FLORIDA POWER CORPORATION

CRYSTAL RIVER - 3

DECAY HEAT PUMPS 1A & 1B BASELINE DATA

BY

EXTERNAL ACCELEROMETER

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AUGUST 30, 1978

THE BABCOCK AND WILCOX COMPANY

1.0 References and Attachments

1.1 FPC, CR-3, Decay Heat Pump 1A Vibration Analysis by External Accelerometer, J. M. Huzdovich, August 28, 1978.

1.2 Vibration Tolerances for Industry, ASME 67-PEM-14, presented by R. L. Baxter and D. L. Bernhard.

1.3 Attachment 1 - Baseline Data for Decay Heat Pumps 1A and 1B.

1.4 Attachment 2 - Bearing Frequencies.

2.0 INTRODUCTION

Reference 1.1 provided the first spectral data regarding both DH Pumps at CR-3. Conclusions were drawn from these data regarding the A Pump performance and recommendations were made to improve that pump's operating condition, namely, bearing replacement. The A-Pump has been overhauled, with new bearings being installed. The B-Pump has undergone a similar overhaul to permit inspections. Since both pumps have now accumulated run-in time (A-Pump: Approx. 150 hours, B-Pump: Approx. 50 hours), baseline data have been taken to document their initial performance for future reference and analysis.

To insure that baseline data are used properly, the A & B Pump baseline data should only be compared to data taken under similar operating conditions as listed for each pump in Attachment 1. For example, the original data acquired in Reference 1.1 were obtained under various conditions, however, all at approximately 100°F. Consequently, the baseline data may not be directly compared to the data of Reference 1.1. If, however, the operating conditions in Attachment 1 are duplicated at the next DH Service Cycle, spectral data acquired at that time can be compared directly to the baseline data for analysis.

The baseline data was acquired at the monitoring points depicted in Figure 1. It was reviewed for frequency content and noise source identification, then reduced by determining the G-RMS level for the dominant rotational, pumping, bearing, and other significant frequency peaks. A tabular listing for both pumps is in Attachment 1. Also listed for each pump in Attachment 1 are the operating conditions and the overall signal noise levels in MV-RMS. Figure 2 depicts a typical signal channel utilized in the baseline data acquisition.

3.0 DATA ANALYSIS

The analysis consisted of comparing the rotational, pumping, bearing, and other significant frequencies to generally accepted industry standards as found in Reference 1.2. The principle standard used to evaluate these baseline data was the IRD Mechanalysis "General Machinery Vibration Severity Chart".

The bearings on both machines are operating in the very good to very smooth region, with velocities of 0.028 in/Sec or less measured for all bearing frequencies. Since there are numerous frequencies for each bearing, the individual velocities are not tabulated in this report. However, the frequencies are listed in Attachment 2 along with a copy of the spectra for position 5 for each pump. Performing a direct spectra comparison is less time consuming and is just as effective as comparing velocity values for obvious noise level changes.

The highest velocity level measured on either pump at the fundamental rotational frequency was 0.021 in/Sec indicating a very good balance condition. However, at twice the rotational frequency, (especially on the A Pump), an unusually high level is observed with the largest readings measured at the second flange off the pump on the suction and discharge piping. The maximum velocity level obtained is 1.91 in/Sec, which was measured at the discharge flange. These high levels appear to be caused by a piping system resonance with some additional affect possibly contributed by 60 HZ electrical noise and cold-to-hot alignment changes.

3.0 DATA ANALYSIS

(Continued)

In addition, locations 12 and 8 which are axial, also show high levels. This is believed to be due to the fact that these locations are influenced by the axial loading transmitted from the shaft through the bearings. Since these pumps are end suction type, they do experience axial loading. While these readings could indicate that the pump is running rough, they appear to be more indicative of piping influence and not a pump anomoly.

The levels associated with the pumping frequencies indicate a fair condition for both pumps. The B Pump exhibits a velocity of 0.135 in/Sec at the worst location, and the A pump exhibits a velocity of 0.106 in/Sec at its worst location. The harmonics of the vane rate (148 HZ) decreased as expected indicating no unusual resonances on the pump.

The other frequencies listed for A Pump are attributable to the piping system. This includes the 1375 HZ frequency discussed in Section 3.2 of Reference 1.1. These noises were traced to the DH heat exchanger valving and were measured on the DH Pump suction valve and second flange off the pump discharge (position 10) at higher levels than elsewhere on the pump. They show up as the highest noise levels on the pump due to it being an anchor point in the piping system. No resonant phenomema was observed being excited by these frequencies on the pump. This is based on the observation that the levels decreased when measured directly on the pump casing or bearing housing. The same can be said for the 1690 HZ peak on B Pump.

4.0 SUMMARY

The baseline data presented in this report should provide a sound basis for future pump analysis at the end of a decay heat service cycle in order to allow for maintenance planning. The dominant influence of the piping system cannot be taken lightly. Its affect can influence the data in the 1-2 KHZ range for each pump and as the data indicates for A Pump, even at lower frequencies. At present, the rotational, pumping, and bearing frequencies associated with each pump indicate an acceptable condition for operation. To further clarify the source of the high 60 Hz level on the "A" Pump, however, it is recommended that a hot alignment check be performed.

LOCATION OF ACCELEROMETERS

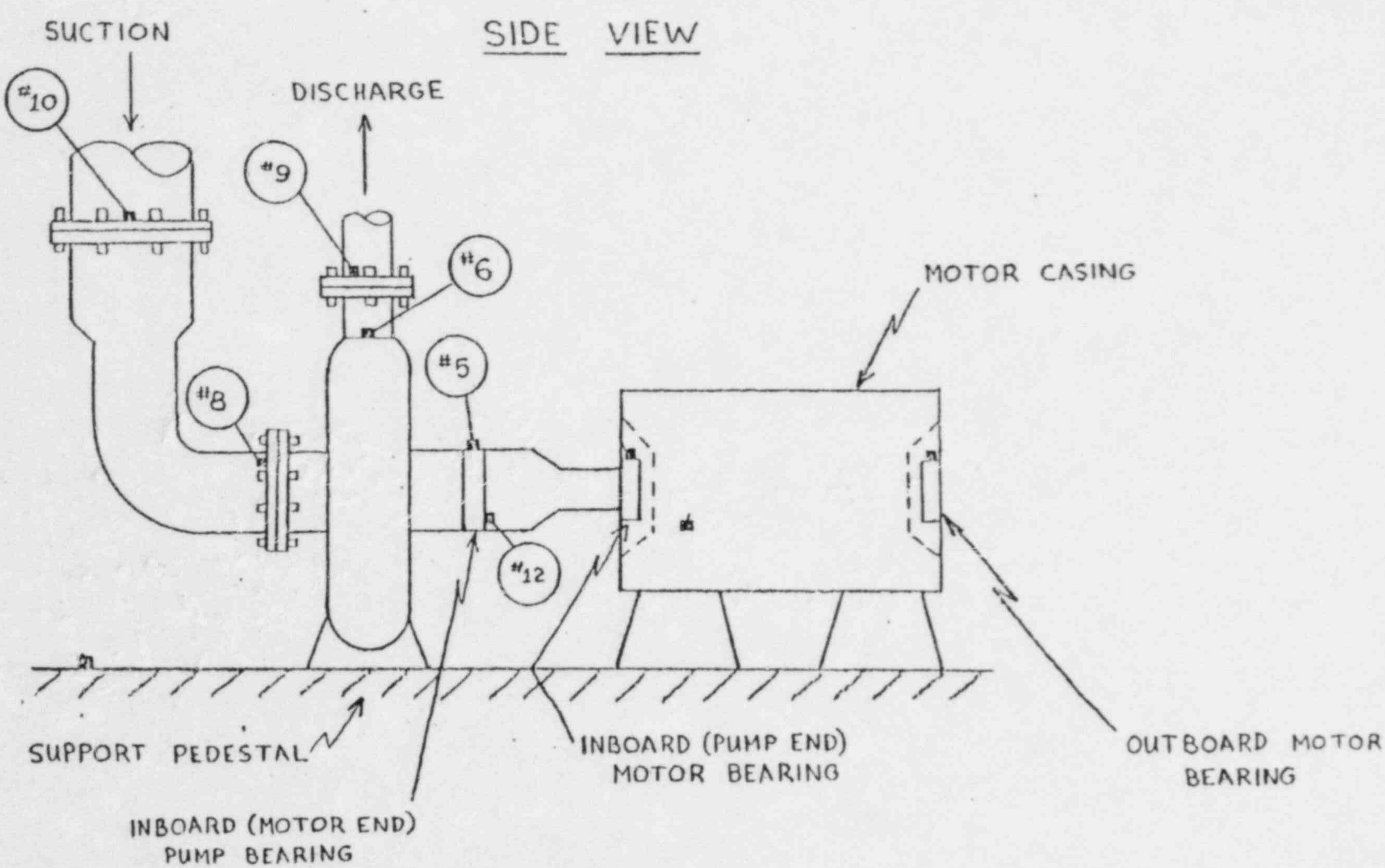
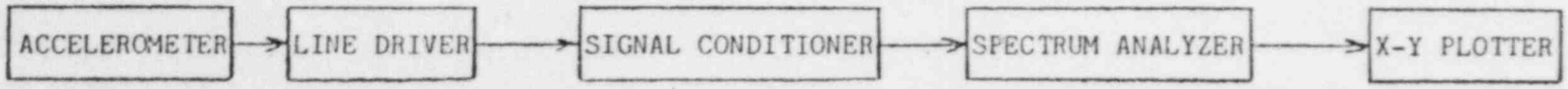


FIGURE - 1



The signal channel was calibrated by attaching the Accelerometers to an NBS traceable Unholtz-Dickie portable shaker and inserting 1 G-RMS through the chain and checking the 1 volt RMS out of the charge amp. This was done on all channels prior to data acquisition.

FIGURE 2

ATTACHMENT 1

BASELINE DATA FOR DECAY HEAT PUMPS 1A AND 1B

TABLE 1-1

A. FREQUENCY LEVELS IN G-RMS

PUMP A BASELINE 8-29-78

CHANNEL:

FREQUENCY	5	12	6	8	9	10	SUCT VLV
Rotational							
29.6	.0036	.003	.0018	.003	.0054	.01	NA
59.2	.021	.3	.0042	1.26	1.29	1.3	
88.8	.039	.012	.015	.0051	.024	.012	
Pumping							
148	.18	.17	.08	.13	.15	.08	
296	.06	.013	.045	.09	.12	.058	
444	.042	.0069	.022	.07	.009	.07	
592	.03	.015	.040	.042	.024	.022	
Other							
1280	1.29	.6	2.2	1.2	.48	6.8	.4
1430	.339	.27	1.26	1.2	.39	1.3	1.6

B. TOTAL NOISE LEVEL MV-RMS

5 - 1780
12 - 1375
6 - 2320
8 - 3000
9 - 1800
10 - 6900

NOTE: These total noise level values are heavily influenced by piping system response and do not necessarily reflect on the condition of the pump.

C. PUMP CONDITION - RECIRC TO VESSEL

Pressure
Suction -240 PSIG
Discharge -390 PSIG

Fluid Temperature - 170°F
Flow - 3000 gpm

A. FREQUENCY LEVELS IN G-RMS

PUMP B BASELINE 8-29-78

FREQUENCY	CHANNEL: 5	12	6	8	9	10
Rotational						
29.6	.009	.003	.0015	.003	.0072	.0035
59.2	.012	.3	.016	.32	.28	.033
88.8	.0032	.0033	.0022	.0073	.0069	.004
Pumping						
148	.23	.12	.10	.07	.16	.14
296	.01	.03	.03	.17	.057	.14
444	.012	.0038	.022	.054	.011	.023
592	.013	.062	.036	.07	.036	.082
Other						
1690	.24	.5	1.59	2.53	2.16	4.0

B. TOTAL NOISE LEVEL MV-RMS

5 - 425
12 - 620
6 - 1710
8 - 2800
9 - 2200
10 - 4000

NOTE: These total noise level values are heavily influenced by piping system response and do not necessarily reflect on the condition of the pump.

C. PUMP CONDITION - RECIRC TO VESSEL

Pressure
Suction -240 PSIG
Discharge -390 PSIG

Fluid Temperature - 170°F
Flow - 3000 gpm

ATTACHMENT 2

BEARING FREQUENCIES

Bearing Frequencies

Radial	5214C3	10 Balls
Thrust	7313B	12 Balls

Radial Bearing - 5214C3

$B = 2.76$
$D = 4.92$
$E = 1/2\ (B + D) = 3.84$
$d = 11/16 = .688$
$N = 10$
$\alpha = 35°$
$f_f = 29.6$

$$f_{EO} = \frac{f_f}{2}\left(1 - \frac{d}{E}\cos\alpha\right) = \frac{29.6}{2}\left(1 - \frac{.688}{3.84}\cos 35°\right) = 14.8\ (1 - .147)$$

$f_{EO} = 12.62$ HZ

$$f_{EI} = \frac{f_f}{2}\left(1 + \frac{d}{E}\cos\alpha\right) = 14.8\ (1.147)$$ $f_{EI} = 16.98$ HZ

$$f_B = \frac{E}{d}\frac{f_f}{2}\left(1 - \frac{d^2}{E^2}\cos^2\alpha\right) = 82.60\ (1 - .022)$$ $f_B = 80.78$ HZ

$f_{BO} = Nf_{EO}$ $f_{BO} = 126.2$HZ

$f_{BI} = Nf_{EI}$ $f_{BI} = 169.8$HZ

Thrust Bearing - 7313B

B = 2.56
D = 5.51
E = 4.04
d = 15/16 = .938
N = 12
α = 40°
f_f = 29.6

$f_{EO} = 14.8\ (1 - \frac{d}{E} \cos\alpha) = 14.8\ (1 - .178)$ $\quad f_{EO}$ = 12.17HZ

$f_{EI} = 14.8\ (1 + \frac{d}{E} \cos\alpha)$ $\quad f_{EI}$ = 17.43 HZ

$f_B = 14.8\ \left(\frac{E}{d}\right) \left(1 - \frac{d^2}{E^2} \cos^2\alpha\right) = 14.8\ (4.31)\ (1 - .032)$ $\quad f_B$ = 61.75HZ

