CONSUMERS POWER COMPANY

PALISADES NUCLEAR PLANT

REACTOR INTERNALS NOISE MONITORING TESTS

January 1981 - December 1981

LIST OF FIGURES

CONTENTS

I Introduction

This report entitled Reactor Internals Noise Monitoring Tests covers the period January 1981 through December 1981. This reporting period encompasses the last two thirds of core four; Palisades shutdown for a refueling outage in August 1981 and returned to power operation December 31, 1981 for a brief ten minutes. Contained in this report is a summary of results obtained from Technical Specification tests, Reference 1, which require data to be taken on reactor internals noise on a weekly and monthly basis. The data collected on a weekly basis, Phase One measurements, consists of the integral probability distribution function, standard deviation, and % RMS in selected frequency bands of reactor internals noise. The data collected on a monthly basis, Phase Two measurements, consists of a power spectral density, phase of transfer function, and coherence for each excore detector combination.

II Description of Noise Analysis Method

As required by Reference 1, reactor internals noise monitoring is taken on a weekly and monthly basis. The weekly surveillance consists of the acquisition of the standard deviation, % RMS, and integral probability distribution (IAPD) of excore detector combinations in the frequency bands (1-3)Hz, (10-16)Hz and (16-20)Hz. The monthly surveillance consists of the acquisition of the phase of transfer function, normalized power spectral density (NPSD) and coherence of excore detector combinations in the frequency band (0-25)Hz. Presented below is a general discussion of each of the surveillance methods.

% RMS

Alert and action limits, M sigma and N sigma respectively, have been assigned to the % RMS values per Reference 2 which are given below.

	M sigma	N sigma
(1-3)Hz	.16%	.24%
(10-16)Hz	.11%	.16%
(16-20)Hz	.11%	.16%

These limits were analytically determined based on information in References 3 and 4 and Palisades core geometry. (A description of the mathematical technique of obtaining sigma and % RMS values from the cross power spectral density is given in Reference 5.)

Integral of Amplitude Probability Distribution (IAPD)

The Integral of the Amplitude Probability Distribution (IAPD) is determined for each excore detector in the frequency bands (1-3)Hz, (10-16)Hz and (16-20) Hz. The IAPD is formed in the following manner: 1) Data in the time domain is received by the fourier analyzer, 2) The fourier analyzer transforms the data to the frequency domain where the frequency band of interest is isolated, 3) This frequency band is then transformed to the time domain. Steps 1, 2 and 3 are performed for 500 entries into the fourier analyzer and the results are added to form a histogram. The histogram is area normalized and integrated to give the IAPD. The ordinate scale of an IAPD ranges between 0 and 1. Through observation of the location of the .5 value, a determination can be made if vibration of the core support barrel or other reactor internals is being impeded in peak to peak swing. Such early termination of peak to peak swing was seen in 1972 and was the result of the core support barrel contacting the snubbers. The IAPD is a backup surveillance to % RMS.

Phase of Transfer Function

A transfer function between two excore detectors is formed by taking the fourier transform of the time domain data from one detector, dividing it by the fourier transform of the time domain data from the second detector and converting the results to polar coordinates.

Coherence

The coherence function between two detectors describes the "common causality" between the two detectors. Its value ranges between 0 and 1 and it is formed through the following expression:

$$(\mathrm{Coh})^2 = \frac{|\overline{G_{12}}|^2}{\overline{G_{11}} \cdot \overline{G_{22}}}$$

where:

$|\overline{G_{12}}|^2$ - square of the magnitude of cross spectrum

$\overline{G_{11}}$ - auto spectrum of detector 1

$\overline{G_{22}}$ - auto spectrum of detector 2

Together with the phase, the coherence forms a qualitative diagnostic tool in which quantification is achieved through the % RMS. The coherence displays those frequencies that are common to two excore detectors and the phase indicates whether the frequency is associated with vibration. Coherence and phase diagrams can be formulated with data from all combinations of excore detectors and shifts of signature values in phase or coherence are readily observed.

Normalized Power Spectral Density (NPSD)

The Normalized Power Spectral Density is formed through the following equation:

$$NPSD = \frac{\overline{F_1 F_1^*}}{N}$$

where:

F_1 - Fourier transfer of data from a detector

F_1^* Complex conjugate of fourier transfer

N - Normalization constant which includes a power and frequency normalization.

The usefulness of the NPSD is to monitor signature frequencies.

III General Core Arrangement and Signal Conditioning

Figure 1 shows the relationship of excore detectors to significant primary system items. The excore detectors NI-05, NI-06, NI-07 and NI-08 are located approximately 45^{o} from the hot legs. The cold legs of the reactor vessel are approximately at the same angular location as the excore detectors. A rough outline of the core is also shown in the figure. Current from the excore detectors is brought through a current to voltage amplifier and then as shown in Figure 2, through a voltage amplifier, a filter and then to the fourier analyzer. The voltage amplifier is AC coupled so that only the fluctuating (noise) component of the signal is amplified. The filters are used to bandpass the signal in range .025Hz to 25Hz. The fourier analyzer, HP5451B, is used to perform all statistical analysis on the noise component.

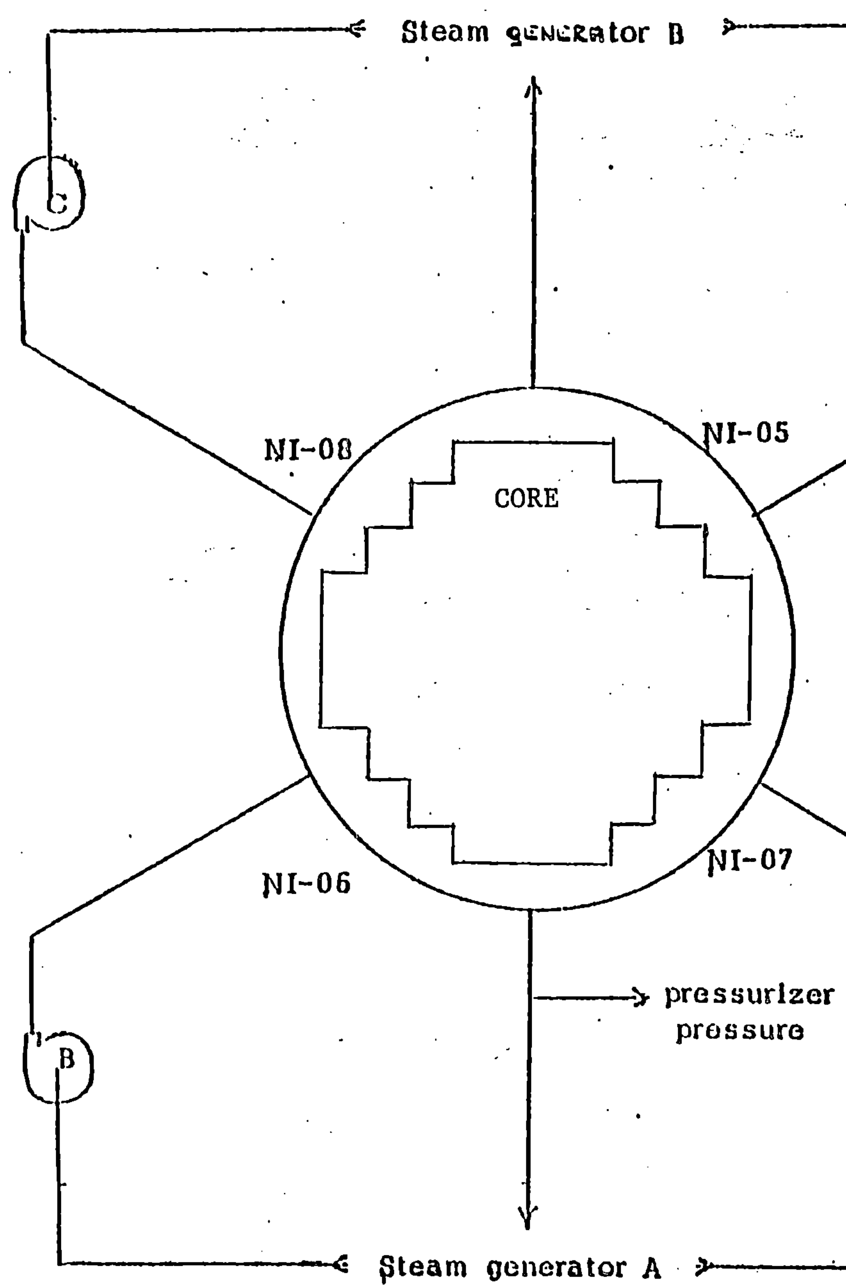
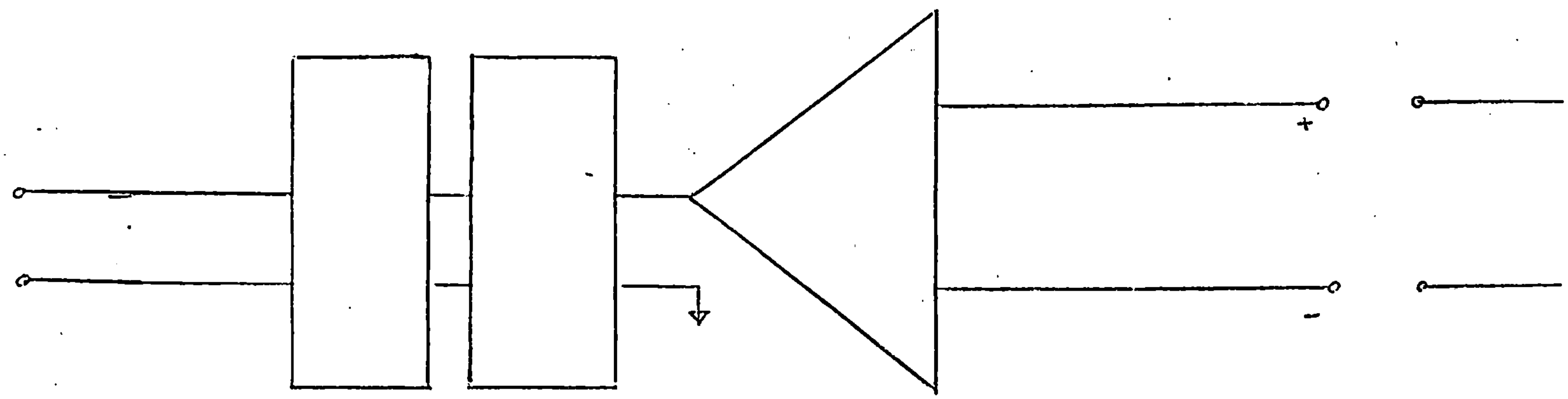


FIGURE 1

Instrumentation locations for noise tests



Input to Fourier Analyzer

Low Pass Filter 24db/oct

High Pass Filter 24db/oct

Operational Amplifier Nominal Gain of 50

Buffered Excore Detector Test Signal

FIGURE 2

SCHEMATIC OF SIGNAL CONDITIONING EQUIPMENT

IV Summary of Noise Analysis Results

Presented below is a summary of the surveillance results for the reporting period. These results are organized by surveillance technique.

% RMS

Table 1 lists % RMS values for the frequency bands (1-3)Hz, (10-16)Hz and (16-20)Hz for all detector combinations. Representative results are listed from tests throughout the reporting period. It is seen that the alert limits of .16% RMS for the frequency band of (1-3)Hz and .11 % RMS for the frequency bands (10-16) Hz and (16-20)Hz have not been exceeded.

