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ABSTRACT

Although acoustic detection of cavitation inception has been shown to agree relatively well with visual detection, acoustic methods have generally not been used to detect cavitation inception during cavitation testing of model propellers. In addition, it has been suggested that noise measurements on model propellers be made at high frequencies to more properly represent the full scale noise. In this thesis, three different methods of acoustic detection were investigated. Two of these methods, the measurement of high frequency one-third octave band levels and the analysis of the complete noise spectrum between 10 and 50 kHz, met with some success, but were not equivalent to the capability of a visual detection method. The third method used, the demodulated analysis of high frequency cavitation noise, gave excellent agreement with visually determined results.

A COMPARISON OF
ACOUSTIC AND VISUAL DETERMINATION OF CAVITATION INCEPTION
ON A MODEL PROPELLER

by

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B.S., College of the Holy Cross
(1967)

SUBMITTED IN PARTIAL FULFILLMENT
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A COMPARISON OF ACOUSTIC AND VISUAL DETERMINATION OF CAVITATION INCEPTION ON A MODEL PROPELLER

by

MARK G. PRESTERO

Submitted to the Department of Ocean Engineering on 11 May 1978, in partial fulfillment of the requirements for the degrees of Ocean Engineer and Master of Science in Naval Architecture and Marine Engineering.

ABSTRACT

Although acoustic detection of cavitation inception has been shown to agree relatively well with visual detection, acoustic methods have generally not been used to detect cavitation inception during cavitation testing of model propellers. In addition, it has been suggested that noise measurements on model propellers be made at high frequencies to more properly represent the full scale noise. In this thesis, three different methods of acoustic detection were investigated. Two of these methods, the measurement of high frequency one-third octave band levels and the analysis of the complete noise spectrum between 10 and 50 kHz, met with some success, but were not equivalent to the capability of a visual detection method. The third method used, the demodulated analysis of high frequency cavitation noise, gave excellent agreement with visually determined results.

Thesis Supervisor: Professor J.E. Kerwin
Title: Professor of Naval Architecture

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

Since the first observation of cavitation associated with marine propellers was reported by Reynolds in 1873, a number of unwanted effects, including loss of propeller efficiency, erosion of propeller surfaces, excitation of hull vibrations, and generation of noise, have been identified and studied. Because of these detrimental effects, it has been, and continues to be, desirable to predict the cavitation performance of a propeller design before the expensive full scale propeller is built. With no exact analytical approach available for predicting the full scale cavitation performance of a propeller, the testing of scale models has been used to aid in cavitation prediction in the propeller design process.

For the model test to properly represent the full scale, it is necessary for similarity conditions be satisfied. For propeller cavitation testing, this amounts to using a geometrically similar propeller operating in a flow which matches the wake where the full scale propeller operates. With these conditions met, it is assumed that cavitation performance for similar values of cavitation index,

$$\sigma = \frac{p - p_v}{\frac{1}{2}\rho\, U_\infty^2}$$

and advance coefficient,

$$J = \frac{V_a}{nD}$$

will be the same for the model and full scale propeller. But this assumption is not precisely correct, and scale effects, which arise from the inability to satisfy all hydrodynamic, thermodynamic and other microscopic similarity requirements, are encountered. These scale effects are usually eliminated by means of empirically or theoretically determined corrections.

In general, the procedure for conducting a model test for determining cavitation inception performance is to operate the model propeller in a variable pressure water tunnel, downstream of a device which produces the desired wake at the plane of the propeller. A water and propeller speed combination are chosen to give the desired value of advance coefficient. Water pressure is changed to change the cavitation index until cavitation is visually observed to either begin or to cease, depending upon the criterion used at the particular test facility. This process is then repeated for several different values of advance coefficient. The final result is a curve of inception cavitation index, σ_i, versus advance coefficient.

Although visual observation is the usual method for determining the presence or absence of cavitation, it is not the only available means. It is possible to use the detection of cavitation-generated noise to determine, or to assist visually determining, the inception of cavitation. Good correlation between acoustic and visual inception determination has been reported (Lehman, 1964). It has also been reported

that "numerous" facilities use an acoustic technique for this purpose (ITTC, 1978), but the details of these methods were not available. It is proposed for this investigation to consider several different schemes for detecting cavitation-generated noise as a method for inception determination, and to compare acoustically-determined inception data with visual observations of inception for a model propeller.

II. BACKGROUND

The sound generated by cavitation comes primarily from the growth and collapse of the cavitation bubbles. The theoretical energy spectrum for the sound generated by a single bubble has been shown to contain maxima at frequencies which correspond to the reciprocal of the time required for the growth and collapse of the bubble (Fitzpatrick and Strasberg, 1959). Experimental investigations into the spectrum of cavitation noise have found that the shape of the measured spectrum resembles the theoretical spectrum quite closely (Ross, 1976; Strasberg, 1977).

Strasberg also notes that the peak of the observed spectra move toward lower frequencies as the cavitation becomes more severe. The larger maximum size of the bubbles in the more developed cavitation corresponds to the observed peak at a lower frequency. Ross points out that the energy radiated per collapse is proportional to the product of the collapse pressure and the maximum bubble volume. So, when cavitation becomes more severe, and a larger number of bubbles,which also have a greater diameter, are produced, the amount of sound energy radiated becomes greater, the magnitude of the peak in the spectrum increases, and the frequency of the peak becomes lower. If the various spectra are non-dimensionalized in the manner of Fitzpatrick and Strasberg, the spectra for different degrees of cavitation intensity all agree well with the non-dimensionalized theoretical spectrum (Strasberg, 1977).

Continuing on with the scheme given by Strasberg, if the propeller diameter is used for the non-dimensionalizing length scale instead of the maximum bubble radius, a similarity condition for relating frequencies of interest between a model and a full scale propeller is obtained. For a given ratio of maximum bubble radius to propeller diameter (which can be interpreted as a measure of relative cavitation intensity), the non-dimensional frequency of the peak in the cavitation noise spectrum will remain invariant between different length scales. It should then be possible to compare cavitation noise measurements made at a given actual frequency on a full scale propeller with measurements made at the same non-dimensional frequency on a model propeller, so long as other similarity requirements are satisfied. For example, with the submarine propeller cavitation noise measurements used by Strasberg (1977), assuming that the full scale measurements were made at a submergence depth of 200 feet, the model measurements were made at an ambient pressure of 1 atmosphere, the same fluid was used in each case, and the length scale ratio was 8, the ratio between the frequency of interest with the model (f_M) to the frequency of interest with the full scale propeller (f_P) is:

$$\frac{f_M}{f_P} = \frac{D_P}{D_M} \cdot \left(\frac{P_M}{P_P} \right)^{\frac{1}{2}}$$

$$= 8 \cdot (34 \div 234)^{\frac{1}{2}} = 3.05$$

So, for cavitation noise measurements, the frequency of interest in model scale is about three times the full scale frequency for equivalent severity of cavitation in the two cases.

There are several considerations about the model cavitation noise which this concern with frequency alone does not show:

1) The size of the cavitation bubbles for the model will be one eighth the actual size of the full scale bubbles and might, consequently, be too small to see

2) At the same distance from the propeller as in model measurements (assuming the distances are large enough to avoid near field effects) the sound pressures, $\tilde{p}$, would have the ratio of

$$\frac{\tilde{p}_M}{\tilde{p}_P} = \frac{P_M}{P_P} \times \frac{D_M}{D_P}$$

$$= \frac{34}{234} \times \frac{1}{8} = 1.8 \times 10^{-2}$$

or approximately 35 db lower for the model, if the non-dimensionalization of Strasberg (1977) is used with the same bandwidth, distance and non-dimensional frequency.