$f_{BO} = N f_{EO}$ $\quad f_{BO}$ = 146HZ

$f_{BI} = N\ f_{EI}$ $\quad f_{BI}$ = 209HZ

7313B THRUST HARMONICS

1	2	3	4	5	6	7	8	9
12.17	24.34	36.51	48.68	60.85	73.02	85.19	97.36	109.53
17.43	34.86	52.29	69.72	87.15	104.58	122.01	139.44	156.87
61.75	123.5	185	247	308	370	432	494	555
146	292	438	584	730	876	1022	1168	1314
209	418	627	836	1045	1254	1463	1672	1881
5214C3 RAD								
12.62	25.24	37.86	50.48	63.1	75.72	88.34	100.96	113.58
16.98	33.96	50.94	67.92	84.9	101.88	118.86	135.84	152.82
80.78	161	242	323	403	484	565	646	727
126.2	252	378	504	631	757	883	1009	1135
169.8	340	509	679	849	1018	1188	1358	1528

Bearing Frequency Calculations

Nomenclature:

B = Bore, inside bearing diameter (inches)

D = Outside bearing diameter (inches)

E = Pitch diameter = 1/2 (B+D) (inches)

d = Ball diameter (inches)

N = Number of balls

α = Contact angle (degrees)

f_f = Fundamental rotational frequency (RPM/60) (HZ)

Formulas

Frequency (HZ)	Approximate	Contact Angle	Remarks
Cage to outer ring frequency (f_{EO})	$\frac{f_f}{2}(1-d/E)$	$\frac{f_f}{2}(1-\frac{d}{E}\cos\alpha)$	Fundamental cage (train) frequency when the inner ring is rotating and the outer ring is stationary.
Cage to inner ring frequency (f_{EI})	$\frac{f_f}{2}(1+d/E)$	$\frac{f_f}{2}(1+d/E\cos\alpha)$	Fundamental cage (train) frequency when the inner ring is stationary and the outer ring is rotating.
Ball frequency (f_B)	$\frac{Ef_f}{2d}(1-d^2/E^2)$	$\frac{Ef_f}{2d}(1-\frac{d^2}{E^2}\cos^2\alpha)$	Spin frequency of a rolling element. A rough spot or indentation produces twice this frequency.
Outer ballpass (f_{BO})	Nf_{EO}	Nf_{EO}	Frequencies generated due to an irregularity on the stationary raceway.
Inner ballpass (f_{BI})	Nf_{EI}	Nf_{EI}	Frequencies generated due to an irregularity on the stationary raceway.
Cage to rotating ring (f_{ER})	f_f-f_{EI} or f_f-f_{EO}	f_f-f_{EI} or f_f-f_{EO}	Frequency due to the relative rotation between the cage and the rotating ring. For an irregularity in the ring, a frequency of (f_{ER}) will be generated.

Note: In the case of many irregularities, the harmonics of the above frequencies will be evident in the noise spectrum.

Figure 2-1

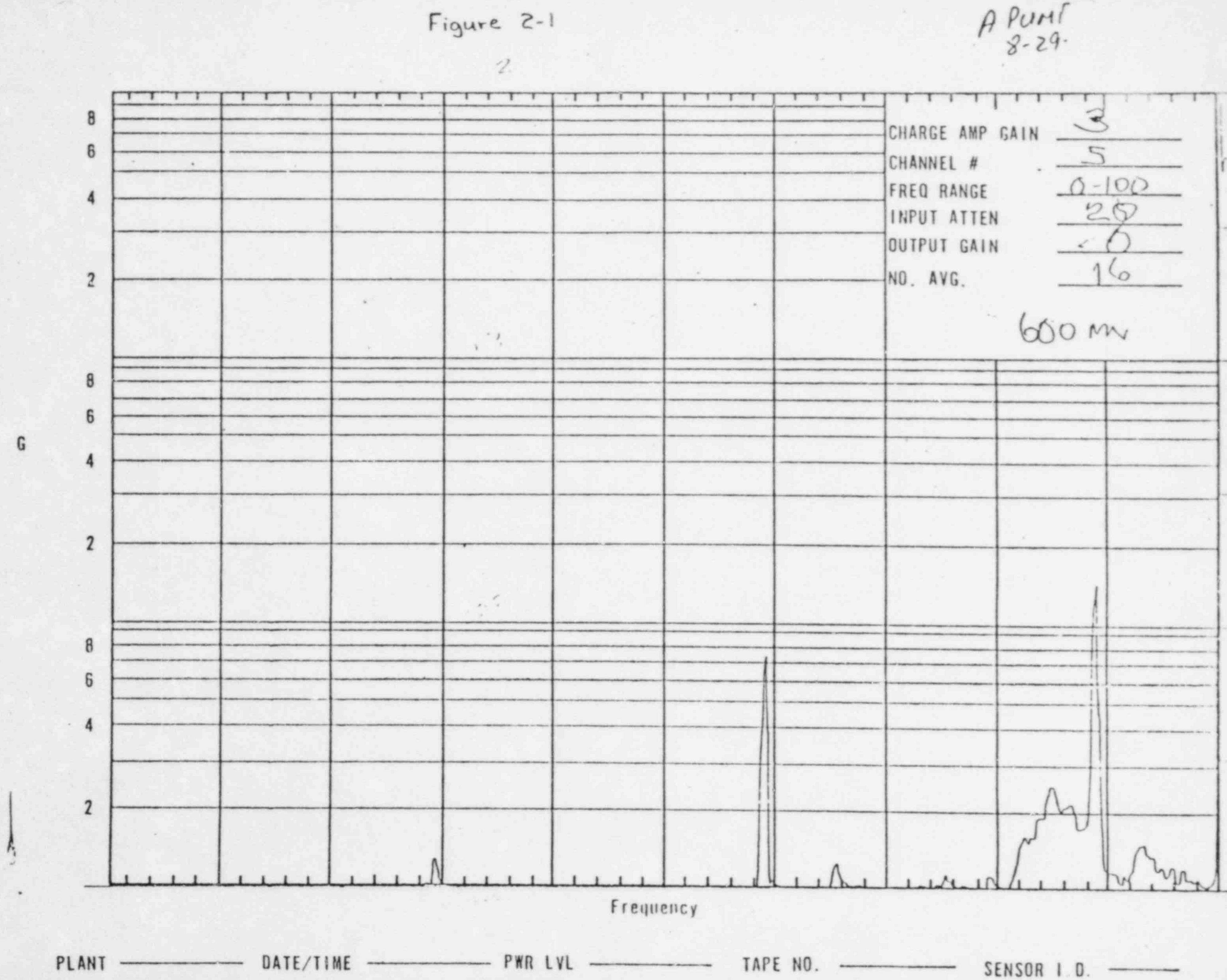
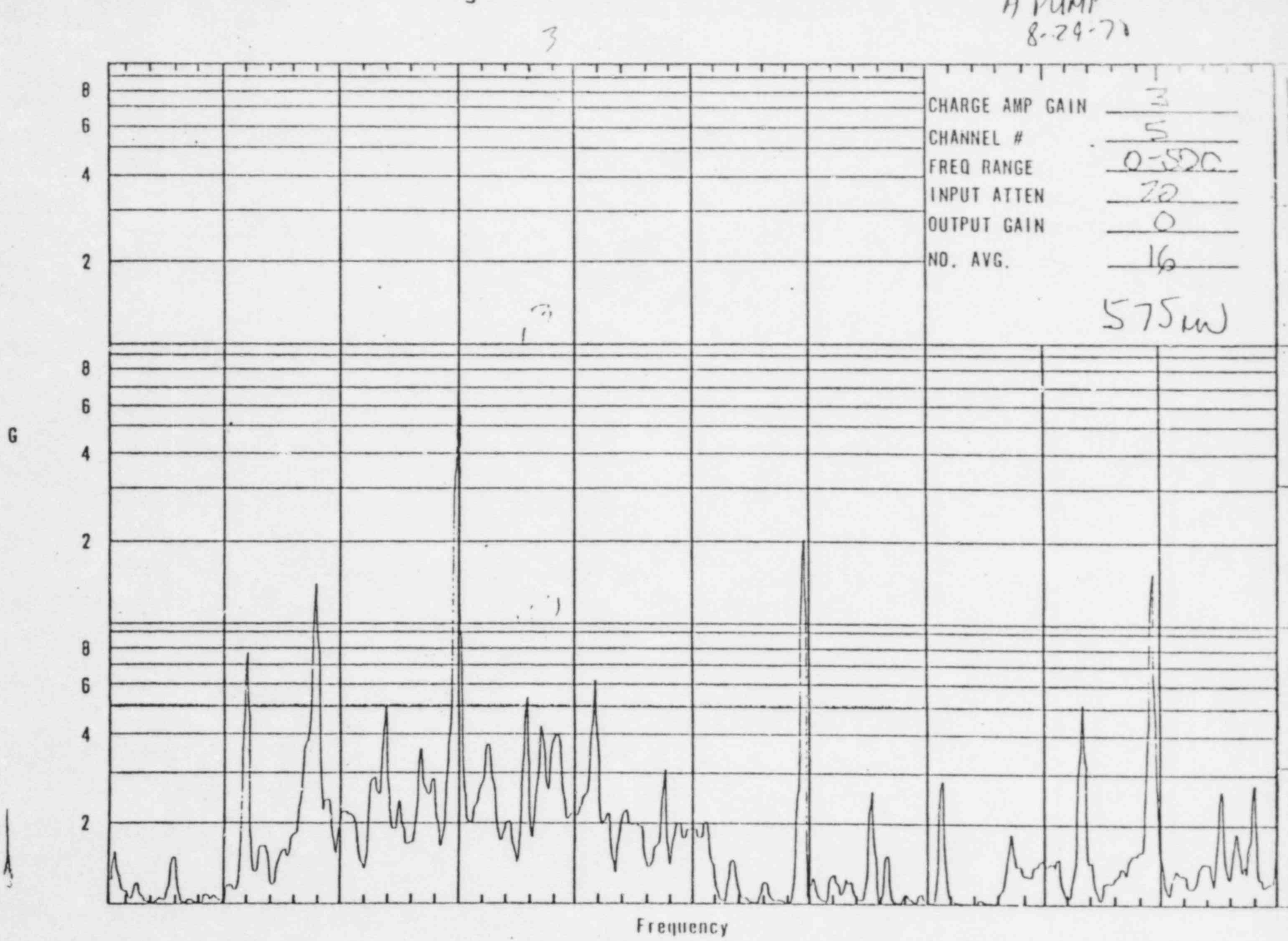

A PUMP
8-29
8
6
4
2
G
CHARGE AMP GAIN 3
CHANNEL # 5
FREQ RANGE 0-100
INPUT ATTEN 20
OUTPUT GAIN -0
NO. AVG. 16
600 MW
Frequency
PLANT
DATE/TIME
PWR LVL
TAPE NO.
SENSOR I.D.

