Consumers Power Company 50-255 Palisades

Report entitles "Reactor Internal Nosie Monitoring".....

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CONSUMERS POWER COMPANY
BULK POWER
PALISADES NUCLEAR PLANT

REACTOR INTERNALS NOISE MONITORING TESTS

COMPLETION OF REACTOR BASELINE NOISE DATA

May 22, 1975

REACTOR INTERNALS NOISE MONITORING TESTS

Abstract

In compliance with Technical Specification 4.13, nuclear noise surveillance is being conducted on the Palisades core. Initial data was taken in 1974 for baseline measurements at 25% and 50% of full power. The unit was subsequently removed from service and placed in cold shutdown for main turbine condenser retubing and Steam Generator tube repairs for the remainder of 1974. In 1975 the unit was returned to service and passed the 25% power level, which marked the reinitiation of PHASE I and PHASE II measurements, on April 3, 1975. Measurements of amplitude probability distributions (APD), power spectral densities (PSD), coherence, and phase angle relationships of excore neutron flux detectors were recorded. The findings substantiate that the maximum core barrel motion in any mode of movement is no greater than 1.0 mil (0.0010 inches) peak-to-peak. The noise data presented within contends that the core barrel is firmly attached at the reactor flange and that there is no indication of wearing, rubbing or unanticipated motion.

Introduction:

Historically at Palisades neutron noise analysis techniques were used to investigate anomalous reactor noise signals.[1,2] These techniques accurately predicted the mode and the amount of internals wear, that was subsequently discovered upon a physical reactor internals examination in October of 1973.[3]

After the reactor internals repairs extensive noise analysis is being employed to determine if the previous anomalous core barrel motion has been arrested.

Signal Analysis:

The out of core power range uncompensated ion chambers are utilized as the primary source of information in analyzing core barrel motion at Palisades. These detectors are referred to as excores and these locations with respect to the core are shown in Figure No. 1. In addition, data from these sensors has been acquired to complement the gathering of baseline noise parameters. These other sensors include Steam Generator differential pressure sensors, primary system pressure sensors, reactor vessel exterior-mounted accelerometers, cobalt incore detectors and reactor coolant loop resistance temperature devices.

Excore signals are processed prior to reactor noise analysis to remove the DC component of the signal and provide additional amplification of the noise or "ripple" content of the signal. Low pass digitally tuned filters are employed as anti-aliasing devices. The signal processing path is shown in Figure No. 2.

Real Time Noise

Recordings of real time noise signals are shown in Figure No. 3. These signals were high pass filtered a 0.025Hz and low pass filtered at 20.0 Hz. The excores are 180° across the reactor core. It can be seen that the low frequency (approximately 1/2 Hz) noise is in-phase in some cases, whereas in other cases no phase relationship is apparent. The peak to peak magnitude is about 20 millivolts and the DC level at which this data was taken is 7.20 volts.

Figure No. 3a compares the noise seen at present to that recorded while reactor internals wearing was occurring. Note that the scales for each are identical and that the phase relationship for the same two excores located across the core was 180° in 1973.

It is important to note that present data in the low frequency regions below about 4 Hz is in phase for all excores whereas previous data in 1973 indicated out of phase relationships for all excores across the core.

The phase relationships are utilized to detect core barrel motion based upon the fact that a decrease in the core barrel to reactor vessel water annulus as the barrel moves results in an increase in the flux at the local detector. If this is occurring in a cantilever mode, the excore across the core will notice a decrease in flux corresponding to the barrel motion away from it and the subsequent increase in water annulus. Detection of other modes of core barrel motion are possible and they will be discussed later.

Power Spectra

Figures No. 4 through No. 11 represent power spectral densities for the excore detectors measured at essentially full power. They are computed over ranges of 0.025Hz to 25.0Hz and 0.025Hz to 50.0Hz. The 50.0Hz spectra provide better perspective of the dynamic range (> 60dB) available for these analyses.

During the reactor internals wearing in 1973, the core barrel movement was essentially a combination of cantilevered and rocking modes. Interpreting data in this case was obvious to the naked eye on real time charts of the excore signals. Present data requires the ability to conduct analyses on signal levels less than 1 millivolt "ripple" out of a 10 volt DC level signal. Computing power spectral information for such requires about 40dB to 50dB dynamic range hardware at a minimum, coupled with appropriate double precision software. The equipment employed, including software, has a dynamic range of at least 60dB which is adequate for these analyses.

The apparent areas of interest are in the 0.025Hz to 5.0Hz region and in the 11.0Hz to 20Hz region. The sharp peak seen at 40.0Hz is a result of aliasing of the 60 cycle E-M pickup. The sharp peak at 14.8Hz (888 rpm) is the primary coolant pumping frequency. This has historically been present in all spectra taken at Palisades and elsewhere. In some spectra the second harmonic (29.6Hz) can also be identified.

It should be noted that all of the spectra (PSD's) are normalized to units of Hz^{-1} and are plotted in dB, decibels, (where 0 dB would be equivalent to 100% of the DC level) versus linear frequency. Previous levels of power spectral densities (PSD) of excores at Palisades were 20 dB (100 times) higher when the reactor internals wearing occurred. This comparison is shown in Figure No. 12.

Coherence and Phase Relationships

The coherence of two signals represents the relative commonality between those signals as a function of frequency. Absolute correlation of two signals without extraneous noise in the frequency range of interest would result in a coherence of 1.0. No correlation results in 0.0 coherence. The coherence is computed by the standard formula

$$COH = \quad (f) = \frac{|CPSD\ (f)\ |^2}{PSD_A\ (f)\ PSD_B\ (f)}$$

where:

$CPSD\ (f)$ = cross power spectral density of signals A and B as a function of frequency.

$|CPSD\ (f)|^2$ = magnitude squared of CPSD (f).

$PSD_A\ (f)$ = power spectral density of signal A.

$PSD_B\ (f)$ = power spectral density of signal B.

A summary of the coherences measured to date are as follows:

DETECTORS ON SAME SIDE OF CORE

Frequency	Detectors	Coherence (Max)	Phase Angle (Ø)
0.025 Hz to 5.0 Hz	NI-05 & NI-07	0.7	0°
11.0 Hz to 14.5 Hz	NI-05 & NI-07	0.3	0°
15.0 Hz to 17.5 Hz	NI-05 & NI-07	0.7	180°
17.5 Hz to 20.0 Hz	NI-05 & NI-07	0.8	180°
0.025 Hz to 5.0 Hz	NI-06 & NI-08	0.7	0°
11.0 Hz to 14.5 Hz	NI-06 & NI-08	0.3	0°
15.0 Hz to 17.5 Hz	NI-06 & NI-08	0.7	180°
17.5 Hz to 20.0 Hz	NI-06 & NI-08	0.7	180°
0.025 Hz to 5.0 Hz	NI-06 & NI-07	0.7	0°
11.0 Hz to 14.5 Hz	NI-06 & NI-07	0.4	180°
15.0 Hz to 17.5 Hz	NI-06 & NI-07	0.7	180°
17.5 Hz to 20.0 Hz	NI-06 & NI-07	0.4	0°
0.025 Hz to 5.0 Hz	NI-05 & NI-08	0.7	0°
11.0 Hz to 14.5 Hz	NI-05 & NI-08	0.3	180°
15.0 Hz to 17.5 Hz	NI-05 & NI-08	0.7	180°
17.5 Hz to 20.0 Hz	NI-05 & NI-08	0.3	0°

DETECTORS ACROSS THE CORE

Frequency	Detectors	Coherence (Max)	Phase Angle (Ø)
0.025 Hz to 5.0 Hz	NI-05 & NI-06	0.5	0°
11.0 Hz to 14.5 Hz	NI-05 & NI-06	0.4	0°
15.0 Hz to 17.5 Hz	NI-05 & NI-06	0.4	0°
17.5 Hz to 20.0 Hz	NI-05 & NI-06	0.8	180°
0.025 Hz to 5.0 Hz	NI-07 & NI-08	0.5	0°
11.0 Hz to 14.5 Hz	NI-07 & NI-08	0.2	0°
15.0 Hz to 17.5 Hz	NI-07 & NI-08	0.7	0°
17.5 Hz to 20.0 Hz	NI-07 & NI-08	0.2	180°

ADJACENT DETECTORS

Frequency	Detectors	Coherence (Max)	Phase Angle (Ø)
0.025 Hz to 5.0 Hz	NI-05 & NI-09	0.9	0°
11.0 Hz to 14.5 Hz	NI-05 & NI-09	0.7	0°
15.0 Hz to 17.5 Hz	NI-05 & NI-09	0.8	0°
17.5 Hz to 20.0 Hz	NI-05 & NI-09	-	0°
0.025 Hz to 5.0 Hz	NI-08 & NI-10	0.9	0°
11.0 Hz to 14.5 Hz	NI-08 & NI-10	0.7	0°
15.0 Hz to 17.5 Hz	NI-08 & NI-10	0.8	0°
17.5 Hz to 20.0 Hz	NI-08 & NI-10	-	0°
0.025 Hz to 5.0 Hz	NI-05 & 7-5*	0.9	0°
0.025 Hz to 5.0 Hz	7-5 & 26-5*	0.9	0°

* cobalt full length incores

All of the low frequency noise (0.025 Hz to 5.0 Hz) is in phase in all measurements to date. Also, there exists large coherence between adjacent detectors over the entire frequency range.

Example phase and coherence plots are shown in Figures No. 13 through No. 17 for various combinations of excores. Note that the coherence is represented by the dots which are scaled from 0.0 to 0.8 (y - axis) while the phase is the solid line from -180° through +180° (y - axis) and both are versus linear frequency (x - axis).

Amplitude Probability Distributions:

Daily recording of these functions continues for excores. The APD's can be shown to be gaussian using a rigorous test of plotting the IAPD on probability paper. Sample APD's are shown in Figures No. 18 and No. 19.

When using the PSD information in conjunction with the APD, one can see that the APD (when the signal is filtered from 0.025 Hz to 20.0 Hz) is essentially the amplitude-histogram of the low frequency noise from 0.025 Hz to about 3.0 Hz. Since previous core internals motion was exhibited in the low frequency ranges (up to 1.5 Hz) and these noise signals were the predominate part of the excore noise spectrum, the APD became useful in representing such phenomena as clipping.[1] This later was shown to be directly related to reactor internals snubbing in conjunction with reactor physical clearances. Present data indicates that the low frequency noise is not core barrel movement-related but instead is a reactivity-related phenomena. Indications are that the high coherence region at about 15.5 Hz is representative of true core barrel motion. To assess whether this noise is indeed random, the excore signals were band pass filtered at 15 Hz (with a 24dB/octave roll off) and the APD computed. This type of "Zoom-APD" looks discreetly at the noise in the 15 Hz region of the spectra. The results are shown in Figures No. 20 through No. 22. The x - axis is normalized to the DC level of the excore while the y - axis is an arbitrary linear scale. The results indicate that the noise about 15 Hz is indeed random and shows no preferred or restricted motion.

Noise Amplitudes:

Throughout the Baseline Program, noise levels have been quantified in % RMS. Previously reported values have been recalculated based upon software and other modifications since the origin of the surveillance program in October of 1974. As a result, the previous noise amplitude values reported have been slightly altered. A summary of the data for the noise amplitudes are shown below:

$$\% \text{ RMS} = (\sigma/\text{Mean}) \times 100\%$$

25% FULL POWER

	0.025 Hz to 2.5 Hz	2.5 Hz to 25 Hz
NI-05	0.104%	0.023%
NI-06	0.098%	0.023%
NI-07	0.095%	0.021%
NI-08	0.096%	0.022%
NI-09	0.081%	0.025%
NI-10	0.081%	0.025%

50% FULL POWER

	0.025 Hz to 2.5 Hz	2.5 Hz to 25 Hz
NI-05	0.087	0.020
NI-06	0.080	0.021
NI-07	0.078	0.020
NI-08	0.088	0.019
NI-09	0.078	-
NI-10	0.076	-

75% FULL POWER

	0.025 Hz to 2.5 Hz	
NI-05	0.070	0.019
NI-06	0.065	0.019
NI-07	0.064	0.019
NI-08	0.070	0.019
NI-09	0.074	-
NI-10	0.074	-

90% FULL POWER

	0.025 Hz to 2.5 Hz	2.5 Hz to 25 Hz
NI-05	0.073	0.017
NI-06	0.065	0.018
NI-07	0.063	0.018
NI-08	0.070	0.018
NI-09	0.072	-
NI-10	0.075	-

In addition, Noise Amplitude Calculations were performed in the 10.0 Hz to 20.0 Hz regions where coherence and phase information was appliable. The results for all excores are as follows:

	10.0 Hz to 14.5 Hz	14.5 Hz to 20.0 Hz	15.0 Hz to 20.0 Hz
NI-05	0.0046	0.0077	0.0060
NI-06	0.0038	0.0059	0.0049
NI-07	0.0052	0.0072	0.0051
NI-08	0.0045	0.0074	0.0054

Additional Analyses:

Spectral analyses were run on the steam generator signals in conjunction with various excore detectors. Figure No. 24 shows the comparison of F1A-0102, which is a summation of the steam generator signals, superimposed upon a representative excore detector PSD. Note that both PSDs are normalized to Hz^{-1} . There is a large **qualitative** resemblance between spectra but based upon the coherence shown in figure #25 no conclusive results are formulated at this time.

Comparison to Previous Data:

Prior to the Reactor Internals repair at Palisades computations of the % RMS were made. The present values for the baseline program are compaired for the 0.025 hz to 5.0 hz region.

% RMS

	Prior to Repair	Post Repair
NI-05	0.80	0.079
NI-06	0.69	0.073
NI-57	0.57	0.068
NI-08	0.70	0.080
NI-09	0.96	0.077
NI-10	0.94	0.078

There has been a slight reduction in the % RMS calculated for the baseline program as power was increased. This is probably due to the improved resolutions of the excore signal to white noise ratio. As can be seen the data shows a reduction of noise levels by a factor of ten in this frequency region. There is additional supporting information from phase relationships (0° all around the core) that this area of the excore spectra is not related to core barrel motion. In addition data taken on a cobalt incore (7-5) indicates a coherence of 0.9 with excore NI-05 and a coherence of 0.9 with another cobalt incore (26-5), located at the core center, in the 0.025 Hz to 4.0 Hz region. This information coupled with the 0° phase between NI-05 and NI-06 also contradicts previous measurements in 1973. At that time (1973) incore 7-5 was shown to be 180° (out of phase) with excore NI-06. The noise in the 0.025 Hz to 5.0 Hz region is presumably a complex combination involving the following factors:

1) The 0.5 Hz hydraulic resonance of the individual primary coolant loops. Note that this was measured to be 0.49 Hz for loop A and 0.52 Hz for loop B where high coherence exists within loops but no loop to loop coherence was obviously evident.

2) A random/reactivity noise.
3) The effects of hydraulic flow pertubations exciting the fuel rod harmonics about 1.8 Hz.
4) Effect of flow pertubations upon the annulus between the core barrel and the reactor vessel, thus, causing fluctuations in the "window" through which the excore perceives flux information.
5) Mechanical motion in the loop hot legs and/or steam generator.

In examing frequency regions of the spectra a useful relationship employed is the product of the coherence times the PSD. This presents what areas of the spectra (in the case of two excores) are of interest and weights them by their relative correlation (i.e. coherence) to each other. Sample plots are shown in figures No. 26 and No. 27. Again this emphasizes the 0.025 Hz to 3.0 Hz region containing peaks at 0.5 Hz and 1.8 Hz, the 10.0 Hz to 15.0 Hz region containing peaks at 10.75 Hz, 14.0 Hz, and 14.8 Hz, and the 15.0 Hz to 20.0 Hz region containing peaks at 15.5 Hz and 18.0 Hz.

A summary of the phase plots is shown in figure # 28. The 15.5 Hz peak exhibits a mode of core barrel vibration that is presumably shell-type. The mode has been described in detail by J. Thie[5] based upon these results. Essentially the modes of such a shell movement are located at 0°, 90°, 180° and 270°. Figure #29 exhibits this experimentally suggested mode.

Previously published calculations[3] state that the core barrel shell mode frequency was found at 21 to 23 Hz. There is a peak seen in the excore spectra (refer to figures No. 4 through No. 7) at about 23 Hz; However, analyses conducted by band passing the signal from 20.0 to 30.0 Hz showed no observable coherence around 23.0 Hz.

The peaks in the 10.0 Hz to 15.0 Hz regions show some coherence with external vessel accelerometers[5] and may indicate either cantilevered movement in the east-west direction or actual reactor vessel movement in that direction.

The 18.0 Hz peak based upon phase and coherence information preliminarily indicates a cantilevered mode of vibration in the north-south direction.

By employing the most conservative conversion factor for % rms to mils of movement[3], 0.02 % rms/mils, the following numbers are generated:

		Postulated Movement	Mils (Rms)
10.0 to 15.0 Hz		Core Barrel E-W Cantilevered	0.10
	or	Reactor Vessel E-W Movement	0.10
15.5 Hz		Core Barrel and Core Shell Mode	0.35
18.0 Hz		Core Barrel N-S Cantilevered	0.25

The noteworthy results show motion calculated in micro inches (100, 250 and 300) which well represents the sensitivity available when utilizing neutron noise techniques..

