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Progress Report

(Phase - I)

Sound and Vibration Measurements
at Flatiron Power and Pumping Plant
Loveland, Colorado
Summer 1986

by

M. M. Skinner

September 30, 1986

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PROGRESS REPORT

(Phase - I)

SOUND AND VIBRATION MEASUREMENTS AT FLATIRON POWER AND PUMPING PLANT

Loveland, Colorado

Summer 1986

by

M. M. Skinner

for

U. S. Bureau of Reclamation

Division of Research and Laboratory Services

Denver, Colorado

September 30, 1986

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ADVANCE SUMMARY

During the period June 22, 1986 - August 22, 1986, accelerometer, microphone, and hydrophone measurements were made on Units #1 and #2 at the Flatiron Power and Pumping Plant located near Loveland, Colorado. Time and frequency domain records were obtained and analyzed with a Hewlett-Packard Model 3561A Dynamic Signal Analyzer. Hard copy records of the analyzer output were made on a Hewlett-Packard model 7470A Plotter and tape recordings were made on a Nagra type 4.2L, reel-reel 1/4-inch tape recorder. Measurement procedures were developed and some analyses of results were performed. Copies of original trials of a variety of analyses are included in the packet at the back of this report. Unit #2 was dewatered and inspected during an annual scheduled inspection and maintenance; selected photos are included showing condition of the suction side of the runner, buckets, wicket gates, butterfly valve leaf, and valve leaf seat. Recommendations for Phase II investigations are given.

INTRODUCTION

For the period from June 22, 1986 - August 22, 1986 an assignment agreement for Dr. Morris M. Skinner was initiated between the Bureau of Reclamation, Division of Research and Lab Services and Colorado State University, Civil Engineering Department. The mobility assignment was for the purpose of developing data acquisition procedures for evaluating critical operating conditions at hydropower plants. A three phase study was planned to extend over approximately three calendar years:

Phase I - Summer 1986, develop procedures.

Phase II - Fall 1986 - Summer 1987, develop base-line spectra and expand measurements to a variety of different units.

Phase III - Fall 1987 - Summer 1988, Training of hydropower personnel.

The detection of damaging flow conditions in a turbine at various operating points and the use of sound and vibration spectra for monitoring the condition of a turbine were of prime interest. Efforts were directed towards the goal of developing practical procedures for minimizing maintenance costs and downtime.

Four (4) specific tasks were defined:

A. Develop and implement a data acquisition plan to collect vibration, pressure, sound, and other data at the Bureau of Reclamation's Flatiron Powerplant in Loveland, Colorado. The Hewlett-Packard 3561A Dynamic Signal Analyzer would be the primary piece of equipment used. The type of analysis would include run-up and coast-down (waterfall display) of sound and vibration spectra, one-third octave analysis and measurement of pressure transients.

B. Work closely with the Bureau of Reclamation engineers to develop appropriate techniques and instrumentation to differentiate between cavitation in the flow versus cavitation against a boundary (such as a turbine blade) and to develop methods to locate the source of a signal. The Bureau of Reclamation would supply supplemental instrumentation to investigate various methods.

C. Develop a hypothesis based on a background appraisal of cavitation in turbines and other information in the literature that accounts for the observed data within a theoretical framework and can be used as a basis for further investigation.

D. Report on the findings of the first phase of the study.

PLANT DESCRIPTION

The Flatiron Power and Pumping Plant, part of the Colorado Big Thompson project, began initial operation in 1954 and is located approximately ten (10) miles southwest of Loveland, Colorado. Units #1 and #2 are 35 megawatt Francis type turbines turning at 514 RPM and used primarily as peaking plants. Difference in elevation between the Forebay Reservoir (Pinewood Lake) and the Tailrace (Flatiron Reservoir) is approximately 1100 feet. The two separate penstocks are 84-inch welded, plate steel, 5790 feet long with 84 inch butterfly valves at the power house. A flow rate of approximately 550 cubic feet per second can be delivered to each unit. A snorkel tube mounted in each draft tube provides outside air to the vortex over a set range on the wicket gates. Also a pump-turbine unit (Unit #3) operates at two (2) speeds; 300 RPM for delivering 370 cubic feet per second to Carter Lake against a head of 240 feet, and 257 RPM when producing 8.5 megawatts at a net effective head of 250 feet and 100% power factor. Unit #3 was one of the first pump-turbines installed in the U.S.

MEASUREMENTS

Accelerometer measurements were made on the draft tubes of units #1 and #2 at the general location shown in Fig.-1. Cementing studs were attached to the steel plate with super glue.* Several other different

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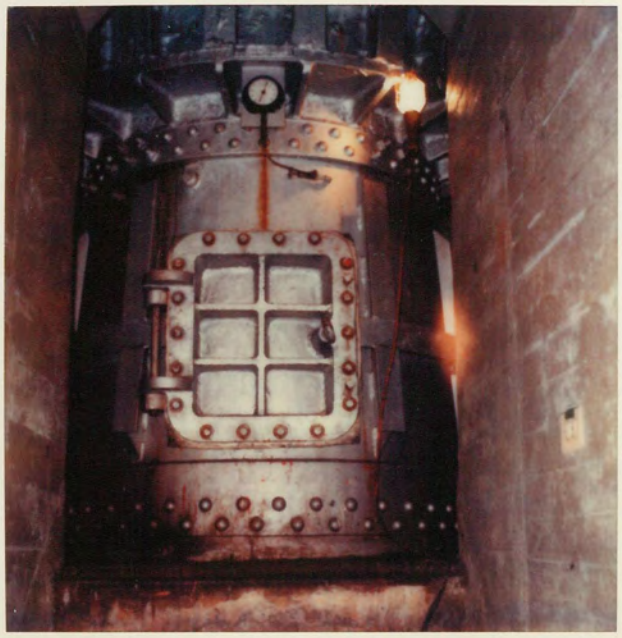
* Victor Automotive Products, Inc.



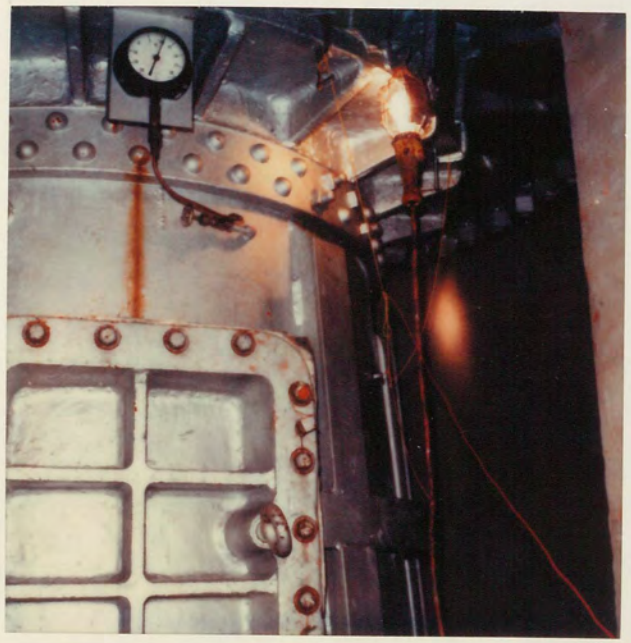


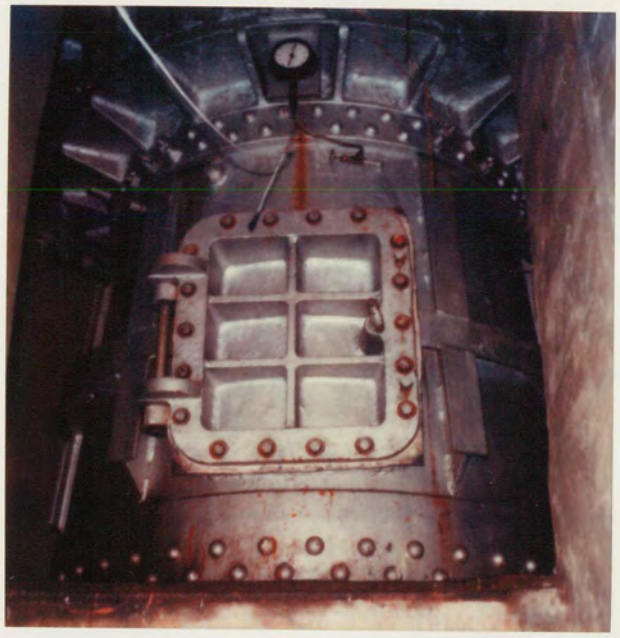
Fig-1. Draft tube of unit 2 and cementing studs used to mount accelerometer

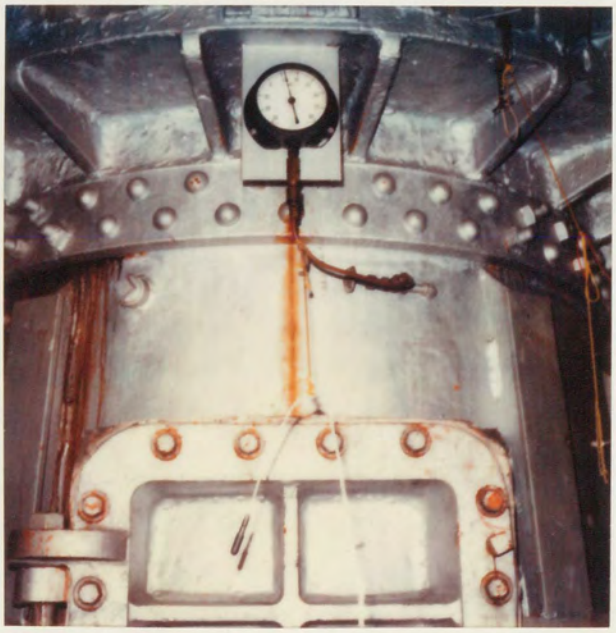
adhesive materials, including hot glue, were tried without success. The cool (60 degrees F), damp steel had to be dried with a heat gun for several minutes prior to affixing a cementing stud. In the future, magnetic mountings should be more practical when several points on the machine are to be sampled and when the mounted resonant frequency does not interfere with the desired measurement frequency range.

Detailed evaluation of the B & K "Delta Shear Design" type 4370 accelerometer should be accomplished during Phase II; good low frequency response range (less than 10 hz) and low response to temperature change is desirable.

Microphone measurements were made approximately one (1) foot in front of the man-door of the draft tube as shown in Fig.-2. The B & K hydrophone type 8103 may be used in either water or air. In air the frequency response range is reduced to about 15 khz. The B & K hydrophone type 8103 used as a microphone, however, seems to be a very practical transducer to use for turbine testing work since it is sturdy and not affected by high humidity conditions. Comparative measurements between the near field and far field need to be examined in future work. A demonstration of the B and K sound intensity probe type 3519 would be useful during phase II.

Hydrophone measurements were made in the tailrace a few feet below the water surface and in line with the discharge from the draft tube of each turbine. Both the B & K hydrophone type 8103 and an Interoceans hydrophone were used. The Interoceans hydrophone has a limited frequency response of 20 hz to 10 khz. Various tailrace locations should be carefully evaluated as one of the best places to make sound measurements for future work. The low frequency signals (less than 400





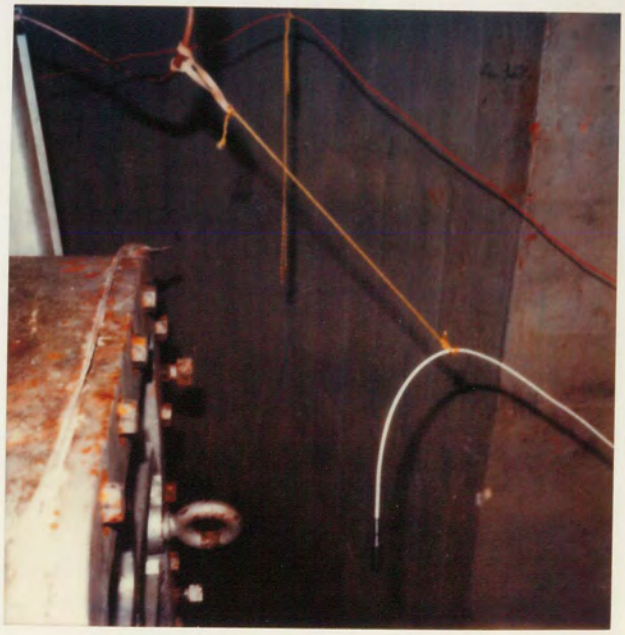


Fig-2. Location of B & K Hydrophone Type 8103 (used as a microphone)

hz) are strong, access is no problem, measurement environment is comfortable, and has minimum interference with the normal flow of plant operation personnel. Environmental conditions, however, such as wind and various forms of precipitation can alter the sound levels. The B & K type 8104 hydrophone should be evaluated as the primary sensor for tailrace measurements.

ANALYSES

The data may be analyzed in a variety of ways using the HP-3561A dynamic signal analyzer. Three (3) forms of averaging include RMS, Peak hold, and time synchronous averaging. The time synchronous averaging was triggered by a once per revolution pulse off of the turbine shaft.* A sharp, clean pulse is obtained if a strip of dark tape is used under the reflective tape. Fluorescent lights should be turned off during the measurements in order to reduce the 60 hz signal.

Narrow band and one third octave measurement modes were used on the 3561A. Log magnitude, waterfall plots, single, front-back, and upper-lower format displays were very effective. A closed-circuit, black and white TV camera with monitor proved to be very useful for correlating measurements with plant load. Either the wicket gate opening indicator or the megawatt dial in the control room can be monitored. There seems to be a step-function reponse between wicket gate opening and the megawatt dial. The basic equipment used during Phase I of the study is listed on the following page.

Data storage for future spectra comparisons and evaluations is of prime concern. The HP-3561A DSA can provide hard copy via an HP-IB

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*Monarch Optical Trigger, Model SPS-5

INSTRUMENTATION AND TRANSDUCERS

Item	Manufacturer	Serial No.	Owner
1.) 3561A Dynamic Signal Analyzer w/bubble memory	Hewlett Packard	2338A01027	CSU
2.) Acoustic Listening and Calibration System Model 902	Interocean Systems, Inc.	3955015	CSU
3.) Hydrophone Type 8103	Brüel and Kjaer	812703	USBR
4.) Charge Amplifier Type 2635	Brüel and Kjaer	795728	USBR
5.) Accelerometer Model 3030	Columbia	203	USBR
6.) Charge Amplifier Model 4102	Columbia	574	USBR
7.) 7470A Plotter	Hewlett Packard	2308A36635	M.M.Skinner
8.) 1/4-inch, reel-reel tape recorder	Nagra 4.2	L102194	CSU
9.) Optical Trigger Model SPS-5	Monarch	189055	CSU
10.) TV Camera Model WV-1500	Pansonic	3YA09419	CSU
11.) Video Monitor Model TR-930	Panasonic	KD6220381	CSU
12.) SLR AutoFocus Camera	Polaroid	7G976373237	M.M.Skinner

interface to the 7470A plotter and/or records can be stored in the internal bubble memory of the DSA. Future data collection systems need to incorporate a desk top computer (Hewlett Packard Model 310) to access disk drives for spectra storage and retrieval.

RESULTS

(TASK A) A vibration and sound (in air and water) data acquisition plan was developed. Pressure transient measurements in the penstock were not accomplished, but need to be started in the next phase. Run-up tests were tried, but didn't appear to be useful. Waterfall plots, however,are valuable for checking consistency of a given frequency. One-third octave displays will be very useful for long-term monitoring of machine condition and for detecting the occurrence of general cavitating flow. Acoustic emission (AE) measurements need to be initiated for detecting cavitation on the wicket gates and impeller.

(TASK B) Acoustic emissions instrumentation selection and use need to be implemented in Phase II of this study. The shafts from individual wicket gates are easily accessible at the head cover and should provide an ideal location to position the sensor for AE detection. A pickup from the shaft of the impeller will need to be installed to monitor AE's originating on the impeller. Locating the spatial position of cavitation implosions has not been considered in this phase.

(TASK C) Fundamental frequencies related to the rotation speed (8.57 hz), the bucket passing frequency (13 x 8.57 = 111.4 hz), the wicket gate passing frequency (20 x 8.57 = 171.3 hz), and the first and second sidebands of the wicket gate passing frequency; 171.3 hz $\pm$ 1 and 2 x 8.57 = 180 hz,188.5 hz, 163 hz and 154 hz have been observed. The first and second harmonics of the bucket passing frequency (223 hz and

334 hz) are also apparent. For narrow band analyses, a frequency range from 0-400 hz seems to be wide enough to include the fundamentals plus harmonics and sidebands of interest. Monitoring the magnitude of the fundamentals, harmonics, and sidebands may be the parameters of interest to use in "condition based monitoring". Copies of all the original trials made during Phase I after the first week in July are included in the packet at the end of this report. Many of the trials were made under changing loads, but the plots are included for possible reference in future work.

INSPECTION OF UNIT 2: The opportunity to inspect the inside of Unit #2 during a scheduled maintenance shutdown was of great interest. Some cavitation damage was evident, but the runner and wicket gates appeared to be in fair condition considering the age of the unit. General roughening on the suction side of all the wicket gates and localized damage on the pressure side of some of the buckets were observed. The four-inch ventilation pipe for the snorkel in the draft tube caused some cavitation damage on the walls of the draft tube. Epoxy repair on the suction side of the runner was extensive; see Fig.-3. Apparently, the butterfly valve leaf and seat were eroded while the valve was in a closed position. Considerable noise was noted at times during the summer when the valve was in the shut-off position and the high pressure flow leaked past the seal. Fig.-4 shows some of the damage.

Viewing the internal geometry of the turbine helped in developing some hypothesis about the characteristic frequencies that were observed. For example, vortex shedding off of the stay vanes and wicket gates, particularly when they are at some angle of attack, can certainly induce mechanical vibrations (to be sensed by accelerometers) and acoustic

Fig-3. Interior views of wicket gates, runner, and snorkel tube.

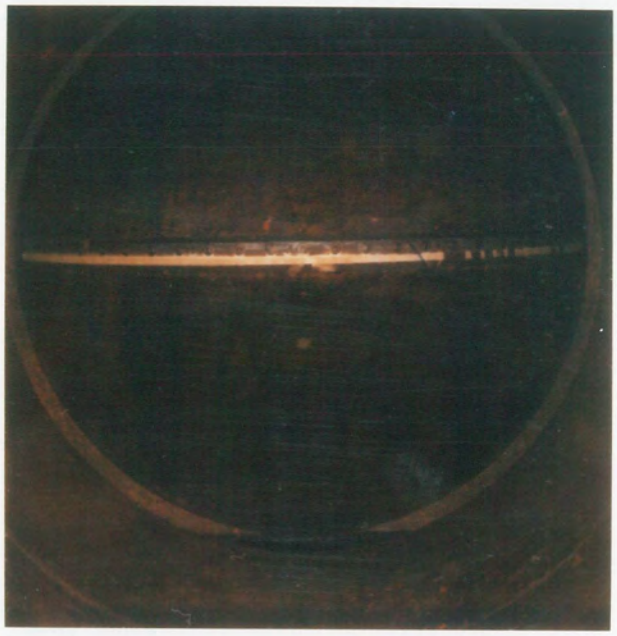

Fig-4. 84-inch butterfly valve leaf and seat damage.

signals (for detection by hydrophone or microphone). Typically two (2) cycles of pressure oscillation parallel to the free stream would be caused by every one (1) cycle perpendicular to the free stream.*

RECOMMENDATIONS FOR PHASE II

Hydrophone measurement should be continued in the tailrace. The appropriate location for accelerometer and microphone measurements in the draft tube area, the head cover area, and on the scrollcase need to be investigated further. Measurements should be made under steady flow conditions and confirmed by a pressure transducer in the penstock just upstream of the 84-inch butterfly valve. A computer aided testing system for managing data acquisition, analyses, and display should be considered for implementation during the latter part of Phase II.

A B & K hydrophone type 8104 with about 400 feet of cable connected to a B & K charge amplifier type 2635 should be the primary device for tailrace measurements. The B & K hydrophone type 8103 with about 400 feet of cable connected to a B & K charge amplifier type 2635 should be the primary device for measuring airborne sound near the draft tube and the head cover. B & K accelerometer type 4370 with about 400 feet of cable connected to a B & K charge amplifier type 2635 is also recommended as a standard device for Phase II. One (1) B & K type 2635 charge amplifier can service all three (3) sensors. With this configuration, data acquisition can be accomplished from a convenient location in the control room. The closed-circuit TV camera can monitor

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*Unit #2 has ten (10) stay vanes, but only nine (9) actively divide the flow for producing vortex shedding. The Strouhal number(s) for the stay vanes on unit #2 should be about 0.2; since $f_s = \frac{sv}{d}$, then $f_s \approx \frac{0.2v}{0.2} = |v|hz$

the wicket gate opening on the appropriate unit. The pressure transducer output on the penstock also needs to be cabled to the control room.

Efforts during Phase II need to concentrate on collecting calibrated baseline spectra for units #1 and #2 and other units. Output should be calculated directly in Pascals vs frequency for sound measurements and in meters per second squared vs frequency for the accelerometers. Both narrow-band (0-400 hz) and 1/3 octave (3.15hz-5khz, band #s 5-37) measurement modes should be used. Time-synchronous averaging should be triggered from the turbine shaft. Field calibration needs to be accomplished with a B & K type 4294 calibration exciter (for accelerometer) and B & K type 4223 calibrator (for hydrophone). A B & K acoustic emissions system should be evaluated during Phase II. A demonstration of the B & K sound intensity probe type 3519 should be scheduled. Other turbines should be analyzed to obtain a wider experience base on different types and sizes of units: Estes, Marys Lake, Pole Hill, Alcova, Fremont Canyon, Seminole, Kortes, Blue Mesa, Morrow Point, Crystal, and Mount Elbert are being considered. Controlled tests on the Grand Coulee #3 model (presently at Estes) would be very helpful.

ACKNOWLEDGEMENTS

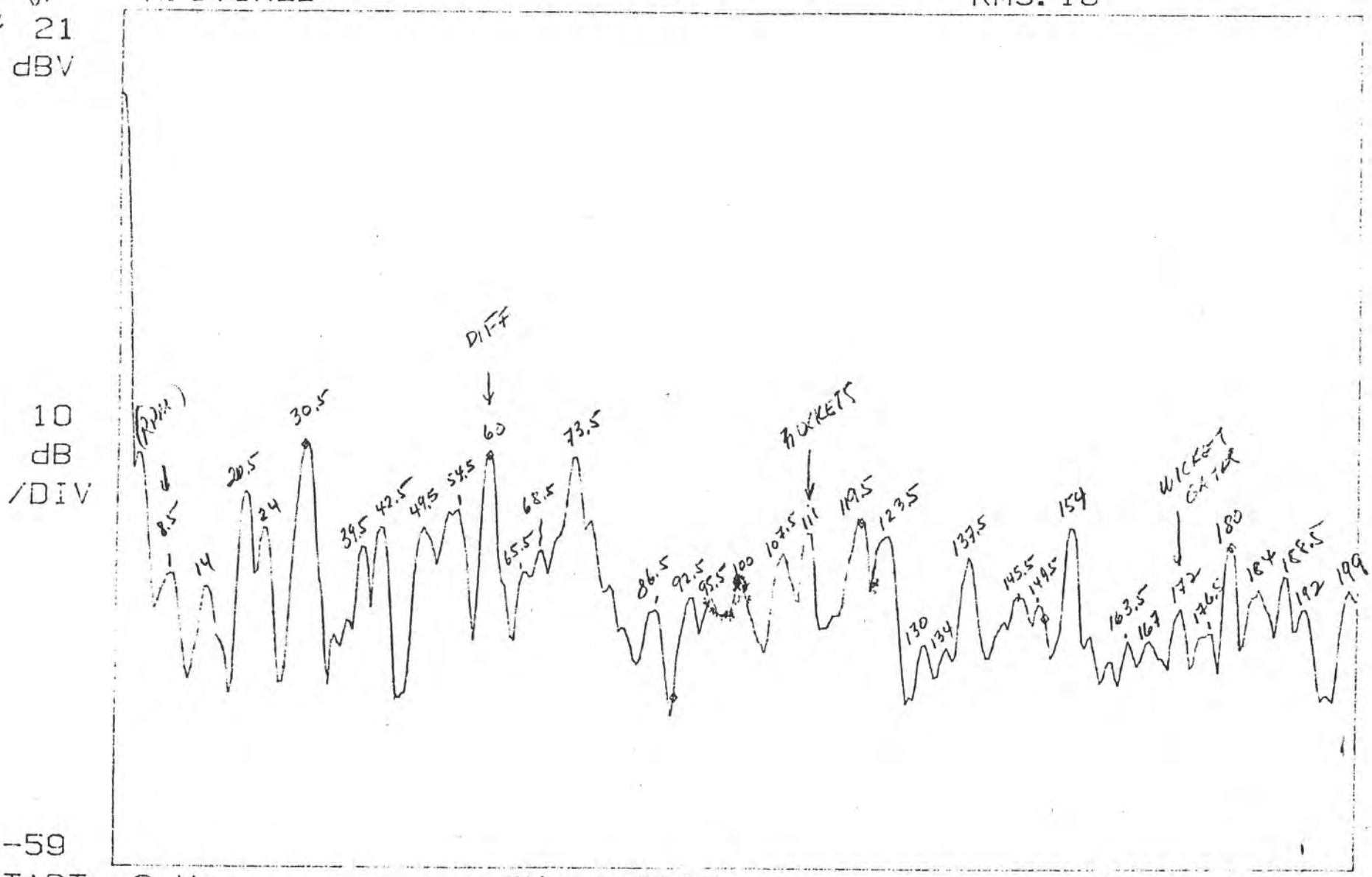
The generous cooperation of the personnel at Flatiron during the summer of 1986 made Phase I of this study a very enjoyable and enlightening experience. The plant operators and management provided many helpful suggestions and turbine operation details directly related to the successful data collection development program.

7-8-86
B&K MIC -
#2 STOPPED
#1 RUNNING - 29 mW
(OUTSIDE DT. #2)

SUCCESS!
A: STORED

RANGE: -51 dBV

STATUS: PAUSED
RMS: 10



START: 0 Hz
BW: 1.9097 Hz
STOP: 200 Hz
X: 100 Hz
Y: -32.78 dBV
THD: 0.59 dB

7-8-86
DEK MIC.
#1 - 23 AW
#2 - STOP
(OUTSIDE #2 DT.)

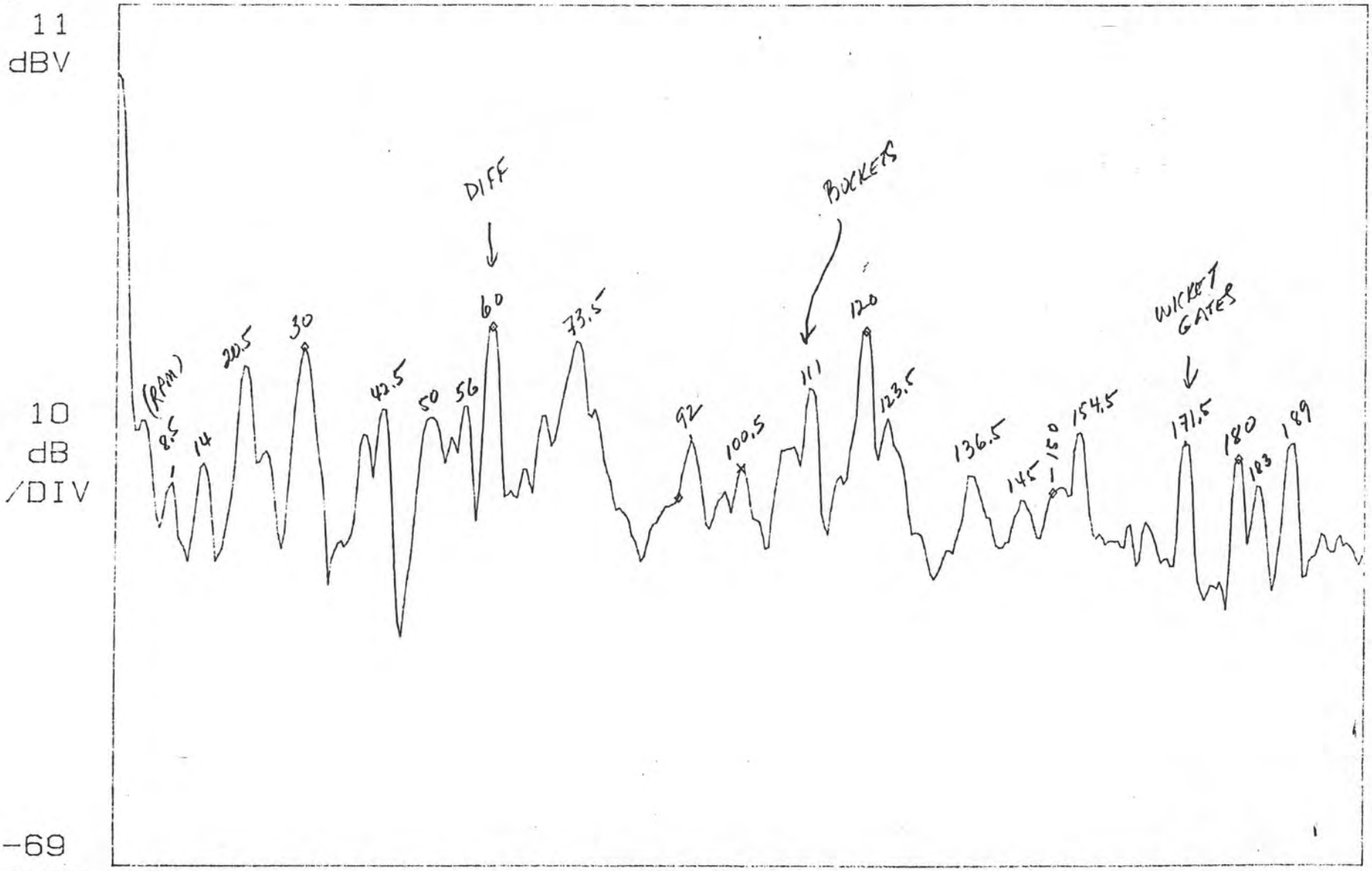
PM-1

RANGE: -51 dBV

STATUS: PAUSED

A: STORED

RMS: 10



START: 0 Hz

BW: 1.9097 Hz

STOP: 200 Hz

X: 100 Hz

Y: -32.16 dBV

THD: 4.99 dB

7-8-82
#1 Running
#2 STOPPED
B&K MIC (BACKGROUND)
#1 - 29 MW.