3) The actual cavitation does not, in general, occur uniformly for all angular positions for all blades.

Operation of the propeller in a non-uniform wake causes variations of inflow velocity seen by the propeller which are periodic, with a frequency that corresponds to once per revolution. This periodic flow variation causes the inception,

growth, decrease, and disappearance of cavitation to occur in a periodic fashion on a given blade. For a given average level of cavitation intensity, the amplitude of the cavitation noise will vary over one propeller revolution. This change in amplitude will have two effects - it will shift the peak frequency of the noise spectrum over the time span of one revolution of the propeller, and it will vary the amplitude of the noise spectrum.

If all blades of the propeller are the same, the amplitude modulation of the noise occurs at blade passing rate - once for each blade for each revolution of the shaft. Since the blades are generally not identical, one blade will usually begin to cavitate ahead of the others, and the modulation of the noise will occur, in addition, at the shaft rate (Strasberg, 1946; Ross, 1976).

It is intended, then, to investigate the use of these two aspects of cavitation noise, frequency scaling and amplitude modulation, either independently or together, as a means of detecting cavitation inception on a model propeller. It is expected that this approach would have certain advantages as a part of the process for predicting full scale cavitation performance:

(1) Visual determination of inception is very dependent upon a number of conditions outside the test tunnel for repeatable results. Lighting conditions, as well as the location and visual acuity of the observer, can have a

substantial effect upon the outcome of a test. With an appropriate criteria for determining cavitation inception from acoustically obtained data, this sort of variation could be eliminated.

(2) For many ships, cavitation inception determination for the full scale propeller is accomplished using acoustic information. An acoustic method on model scale would more closely approximate the full scale test.

(3) Based upon bubble size considerations, an acoustic method might be able to detect the presence of cavitation bubbles before they are visible.

But there are disadvantages associated with using acoustic information for this purpose:

(1) The equipment to make the acoustic measurements is substantially more expensive than that needed for the visual determination of inception. For a very large length scale ratio, the frequency of interest at the model scale might become so high that the normal analysis equipment for acoustic measurements would not be usable, or the level of the acoustic signal from cavitation noise might be too low to be detected.

(2) If it is used alone, an acoustic method would appear to be less useful to the designer, since the method would not directly identify the type of cavitation causing the noise. The steps necessary to improve the cavitation performance of an unsatisfactory design would be less clear.

III. EXPERIMENTAL PROCEDURE

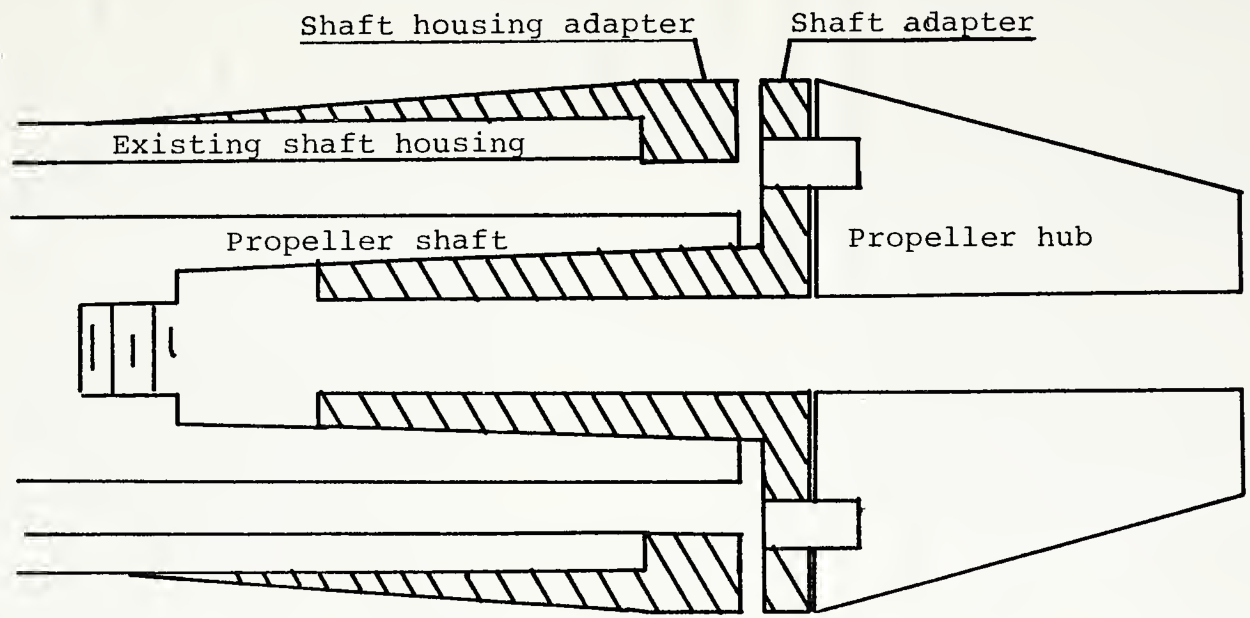
A. Equipment Setup

Experiments were conducted in the MIT Variable Pressure Water Tunnel, which has a 20 in square closed jet test section with a length of 54 in. All four walls of the test section have a 16 in by 44.5 in plexiglass viewing window insert. The propeller is located at the vertical and horizontal centerlines of the test section, and is driven by an upstream propeller shaft.

The propeller used for this test was the David Taylor Naval Ship Research and Development Center (DTNSRDC) model 3927, which had a diameter of 10.8 in and had seven blades. The tapered hub of the propeller had a maximum diameter of 2.8 in, which required the use of an adapter to provide a smooth transition between the 2.375 in diameter of the propeller shaft housing and the hub. Figure 1 shows this adapter. The propeller was installed on the shaft with no hub fairwater cap, leaving the mounting capscrew and lockwasher exposed.

Attached to the shaft housing 20 in upstream of the plane of the propeller was the holder for the screen which generated the desired wake at the propeller. The design of this screen used a scheme proposed by McCarthy (1963) as a starting point. The details of this process are given in Appendix A.

The wake prescribed for testing this propeller is

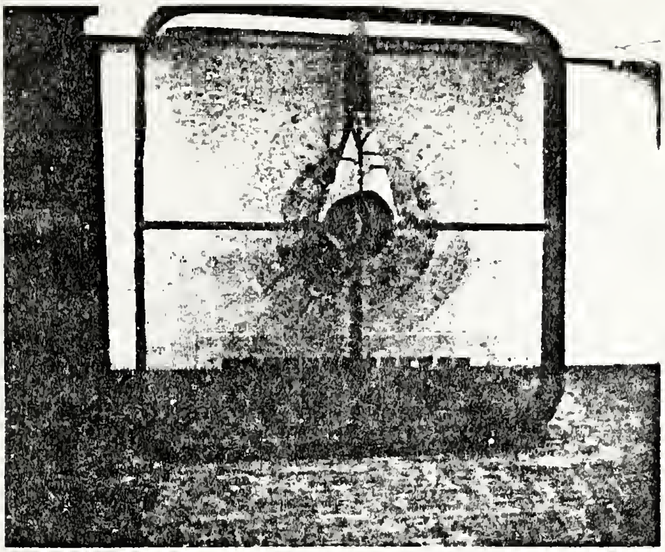


Shaft Adapter Fittings

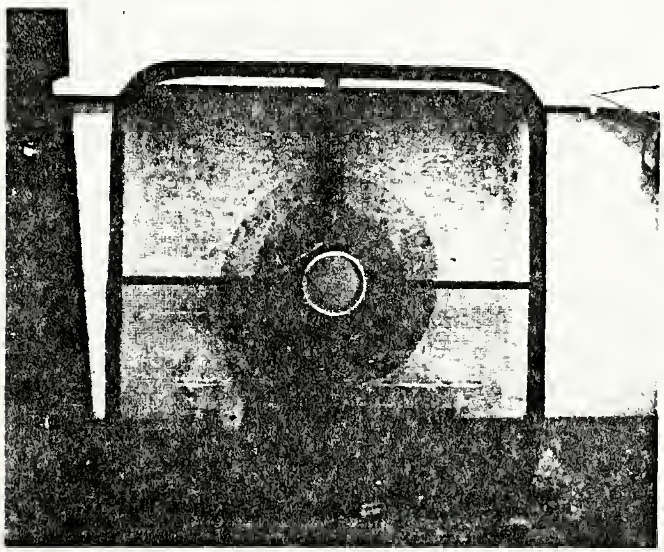
Figure 1

axisymmetric, with a specific radial distribution of longitudinal velocity. For the first variation of the wake, the velocity distribution was measured along a diameter on a diagonal, but at the radii where the values of longitudinal velocity were given. The values for the two radii were averaged and compared to the specified values. An error of less than 10-12% was considered acceptable.