Summary of Findings and Recommendations:

1. Present data and calculations for the Reactor Noise Baselines indicate a complex core barrel motion well within design limitations and conservative estimates. This is located in the 15.0 to 20.0 Hz regions.
2. The low frequency noise (up to 5.0 Hz) is a result of Fuel/Reactivity random effects.
3. Flow pertubations effect both the core flux directly via reactivity noise and indirectly by effecting the annulus through which the excore detector sees the core.
4. Based upon known physical clearances for the core tongue and groove snubbers and upon a conservative conversion for % rms noise to physical movement the best conservative levels appear to be as follows:

A. N SIGMA (ACTION LEVEL) 0.48% RMS

Where

$$\%RMS = \frac{\sigma}{\mu} \times 100\%$$

μ = Mean DC Signal Valve

$$\sigma = \int_{f_1}^{f_2} PSD\ (f)\ df$$

- f_1 to f_2 is the frequency region found in which a phase relationship of 180° exists between two excores across the core thus indicating cantilever, rocking, or beam type core barrel movement
- where the % RMS for at least two excores shall exceed the above stated limit.

N SIGMA ACTION

Within 24 hours of exceeding the limit action shall be taken to reduce unit power to a licensed level where 3 primary coolant pump operation shall be commenced in conjunction with data for measurements of the phase, coherence, power spectral density, sigma, % RMS and amplitude probability distributions will be taken daily and analyzed weekly on all operable excore detectors to show that the noise level is reduced below the action level (0.48% RMS). If the action level is exceeded under these conditions the unit will be taken to Hot Shutdown within 48 hours.

The reportability requirements for exceeding the action limit shall be the same as for an abnormal occurrence.

Note: This limit is based upon the known physical snubber clearances including a contigency for statistical accuracies expected.

M SIGMA (ALERT LEVEL) 0.250% RMS

Where M Sigma shall be calculated as frequency independent

M SIGMA ACTION

Within 24 hours of exceeding the M Sigma Limit Data for measurements of the phase, Coherence, Power Spectral Density, Sigma, % RMS and Amplitude Probability Distributions will be taken daily and analyzed weekly on all operable excore detectors until such time that the noise level can be shown to be below the alert level (0.250% RMS), or that the cause of the noise increase can be shown to not be related to core barrel motion.

The reportability requirements for exceeding the alert limit shall be the same as for an abnormal occurrence.

Note: Present flow noise is nominally 0.70% RMS. Previous analyses have shown that the indicated reactor internals clamping force deterioration was reported by increases in the % RMS which approached levels of the flow noise % RMS. The present baselines show that the excore acceptable noise level of about 0.07% RMS is indicative of healthy reactor internals. The alert limit is placed half-way between what is considered normal and what is considered a situation of potential impacting due to physical tolerences. This limit is above statistical inaccuracies and is considered that reaching this limit would constitute a significant change in the reactor noise present warranting investigative action. It has been shown, however, that reactivity changes throughout core life to parameters such as Beta effective and the moderator temperature coefficient have caused significant changes in nuclear noise levels. In light of this fact alert level action may be discontinued is such can be ascertained and reported.

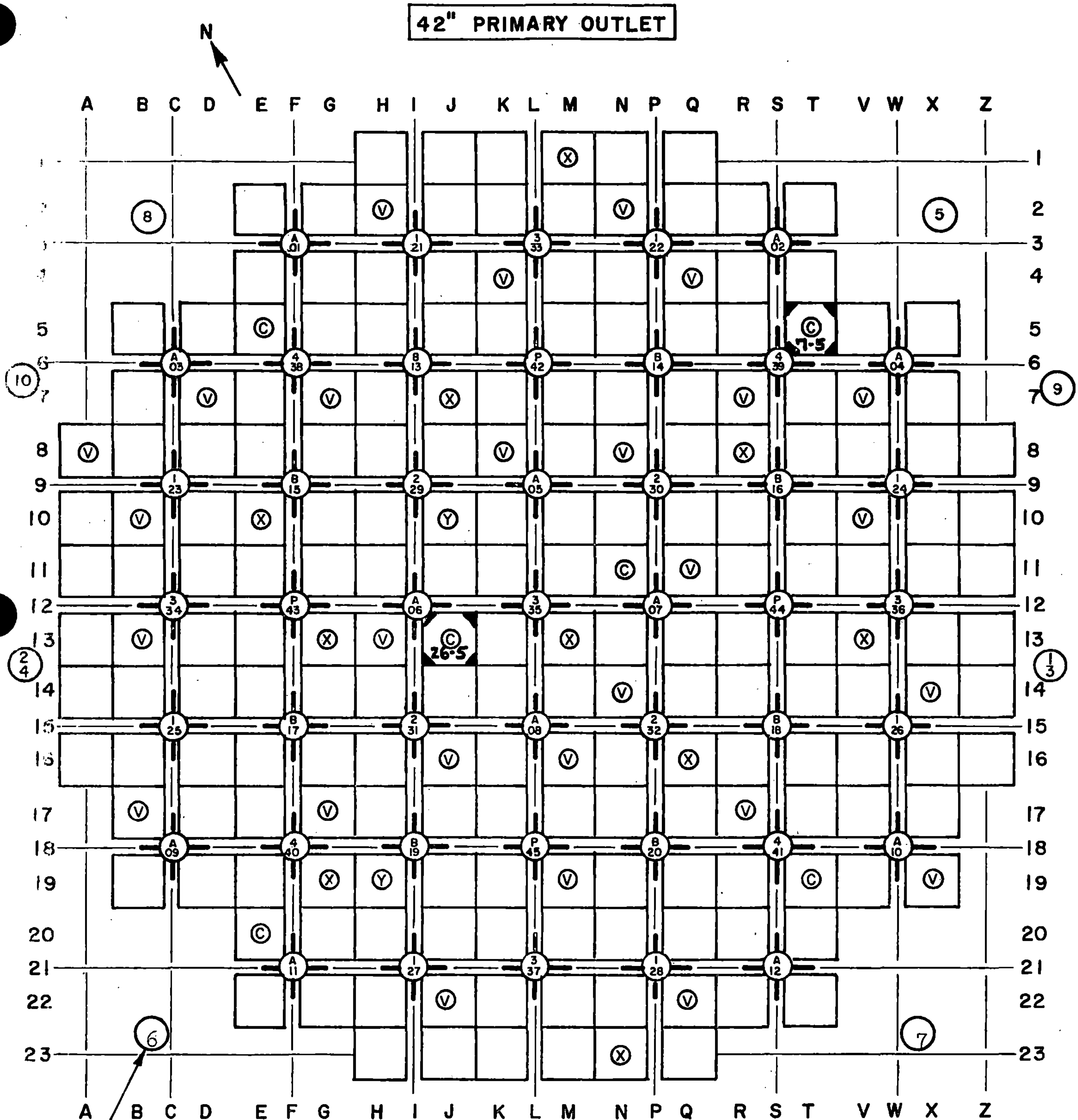
References

1. N.N. Fry, et al, Analysis of Neutron Density Oscillations Resulting From Core Barrel Motion in the Palisades Nuclear Power Plant, ORNL-TM-4570, May 1974.
2. J.A. Thie, Preliminary Low Power Noise Analysis, prepared for Consumers Power Company, October 1974.
3. Combustion Engineering Inc., Palisades Reactor Internals Wear Report CEN-5 (p), March 1974
4. J.A. Thie, Palisades Barrel Motion, prepared for Consumers Power Company, November 1973

5. J.A. Thie, Palisades Noise Analysis to 90% Power, prepared for Consumers Power Company, May 1975.

FIGURE #1

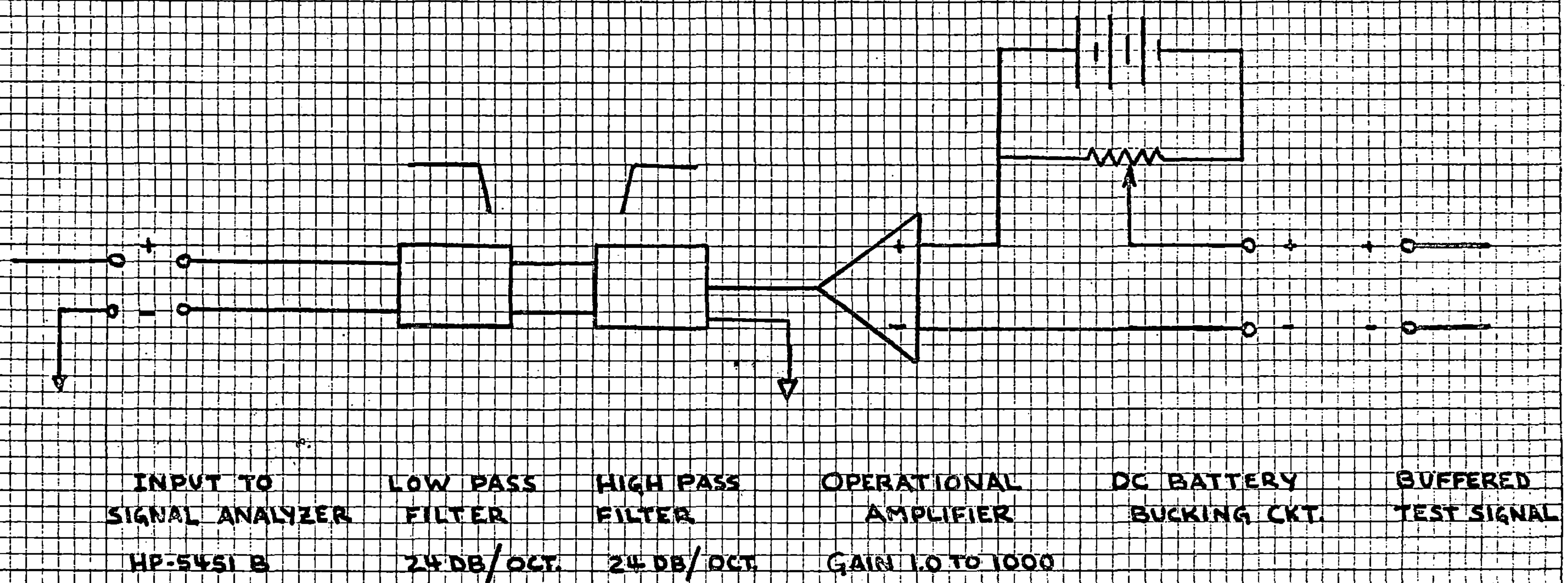
Palisades Plant – Reactor Core Plan



In-core Detectors:

- Ⓥ = Full Length Vanadium
- Ⓒ = Full Length Cobalt
- Ⓧ = Long background
- Ⓨ = Short background

All in-core detectors contain 4 Rhodium detectors and 2 Thermocouples



SIGNAL PROCESSING
FOR NOISE ANALYSIS

FIGURE #2

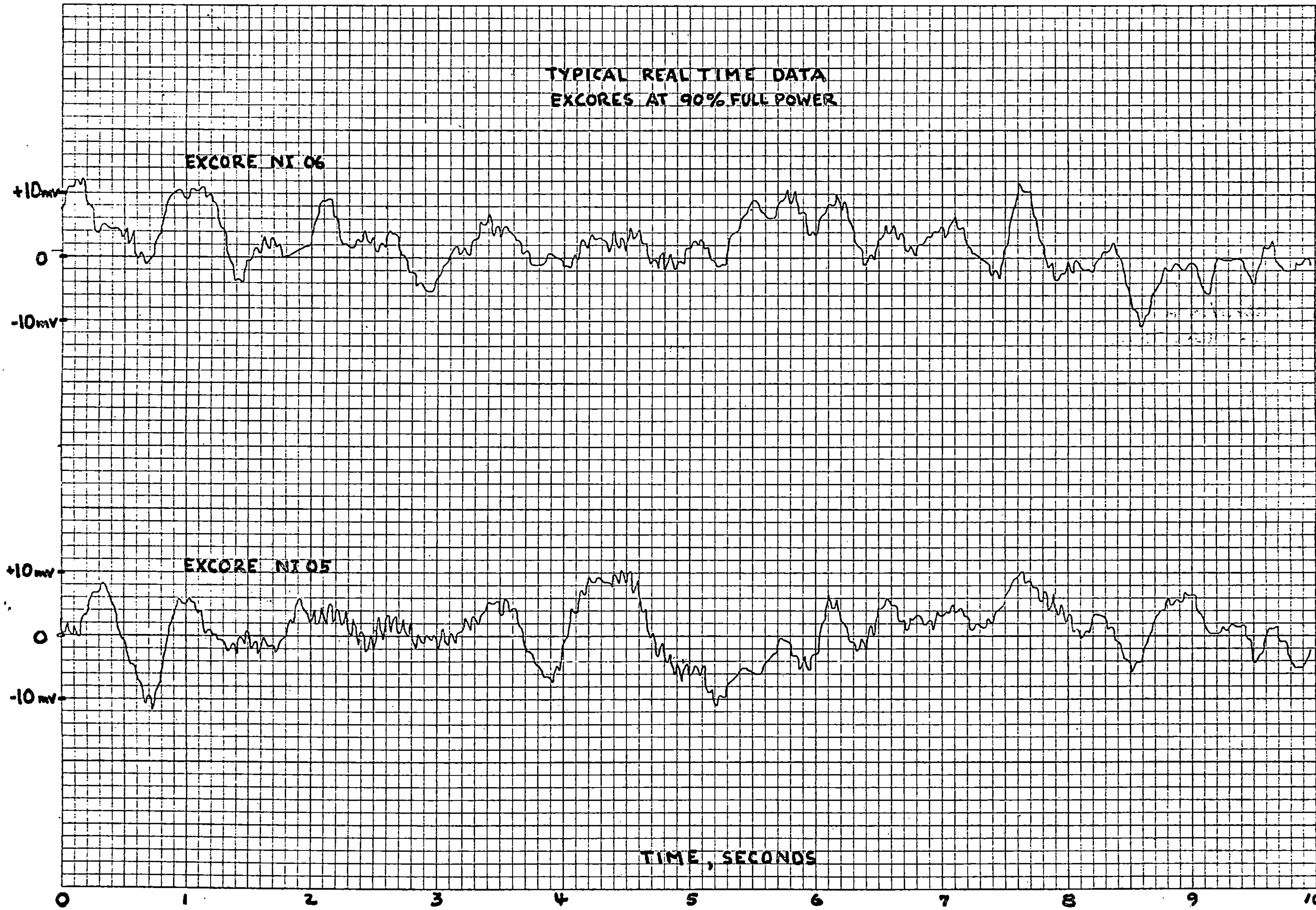
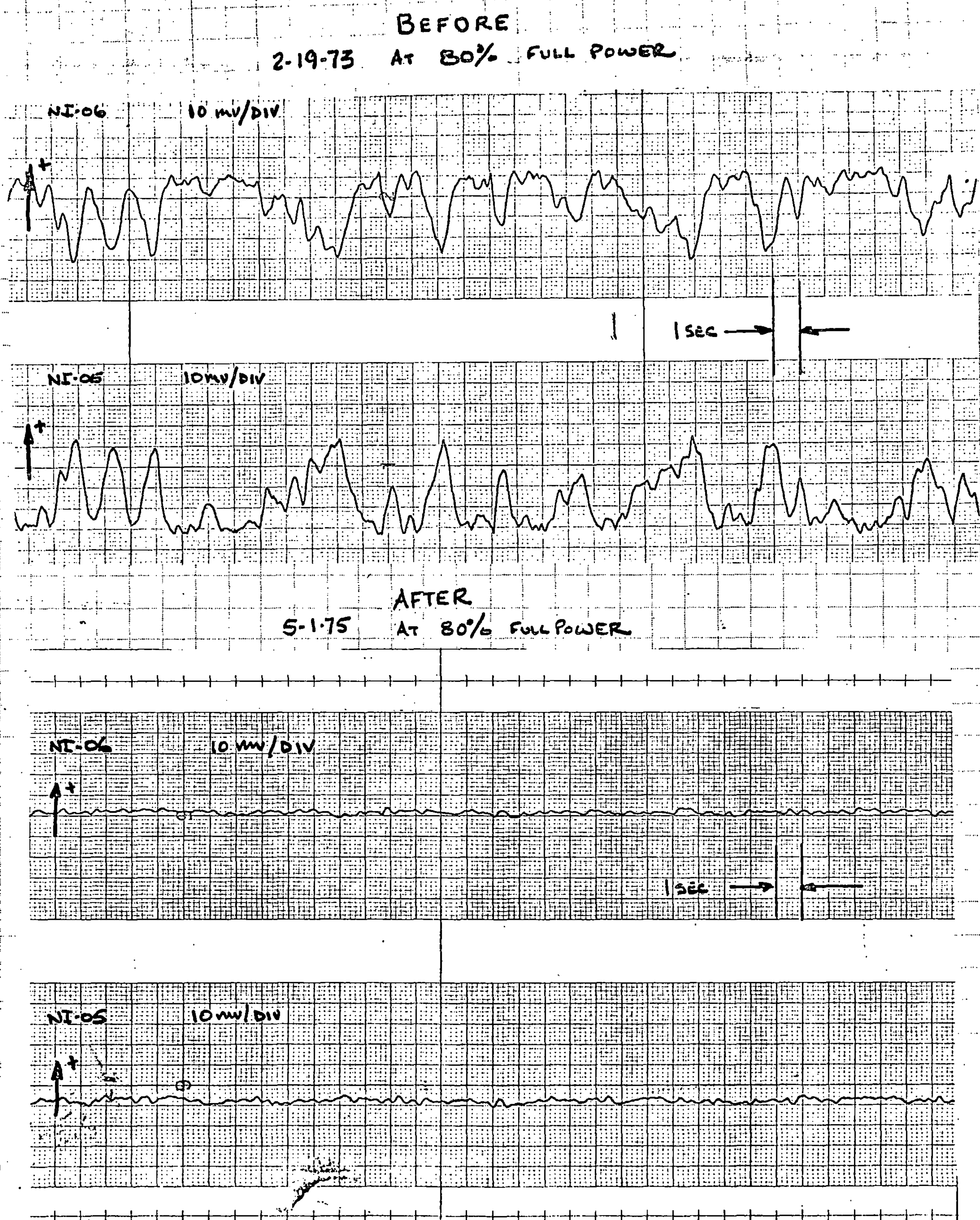

