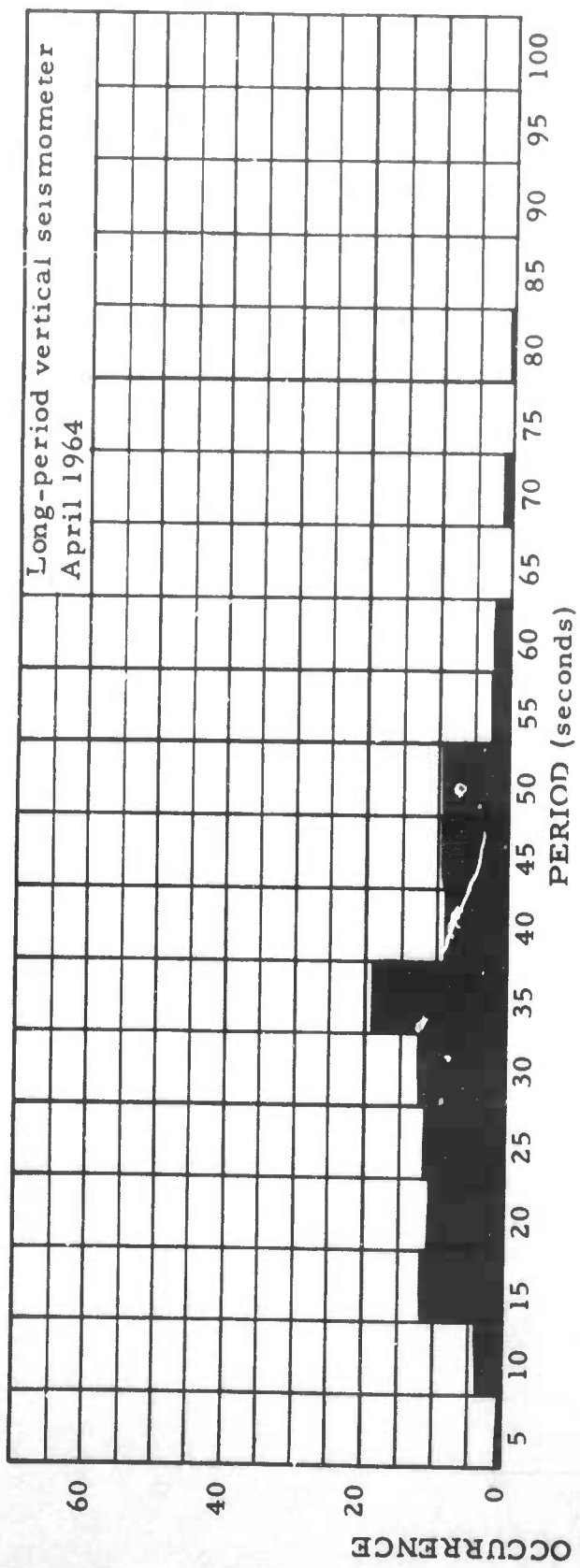
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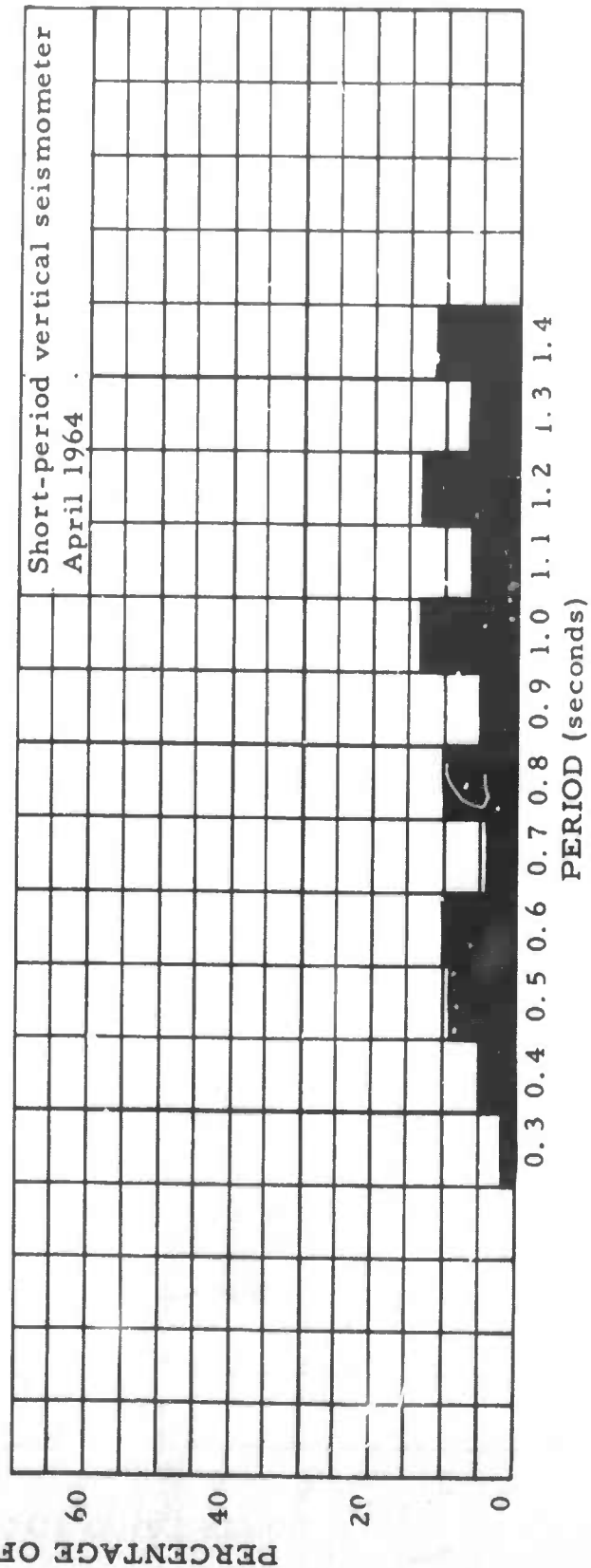
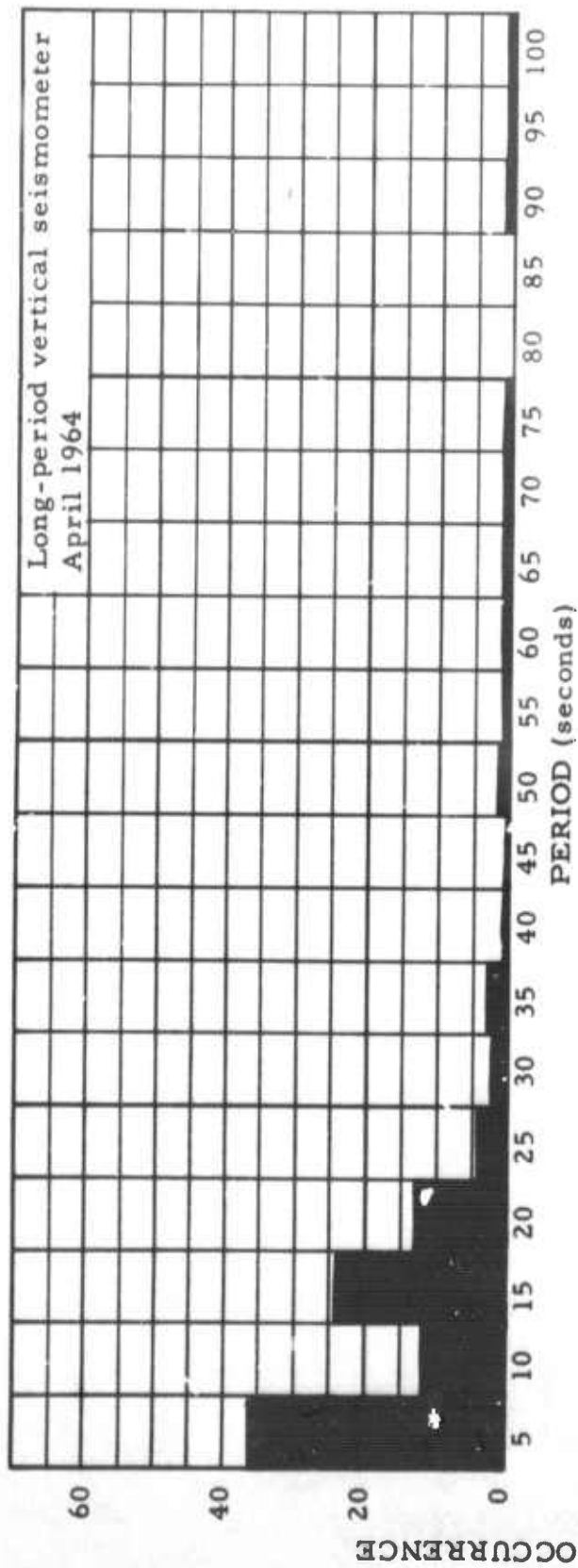
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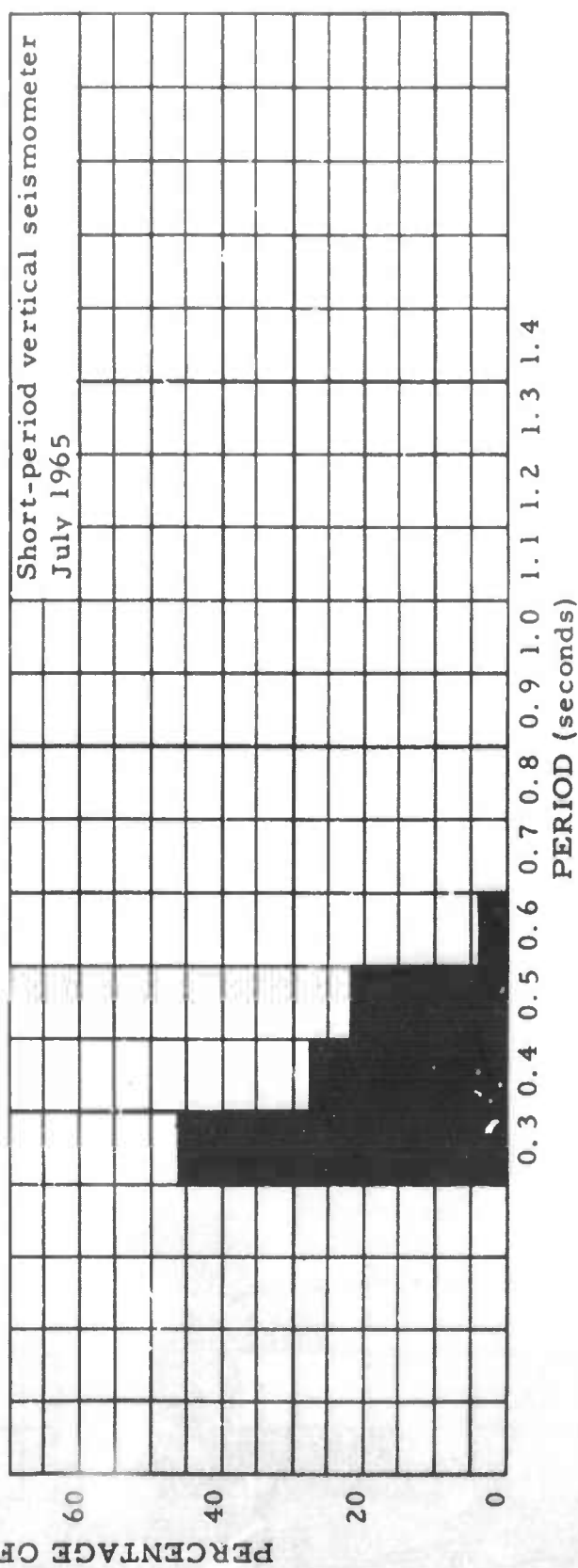
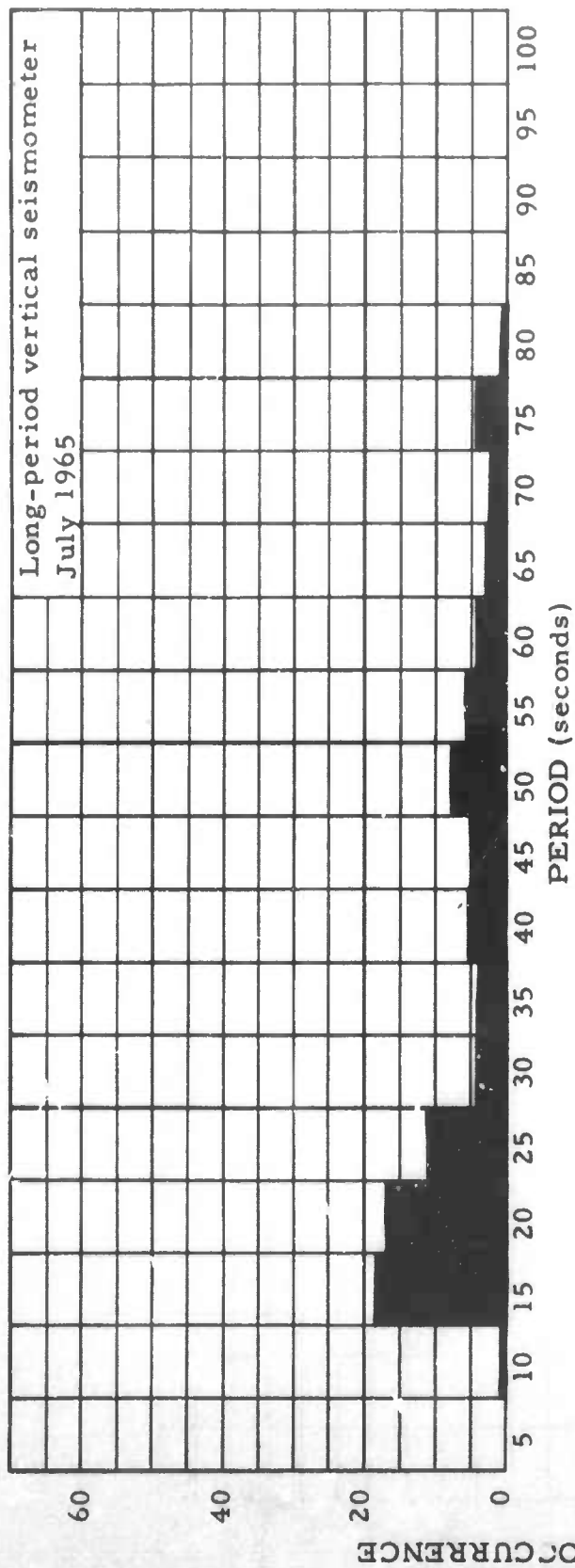
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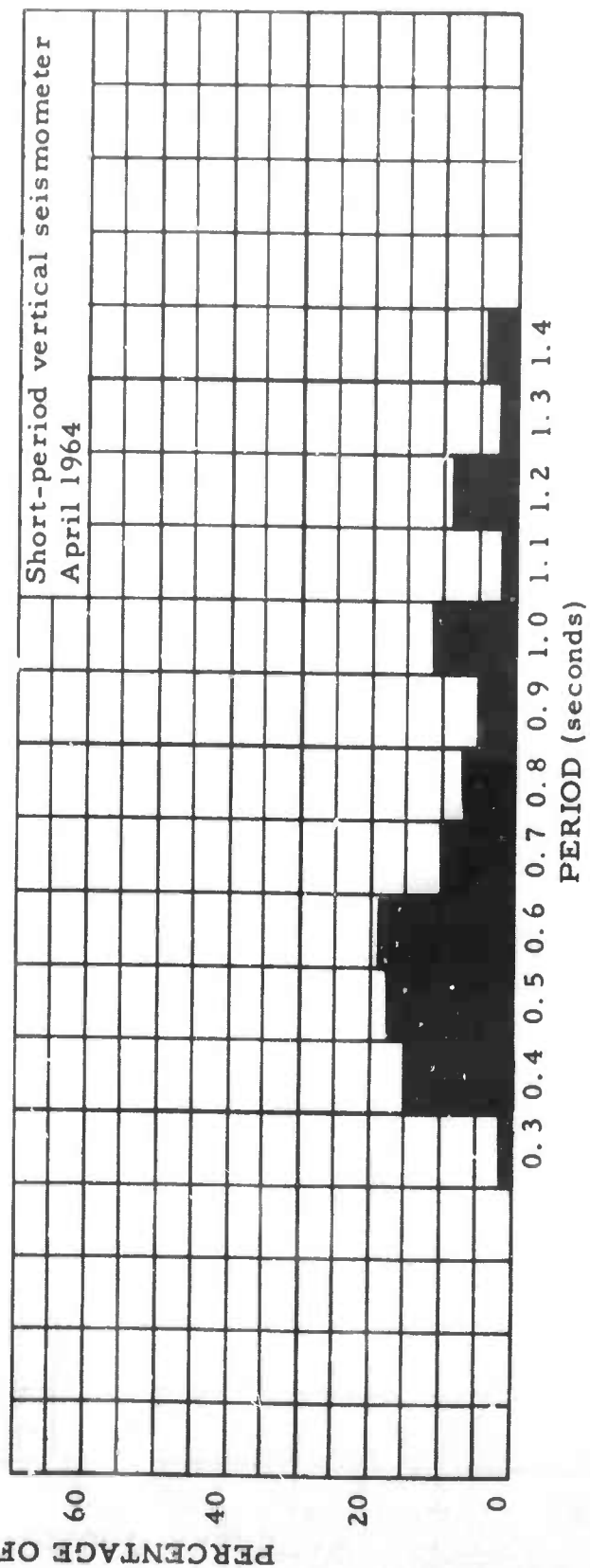
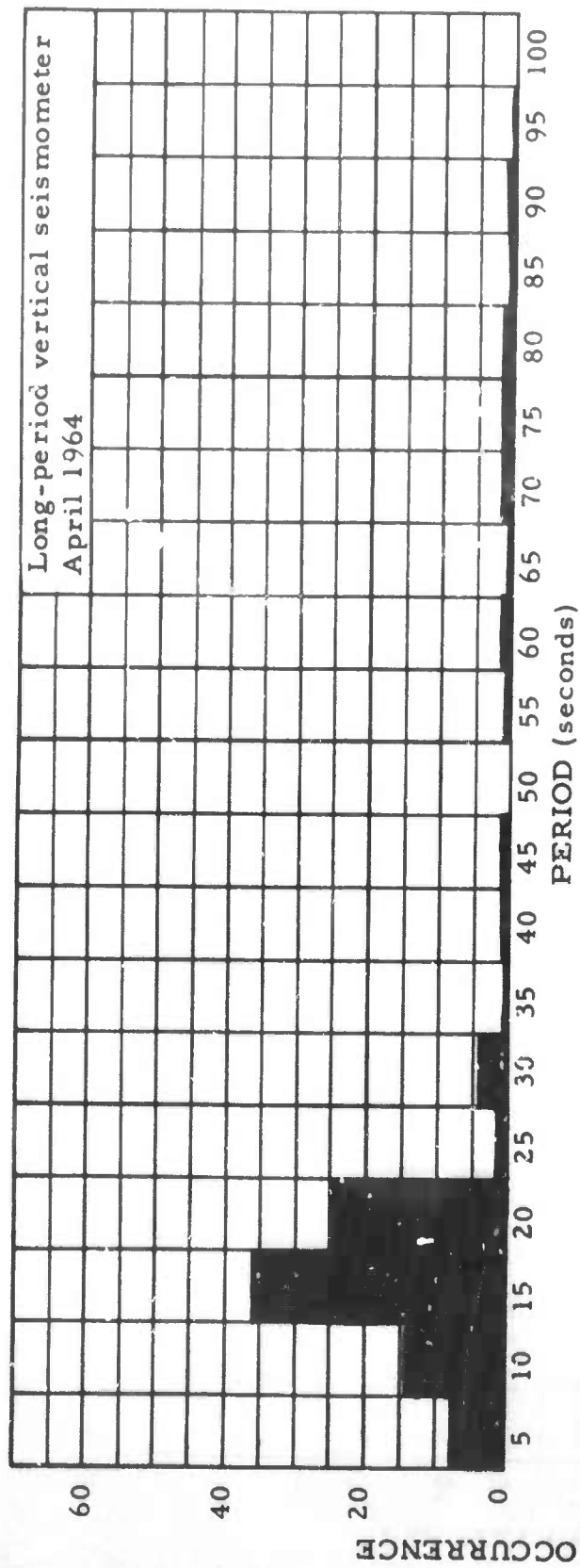
Percentage of occurrence for indicated periods for NL-AZ