TABLE 1

% RMS FOR DETECTOR COMBINATIONS FOR

FREQUENCY BAND (1-3)Hz, (10-16)Hz, (16-20)Hz

	05-06			05-07			05-08			06-07			06-08			07-08		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
2/9/81	.045	.003	0	. 034	.007	. 002	.054	. 004	0	.056	.004	. 0	.034	. 005	0	.044	.004	. 001
4/6/81	.036	.004	.002	.030	.009	. 002	.034	.006	.001	.038	.005	.002	.030	.008	.002	.035	.006	.001
6/29/81	.085	.004	0	.067	.010	0	.072	.005	0	.083	.005	0	.070	.008	.002	.080	.004	0
8/24/81	.057	.005	.001	.048	.010	.002	.048	.007	.002	.055	.006	. 002	.045	. 008	.003	. 053	.006	. 001

1 - 1-3Hz

2 - 10-16Hz

3 - 16-20Hz

IAPD

Figures 3,4, 5 and 6 show the integral of the amplitude probability distribution for the month of June 1981. As stated before, the ordinates of the IAPDS are from 0 to 1. The abscissa is expressed in terms of millivolts. At 100% power the excore detector is 8 volts averaged. On top of the 8 volts exists a millivolt noise component. This is what is measured by the fourier analyzer and why it appears in the IAPD. As can be seen from the figures, when the IAPD has a value of .5 on the ordinate scale, the abscissa is at 0 millivolts. This signifies that vibration is of small enough magnitude that peak to peak motion is not being hindered.

Normalized Power Spectral Density (NPSD)

Figures 7 through 18 show a NPSD for each detector at three different times during core 4, i.e. June 30, 1980, February 9, 1981 and June 29, 1981. These three dates correspond to 9%, 53%, and 92% of core life respectively. Through an observation of the NPSD (and the coherence discussed in the next section) the following frequencies and their postulated sources display a reasonance.

1.	.5Hz	Thermal hydraulic oscillation
2.	2.3Hz	Fuel bundle vibration
3.	11.25Hz	Unknown
4.	12.5Hz	Core support barrel vibration
5.	14.75Hz	Primary coolant pump blade frequency
6.	15.5Hz	Shell mode vibration of reactor vessel
7.	18Hz	Core support barrel vibration
8.	23Hz	Unknown

This signature of frequencies has remained relatively constant throughout the reporting period. A change in this signature over a short period of time would be a strong indication of an anomaly, however this does not exist. Table II lists the peak amplitude of each of the above frequencies.

TABLE II

PEAK AMPLITUDE OF NPSD FOR DESIGNATED FREQUENCIES

NI-05

DATE	.5Hz	2.3Hz	11.25Hz	12.5Hz	14.8Hz	15.5Hz	18Hz	23Hz
6/30/80	-65	-75	-95		-83			-101
2/9/81	-59	-67	-92		-85		-98	-100
6/29/81	-57	-64	-90		-82			-101

NI-06

DATE	.5Hz	2.3Hz	11.25Hz	12.5Hz	14.8Hz	15.5Hz	18Hz	23Hz
6/30/80	-67	-76			-86	-90		
2/9/81	-61	-67		-89	-84	-88	-91	
6/29/81	-59	-64	-88	-88	-84	-87		

NI-07

DATE	.5Hz	2.3Hz	11.25Hz	12.5Hz	14.8Hz	15.5Hz	18Hz	23Hz
6/30/80	-67	-76	-91	-90	-84			
2/9/81	-61	-68	-89	-88	-85			
6/29/81	-59	-64	-87	-87	-85			-101

DATE	.5Hz	2.3Hz	11.25Hz	12.5Hz	14.8Hz	15.5Hz	18Hz	23Hz
6/30/80	-65	-76			-83	-87		
2/9/81	-58	-68	-89	-89	-85	-89	-91	
6/29/81	-57	-65	-88	-87	-82	-88		

NOTE: All values in db; blanks signify no resonance

Coherence & Phase

Figures 19,20 and 21 present phase and coherence diagrams for the months of June 1980, February 1981 and June 1981. The phase at a particular frequency and given detector combination is given by a straight line for 0^o phase and a sinusoidal line for a 180^o phase. A 90^o phase is composed of half a straight line and half sinusoidal line. The coherence for the particular frequency and detector combination is written adjacent to the phase line. Significant points from the coherence and phase diagrams are listed below.

1. The .5Hz frequency displays for all detector combinations and throughout core life a 0^ophase. High coherence is seen across the hot legs whereas low coherence is seen diagonally across the core.
2. The 2.3Hz frequency displays for all detector combinations at beginning of core a 0^o phase whereas later in core life vibration occurs in the direction of the hot legs. This frequency is believed to be fuel bundle vibration, Reference 6.
3. The 11.25Hz frequency displays for detector combinations and throughout core life a 0^o phase.
4. The 12.5 Hz frequency which is also believed to be core support barrel vibration displays a measureable coherence throughout core life.
5. The 18Hz frequency displays throughout core life a vibration in the direction of the hot legs. This frequency is believed to be core support barrel vibration.

V Conclusion

The results from the surveillance methods presented in Section IV show no indication that anomalous or significant reactor internals vibration existed during the reporting period. The magnitude of the % RMS values in the various frequency bands did not exceed alert or action limits. This in conjunction with the other noise analysis data conclusively shows that the core barrel was tightly clamped during the reporting period and no other anomalous vibrations occurred.

K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0702

FIGURE 3

Integral Amplitude Probability Distribution (IAPD) NI-05 6/29/81

06-29-81 05-06
IAPD 05

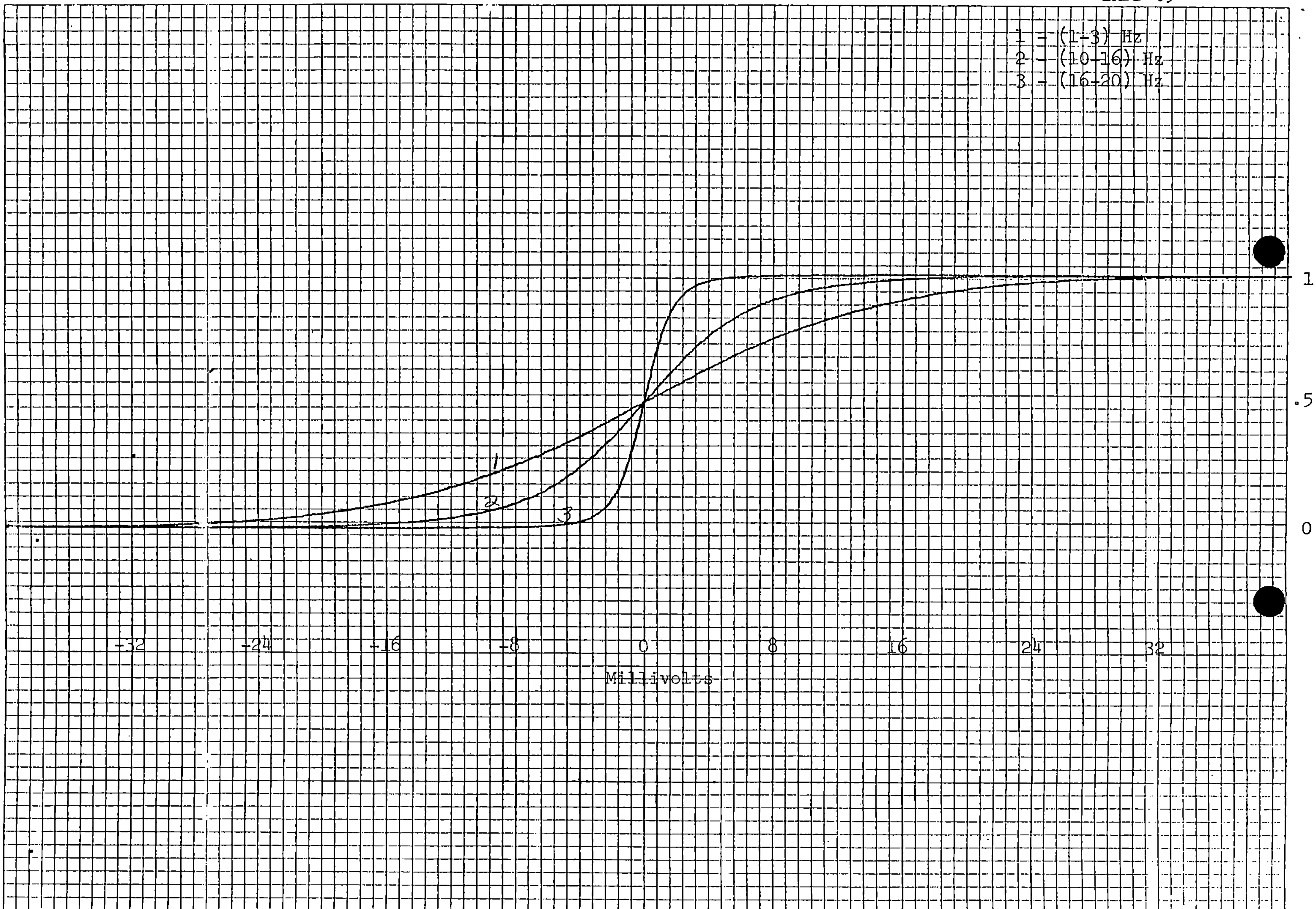
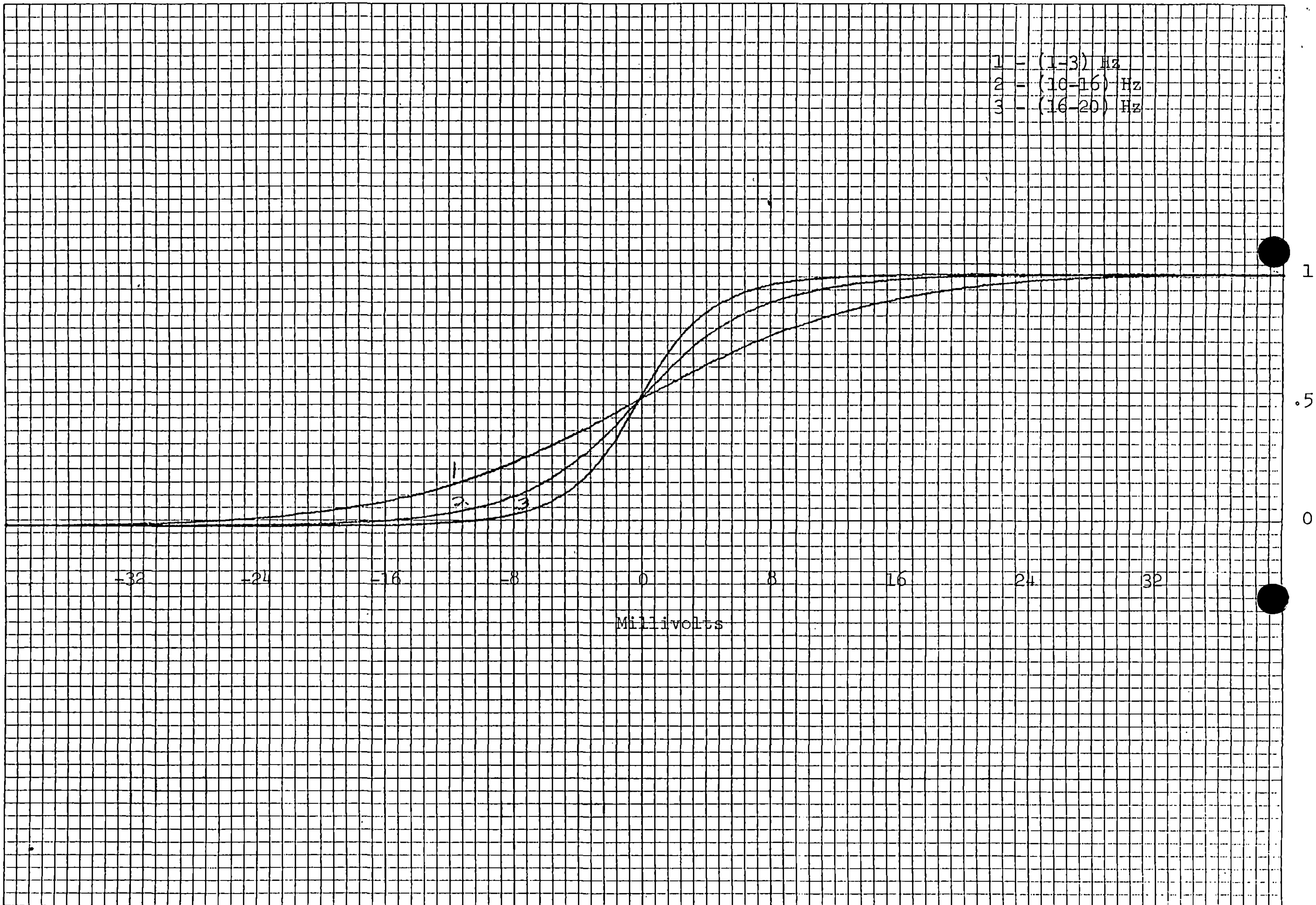