Figure 2-2



PLANT ——— DATE/TIME ——— PWR LVL ——— TAPE NO. ——— SENSOR I.D. ———

Figure 2-3

A PUMP
8-29-70

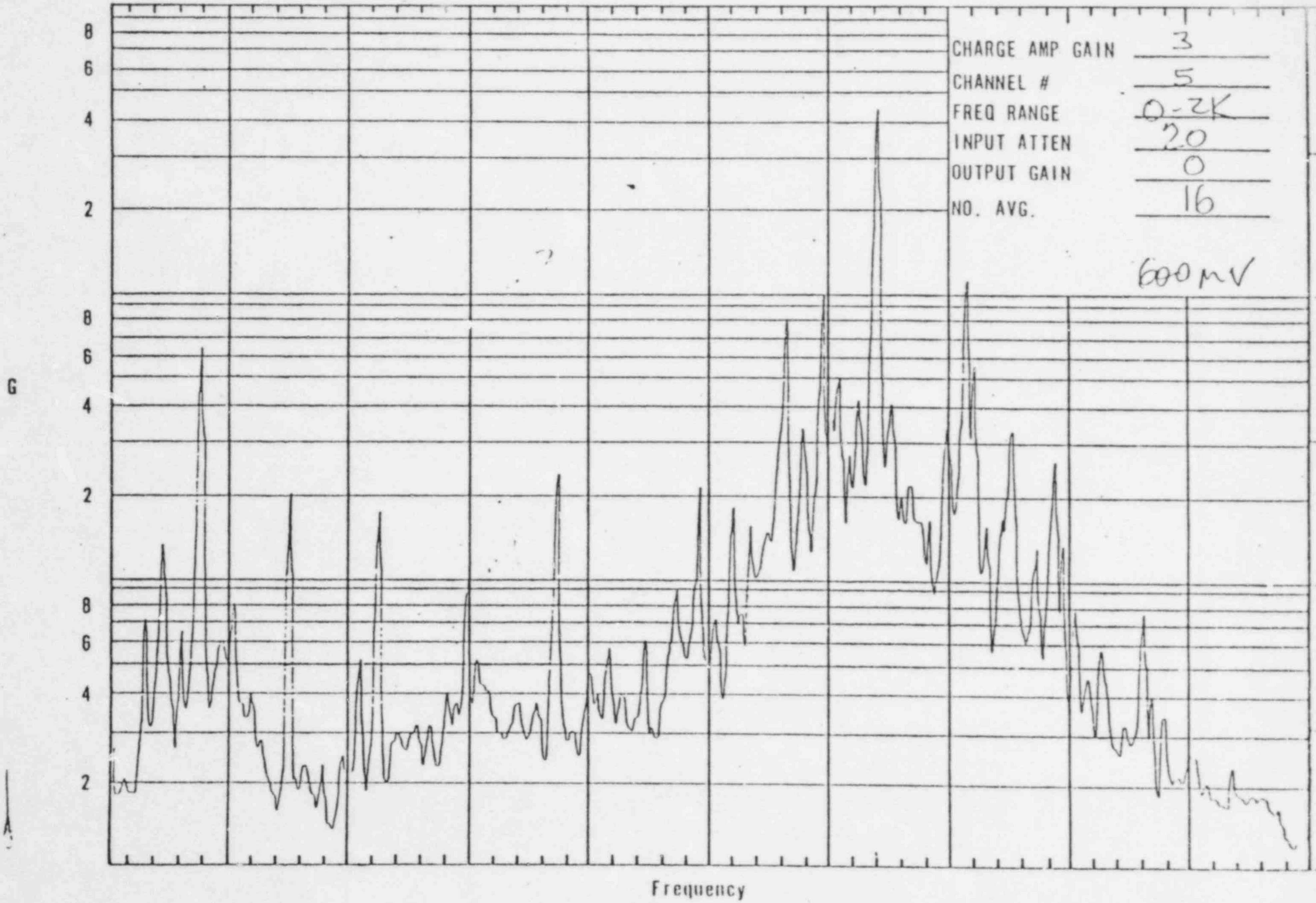


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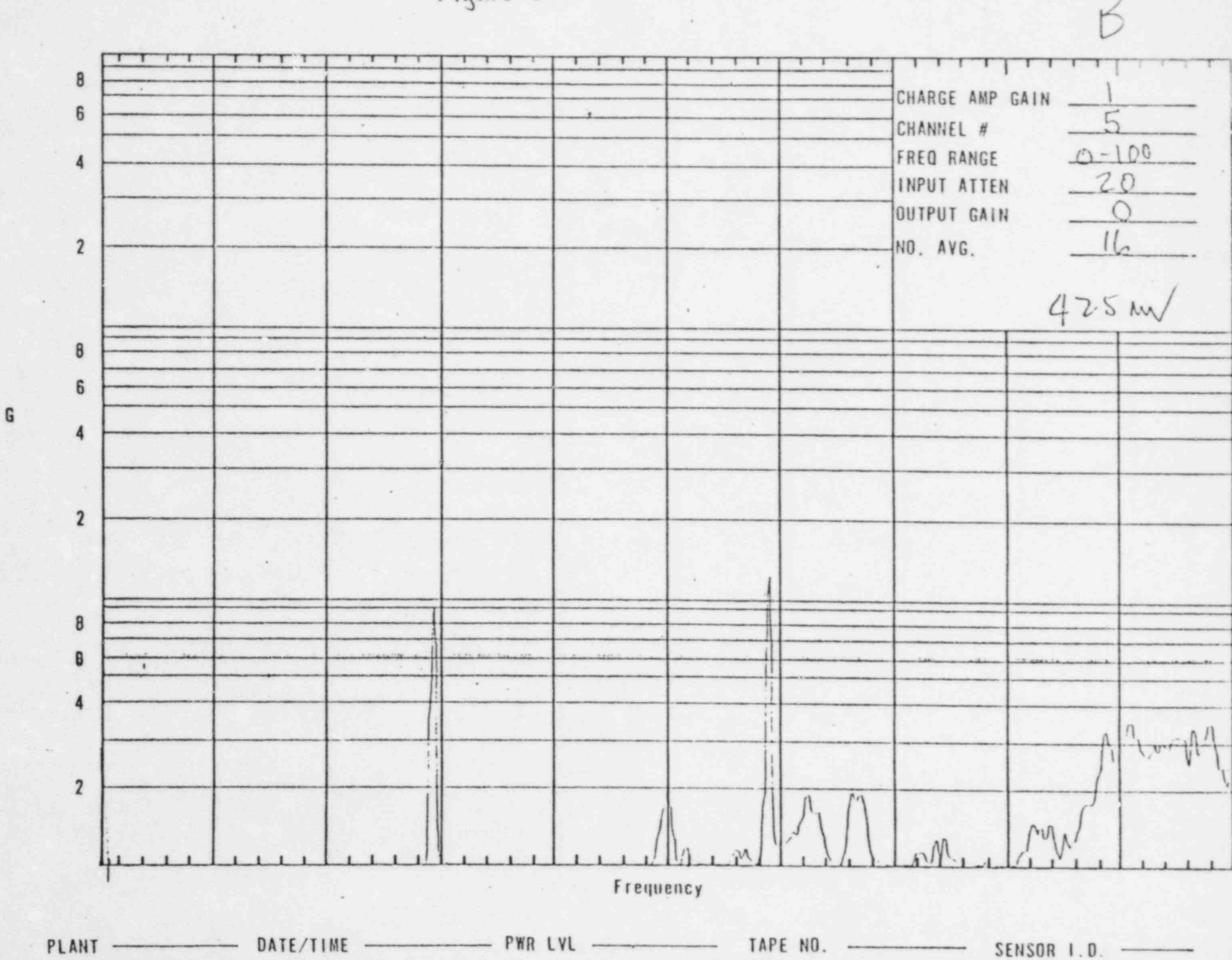
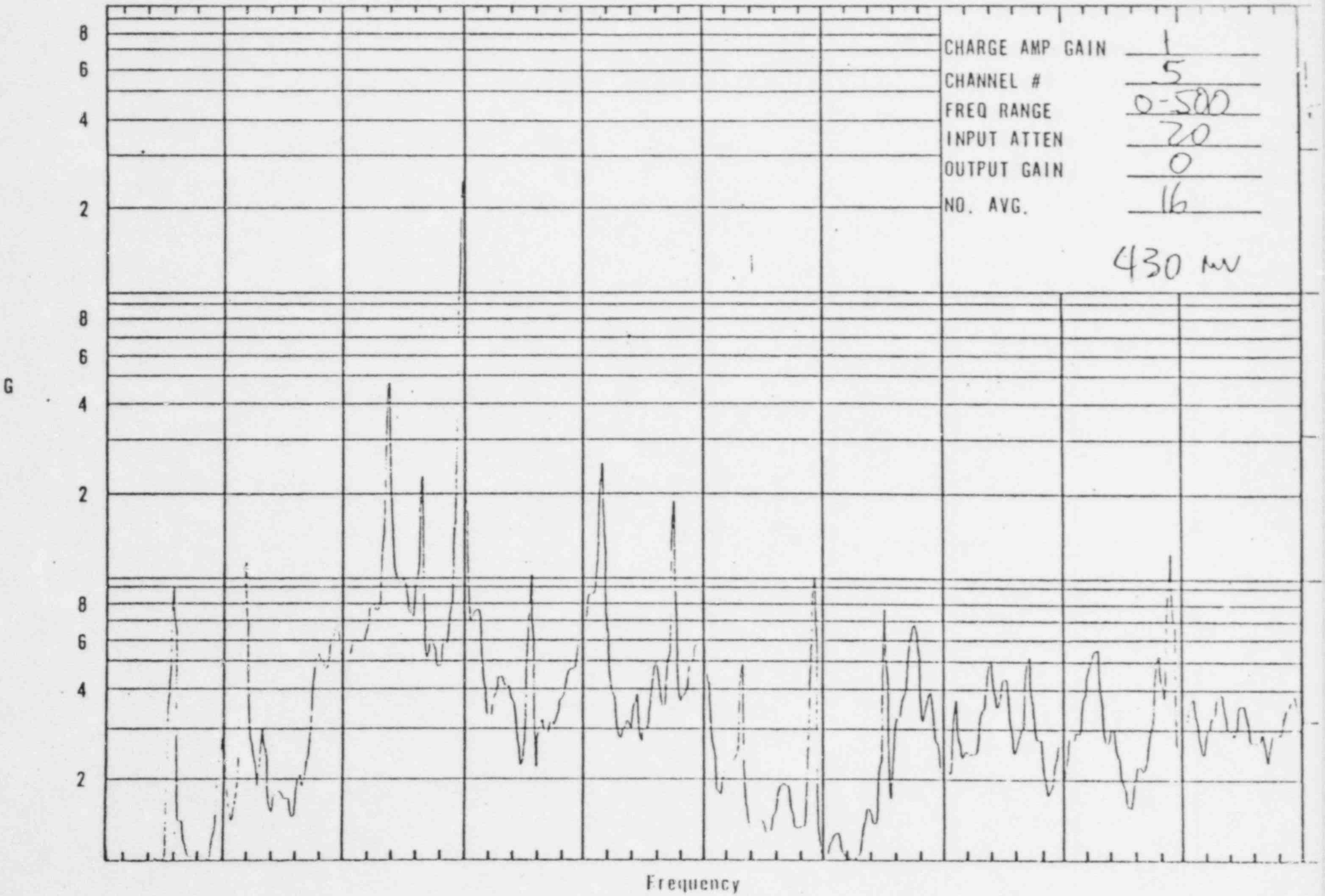
Figure 2-4



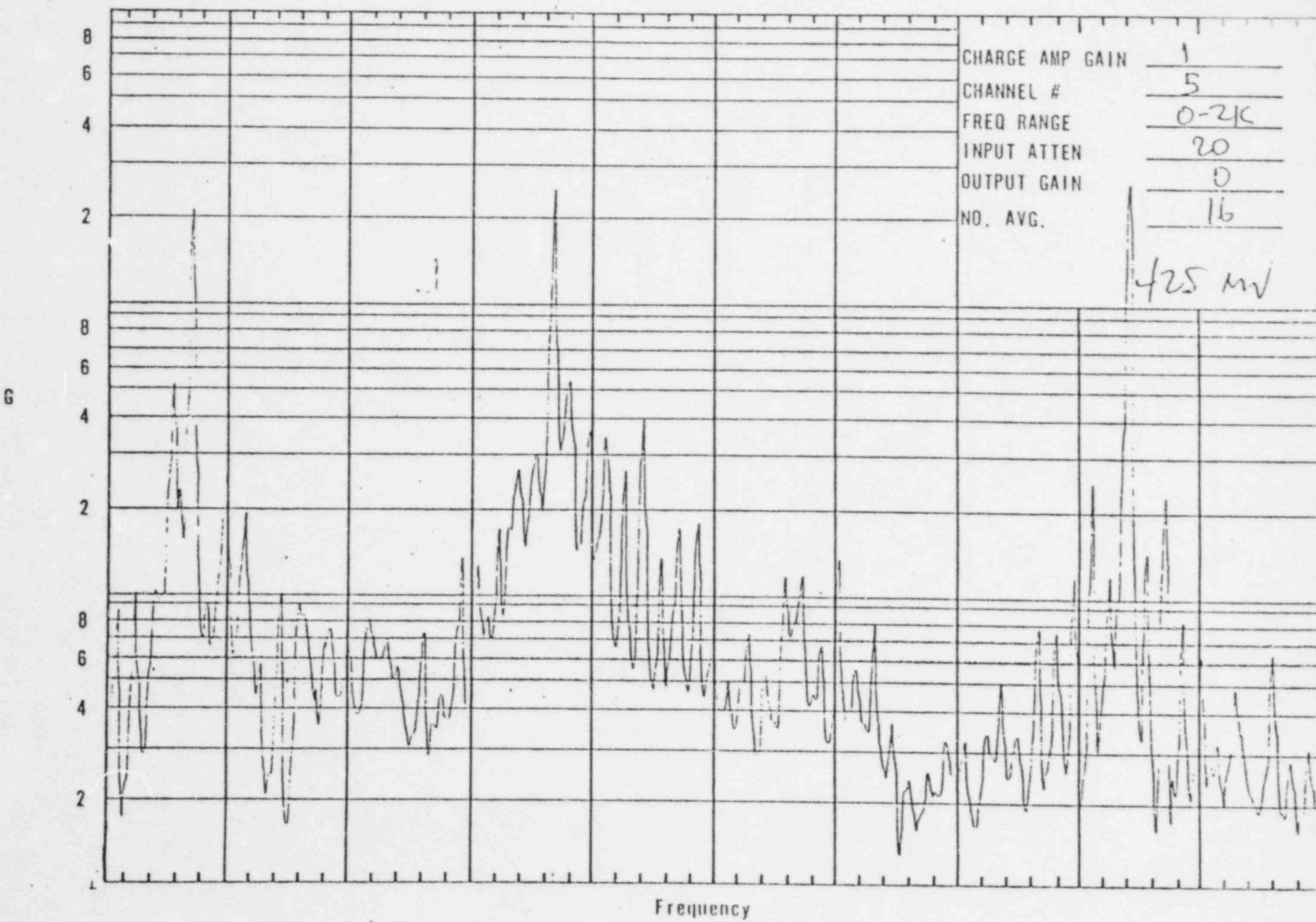
B
CHARGE AMP GAIN 1
CHANNEL # 5
FREQ RANGE 0-100
INPUT ATTEN 20
OUTPUT GAIN 0
NO. AVG. 16
425 MW
G
8
6
4
2
8
6
4
2
8
6
4
2
Frequency
PLANT
DATE/TIME
PWR LVL
TAPE NO.
SENSOR I.D.

Figure i



PLANT ——— DATE/TIME ——— PWR LVL ——— TAPE NO. ——— SENSOR I.D. ———

Figure 1



PLANT —— DATE/TIME —— PWR LVL —— TAPE NO. —— SENSOR I.D. ——

Babcock & Wilcox
Power Generation Group
P.O. Box 1260, Lynchburg, Va.
Telephone: (804) 384-5111

October 13, 1977

Mr. R. S. Burns
CR-3 Engineering Manager
Florida Power Corporation
P.O. Box 14042
St. Petersburg, Florida 33733

Subject: Decay Heat Pump Operation

Reference - Letter, RS Burns from GT Fairburn, dated 7/12/77

Dear Mr. Burns:

This letter is to advise you that B&W has revised the limits on the operation of the Decay Heat Pump during the recirculation mode (85/100) gpm from 30 minutes continuously and 60 minutes total in any 12 month period to 15 hours continuously and 80 hours total within the life of the pump.

This revision is based on the results of a design review meeting at Worthington and their authorization of operation limits of these Decay Heat Pumps.