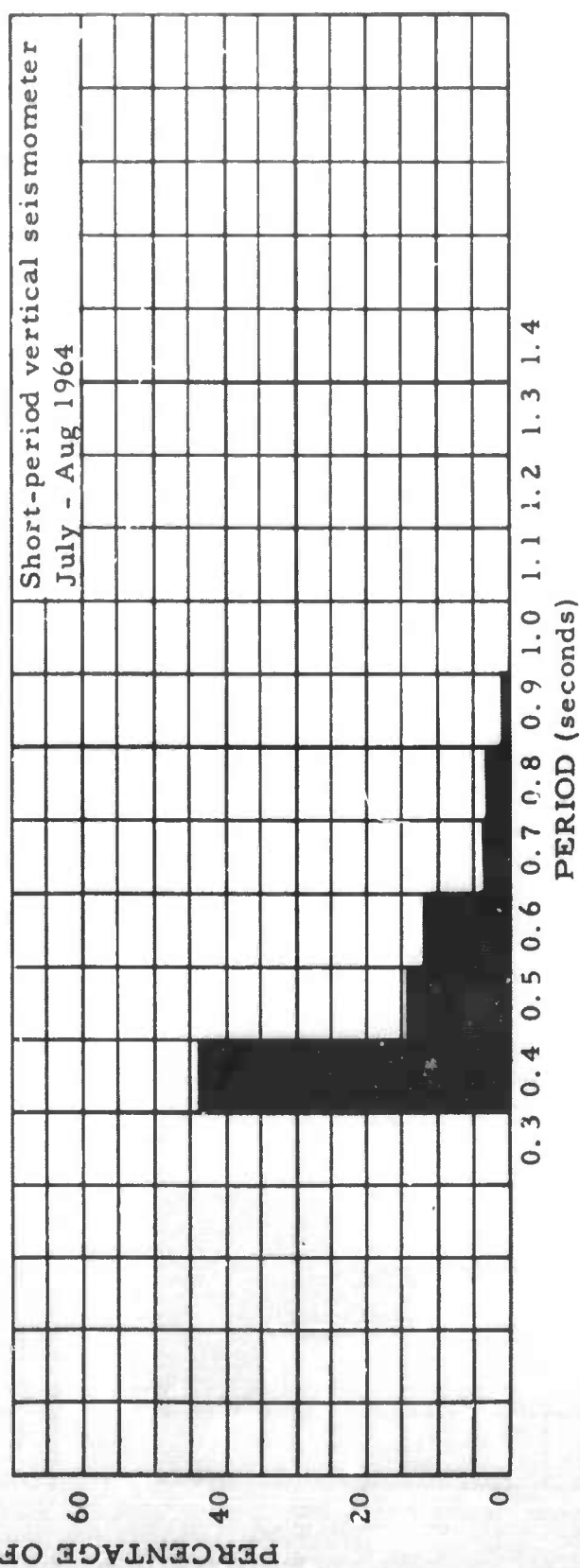
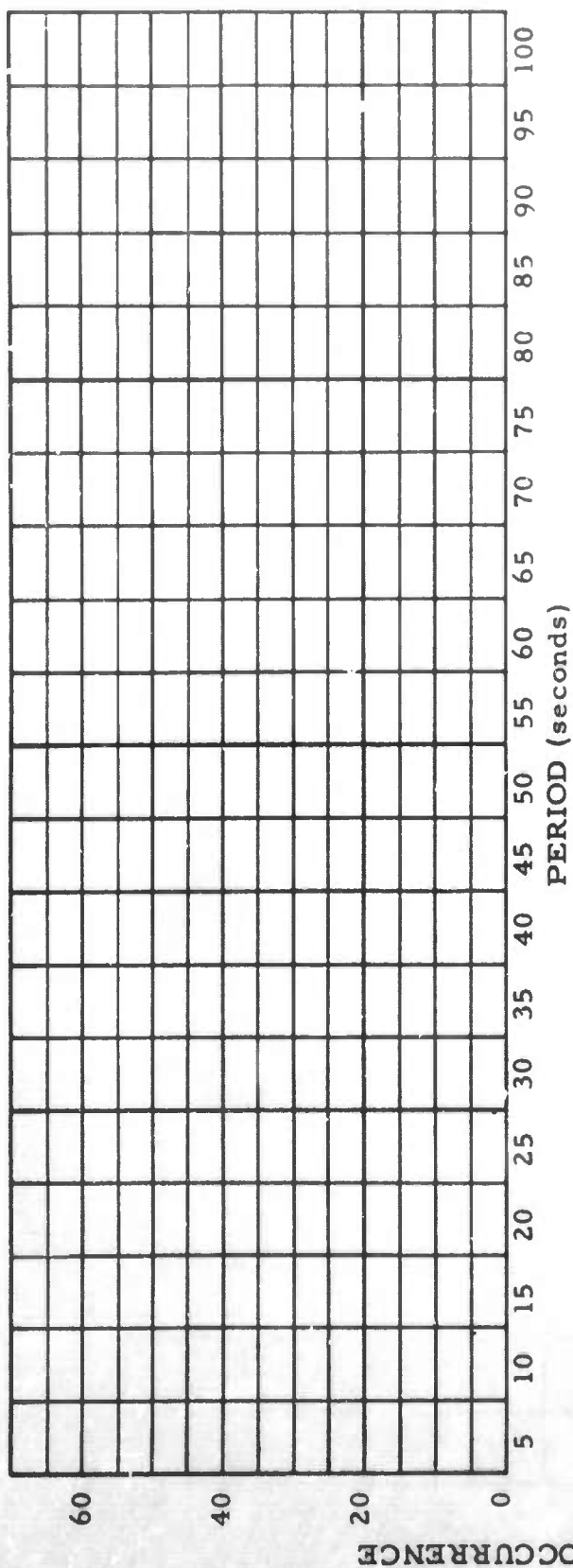
Percentage of occurrence for indicated periods for SN-AZ



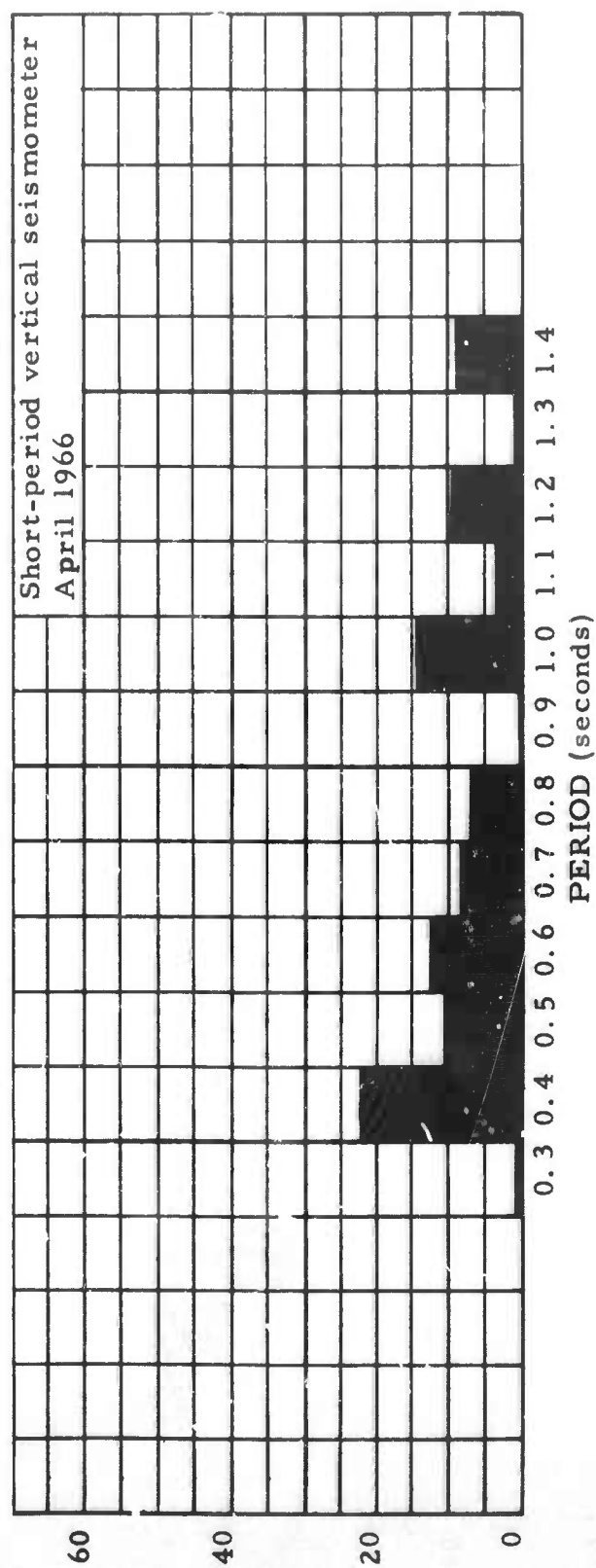
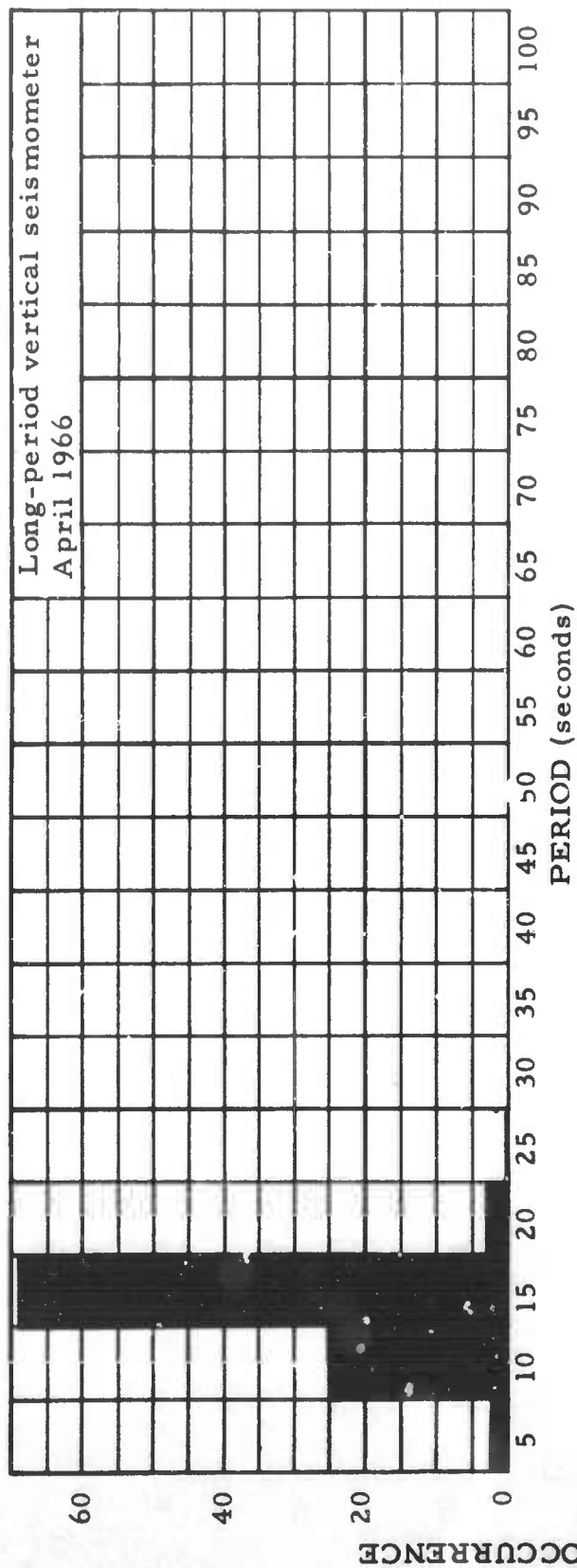
Percentage of occurrence for indicated periods for JR-AZ