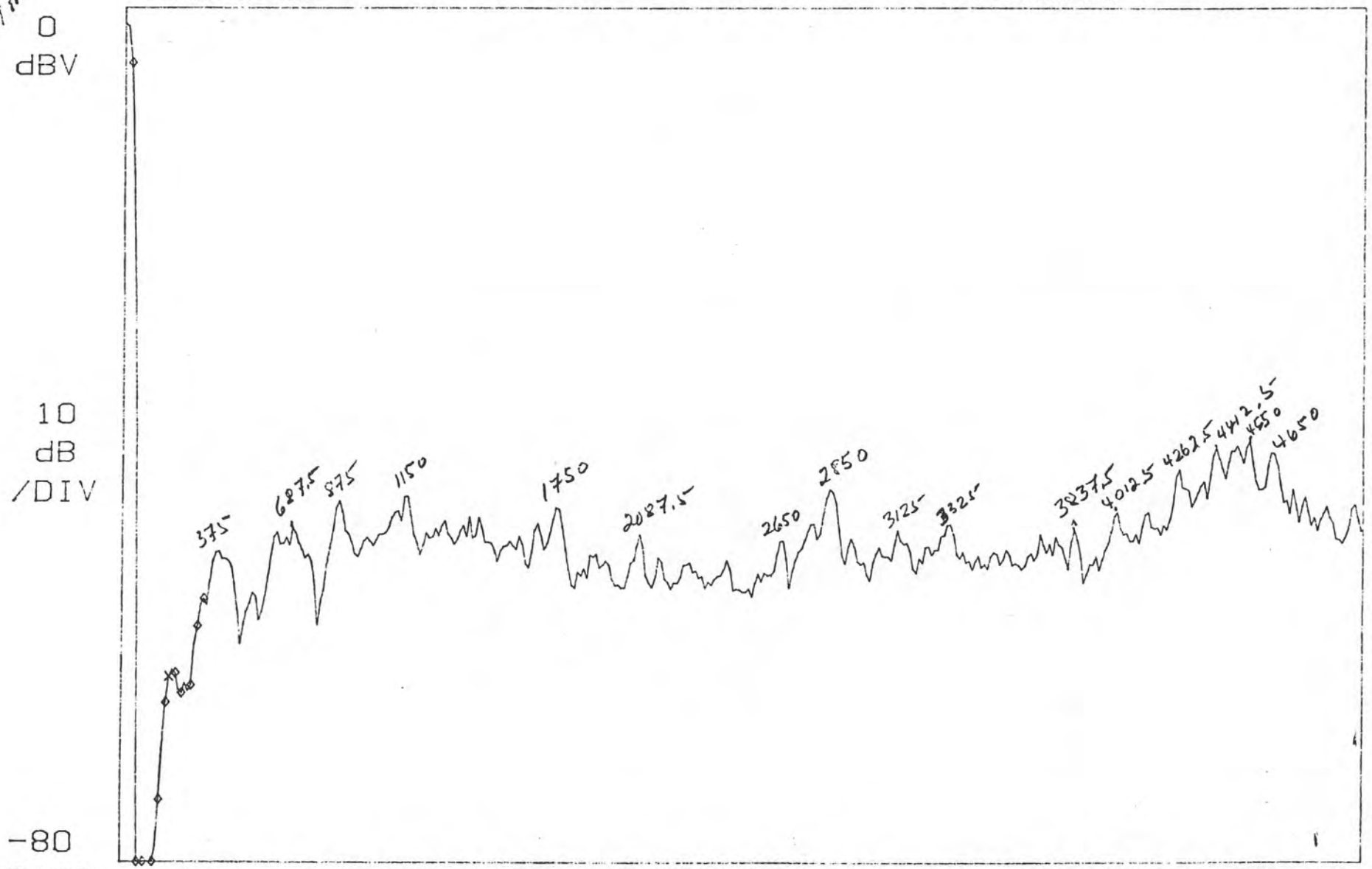
78 STOP

RANGE: -51 dBV

STATUS: PAUSED

A: STORED

PEAK: 69



START: 0 Hz

BW: 47.742 Hz

STOP: 5 000 Hz

X: 187.5 Hz

Y: -62.76 dBV

THD: -46.95 dB

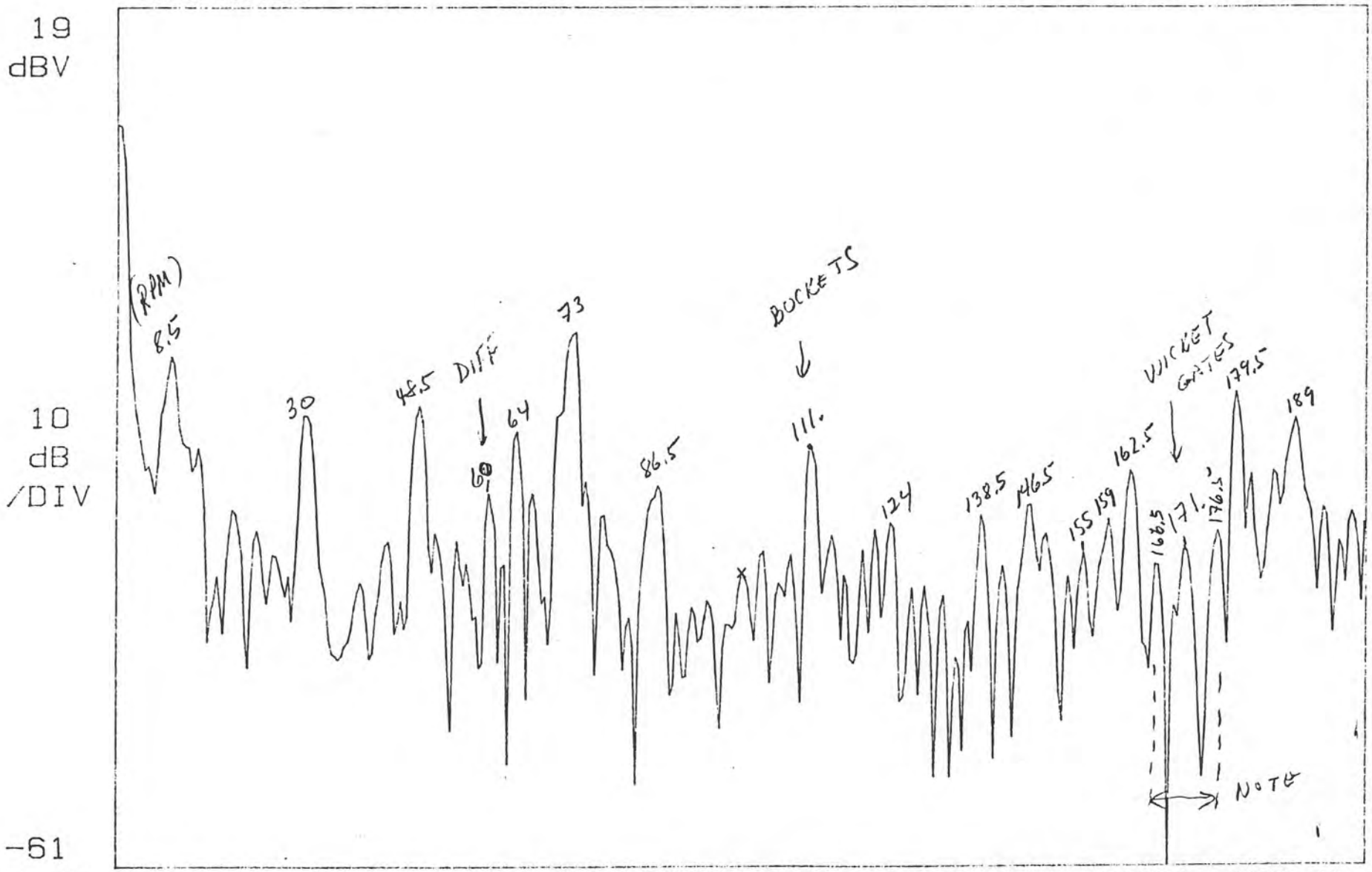
7-8-86
#1 RUNNING
#2 STOPPED
BEIK WIC-

2 UNIRESCTR

RANGE: -51 dBV

STATUS: PAUSED

A: STORED



START: 0 Hz

BW: 1.9097 Hz

STOP: 200 Hz

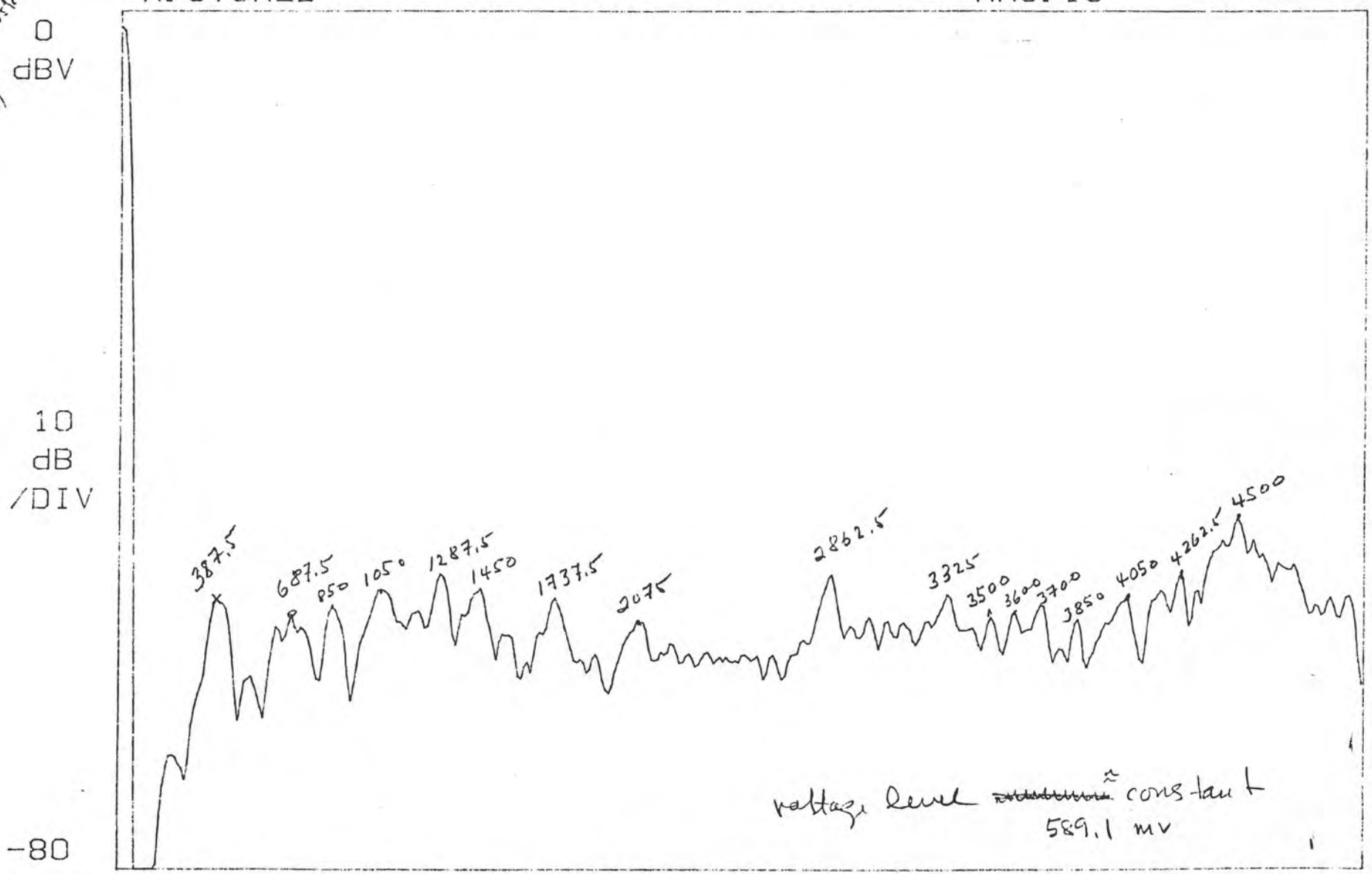
X: 100 Hz

Y: -33.70 dBV

#2
7-8-86
#1 RUNNING
#2 STOPPED
ACC (REGULAR CHARGE AMP)
(BACKGROUND)
10 AM

RANGE: -51 dBV STATUS: PAUSED

A: STORED RMS: 10



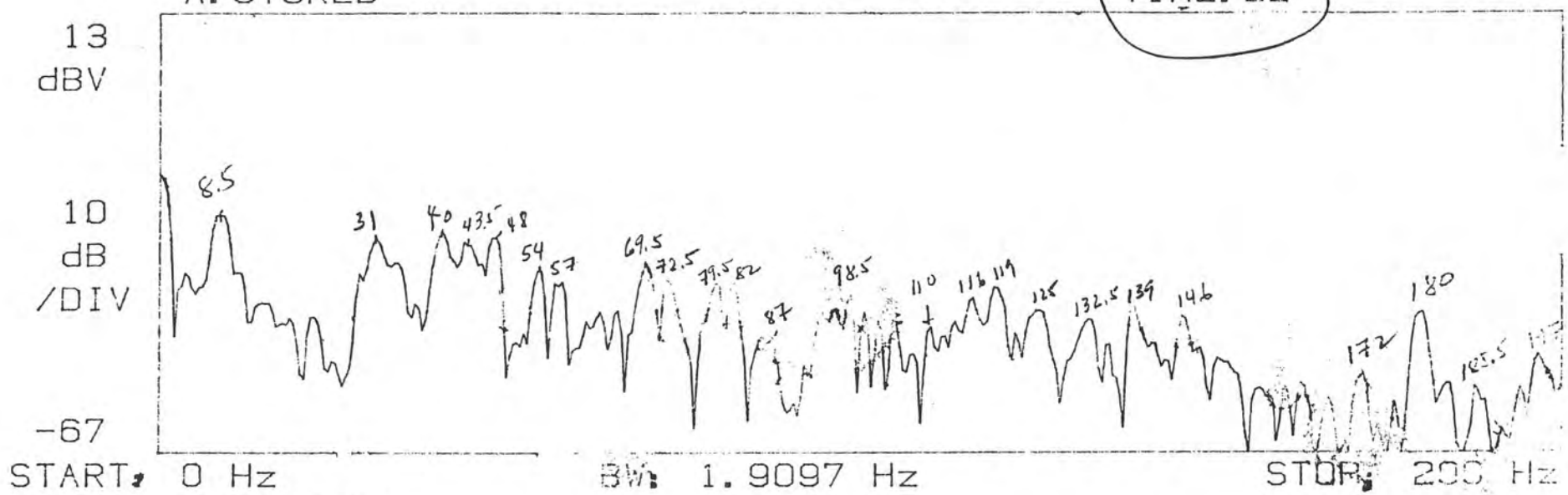
START: 0 Hz BW: 47.742 Hz STOP: 5 000 Hz

X: 387.5 Hz Y: -54.86 dBV

7-9-8
M-1

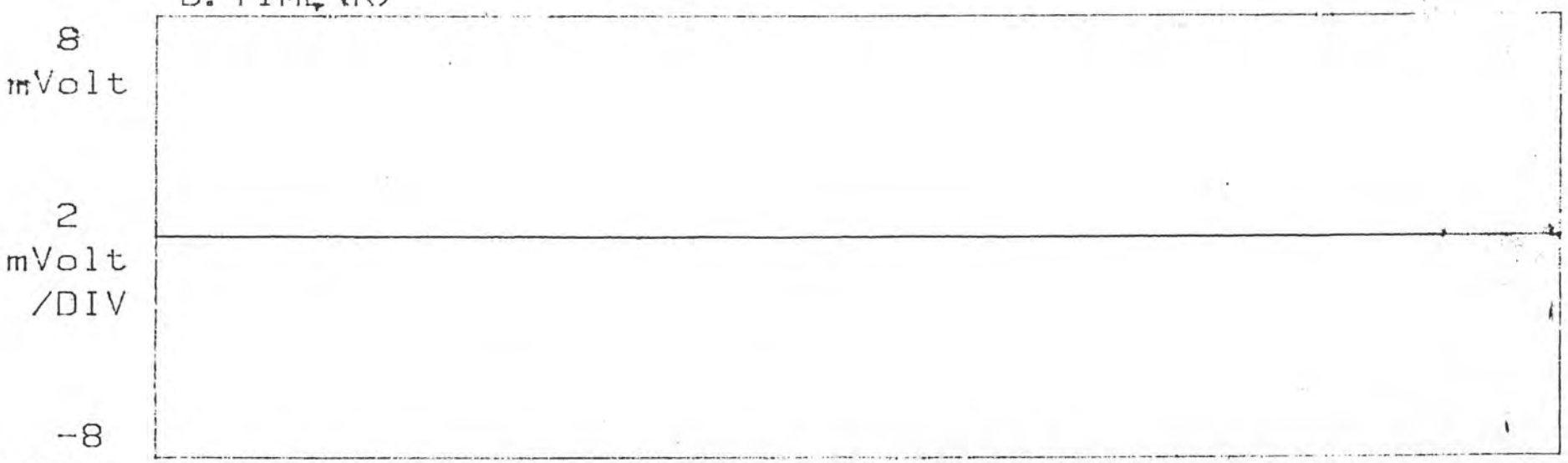
RANGE: -51 dBV STATUS: PAUSED
TIME: 22

A: STORED



START: 0 Hz BW: 1.9097 Hz STOP: 200 Hz

B: TIME (R)



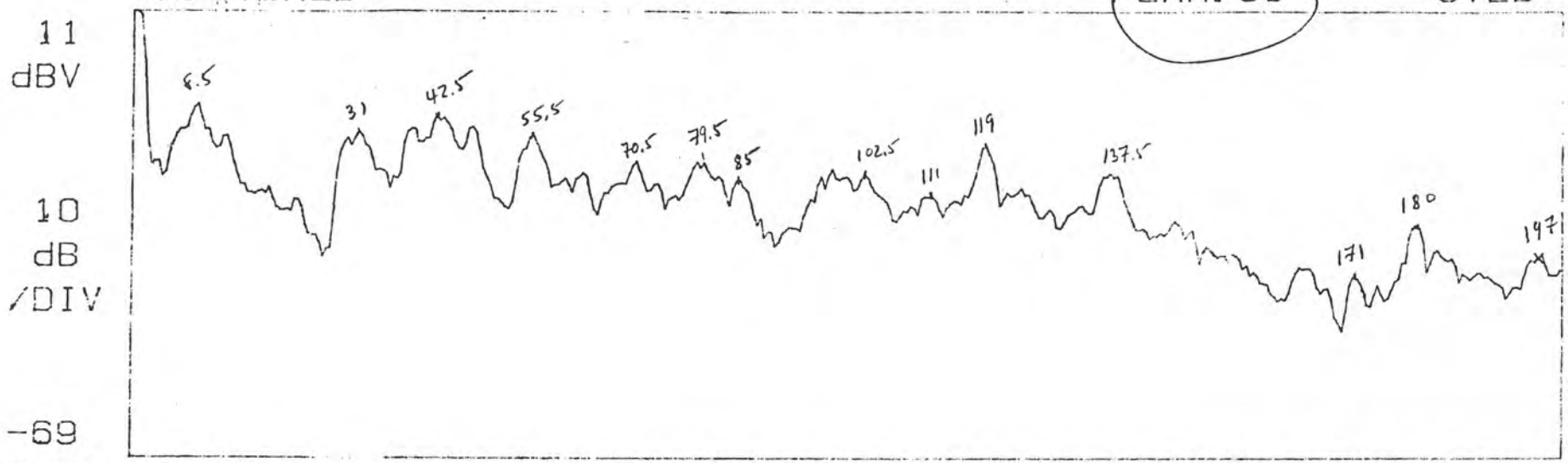
START: 0 Sec STOP: 4 mSec

X: 100 Hz Y: -44.49 dBV

7-9-8L
N-2
SHAFT-(PEAK ...
#2 ⇒ 24 MLD
#1 ⇒ 24 MLD

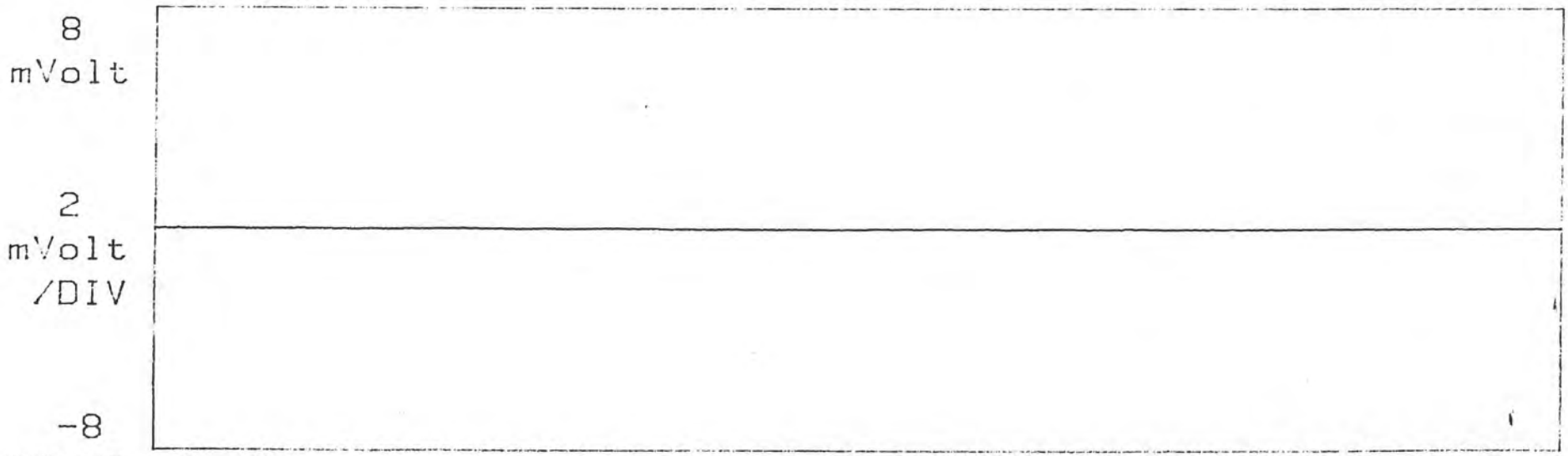
RANGE: -51 dBV STATUS: PAUSED

A: STORED PEAK: 35 OVLD



START: 0 Hz BW: 1.9097 Hz STOP: 200 Hz

B: TIME (R)



START: 0 Sec STOP: 4 mSec

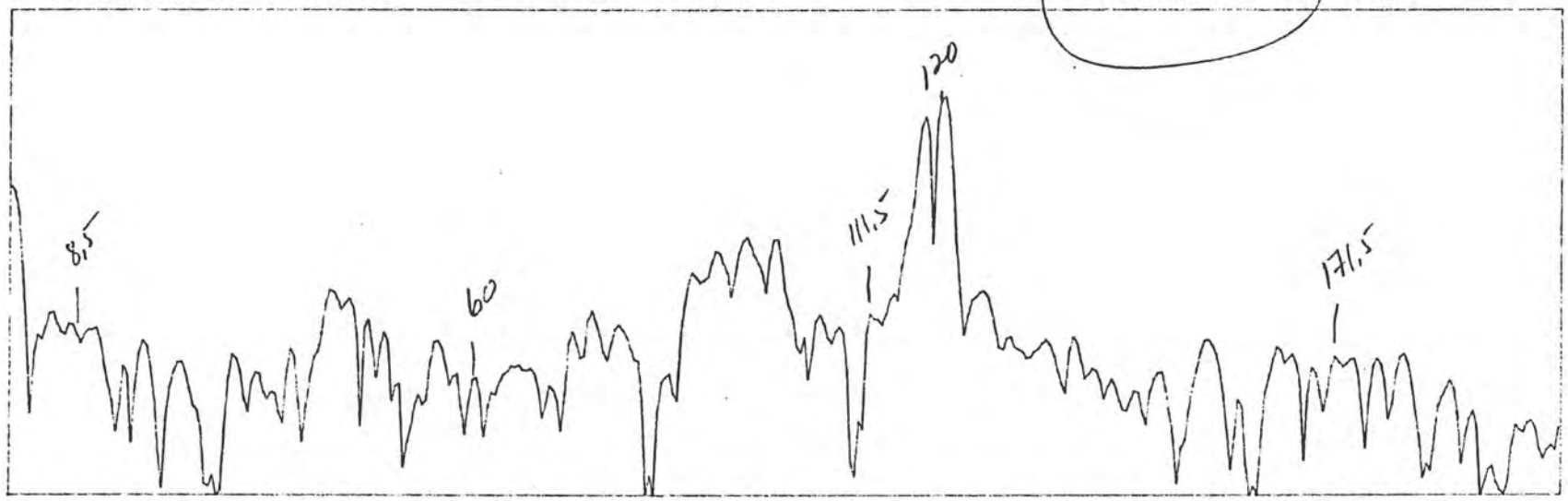
X: 197 Hz Y: -33.25 dBV

7/4/86
B&K MIC
(#2 HEAD COVER)
#1 - 6[illegible]
#2 - [illegible]

RANGE: -51 dBV STATUS: PAUSED

TIME: 30

A: STORED



START: 0 Hz BW: 1.9097 Hz STOP: 200 Hz

B: TIME (R)

START: 0 Sec STOP: 4 mSec

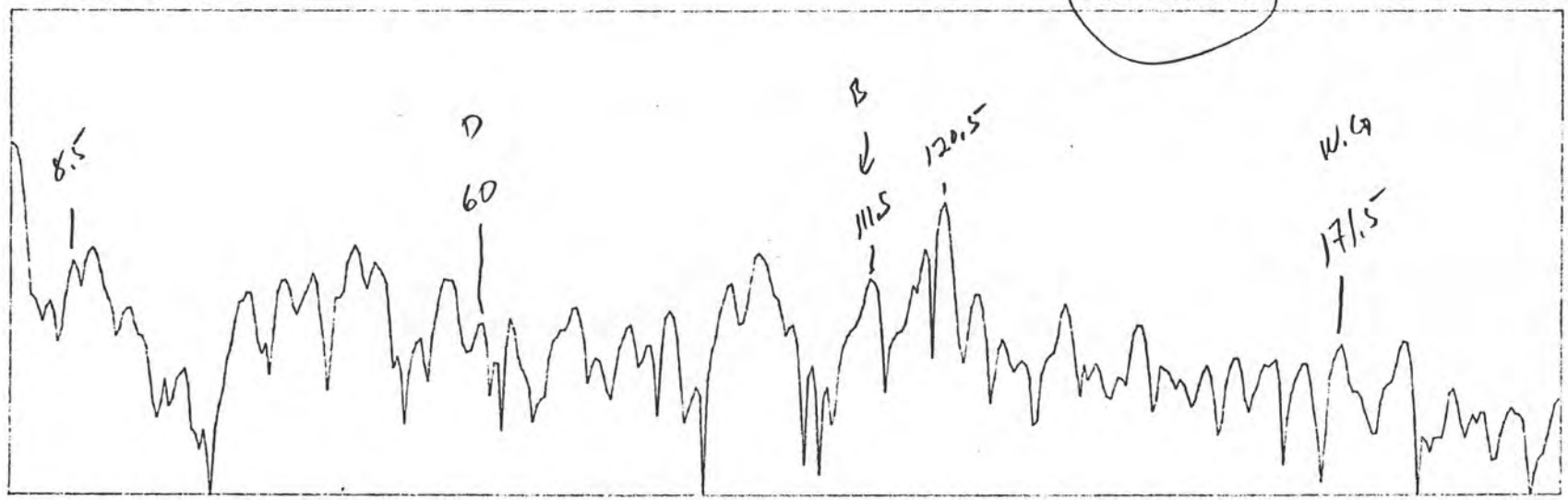
X: 171.5 Hz Y: -50.98 dBV

71486A
B&K Mic
(#2 Hand Cover)
#1 = 6.5 w.g.
#2 = 79 w.g.

RANGE: -51 dBV STATUS: PAUSED

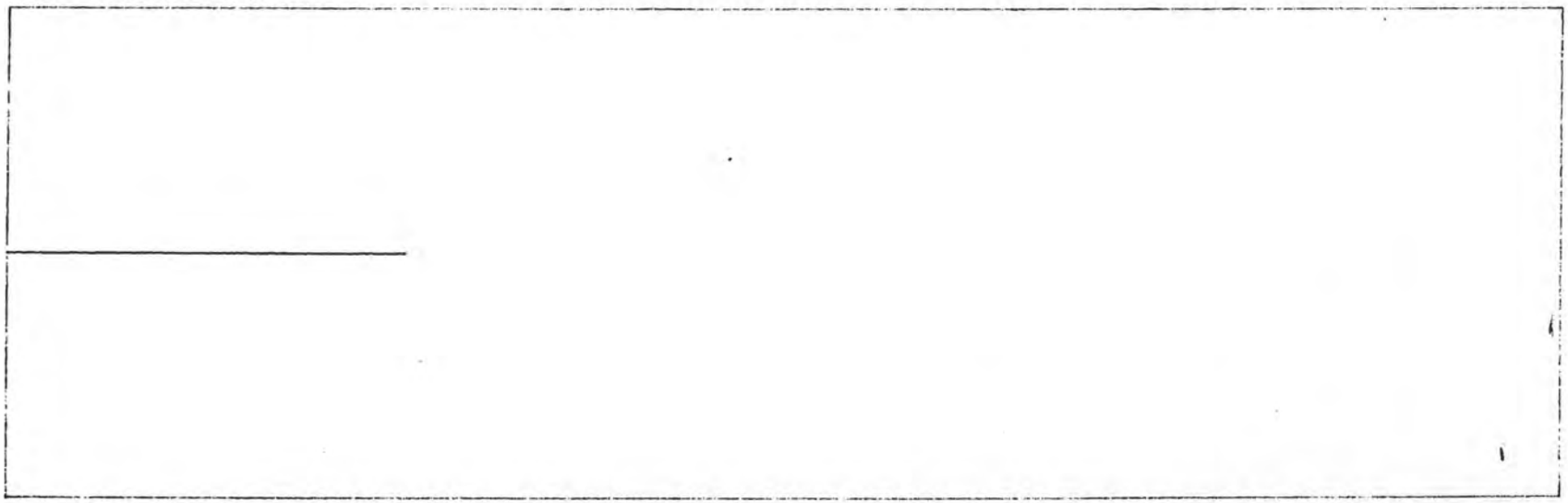
TIME: 25

A: STORED



START: 0 Hz BW: 1.9097 Hz STOP: 200 Hz

B: TIME (R)



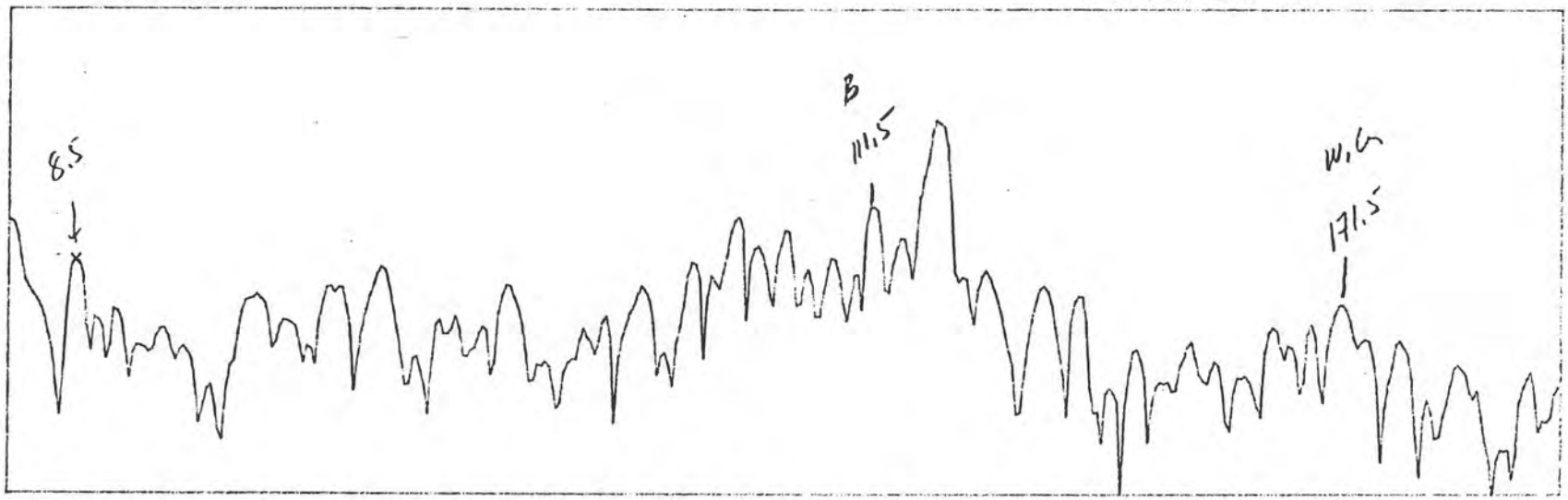
START: 0 Sec STOP: 4 mSec

X: 171.5 Hz Y: -53.16 dBV

71486 B
B&K mic
#2 HEAD cover
#1 = 60% w.G.
#2 = 79% w.G.

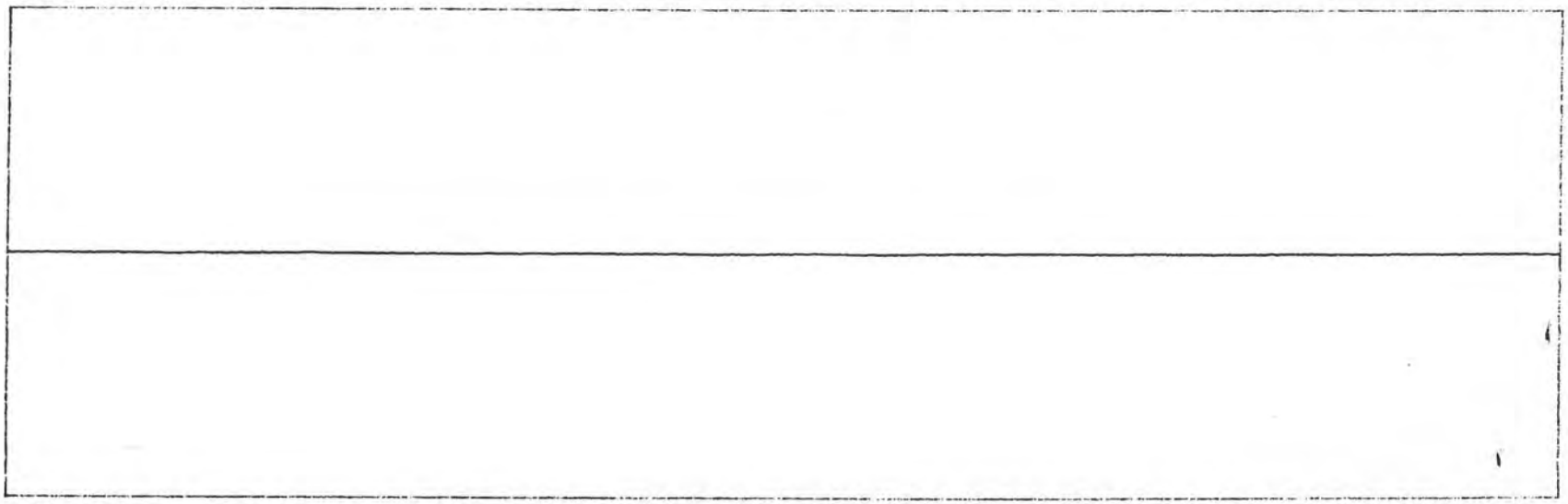
RANGE: -51 dBV STATUS: PAUSED

A: STORED TIME: 15



START: 0 Hz BW: 1.9097 Hz STOP: 200 Hz

B: TIME (R)



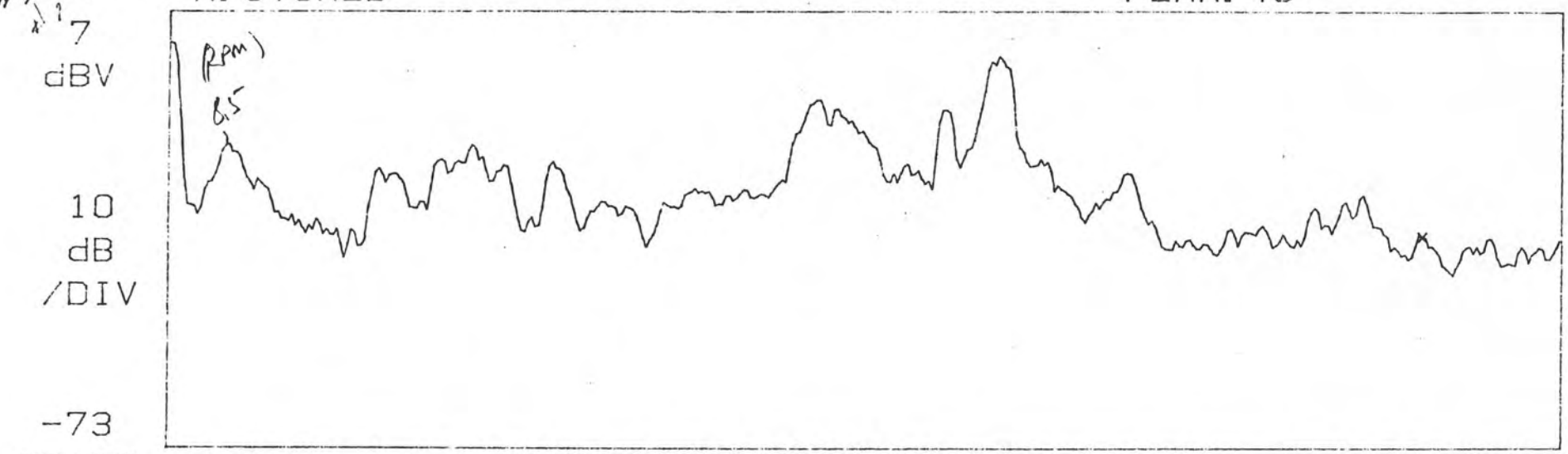
START: 0 Sec STOP: 4 mSec

X: 8.5 Hz Y: -34.39 dBV

71486C
B&K Mic
Top of Rowlock #2
#1 = 60° o/s W.G.
#2 = -79° W.G.