TYPICAL REAL TIME DATA
EXCORES AT 90% FULL POWER
EXCORE NI 06
+10mv
0
-10mv
EXCORE NI 05
+10mv
0
-10mv
TIME, SECONDS
0
1
2
3
4
5
6
7
8
9
10

FIGURE #3

FIGURE 3a


BEFORE
2-19-73 AT 80% FULL POWER
NI-06 10 mv/DIV
1 SEC
NI-05 10 mv/DIV
AFTER
5-1-75 AT 80% FULL POWER
NI-06 10 mv/DIV
1 SEC
NI-05 10 mv/DIV

NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

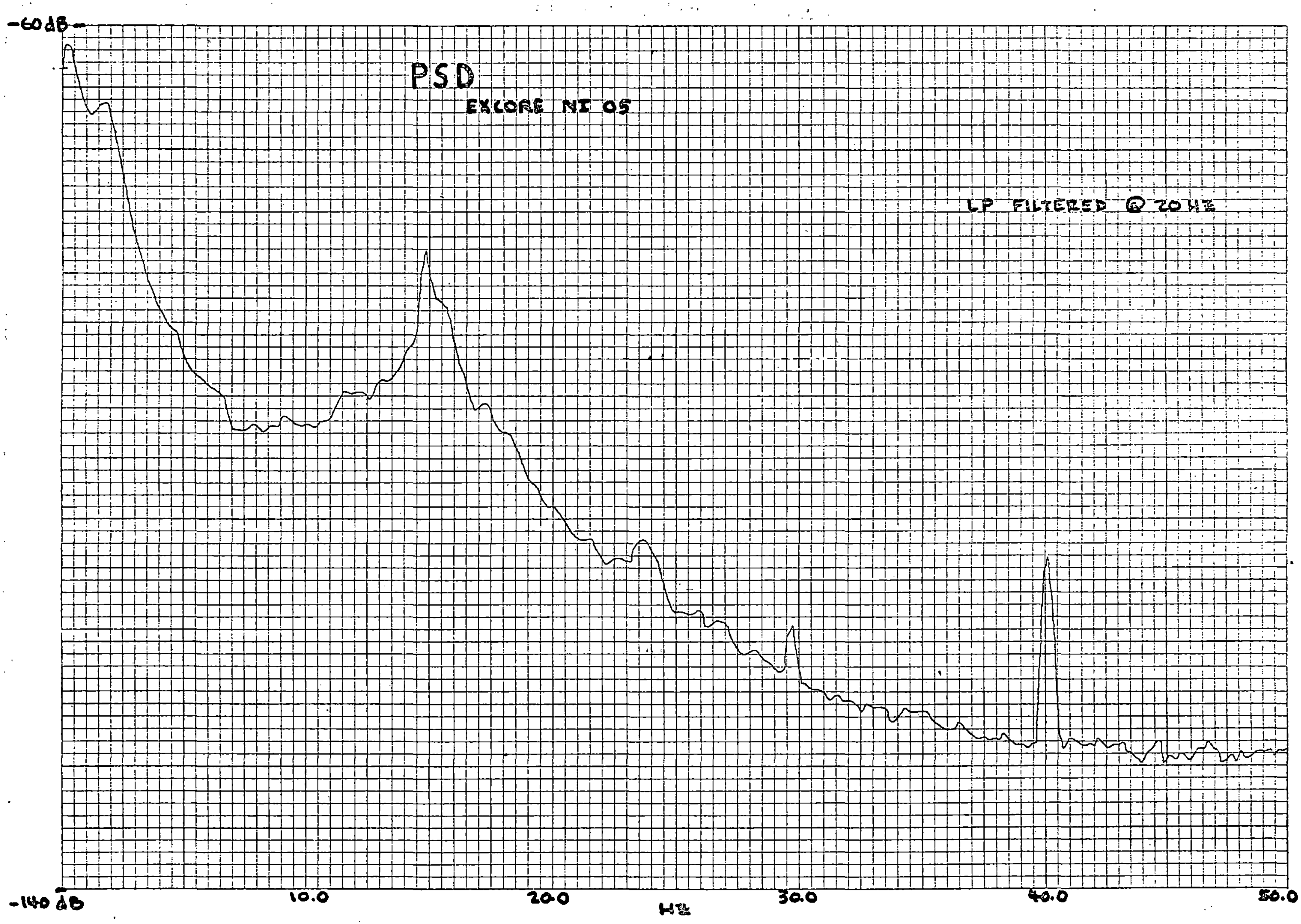


FIGURE #4

NO. 340-10 DIETZGEN GRAPH PAPER
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MADE IN U. S. A.