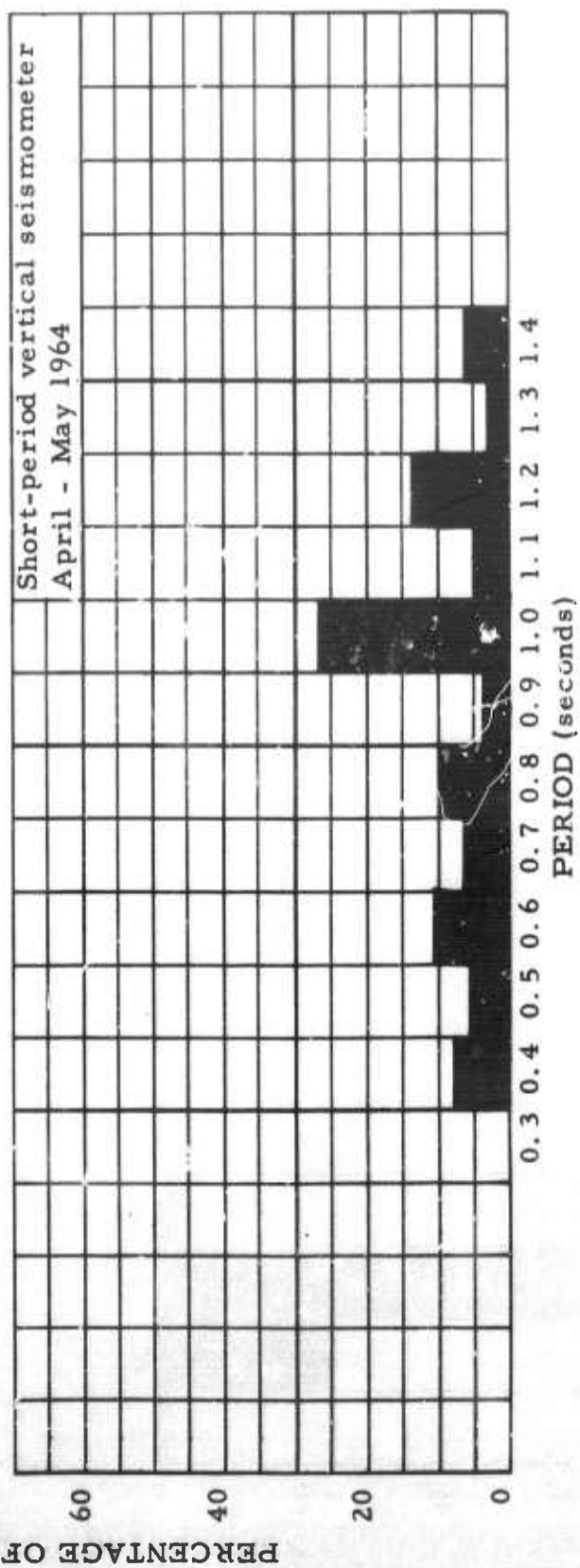
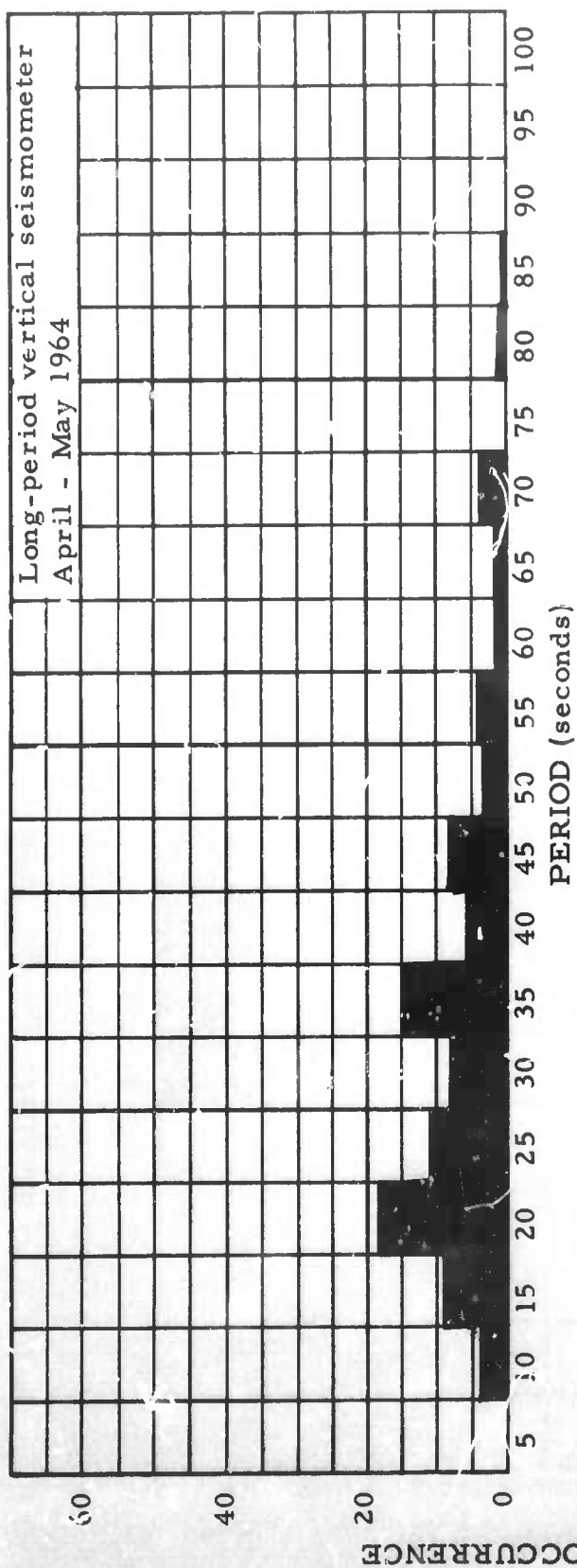
Percentage of occurrence for indicated periods for SG-AZ



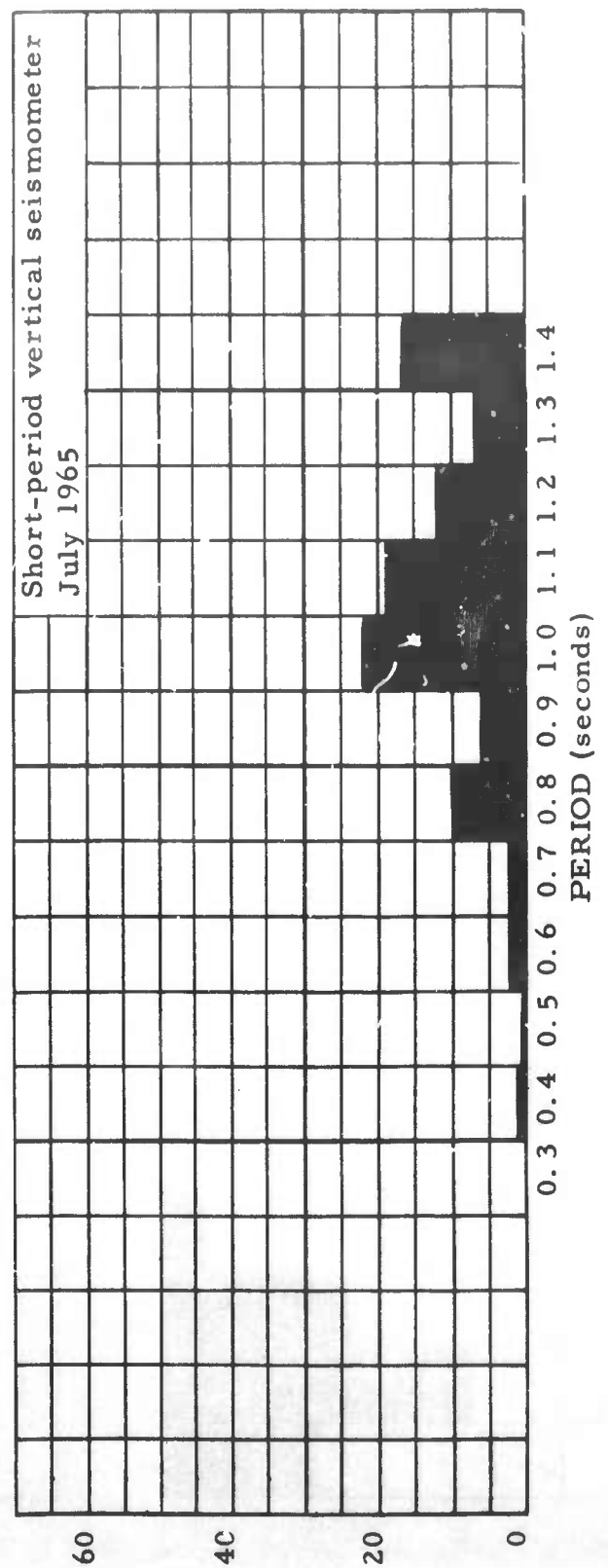
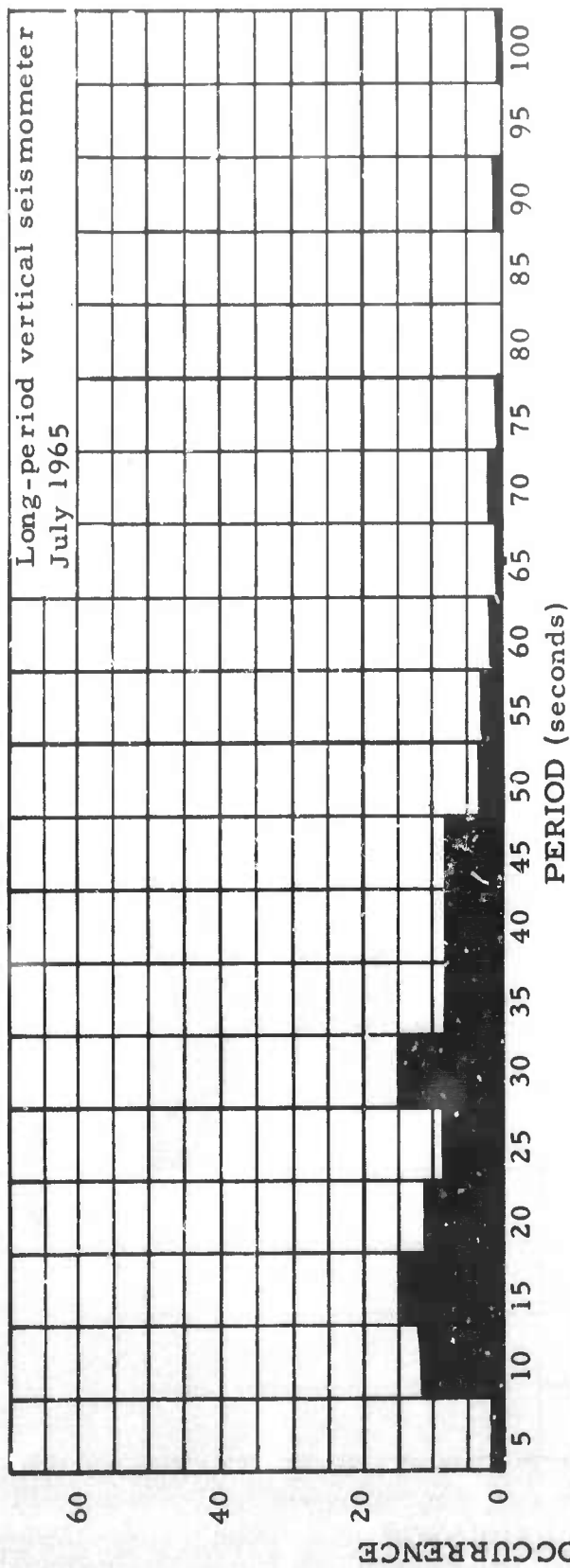
Percentage of occurrence for indicated periods for FO-TX



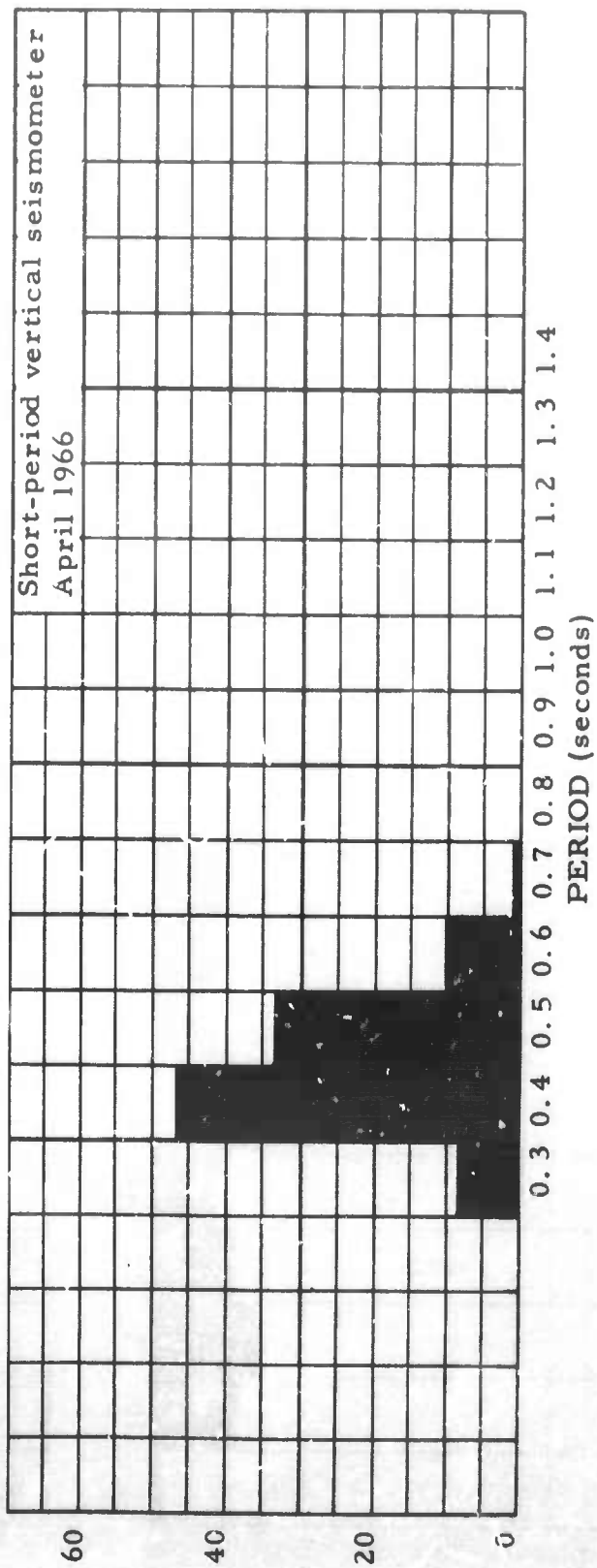
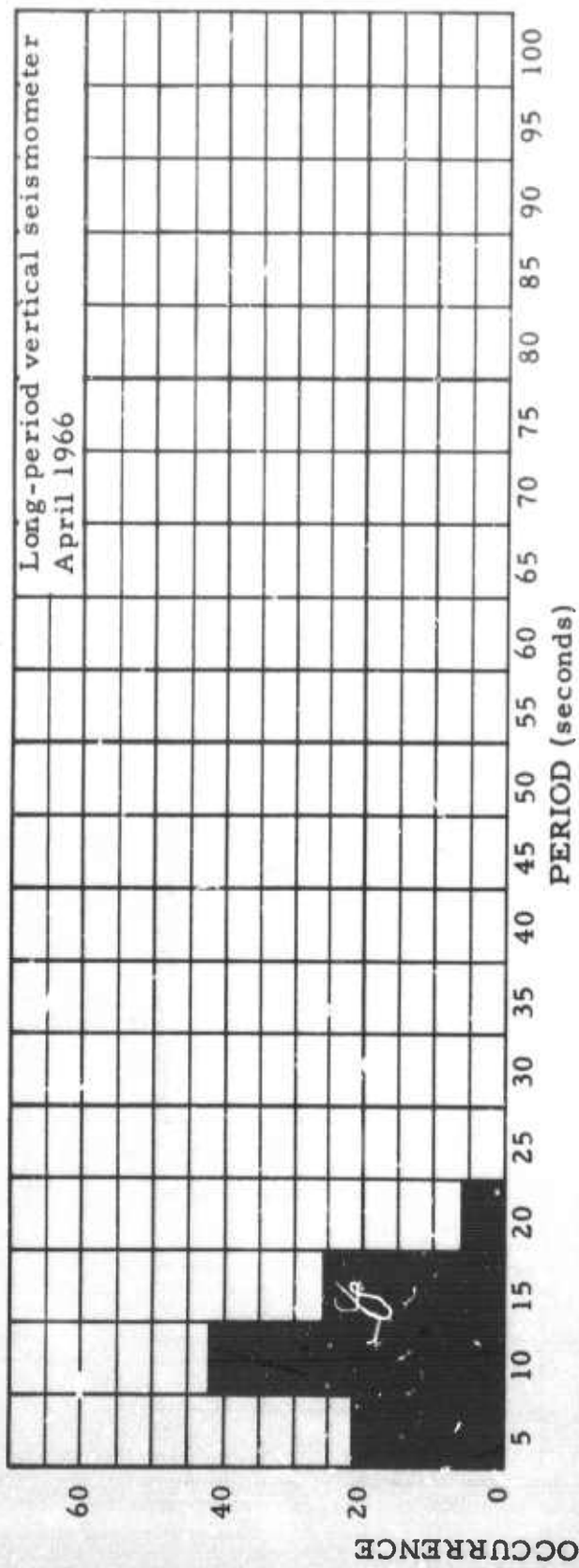
Percentage of occurrence for indicated periods for AX2AL