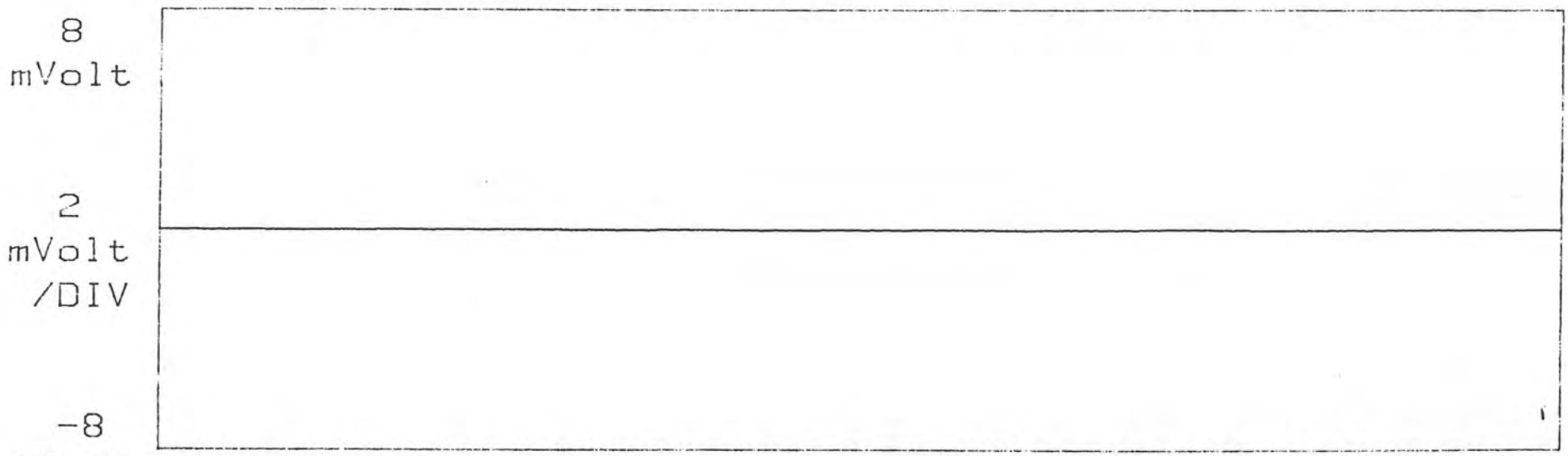
RANGE: -51 dBV STATUS: PAUSED

A: STORED PEAK: 48



START: 0 Hz BW: 1.9097 Hz STOP: 200 Hz

B: TIME (R)



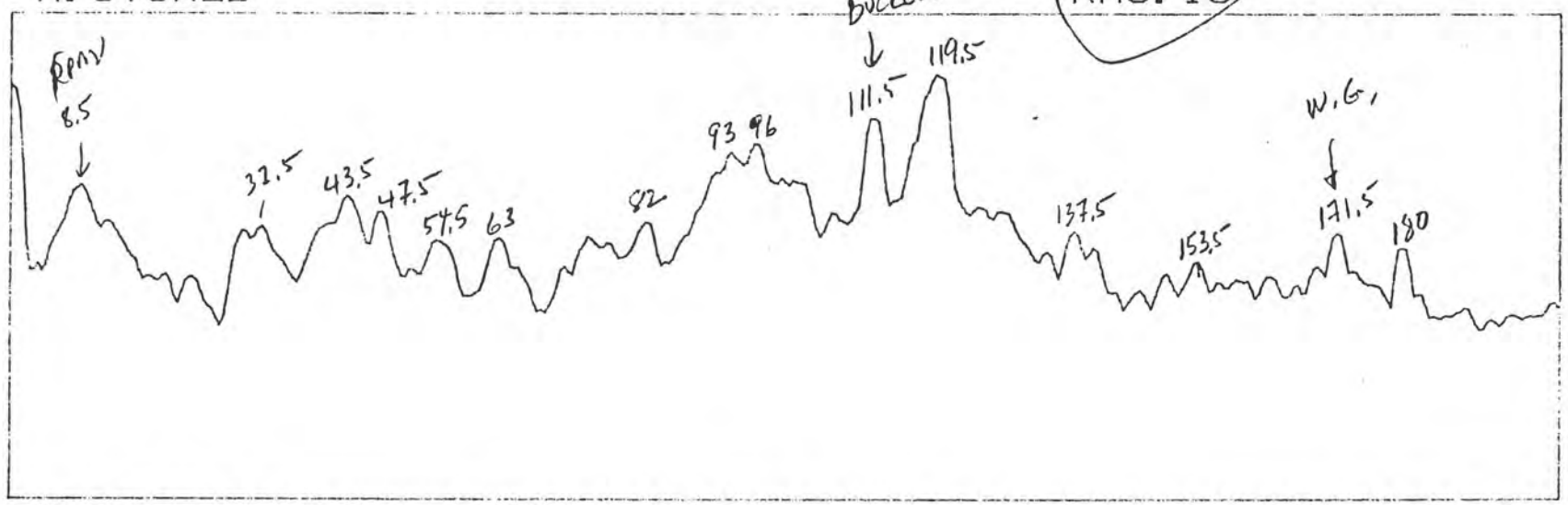
START: 0 Sec STOP: 4 mSec

X: 180 Hz Y: -34.24 dBV

71486D
B&K MIC
TOP OF RUNDOWN #2
#1 = 60% W.G.
#2 = 79% W.G.

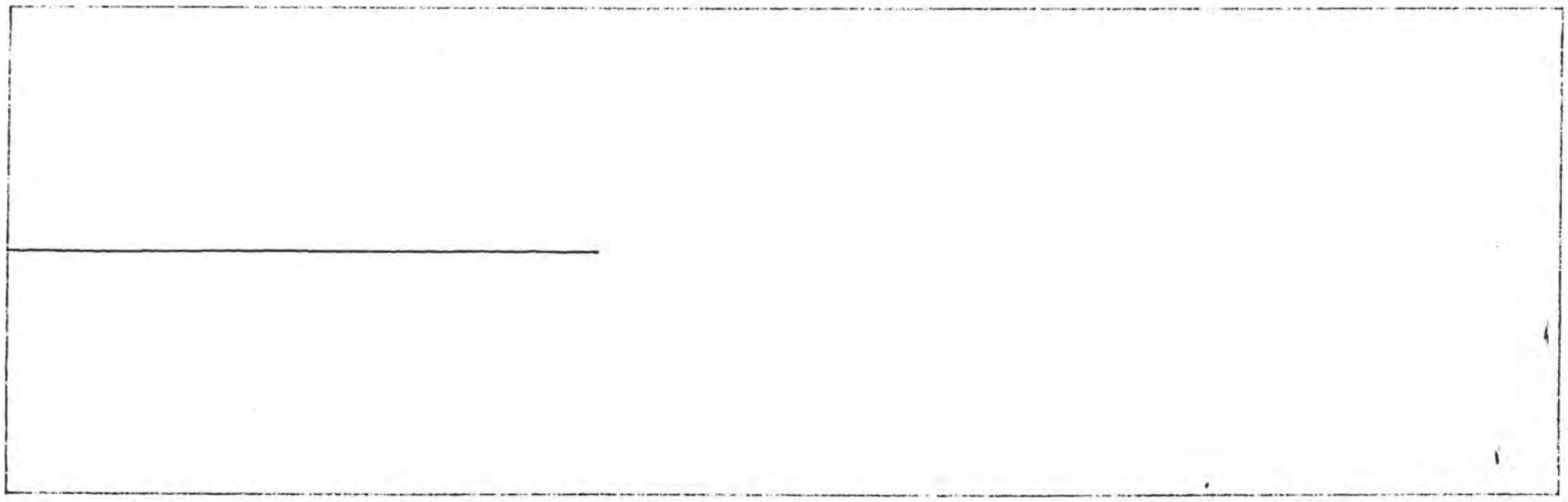
RANGE: -51 dBV STATUS: PAUSED

A: STORED RMS: 10



START: 0 Hz BW: 1.9097 Hz STOP: 200 Hz

B: TIME (R)



START: 0 Sec STOP: 4 mSec

X: 100 Hz Y: -22.84 dBV

7-14-86
Hydrophone
in tank
Interior cross
#1 = 26 mW
#2 = 30 mW

RANGE: 13 dBV STATUS: PAUSED

A: MAG PEAK: 35 OVLD

#2 = 13 dBV

10 dB /DIV

-67

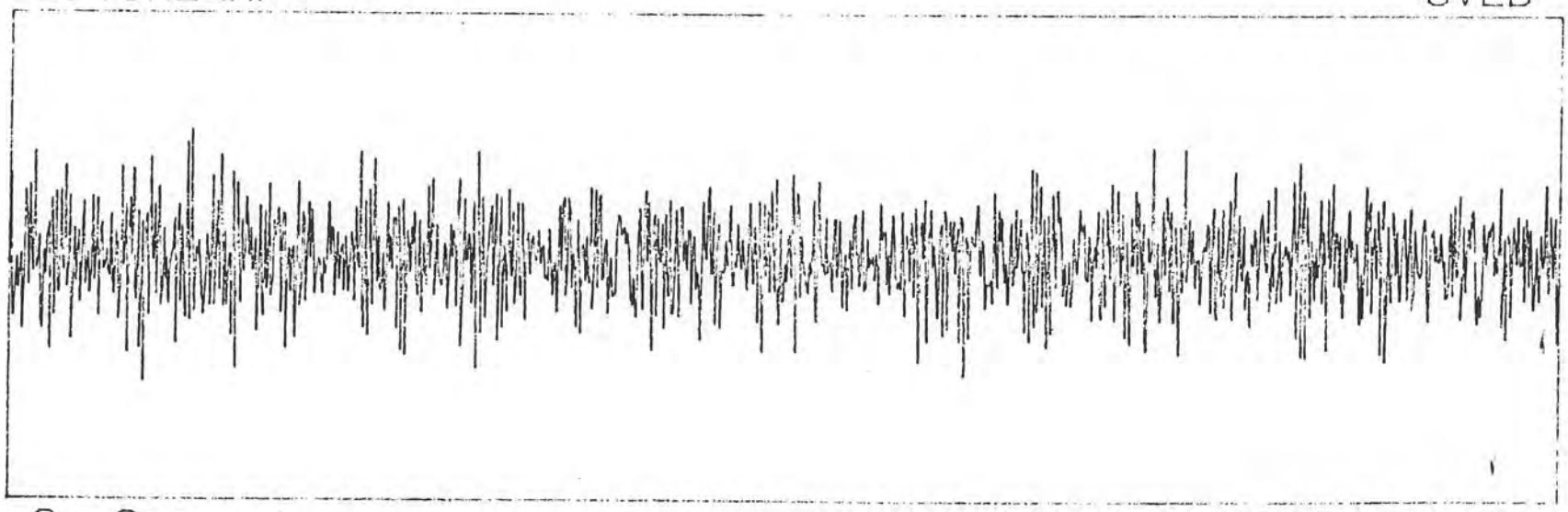
START: 0 Hz BW: 1.9097 Hz STOP: 200 Hz

B: TIME (R) OVLD

8 Volt

2 Volt /DIV

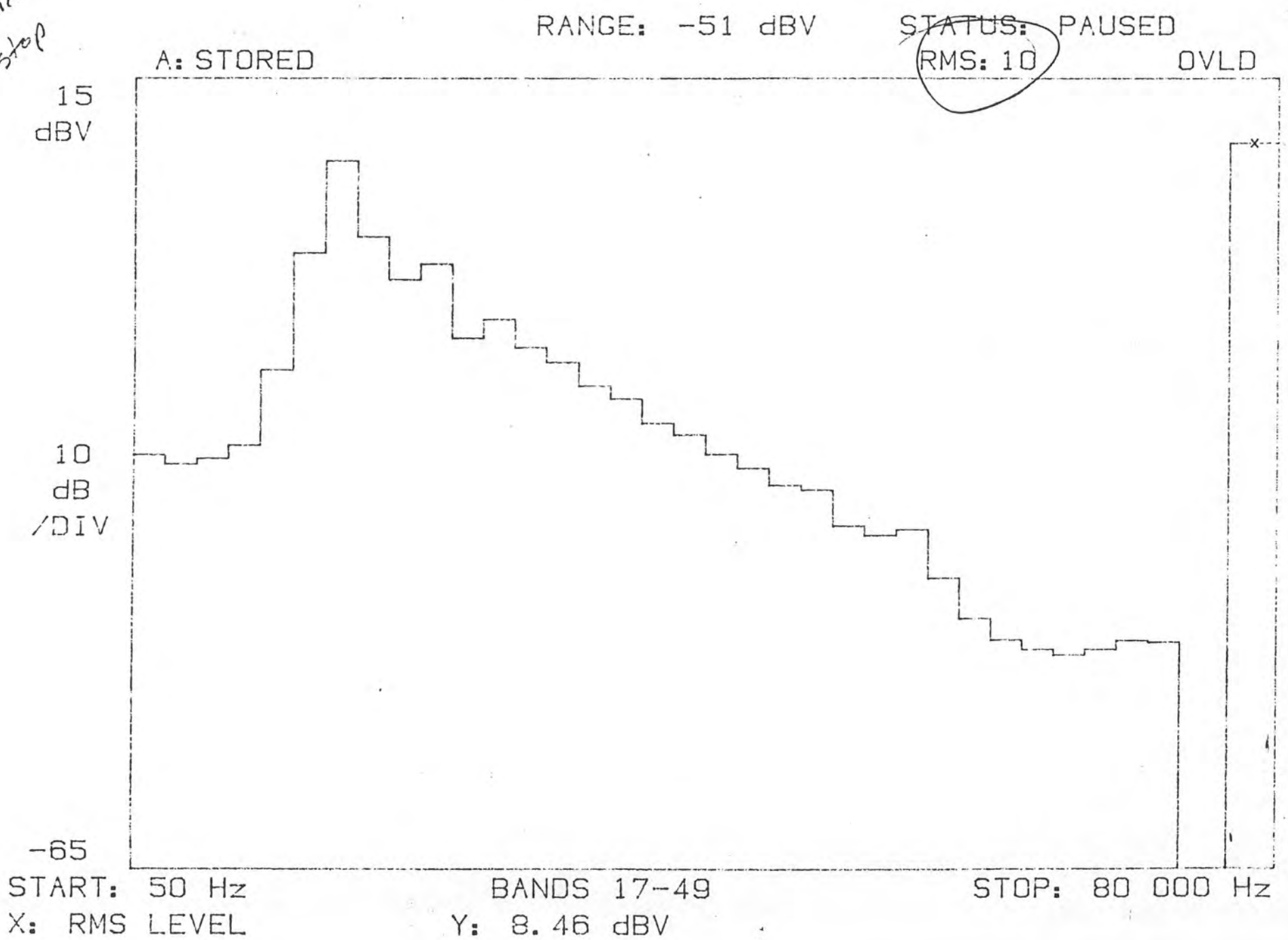
-8



START: 0 Sec STOP: 2 Sec

X: 171 Hz Y: -8.96 dBV

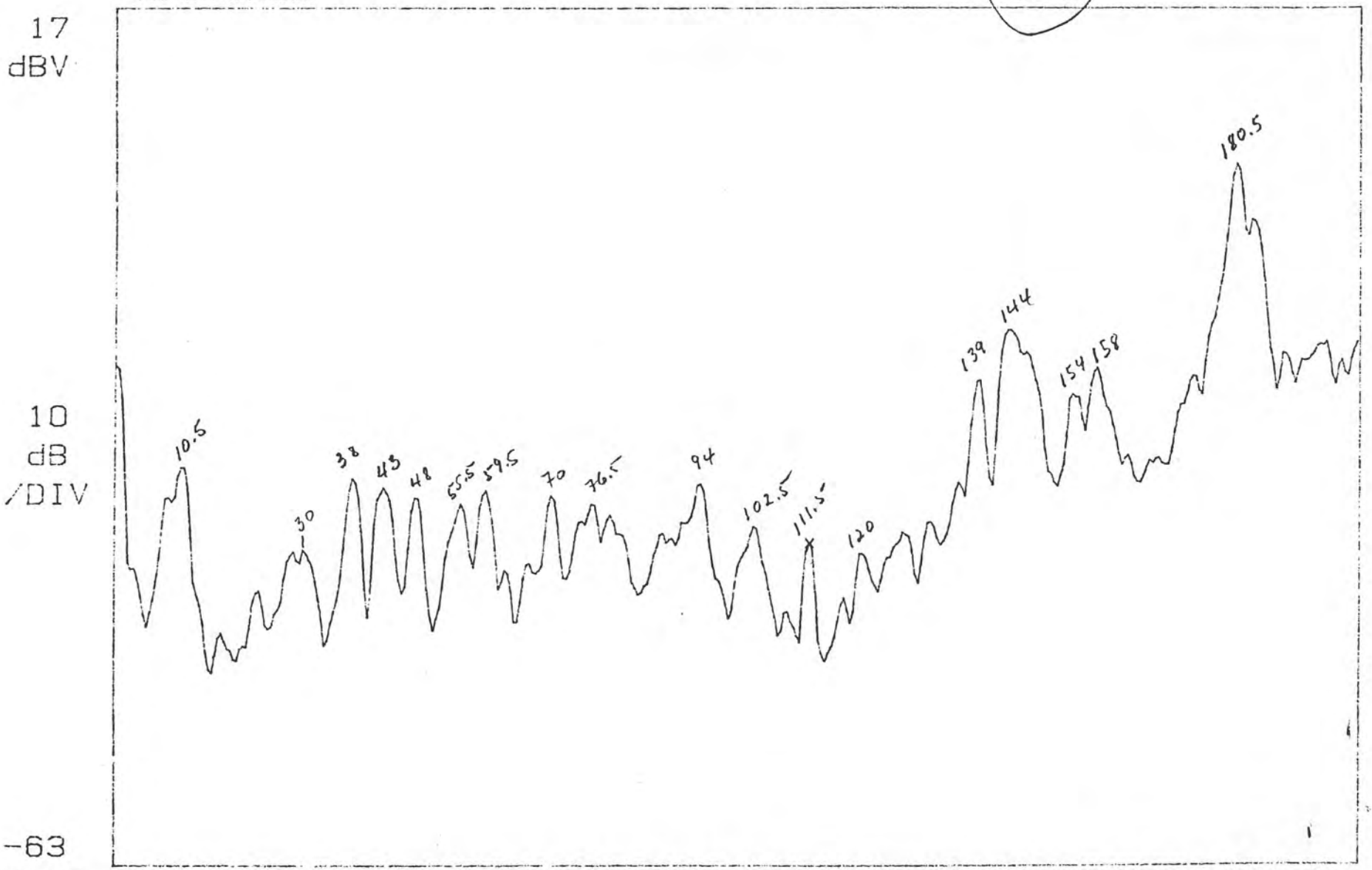
#2
71786 A
#2 → 15 MW
BK Mic - D.T. #2
#1 stop



#2
71786 C #2
15 mm-#2
B&K MIC-DT #2
#1 -STOP

RANGE: -51 dBV STATUS: PAUSED

A: STORED RMS: 10



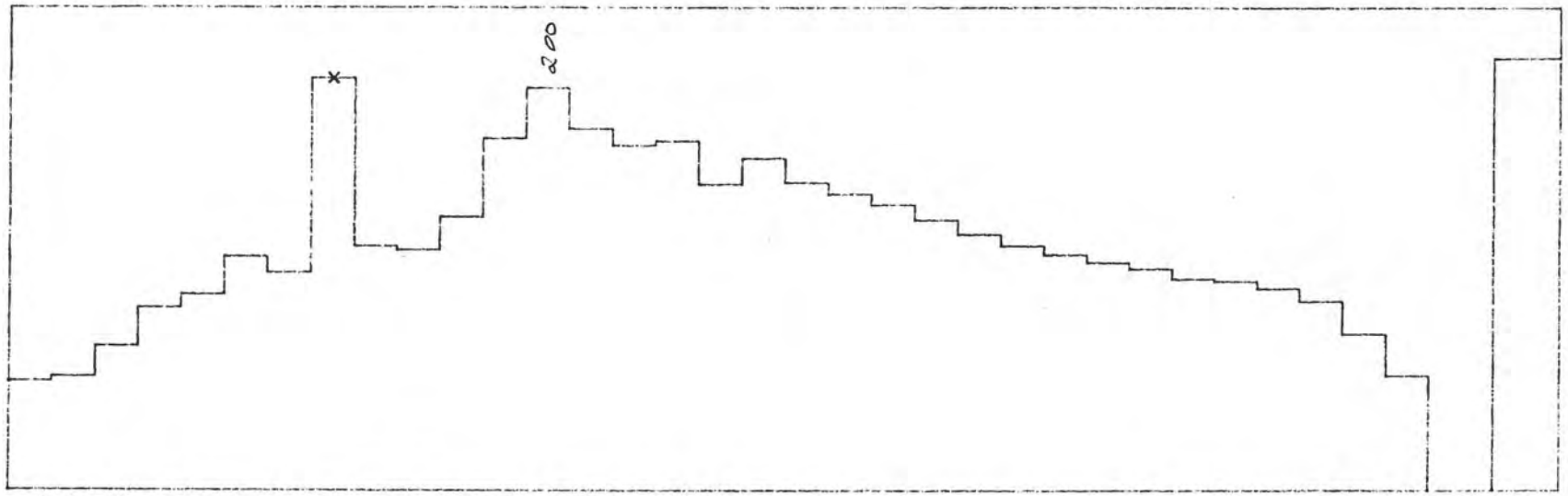
START: 0 Hz BW: 1.9097 Hz STOP: 200 Hz

X: 111.5 Hz Y: -33.11 dBV

#2
7-17-81
15 MW
TAPE
B&K MIC #2 DT
#1 STOP

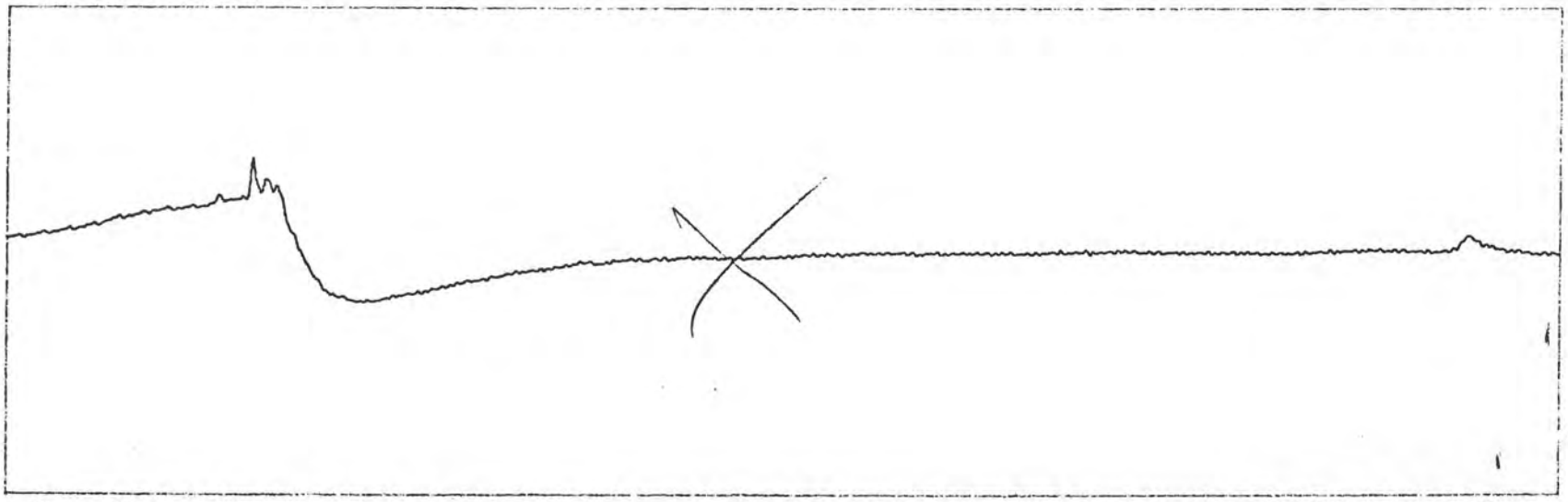
RANGE: -37 dBV STATUS: PAUSED

A: 1/3 OCT RMS: 10



START: 12.5 Hz BANDS 11-43 STOP: 20 000 Hz

B: INP TIME



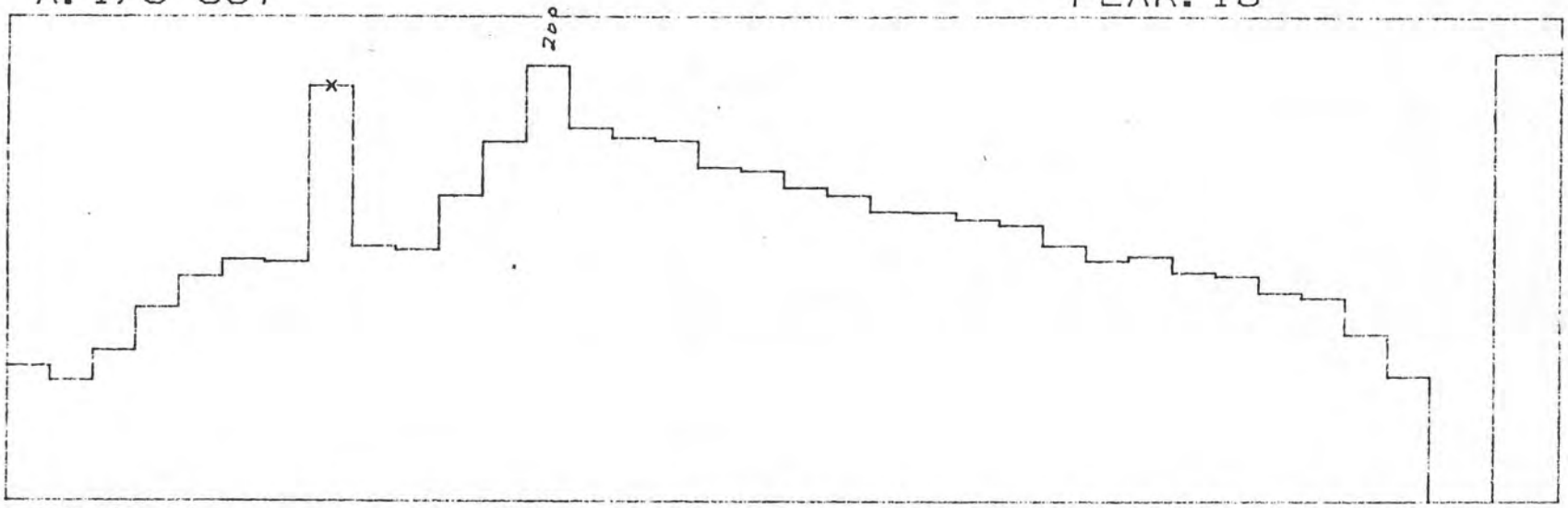
START: 0 Sec STOP: 4 mSec

X: 63 Hz Y: 1.14 dBV

#2
7-17-86
15mW-#2
TAPE
84K MIC #2 D.T.
#1 SCOL

RANGE: -37 dBV STATUS: PAUSED

A: 1/3 OCT PEAK: 10



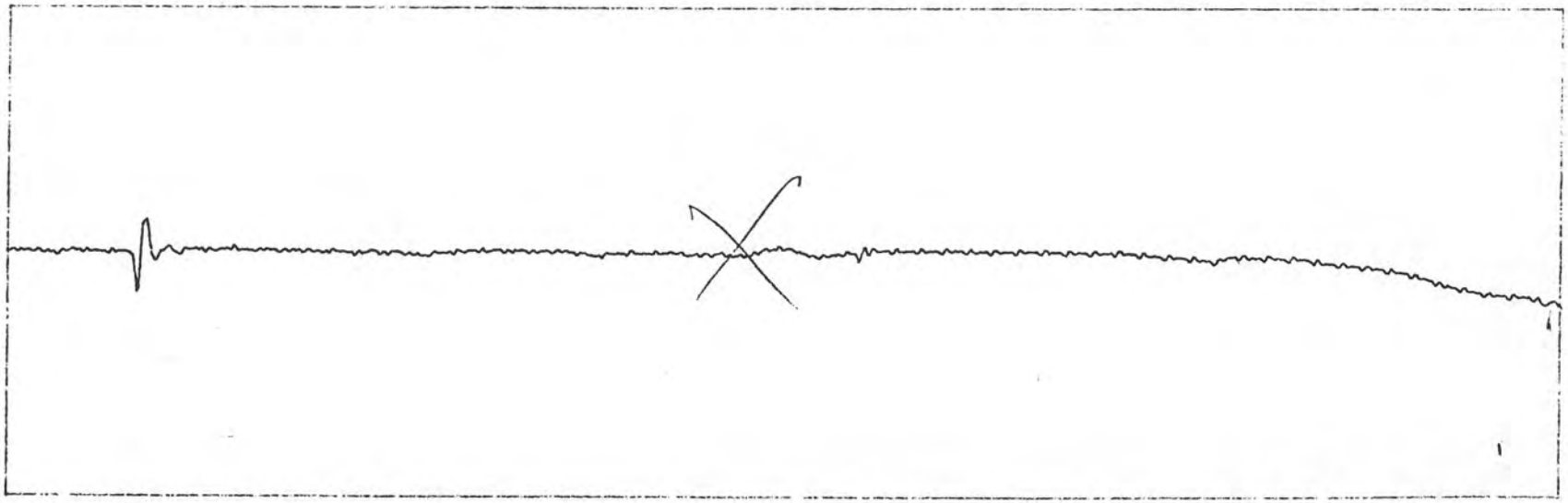
13 dBV

10 dB /DIV

-67

START: 12.5 Hz BANDS 11-43 STOP: 20 000 Hz

B: INP TIME



40 mVolt

10 mVolt /DIV

-40

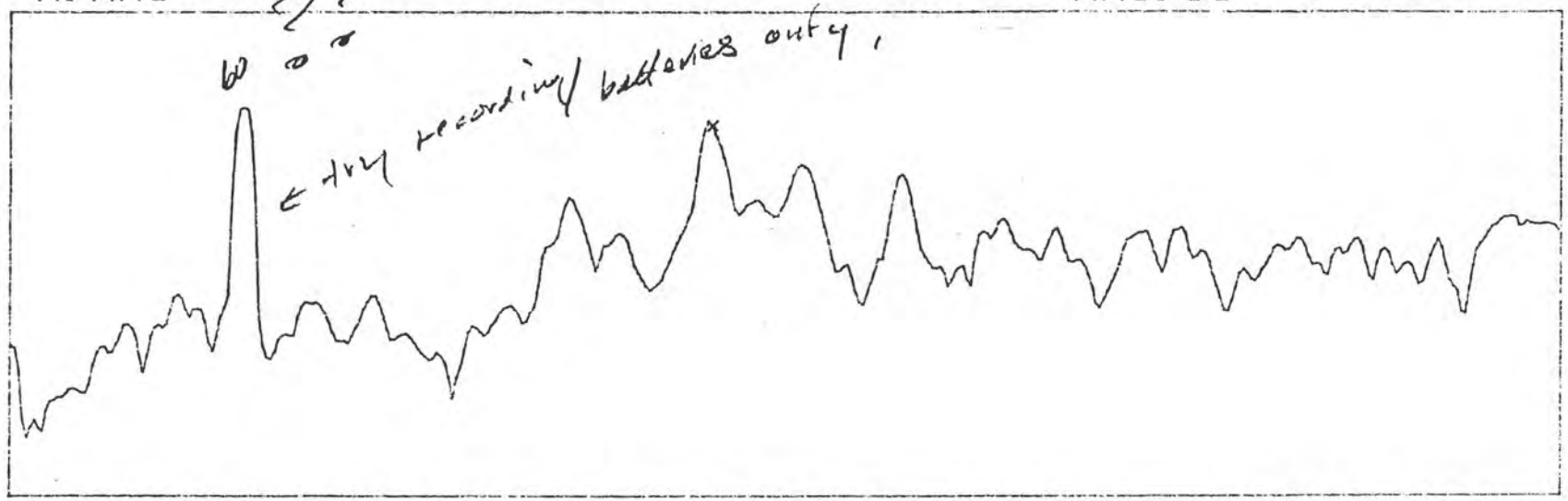
START: 0 Sec STOP: 4 mSec

X: 63 Hz Y: 1.43 dBV

#2
7-17-82
ISWW - #2
TAPE
B&K MIC #2 OT.
#1 STOP

RANGE: -35 dBV STATUS: PAUSED

A: MAG RMS: 10



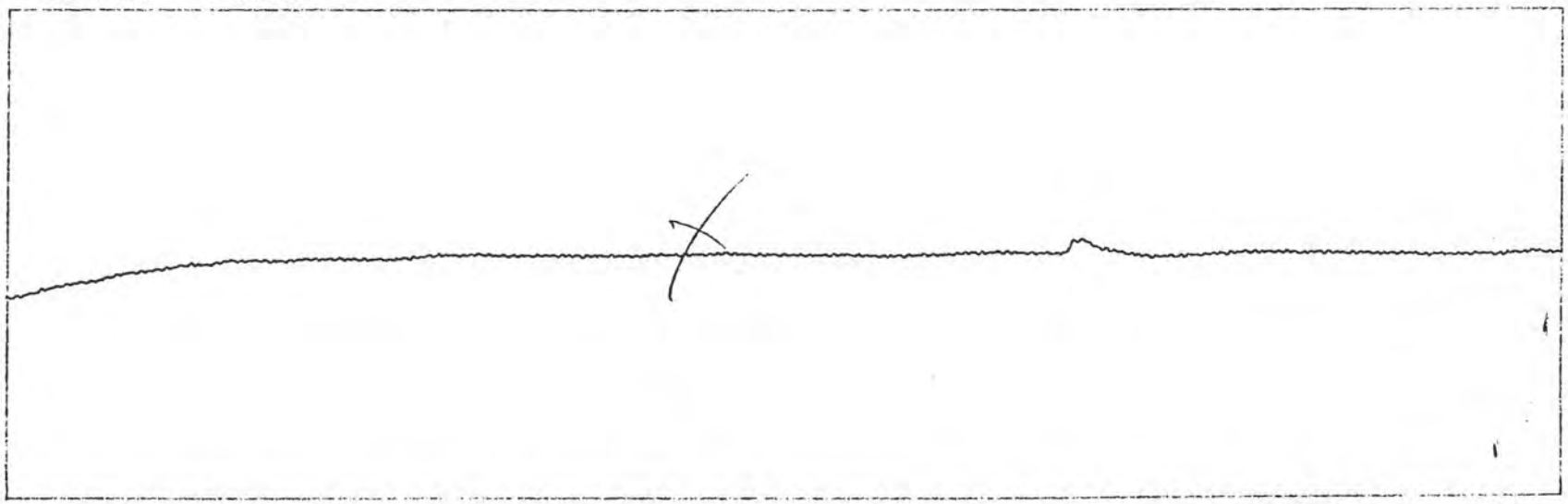
17 dBV

10 dB /DIV

-63

START: 0 Hz BW: 3.8194 Hz STOP: 400 Hz

B: INP TIME



40 mVolt

10 mVolt /DIV

-40

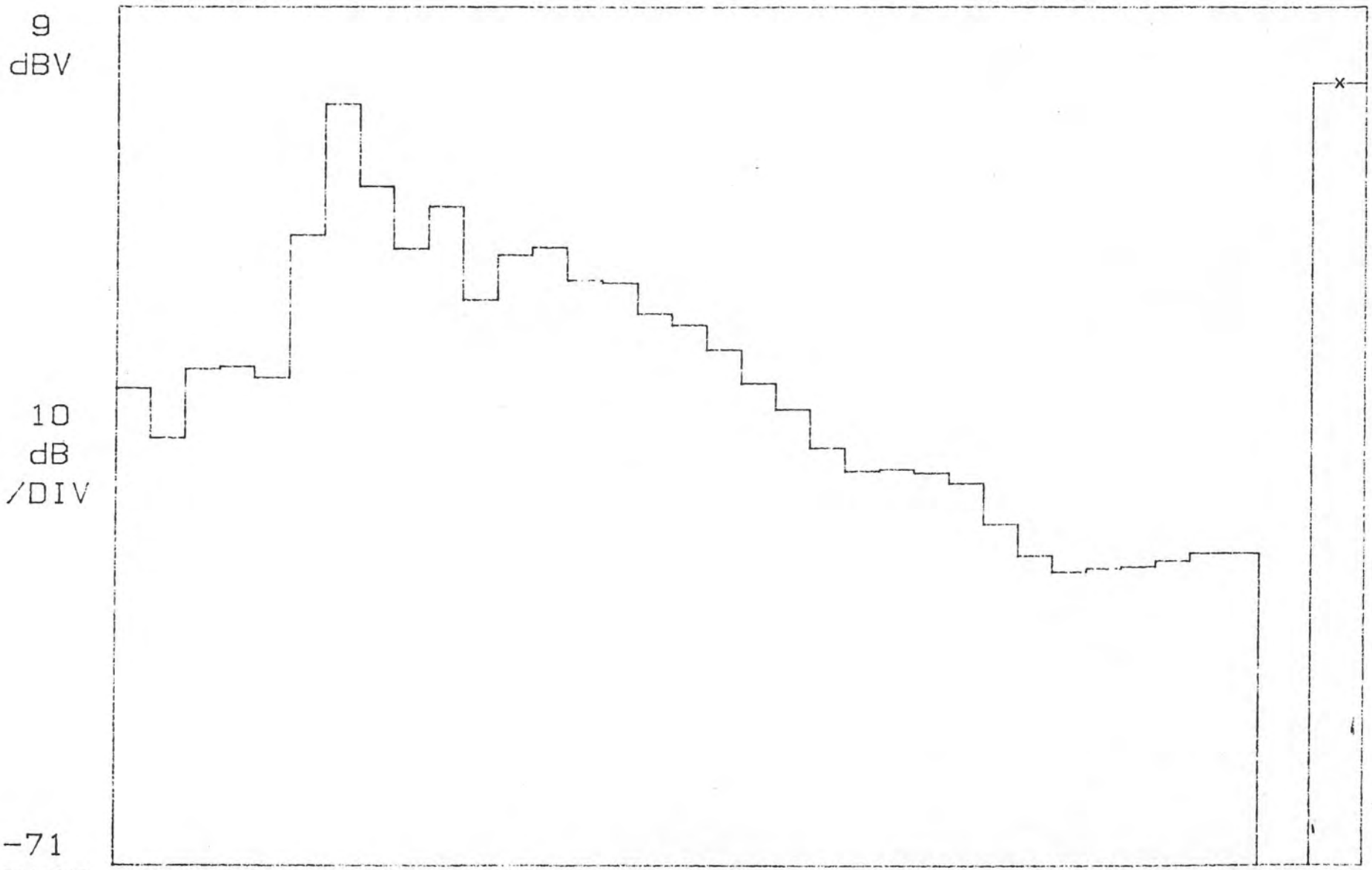
START: 0 Sec STOP: 4 mSec

X: 181 Hz Y: -1.90 dBV

#2
71886A
#2 → 25 MW
#1 - STOP
B&K MIC #2 D.T.