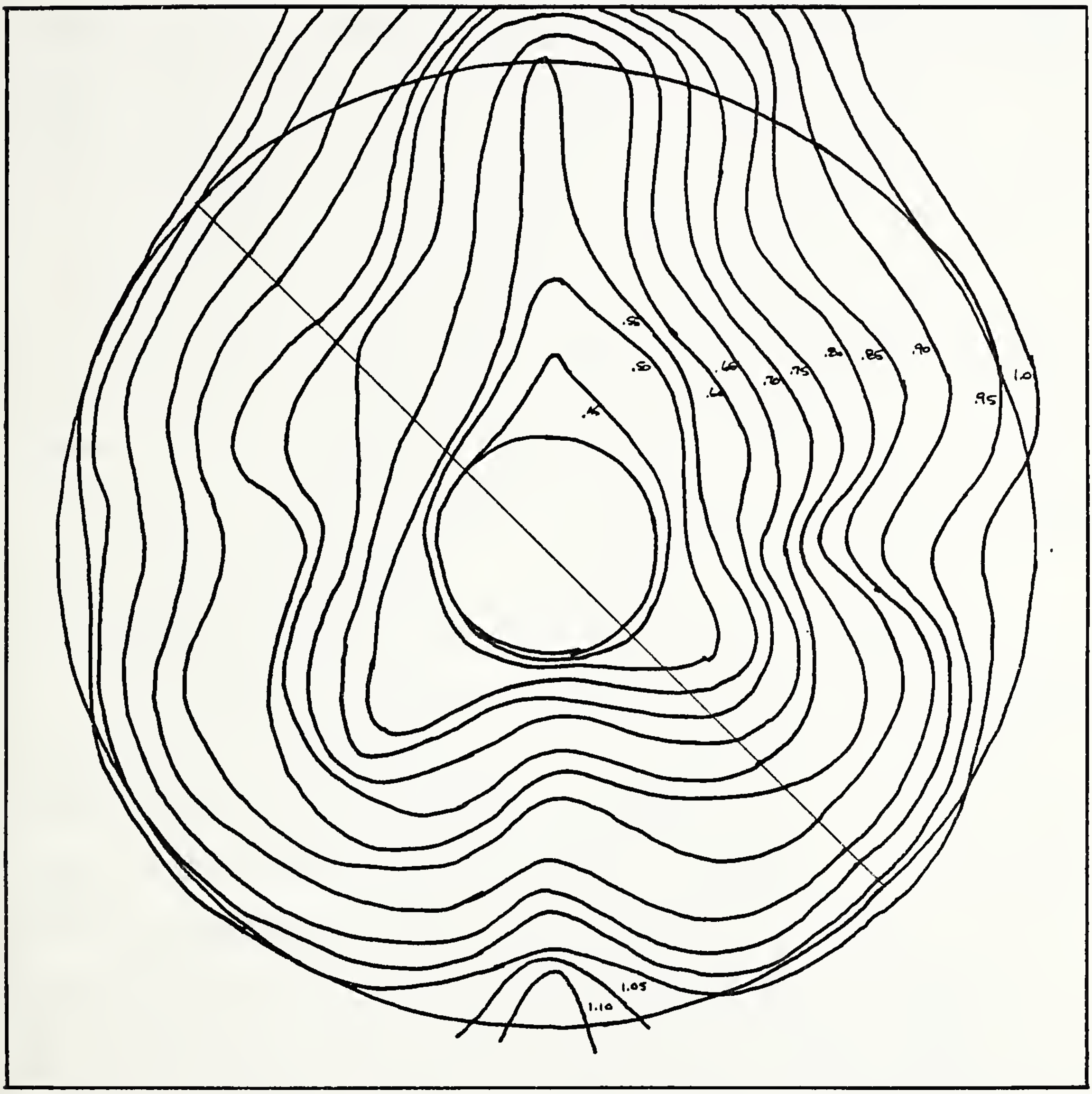
During the initial testing of the propeller it was discovered that face cavitation would occur behind the supports of the wake screen holder. This indicated a velocity increase as the propeller blade entered the region downstream of the supports, and was attributed to boundary layer viscous effects as the flow passed the wake screen holder supports. At the same time it was noted that modulation of the cavitation noise for other than this face cavitation was not detectable with the equipment being used. This indicated that a severe, once per revolution, velocity defect was desirable. This defect was achieved by using screen material to make the topmost support much thicker and tapered. No effort was made to maintain the same circumferential mean wake. The final wake screen used is shown in the photographs in figures 2A and 2B. Figure 3 shows the results of the wake survey made with a 1 in square grid, in a plane 2.5 in downstream of the blade root leading edge, but with the propeller removed, after the upper support was altered. The diagonal line indicates where the initial screen velocity measurements were made, as well as the data from the final