FIGURE 4

Integral Amplitude Probability Distribution (IAPD) NI-06 6/29/81

06-29-81 05-06
IAPD 06



46 0702

FIGURE 5

Integral Amplitude Probability Distribution (IAPD) NI-07 6-29-81

06-29-81 07-08
IAPD 07

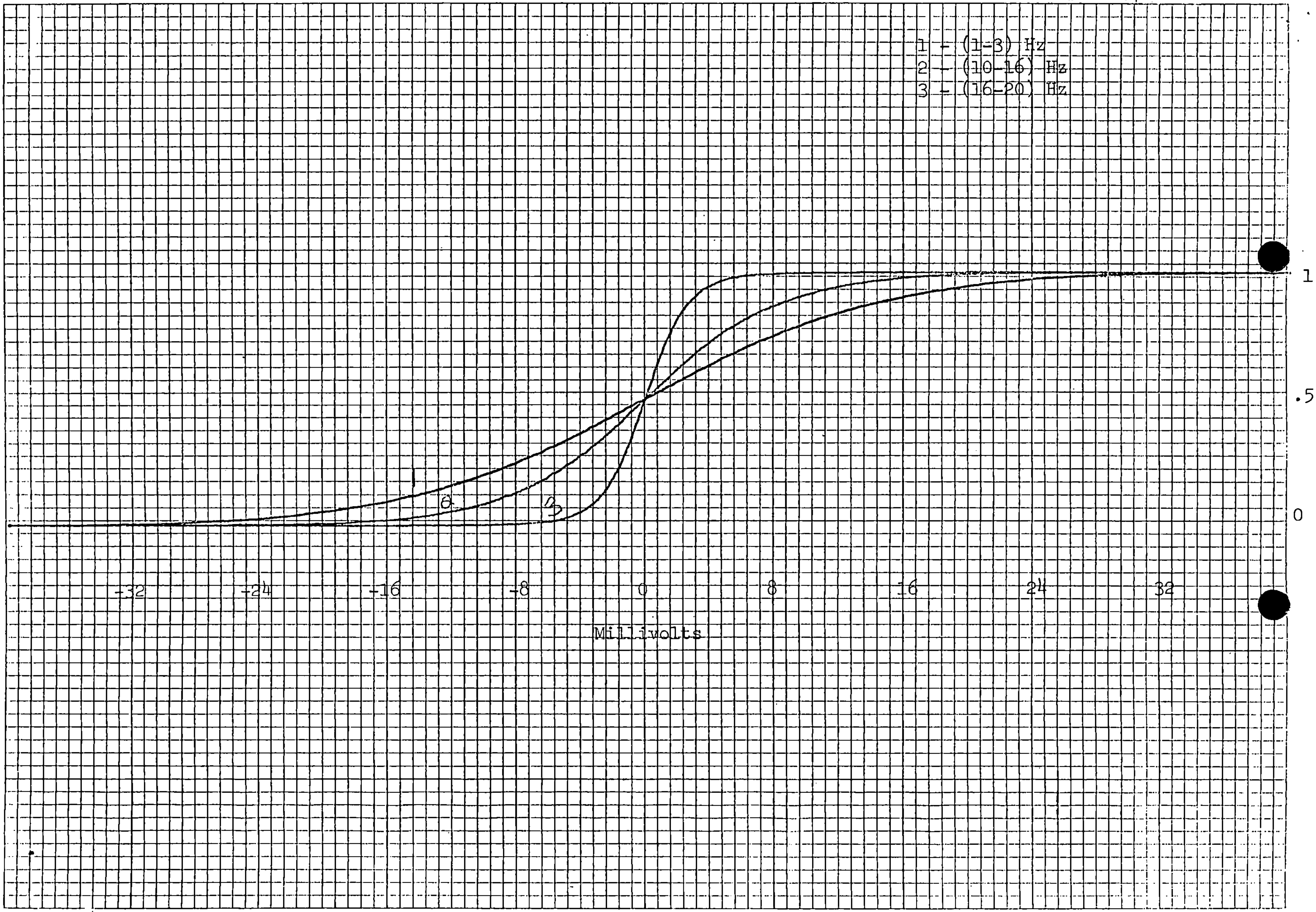
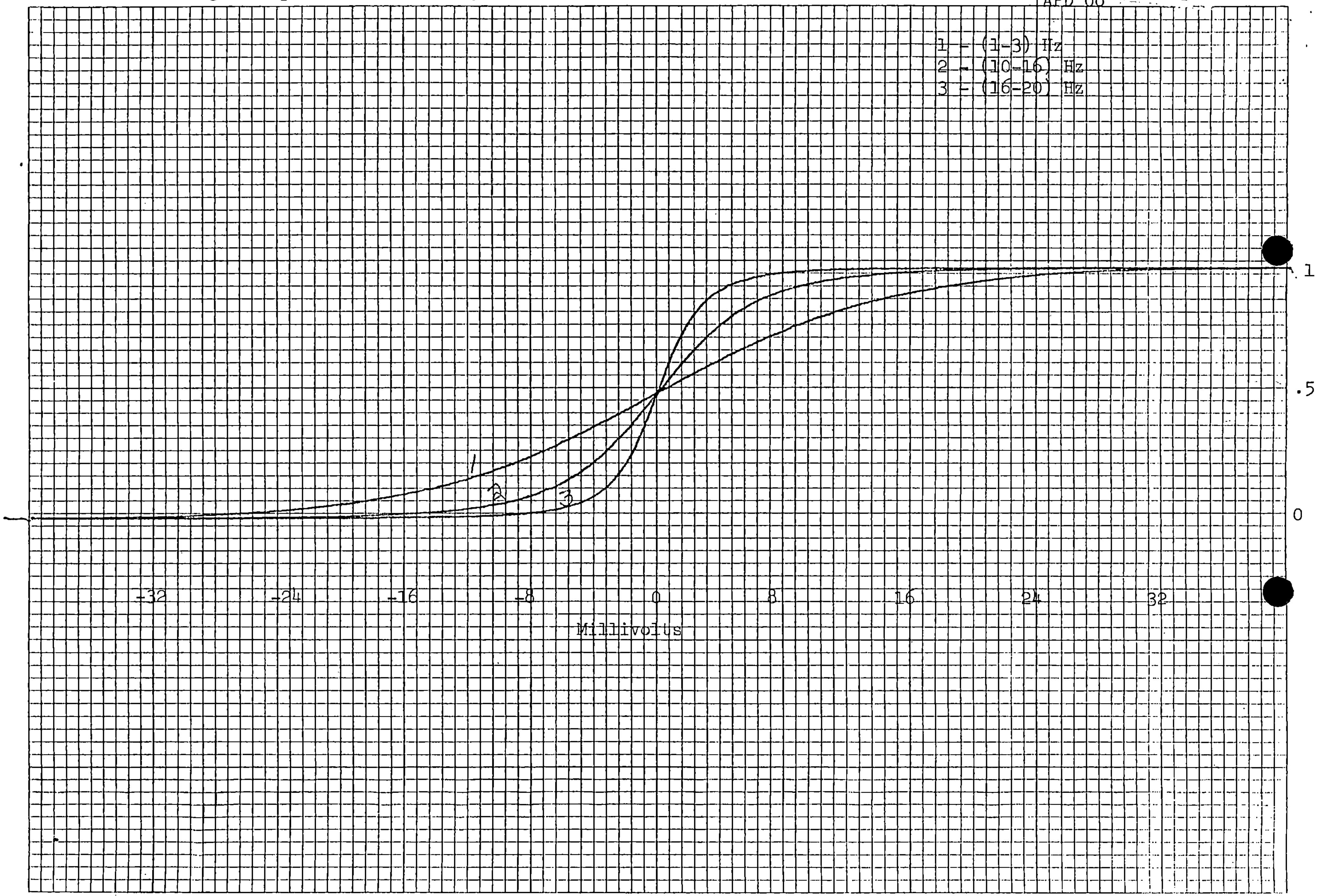


FIGURE 6

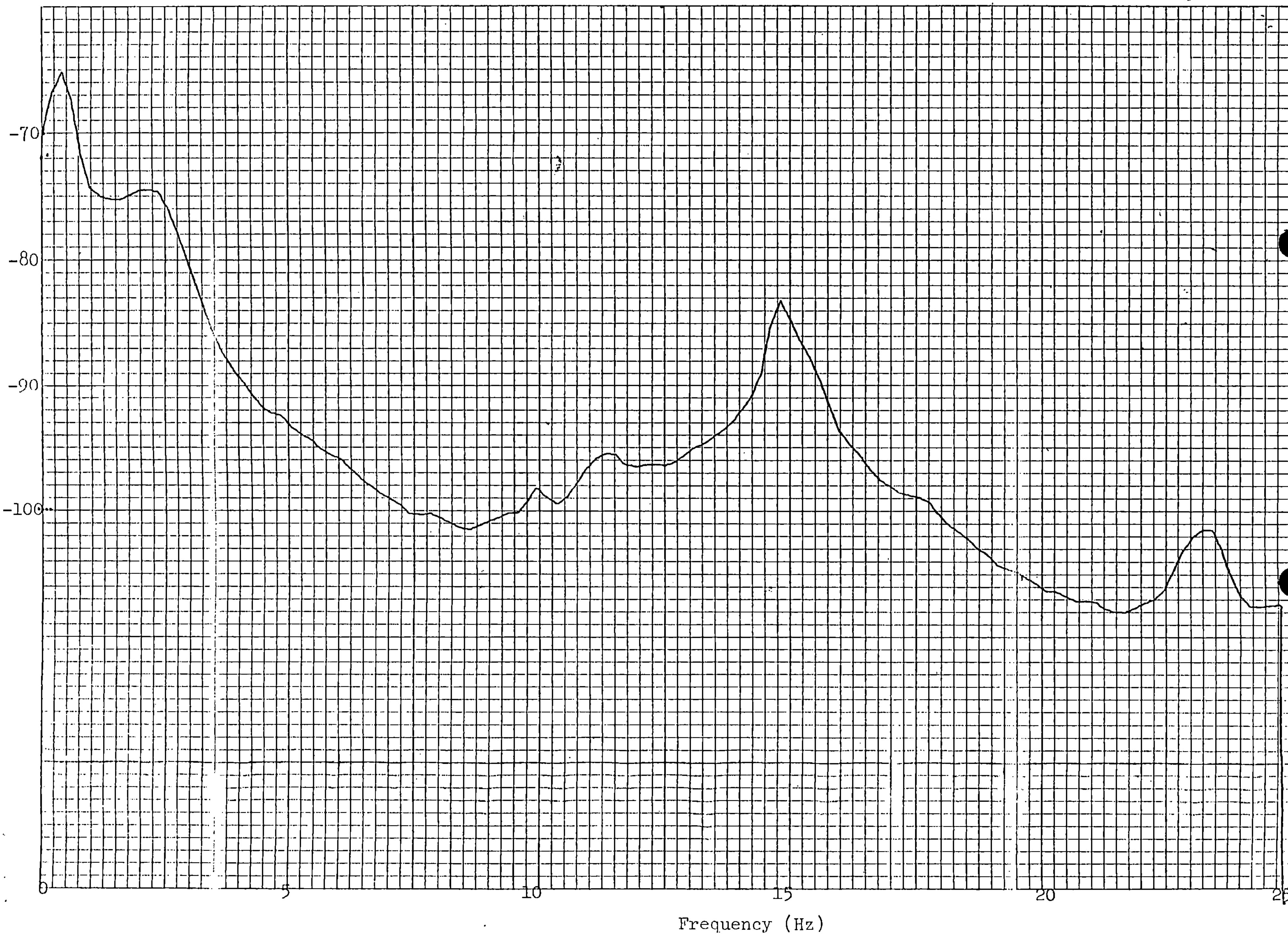
Integral Amplitude Probability Distribution (IAPD) NI-08 6-29-81