RANGE: -51 dBV STATUS: PAUSED

A: STORED RMS: 10



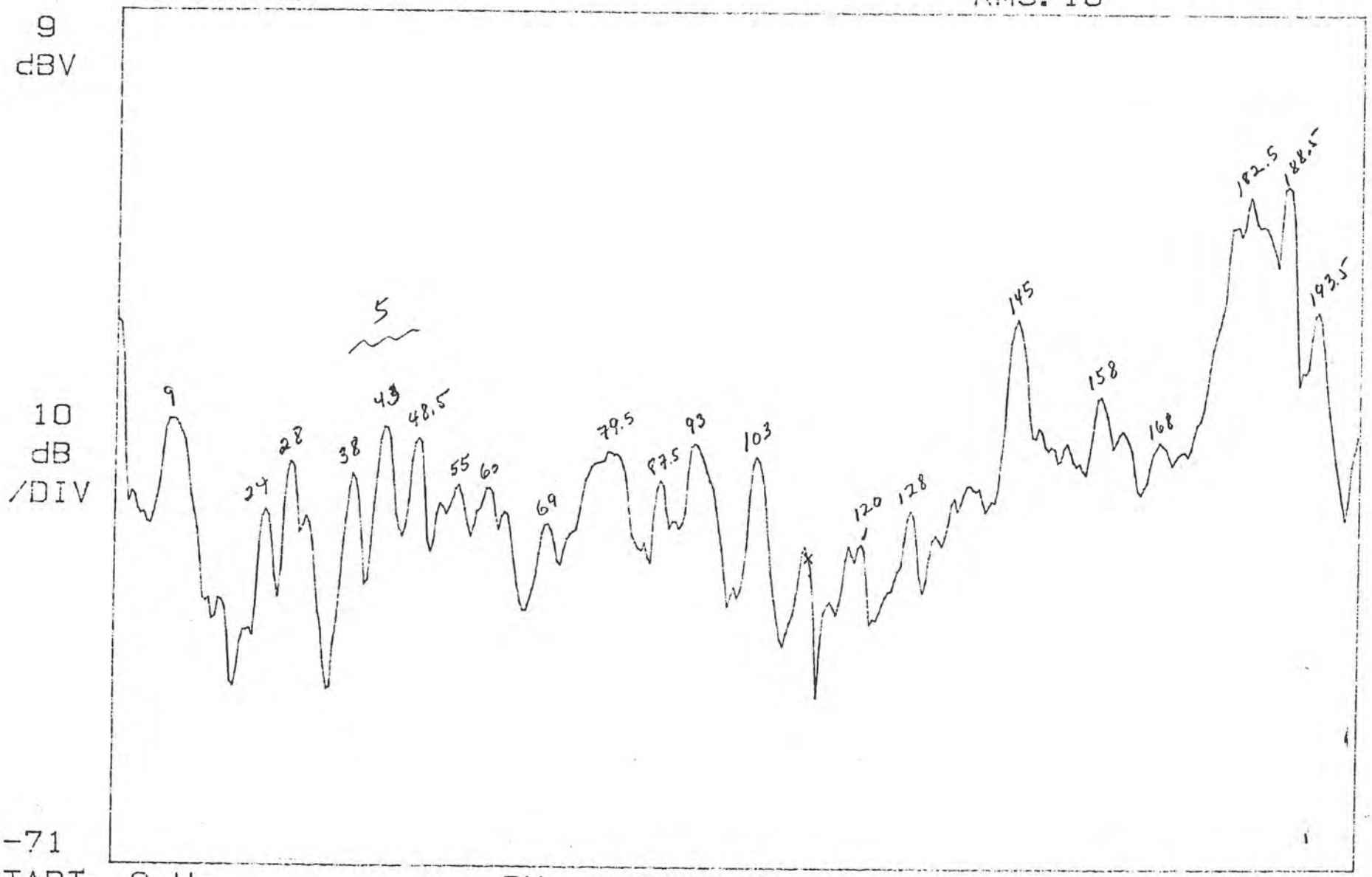
START: 50 Hz BANDS 17-49 STOP: 80 000 Hz

X: RMS LEVEL Y: 1.86 dBV

#2
71886C
25MW #2
#1-STOP
B&K MIC, #2 D.T.

RANGE: -51 dBV STATUS: PAUSED

A: STORED RMS: 10



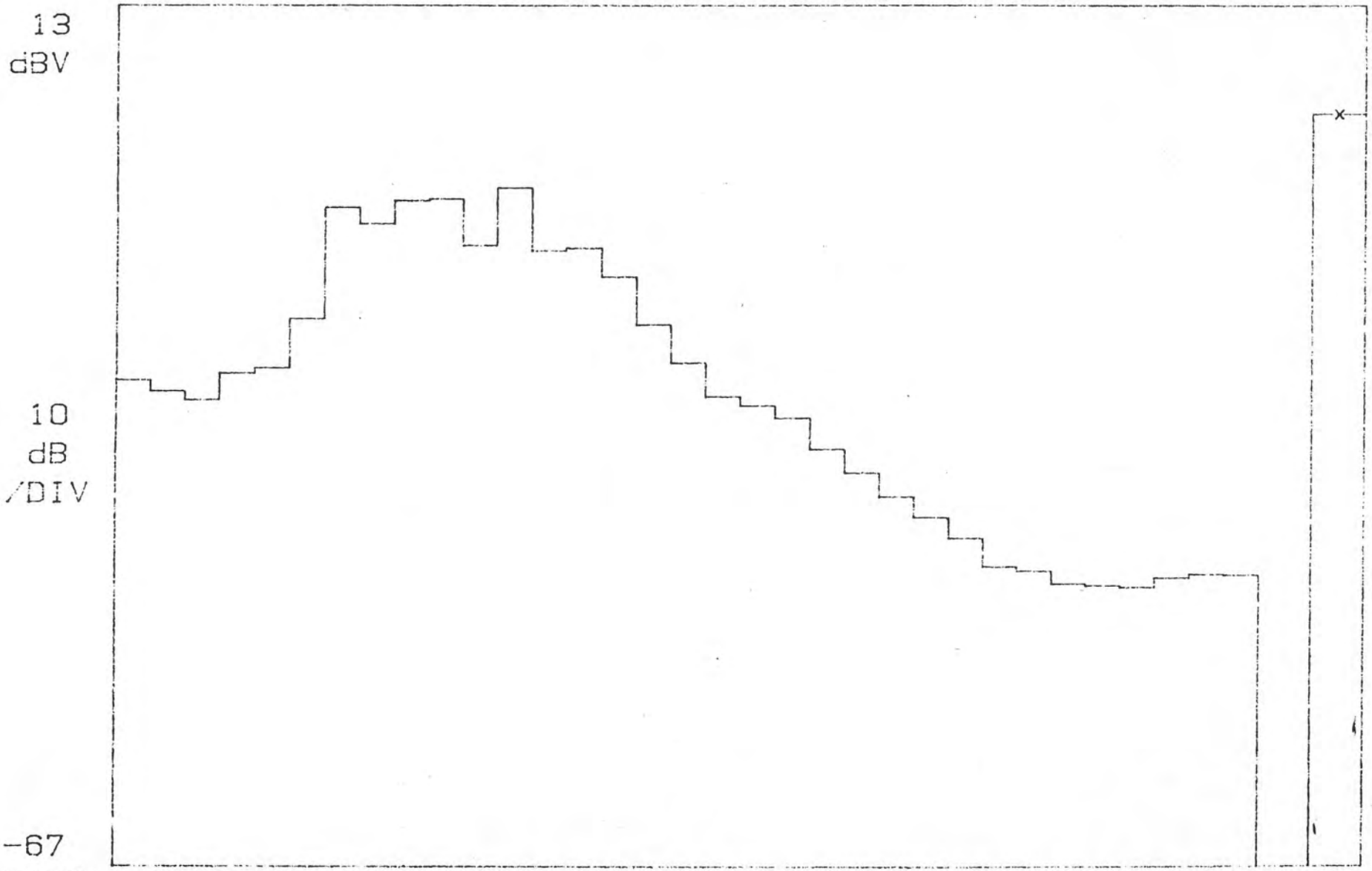
START: 0 Hz BW: 1.9097 Hz STOP: 200 Hz

X: 111.5 Hz Y: -42.07 dBV

#2
73086
#2 - 35 mm
#1 - 12 mm
B&K MIC, #2. DIT.

RANGE: -51 dBV STATUS: PAUSED

A: STORED RMS: 10



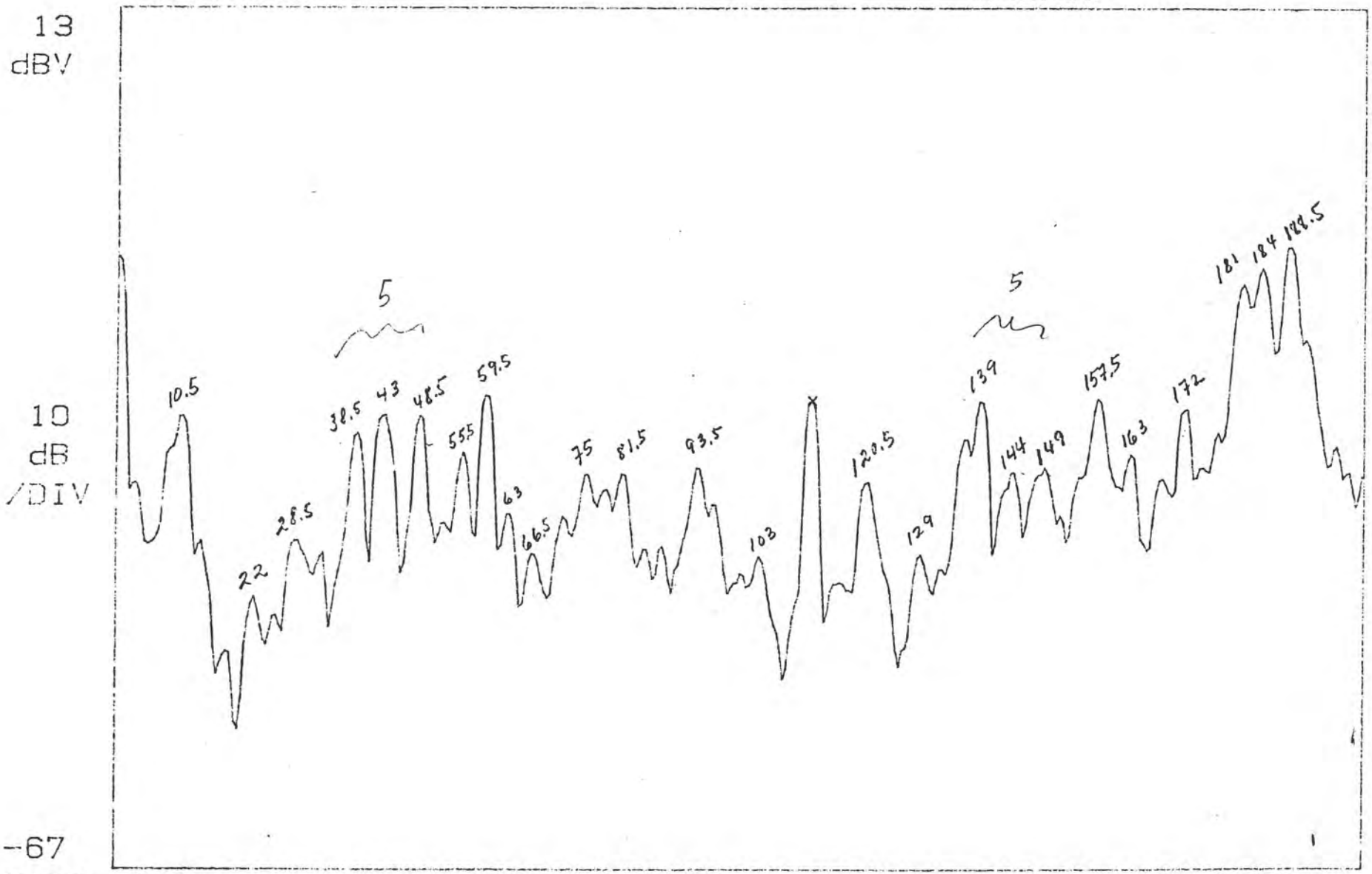
START: 50 Hz BANDS 17-49 STOP: 80 000 Hz

X: RMS LEVEL Y: 2.86 dBV

#2
73086C
H2 - 35 mW
#1 - 12 mW
@ #16 MIC - DT. #2

RANGE: -51 dBV STATUS: PAUSED

A: STORED RMS: 10



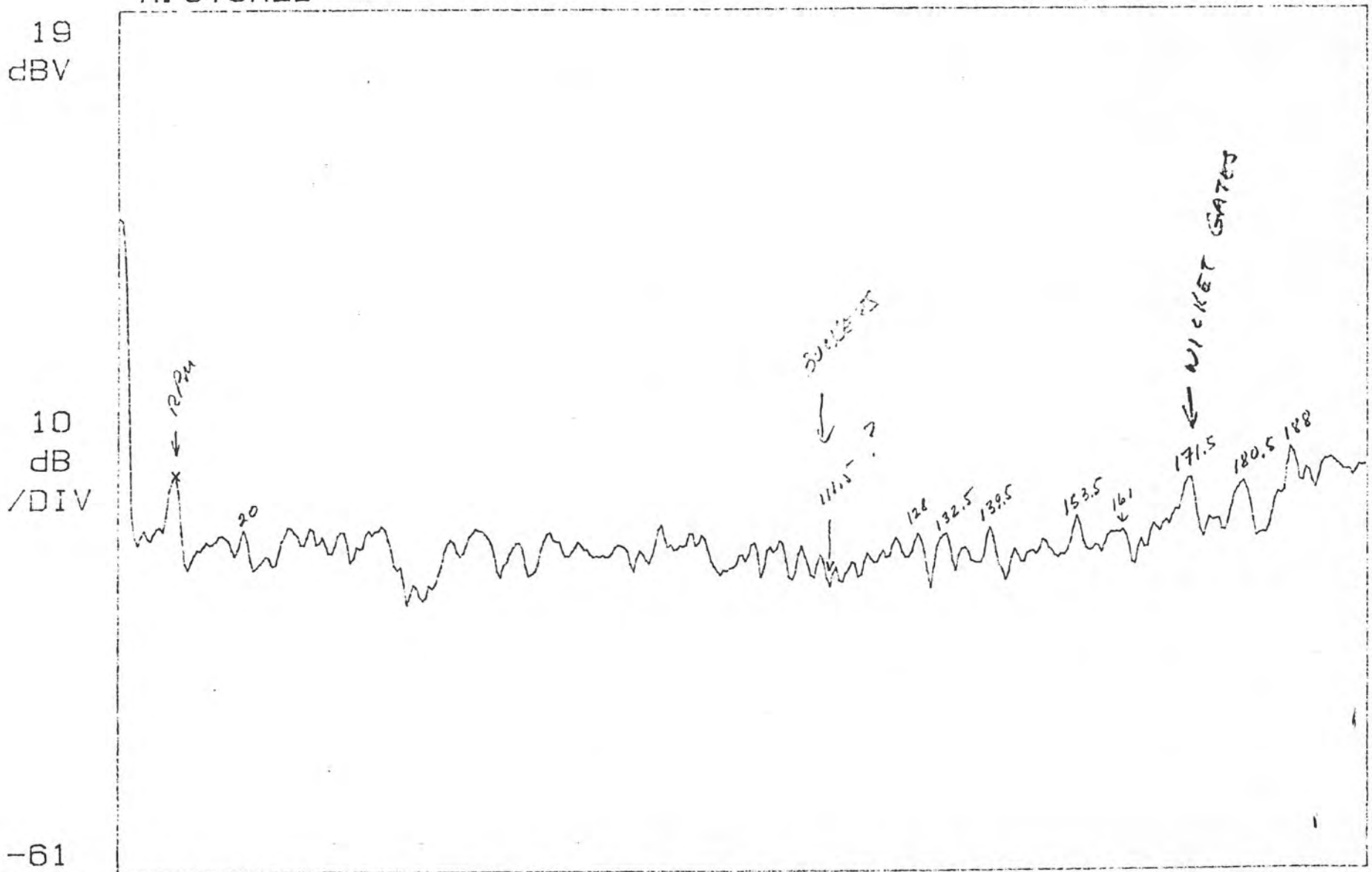
START: 0 Hz BW: 1.9097 Hz STOP: 200 Hz

X: 111.5 Hz Y: -23.63 dBV

#2
#3086 I
35 mm-#2
#1-12 mm.
COLUMBIA REC. DT. #2

RANGE: -51 dBV STATUS: PAUSED

A: STORED RMS: 10 OVLD



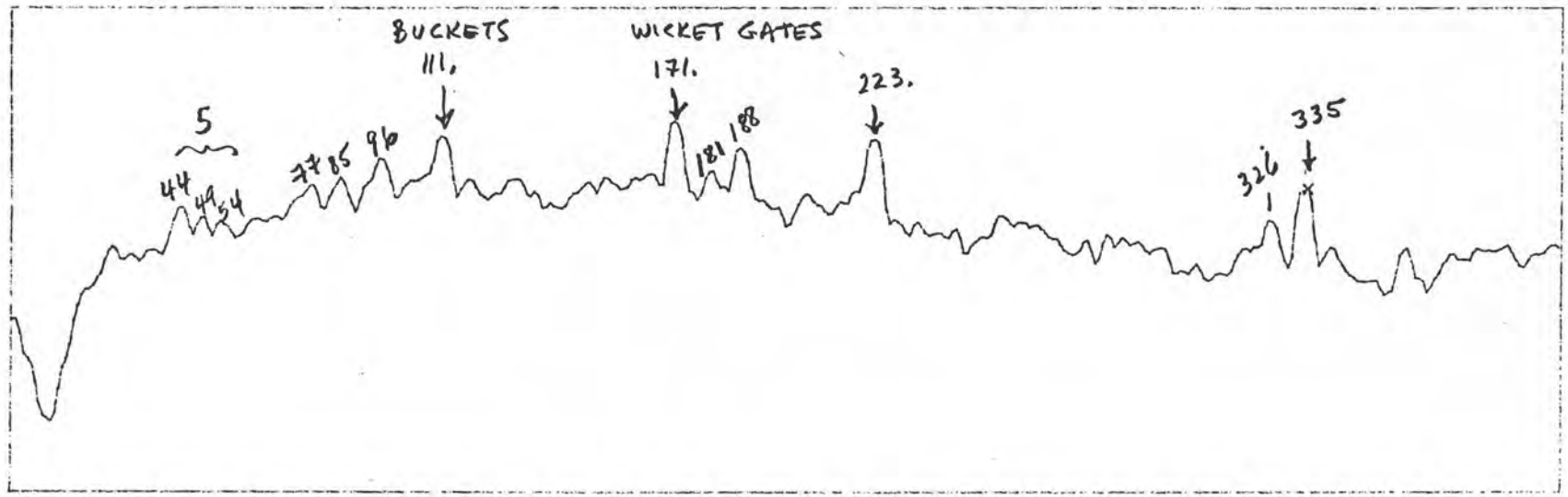
START: 0 Hz BW: 1.9097 Hz STOP: 200 Hz

X: 9 Hz Y: -24.32 dBV

#1
30MW-#1
85&6A
#2-DOWN
#1-30MW
10/HYDRO-TURBINE #1

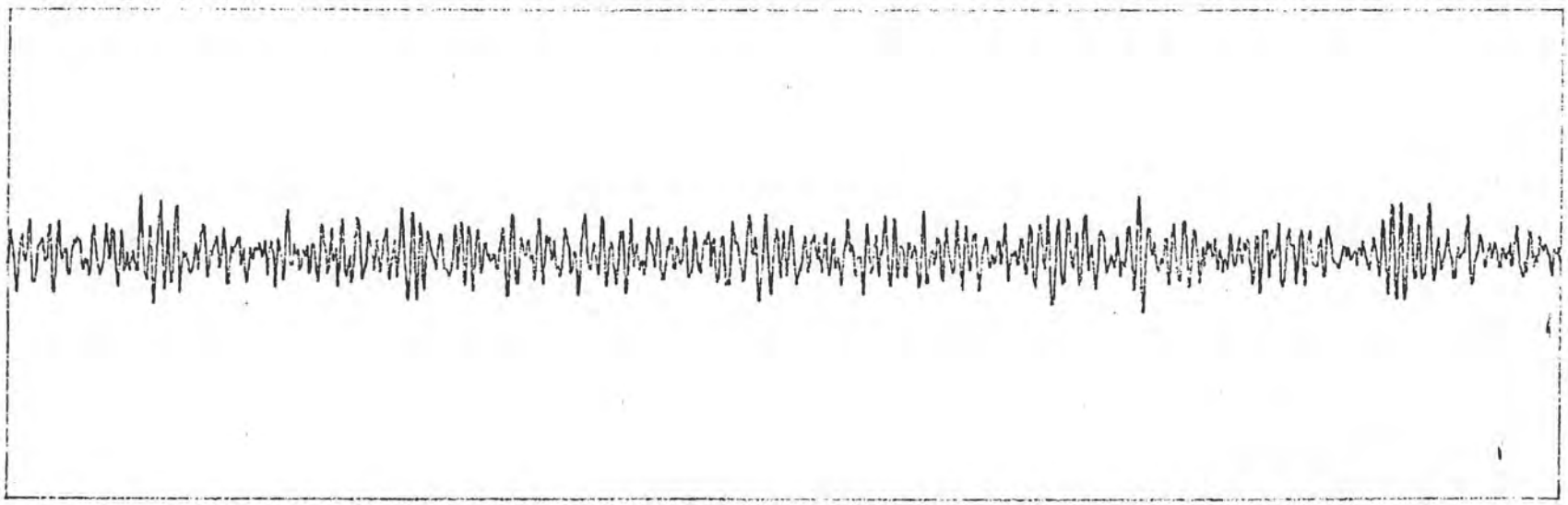
RANGE: 15 dBV STATUS: PAUSED

A: MAG RMS: 10



START: 0 Hz BW: 3.8194 Hz STOP: 400 Hz

B: TIME (R)



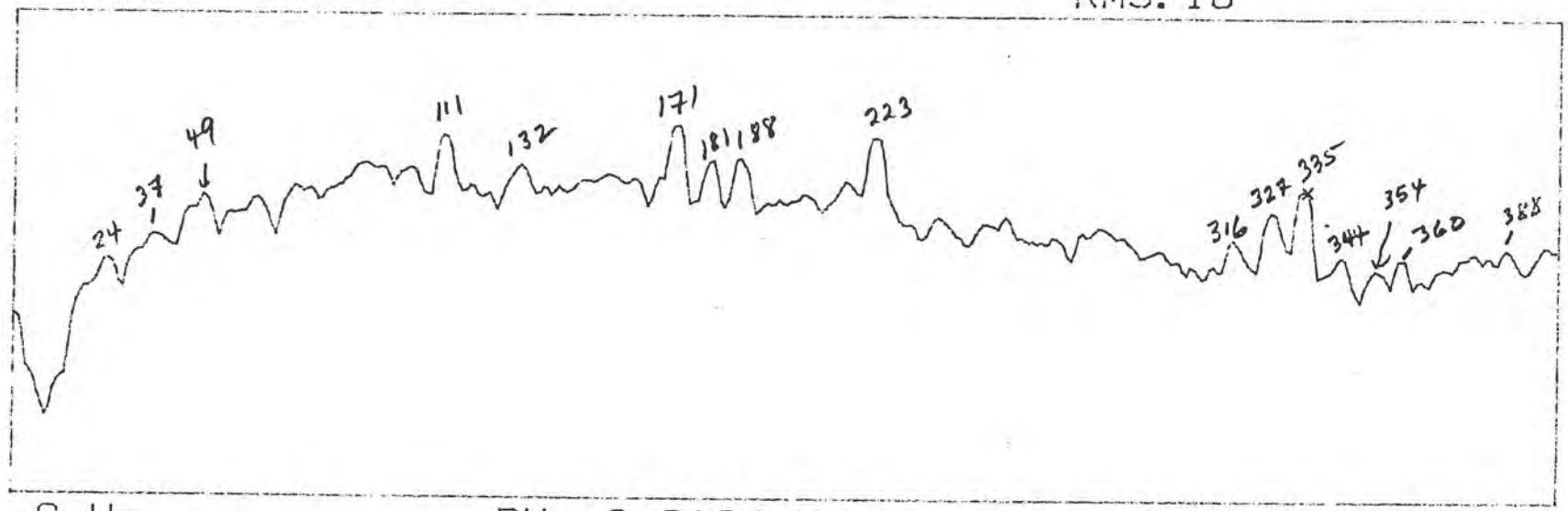
START: 0 Sec STOP: 1 Sec

X: 335 Hz Y: -15.01 dBV

#1
30mm #1
8586B
#2 - DOWN
I0/HADD/TAILPIPE #1

RANGE: 15 dBV STATUS: PAUSED

A: MAG RMS: 10



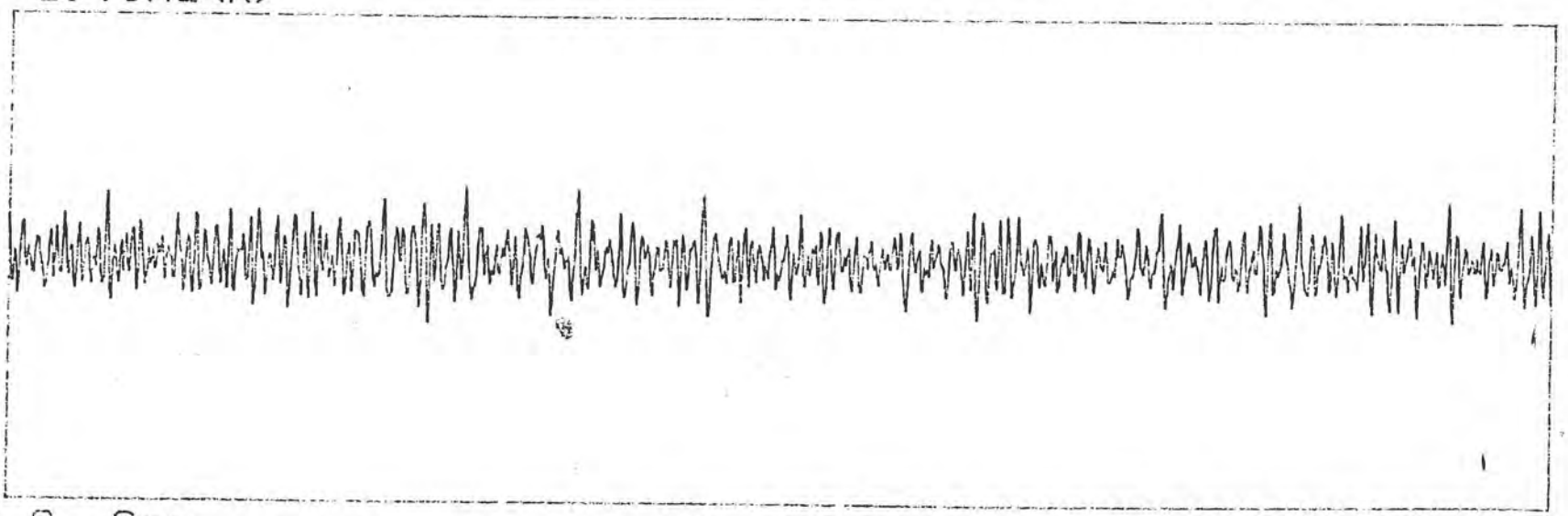
15 dBV

10 dB /DIV

-65

START: 0 Hz BW: 3.8194 Hz STOP: 400 Hz

B: TIME(R)