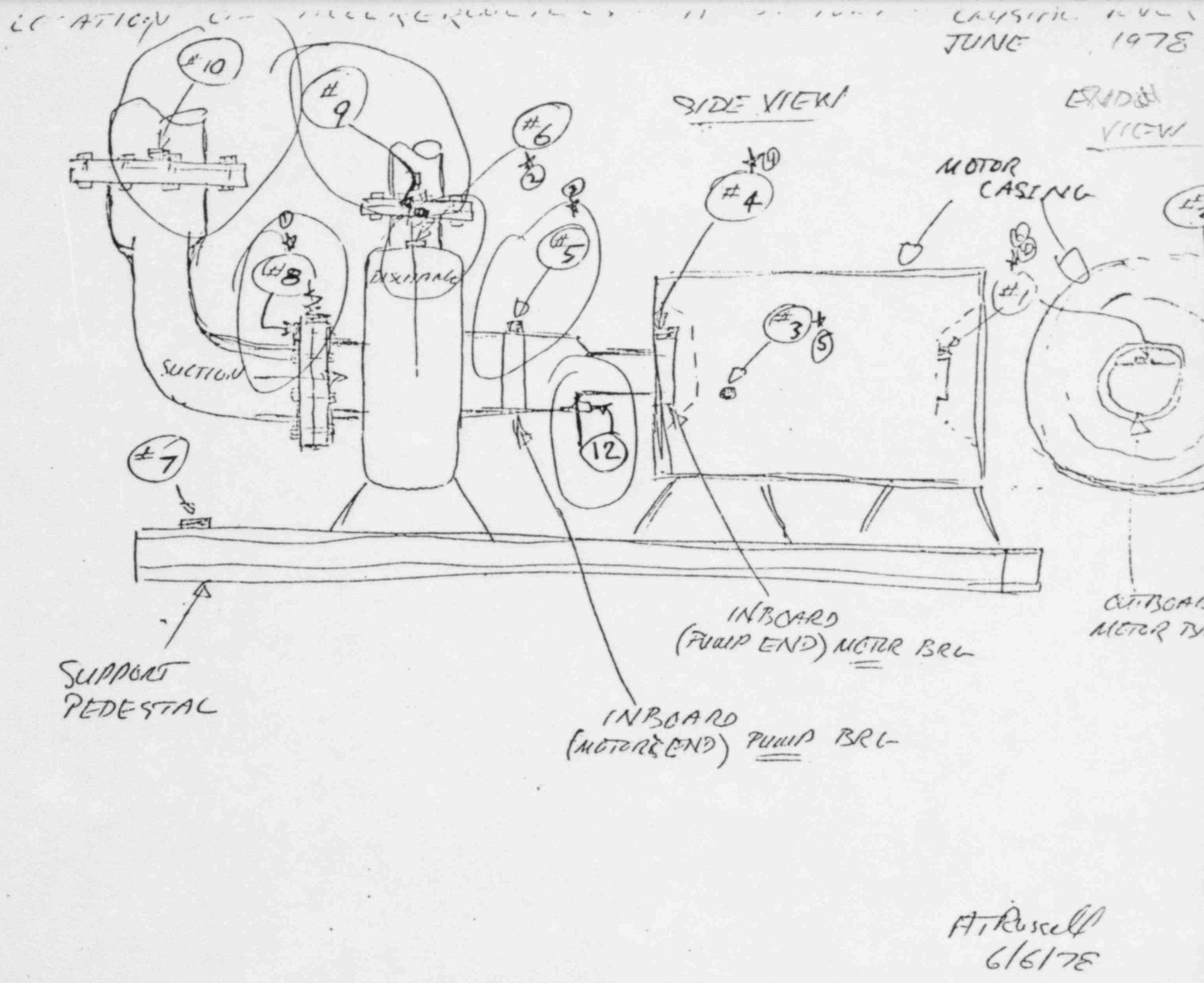
Very truly yours,

G. T. Fairburn

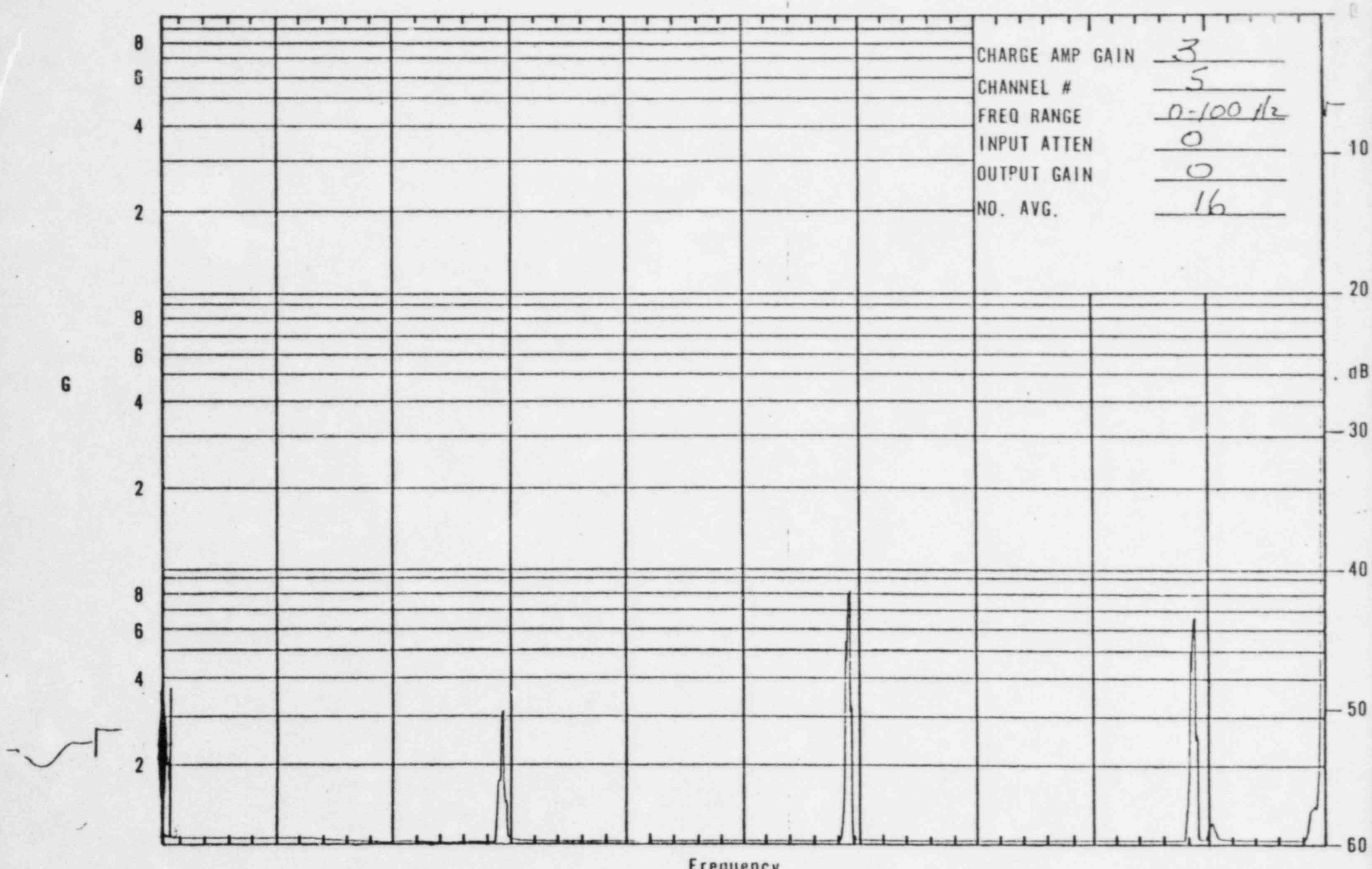
G. T. Fairburn
Service Manager

GTF/hh

cc: EC Simpson
JS Laing
SP Melancon

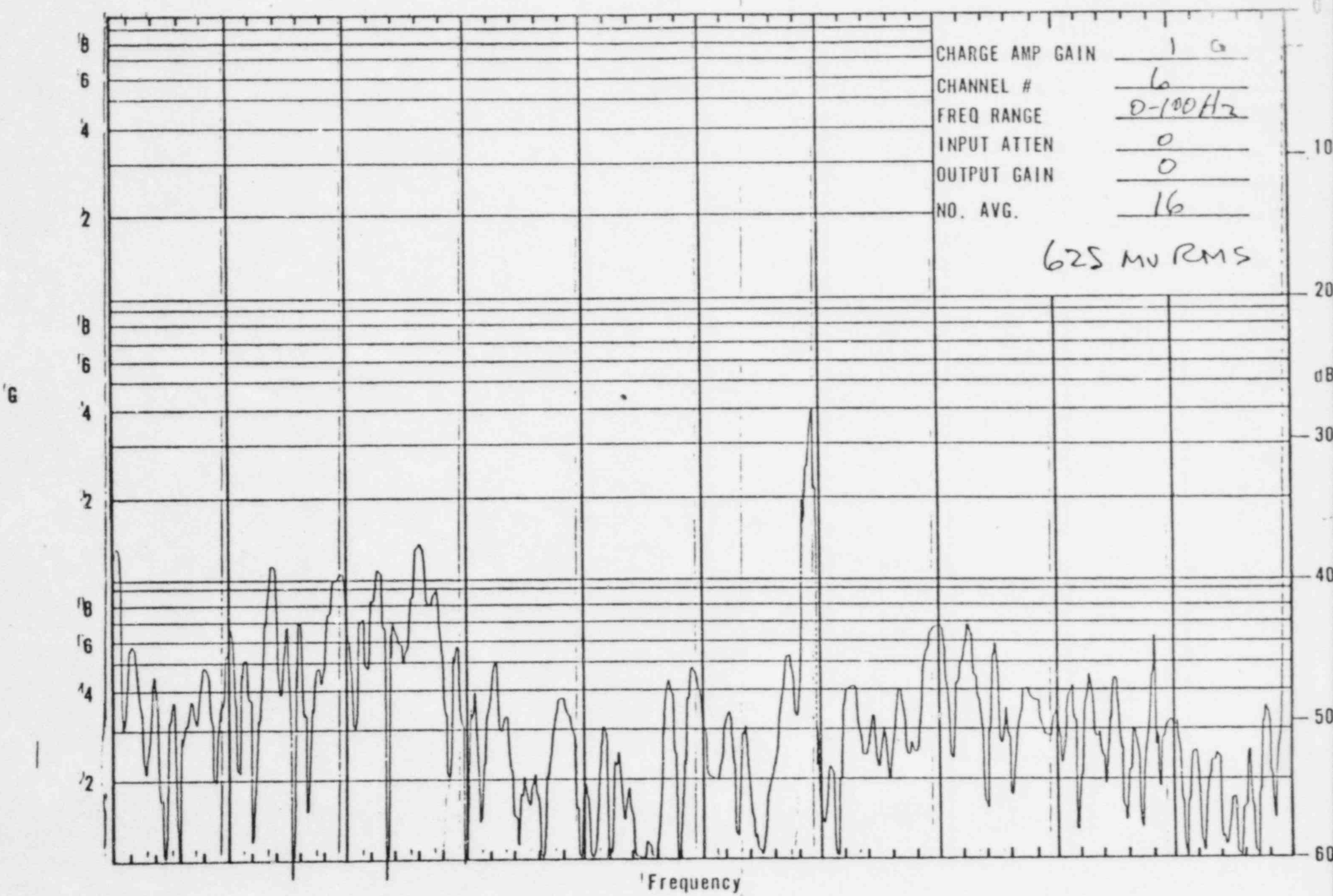

JUNE 1978
SIDE VIEW
END VIEW
#10
#9
#6
#4
#5
#8
#3
#1
#7
12
SUCTION
MOTOR CASING
INBOARD (PUMP END) MOTOR BRG
INBOARD (MOTOR END) PUMP BRG
SUPPORT PEDESTAL
A.T. Russell
6/6/78

B Pump



PLANT FPC CR-3 DATE/TIME 8/3/78 PWR LVL SD TAPE NO. ______ SENSOR I.D. ______

B.



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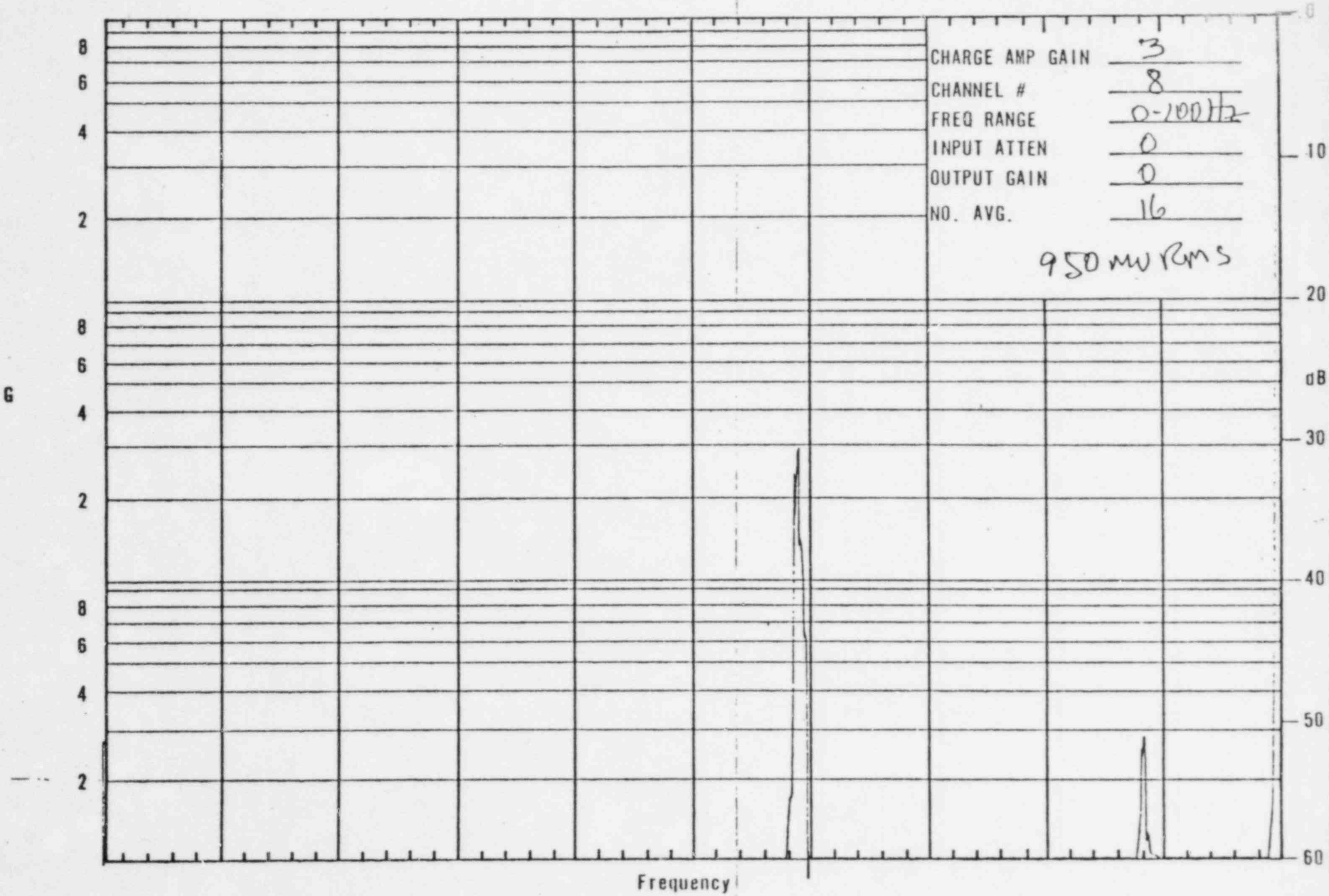
B Run