06-29-81 07-08
IAPD 08



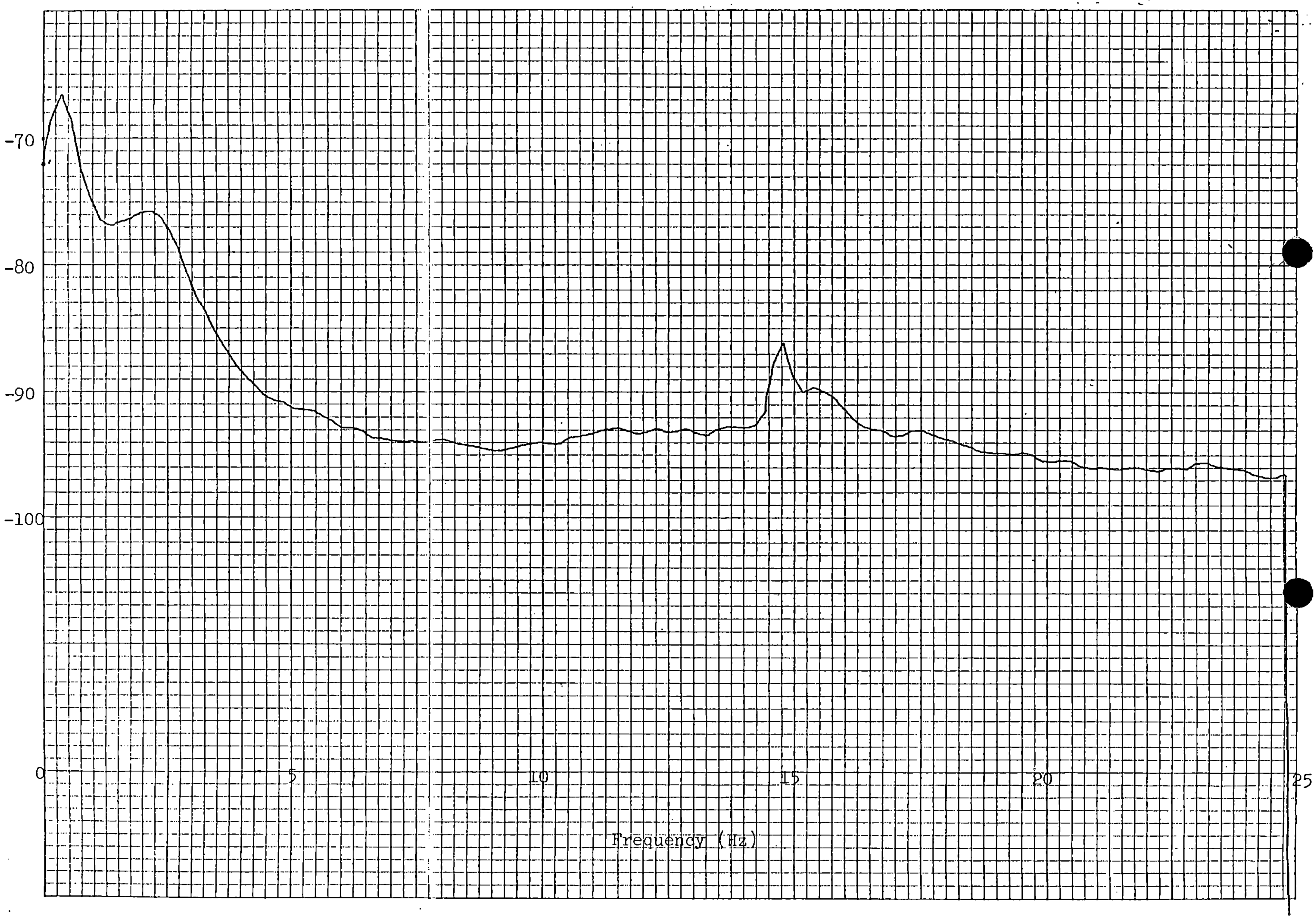
0579 1380 46 0702

FIGURE 7 Normalized Power Spectral Density (NPSD) NI-05 6/30/80



0579 1381 46 0702

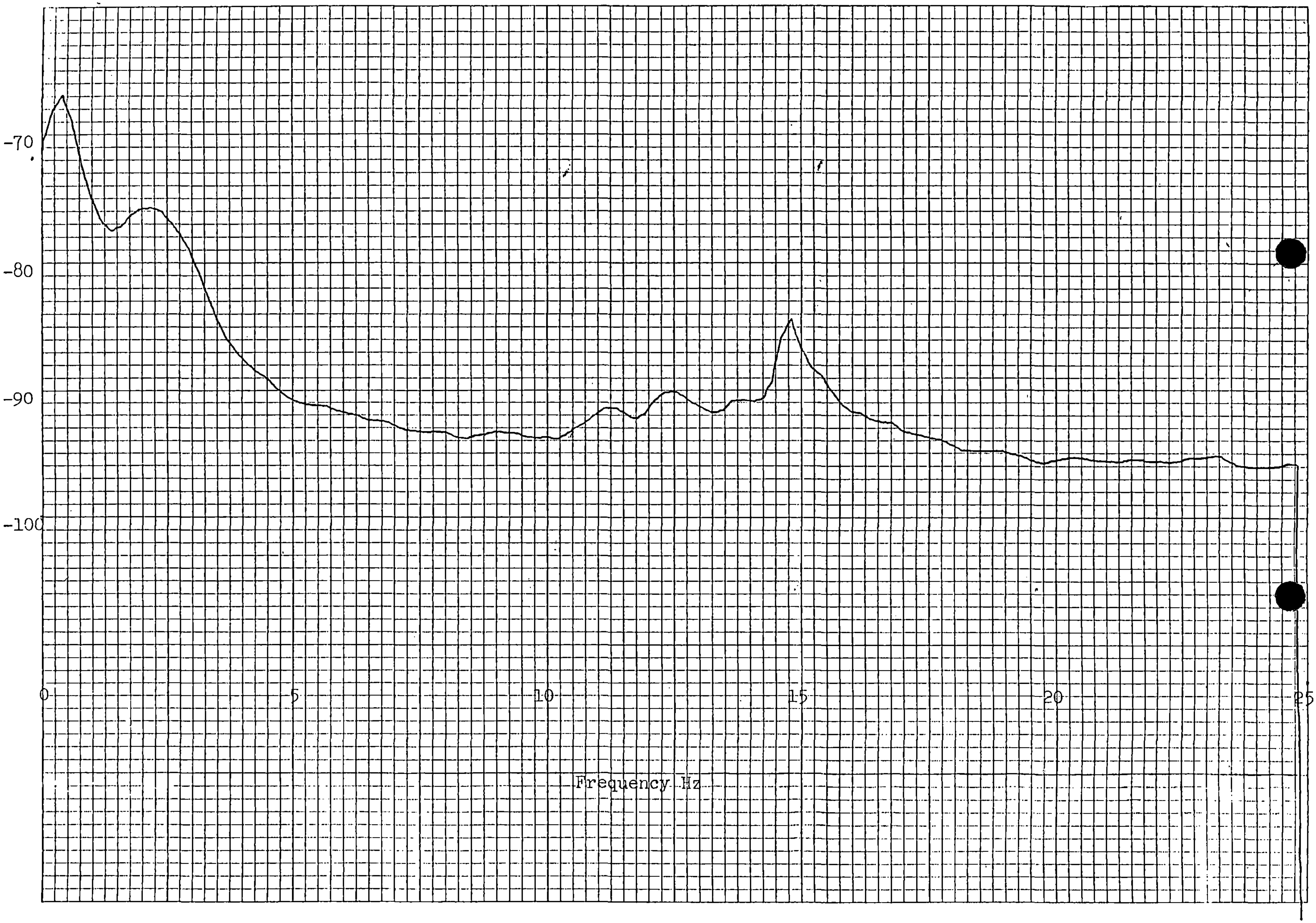
FIGURE 8 Normalized Power Spectral Denisty (NPSD) NI-06 10-30-80



0 5 7 9   1 3 8 7

K+E 10 X 10 TO THE INCH • 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.   46 0702