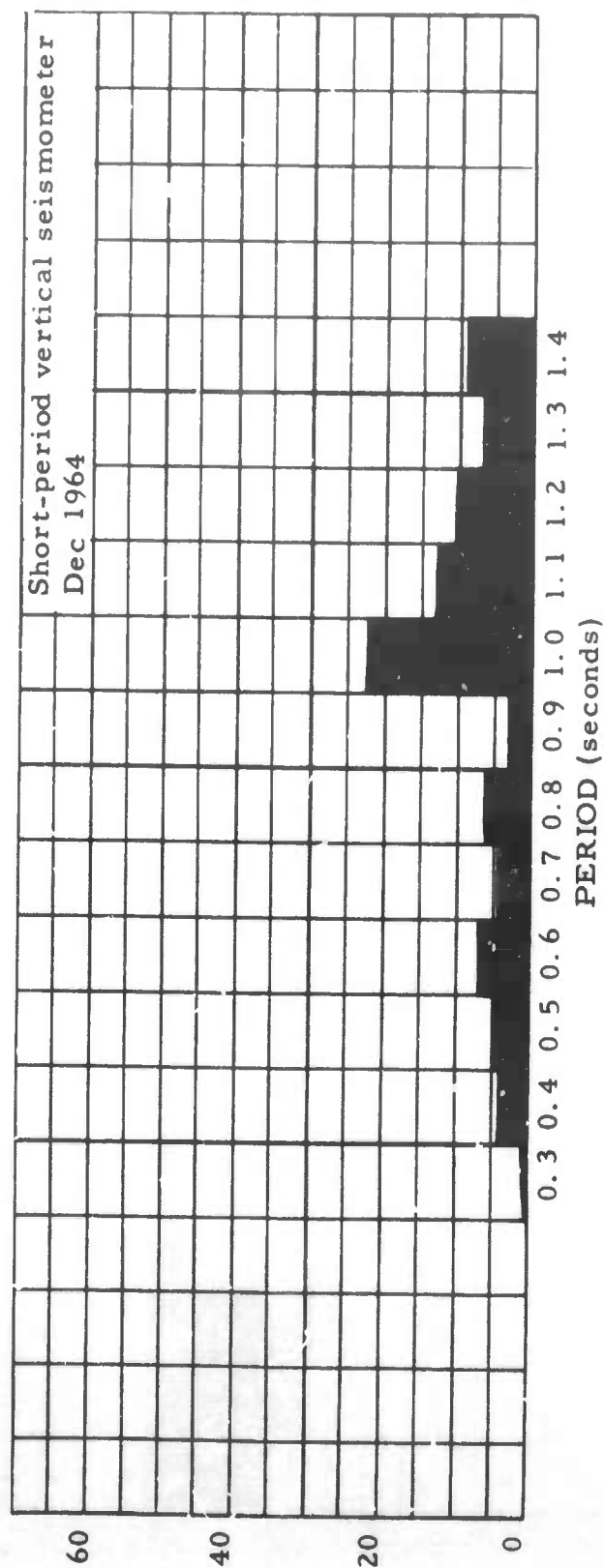
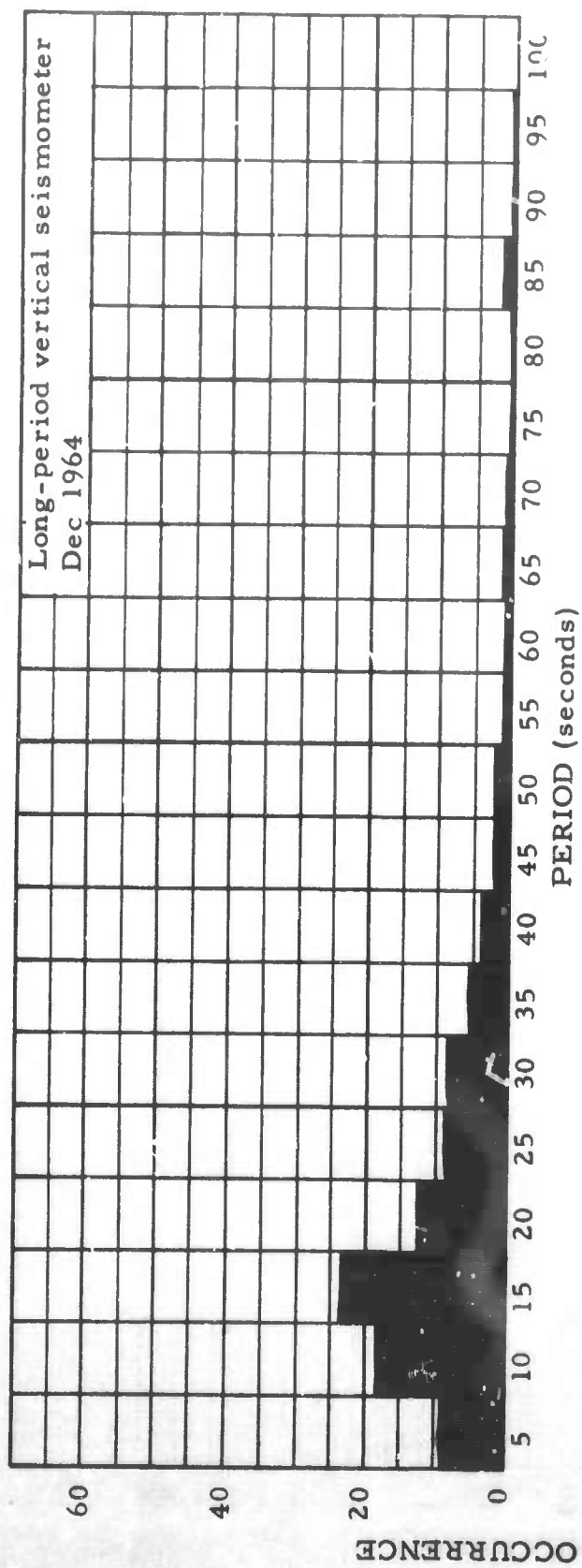
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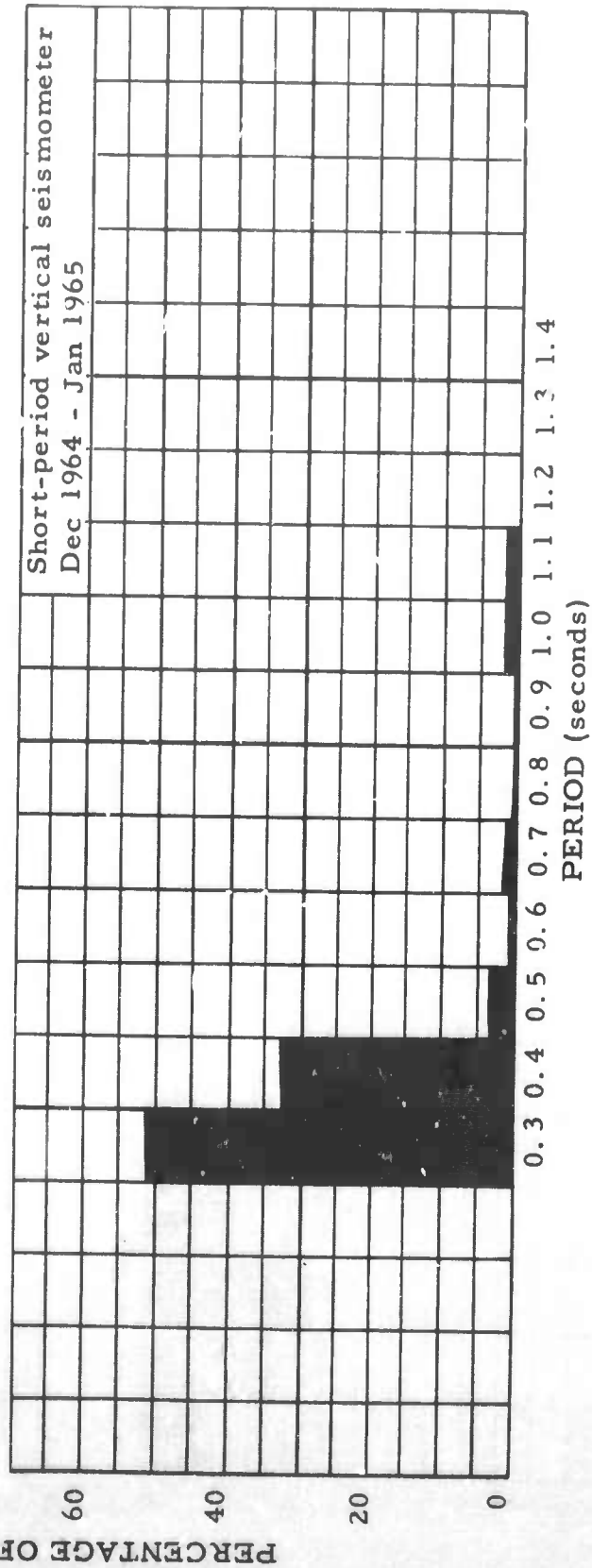
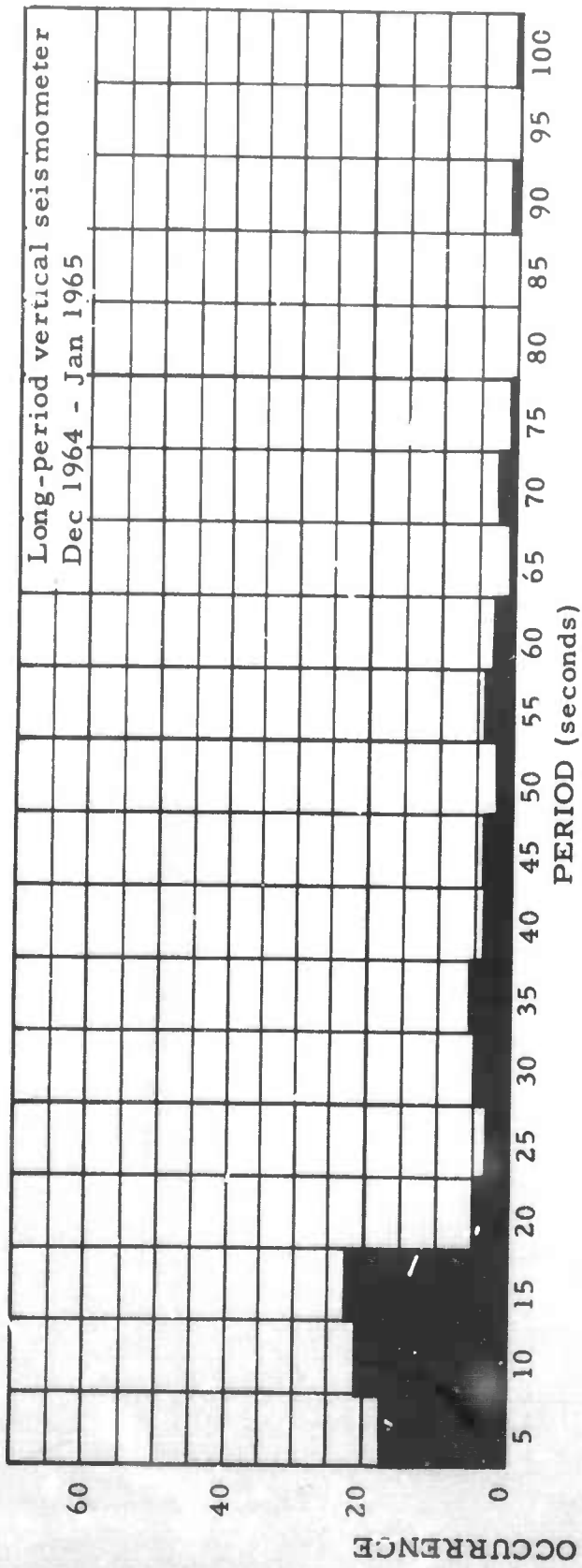
Percentage of occurrence for indicated periods for CG-VA