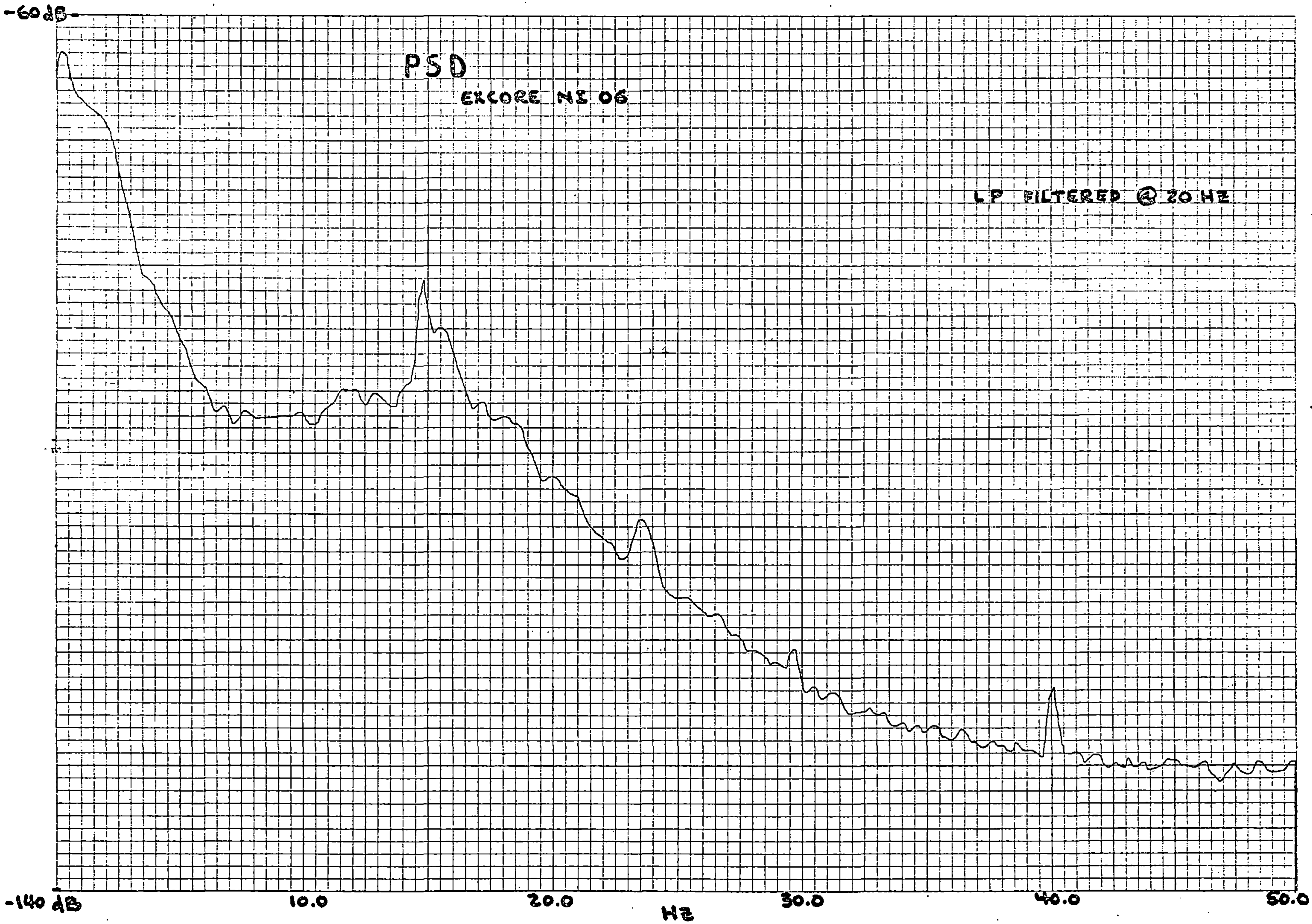


Figure #5

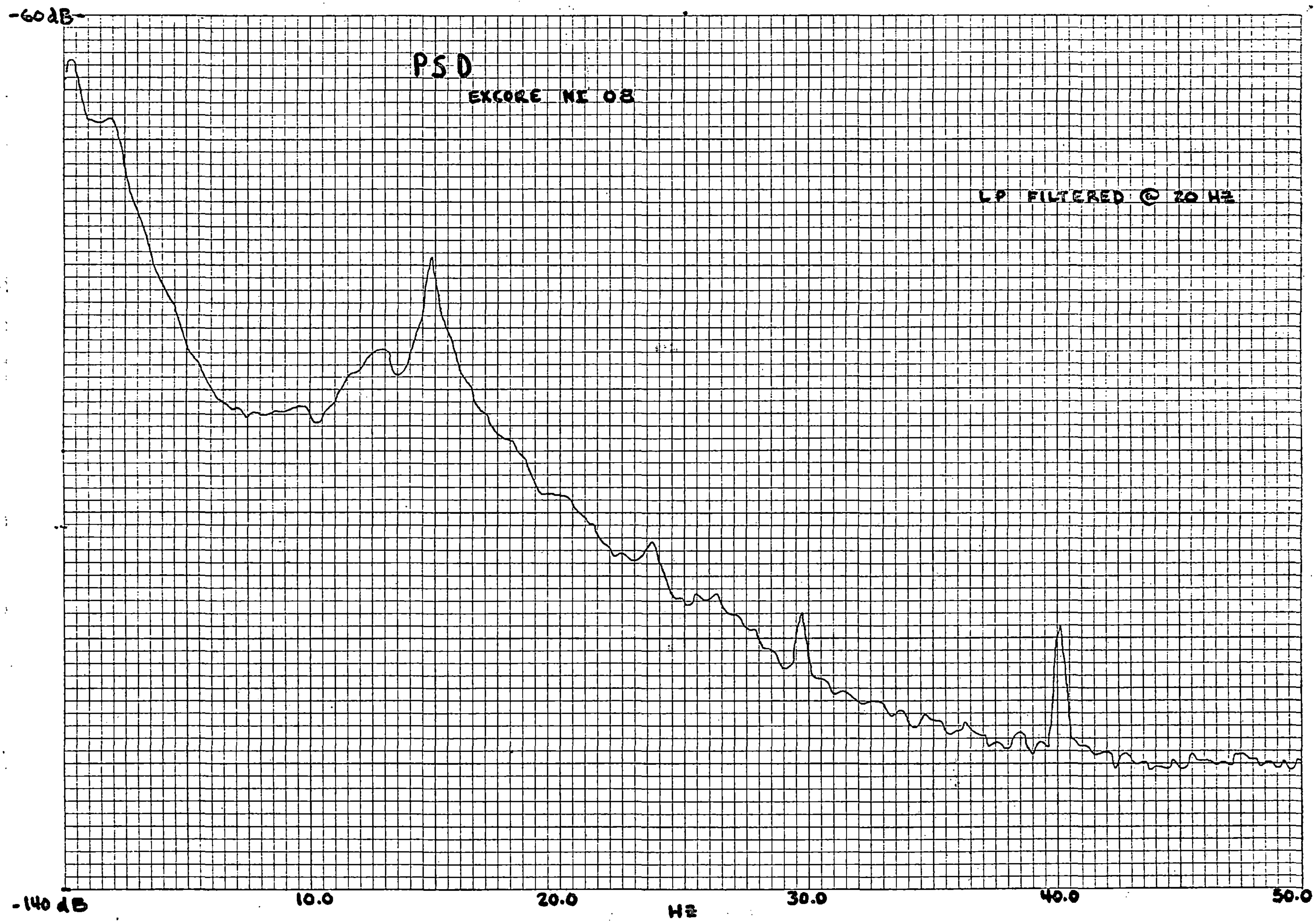

-60 dB
PSD
EXCORE NI 08
LP FILTERED @ 20 HZ
-140 dB
10.0
20.0
30.0
40.0
50.0
HZ

FIGURE # 6

NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

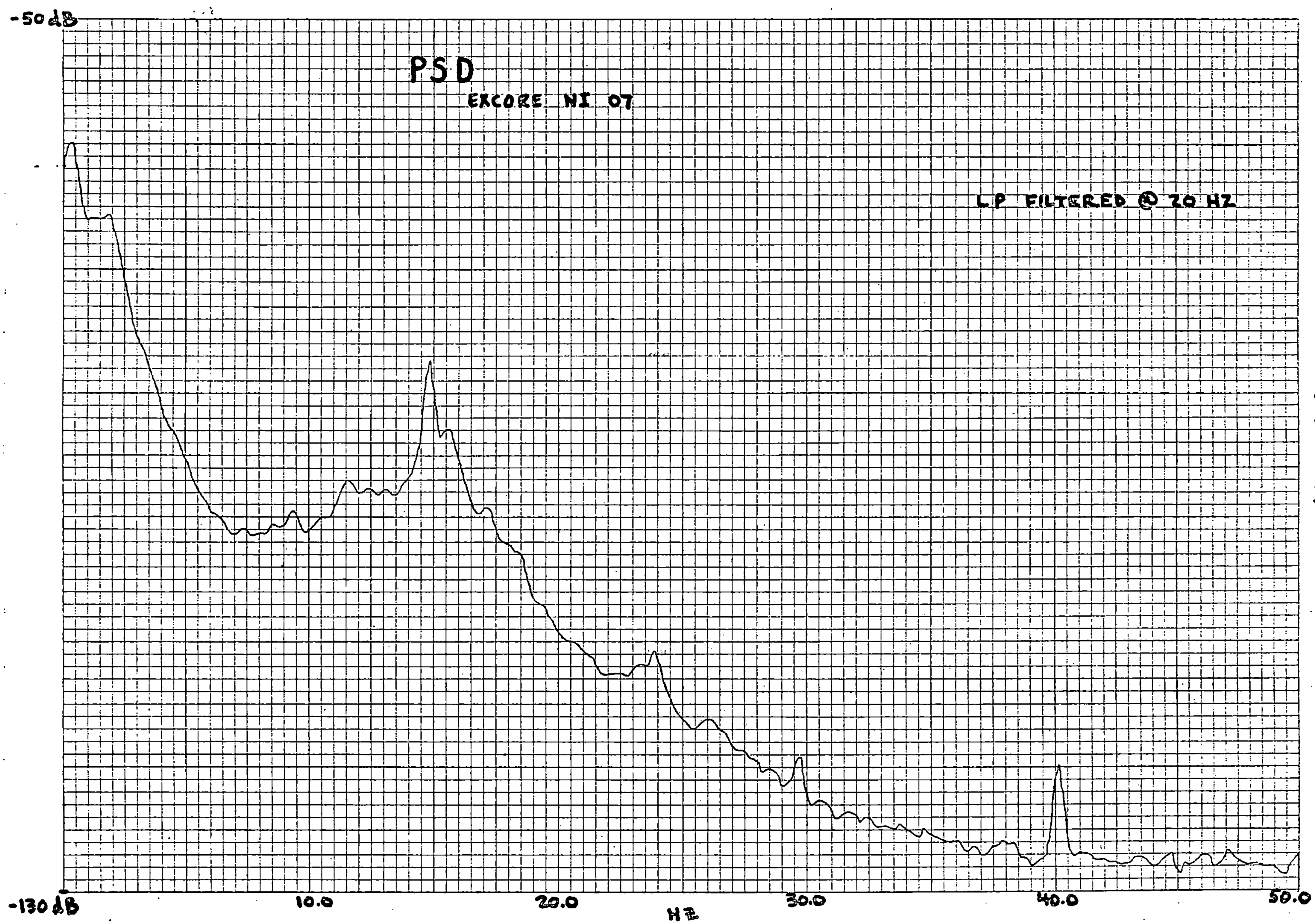


FIGURE #7

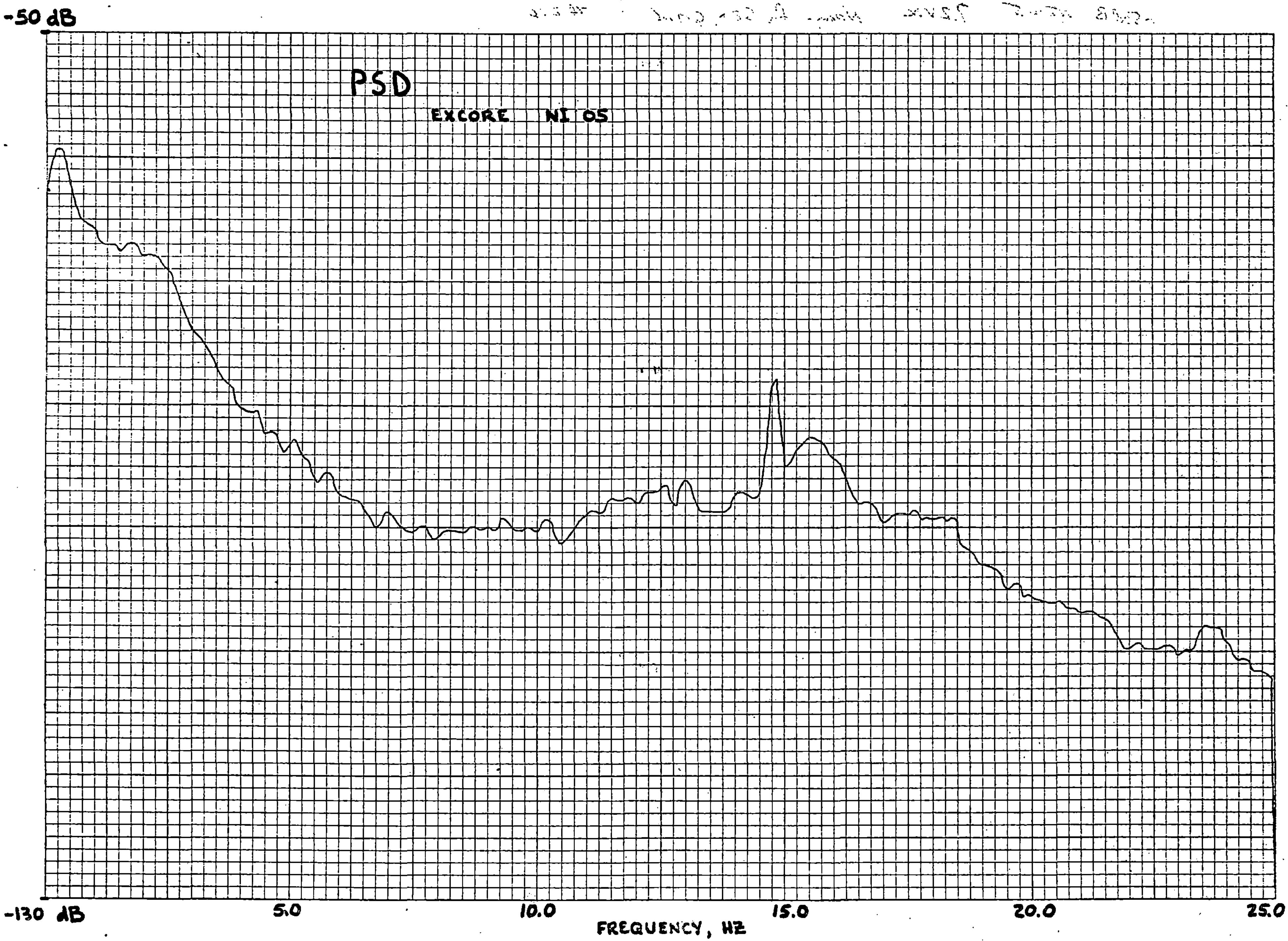


FIGURE #8

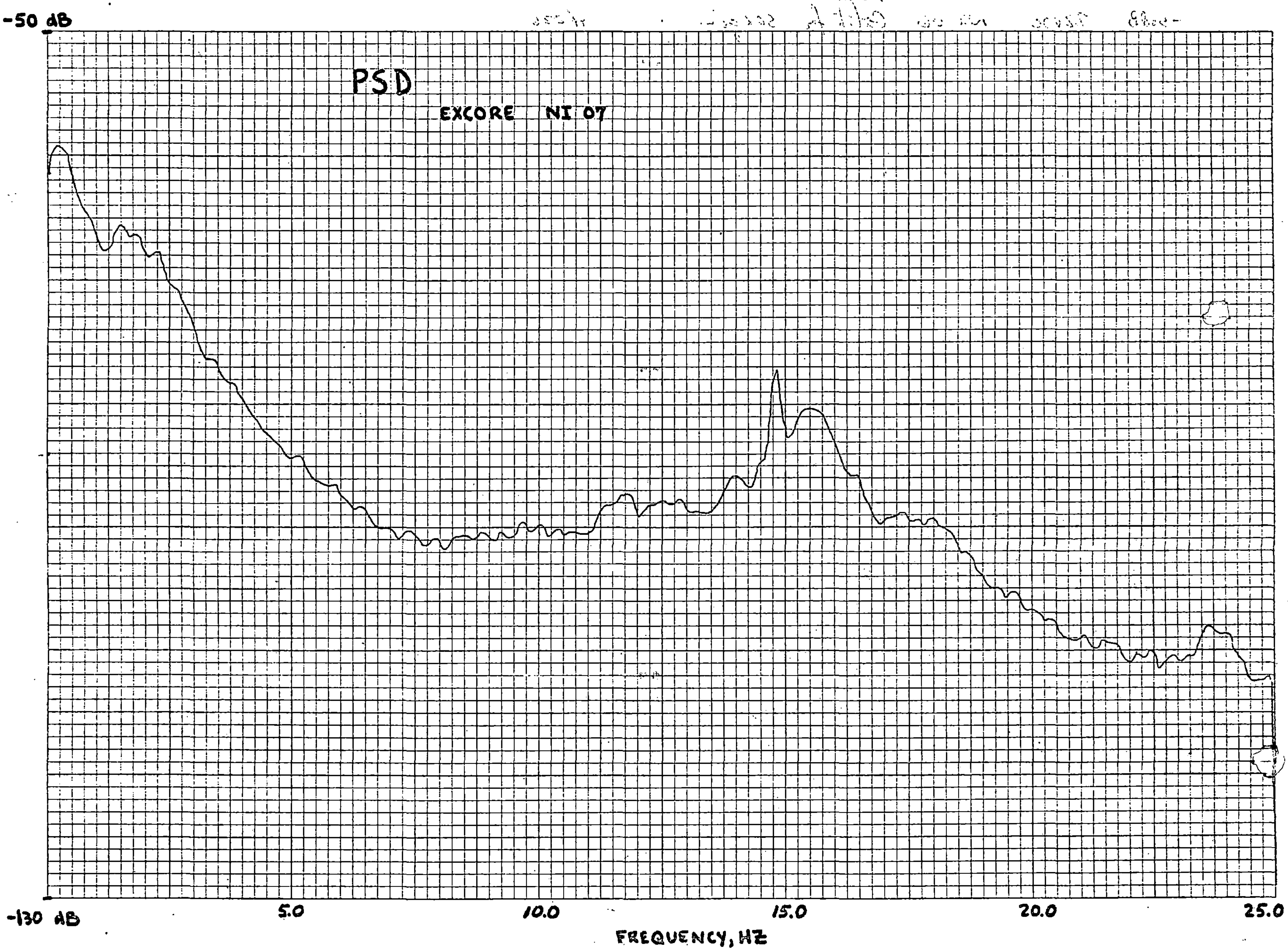


FIGURE # 9

NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

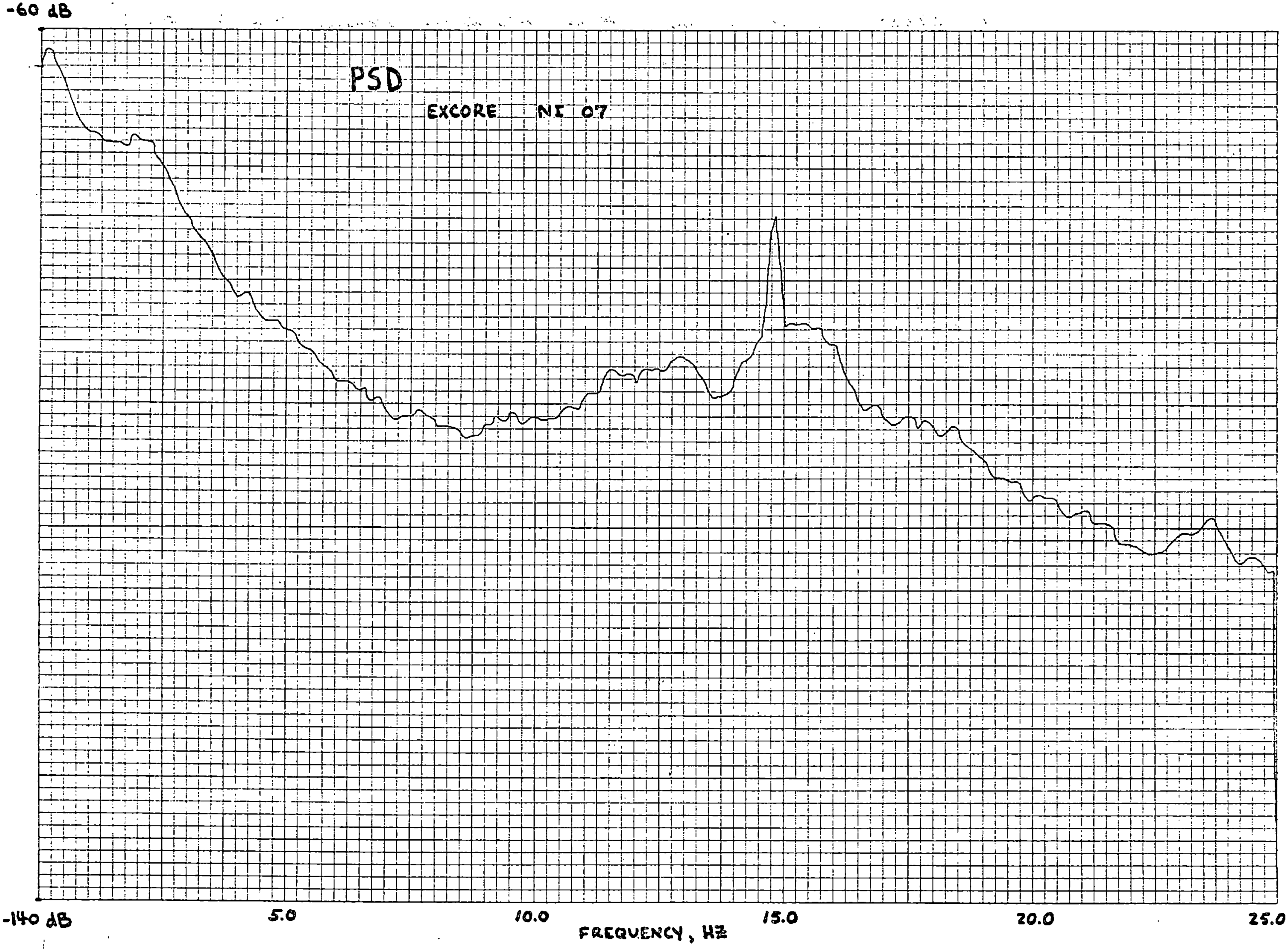


FIGURE #10

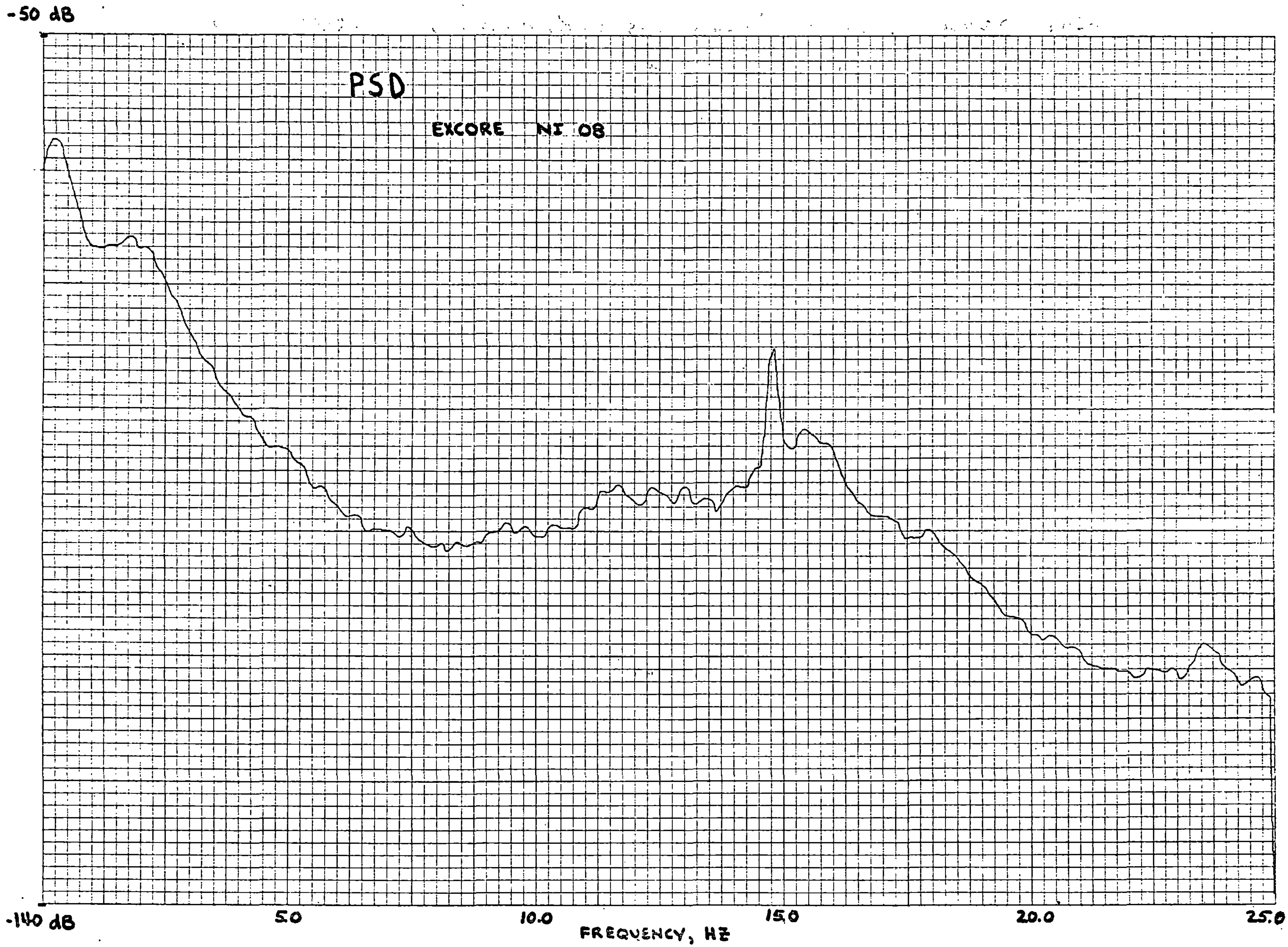
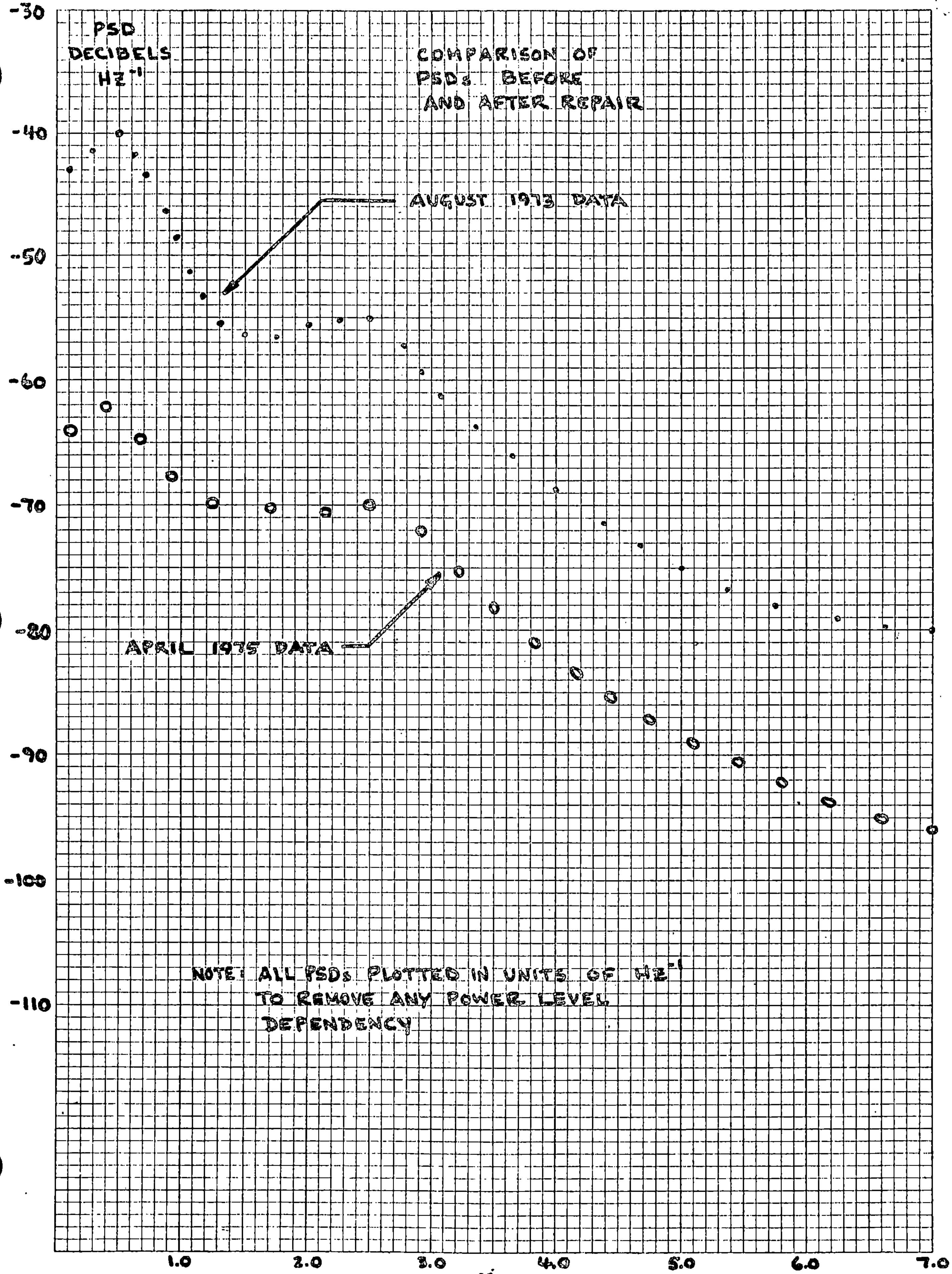