FIGURE 9   Normalized Power Spectral Density (NSPD) NI-07 6/30/80



0579 1388

46 0702

FIGURE 10

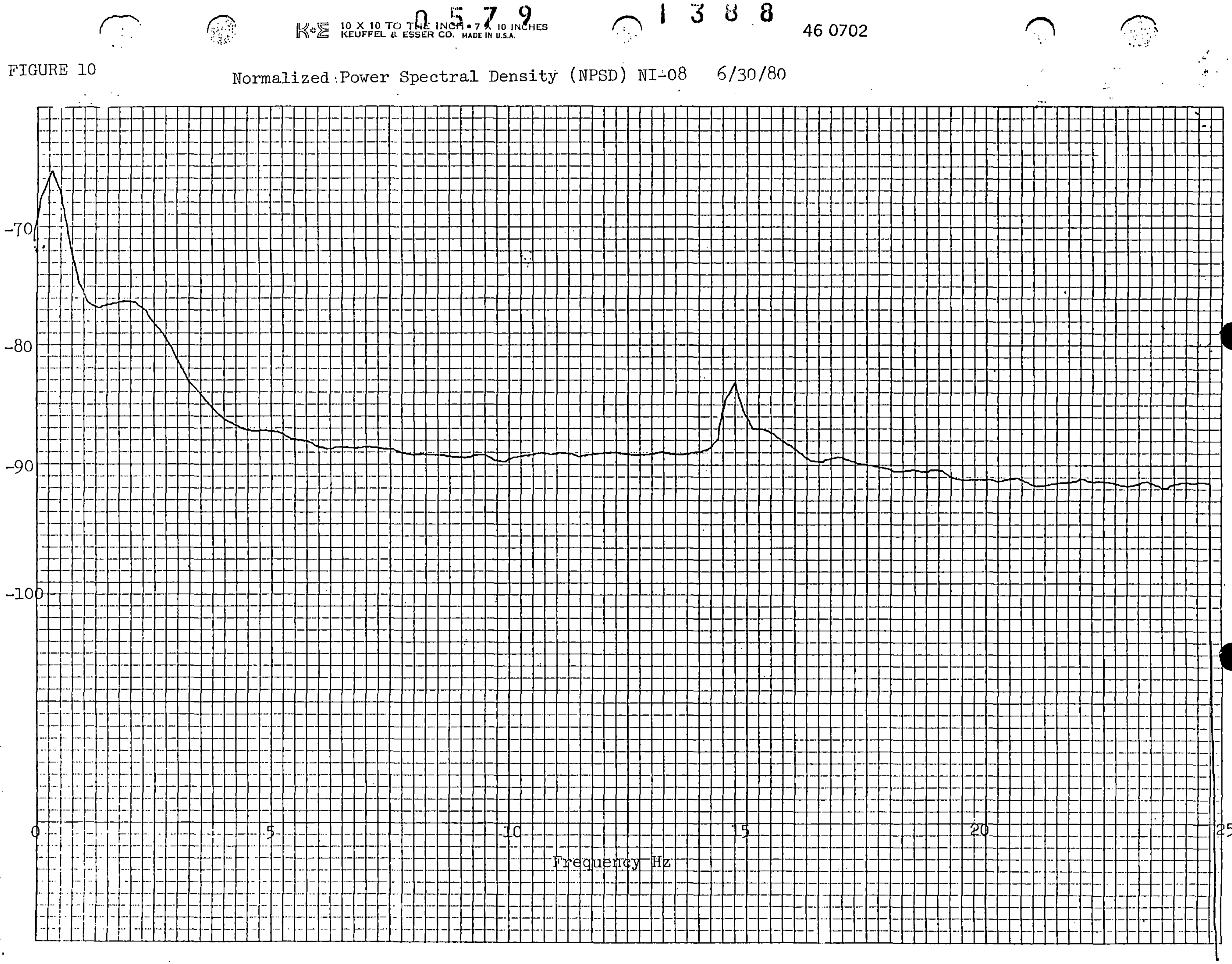


FIGURE 11

Normalized Power Spectral Density (NPSD) NI-05 2-9-81

2-9-81 05-06
NPSD 05

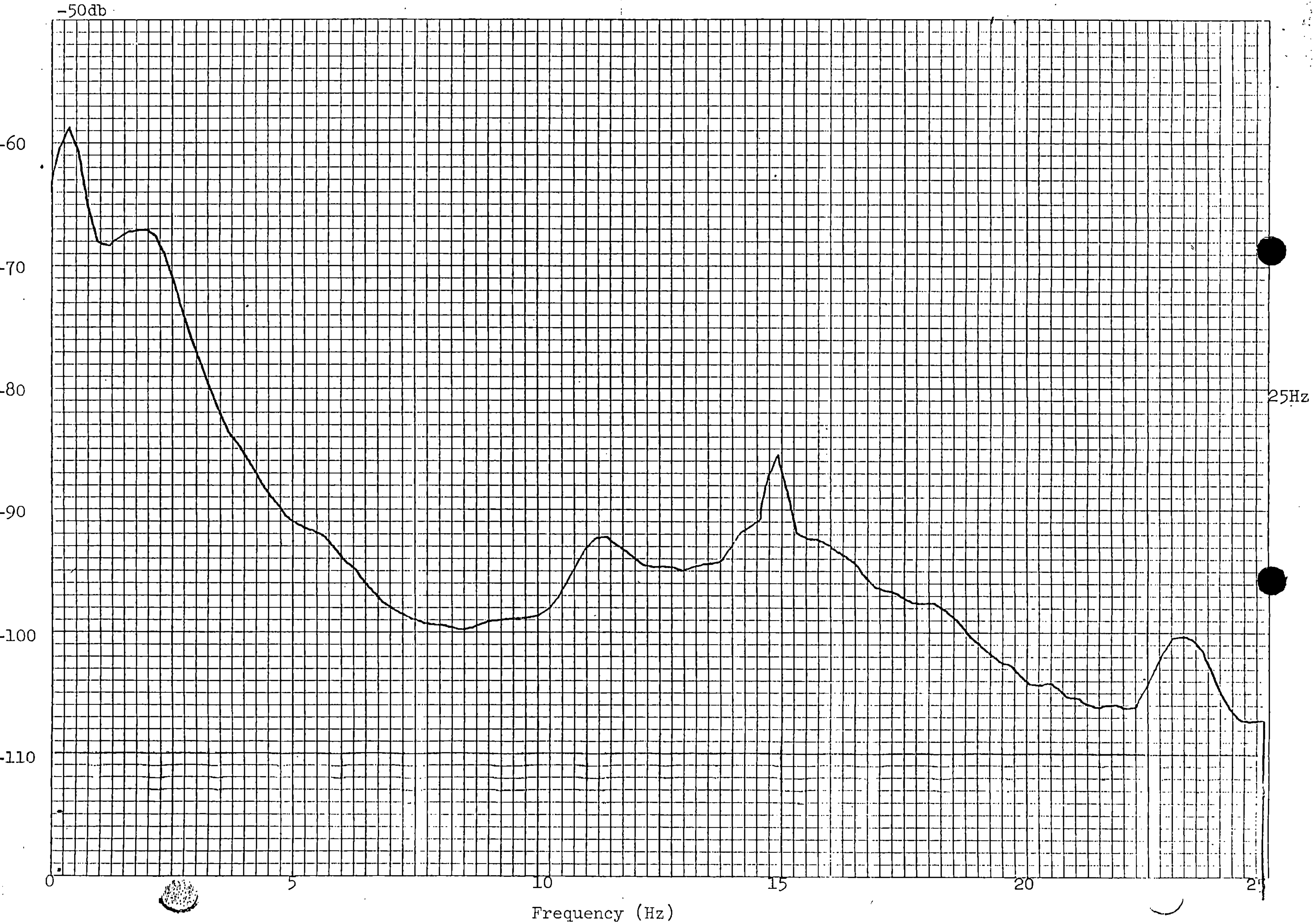


FIGURE 12

2-9-81 05-06
NPSD - 06

Normalized Power Spectral Density (NPSD) NI-06 2-9-81

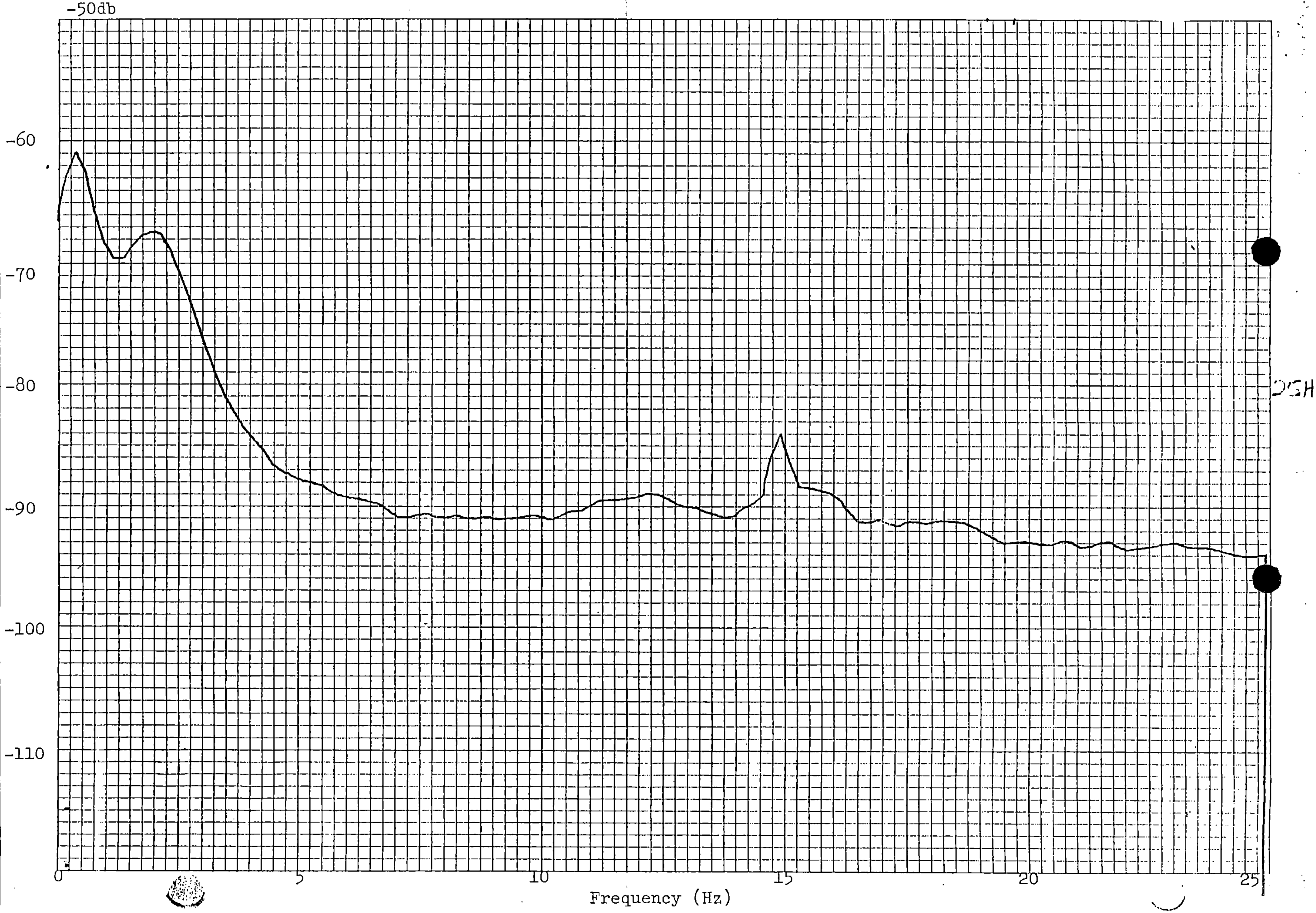
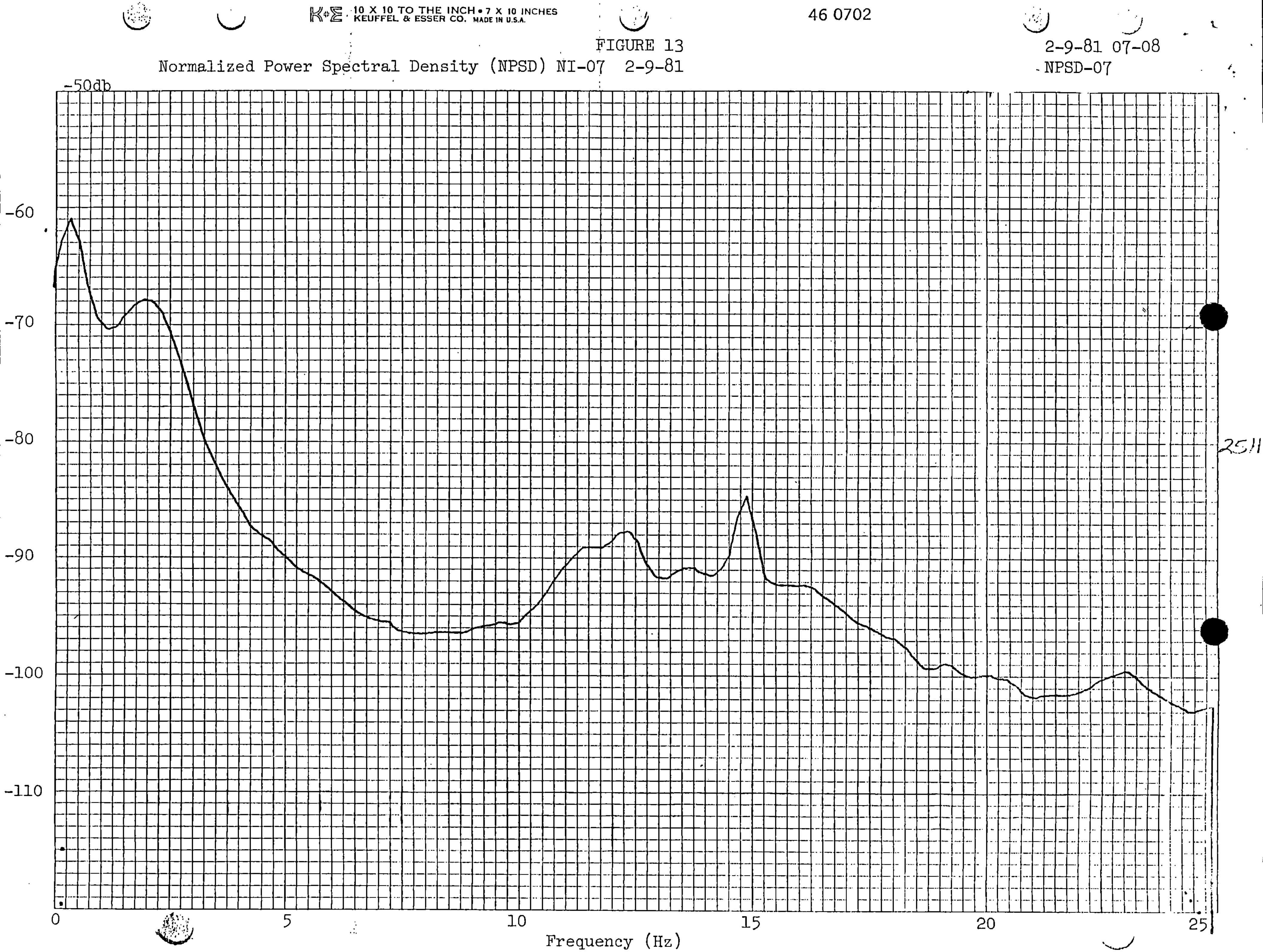