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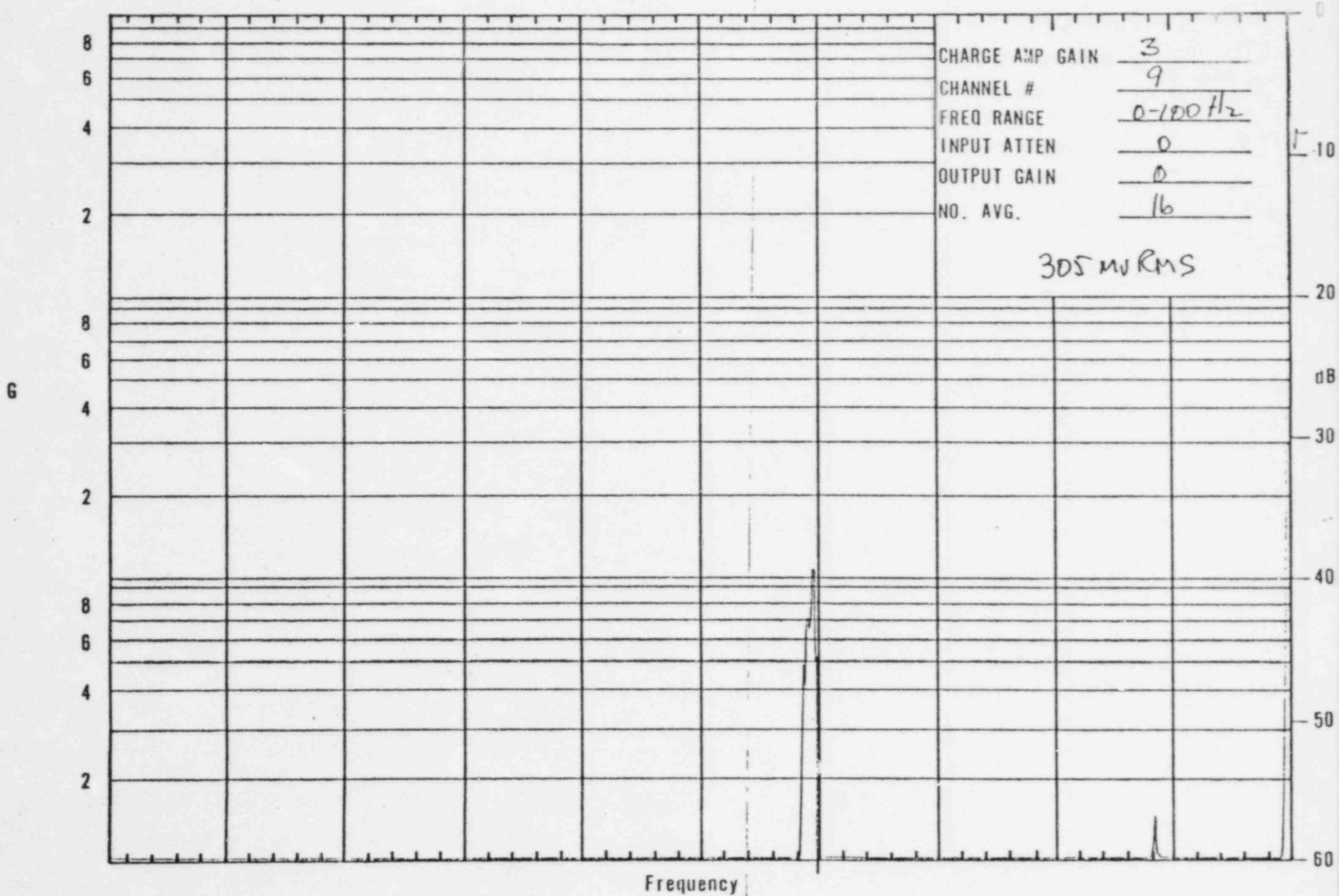
B pw



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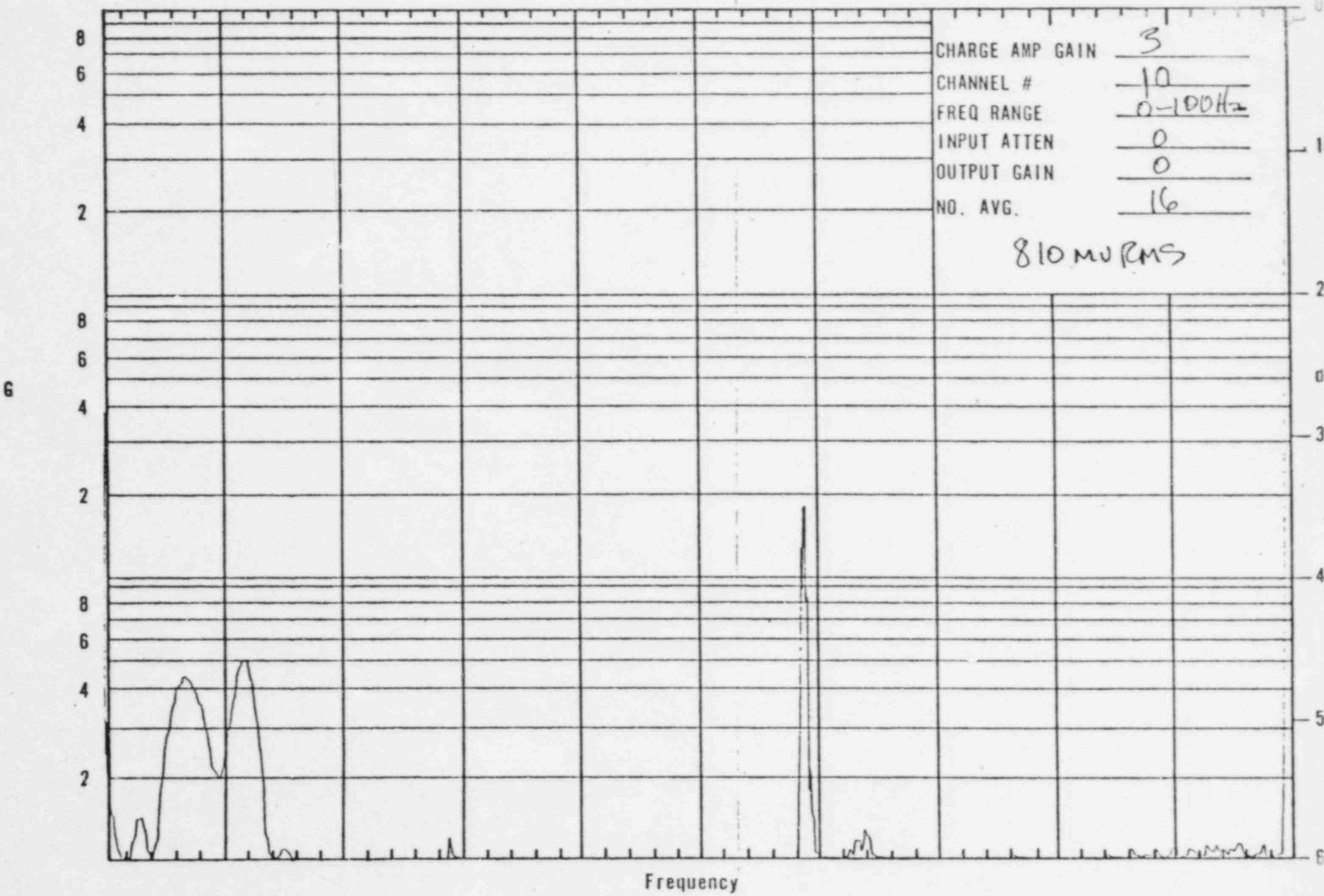
Br P