20 Volt

5 Volt /DIV

-20

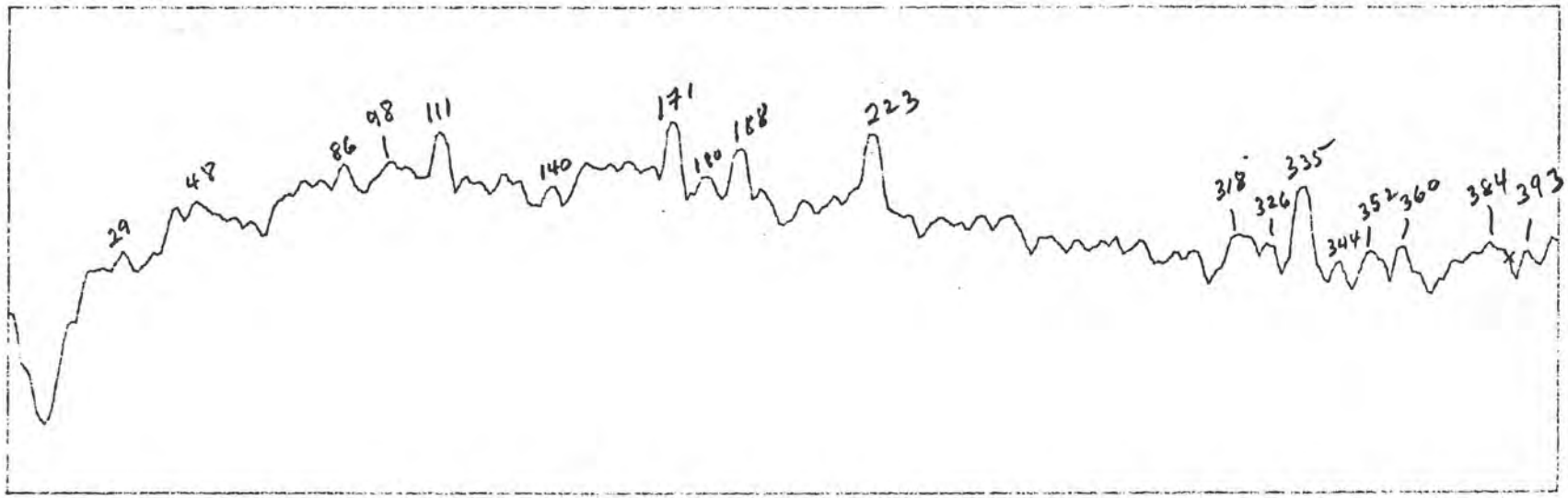
START: 0 Sec STOP: 1 Sec

X: 335 Hz Y: -13.68 dBV

#1
30mm-#1
ESBC
#2 - DOWN
10/HEAD/TACHABLE #1

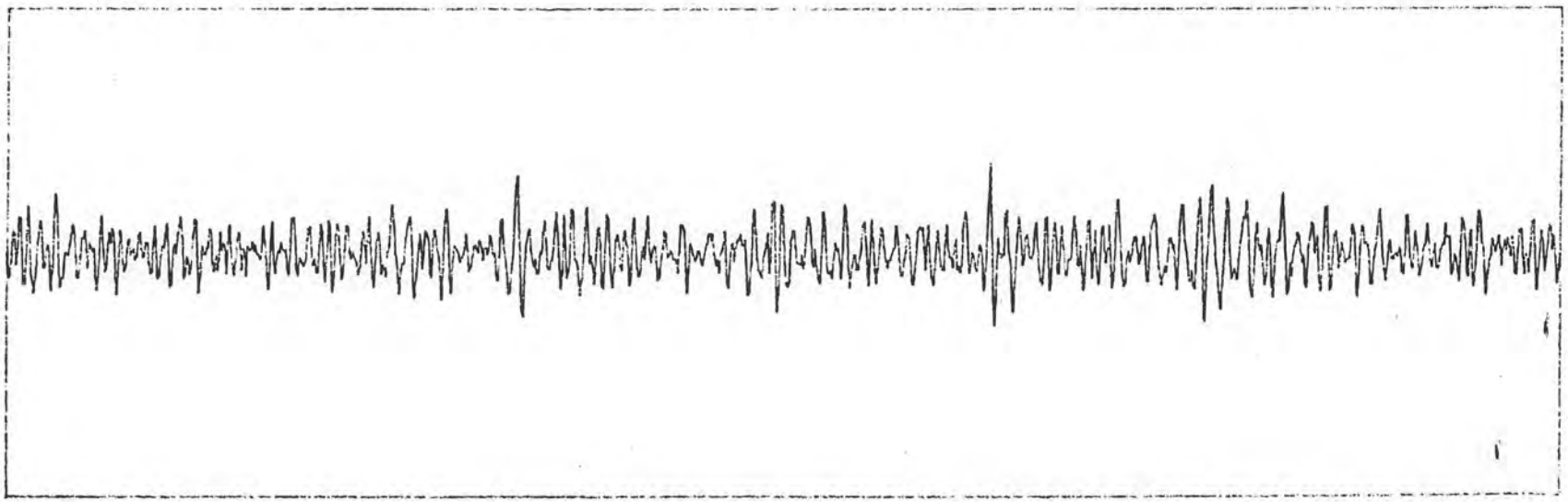
RANGE: 15 dBV STATUS: PAUSED

A: MAG RMS: 10



START: 0 Hz BW: 3.8194 Hz STOP: 400 Hz

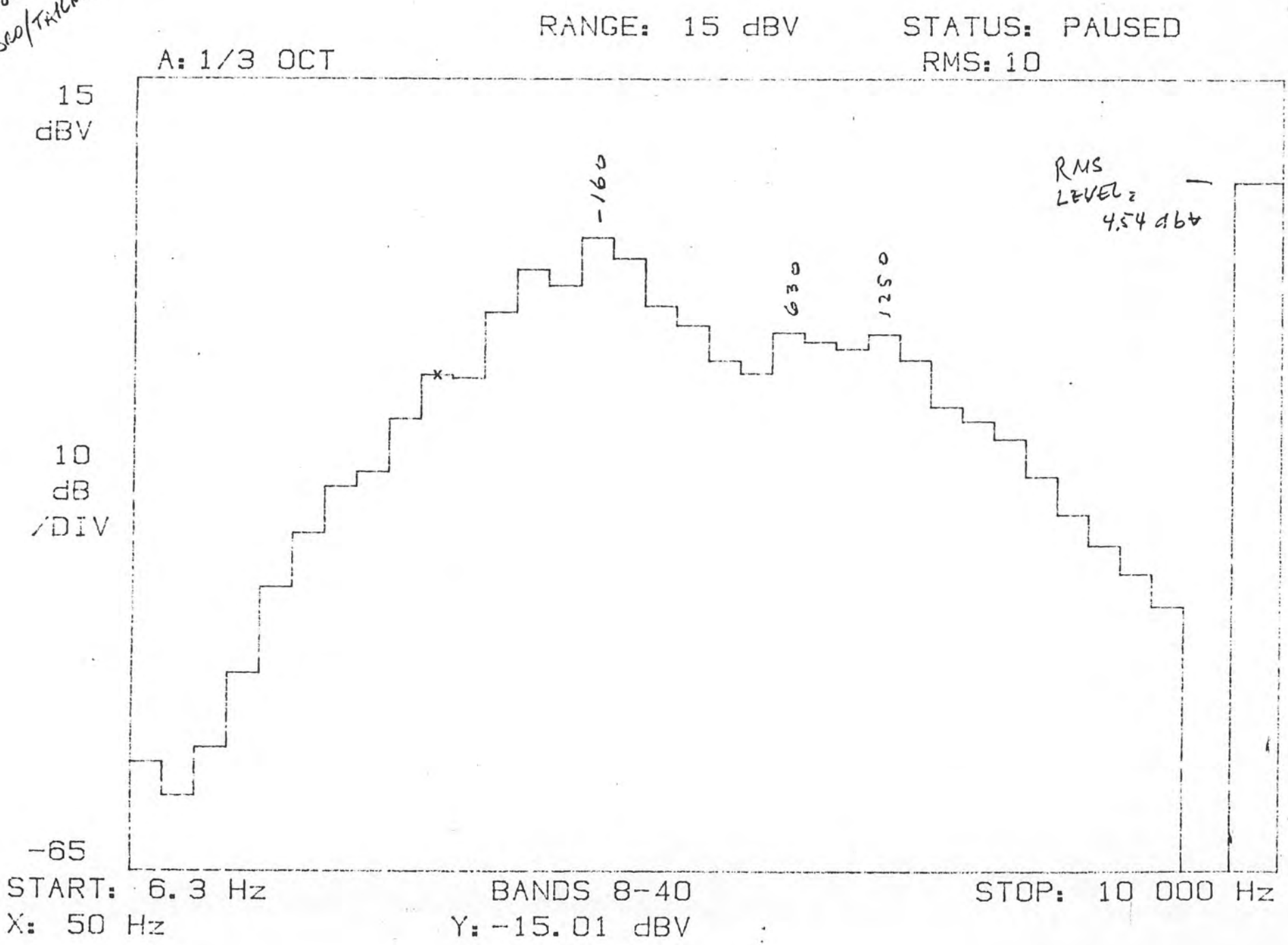
B: TIME (R)



START: 0 Sec STOP: 1 Sec

X: 388 Hz Y: -26.31 dBV

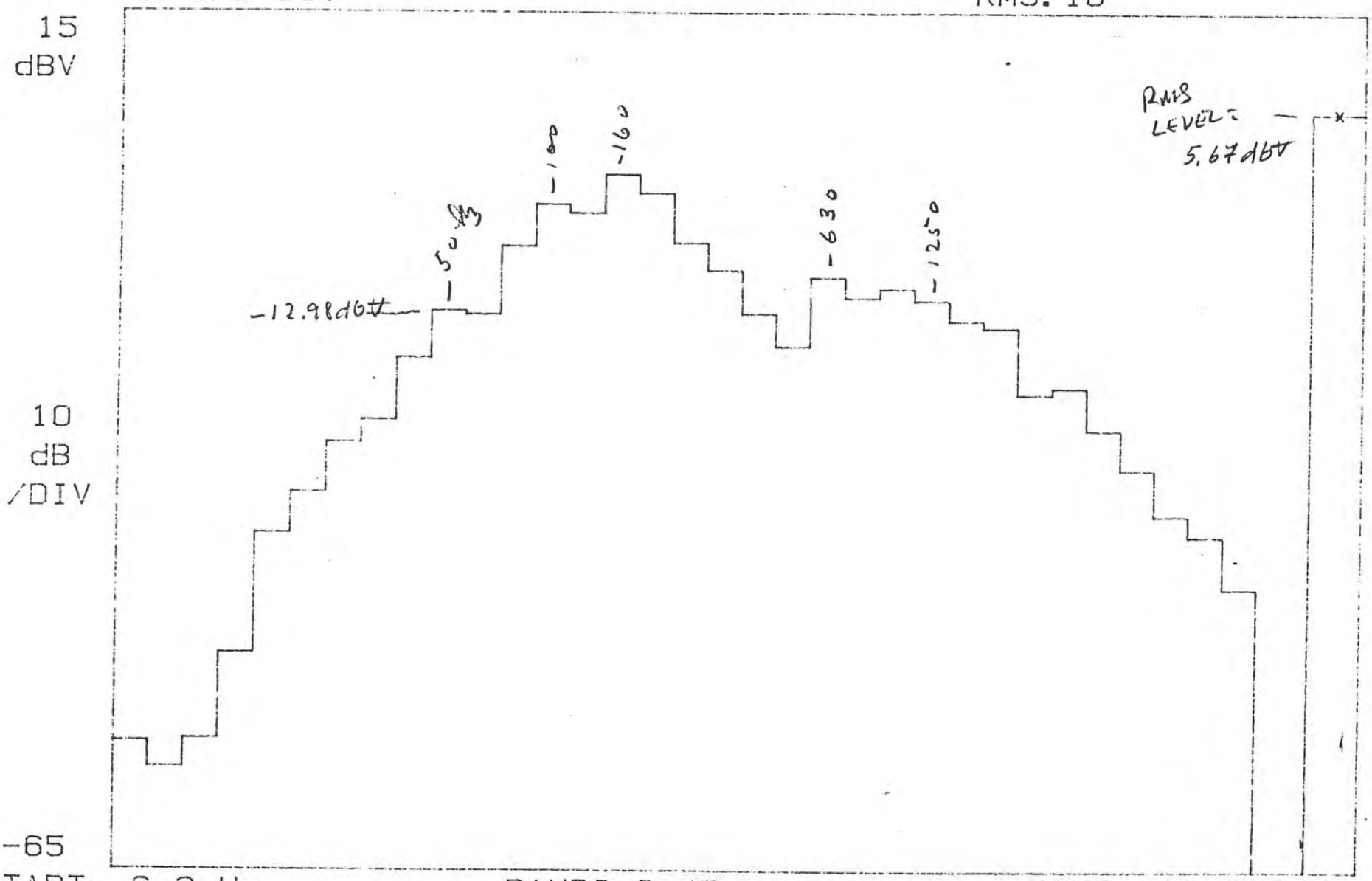
#1
30MW #1
85B3
#2 DOWN
10(HYDRO/TRACKER #1



#1
#1-30mW
8588 E
#2 DOWN
ID/HIDDEN/TAILRACE #1

RANGE: 15 dBV STATUS: PAUSED

A: 1/3 OCT RMS: 10



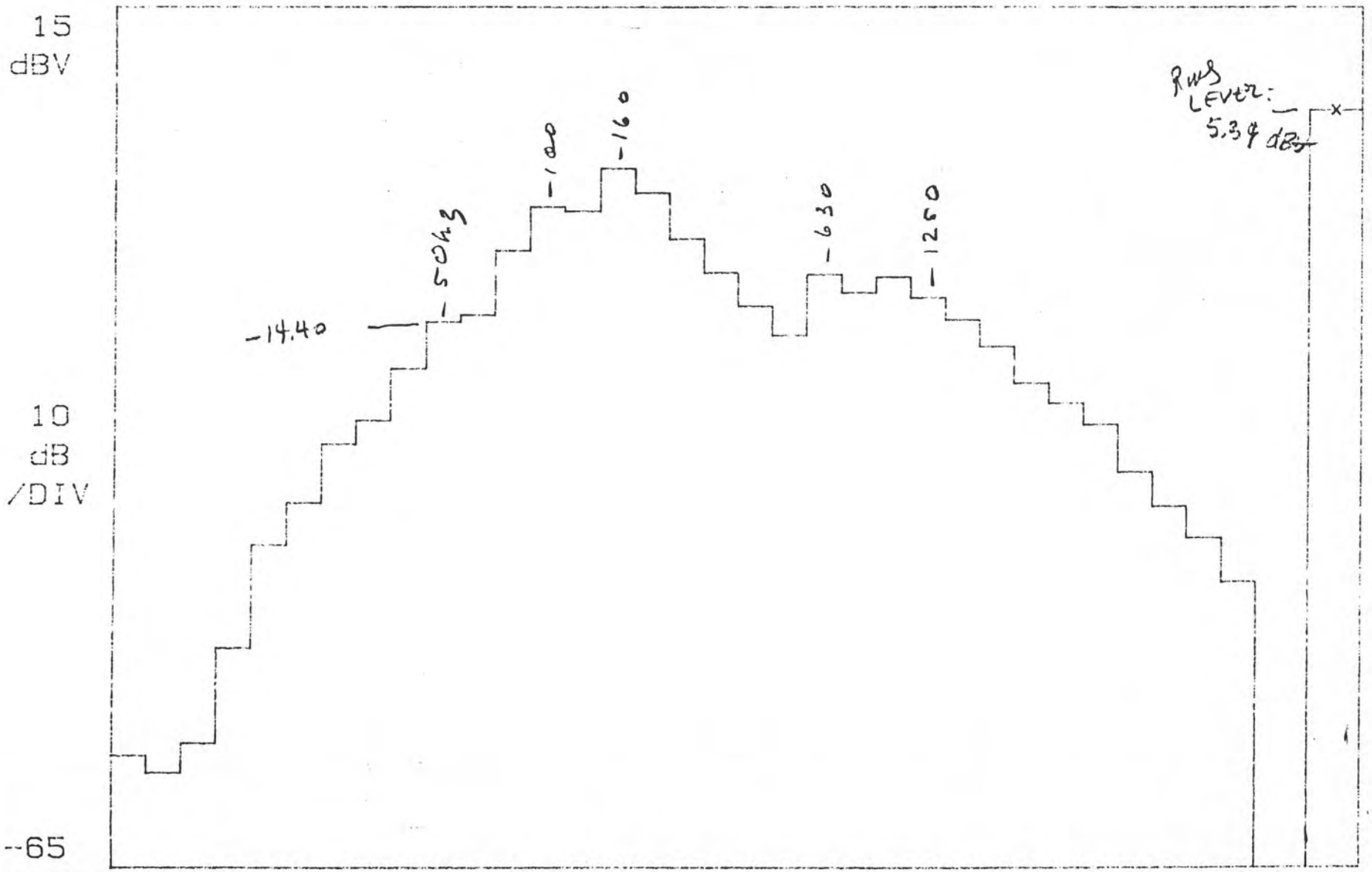
START: 6.3 Hz BANDS 8-40 STOP: 10 000 Hz

X: RMS LEVEL Y: 5.67 dBV

#1
30MW → #1
85% F
#2 DOWN
IO/AMDW/TACPACK #1

RANGE: 15 dBV STATUS: PAUSED

A: 1/3 OCT RMS: 10



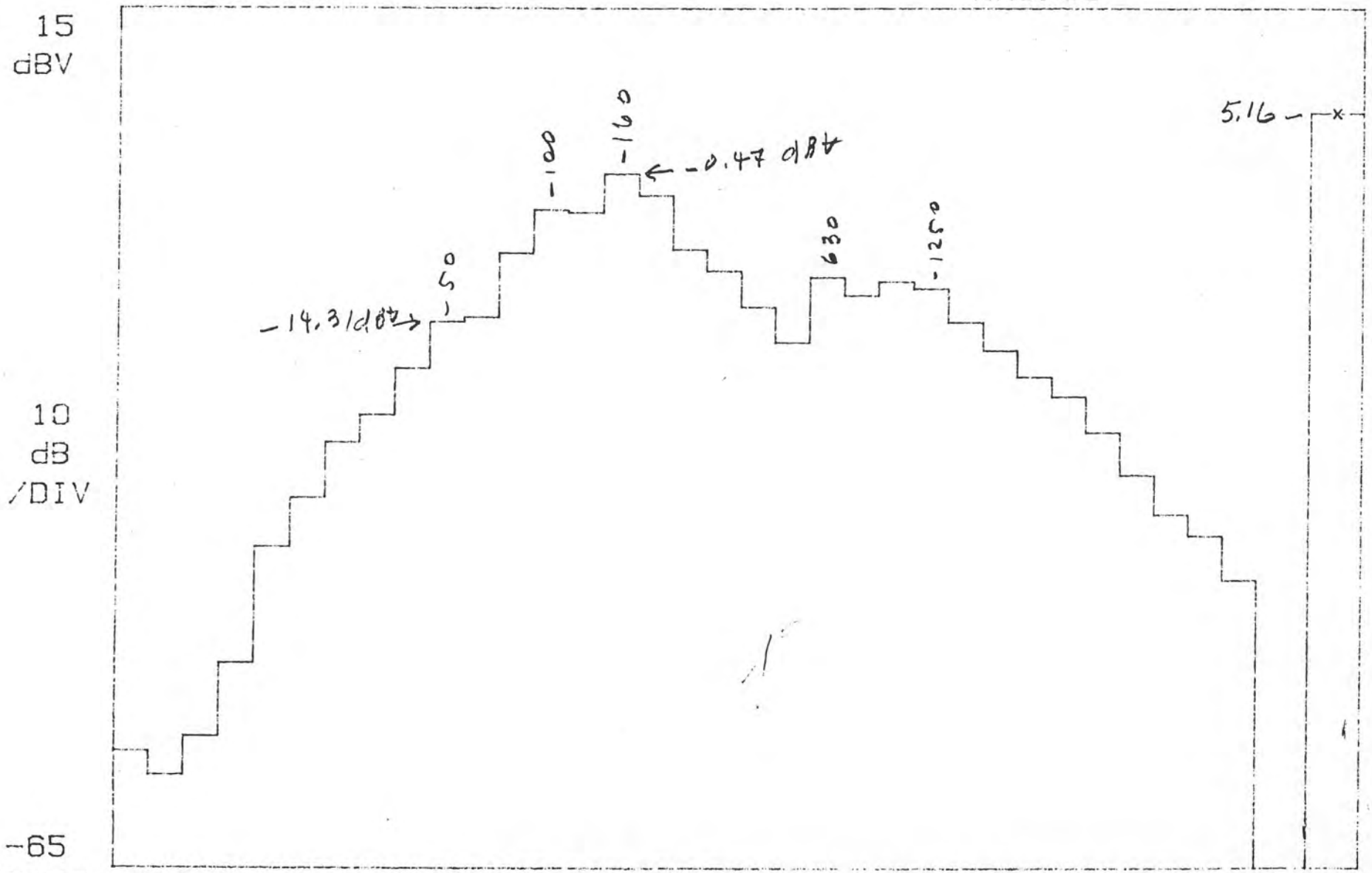
START: 6.3 Hz BANDS 8-40 STOP: 10 000 Hz

X: RMS LEVEL Y: 5.34 dBV

#1
30MM #1
8586 G
#2 DOWN
P/HYDRO FAIRCRAFT #1

RANGE: 15 dBV STATUS: PAUSED

A: 1/3 OCT RMS: 50



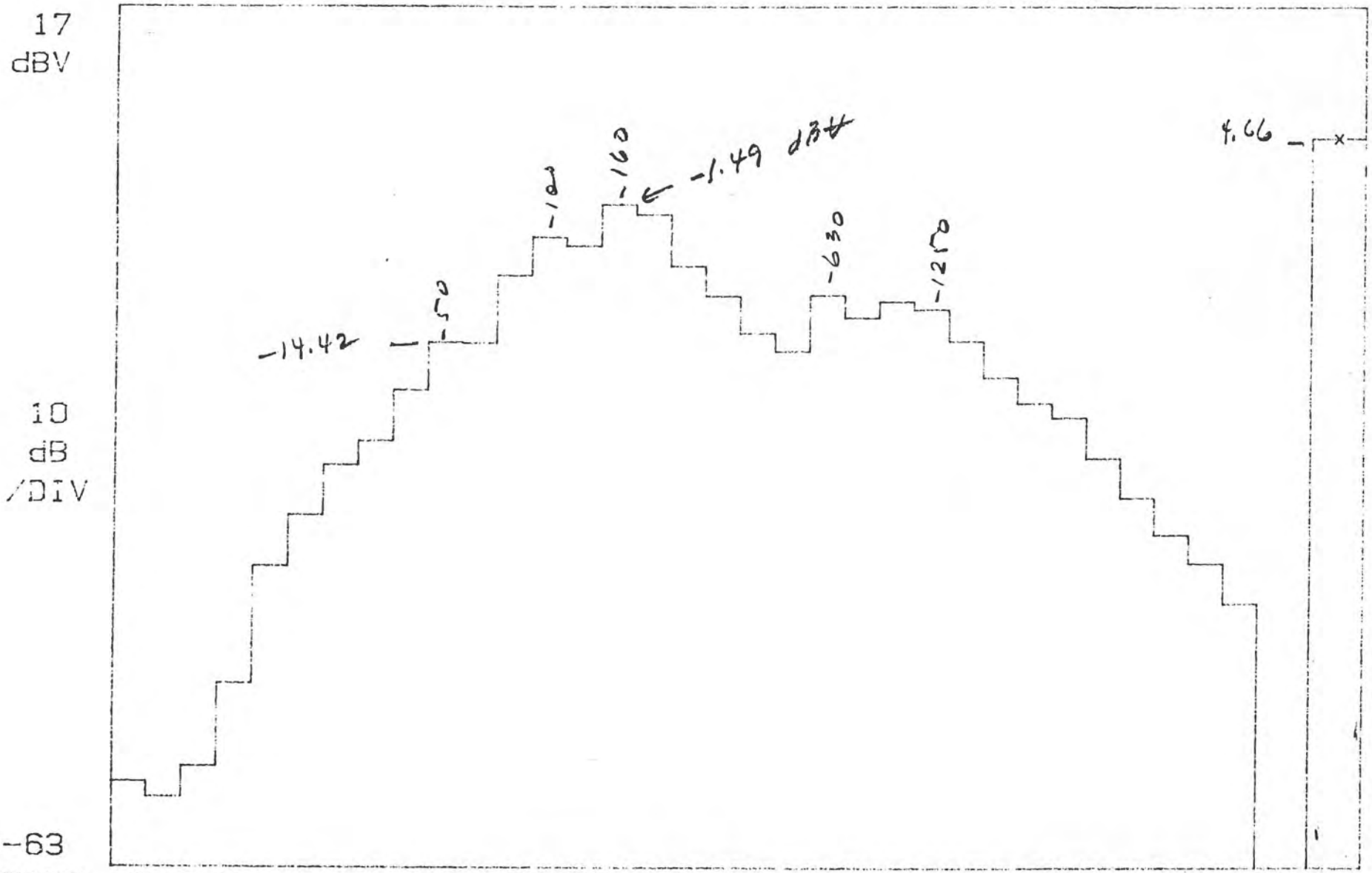
START: 6.3 Hz BANDS 8-40 STOP: 10 000 Hz

X: RMS LEVEL Y: 5.16 dBV

#1 BOWL → #1 SC86 H
#2 DOWN
10/4/1990 TAKE RACE #1

RANGE: 17 dBV STATUS: PAUSED

A: 1/3 OCT RMS: 50



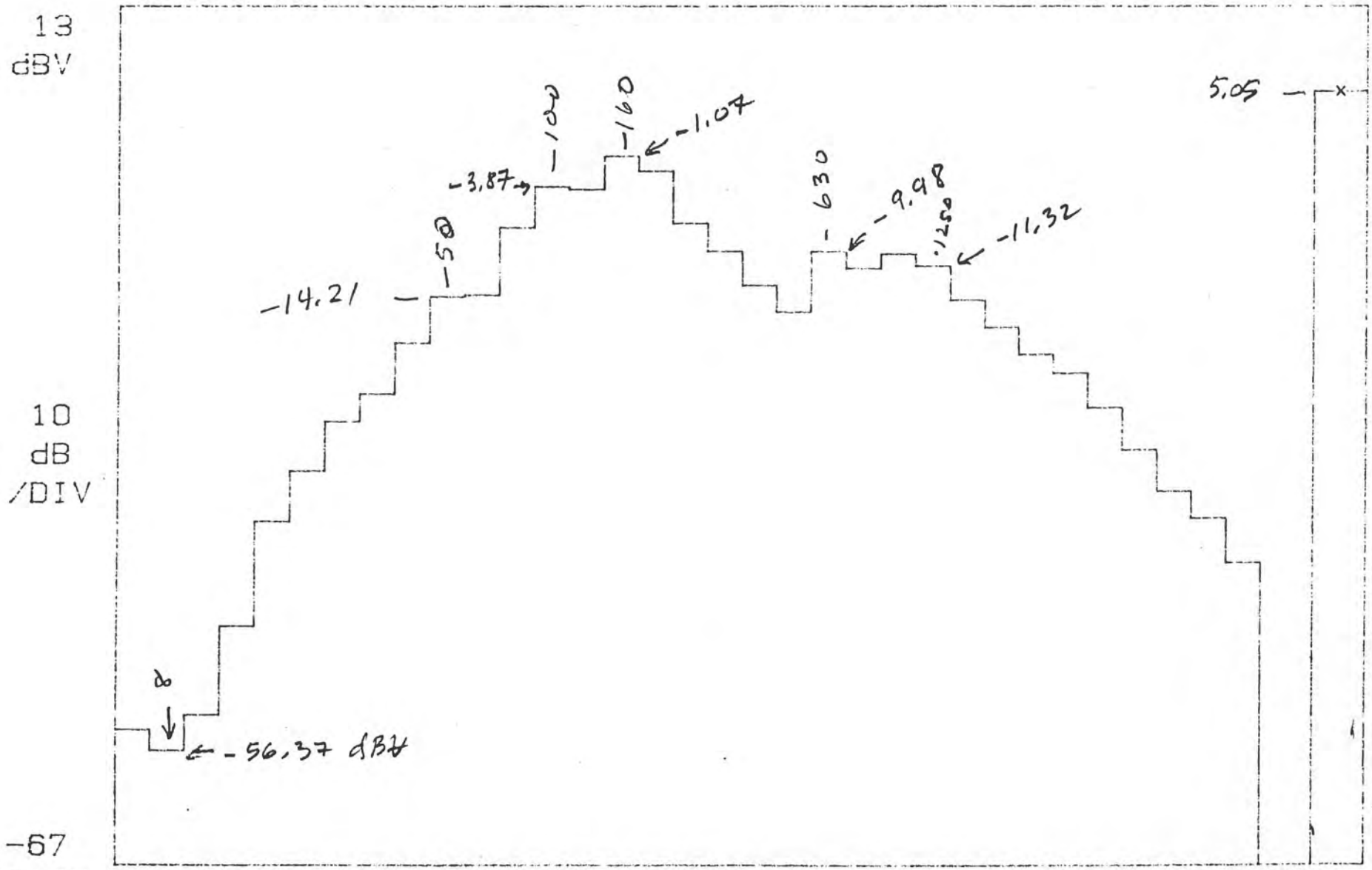
START: 6.3 Hz BANDS 8-40 STOP: 10 000 Hz

X: RMS LEVEL Y: 4.66 dBV

#1
30 Mar 85 #1
8586 I
#2 DOWN
#0/HYDRO/TAILRACE #1

RANGE: 15 dBV STATUS: PAUSED

A: 1/3 OCT RMS: 200 OVLD



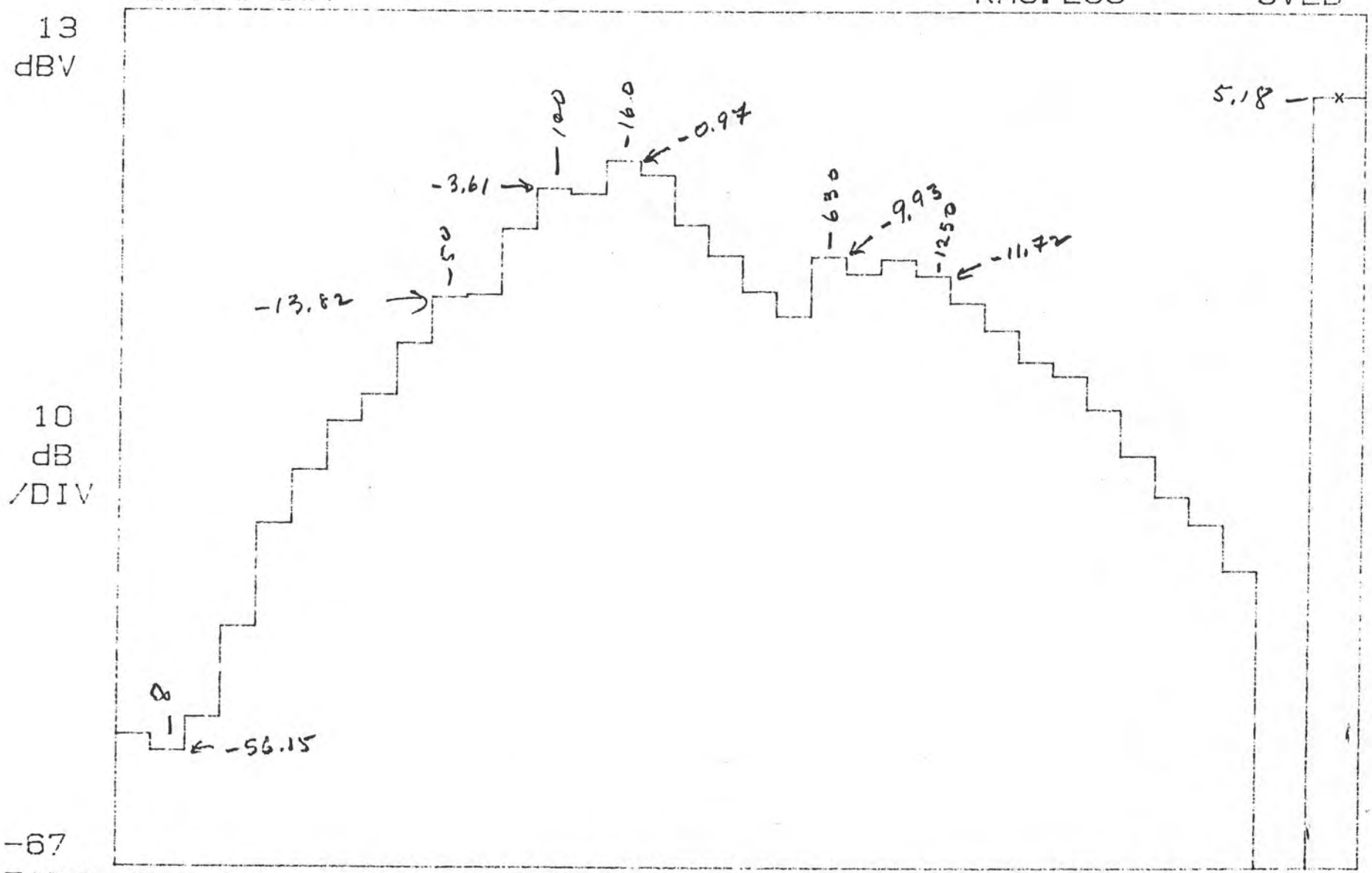
START: 6.3 Hz BANDS 8-40 STOP: 10 000 Hz

X: RMS LEVEL Y: 5.05 dBV

#1
30mm
8586 J
#2 DOWN
JD/HMD/FAILURE #1

RANGE: 13 dBV STATUS: PAUSED

A: 1/3 OCT RMS: 200 OVLD



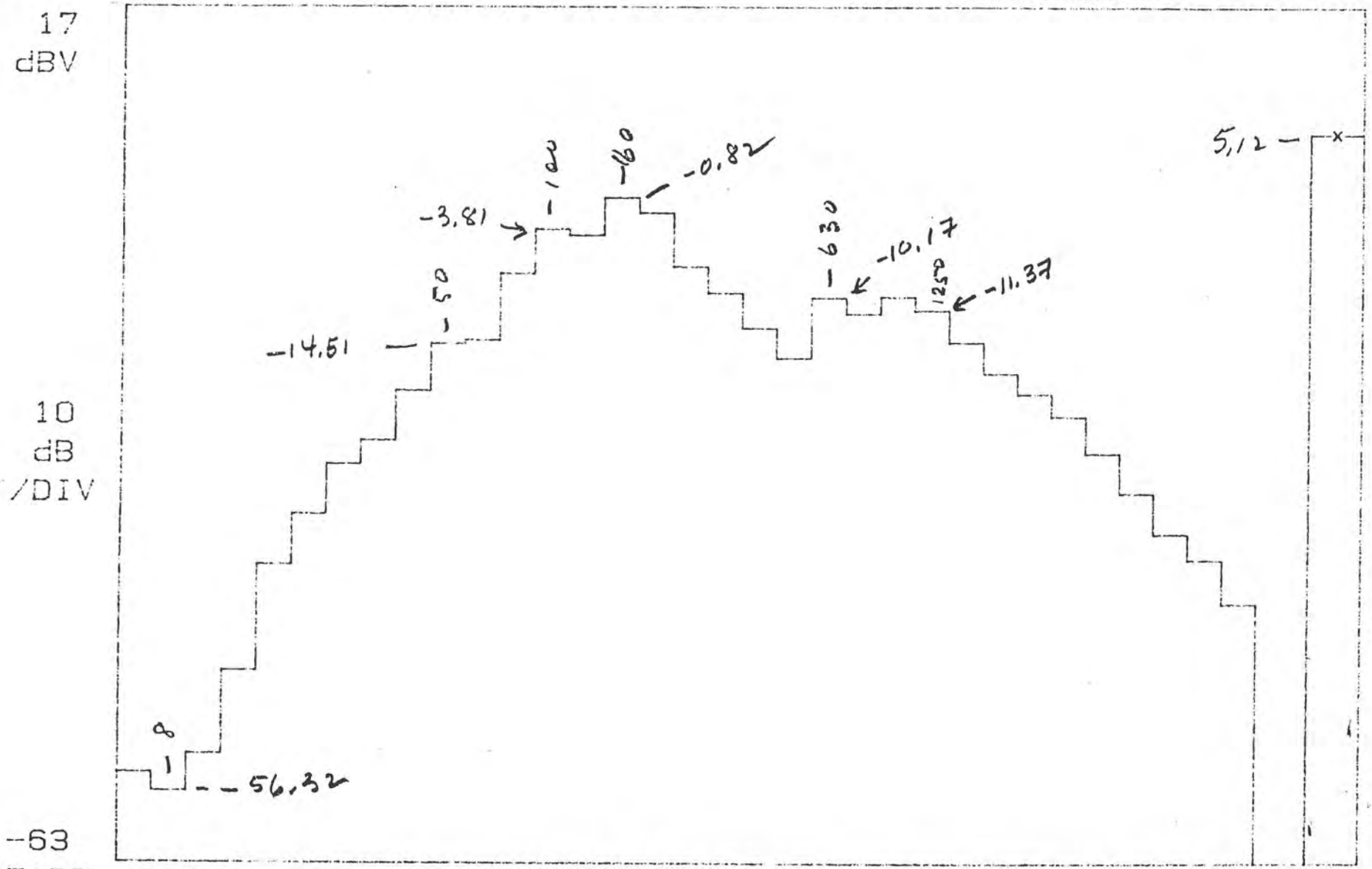
START: 6.3 Hz BANDS 8-40 STOP: 10 000 Hz