10 X 10 PER INCH
MADE IN U. S. A.
-50 dB
PSD
EXCORE NI 08
-140 dB
5.0
10.0
15.0
20.0
25.0
FREQUENCY, HZ

FIGURE 4.11

FIGURE #12


PSD
DECIBELS
HZ⁻¹
COMPARISON OF
PSDs BEFORE
AND AFTER REPAIR
AUGUST 1973 DATA
APRIL 1975 DATA
NOTE: ALL PSDs PLOTTED IN UNITS OF HZ⁻¹
TO REMOVE ANY POWER LEVEL
DEPENDENCY
-30
-40
-50
-60
-70
-80
-90
-100
-110
1.0
2.0
3.0
4.0
5.0
6.0
7.0
HZ

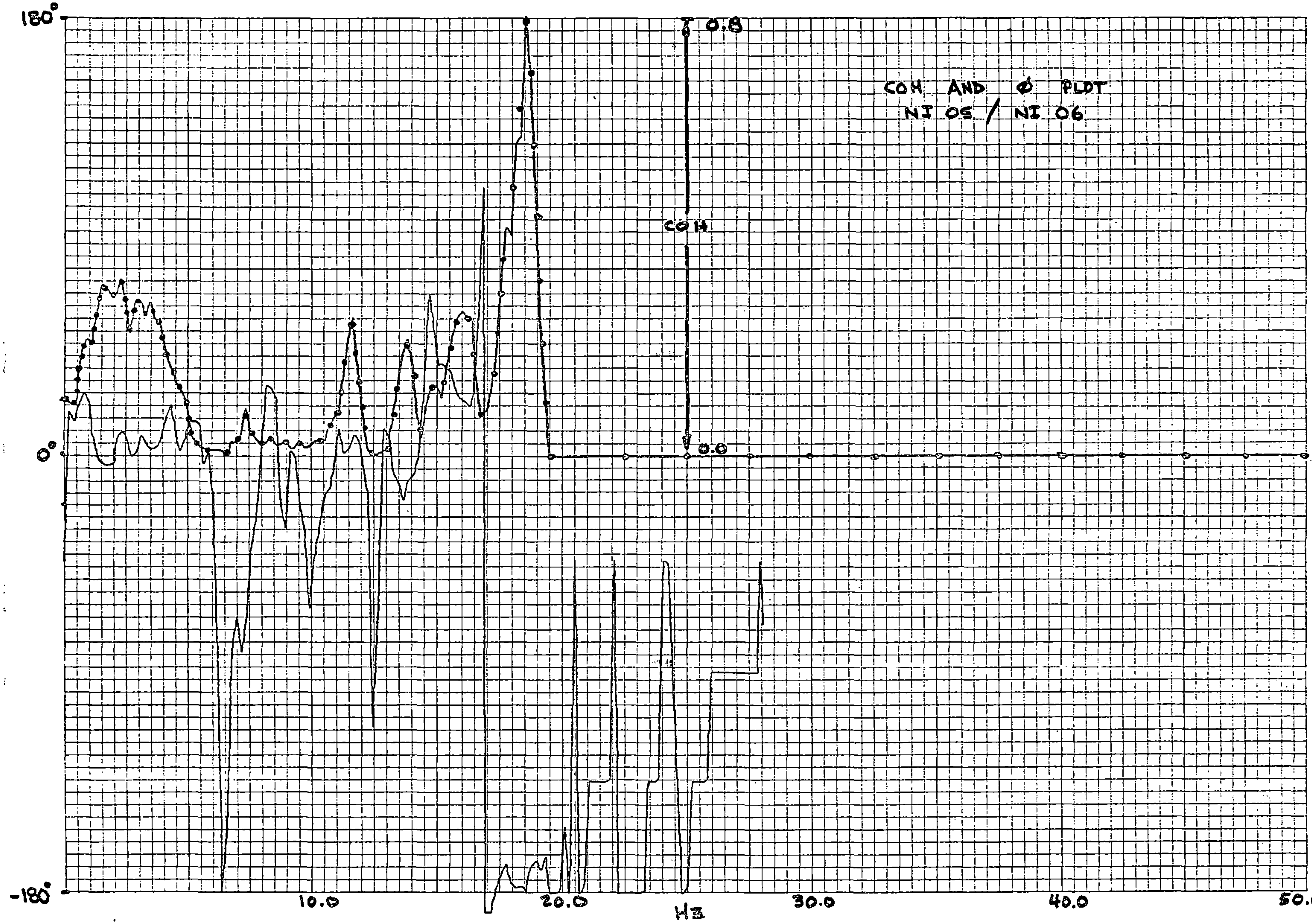

COH AND Ø PLOT
NI 05 / NI 06
180°
0°
-180°
0.8
COH
0.0
10.0
20.0
30.0
40.0
50.0
Hz

FIGURE #13

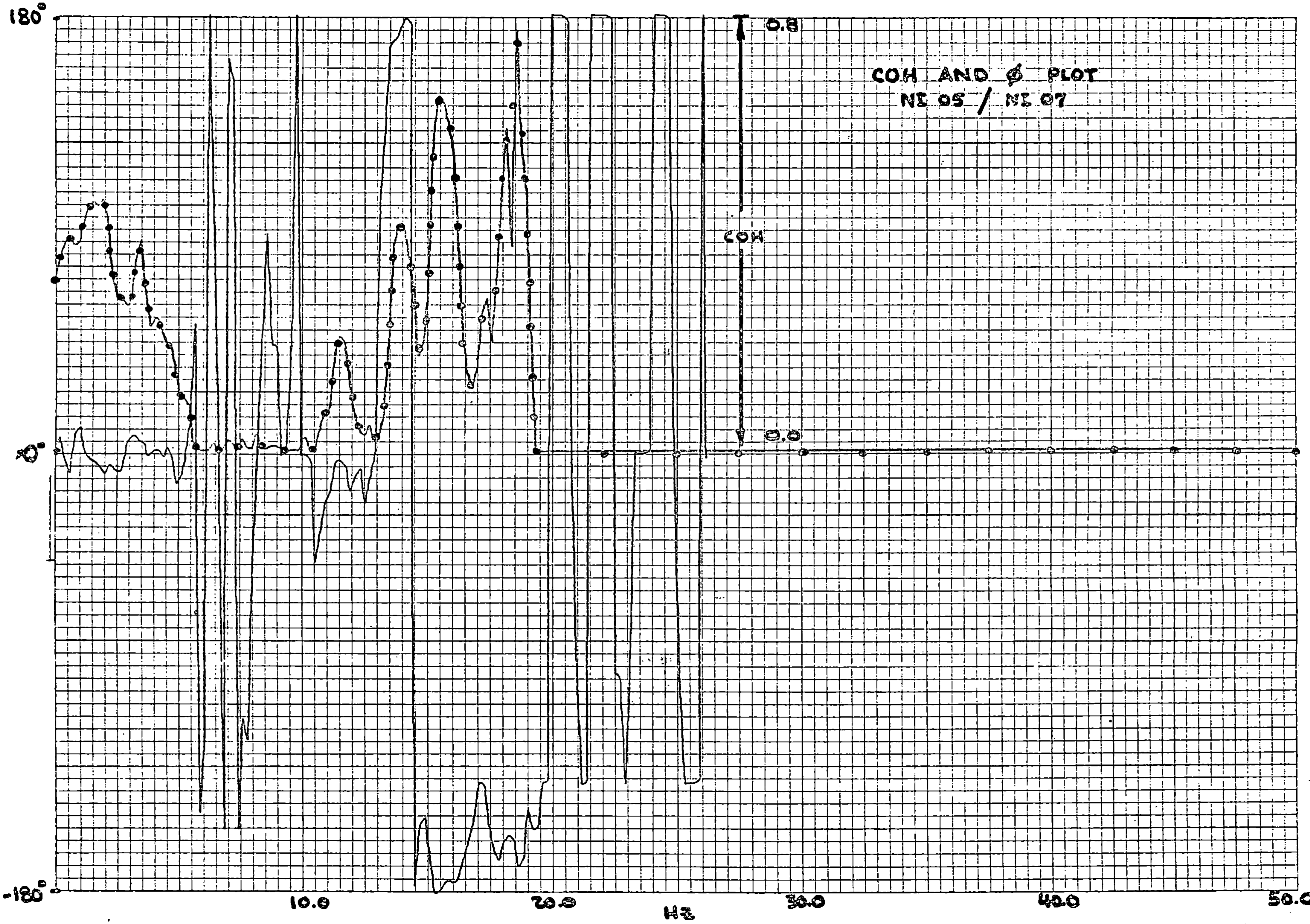

COH AND Ø PLOT
NI 05 / NI 07
180°
0°
-180°
0.8
COH
0.0
10.0
20.0
30.0
40.0
50.0
Hz

FIGURE 41A

NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