Final Wake Screen - Looking Downstream
Figure 2A



Final Wake Screen - Looking Upstream
Figure 2B



Wake Profile

Looking Upstream

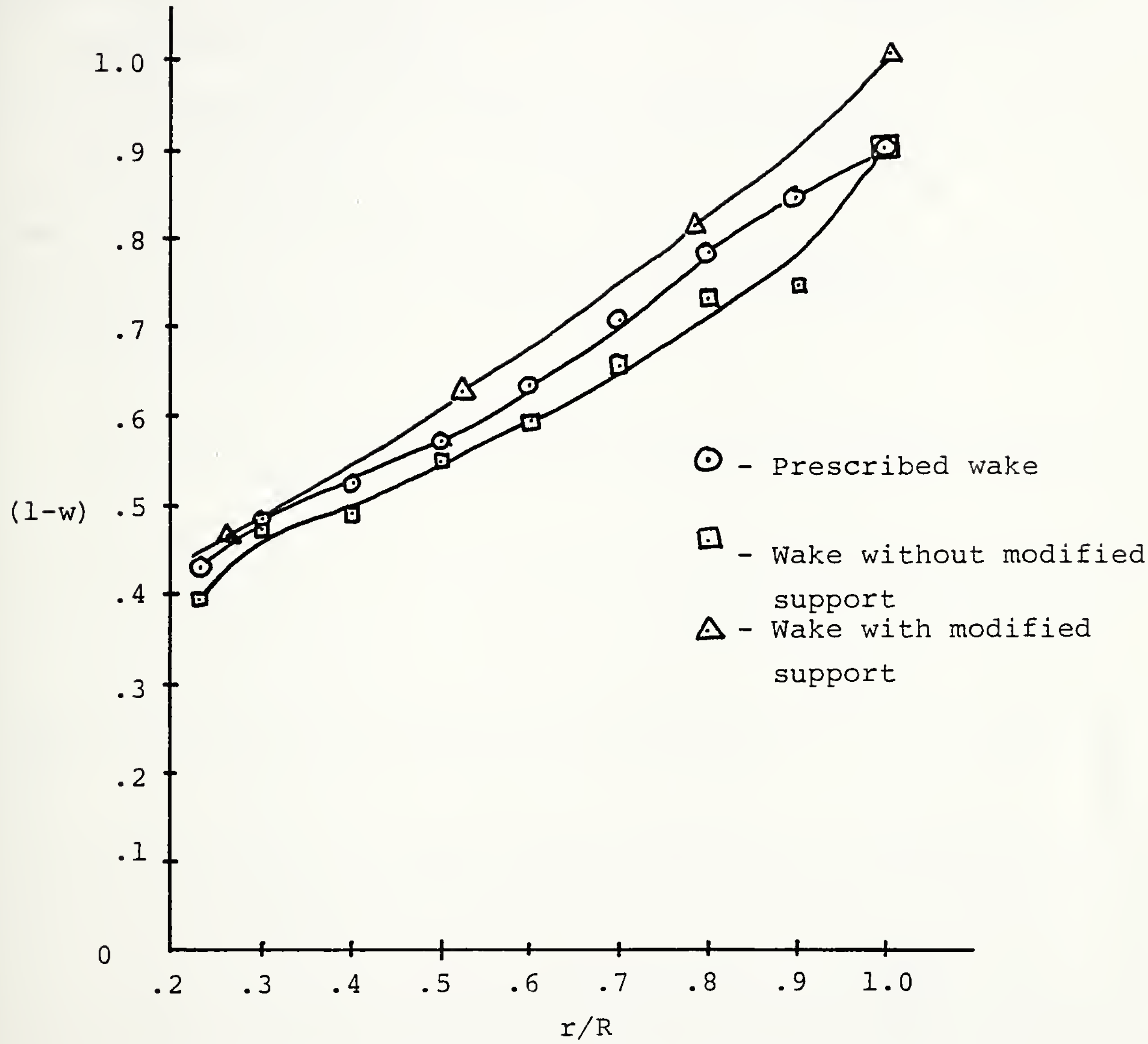
Figure 3

screen velocity measurements, for comparison with the prescribed wake were taken. A plot, comparing the actual and prescribed velocities is shown in figure 4.

Two sensors were used at different times to obtain the acoustic signal. The first, an accelerometer, was a Brüel & Kjaer (B&K) type 4344. The characteristics of this accelerometer are shown in table 1. The accelerometer was mounted directly to one of the viewing windows, as close to the center as possible, using a cyanoacrylate adhesive. The other sensor, a minature hydrophone, was a B&K type 8103. The principal characteristics of this hydrophone are given in table 2. The hydrophone was mounted in the viewing window as shown in figure 5, 2.5 in downstream of the leading edges of the propeller blades. A schematic diagram of the arrangement of the test section is shown in figure 6.

The methods of processing of the signal from the sensor are shown in figures 7A and 7B. In configuration 7A, the Ithaco 4213 filter was used as a band pass filter for one-third octave bands, with the level indicated on the B&K type 2607 measuring amplifier as the output. The other configuration used a Federal Scientific Model UA-15A Ubiquitous Spectrum Analyzer coupled to a model 1015 Spectrum Averager, which, in turn, drove an X-Y plotter to provide an output.

With the spectrum analyzer providing the output, two set-ups were used. The first was to obtain the complete spectrum of the cavitation noise to 50 kHz, the upper



Wake Fraction versus Non-Dimensional Radius

Figure 4

Table 1

Accelerometer Characteristics

Type: B&K 4344 Serial Number: 475507

Reference sensitivity at 50 Hz at 23 °C and including cable capacitance of 106 pF:

Voltage sensitivity: 0.308 mV/ms^{-2} or 3.02 mV/g

Charge sensitivity: 0.344 pC/ms^{-2} or 3.37 pC/g

Capacitance (including cable): 1116 pF

Weight: 22 gm Undamped natural frequency: 121 KHz

Frequency response:

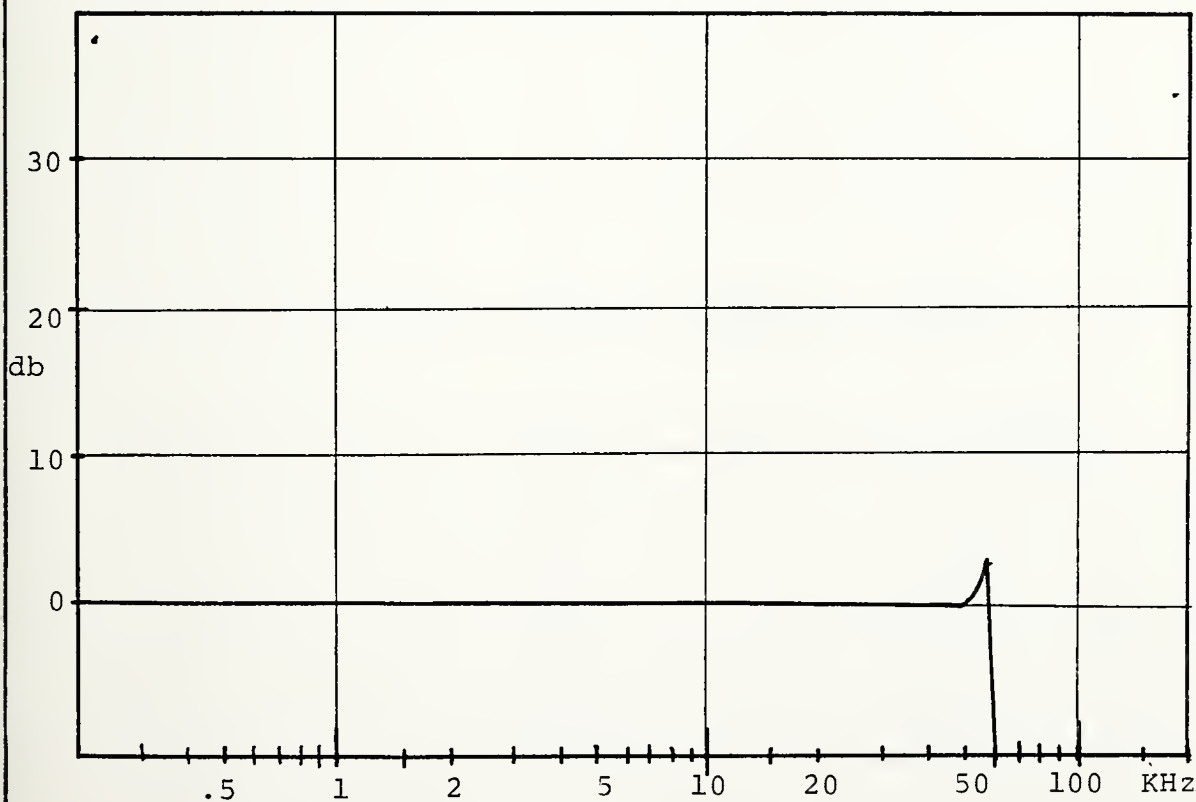


Table 2

Hydrophone Characteristics

Type: B&K 8103 Serial Number: 636764

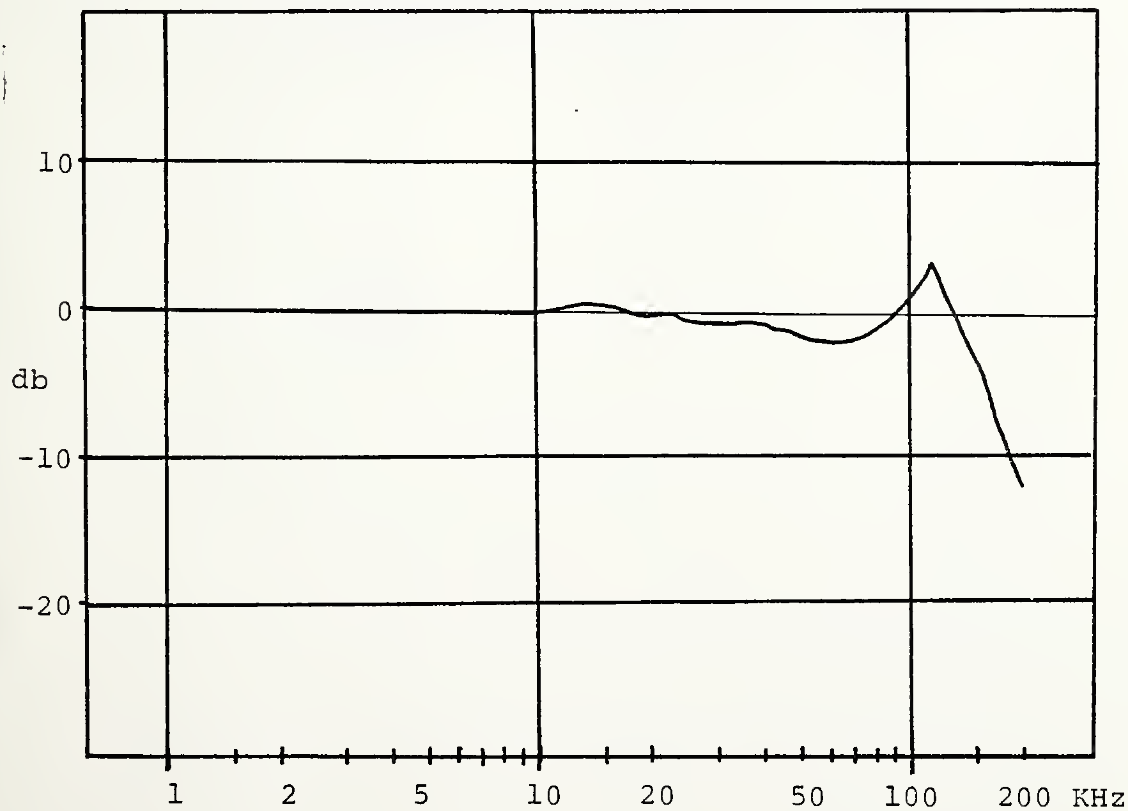
Reference sensitivity at 250 Hz at 23 ^{o}C including 6m integral cable:

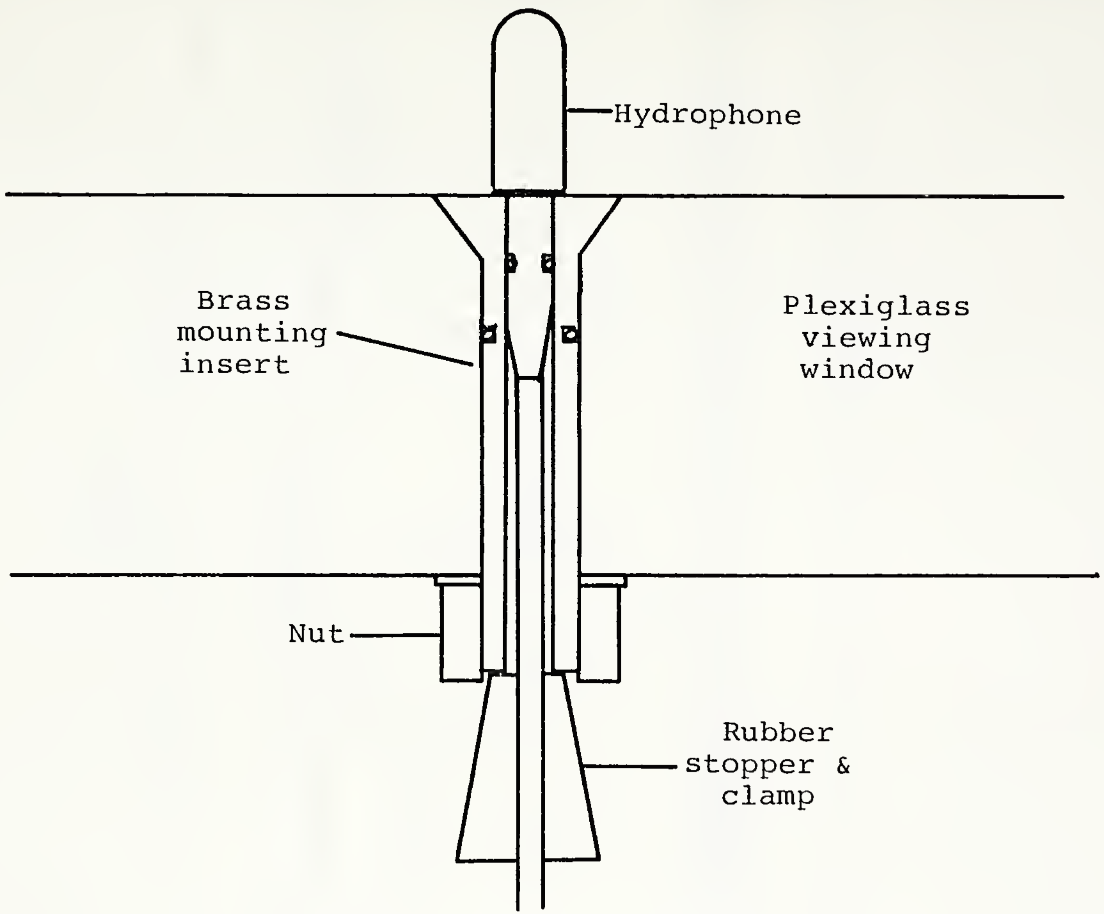
Open circuit sensitivity:

Voltage sensitivity:	-211.6 db re 1V/μPa
	- 91.6 db re 1V/Pa or 26.3 μV per Pa
	-111.6 db re 1V per μbar
Charge sensitivity:	91.5×10^{-3} pC per Pa

Capacitance: 3480 pF

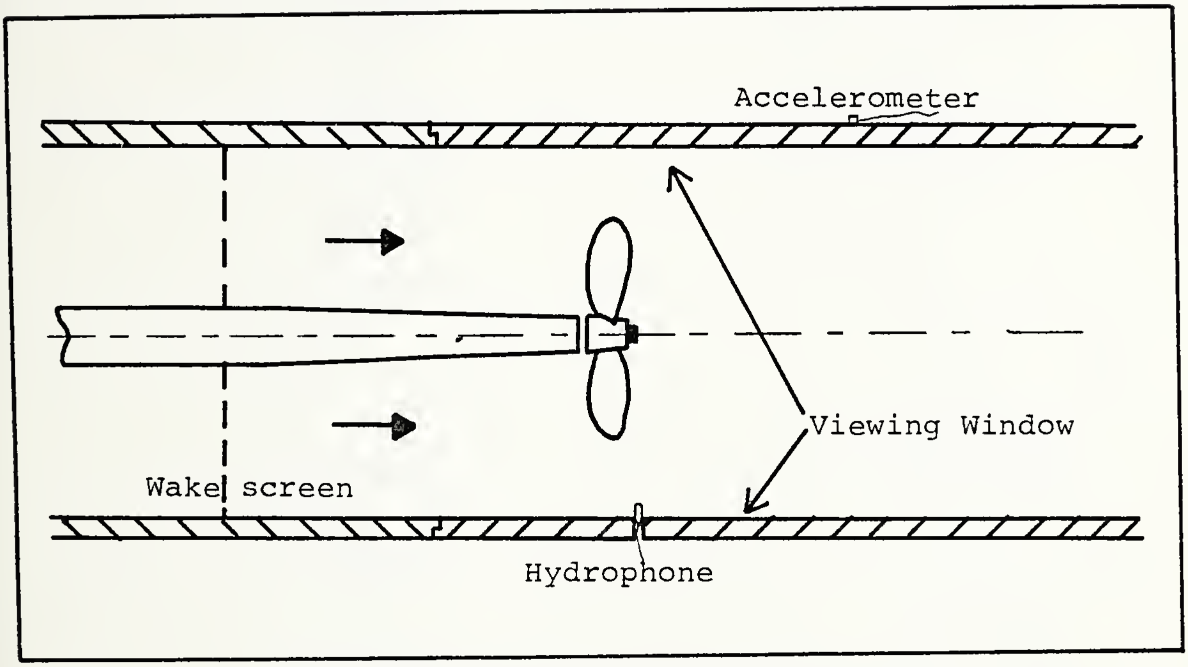
Frequency response:





Hydrophone Mounting

Figure 5



Arrangement of tunnel test section

Figure 6

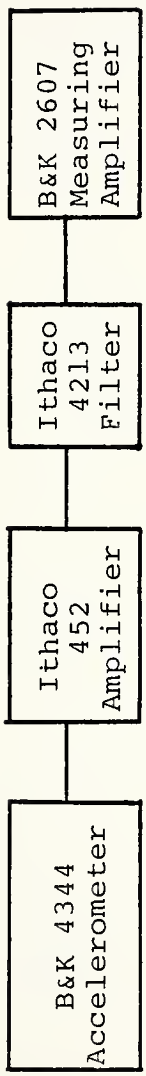


Figure 7A

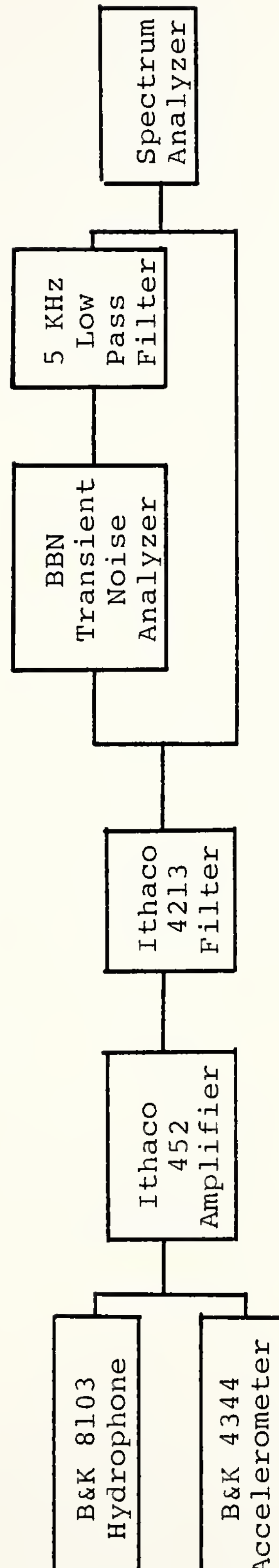


Figure 7B

frequency limit of the spectrum analyzer. In this case, the 4213 filter was used as a 10 kHz high pass filter to prevent the large amount of noise below 10 kHz, little of which was considered to be cavitation related, from overdriving the analysis equipment and preventing a good representation of the high frequency noise. For this analysis, 128 spectra were averaged to provide the output.

The second setup was intended to detect the cavitation by the presence of modulation of the high frequency noise, so that some form of demodulation was required. Demodulation of the signal was performed by passing it first through the Bolt, Beranek and Newman (BBN) Transient Signal Analyzer, which squared the signal, and then through a 5 kHz low pass filter and into the spectrum analyzer. For this setup, the 4213 filter was used either as a 20 kHz high pass filter or a 50-63 kHz band pass filter, so that only the high frequency, cavitation-related noise was being analyzed. (It was necessary to use high frequencies to obtain good results with this method of demodulation.) The spectrum analyzer was used on the 0-500 Hz range, and 32 spectra were averaged to obtain the output.

B. Calibration

It was not intended to attempt to measure the absolute levels of the cavitation noise, so a calibration of the level of the signal was not performed. In addition, a calibration of the frequency display of the spectrum analyzer was not

performed. Consequently, many of the spectra of the demodulated signal do not have peaks at the proper frequencies. But, because the peaks generally showed the proper spacing, this error in the display was not considered significant.

C. Test Procedure

The conventional test procedure of maintaining constant free stream velocity and propeller speed, and varying static pressure was used for this testing. This technique kept the frequency of interest for the demodulated analysis constant for a given test run.

Since it was not possible to determine the air content of the tunnel water, it was decided to perform the acoustic and visual cavitation inception determinations concurrently. Thus variations in air content would affect visual and acoustic results equally.

Prior to beginning data recording for a series of data points, the water was drained from the test section and the propeller was operated in air at about 1000 RPM. At this time, tare loadings for the thrust and torque load cells were recorded and the height of the manometer column was recorded as a no flow condition zero. The test section was refilled with water, an initial atmospheric pressure reading was recorded, and testing began.

For each data point, the following sequence was followed:

(1) A nominal flow speed and propeller RPM were selected to give the desired value of J, and tunnel conditions were adjusted to these values. The flow speed chosen was such that cavitation inception would occur after tunnel static pressure was reduced from atmospheric pressure, but before the pressure was so low that air coming out of solution would begin to cause absorption of the high frequency acoustic signal or to obscure the propeller from view (250-300 mm Hg).

(2) Tunnel static pressure was set to atmospheric pressure. Room air and tunnel water temperatures, and amplifier gain and filter settings were recorded, and the first set of data taken. This data included tunnel static pressure, manometer height, propeller RPM, thrust and torque readings, and the acoustic data, either the one-third octave level or the spectral analysis. A visual observation of the propeller was made using a strobe light triggered by a once per revolution signal from the propeller shaft. A variable triggering delay on the light allowed the observation of all blades at all points in the propeller rotation. The large viewing windows enabled viewing the propeller under conditions of both back and front lighting, from both up and downstream using the one strobe light.

(3) Tunnel static pressure was lowered, and another set of data recorded. This process was continued until cavitation inception had been observed both visually and acoustically.

The sequence above was then repeated at the selected

values of advance coefficient needed to produce the curve of cavitation index at inception versus advance coefficient.
At the end of a day's testing, the water was drained from the test section. The propeller was operated in air, tare loadings, atmospheric pressure and no-flow manometer height were once again recorded. All raw data recorded is contained in Appendix B.

IV. DATA REDUCTION

Reduction of the data for obtaining propeller parameters was accomplished using a program written for a TI-59 programmable hand calculator. This program performed the following functions:

(1) Determined the changes in tare loadings, atmospheric pressure and no-flow manometer height between the beginning and end of a series of test runs. A linear interpolation, based upon run number of a series, was then used to determine the value of these parameters for each run.

(2) Air and water temperatures were used to determine the vapor pressure of water at the two temperatures (p_{vw} and p_{va}). The vapor pressure of water at the room air temperature was used to correct the reading of the mercury column which was used for indication of tunnel static pressure, since this reading (p) was actually static pressure minus the vapor pressure of water at room temperature. Tunnel water temperature was also used to determine its density, ρ, and kinematic viscosity, ν.

(3) Tabulated values for the conversion from manometer height to velocity for the range of values encountered in a given test were entered and stored. They were then used in a linear interpolation to determine flow speed.