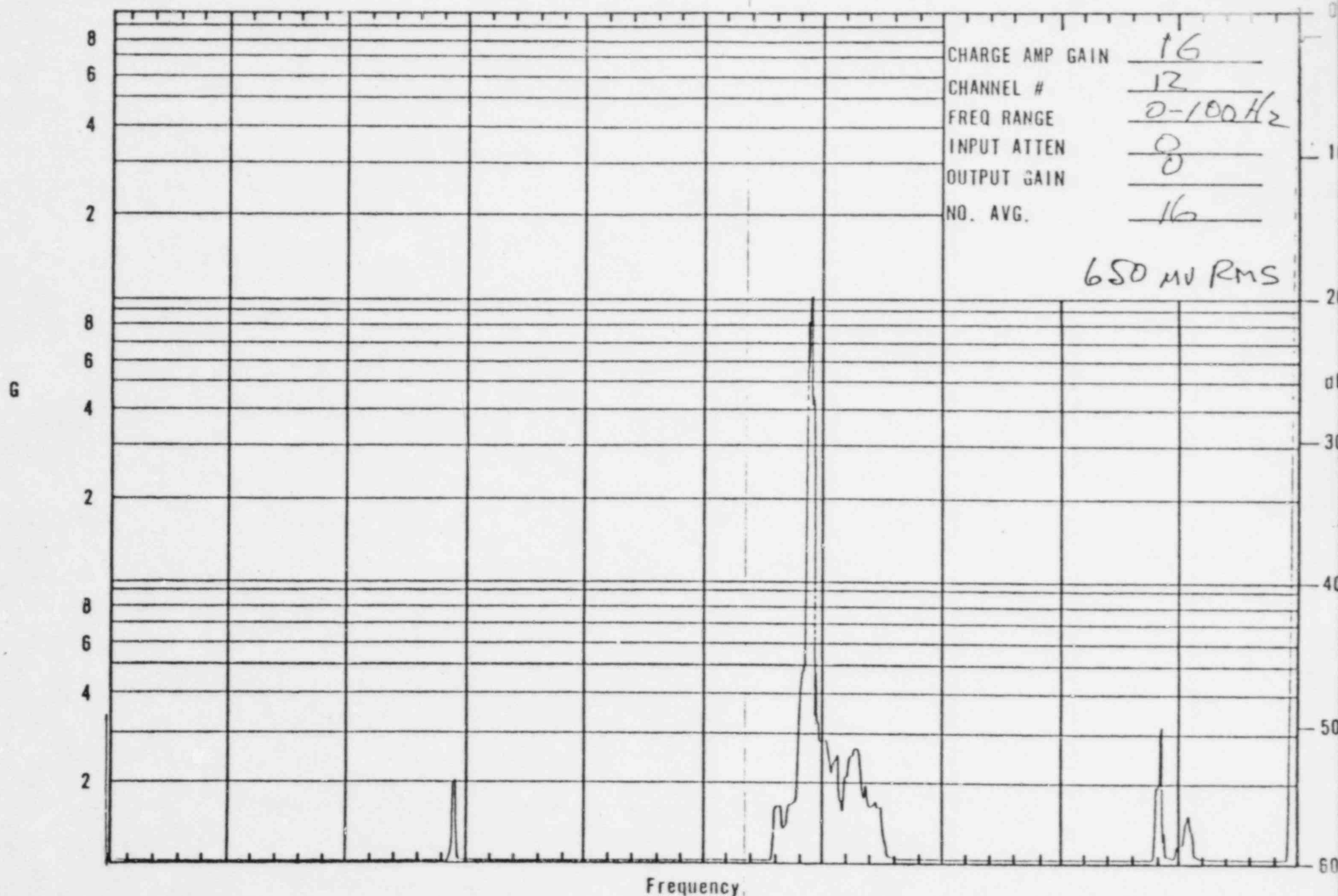


CHARGE AMP GAIN	3
CHANNEL #	10
FREQ RANGE	0-100Hz
INPUT ATTEN	0
OUTPUT GAIN	0
NO. AVG.	16

810 MV RMS

PLANT ——— DATE/TIME ——— PWR LVL ——— TAPE NO. ——— SENSOR I.D. ———

B F



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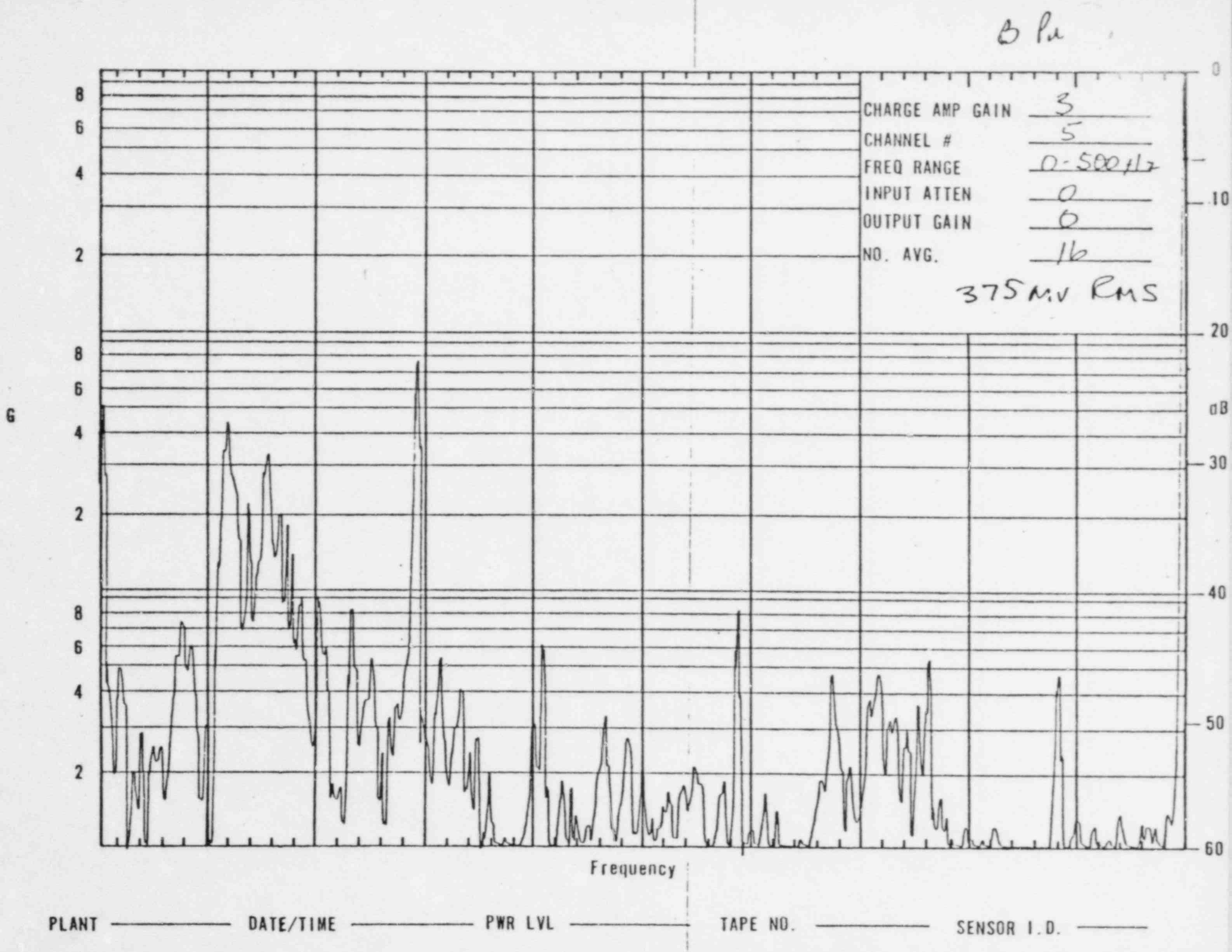
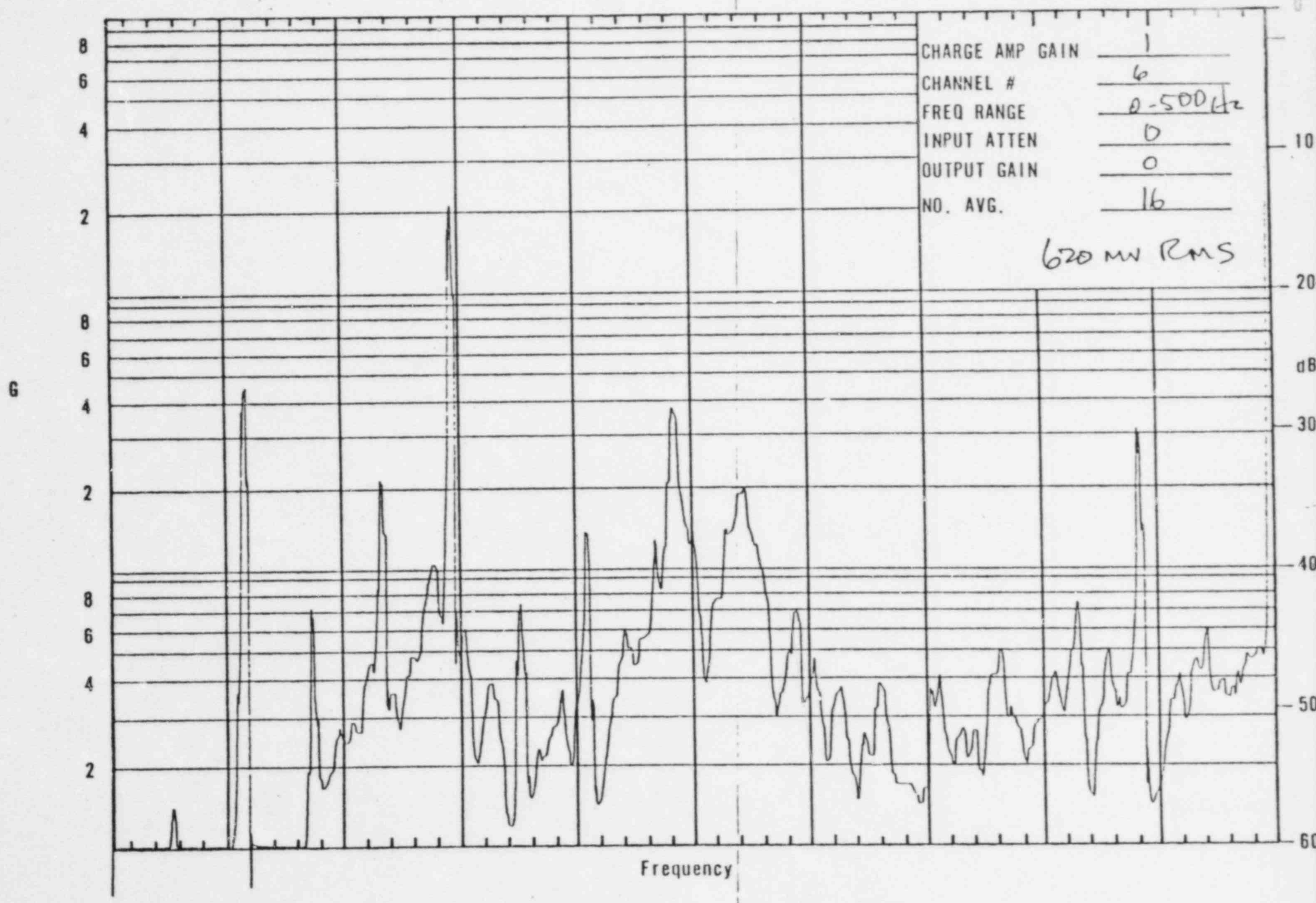

B Pu
CHARGE AMP GAIN 3
CHANNEL # 5
FREQ RANGE 0-500 Hz
INPUT ATTEN 0
OUTPUT GAIN 0
NO. AVG. 16
375 mV RMS
G
dB
0
10
20
30
40
50
60
8
6
4
2
Frequency
PLANT
DATE/TIME
PWR LVL
TAPE NO.
SENSOR I.D.

B fu ?



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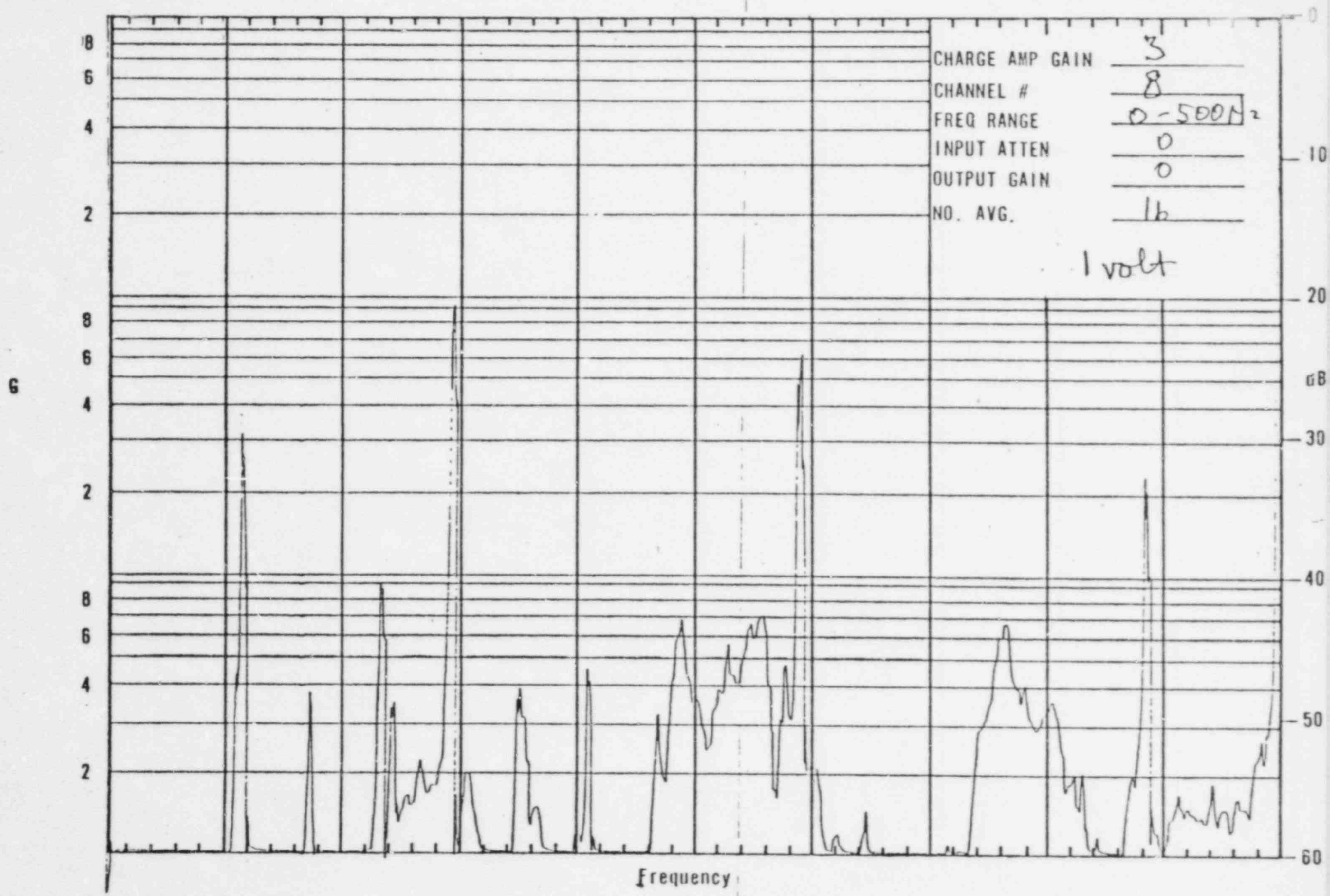
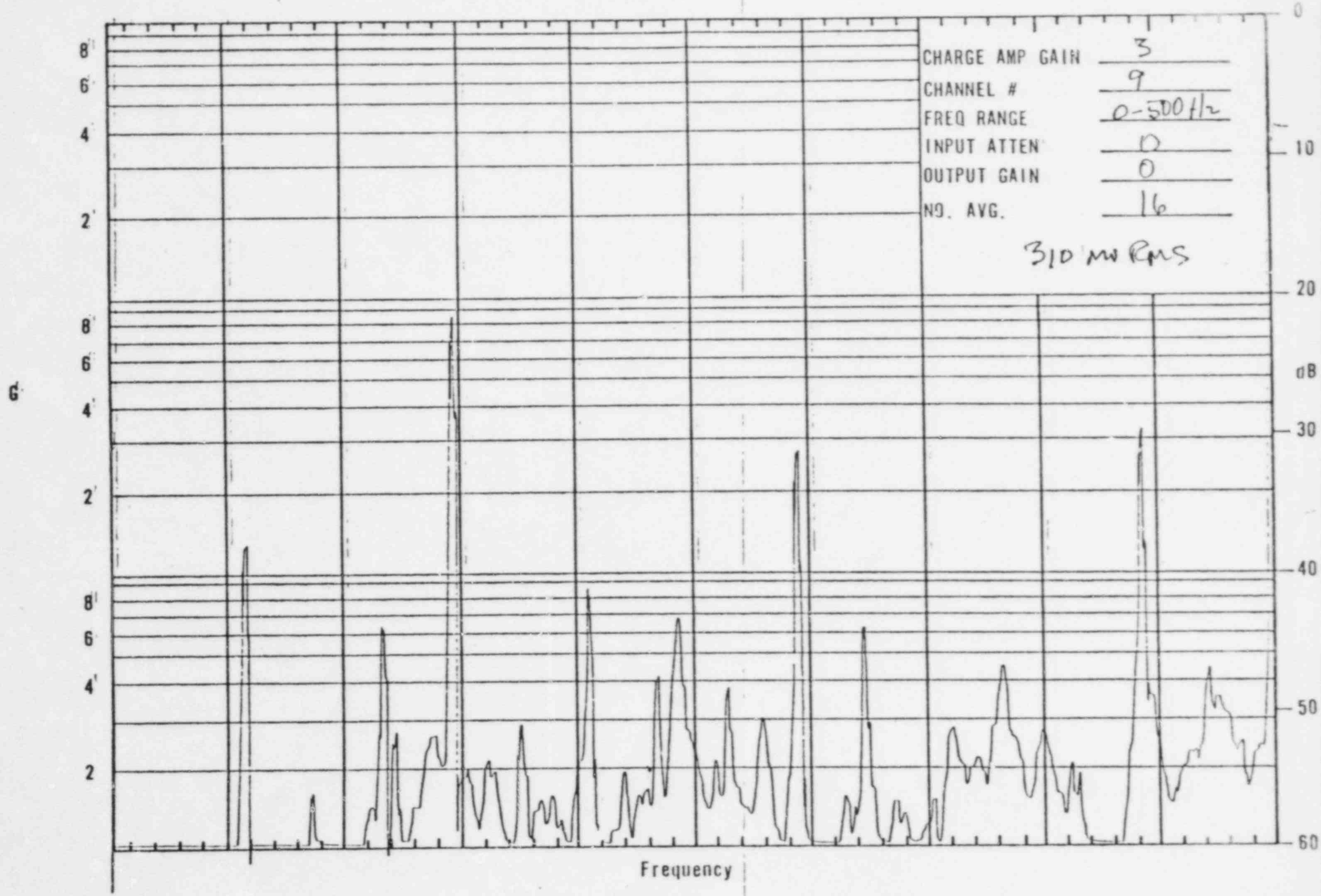
B p P