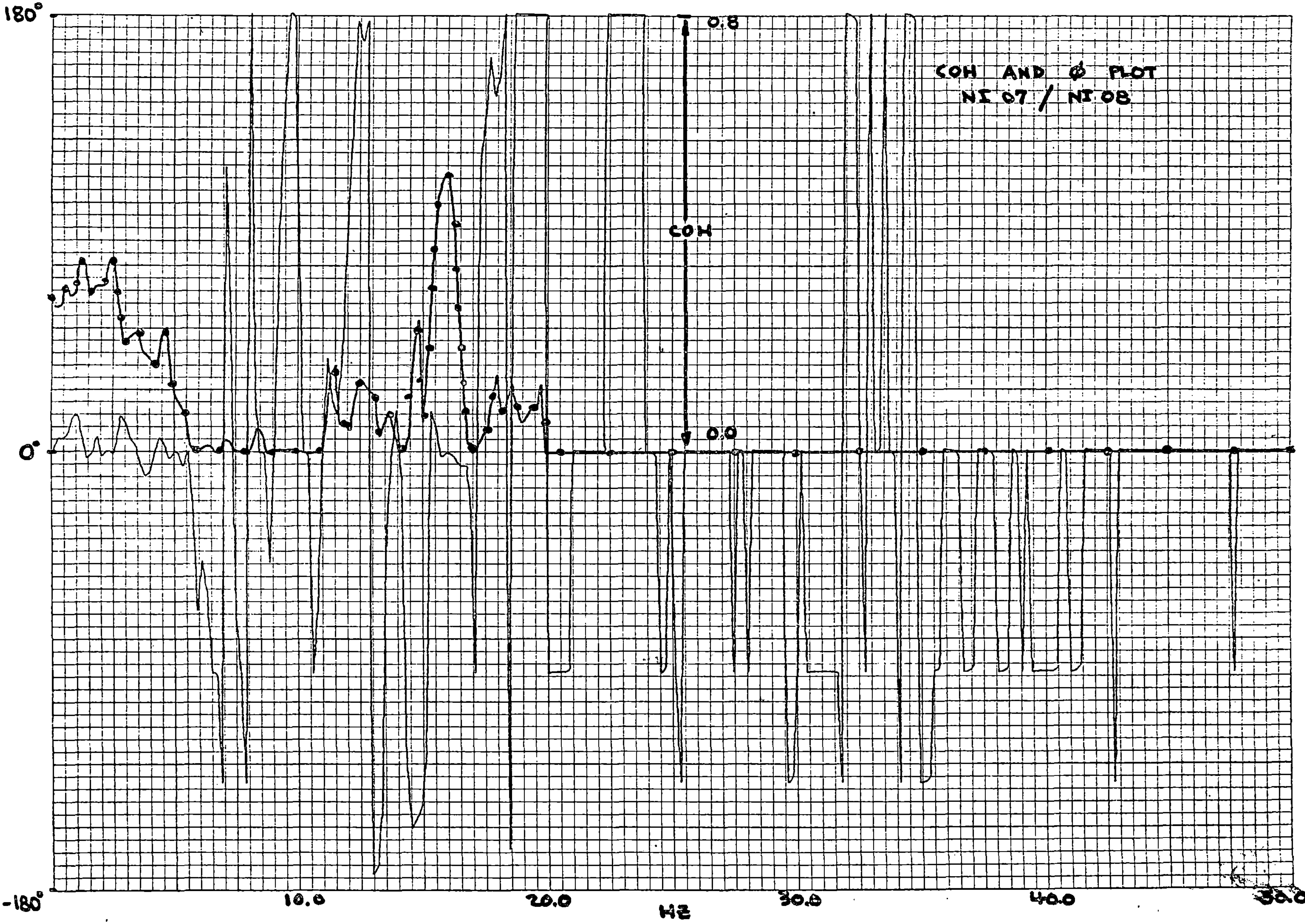


FIGURE #15

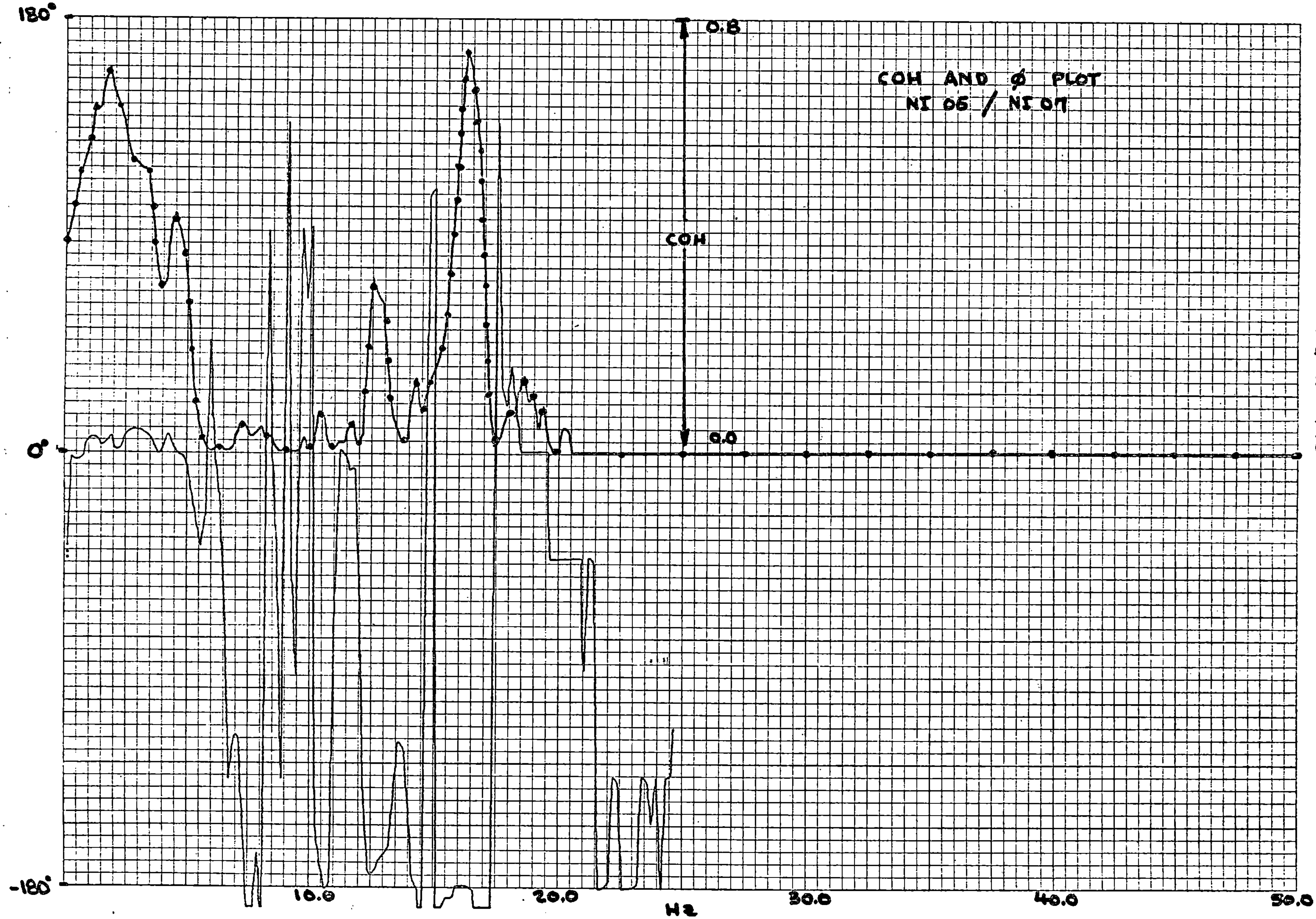


FIGURE #16

NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

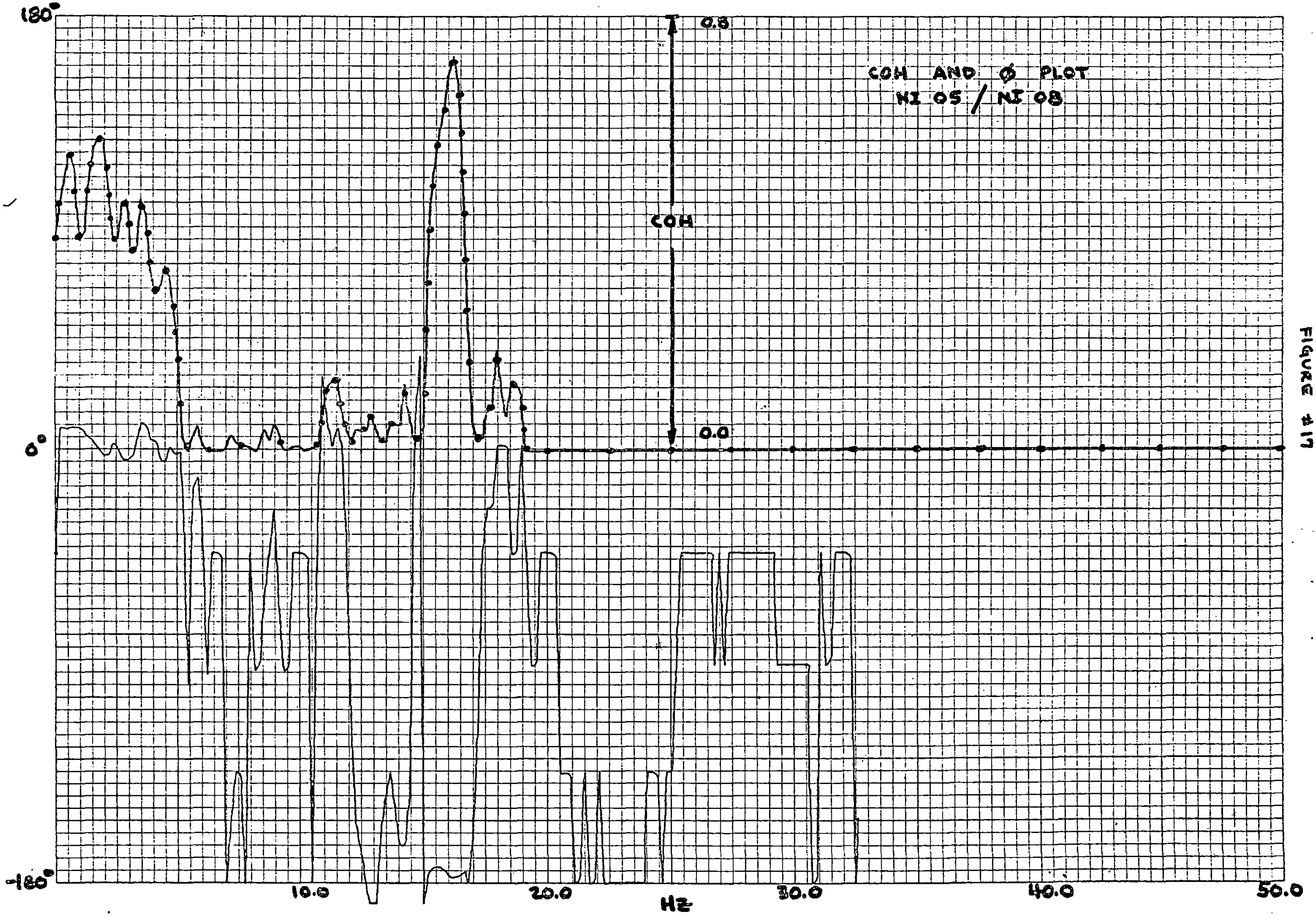


FIGURE #17

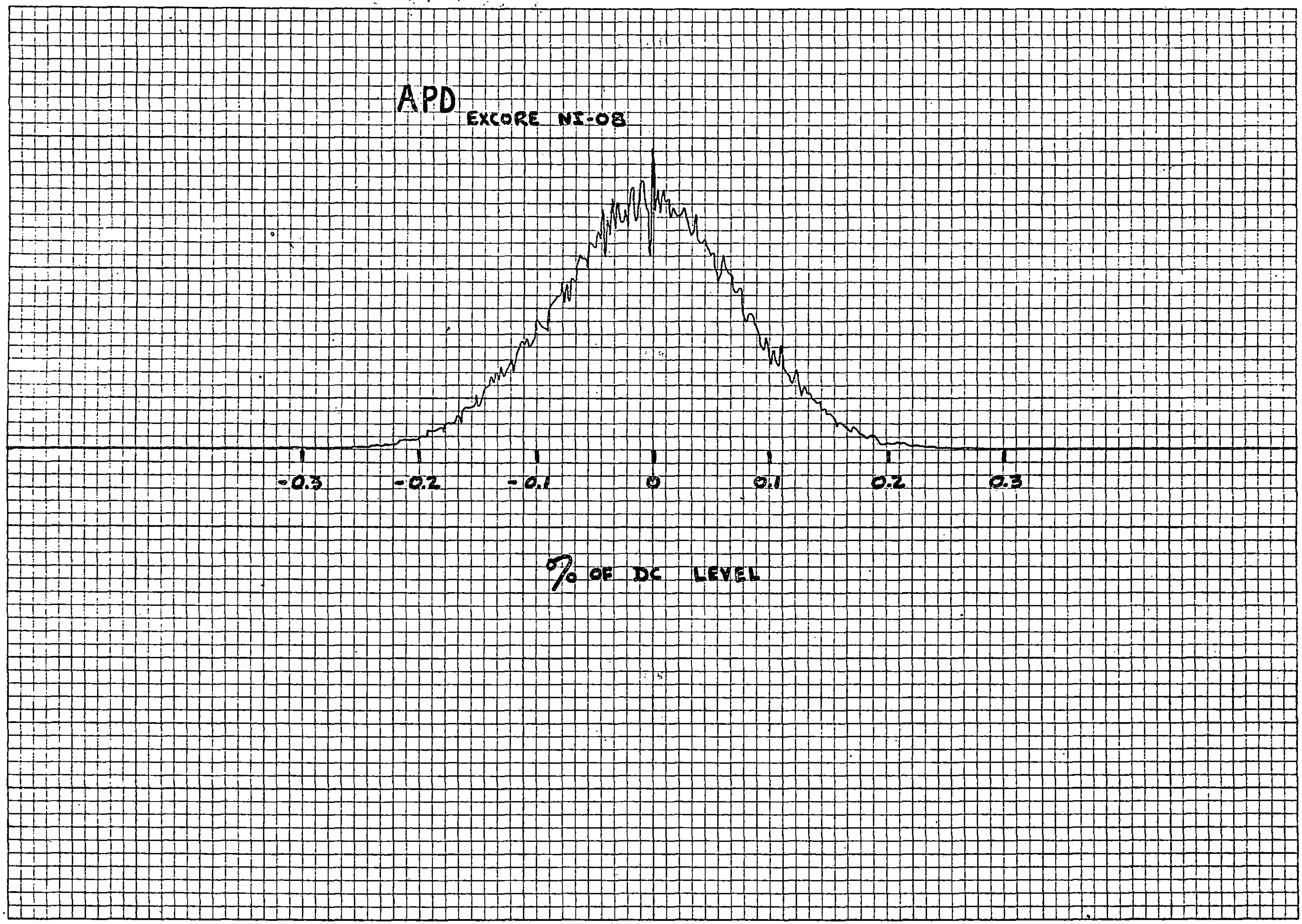


FIGURE #18

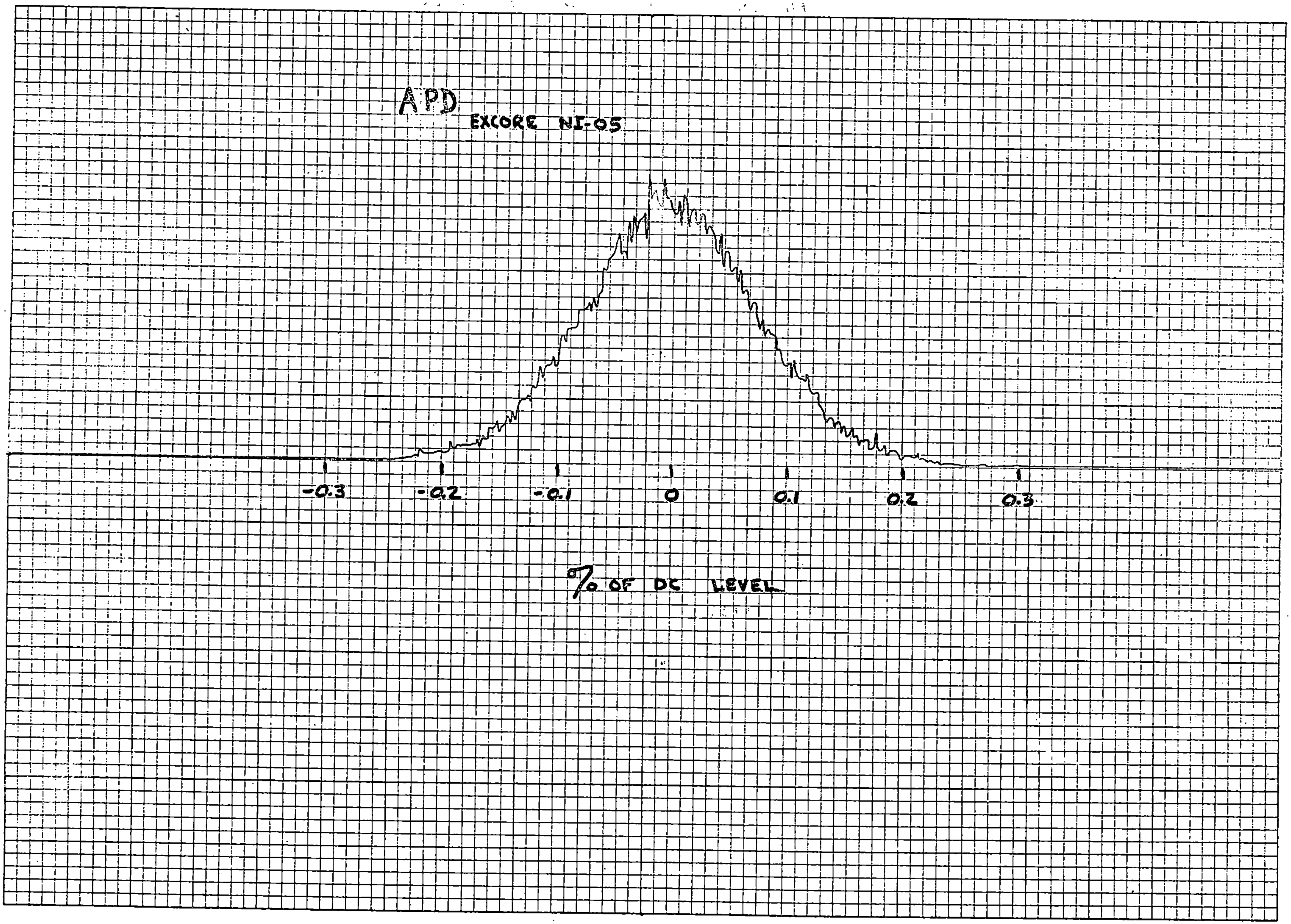


FIGURE # 19

NO 340 DIETZGEN GRAPH PAPER 10 X 10 PER INCH

EUGENE DIETZGEN CO. MADE IN U. S. A.

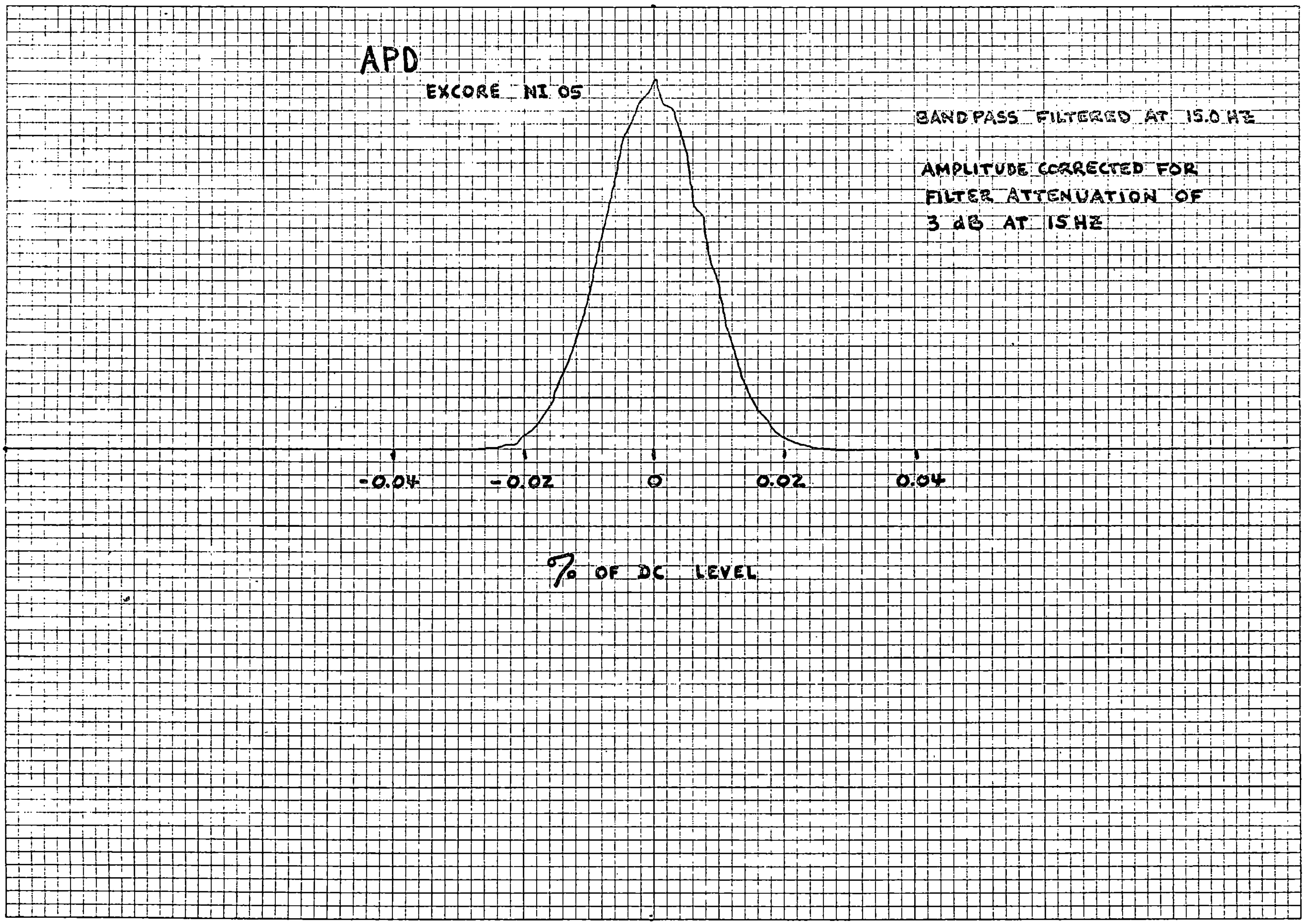


FIGURE #20

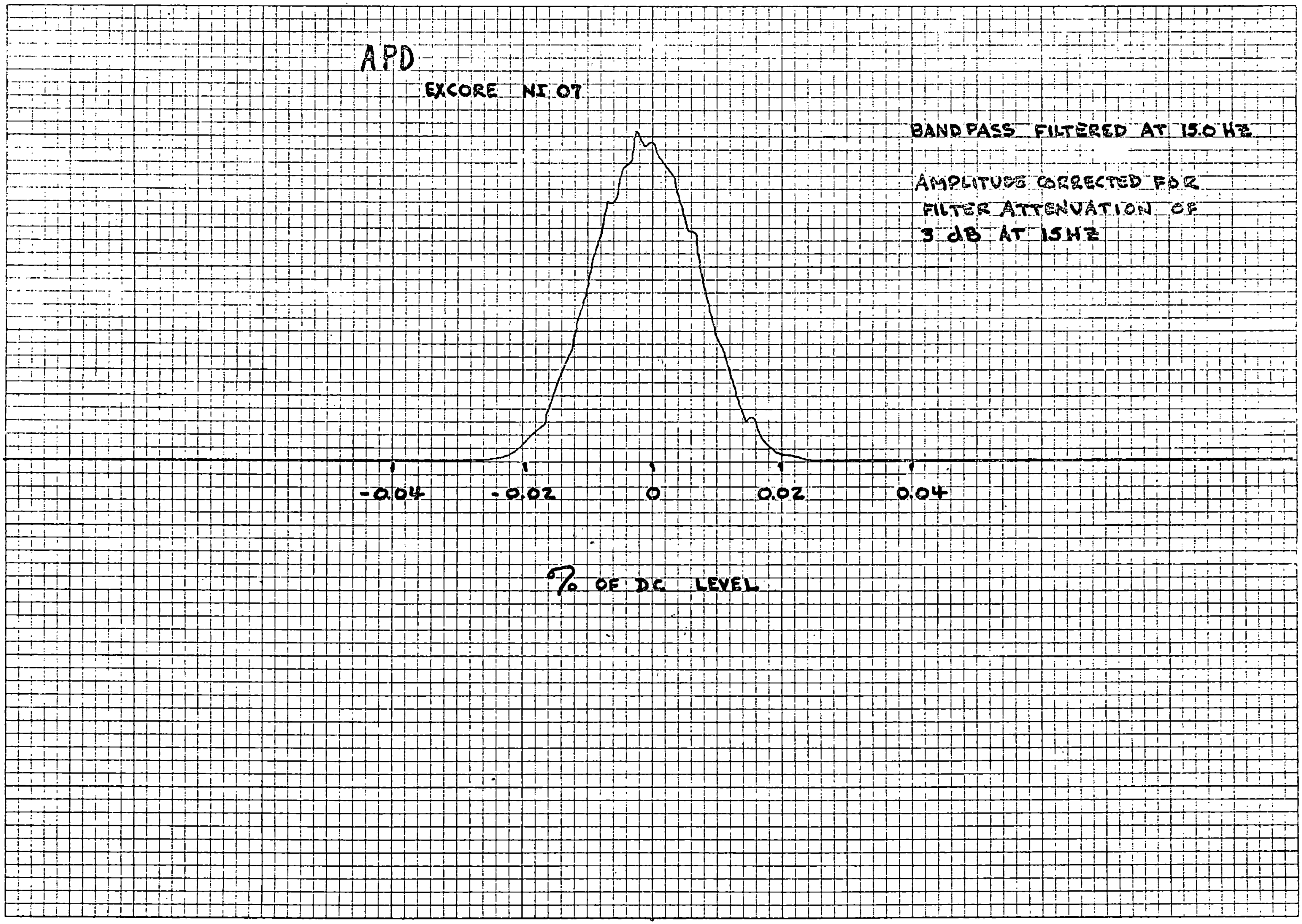

APD
EXCORE NI 07
BAND PASS FILTERED AT 15.0 HZ
AMPLITUDE CORRECTED FOR
FILTER ATTENUATION OF
3 dB AT 15HZ
-0.04
-0.02
0
0.02
0.04
% OF DC LEVEL