(4) For each value of static pressure where data was recorded during the test, the following calculations were made:

(a) Manometer height was entered, corrected for the no-flow zero and converted to flow speed, U_∞, in feet per second.

(b) Static pressure reading, p, was entered. To this value the vapor pressure of water at room temperature, p_{va}, was added to give the true static pressure at the tunnel axis:

$$p_{stat} = p + p_{va}$$

(c) Propeller RPM was entered and converted to revolutions per second, n.

(d) Propeller thrust reading was entered and corrected for the tare loading. A correction for the change in thrust from the pressure differential between tunnel static pressure and atmospheric pressure acting across the 1.317 in diameter propeller shaft was then applied to give the actual thrust, T. The thrust coefficient

$$K_T = \frac{T}{\rho n^2 D^4}$$

where D is the propeller diameter, was then calculated.

(e) This value of K_t was used to determine the advance coefficient, J, from the open water test results provided for this propeller, This value was entered and stored for later use.

(f) For the first pressure increment for each test, the measured torque was then entered, where

it was corrected for the tare loading to give measured torque, Q, and a torque coefficient,

$$K_Q = \frac{Q}{\rho n^2 D^5}$$

was calculated. The open water test results were entered with this value of K_Q to verify that the J obtained in the previous step was reasonable. The value of J obtained from the thrust identity was used for the cavitation inception curve. In addition, at this step, the 0.7 radius Reynolds number,

$$R = \frac{c_{0.7} \times (V_a{}^2 + (0.7\pi nD)^2)^{\frac{1}{2}}}{\nu}$$

where V_a is the average inflow velocity seen at the propeller (calculated from J) and $c_{0.7}$ was the blade chord at the 0.7 radius, was calculated.

(g) Finally, the cavitation number,

$$\sigma = \frac{p_{stat} - p_{vw}}{\frac{1}{2}\rho U_\infty^2}$$

Once the data was reduced, and a value of J and σ could be assigned to each data run, it was necessary to determine which run represented the cavitation index at inception, σ_i, for each value of J. The criteria used to define inception are as follows:

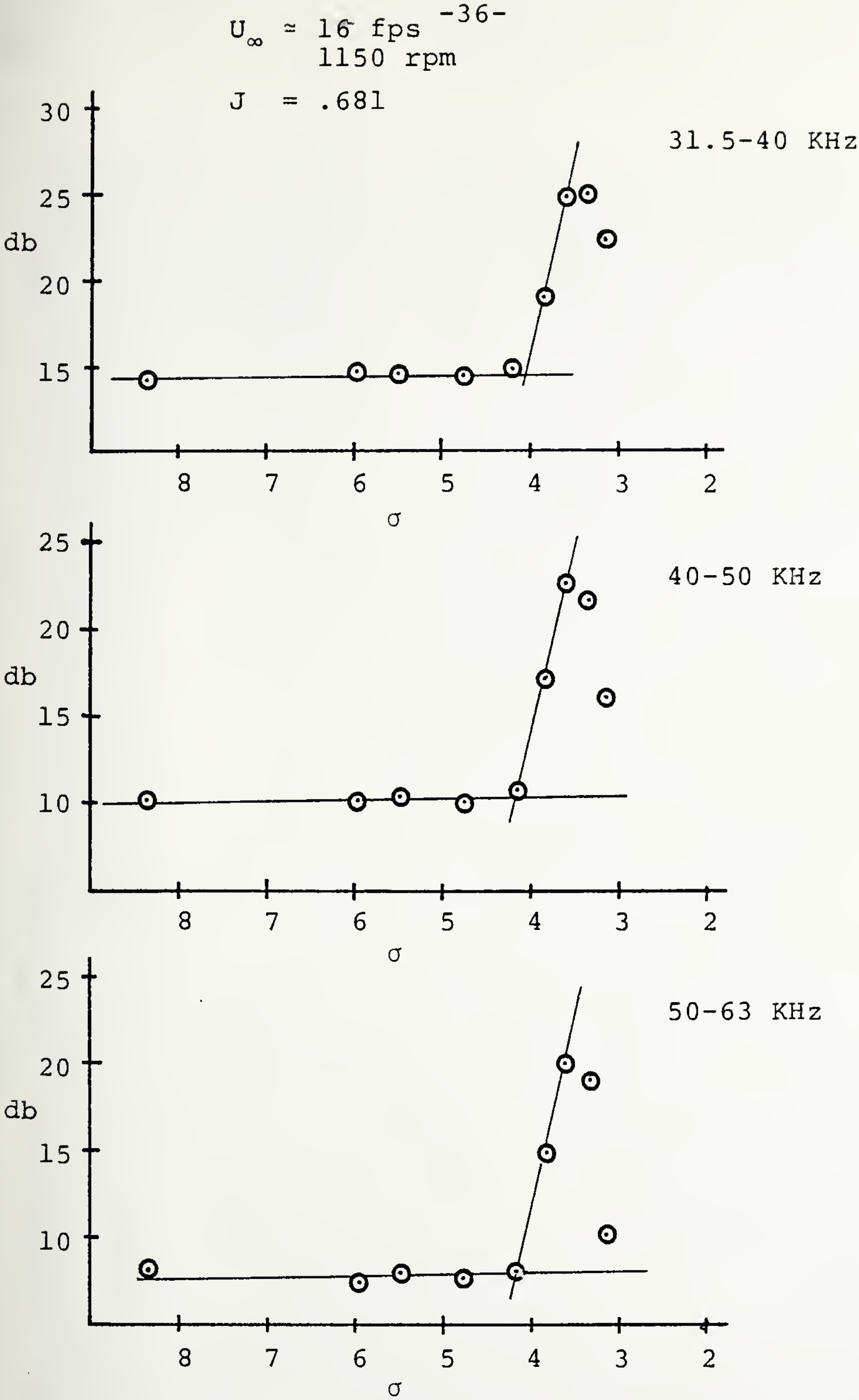
(1) Visual observation - Hub vortex cavitation had a different criterion from all other types. For it, the

appearance of a trail of bubbles from the vicinity of the hub was used as the criterion. For other types of cavitation, the criterion was to have a steady occurrence of that type of cavitation on more than one blade. Steady occurrence meant that the cavitation was present on each revolution of the propeller at one location, but not necessarily throughout the entire revolution.

(2) One third octave band level - the arbitrary db level displayed on the measuring amplifier meter was plotted against decreasing cavitation index as shown in figure 8. The value of σ which corresponded to the curve after the "knee" being 3 db above the extension of the curve before the knee was taken as σ_i.

(3) Spectral analysis, complete spectrum - an increase of 3 db from the level at atmospheric pressure across the 40-50 kHz portion of the spectrum was taken as the criteria. The three spectra in figures 9, 10 and 11 correspond to a fixed J, 0.51, and three different values of σ: that for atmospheric pressure, σ_i for acoustically determined inception and σ_i for acoustically determined inception, respectively. The differences between these spectra are very slight and tend to make the determination of inception difficult and rather arbitrary. For this reason, this method was abandoned in favor of using the demodulated analysis.