PLANT ——— DATE/TIME ——— PWR LVL ——— TAPE NO. ——— SENSOR I.D. ———

b pm



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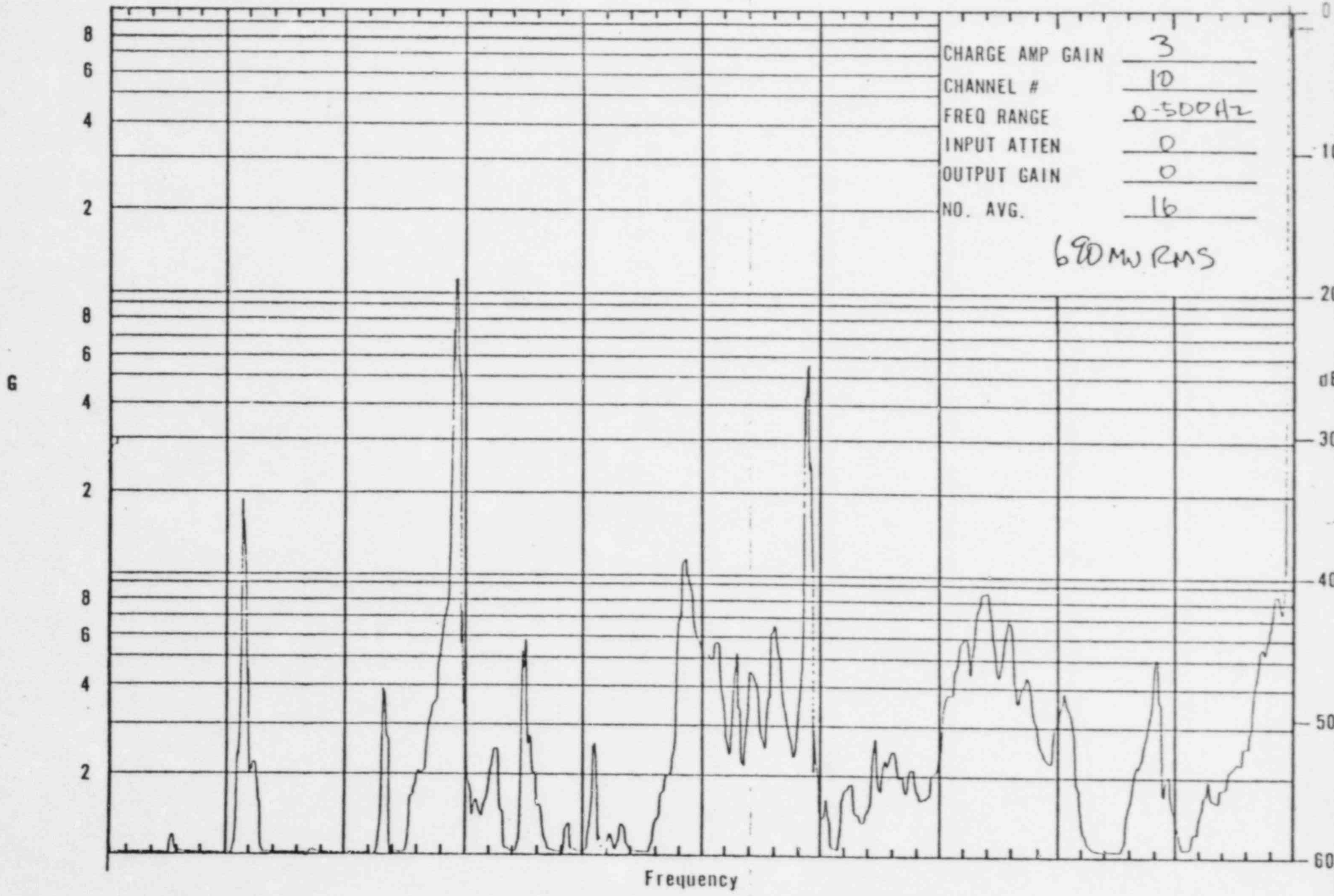
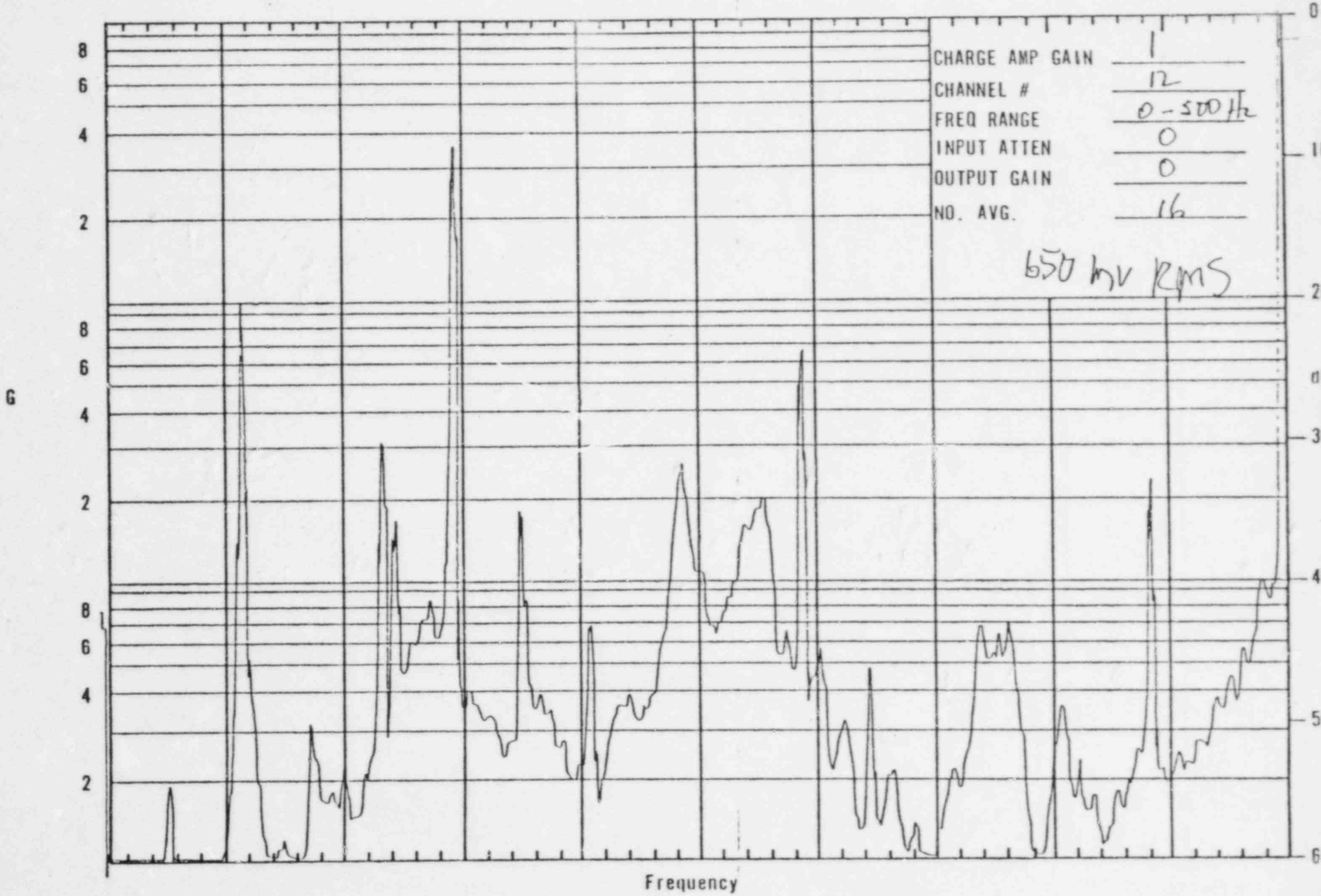
B pu