FIGURE # 21

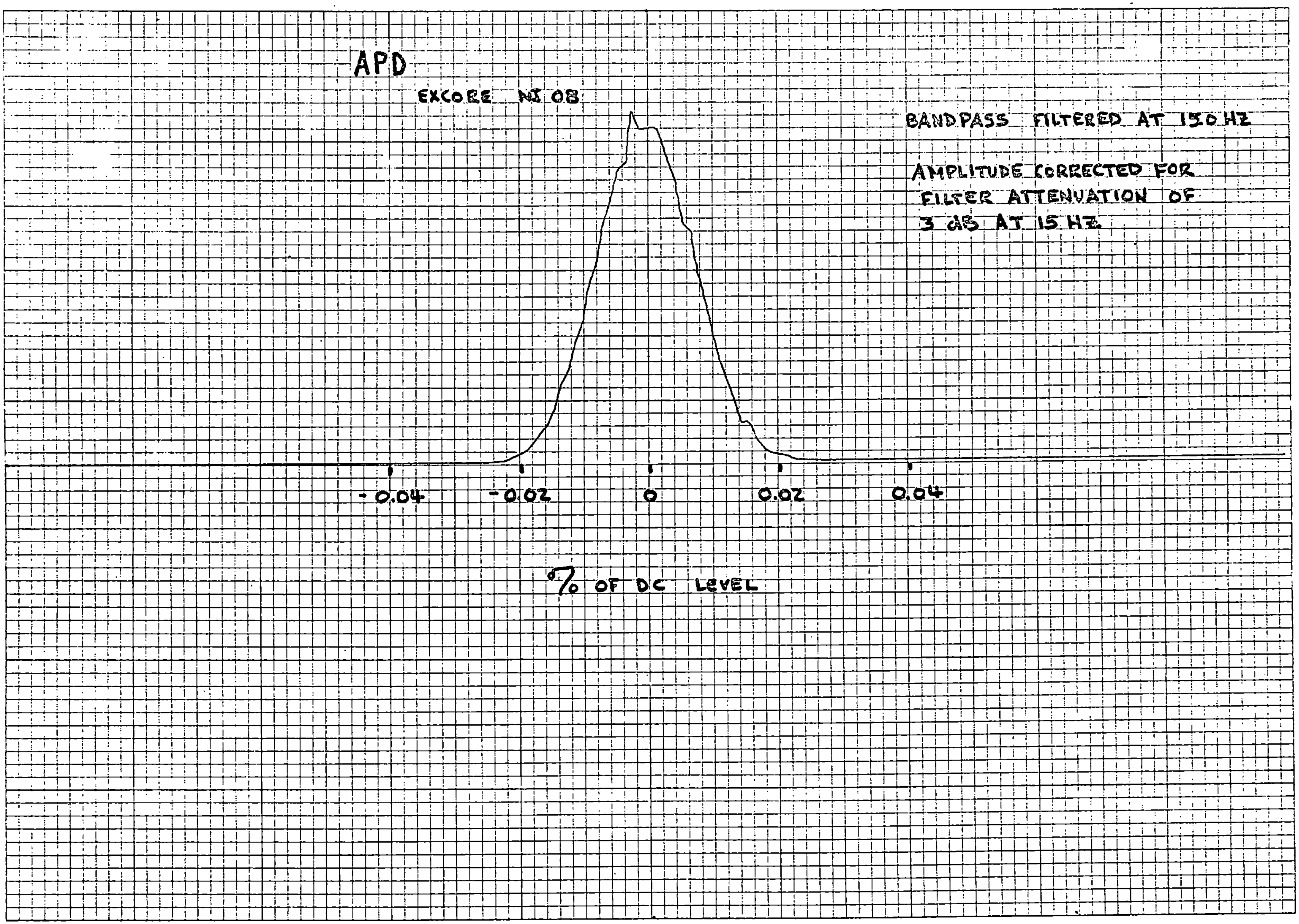

APD
EXCORE NJ 08
BANDPASS FILTERED AT 150 HZ
AMPLITUDE CORRECTED FOR
FILTER ATTENUATION OF
3 dB AT 15 HZ
- 0.04
-0.02
0
0.02
0.04
% OF DC LEVEL