X: RMS LEVEL Y: 5.18 dBV

#1
BOMBS
858 K
#2 DOWN
IO/AMDRO/TAILPIPE #1
LIGHT RAIN

RANGE: 17 dBV
STATUS: PAUSED
RMS: 200

A: 1/3 OCT



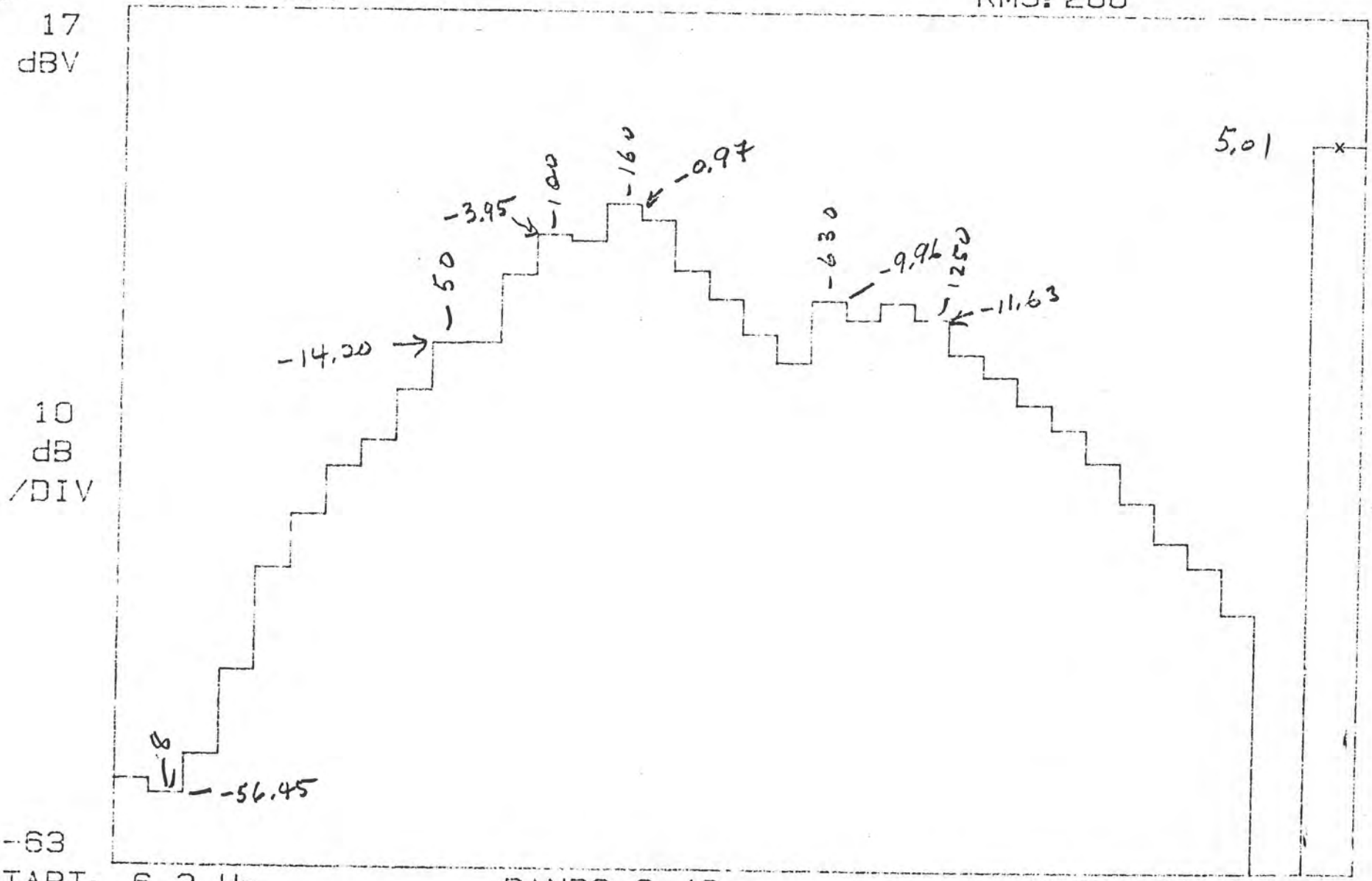
START: 6.3 Hz
BANDS 8-40
STOP: 10 000 Hz
X: RMS LEVEL
Y: 5.12 dBV

#1
30mm
85864
#2 Down
10/14DMD/TAICRALE #1 NO RAIN

RANGE: 17 dBV

STATUS: PAUSED
RMS: 200

A: 1/3 OCT



START: 6.3 Hz
X: RMS LEVEL

BANDS 8-40
Y: 5.01 dBV

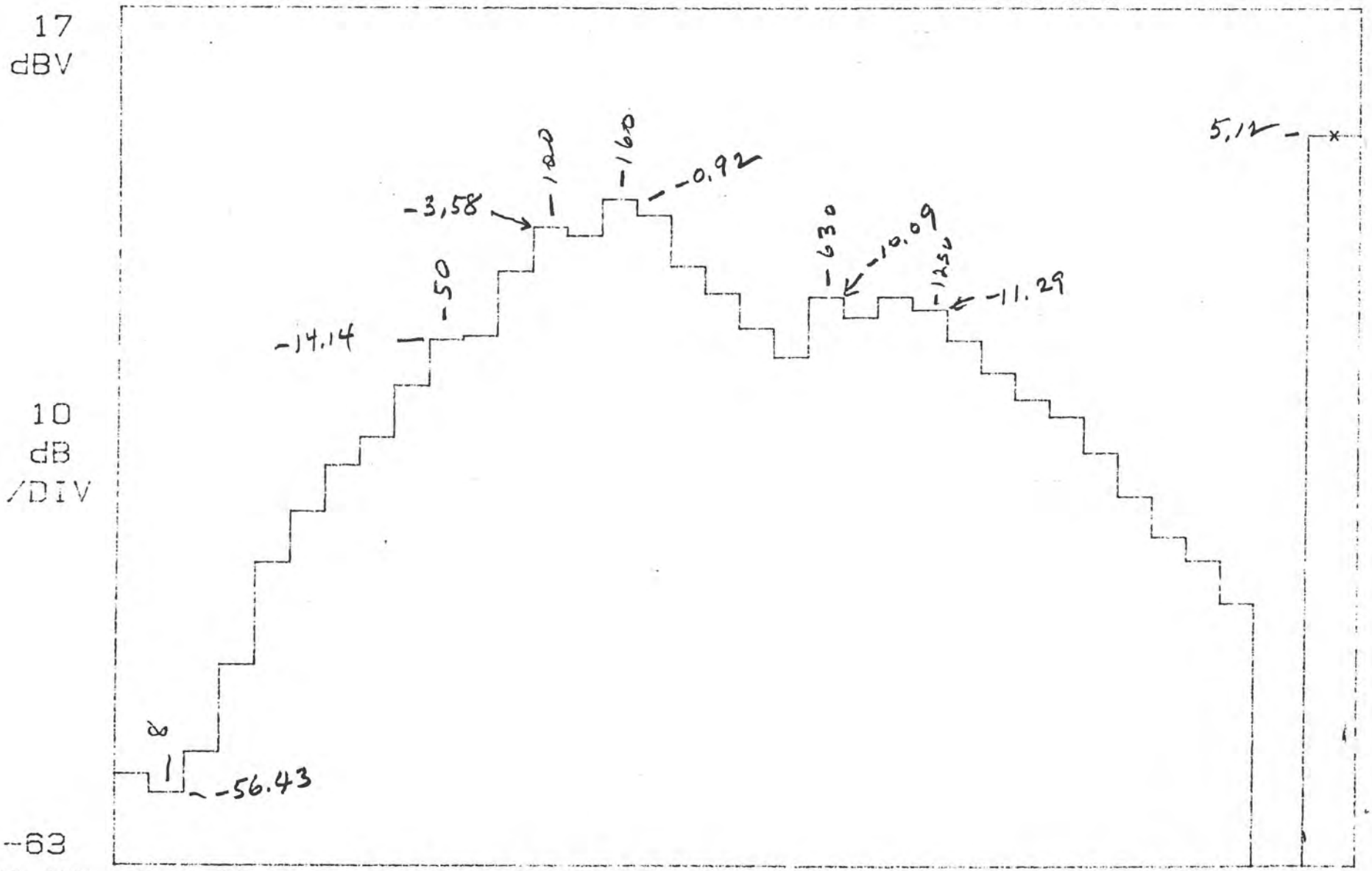
STOP: 10 000 Hz

#1
30mm
8586M
#2 DOWN
IO/#1(D)/TAILRACE #1

NO RAIN

RANGE: 17 dBV STATUS: PAUSED

A: 1/3 OCT RMS: 200



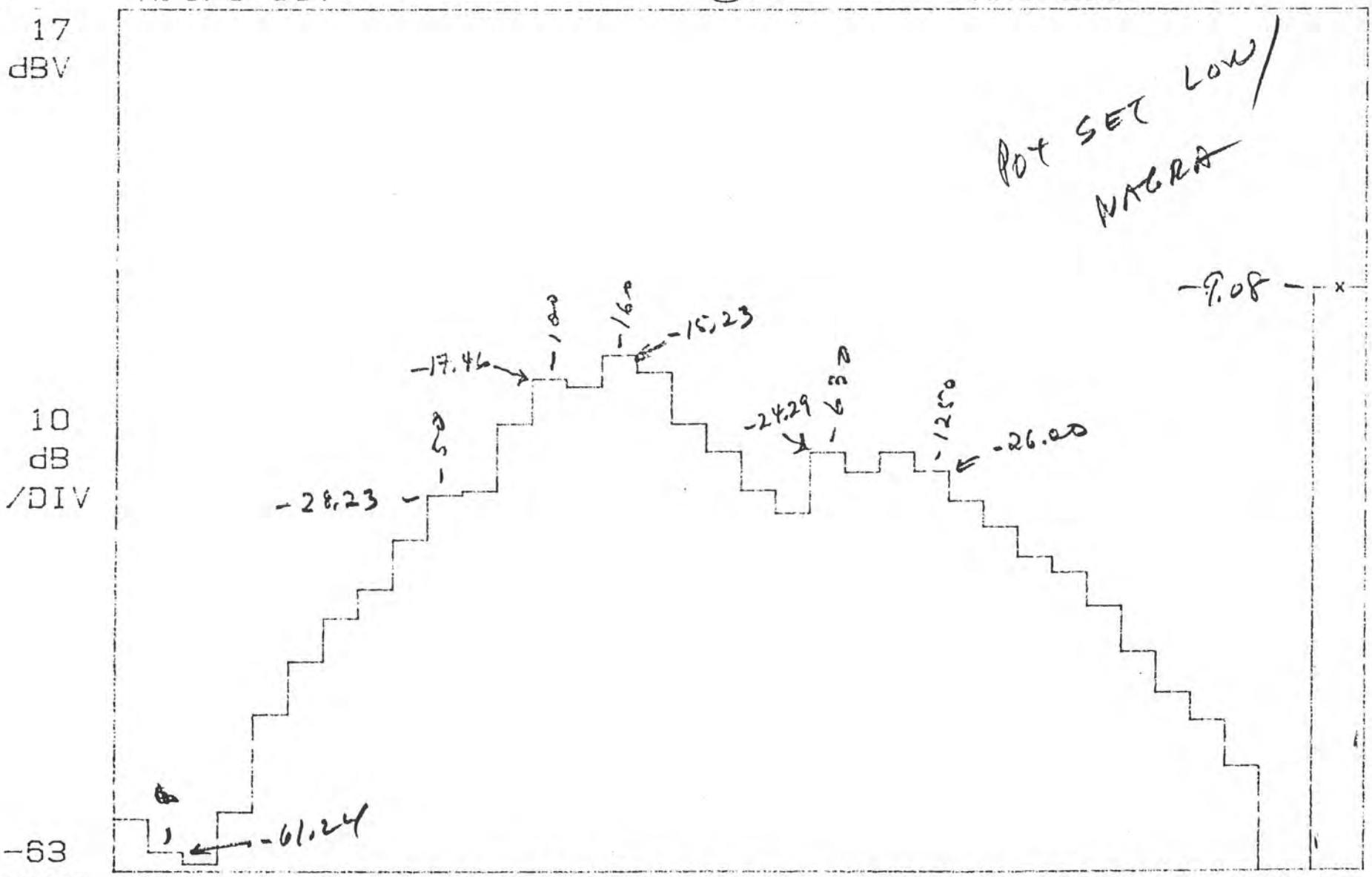
START: 6.3 Hz BANDS 8-40 STOP: 10 000 Hz

X: RMS LEVEL Y: 5.12 dBV

1
30MW
8586 N
Hz Down
10/HPBW/TAIL RAIL #1

RANGE: 17 dBV STATUS: PAUSED

A: 1/3 OCT RMS: 200



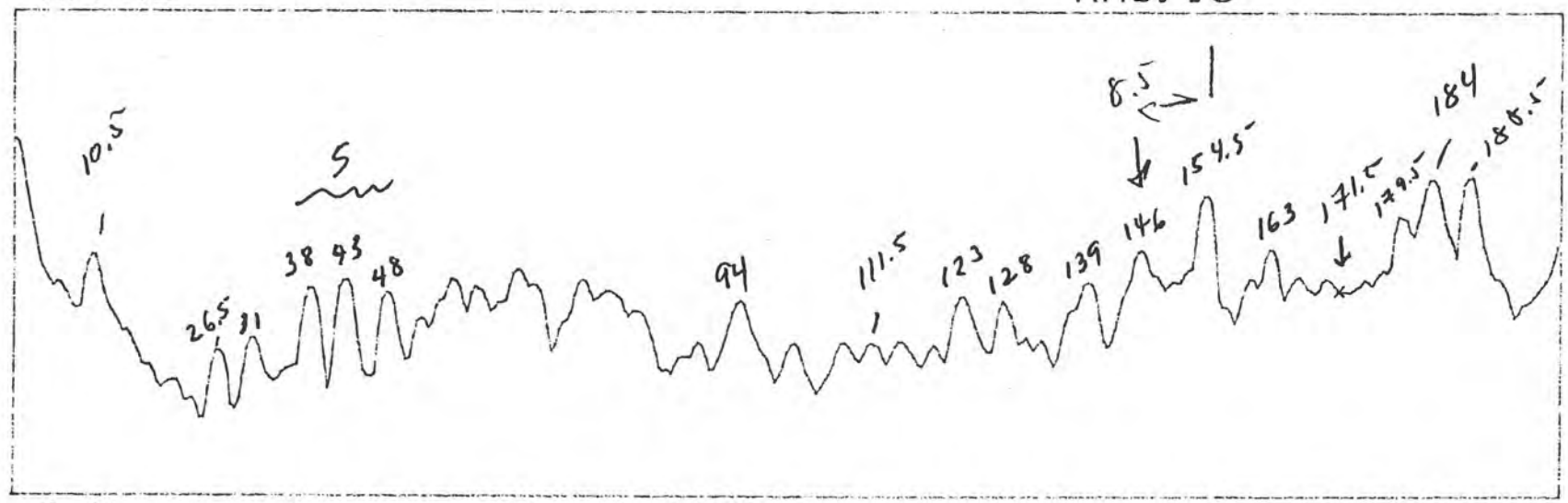
START: 6.3 Hz BANDS 8-40 STOP: 10 000 Hz

X: RMS LEVEL Y: -9.08 dBV

#1
81486A
32 MW
#2 DOWN
B&K MIC - D.T. #1

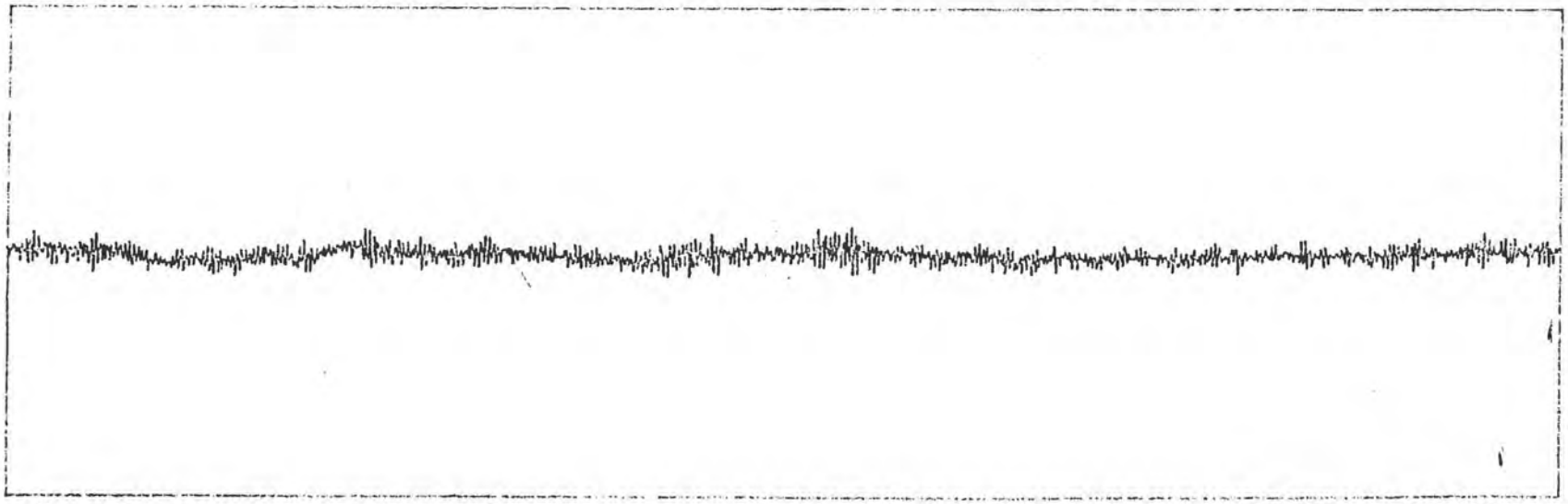
RANGE: 9 dBV STATUS: PAUSED

A: MAG RMS: 10



START: 0 Hz BW: 1.9097 Hz STOP: 200 Hz

B: TIME (R)



START: 0 Sec STOP: 2 Sec

X: 171.5 Hz Y: -37.06 dBV

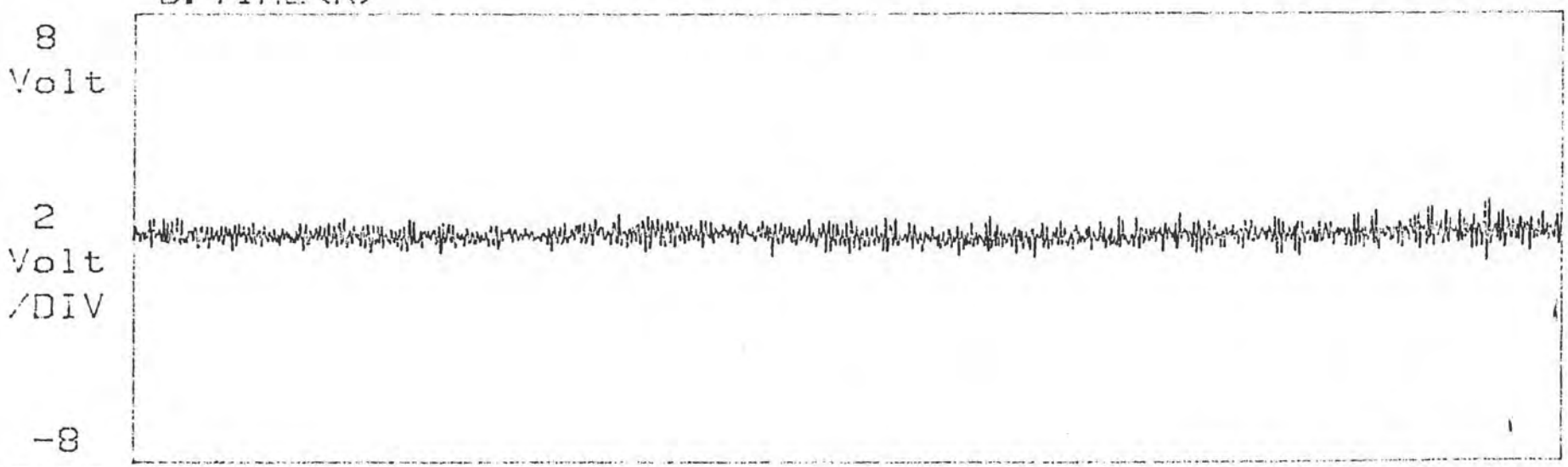
#1
81486B
32 mm
#2 Down
B&K MIC/D.T./#1

RANGE: 9 dBV STATUS: PAUSED

A: MAG RMS: 10

START: 0 Hz BW: 2.3871 Hz STOP: 250 Hz

B: TIME (R)



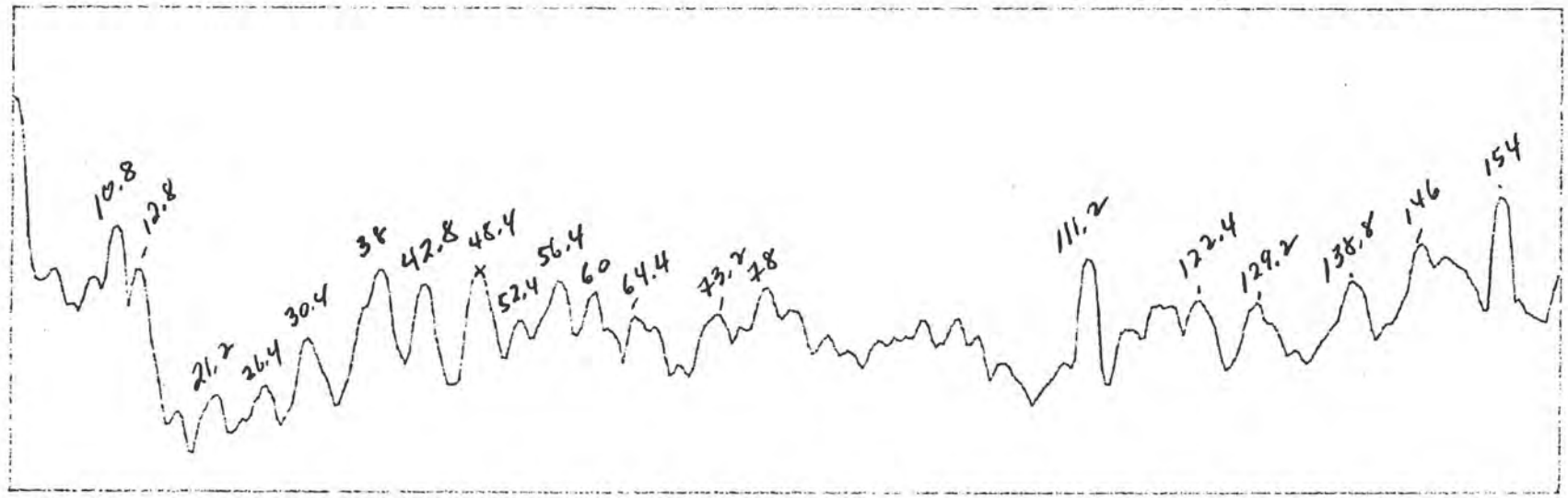
START: 0 Sec STOP: 1.6 Sec

X: 48.125 Hz Y: -34.22 dBV

#1
81486 C
32 mm
#2 Down
B&K MIC/DT #1

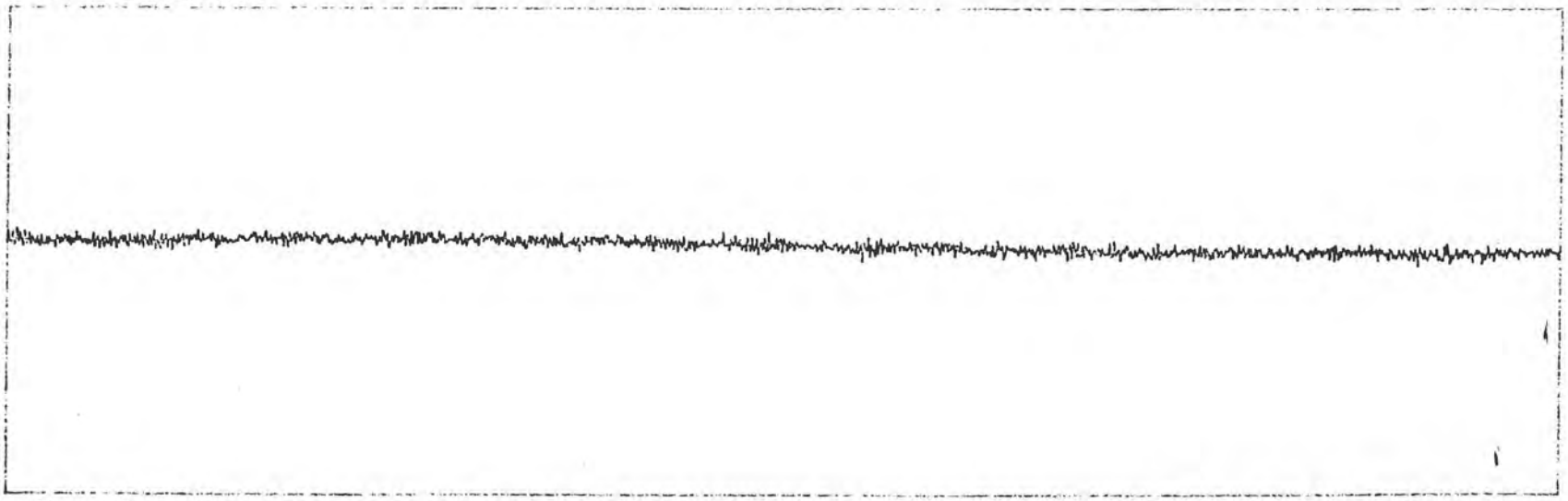
RANGE: 9 dBV STATUS: PAUSED

A: MAG RMS: 10



START: 0 Hz BW: 1.5278 Hz STOP: 160 Hz

B: TIME (R)



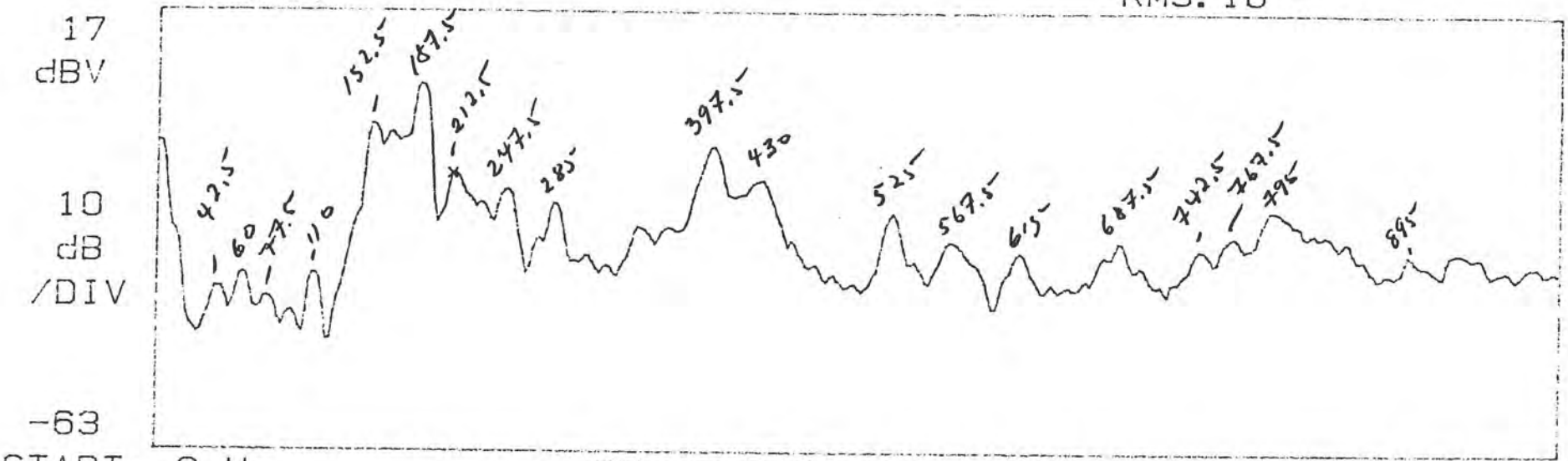
START: 0 Sec STOP: 2.5 Sec

X: 48.4 Hz Y: -34.49 dBV

#1
8148D
32 MW
#2 Down
85K MIC / DT #1

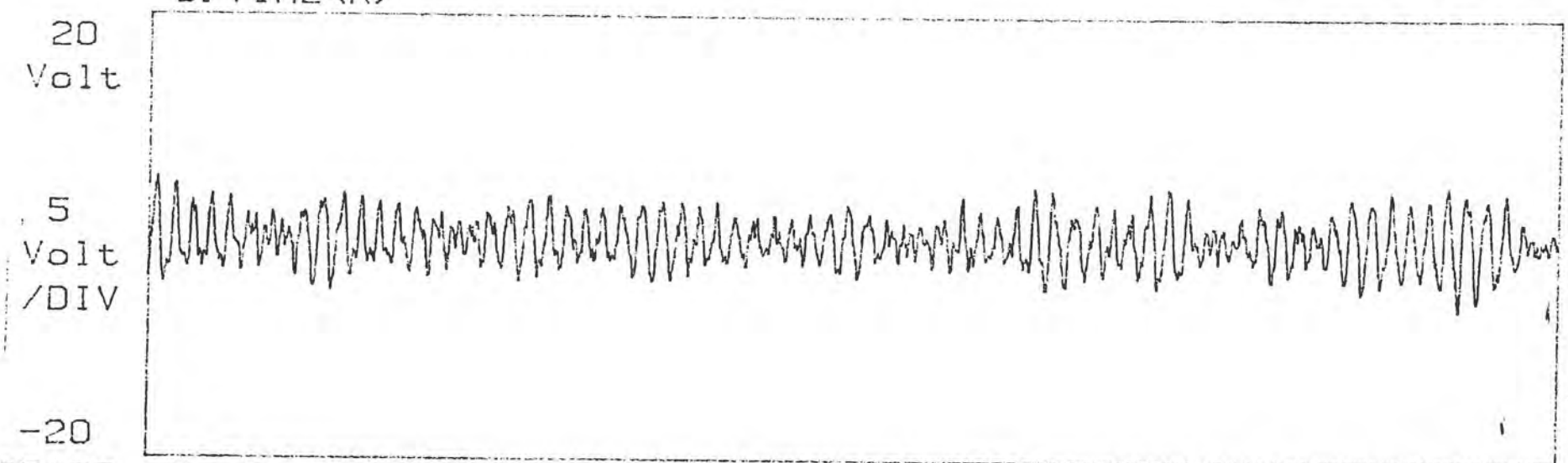
RANGE: 17 dBV STATUS: PAUSED

A: MAG RMS: 10



START: 0 Hz BW: 9.5485 Hz STOP: 1 000 Hz

B: TIME (R)



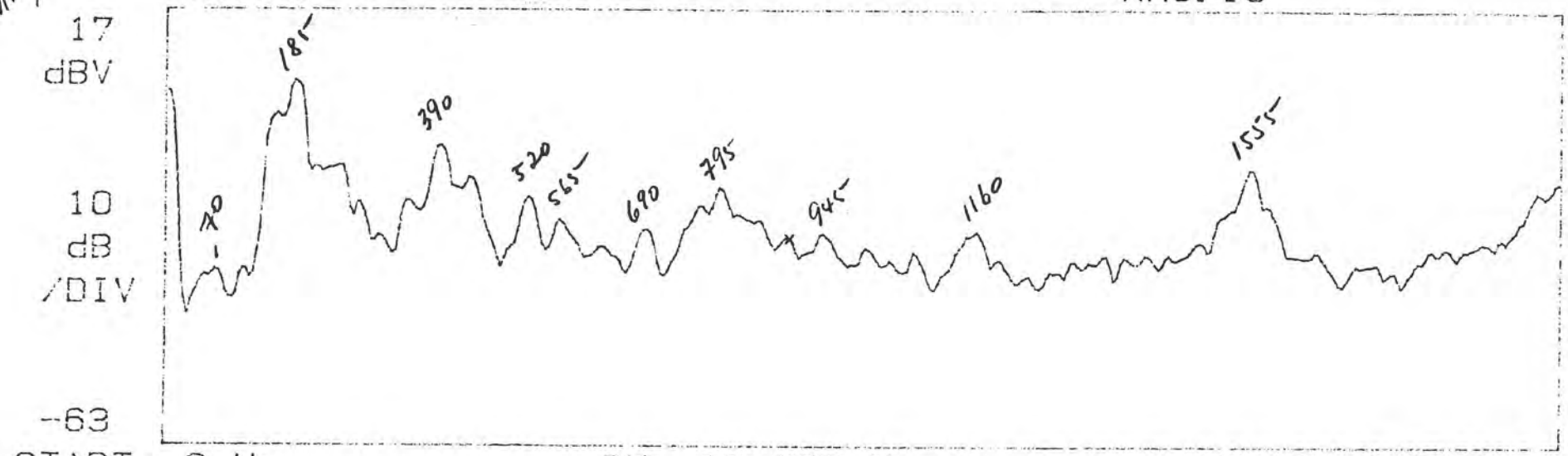
START: 0 Sec STOP: 400 mSec

X: 210 Hz Y: -12.70 dBV

#1
8148 E
32 mW
#2 Power
B&K MIC/DT #1

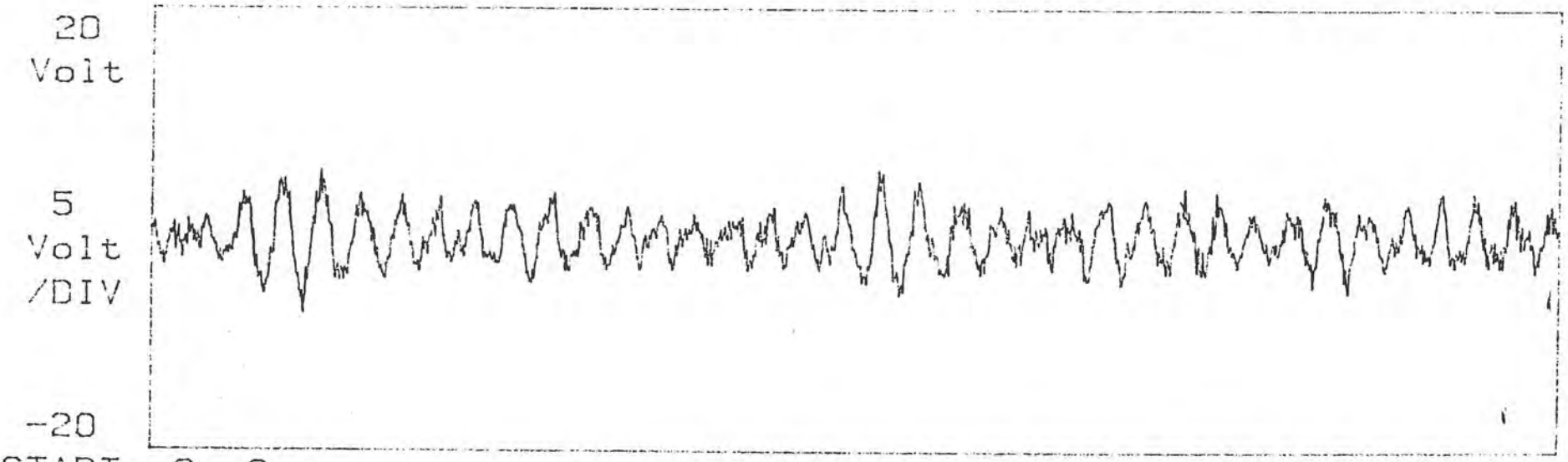
RANGE: 17 dBV STATUS: PAUSED
RMS: 10

A: MAG



START: 0 Hz BW: 19.097 Hz STOP: 2 000 Hz

B: TIME (R)