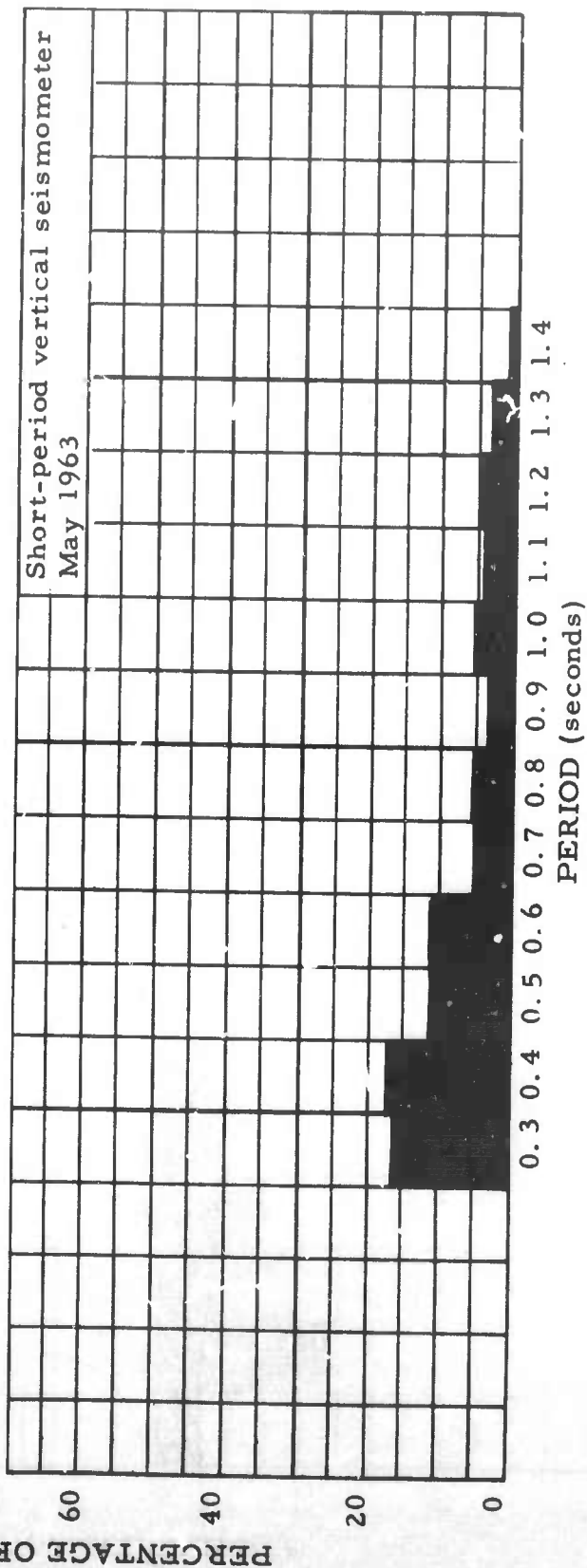
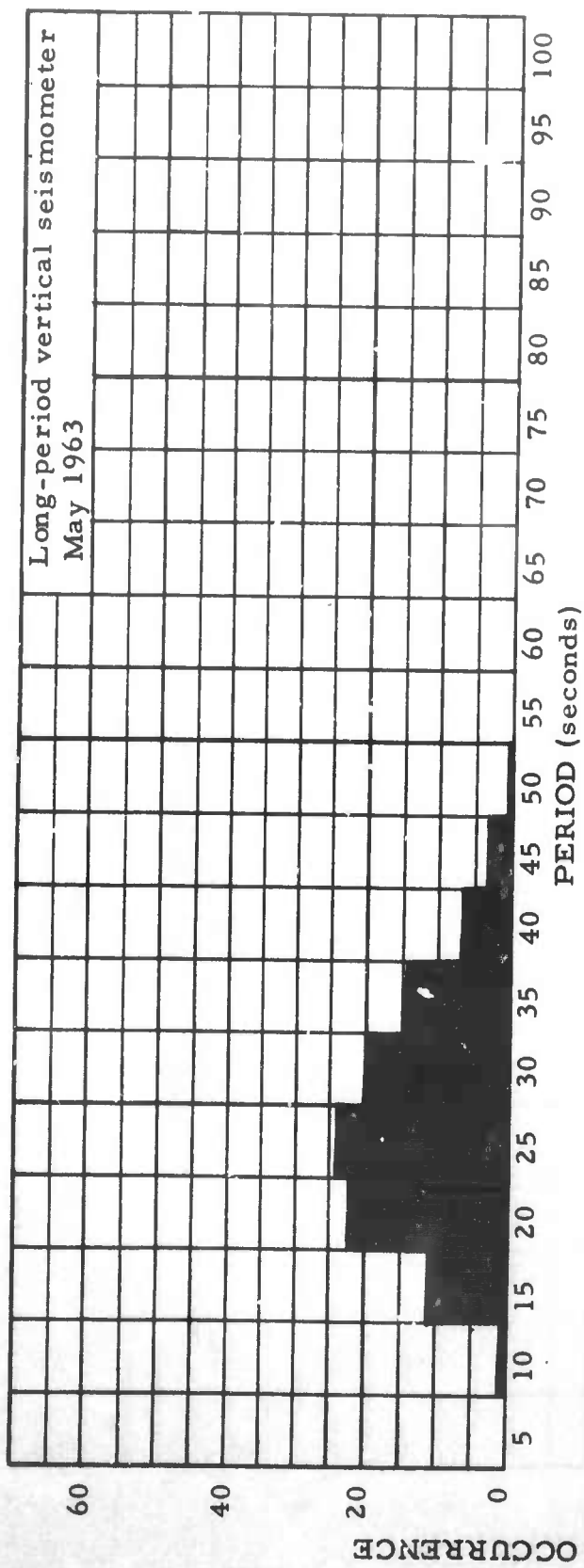
Percentage of occurrence for indicated periods for KC-MO



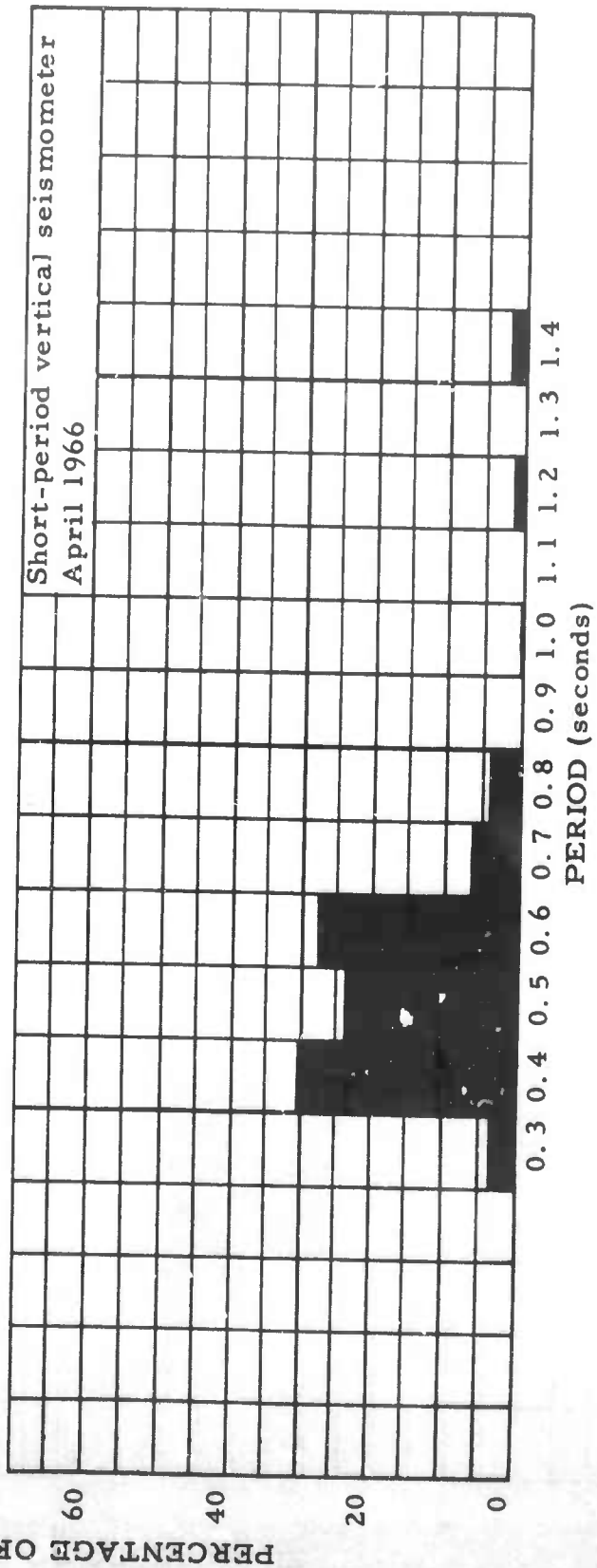
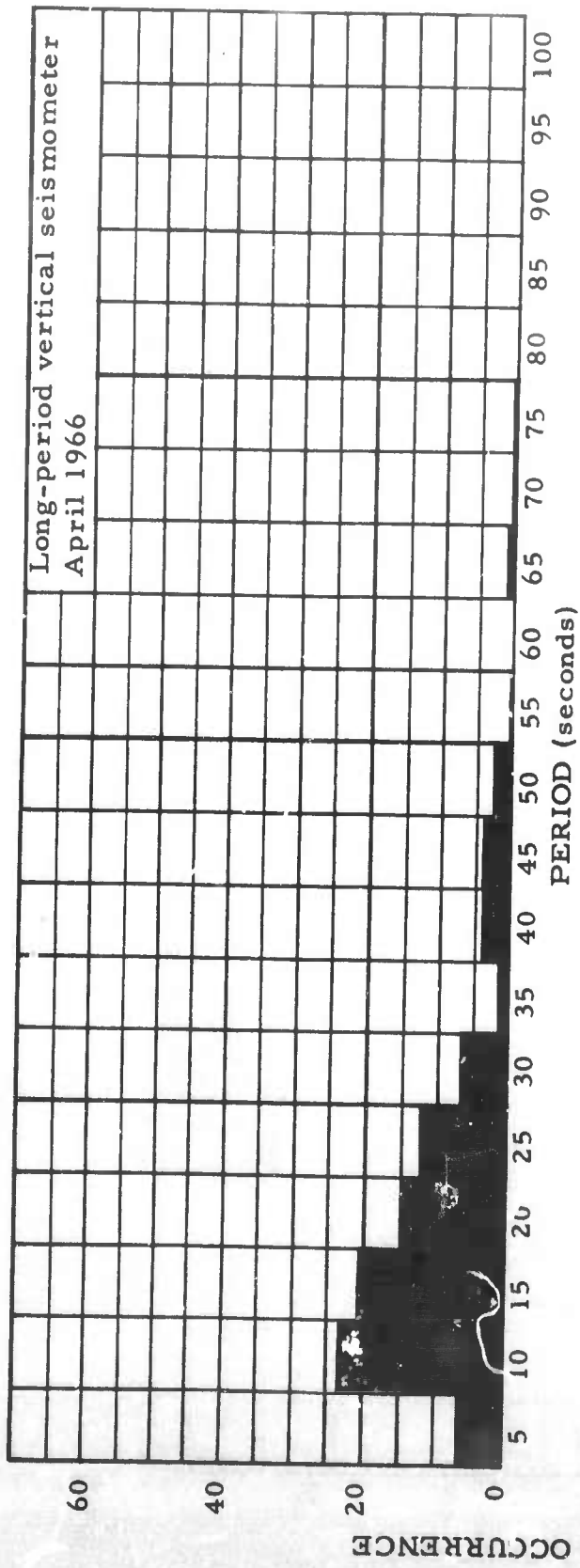
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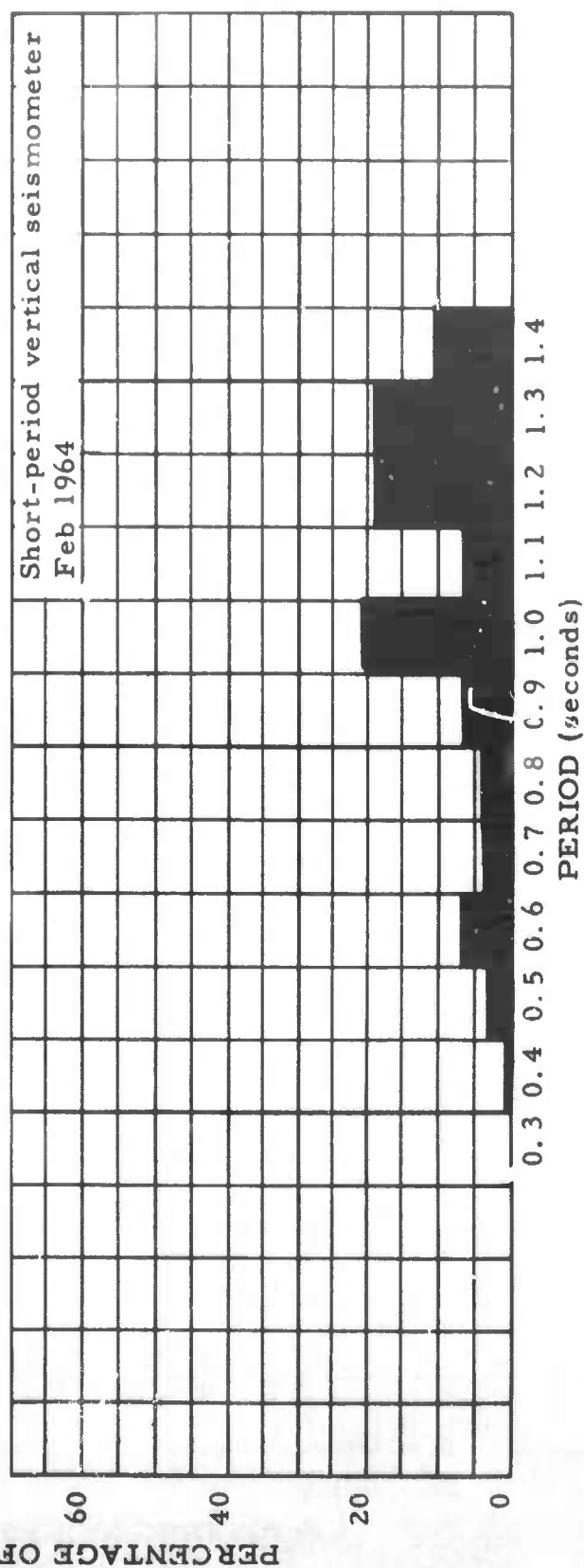
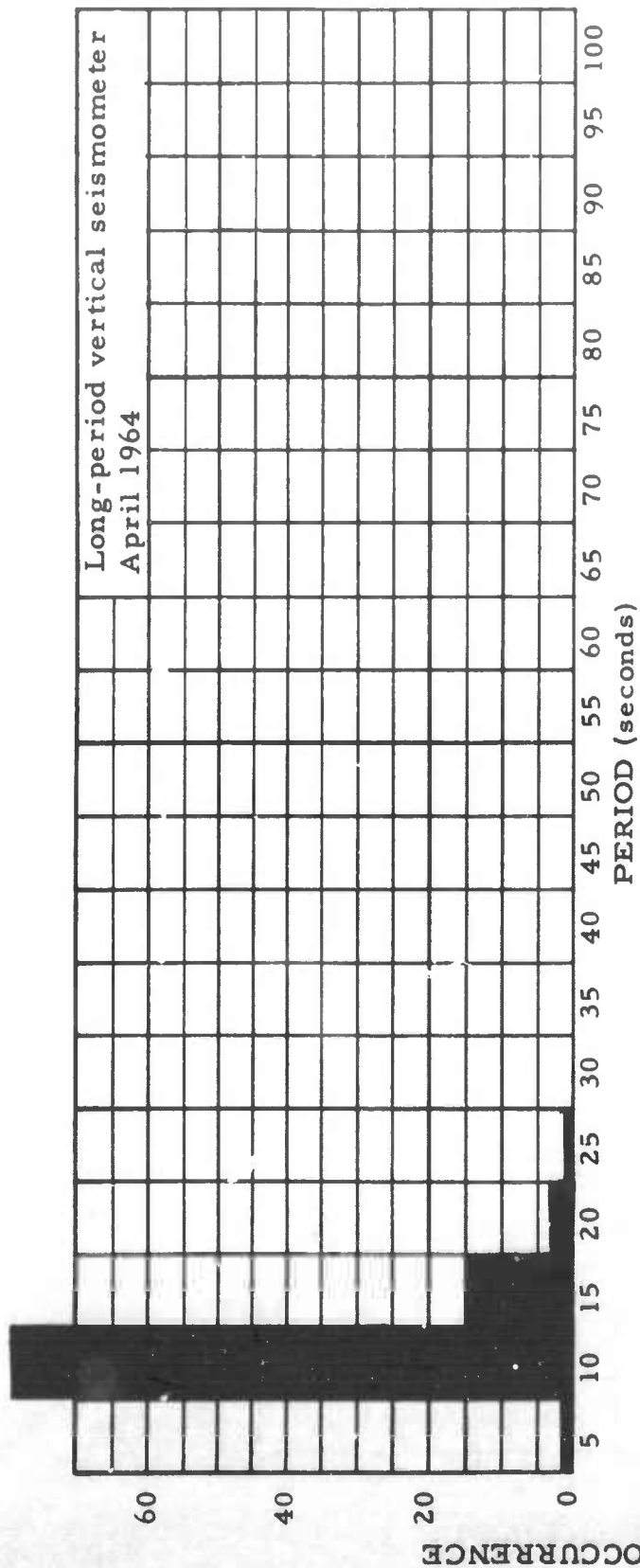
Percentage of occurrence for indicated periods for HD-PA