FIGURE 13

Normalized Power Spectral Density (NPSD) NI-07 2-9-81

2-9-81 07-08
NPSD-07



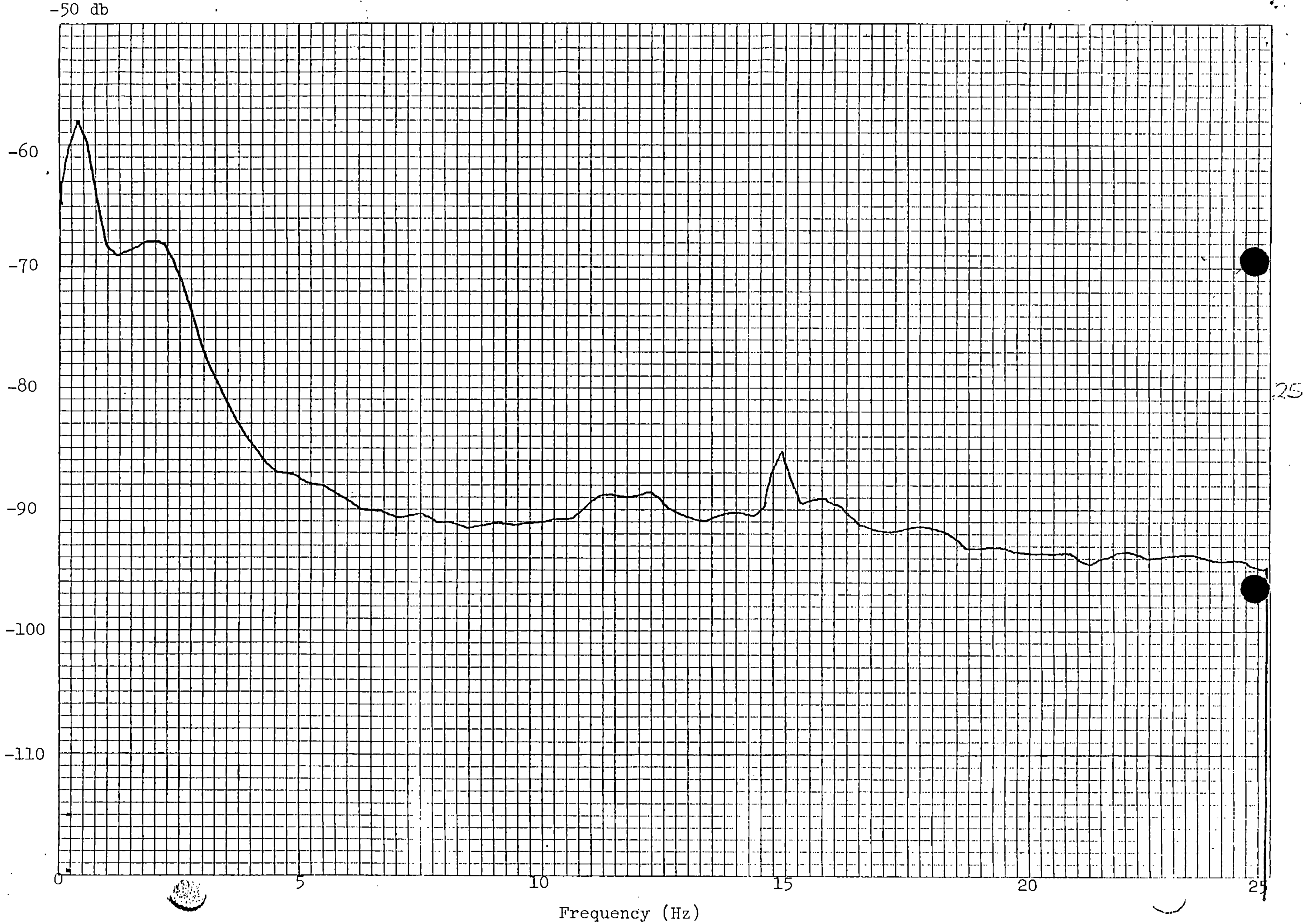
K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0702

2-9-81 07-08
NPSD -08

FIGURE 14

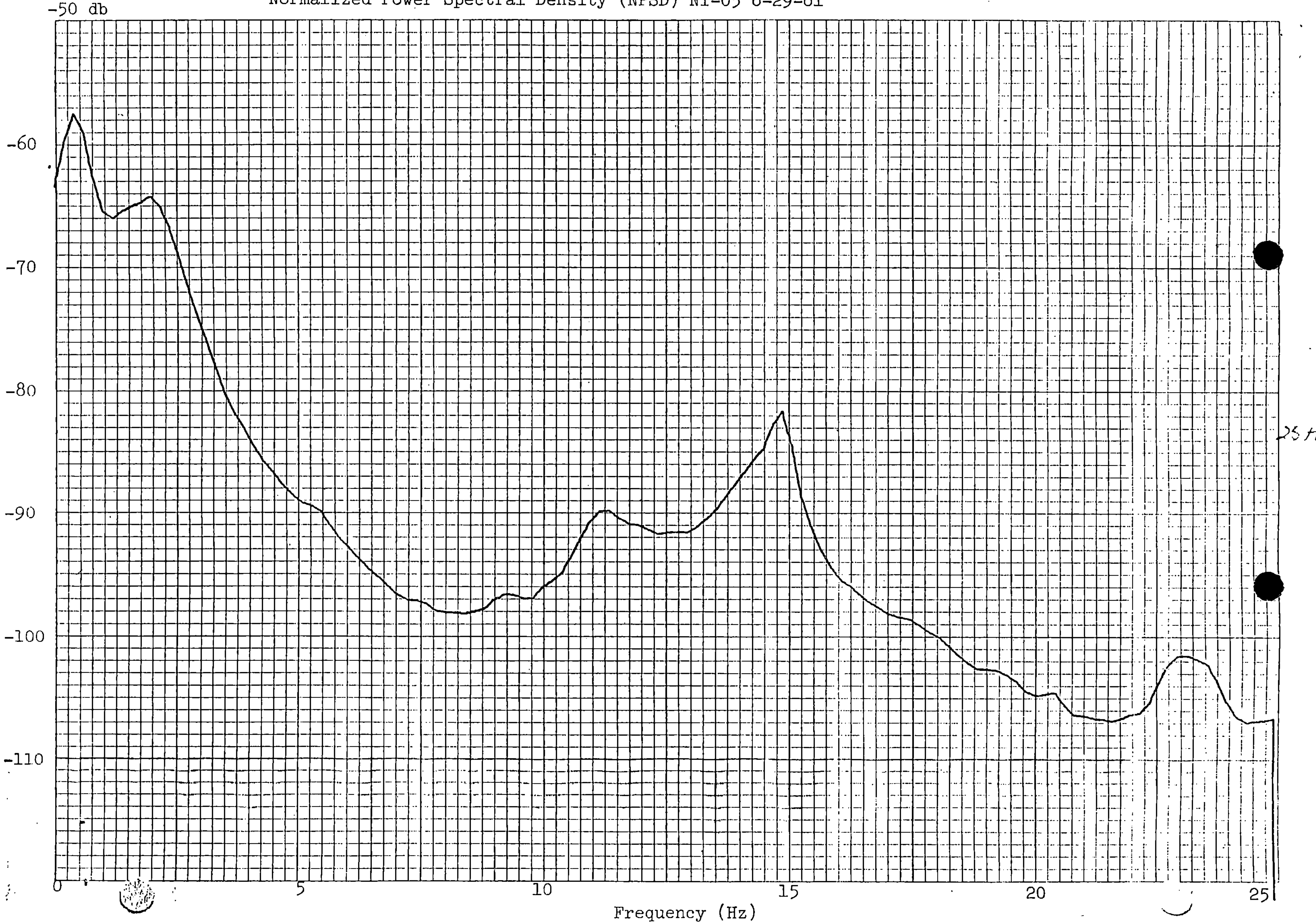
Normalized Power Spectral Density (NPSD) NI-08 2-9-81