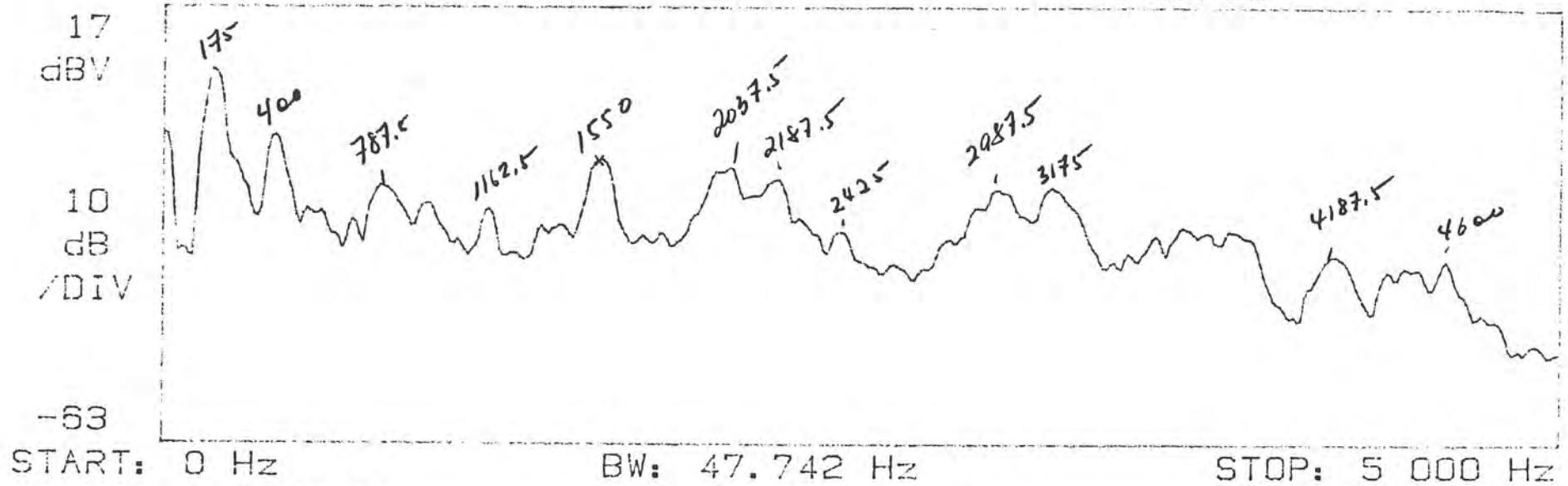
START: 0 Sec STOP: 200 mSec

X: 895 Hz Y: -24.89 dBV

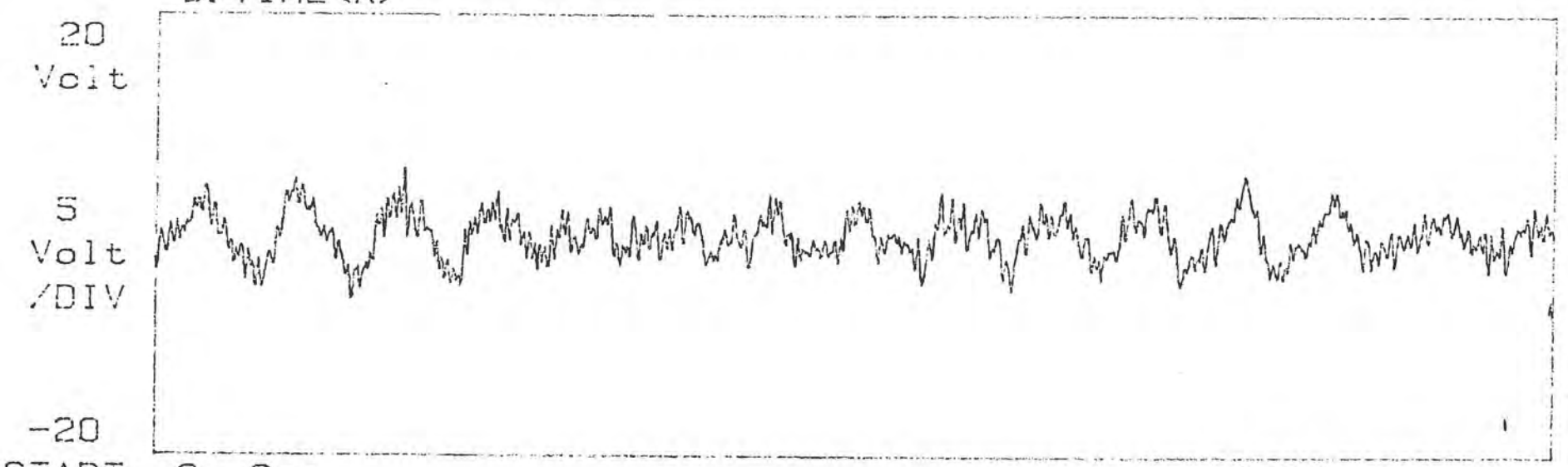
#1
814856 F
32 mm
#2 POWD
BS KNIK / DT #1

RANGE: 17 dBV STATUS: PAUSED

A: MAG RMS: 10



B: TIME (R)

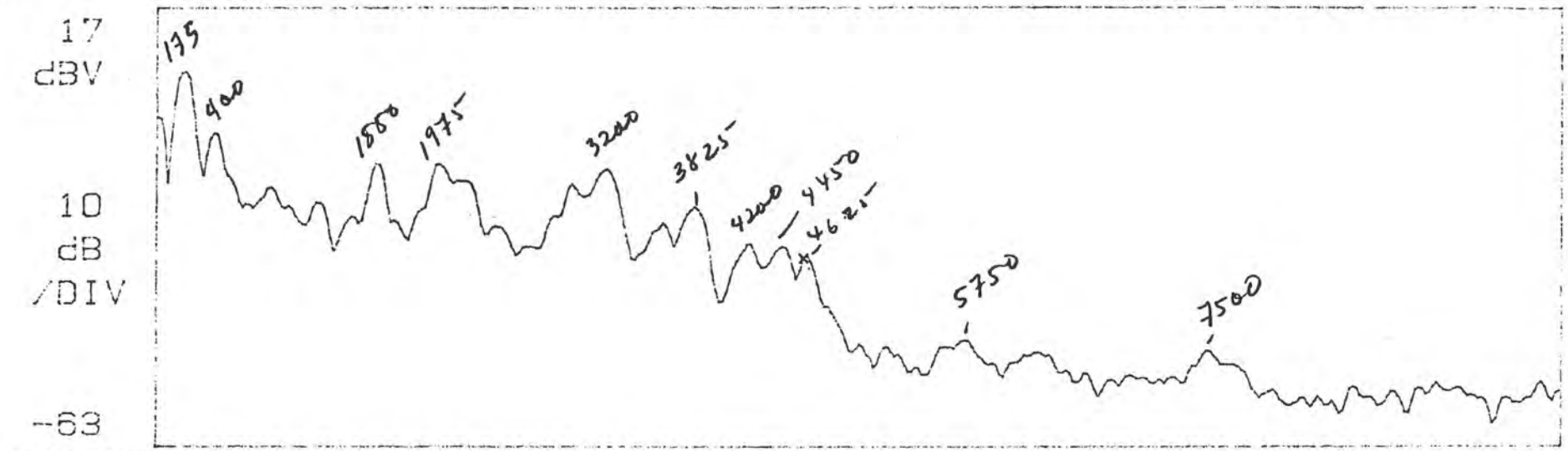


X: 1550 Hz Y: -11.18 dBV

#1
81486 G
3rd mw
#2 pow
B&K MIC/DT #1)

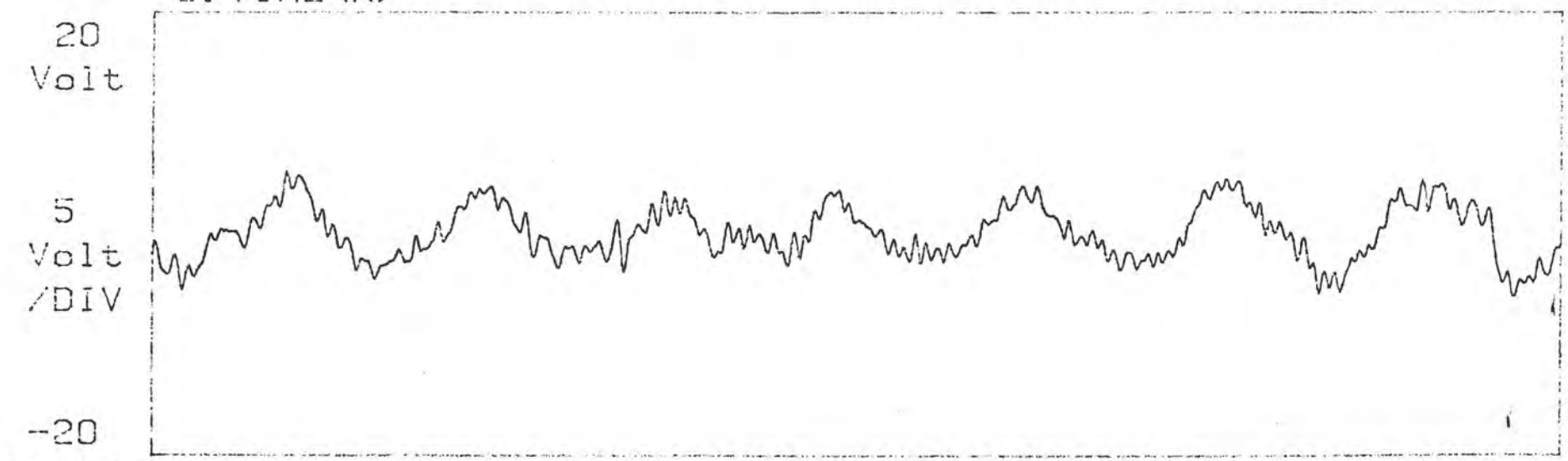
RANGE: 17 dBV STATUS: PAUSED

A: MAG RMS: 10



START: 0 Hz BW: 95.485 Hz STOP: 10 000 Hz

B: TIME (R)

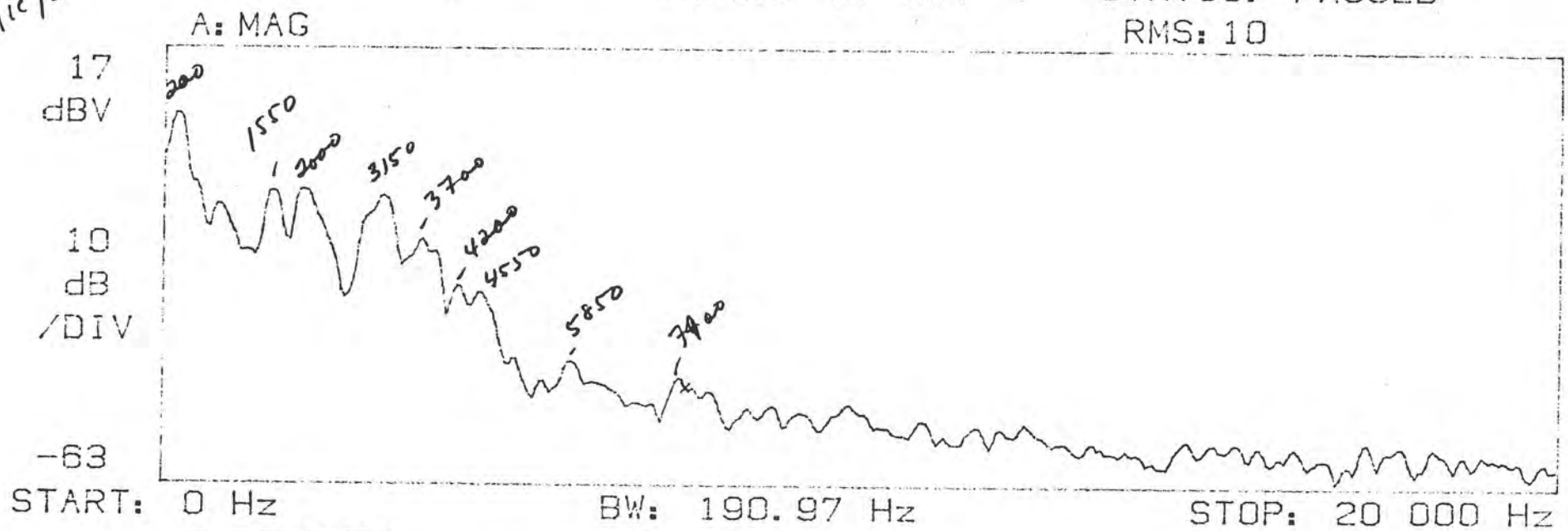


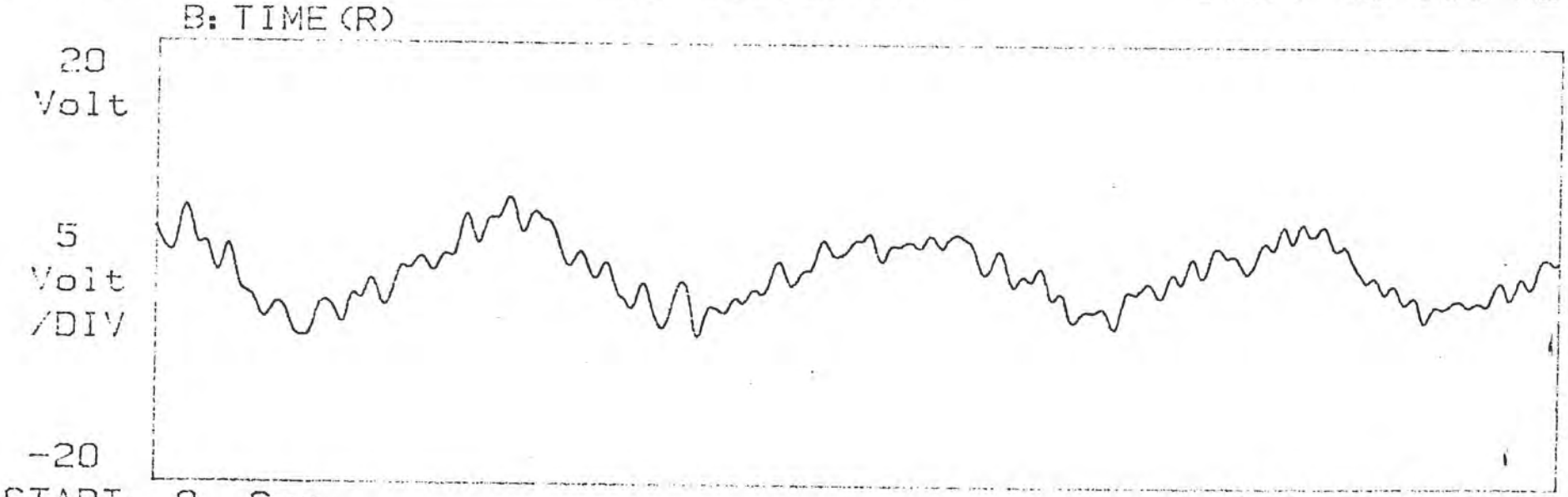
START: 0 Sec STOP: 40 mSec

X: 4600 Hz Y: -28.68 dBV

#1
8148B H
32 mm
#2 Down
B&K Mic/DT #1

RANGE: 17 dBV STATUS: PAUSED
RMS: 10





X: 7500 Hz Y: -45.16 dBV

#1
814&4 I
32 MW
#2 DOWN
COLUMBIA ACC/DT #1)

RANGE: 21 dBV STATUS: PAUSED

A: MAG RMS: 10

21 dBV

10 dB /DIV

-59

8.5 111.5 154.5 163 171.5 180 188.5

SIDEBANDS ON 171.5

START: 0 Hz BW: 1.9097 Hz STOP: 200 Hz

B: TIME (R)

20 Volt

5 Volt /DIV

-20

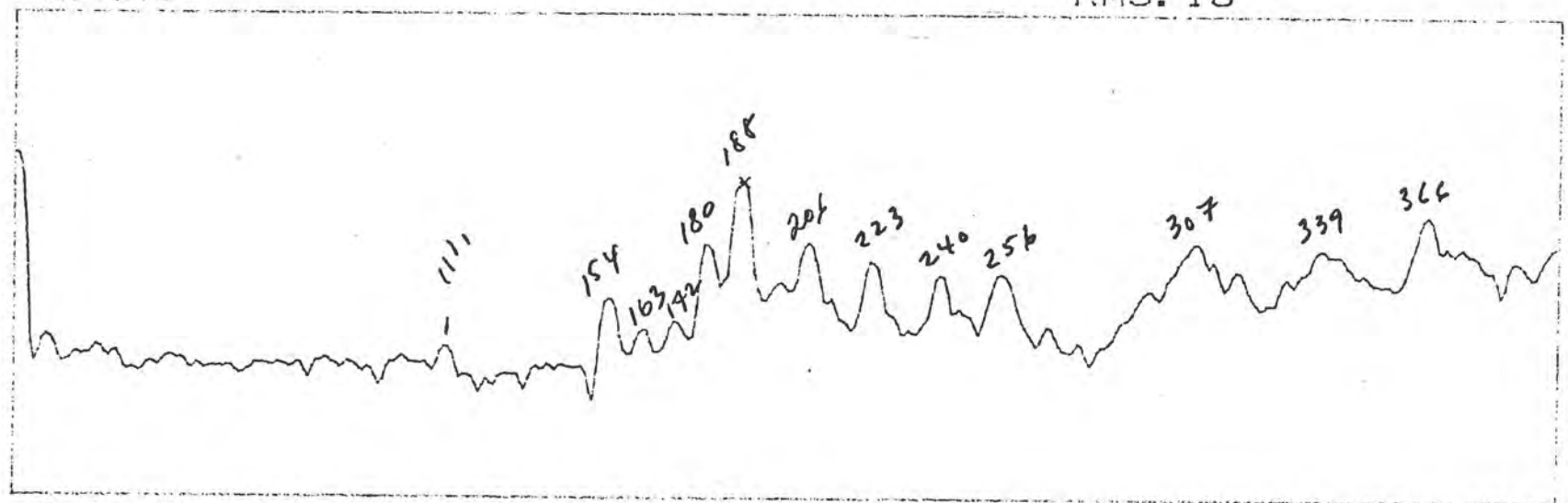
START: 0 Sec STOP: 2 Sec

X: 8.5 Hz Y: -34.22 dBV

#1
814 J
32 mm
1/2 Down
COLUMBIA ACC | PT #1

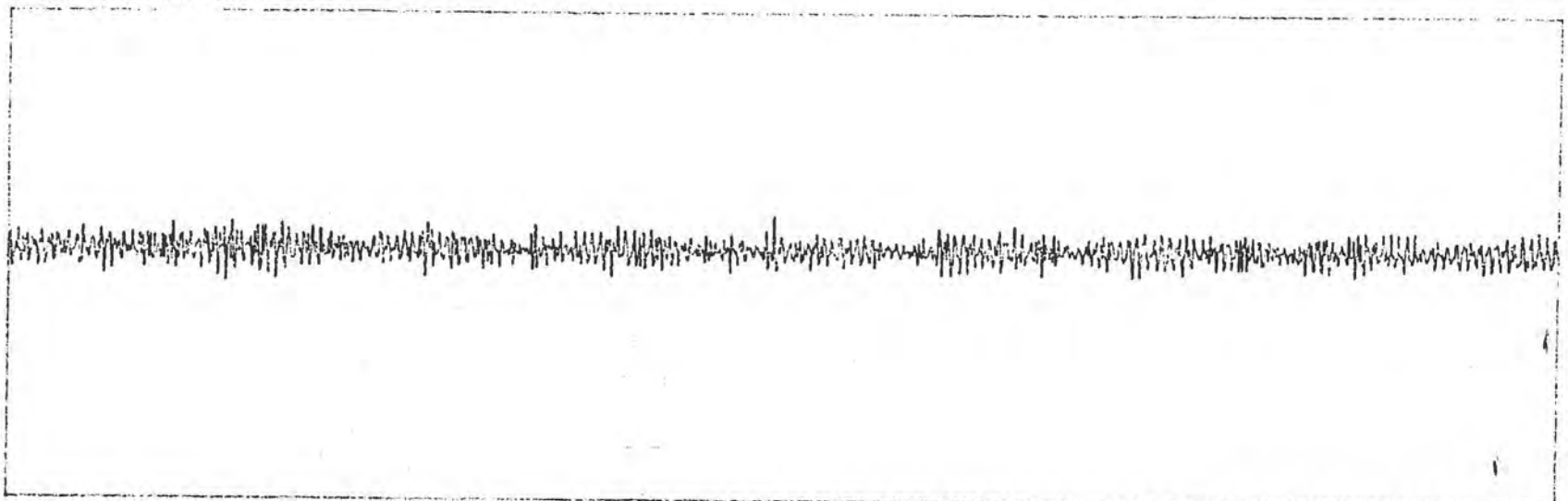
RANGE: 21 dBV STATUS: PAUSED
RMS: 10

A: MAG



START: 0 Hz BW: 3.8194 Hz STOP: 400 Hz

B: TIME (R)



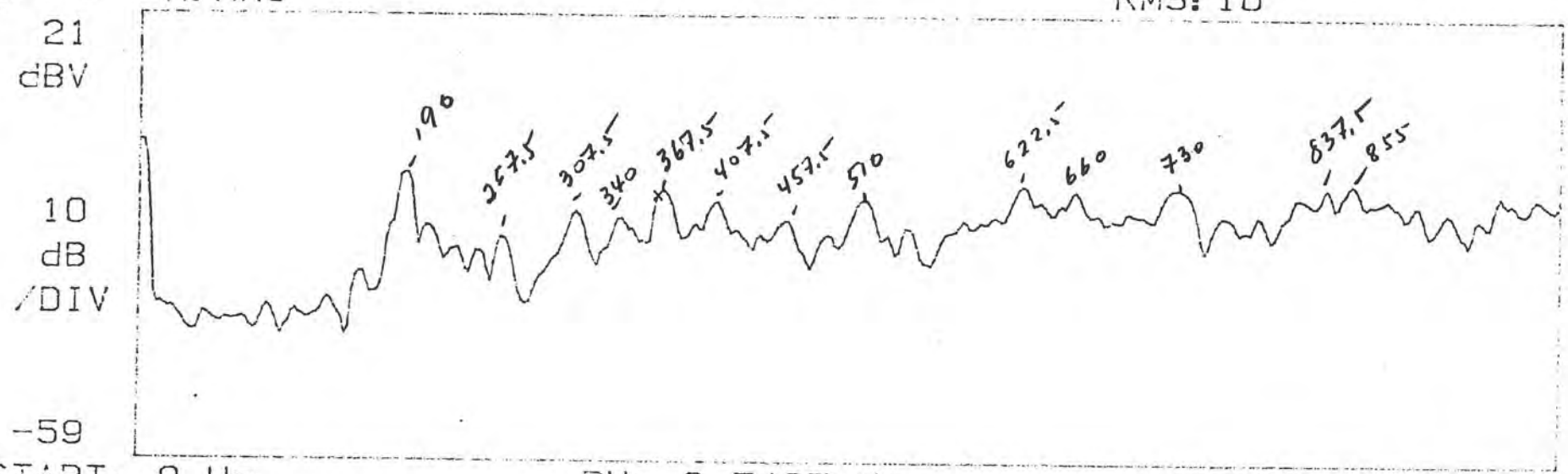
START: 0 Sec STOP: 1 Sec

X: 189 Hz Y: -6.73 dBV

#1
814876K
32 mm
#2 Down
COLUMBIA ACC/DT #1

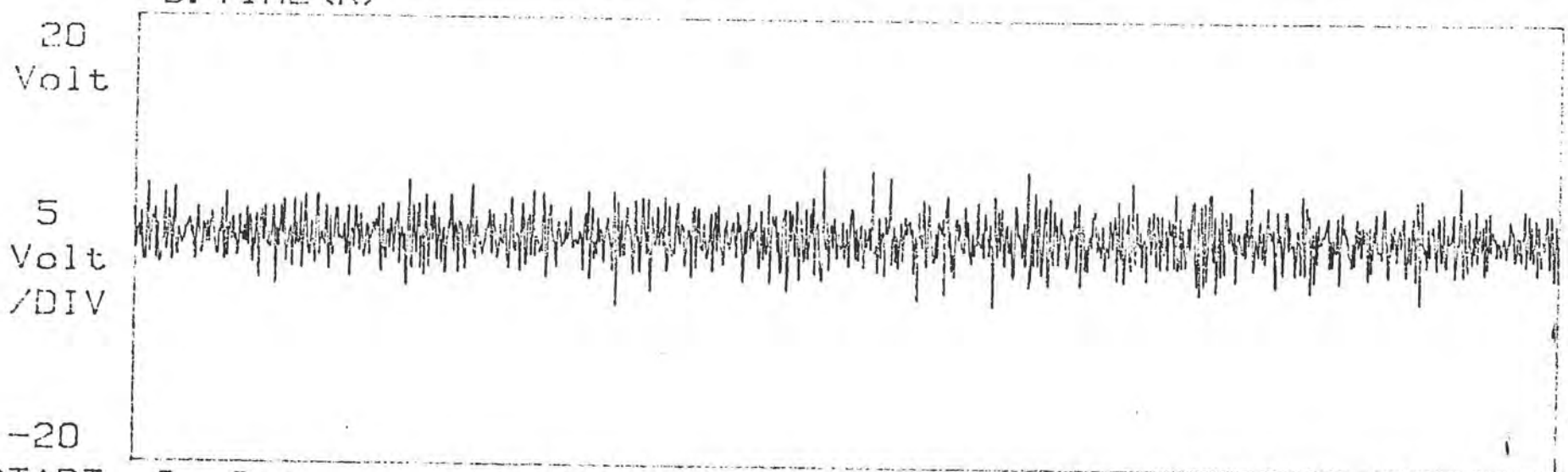
RANGE: 21 dBV STATUS: PAUSED
RMS: 10

A: MAG



START: 0 Hz BW: 9.5485 Hz STOP: 1 000 Hz

B: TIME (R)



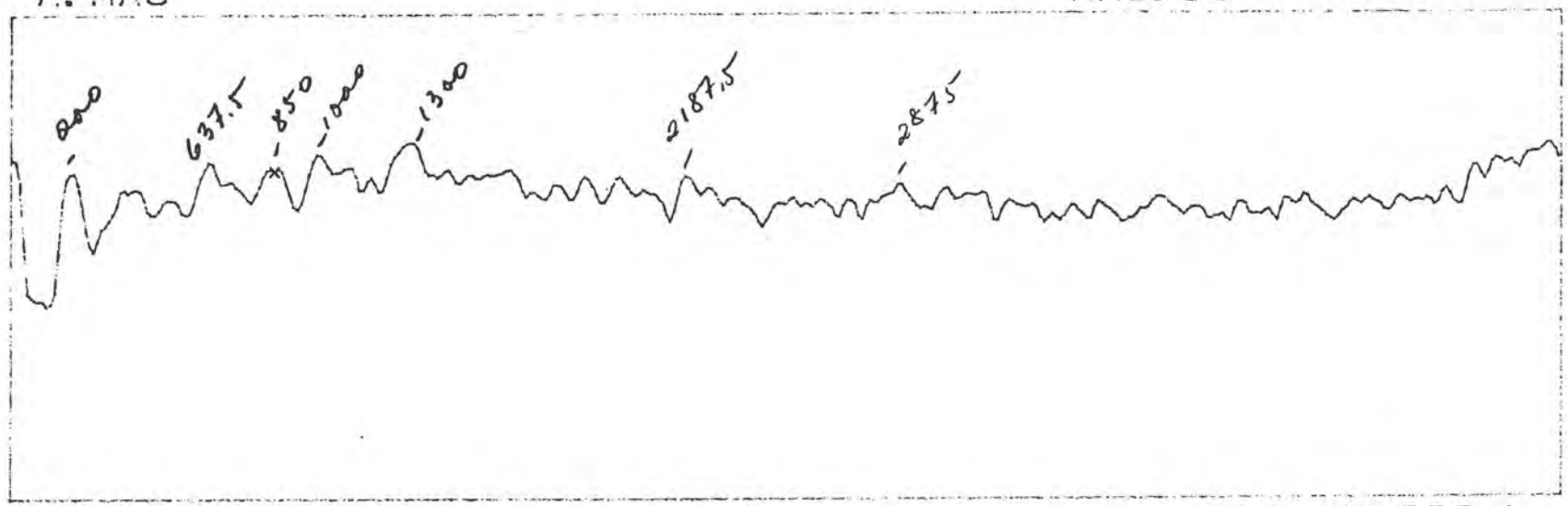
START: 0 Sec STOP: 400 mSec

X: 365 Hz Y: -11.15 dBV

#1
81486 L
32 mm
#2 Dead
Columbia MC/DT #1

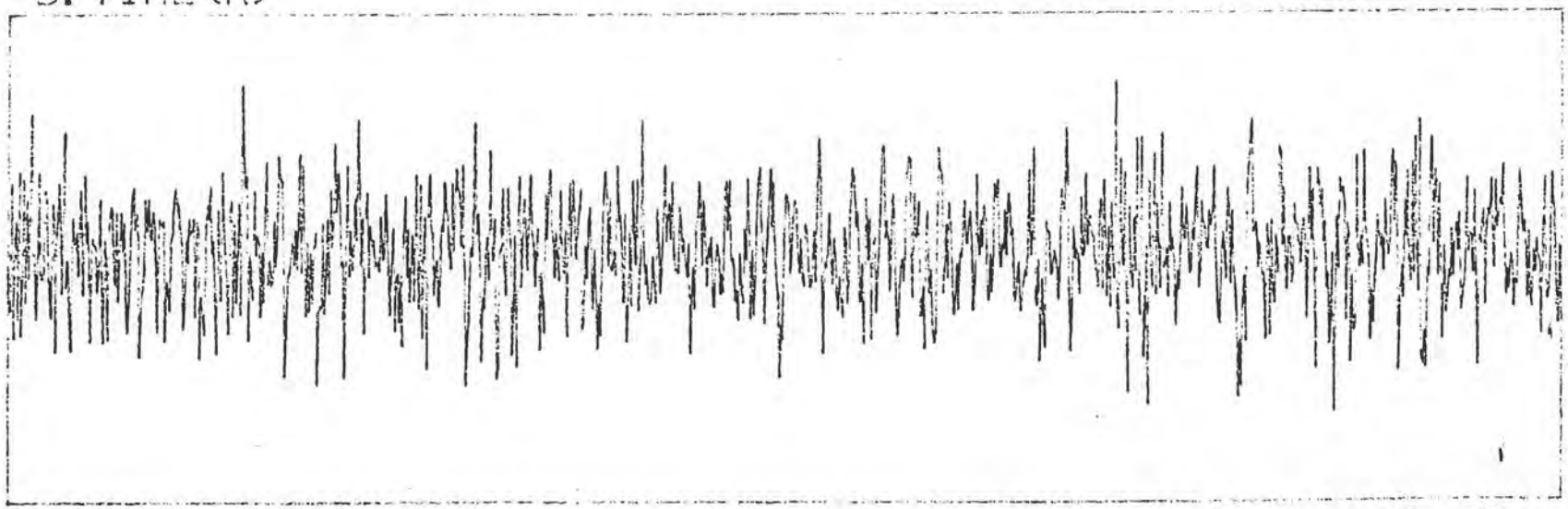
RANGE: 21 dBV STATUS: PAUSED
RMS: 10

A: MAG



START: 0 Hz BW: 47.742 Hz STOP: 5 000 Hz

B: TIME (R)