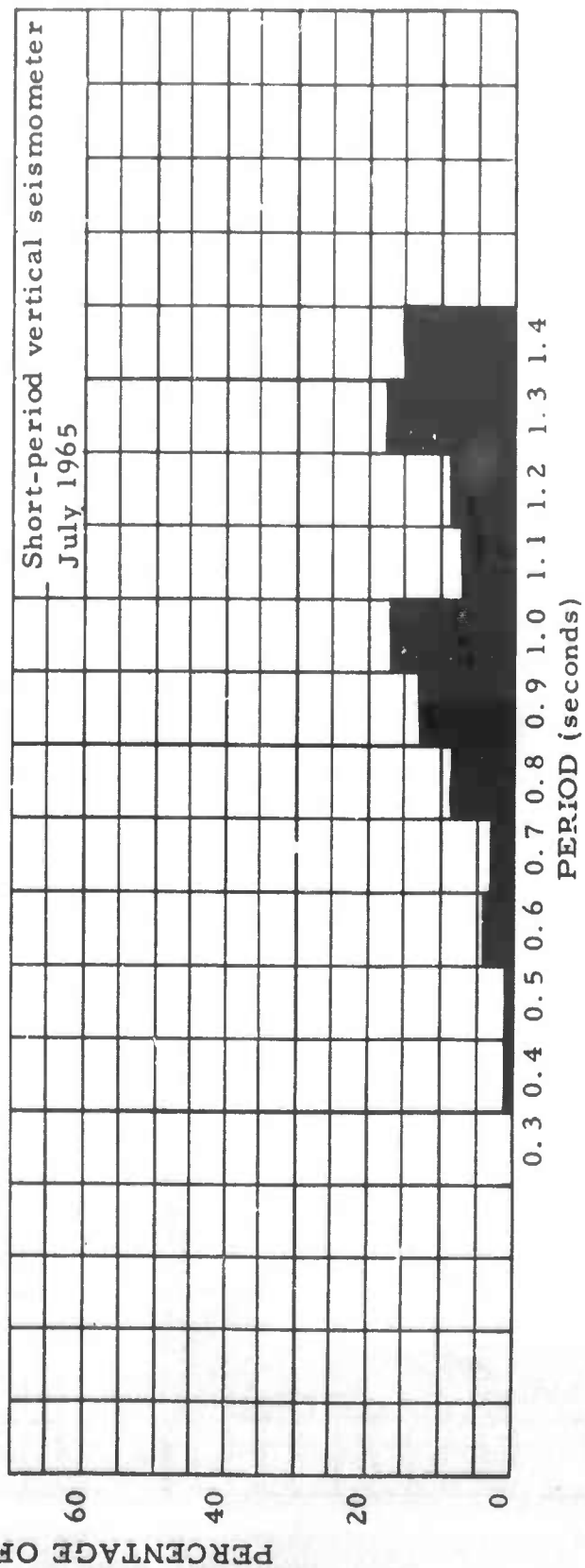
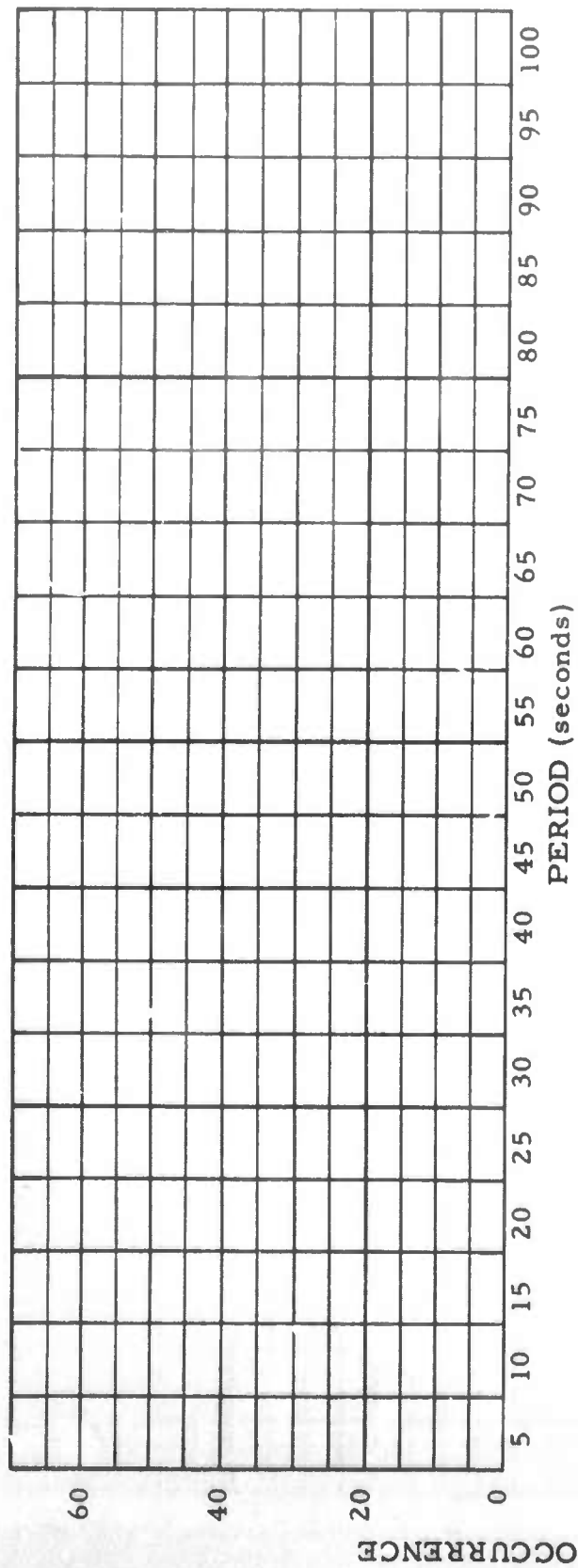
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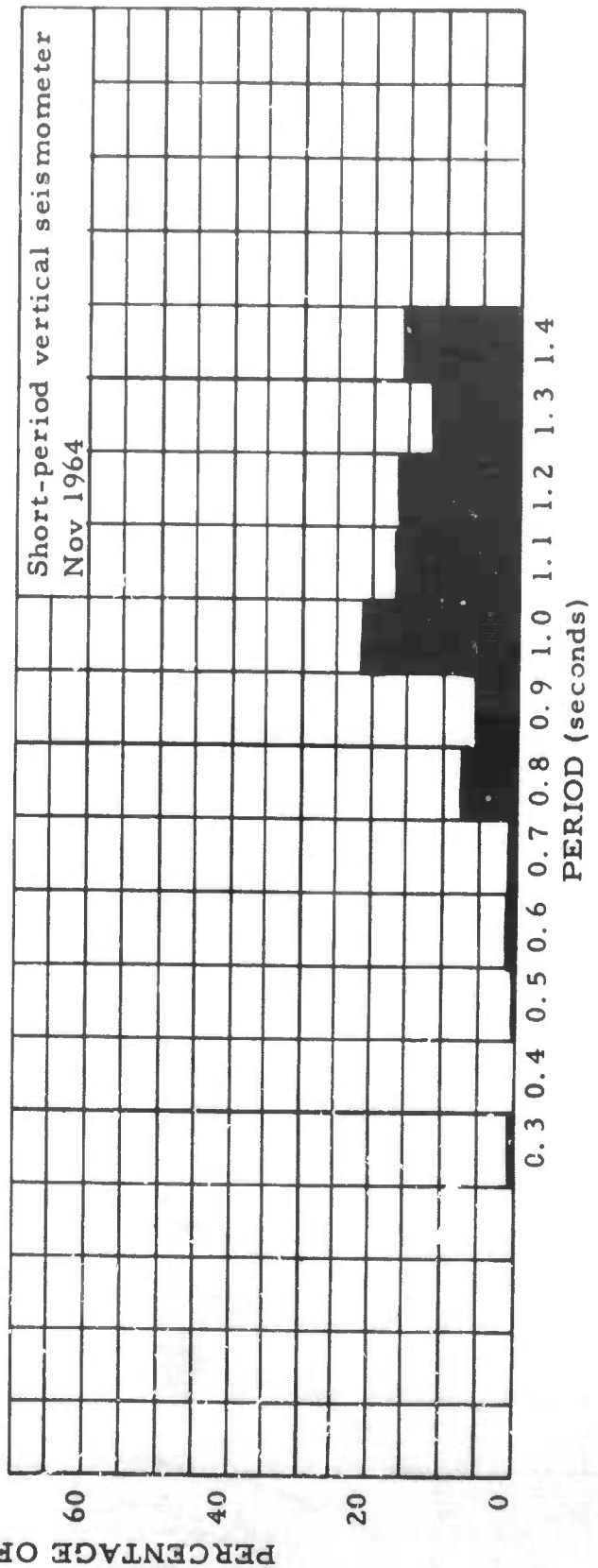
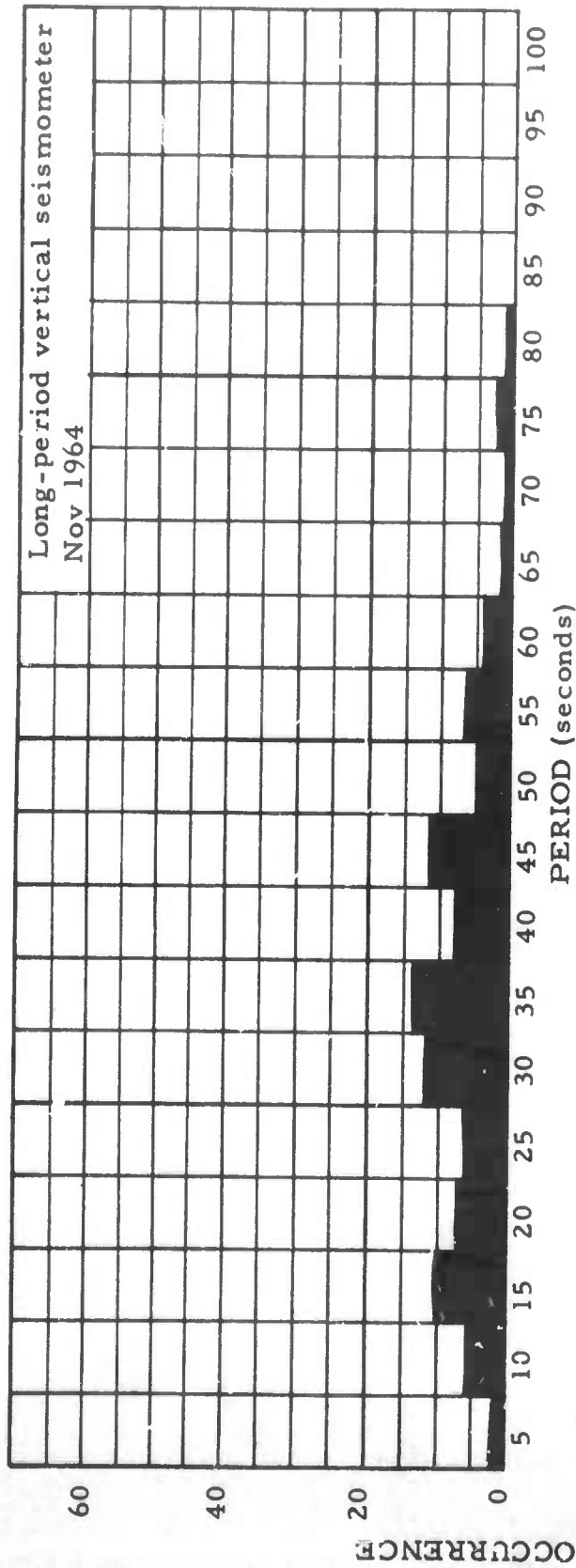
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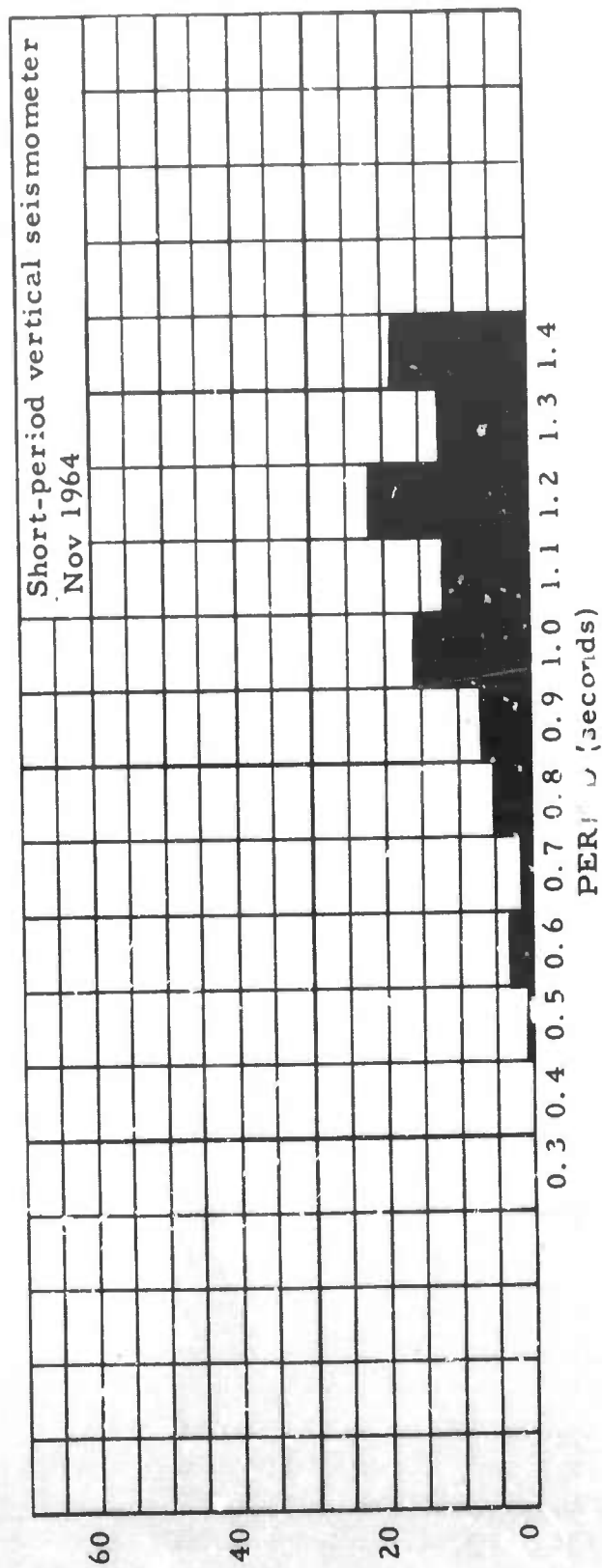
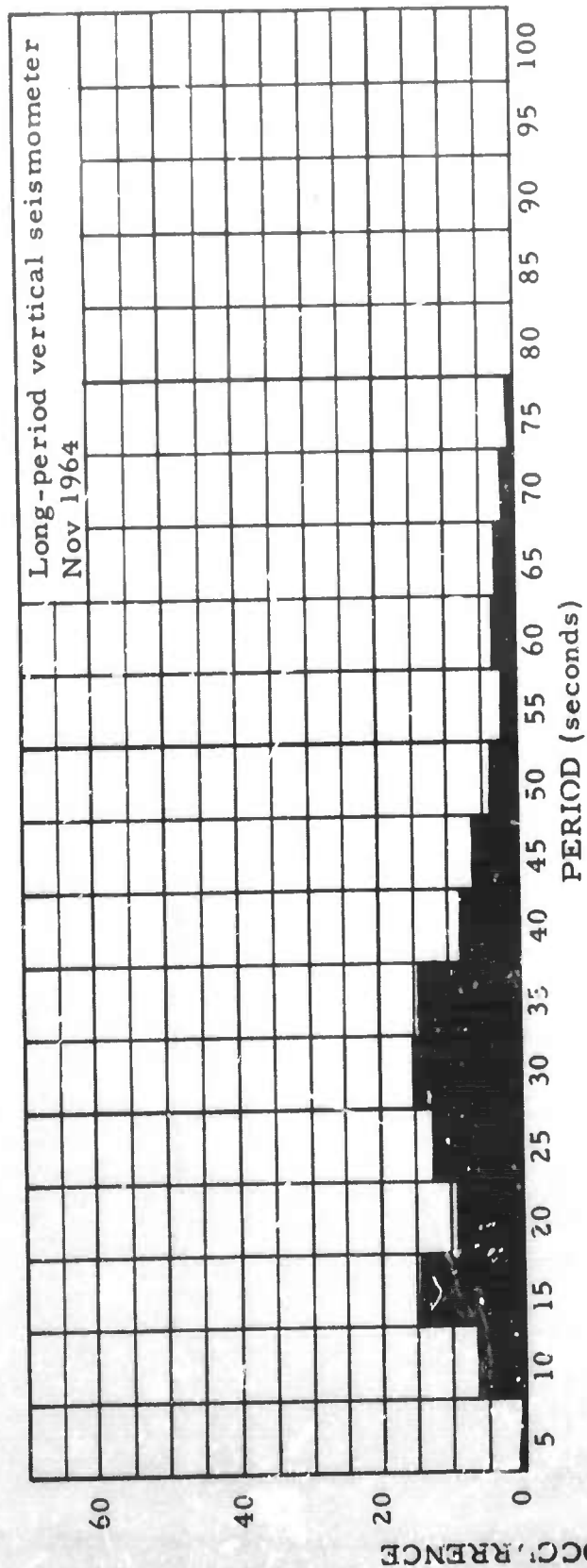
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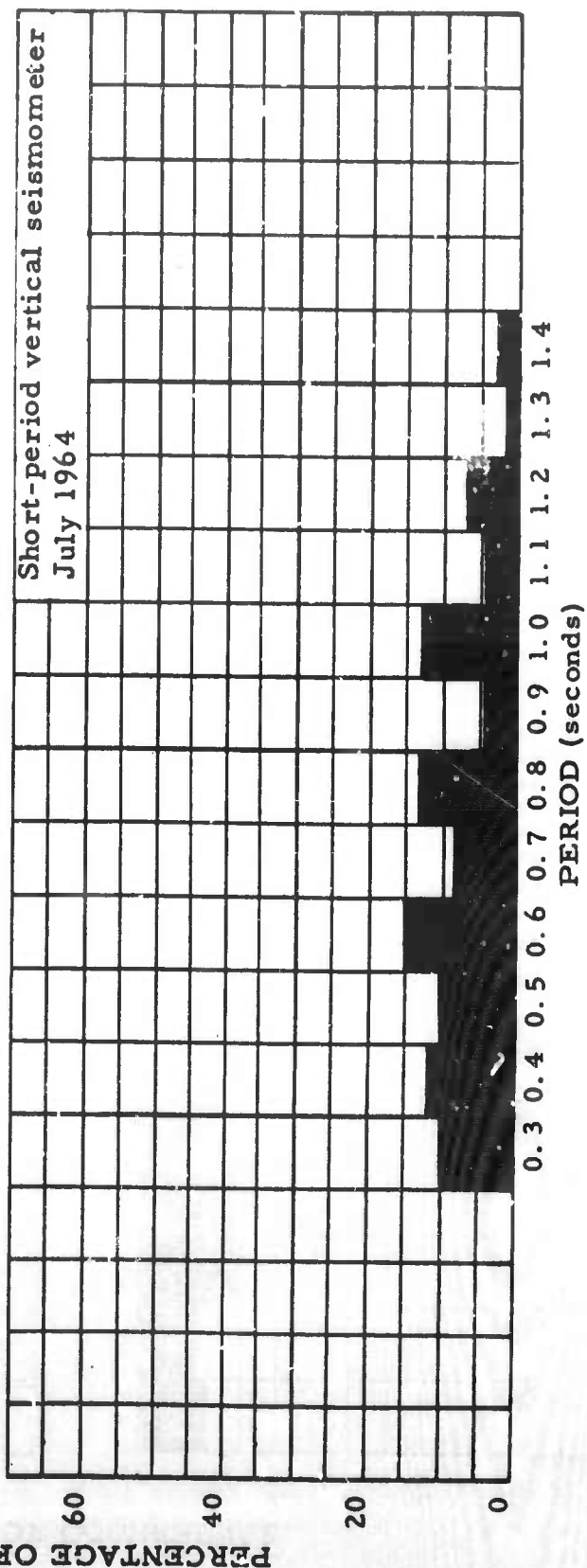
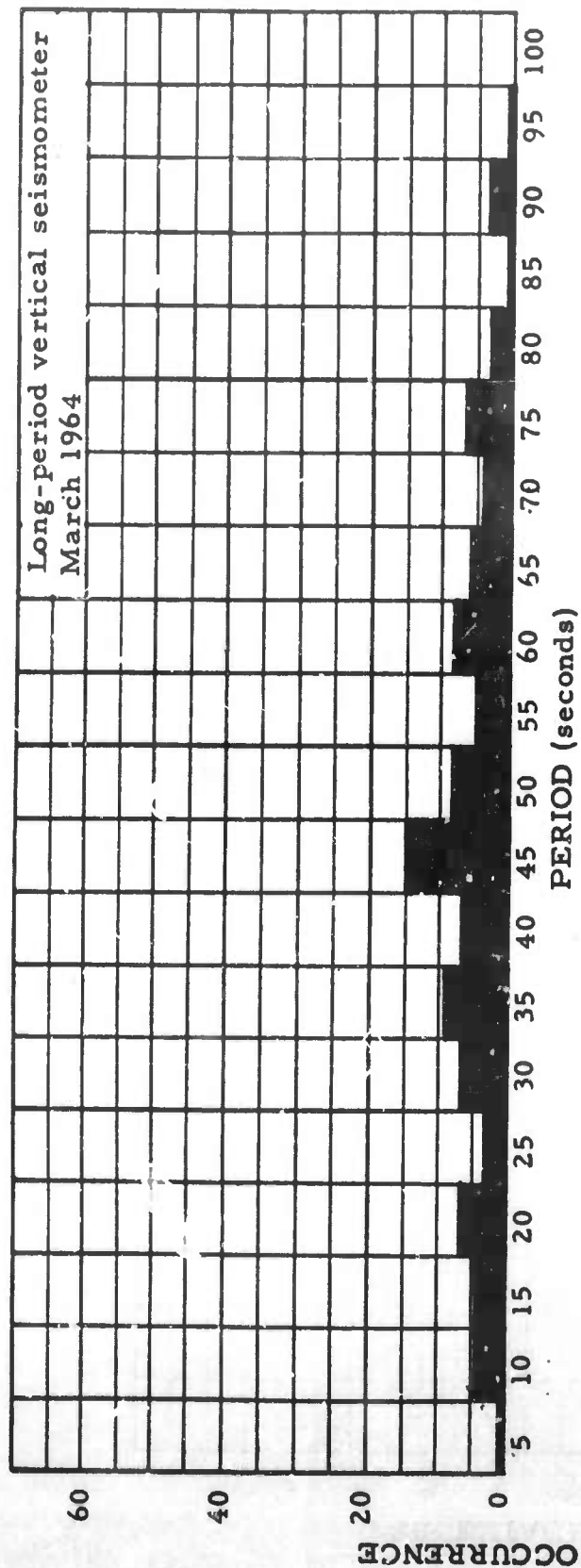