06-29-81 05-06
NPSD 05

FIGURE 15

Normalized Power Spectral Density (NPSD) NI-05 6-29-81



46 0702

06-29-81 05-06
NPSD-06

FIGURE 16
Normalized Power Spectral Density (NPSD) NI-06 6-29-81

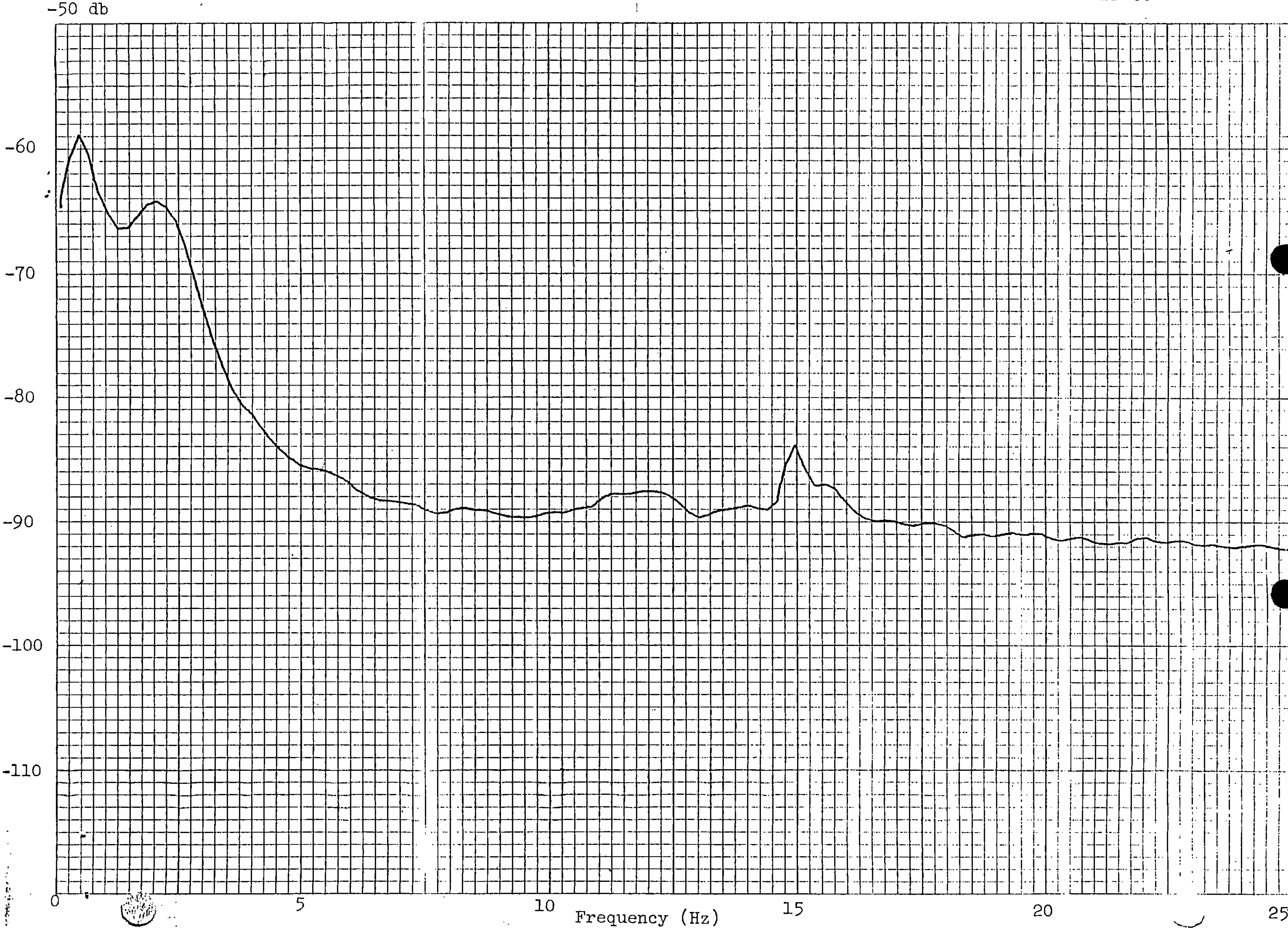
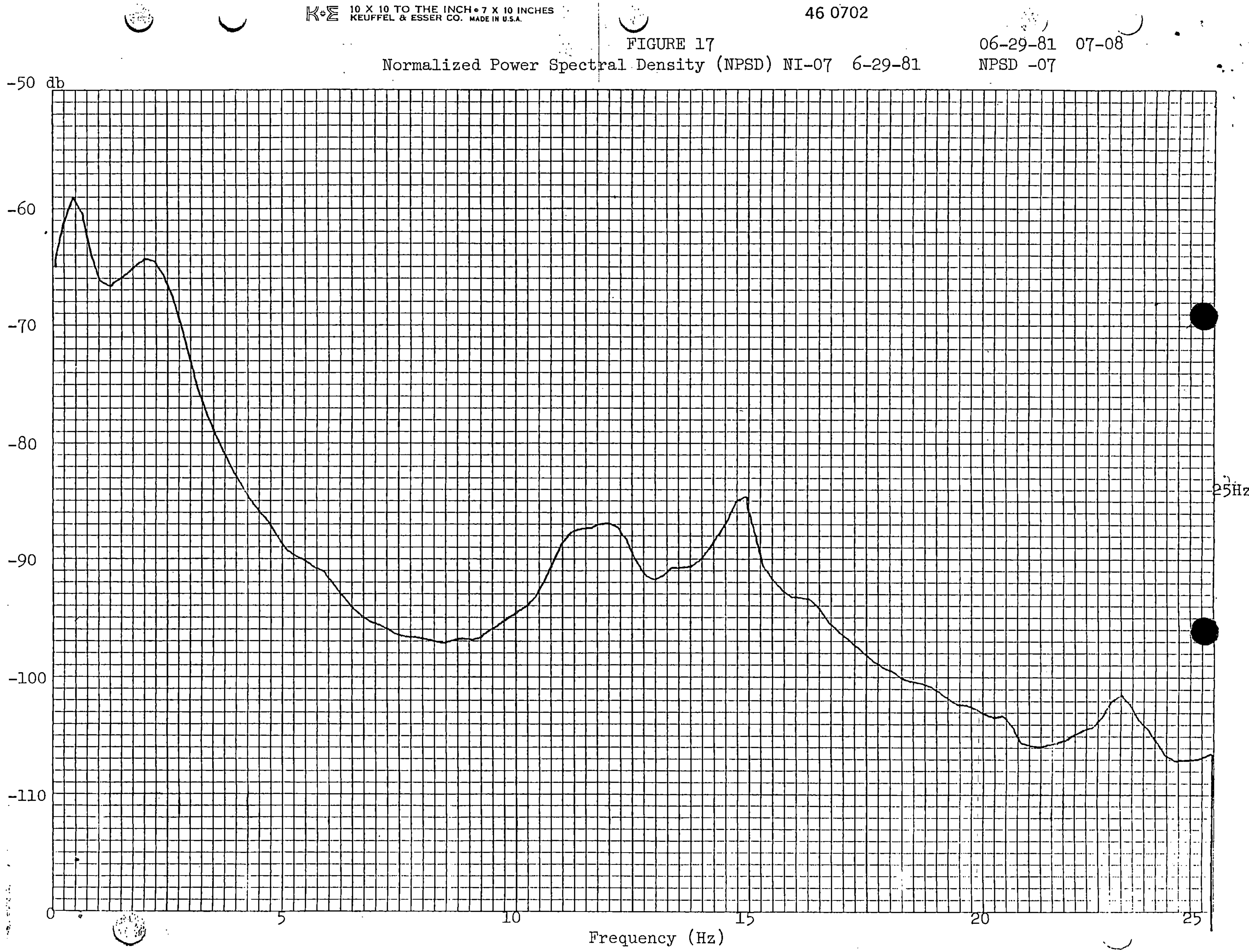


FIGURE 17
Normalized Power Spectral Density (NPSD) NI-07 6-29-81

06-29-81 07-08
NPSD -07



46 0702

FIGURE 18

06-29-81 07-08
NPSD 08

Normalized Power Spectral Density (NPSD) NI-08 6-29-81

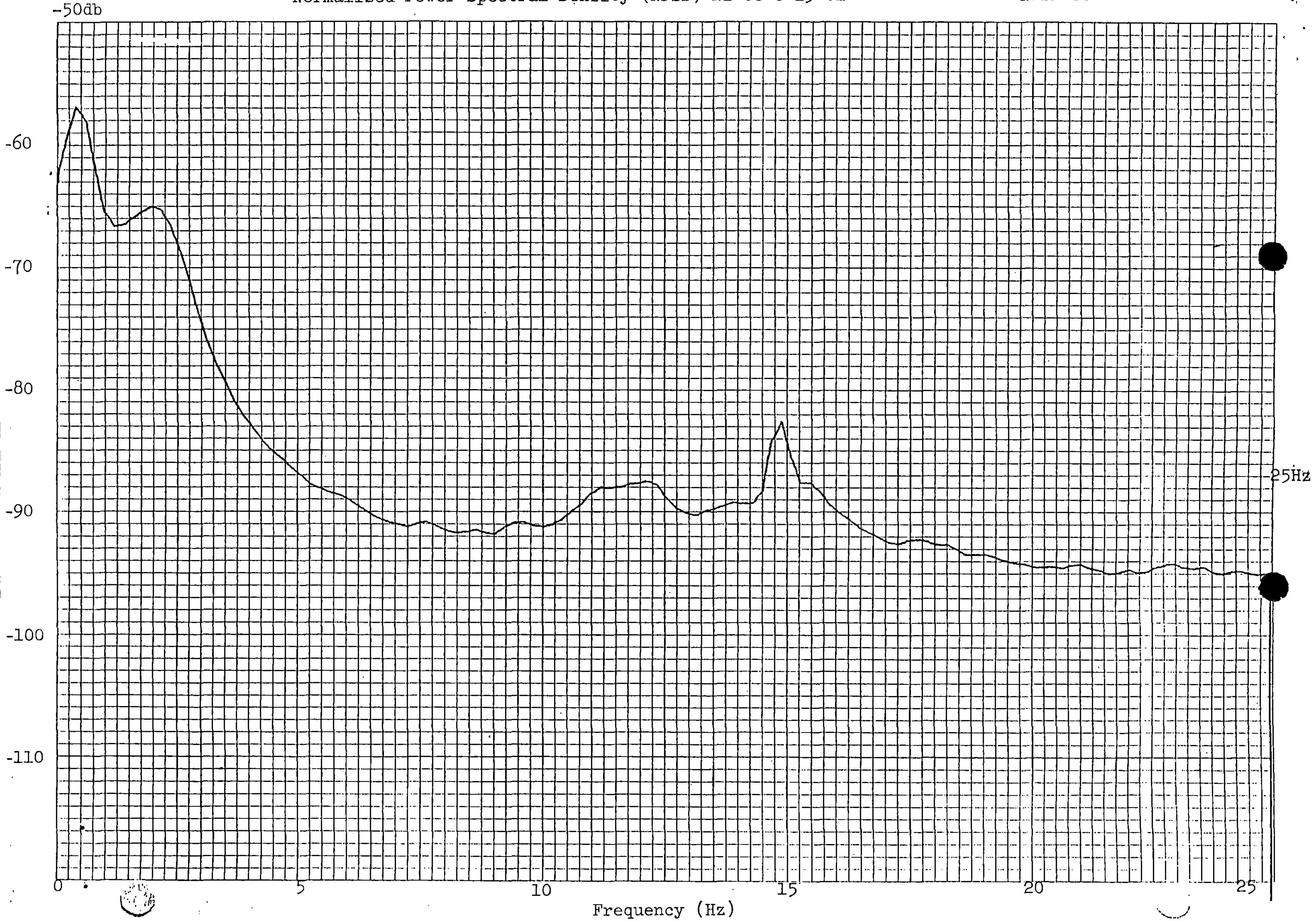
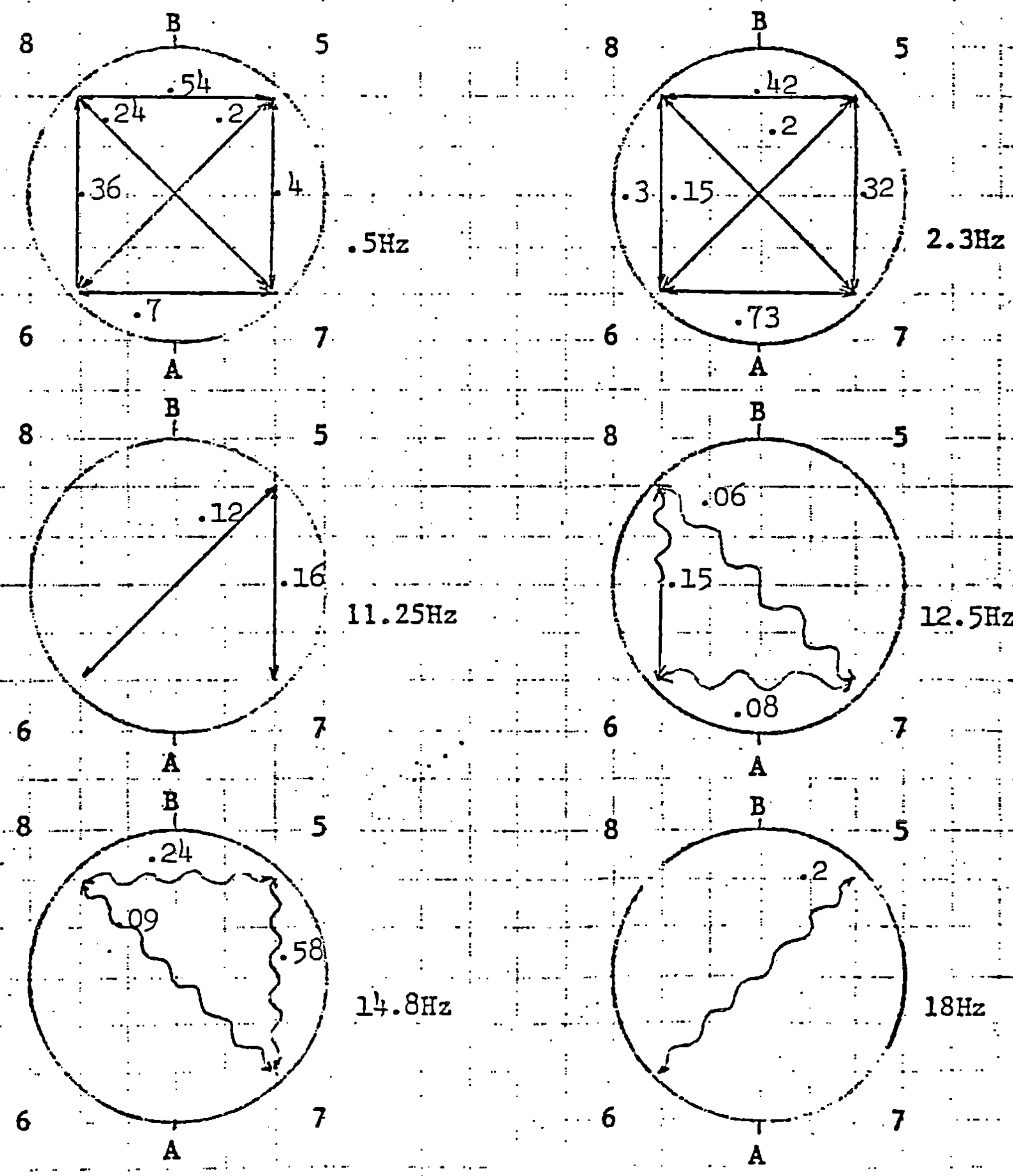