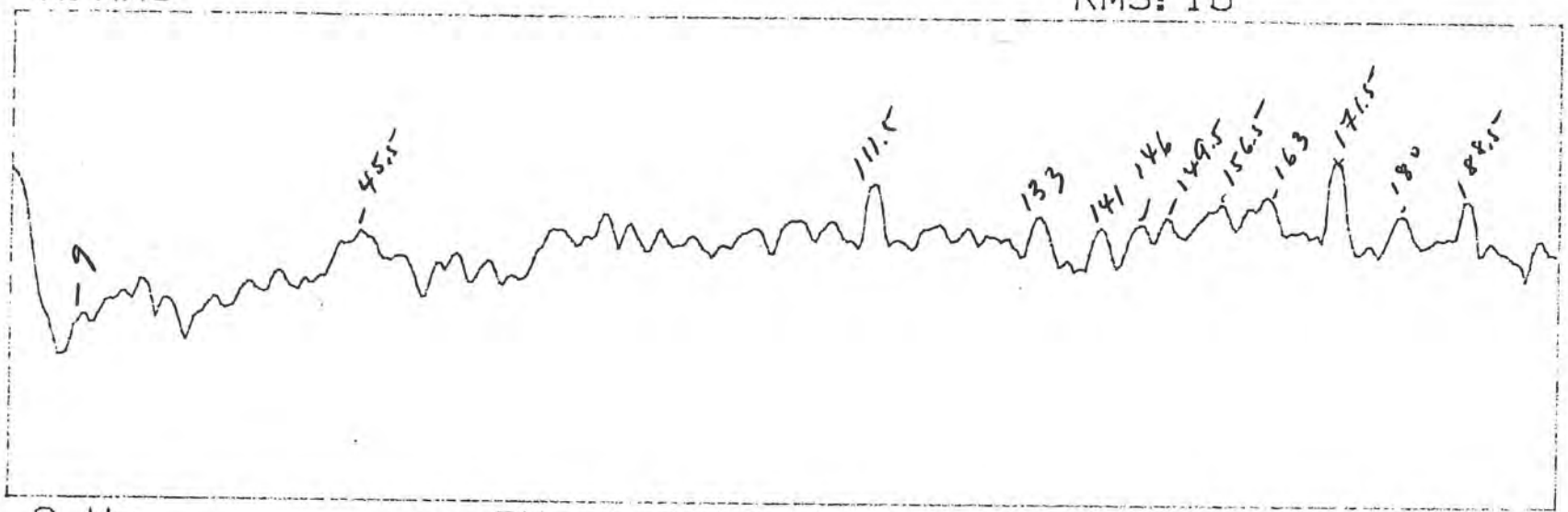
START: 0 Sec STOP: 80 mSec

X: 850 Hz Y: -4.80 dBV

#9
81486 M
32 MW
#2 DOWN
B&K / TAIL PAGE #1

RANGE: 17 dBV STATUS: PAUSED

A: MAG RMS: 10



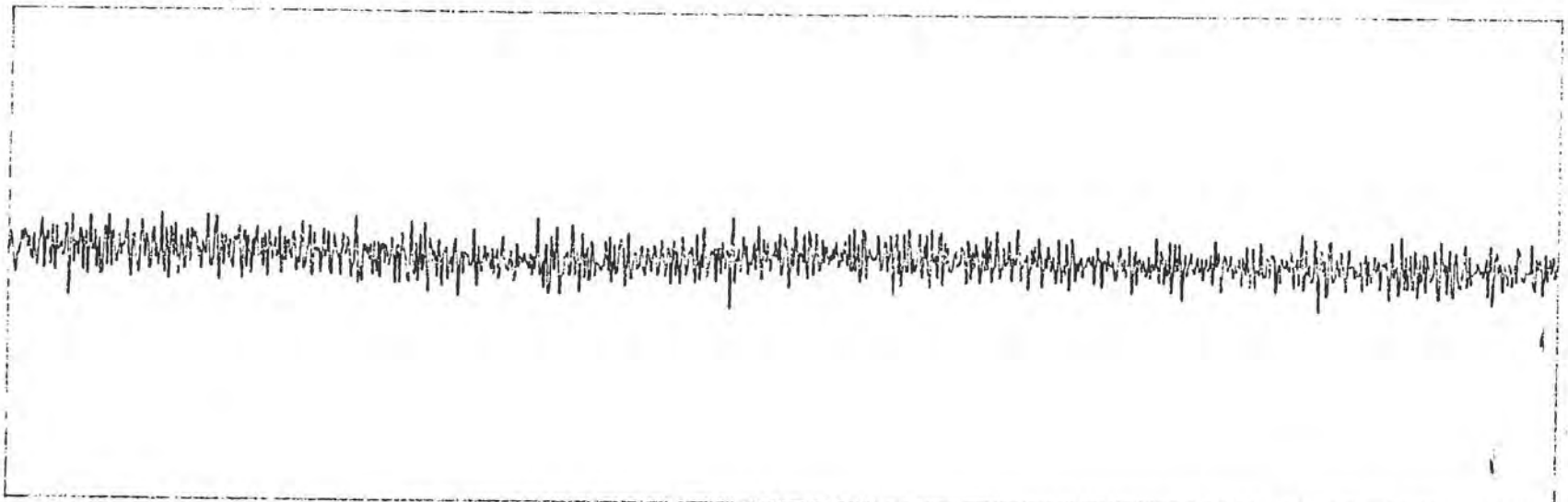
17 dBV

10 dB /DIV

-63

START: 0 Hz BW: 1.9097 Hz STOP: 200 Hz

B: TIME (R)



20 Volt

5 Volt /DIV

-20

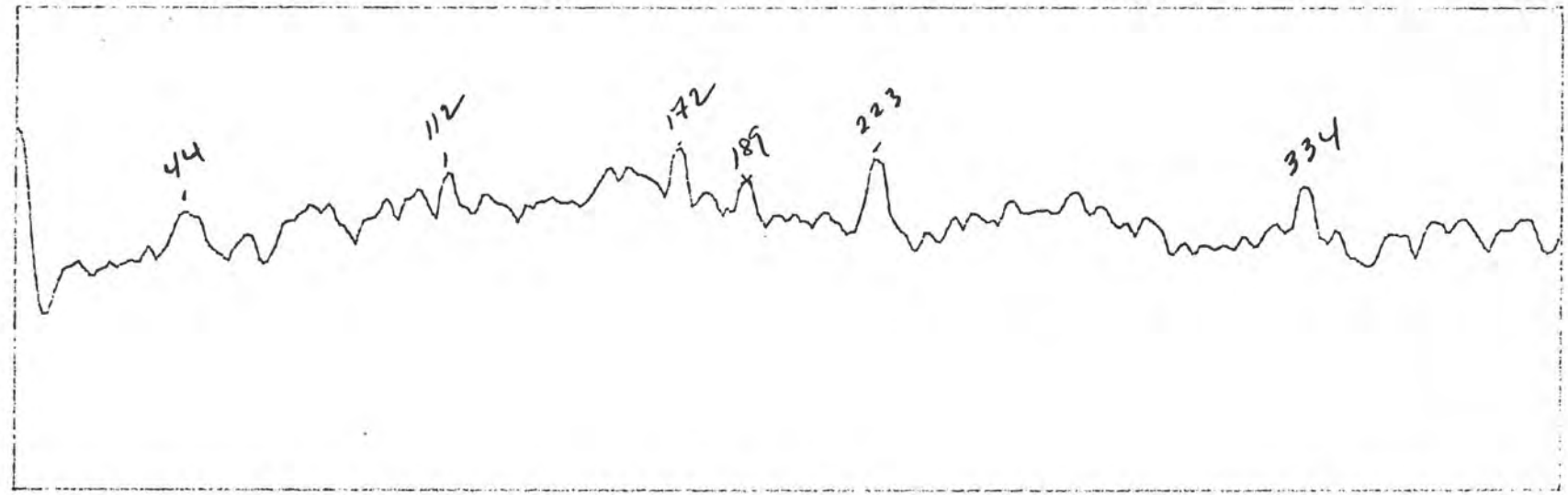
START: 0 Sec STOP: 2 Sec

X: 171.5 Hz Y: -6.29 dBV

#1
8486N
32 mm
#2 Down
B&K / Tailrace #1

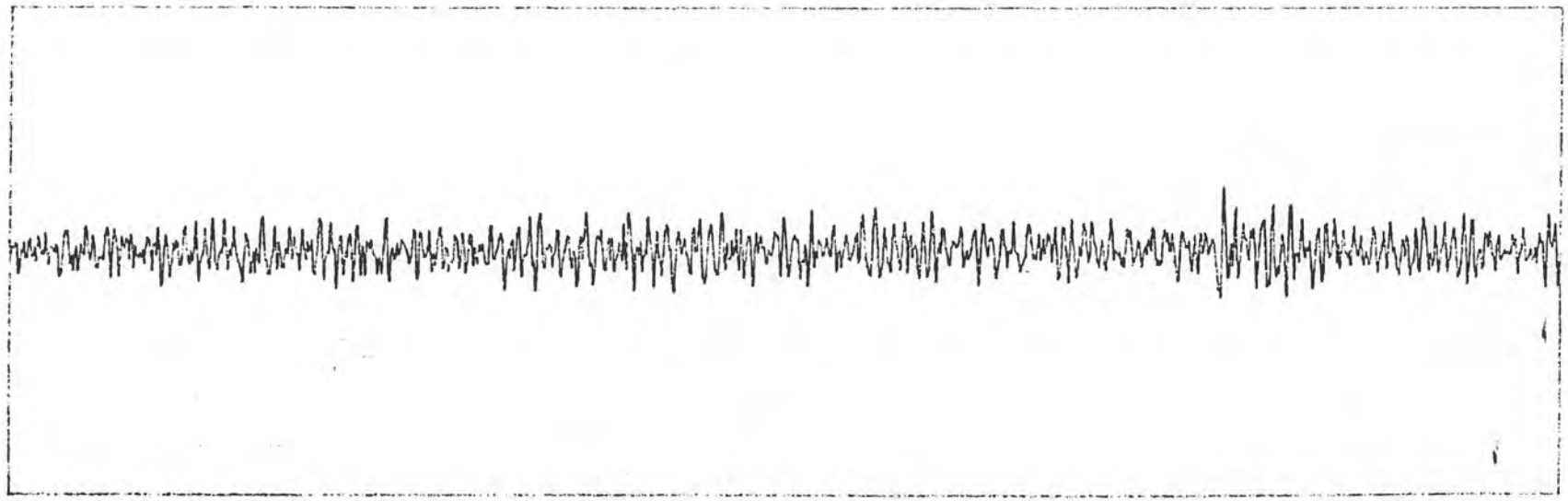
RANGE: 13 dBV STATUS: PAUSED

A: MAG RMS: 10



START: 0 Hz BW: 3.8194 Hz STOP: 400 Hz

B: TIME (R)



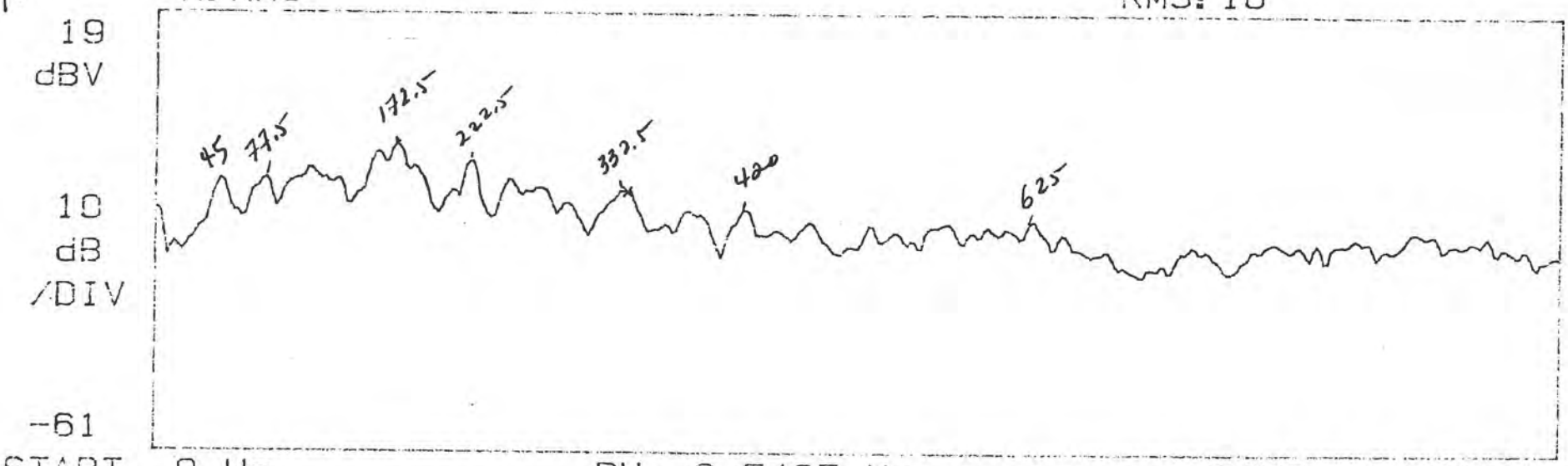
START: 0 Sec STOP: 1 Sec

X: 189 Hz Y: -13.73 dBV

#1
814460
32mm
#2 DOWN
DSK / TAILPAIR #1

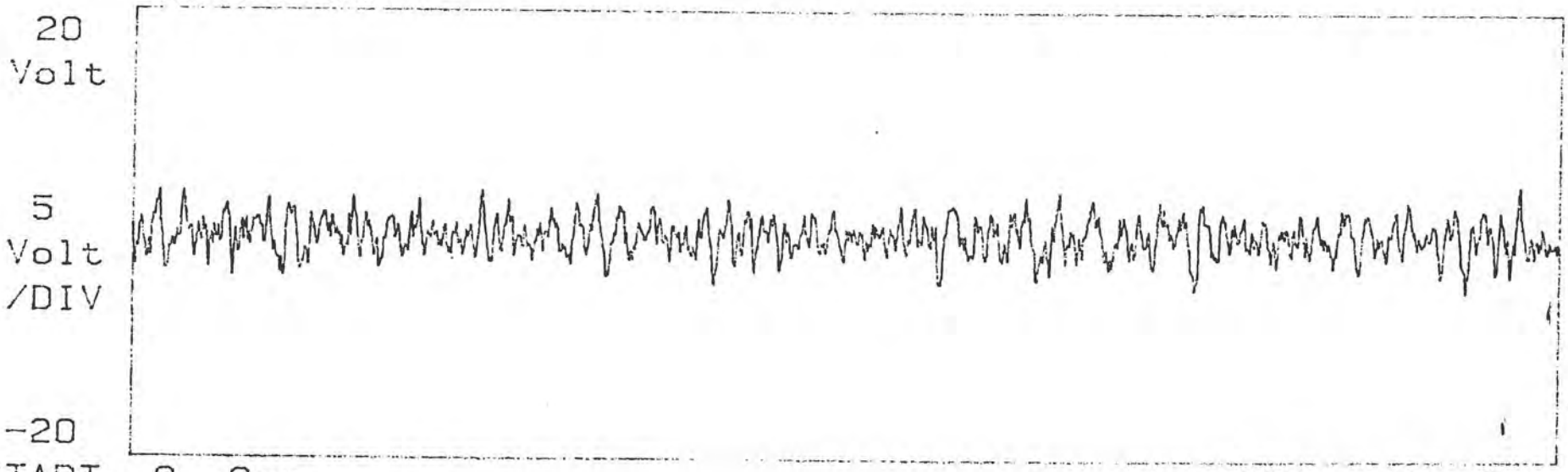
RANGE: 19 dBV STATUS: PAUSED

A: MAG RMS: 10



START: 0 Hz BW: 9.5485 Hz STOP: 1 000 Hz

B: TIME (R)



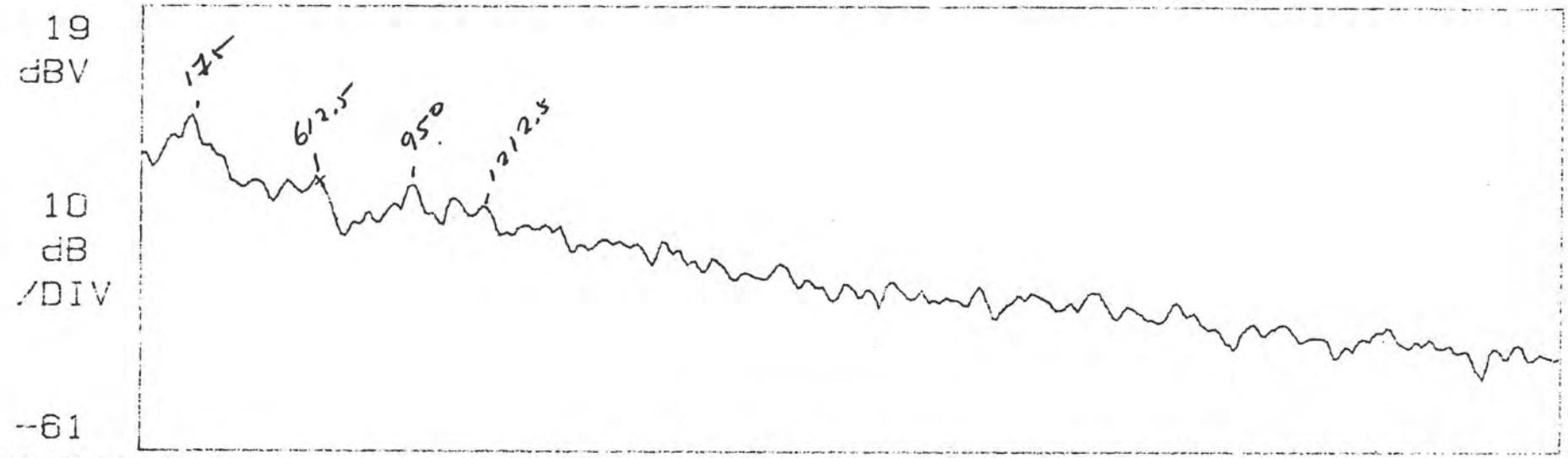
START: 0 Sec STOP: 400 mSec

X: 335 Hz Y: -13.46 dBV

#1
6148 P
32 mm
#2 POWN
BSK/TAIL ROLL #1

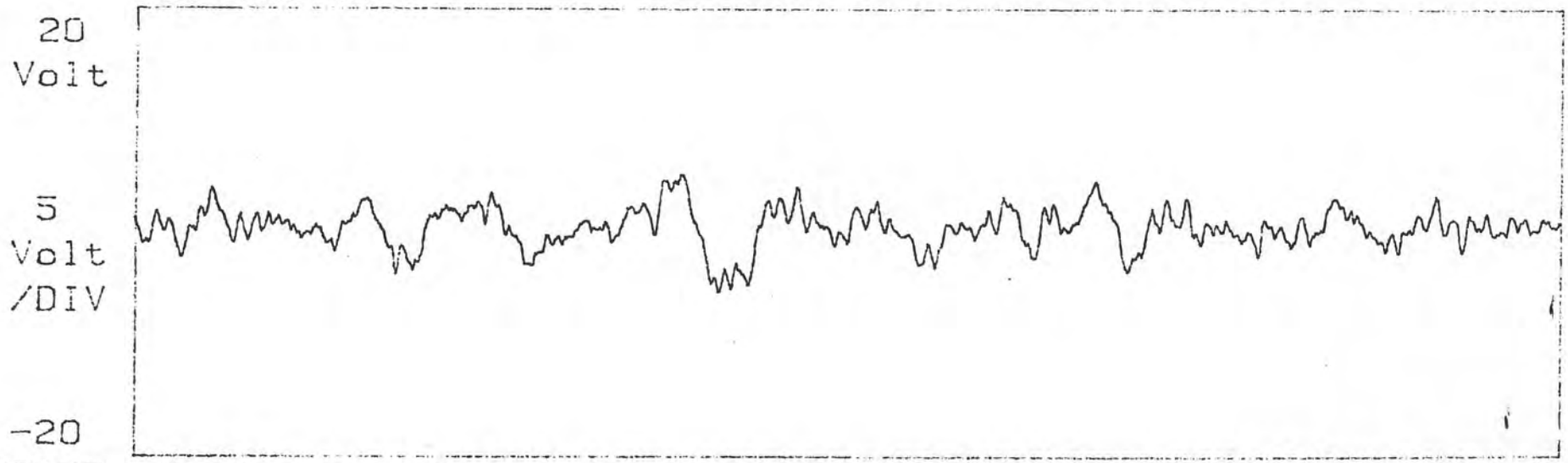
RANGE: 19 dBV STATUS: PAUSED

A: MAG RMS: 10



START: 0 Hz BW: 47.742 Hz STOP: 5 000 Hz

B: TIME (R)



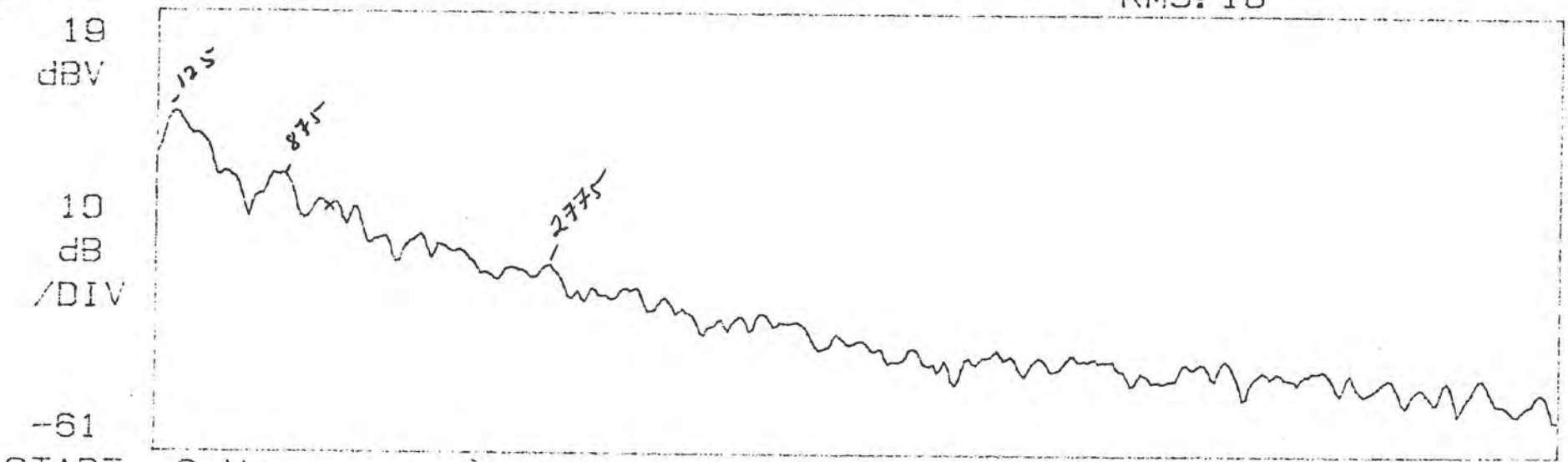
START: 0 Sec STOP: 80 mSec

X: 625 Hz Y: -12.39 dBV

#1
8446 G
32 mm
2 DOWN
B&K/TAILRACE #1

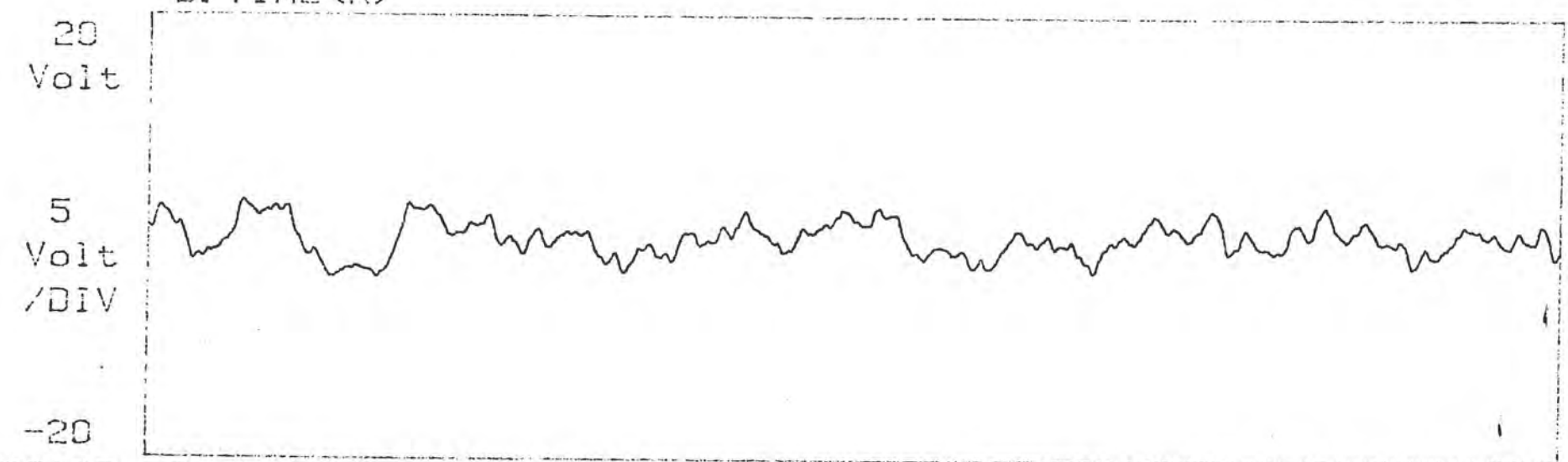
RANGE: 19 dBV STATUS: PAUSED

A: MAG RMS: 10



START: 0 Hz BW: 95.485 Hz STOP: 10 000 Hz

B: TIME (R)



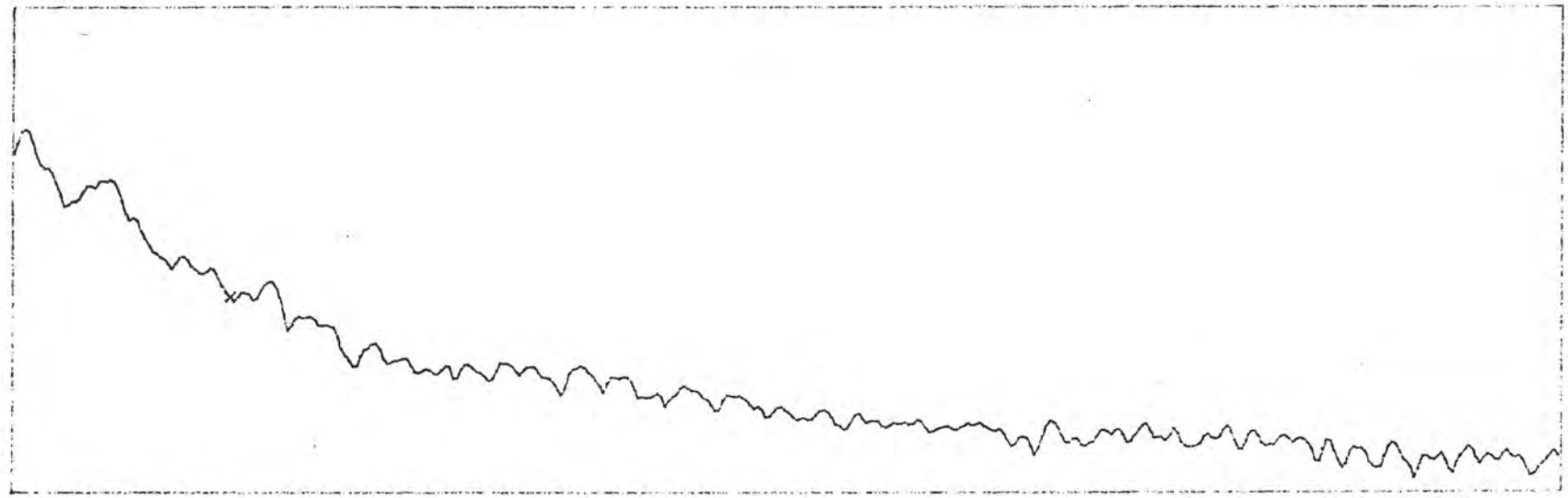
START: 0 Sec STOP: 40 mSec

X: 1225 Hz Y: -16.38 dBV

#1
81486 R
A2 DOWN
B&K/TAIL AIRE #1

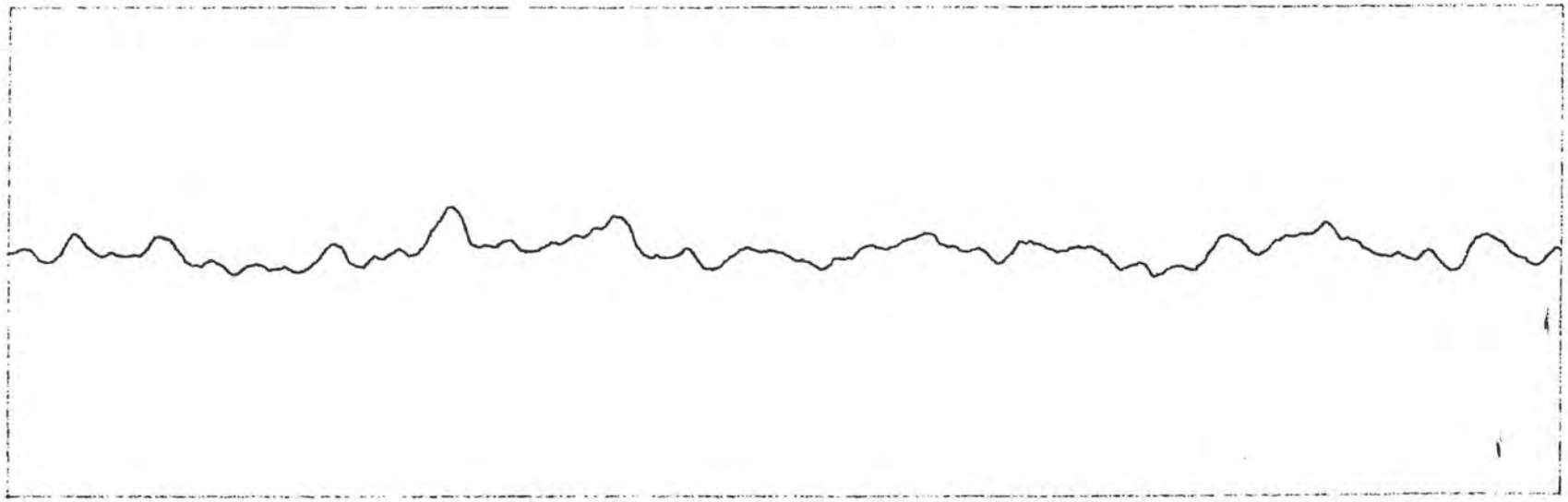
RANGE: 19 dBV STATUS: PAUSED

A: MAG RMS: 10



START: 0 Hz BW: 190.97 Hz STOP: 20 000 Hz

B: TIME (R)



START: 0 Sec STOP: 20 mSec

X: 2800 Hz Y: -28.76 dBV

SA
814815
32 MM
#2 DOWN
BBK/TAILPAGE #1

RANGE: 19 dBV STATUS: PAUSED

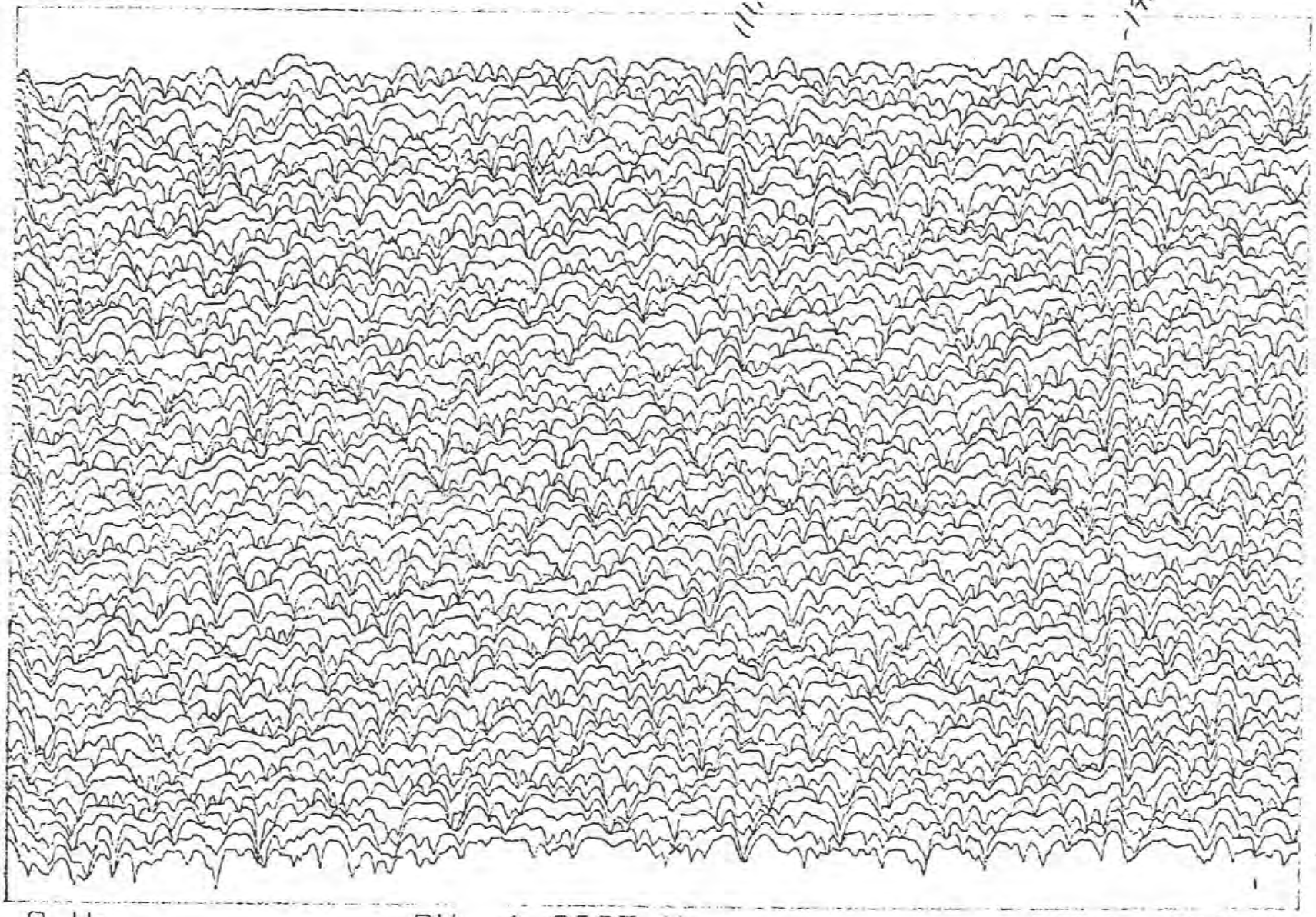
A: MAG

1/60

19 dBV

10 dB /DIV

-61



START: 0 Hz BW: 1.9097 Hz STOP: 200 Hz

X: 103.5 Hz Y: -20.31 dBV

#1
9/18/86 A
9:30 pm
B&K MIC - DT #1

RANGE: 13 dBV STATUS: PAUSED

A: MAG RMS: 10

13 dBV

10 dB /DIV

-67

START: 0 Hz BW: 1.9097 Hz STOP: 200 Hz

B: TIME (R)

8 Volt

2 Volt /DIV

-8

START: 0 Sec STOP: 2 Sec

X: 100 Hz Y: -42.74 dBV