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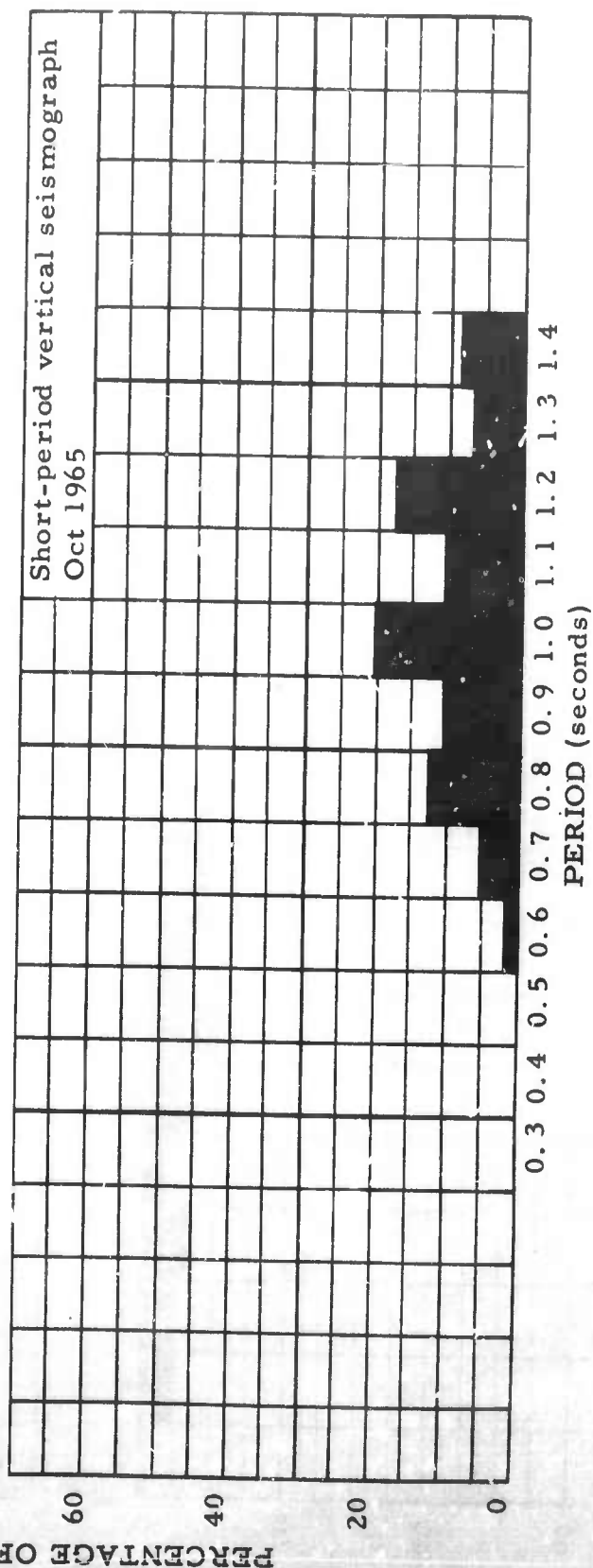
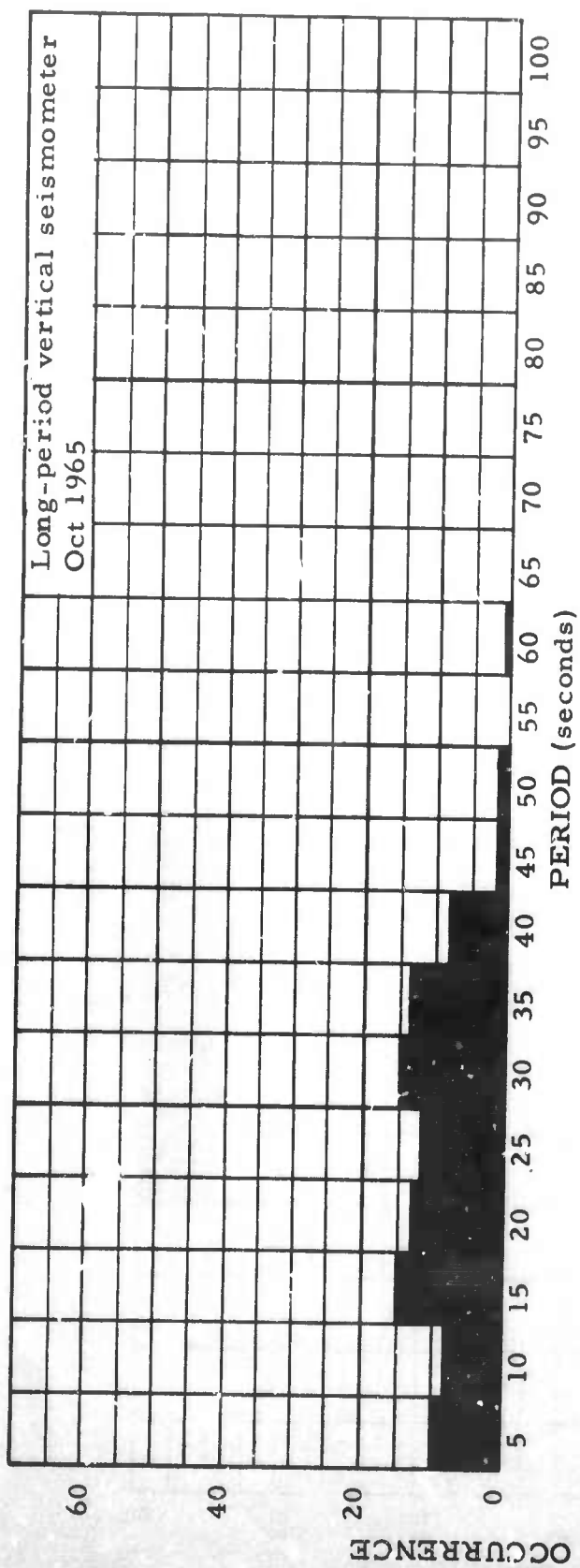
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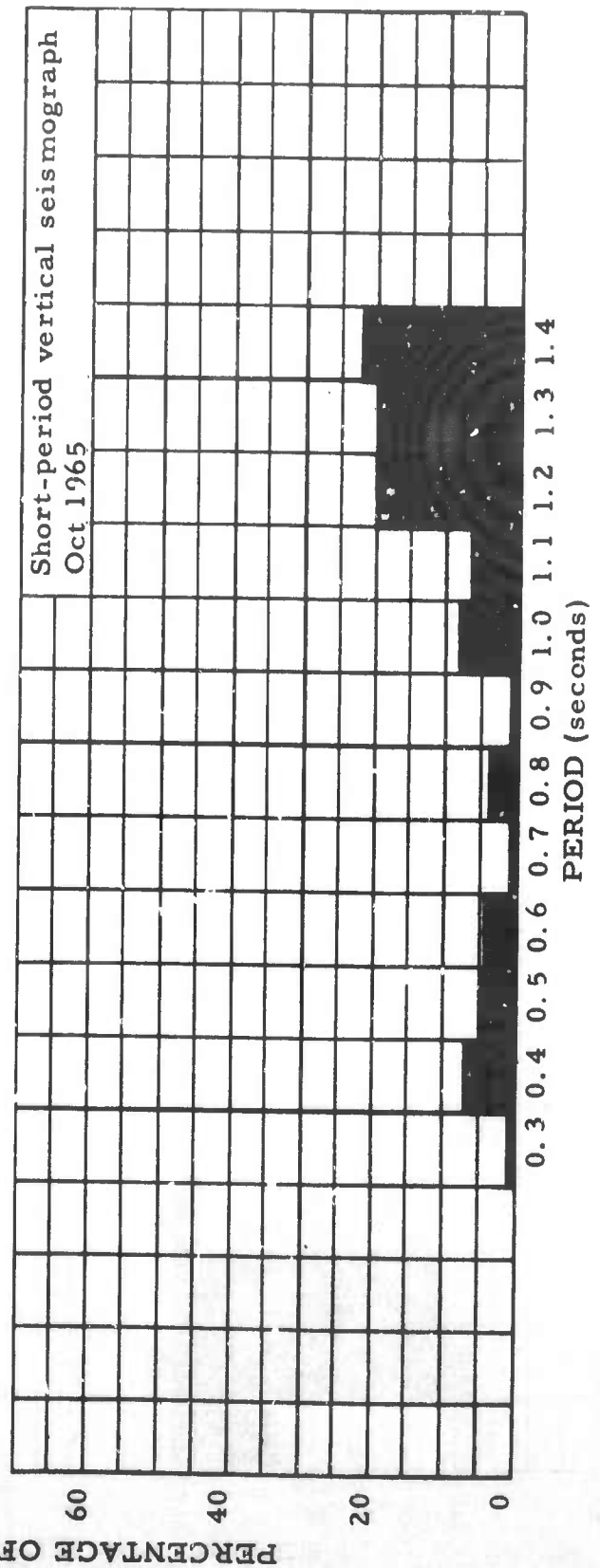
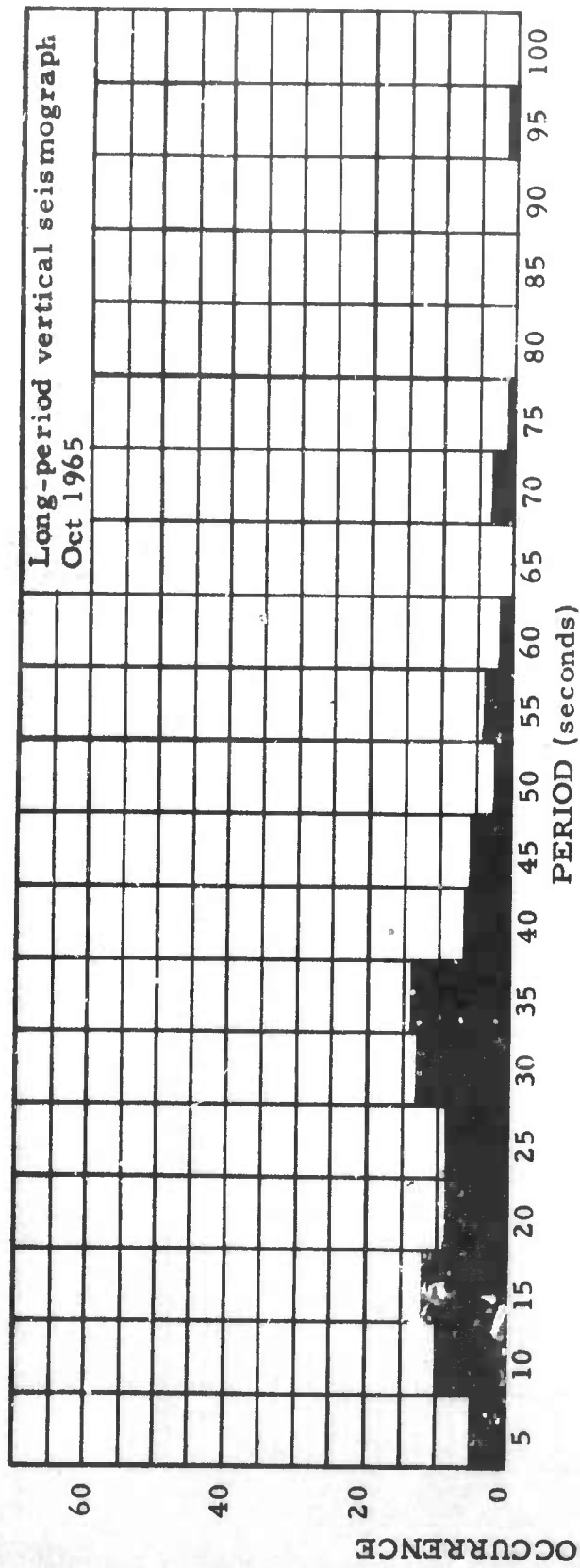
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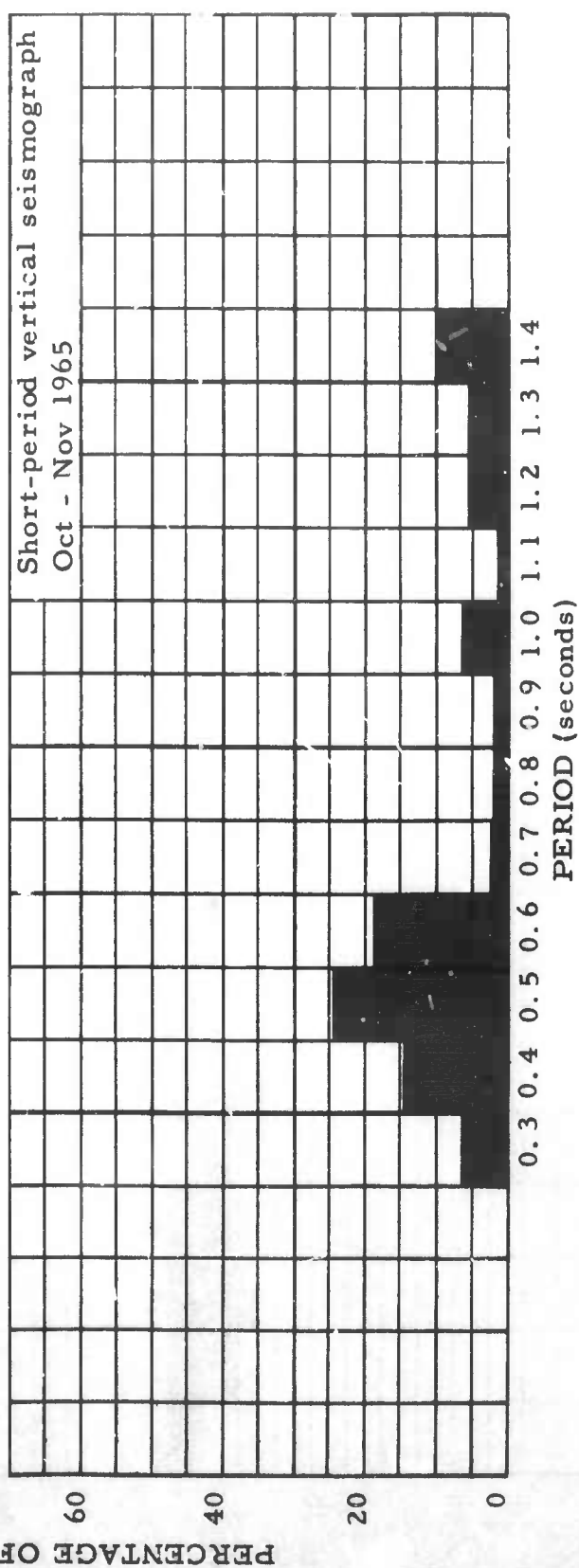
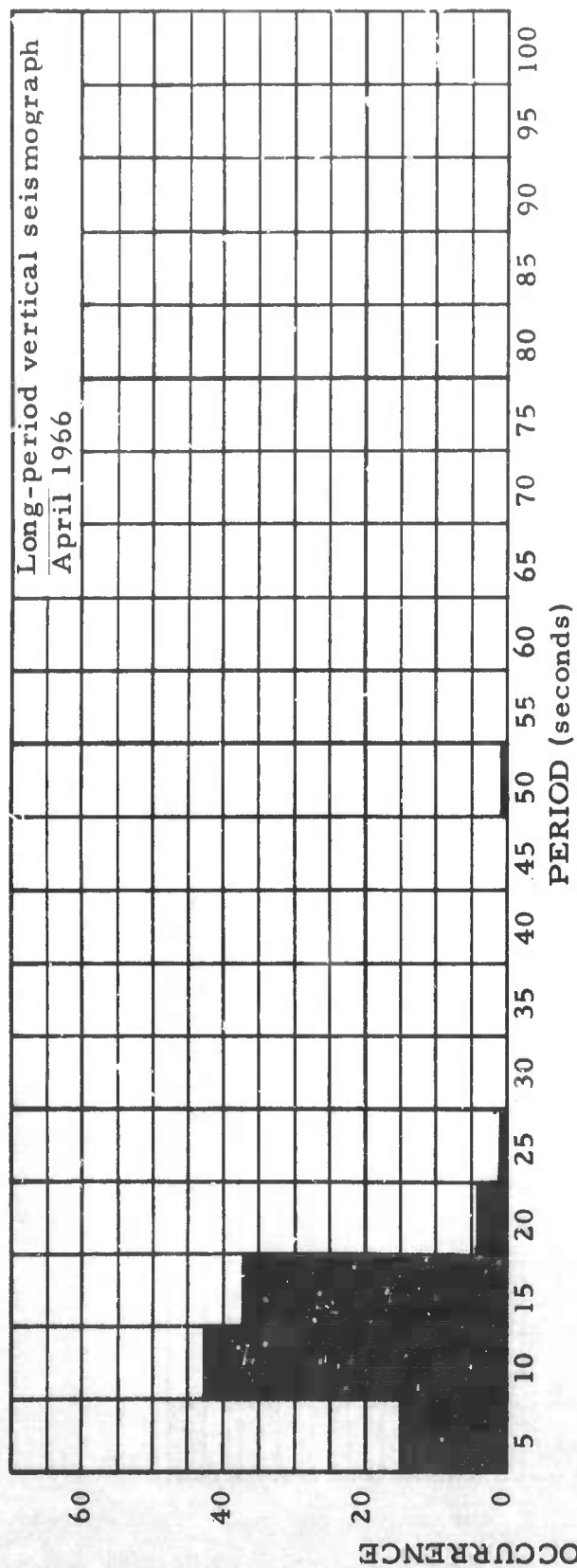
Percentage of occurrence for indicated periods for RK-ON