FIGURE 19

COHERENCE AND PHASE DIAGRAMS

JUNE 1980



Legend: 〰〰→ 180° Phase

⟵⟶ 0° Phase

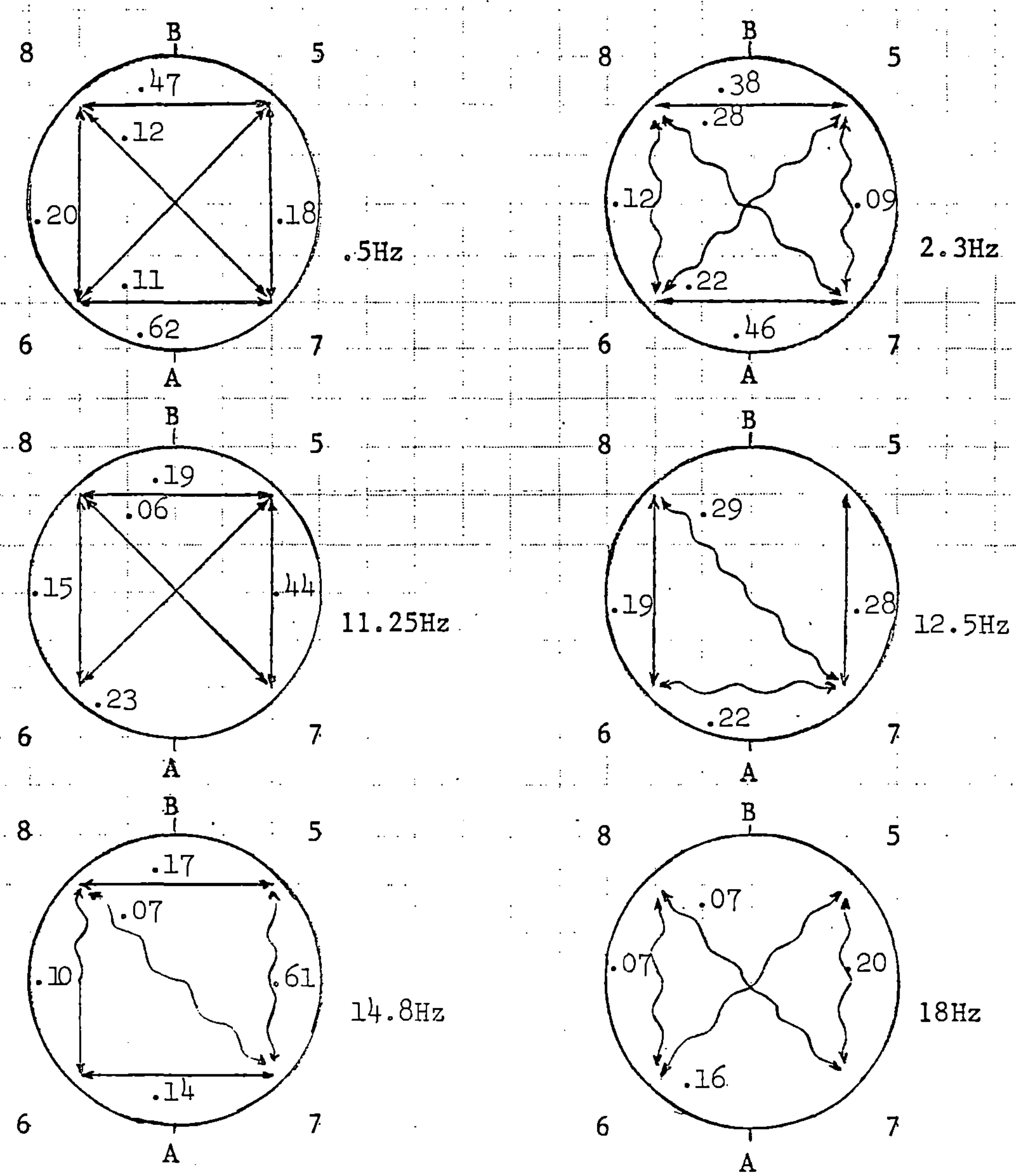
5,6,7,8 Excore Detectors

A,B Hot Legs Steam Generator

FIGURE 20

COHERENCE AND PHASE DIAGRAMS

FEBRUARY 1981



Legend: 180° Phase

0° Phase

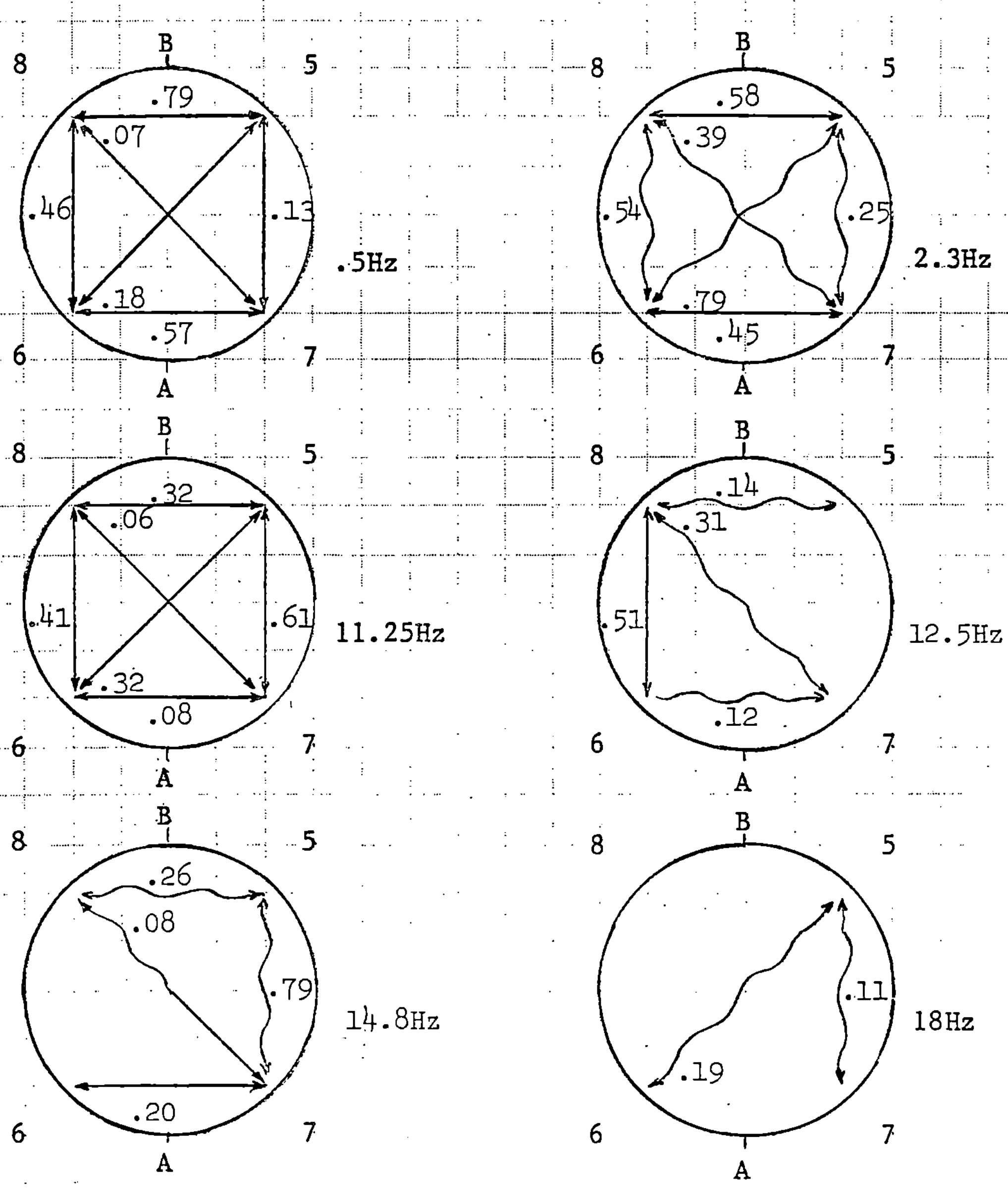
5,6,7,8 Excore Detectors

A,B Hot Legs Steam Generator

FIGURE 21

COHERENCE AND PHASE DIAGRAMS

June 1981



Legend: 180° Phase

0° Phase

5,6,7,8 Excore Detectors

A,B Hot Legs Steam Generator

REFERENCES

1. Palisades Plant Technical Specifications, Section 4.13.
2. Letter, DMKennedy to JAMeincke, "Palisades Plant - Reactor Internals Vibration Monitoring M and N Sigma Limits", May 14, 1979.
3. "Calculation of the Scale Factor for Inference of Pressurized Water Reactor Core Barrel Motion from Neutron Noise Spectral Density", Nuclear Technology, Vol. 40, mid August 1978.
4. "Quantification of Core Barrel Motion Using an Analytically Derived Scale Factor and Statistical Reactor Noise Descriptors", Nuclear Technology, Vol.40, mid August 1978.
5. Reactor Noise by Joseph Thie, Rowman and Littlefield, Inc. 1963
6. XN-74-33, Summary of Mechanical Tests of Palisades Fuel Bundle and Component Parts, September 3, 1974.