PLANT ——— DATE/TIME ——— PWR LVL ——— TAPE NO. ——— SENSOR I.D. ———

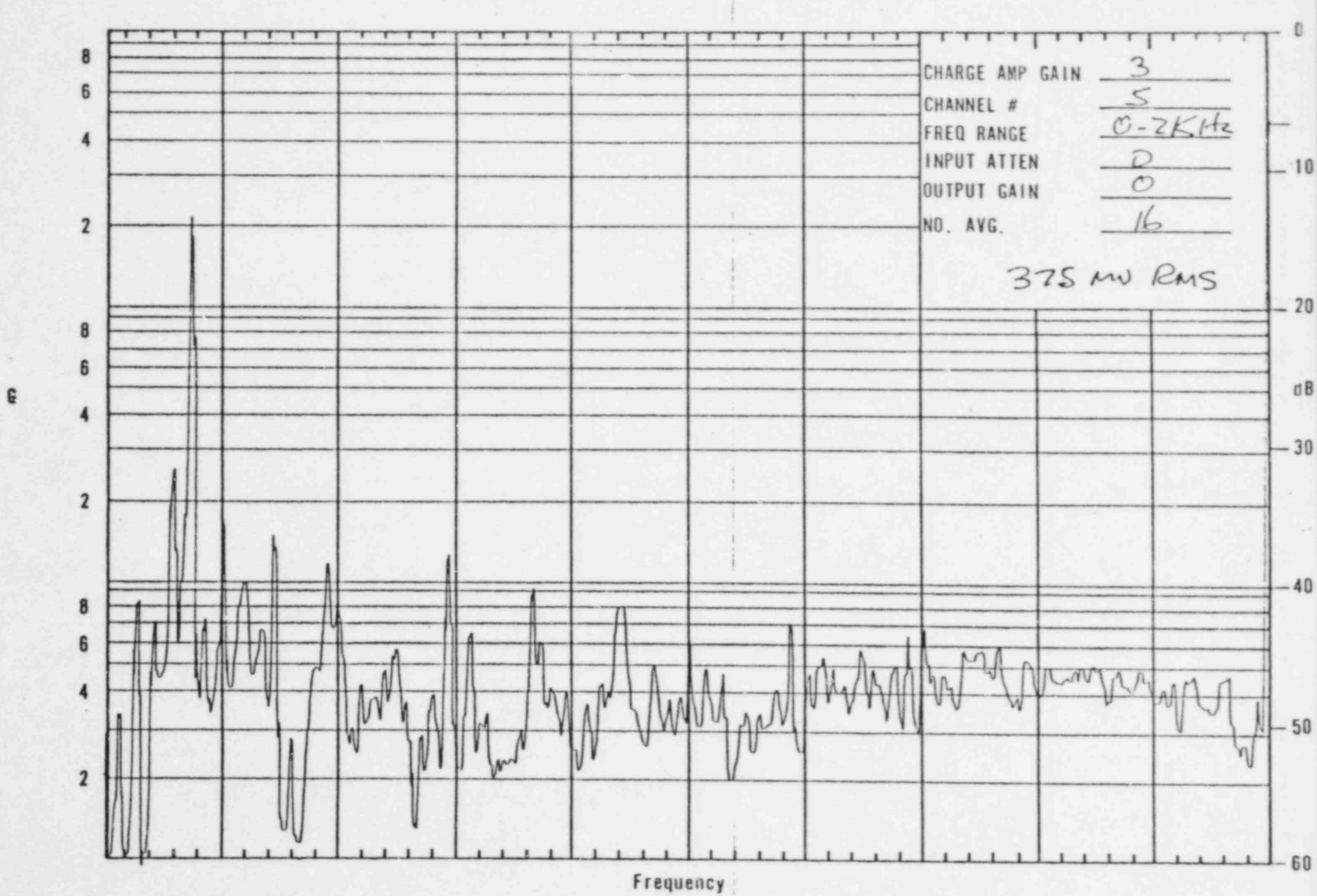
B1 P



CHARGE AMP GAIN	1
CHANNEL #	12
FREQ RANGE	0-500 Hz
INPUT ATTEN	0
OUTPUT GAIN	0
NO. AVG.	16

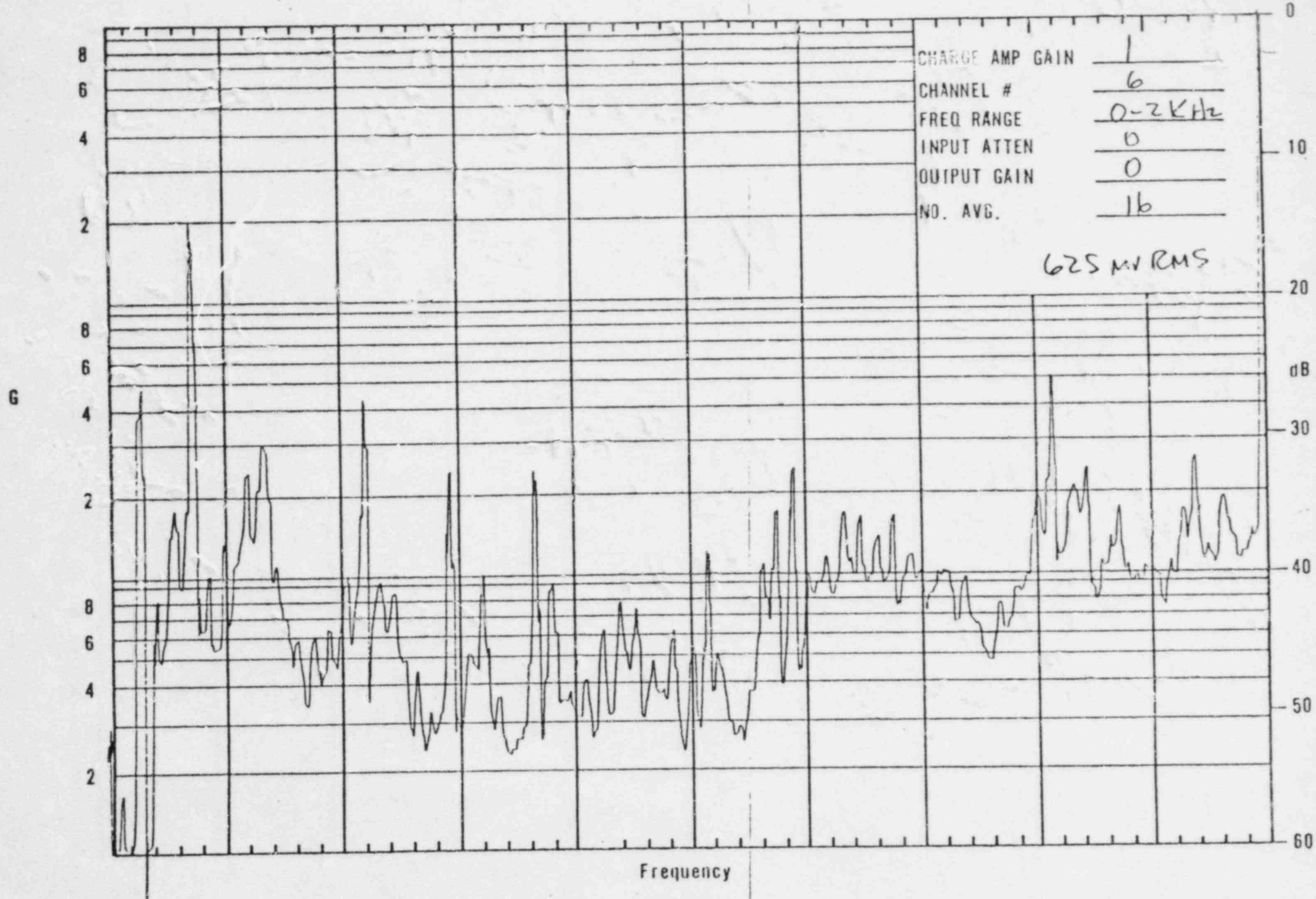
650 mV RMS

PLANT ——— DATE/TIME ——— PWR LVL ——— TAPE NO. ——— SENSOR I.D. ———



PLANT ______ DATE/TIME ______ PWR LVL ______ TAPE NO. ______ SENSOR I.D. ______

B pump

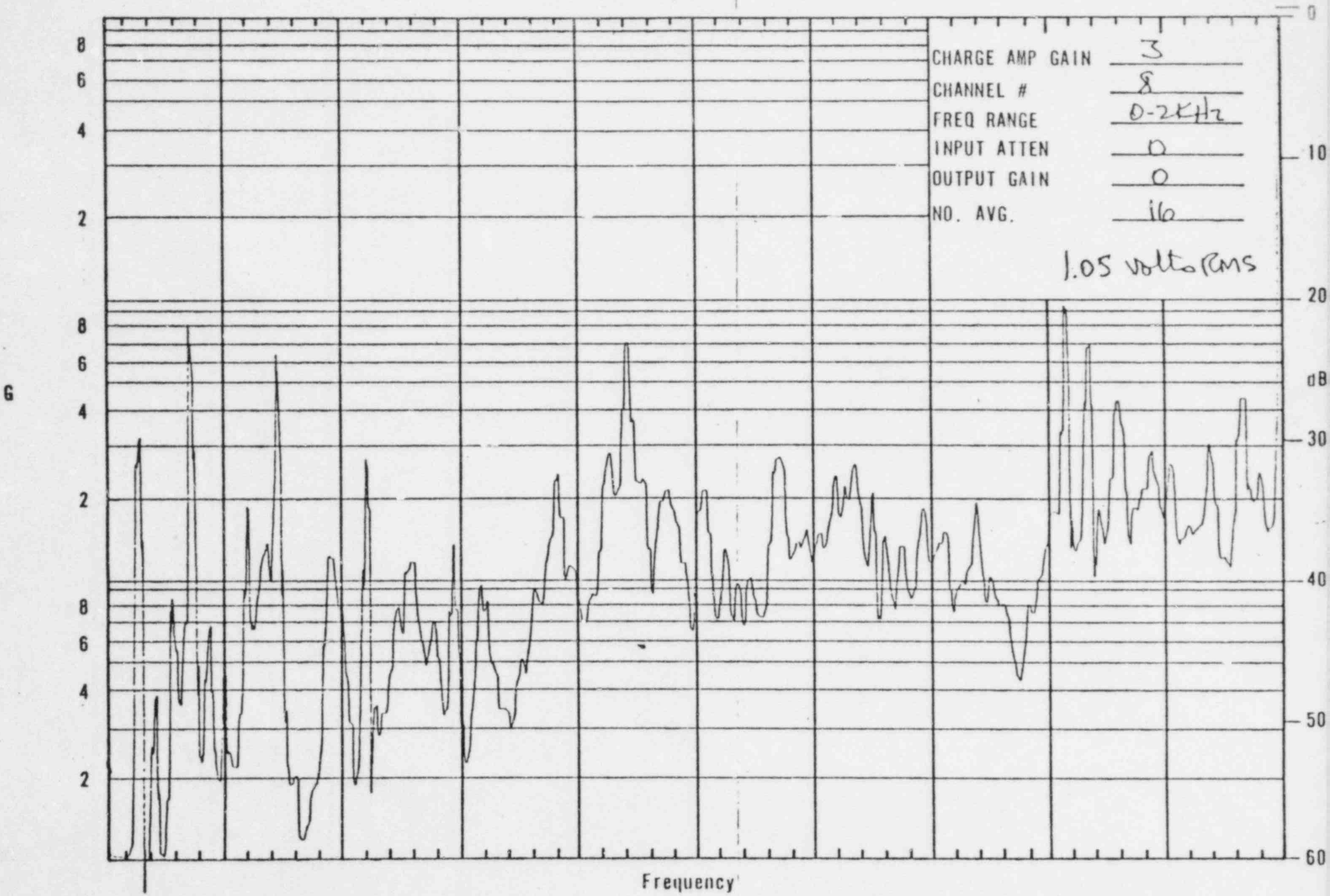


CHARGE AMP GAIN 1
CHANNEL # 6
FREQ RANGE 0-2KHz
INPUT ATTEN 0
OUTPUT GAIN 0
NO. AVG. 16

625 mV RMS

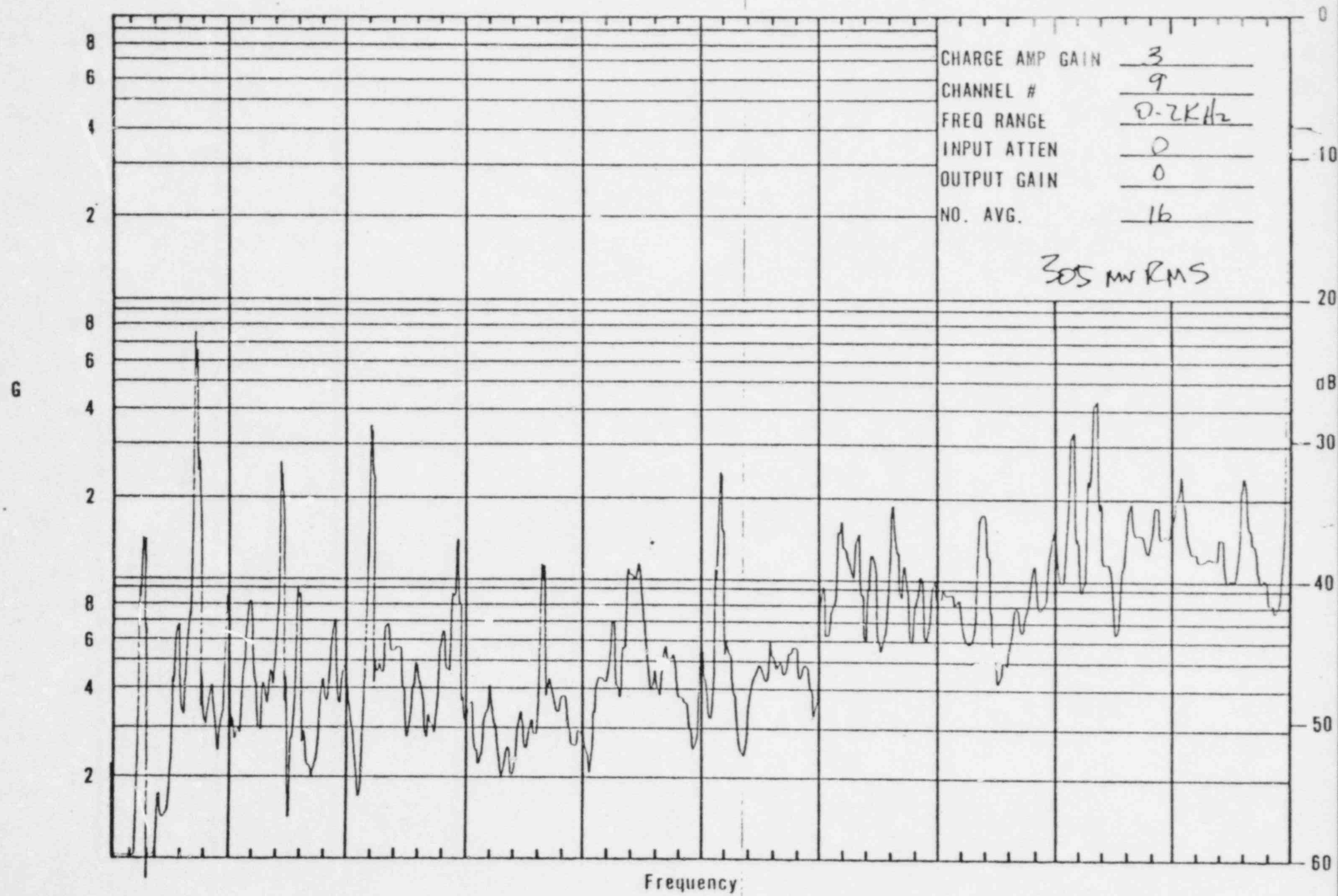
PLANT ——— DATE/TIME ——— PWR LVL ——— TAPE NO. ——— SENSOR I.D. ———

B pi



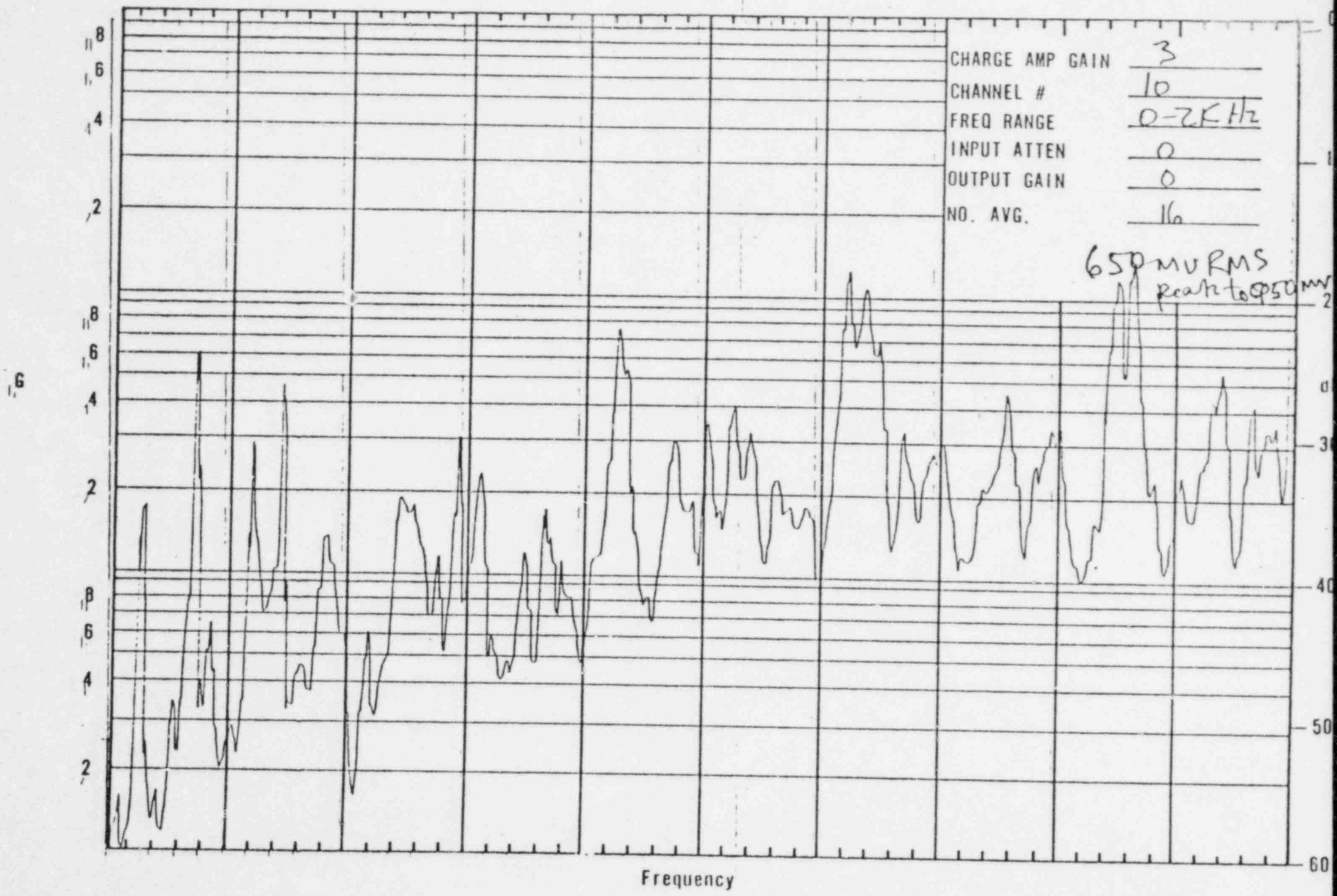
PLANT ______ DATE/TIME ______ PWR LVL ______ TAPE NO. ______ SENSOR I.D. ______

B prm

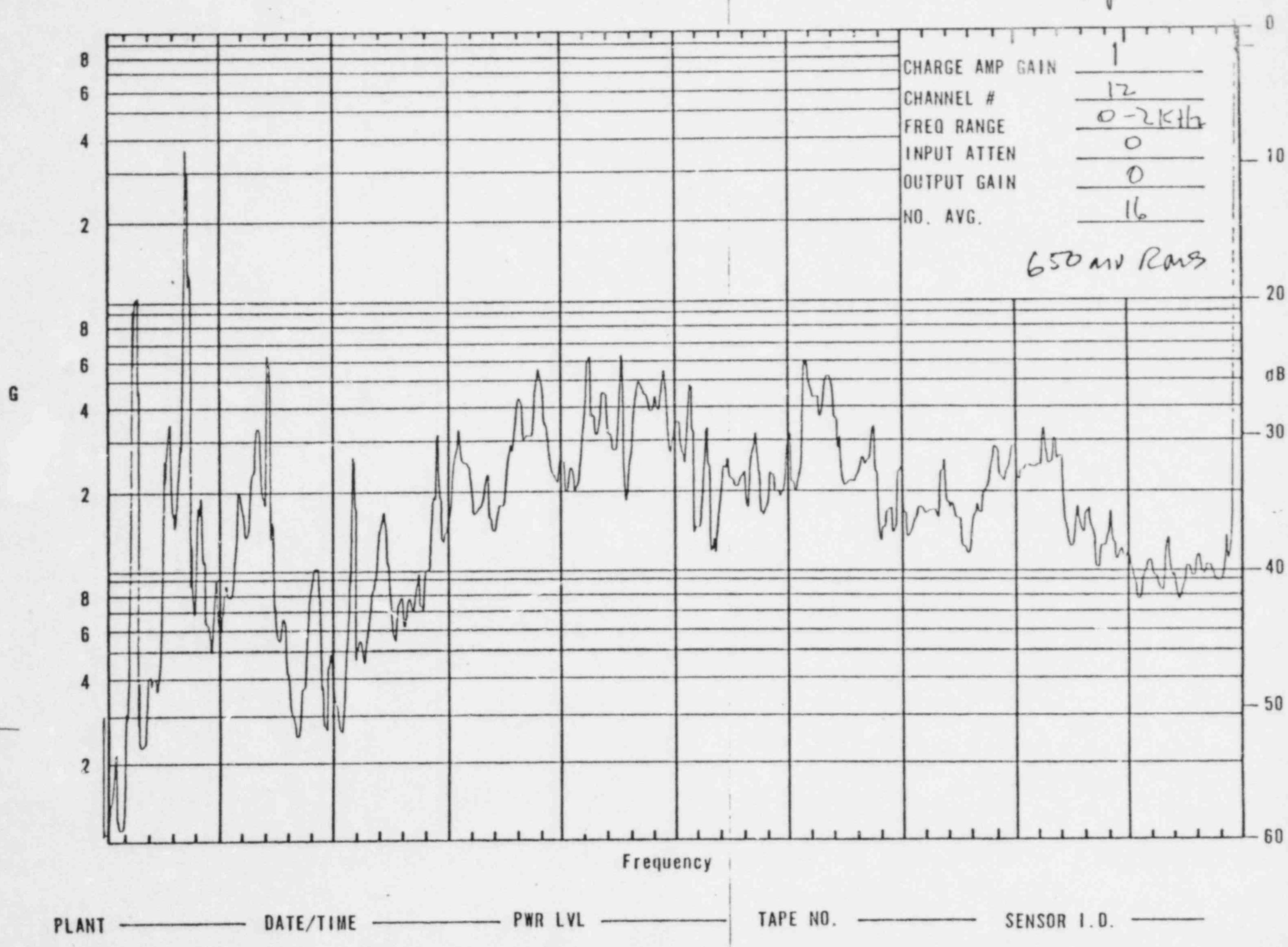


PLANT ——— DATE/TIME ——— PWR LVL ——— TAPE NO. ——— SENSOR I.D. ———

B1 P



PLANT ______ DATE/TIME ______ PWR LVL ______ TAPE NO. ______ SENSOR I.D. ______



Bpi
CHARGE AMP GAIN 1
CHANNEL # 12
FREQ RANGE 0-2KHz
INPUT ATTEN 0
OUTPUT GAIN 0
NO. AVG. 16
650 mv Rms
G
8
6
4
2
dB
0
10
20
30
40
50
60
Frequency
PLANT
DATE/TIME
PWR LVL
TAPE NO.
SENSOR I.D.