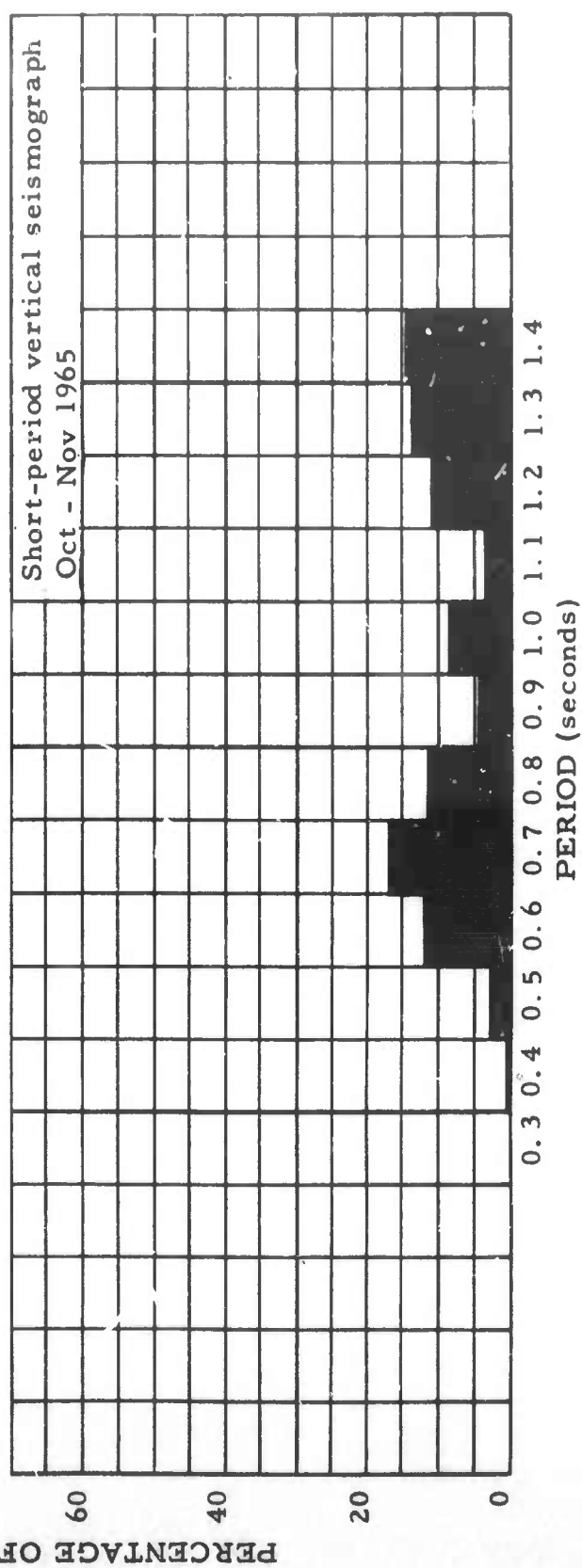
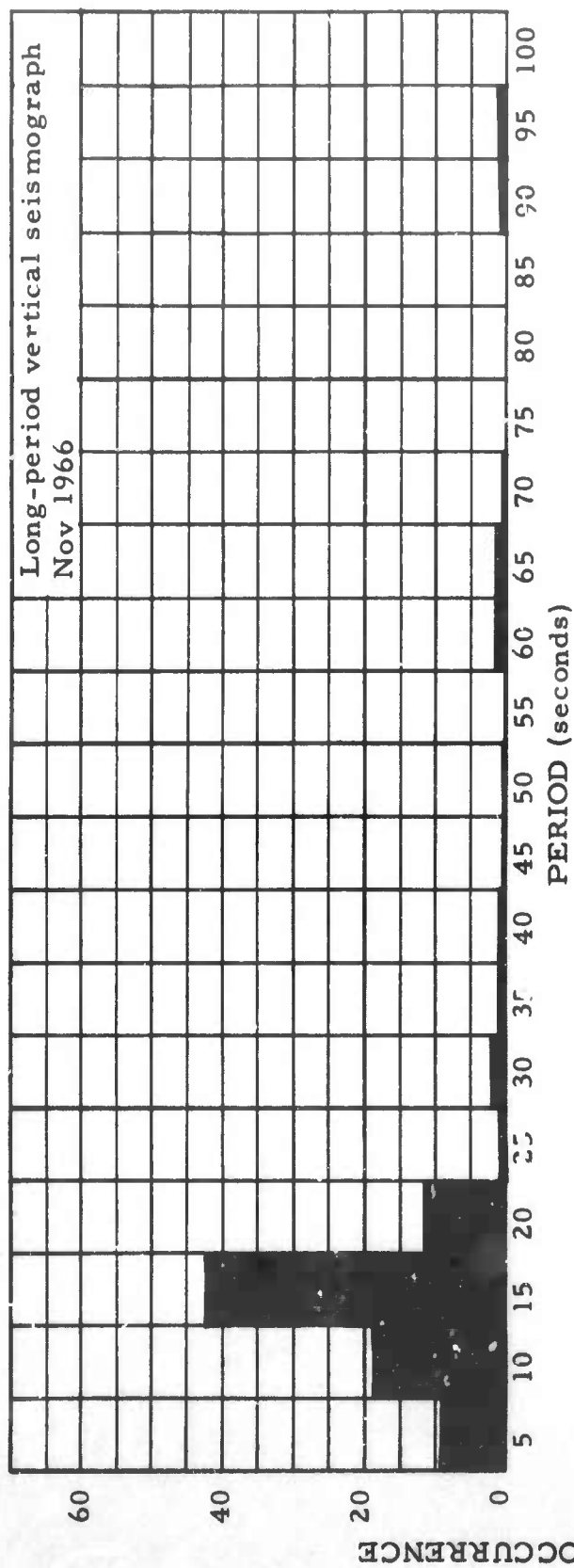
Percentage of occurrence for indicated periods for SV3QB



Percentage of occurrence for indicated periods for SI-BC



Percentage of occurrence for indicated periods for JP-AT



Percentage of occurrence for indicated periods for PG-BC

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13. ABSTRACT		
This report is the third in a series of studies which evaluate seismic noise levels at LRSM sites. Data from the short- and long-period vertical seismographs from 33 sites are reviewed, and standardized data compilation methods are discussed. Cumulative probability distribution of amplitude curves and noise spectrum curves are developed for each site studied.		

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Seismic Noise Survey Long-Range Seismic Measurement Program Short-Period System Long-Period System						

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