FIGURE # 22

DIFFERENTIAL PRESSURE SENSORS

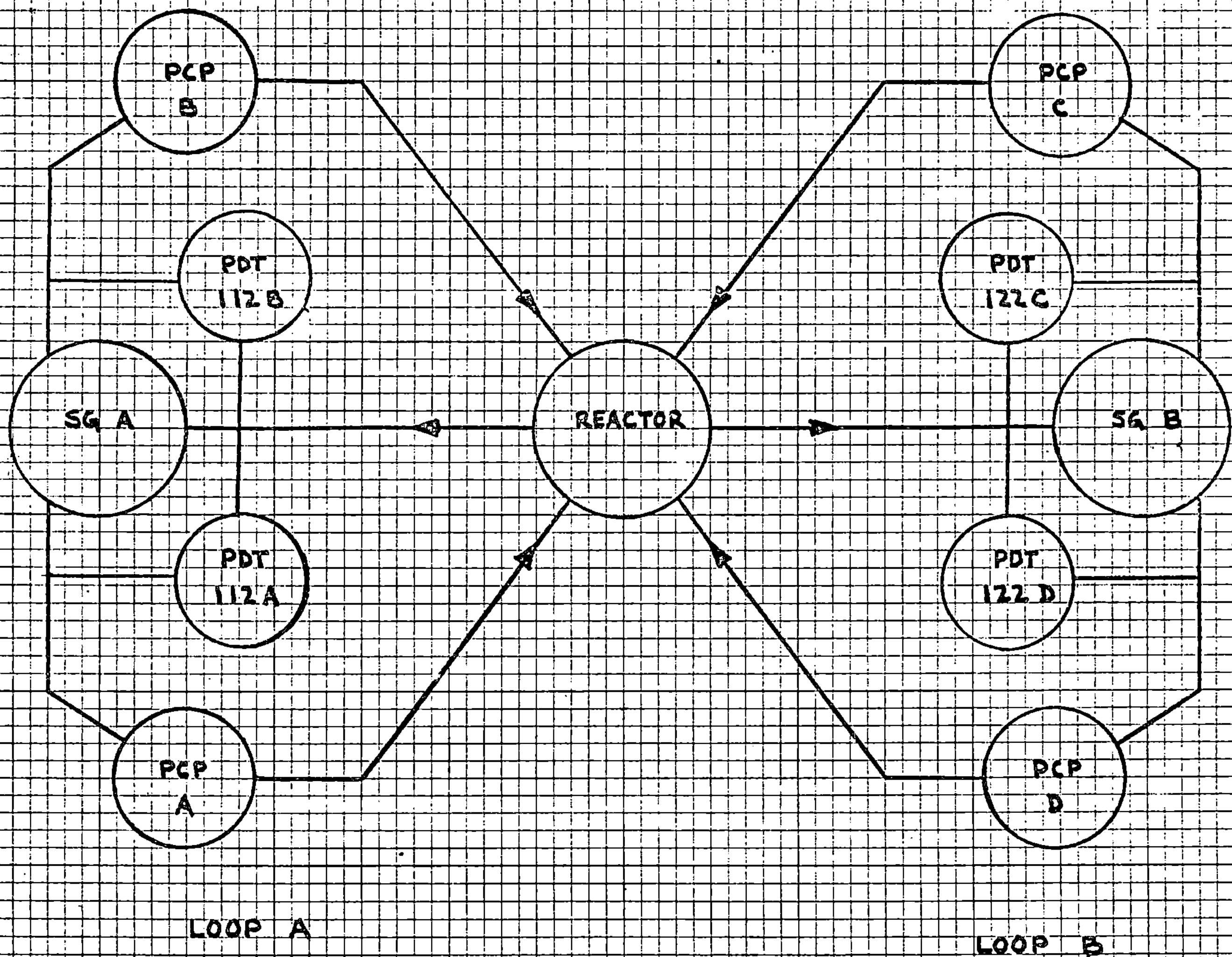


FIGURE #23

NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

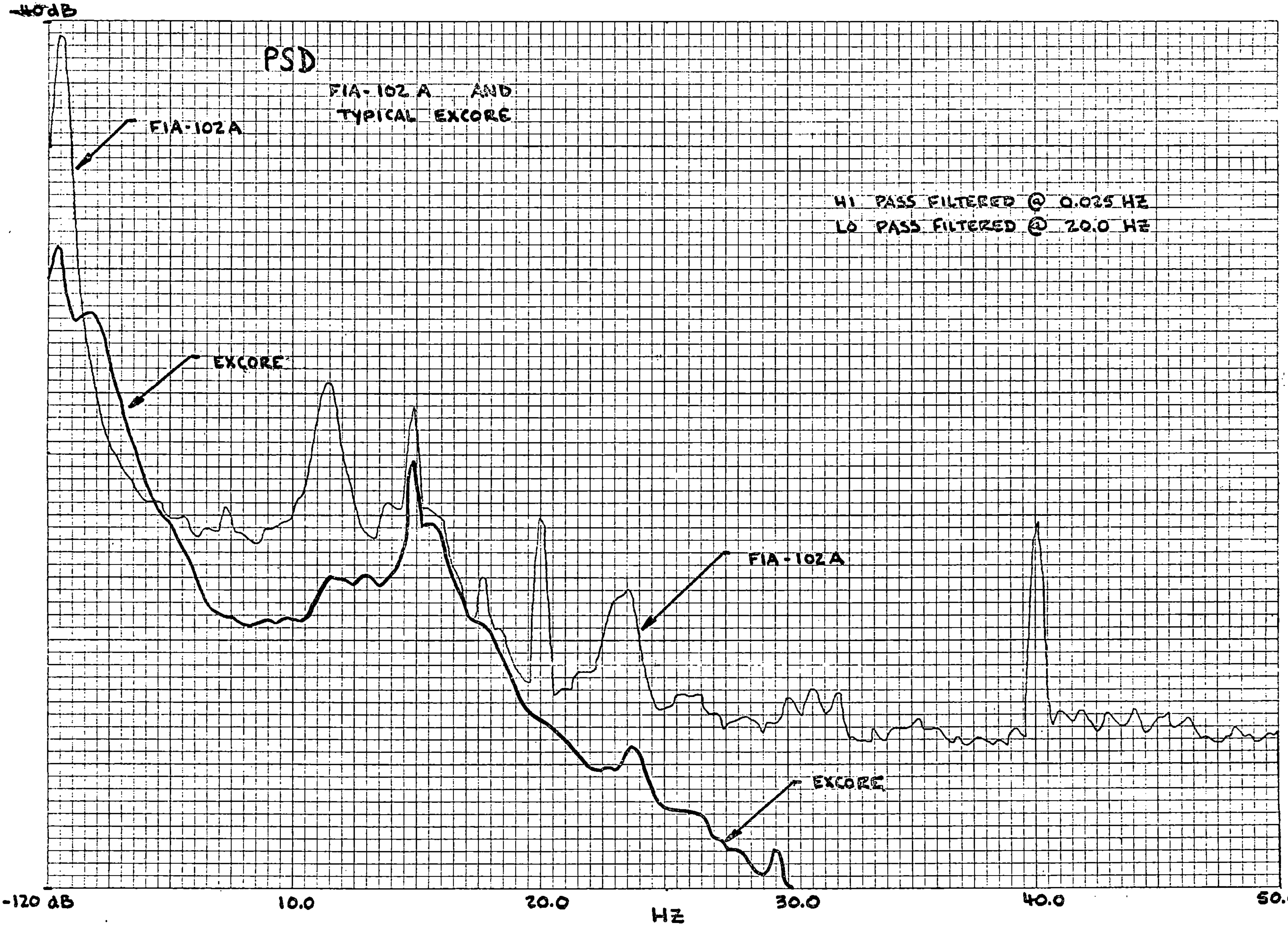


FIGURE #24

NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

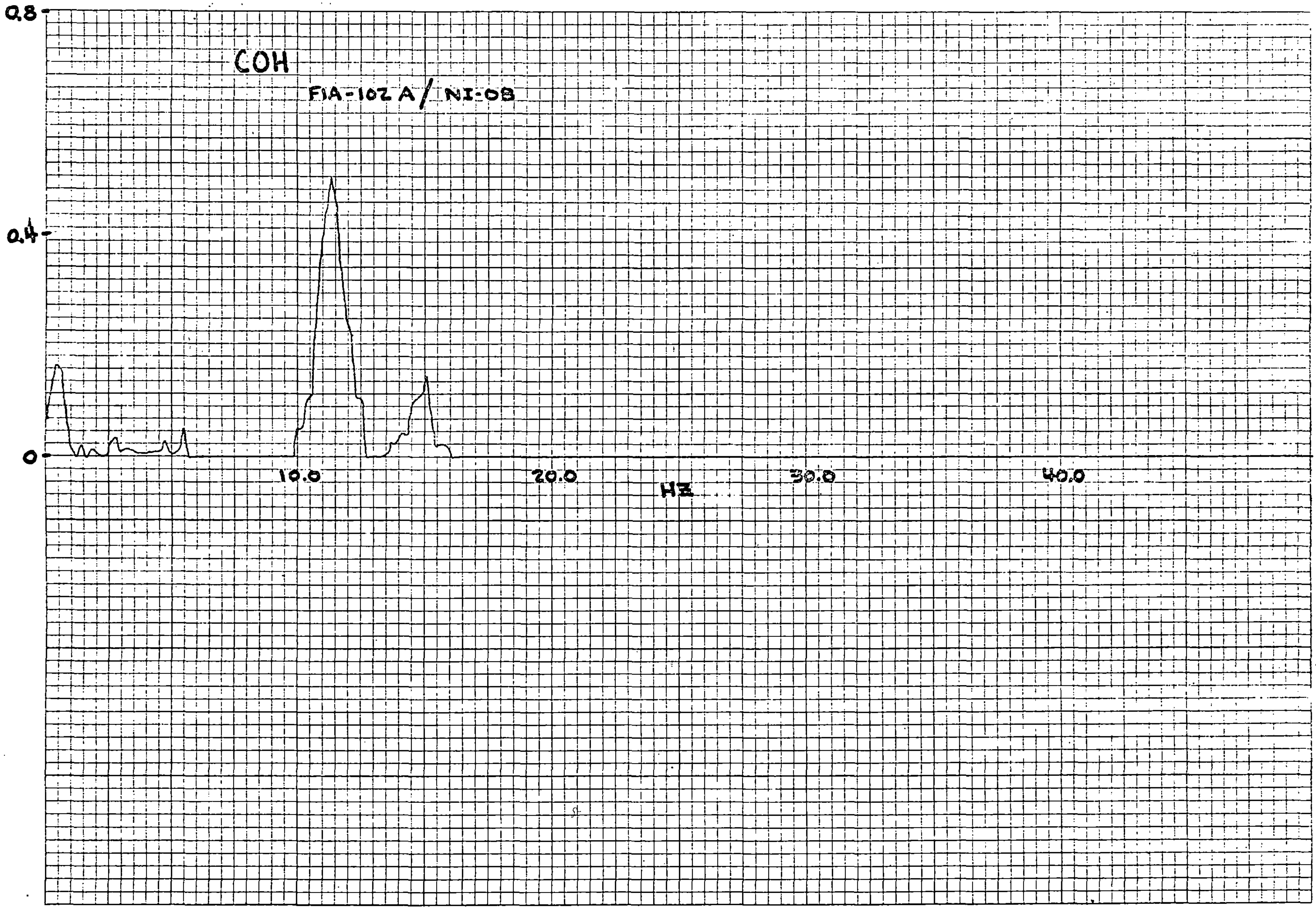


FIGURE # 25

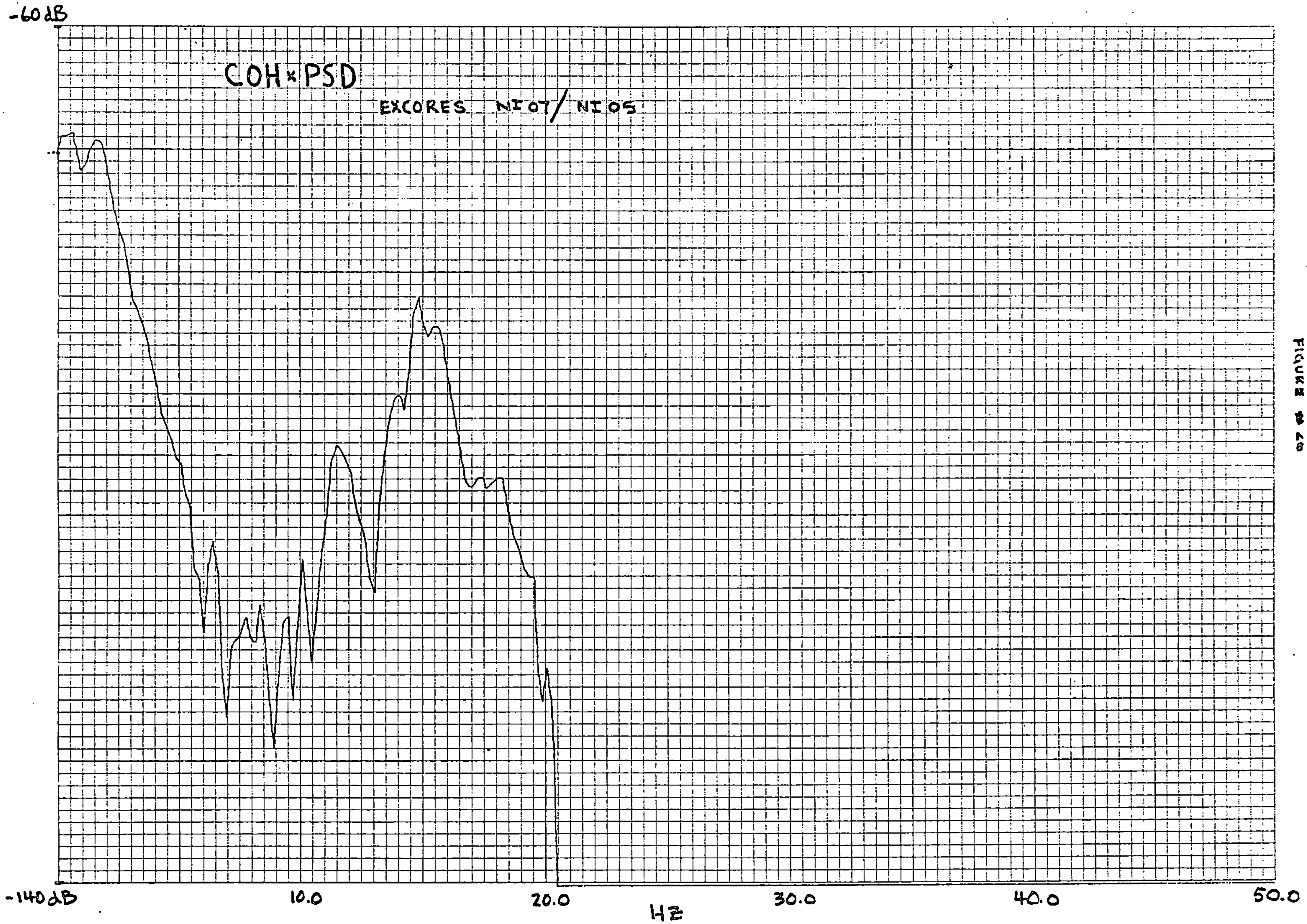


FIGURE 48

NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

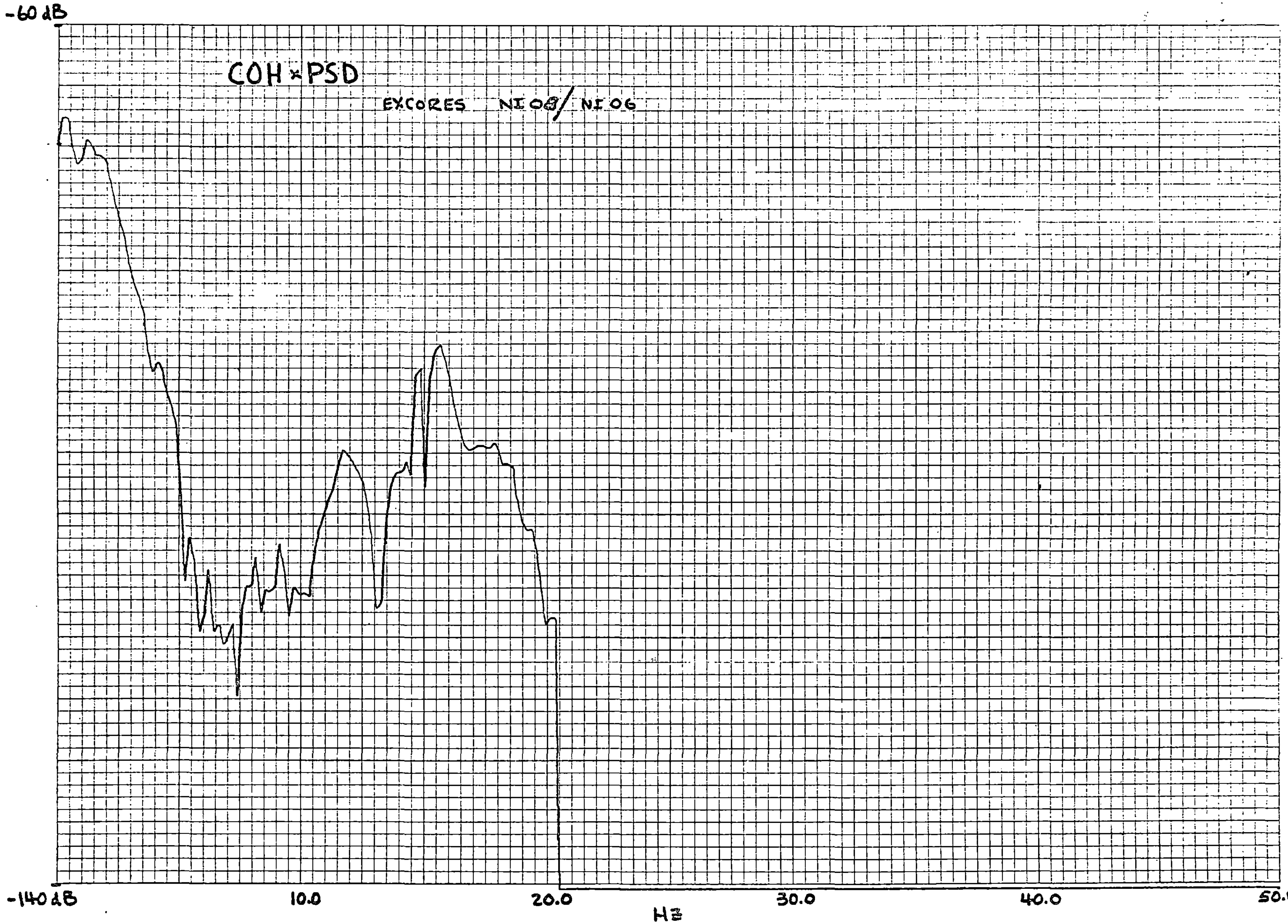
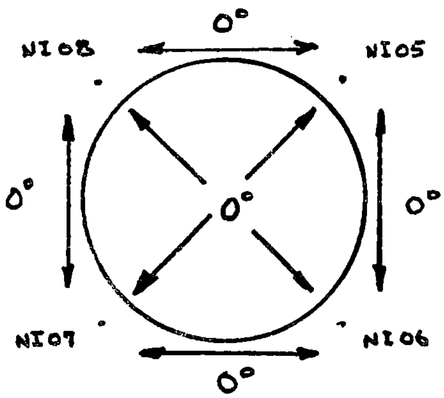


FIGURE #27

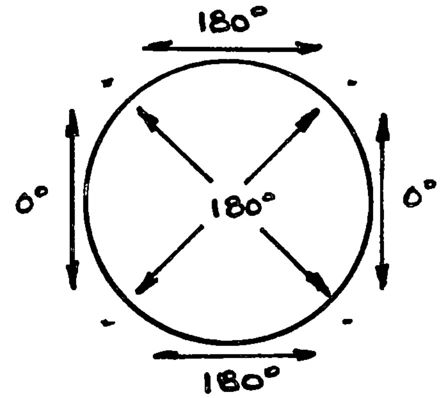
FIGURE #28

SUMMARY OF PHASE PLOTS

BASELINE NOISE - PALISADES

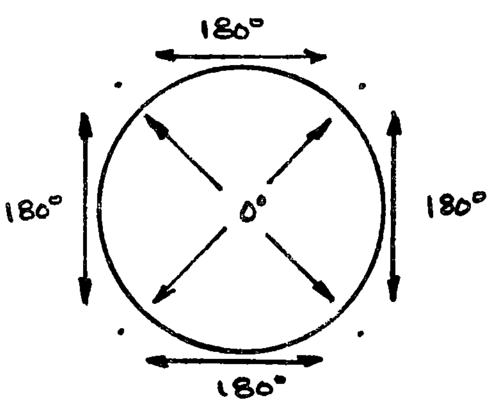


0 TO 5 HZ REGION



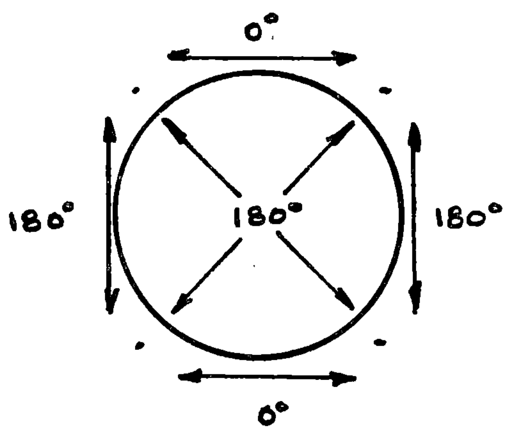
10 TO 14 HZ REGION

@ 12.8 HZ



15 TO 17 HZ REGION

@ 15.5 HZ

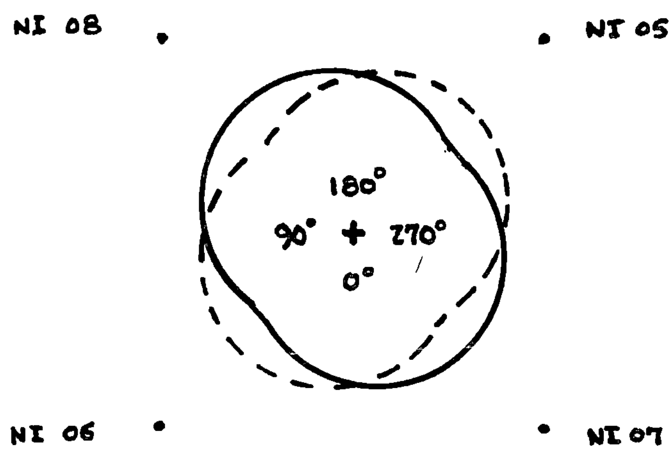


17 TO 20 HZ REGION

@ 18.0 HZ

FIGURE #29

POSTULATED SHELL MODE VIBRATION
AT 15.5 HZ - PALISADES



NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

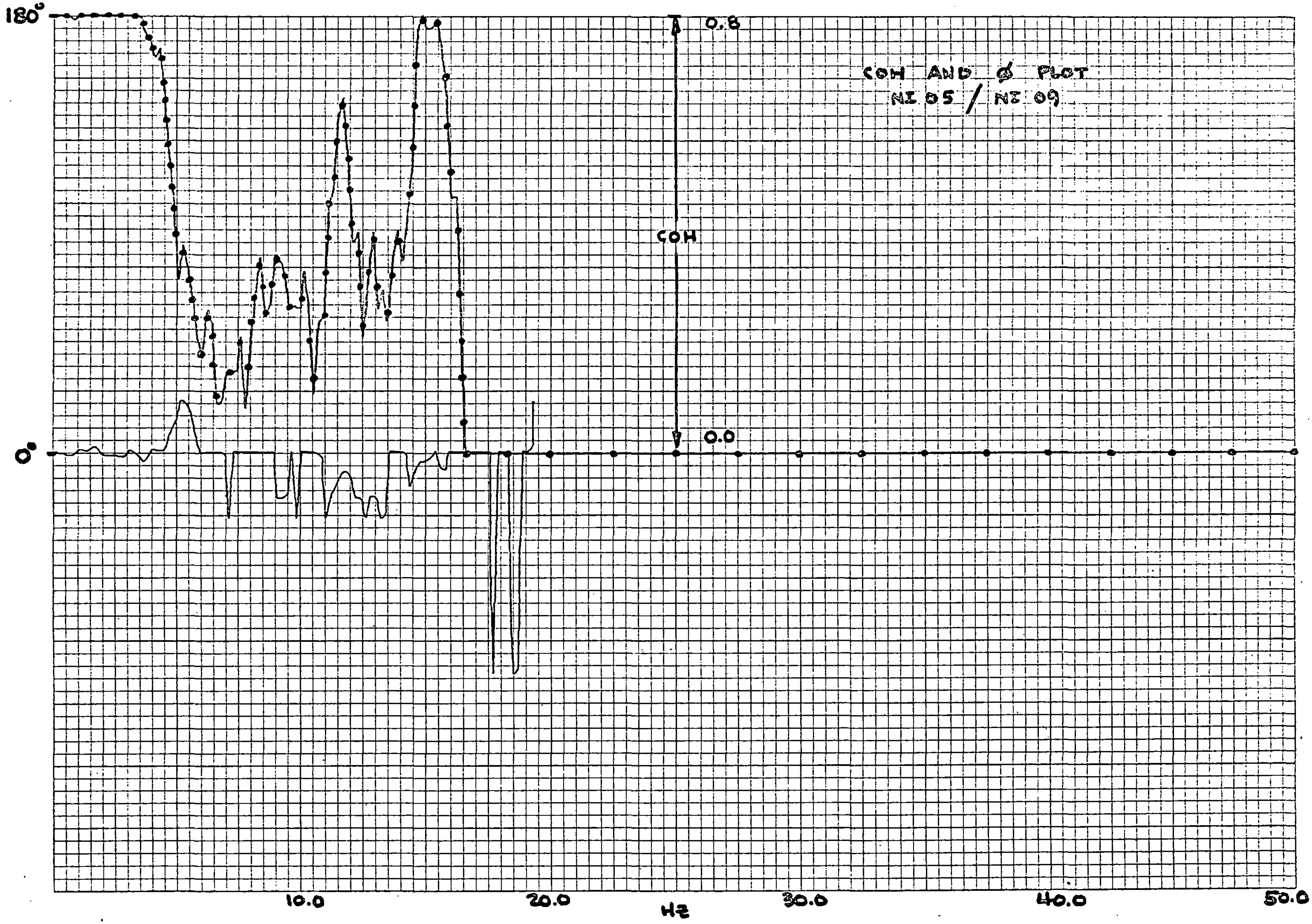


FIGURE #30

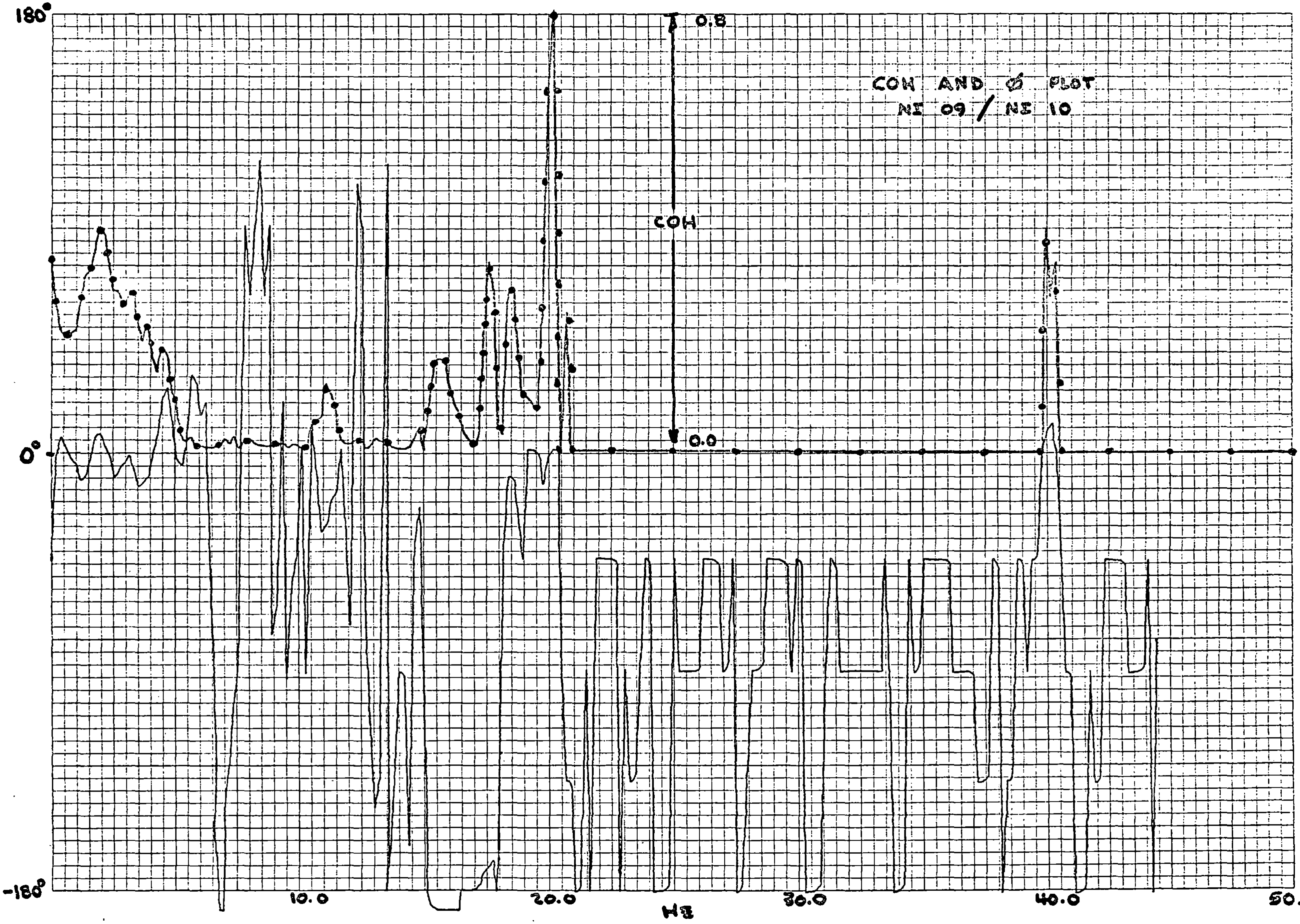

COH AND Ø PLOT
NI 09 / NI 10
180°
0°
-180°
0.8
COH
0.0
10.0
20.0
30.0
40.0
50.0
Hz

FIGURE #31