(4) Spectral analysis, demodulated signal - it was assumed that the presence of a sharp peak ("line") at shaft rate frequency indicated one blade cavitating, and that a



Typical One-Third Octave Band Levels vs. Cavitation Index
Figure 8

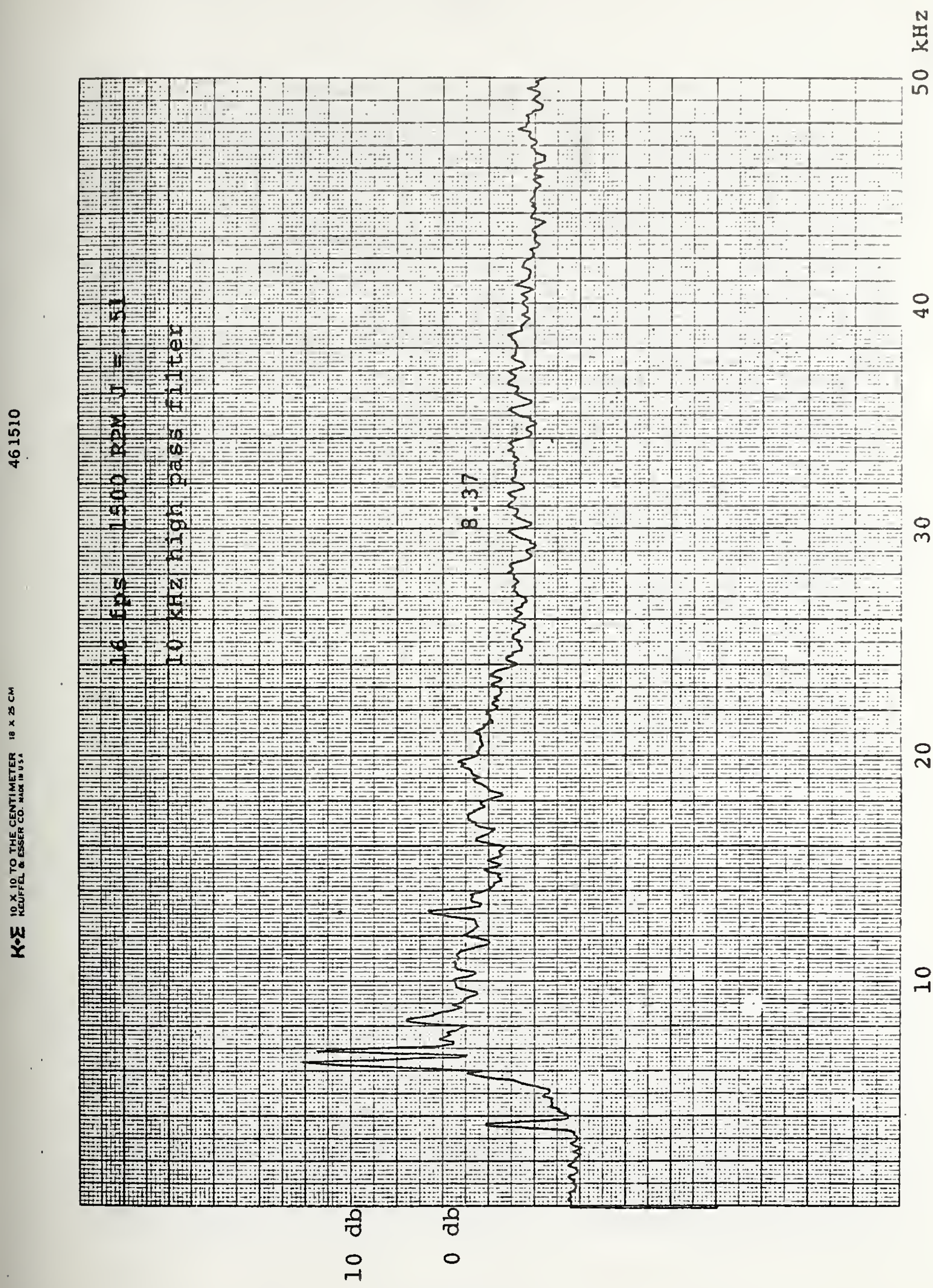

16 fps 1500 RPM J = .51
10 kHz high pass filter
8.37
10 db
0 db
10
20
30
40
50 kHz
461510
K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM
KEUFFEL & ESSER CO.

Figure 9

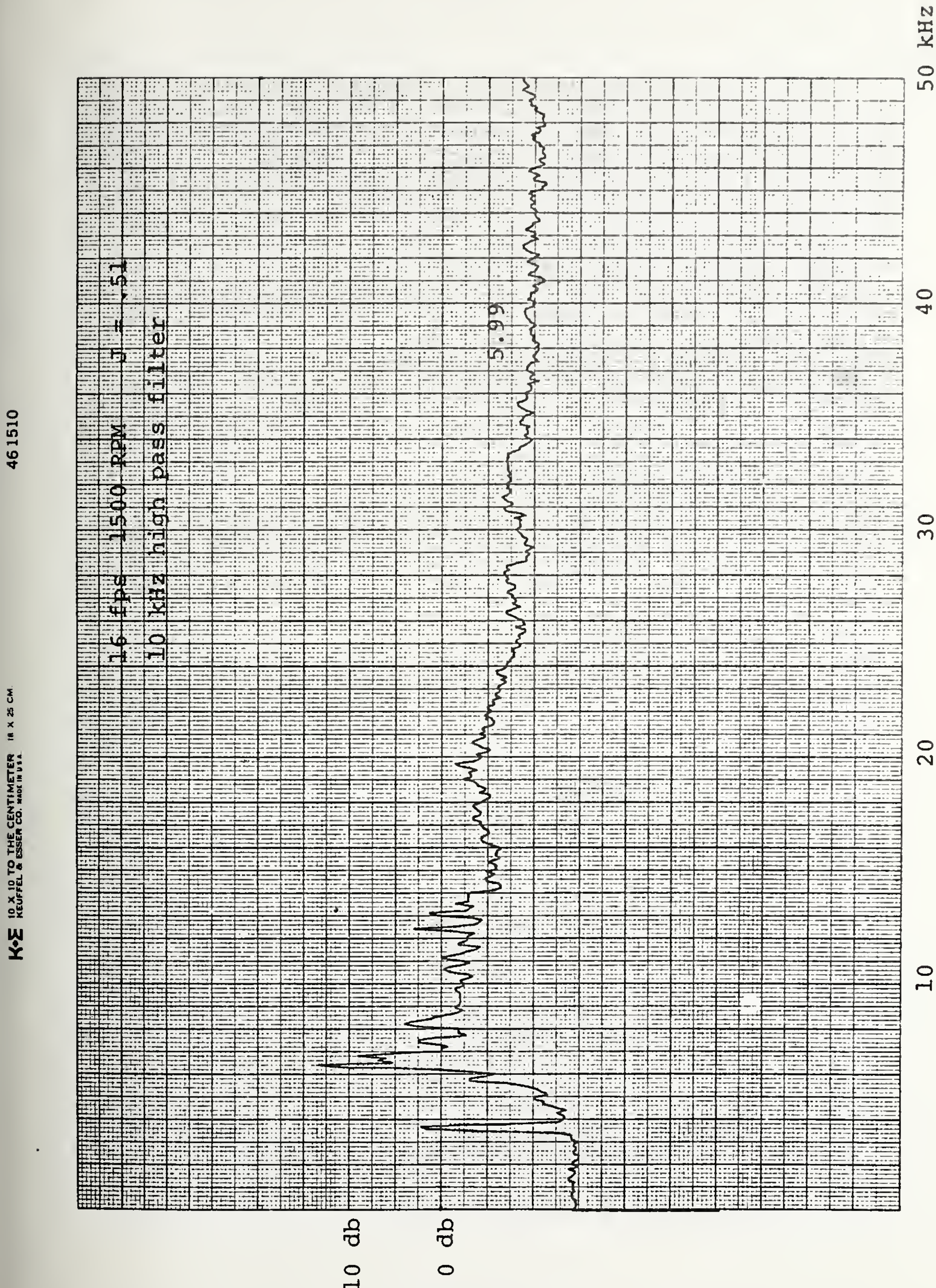

16 fps 1500 RPM J = .51
10 kHz high pass filter
5.99
10
20
30
40
50 kHz
10 db
0 db

Figure 10

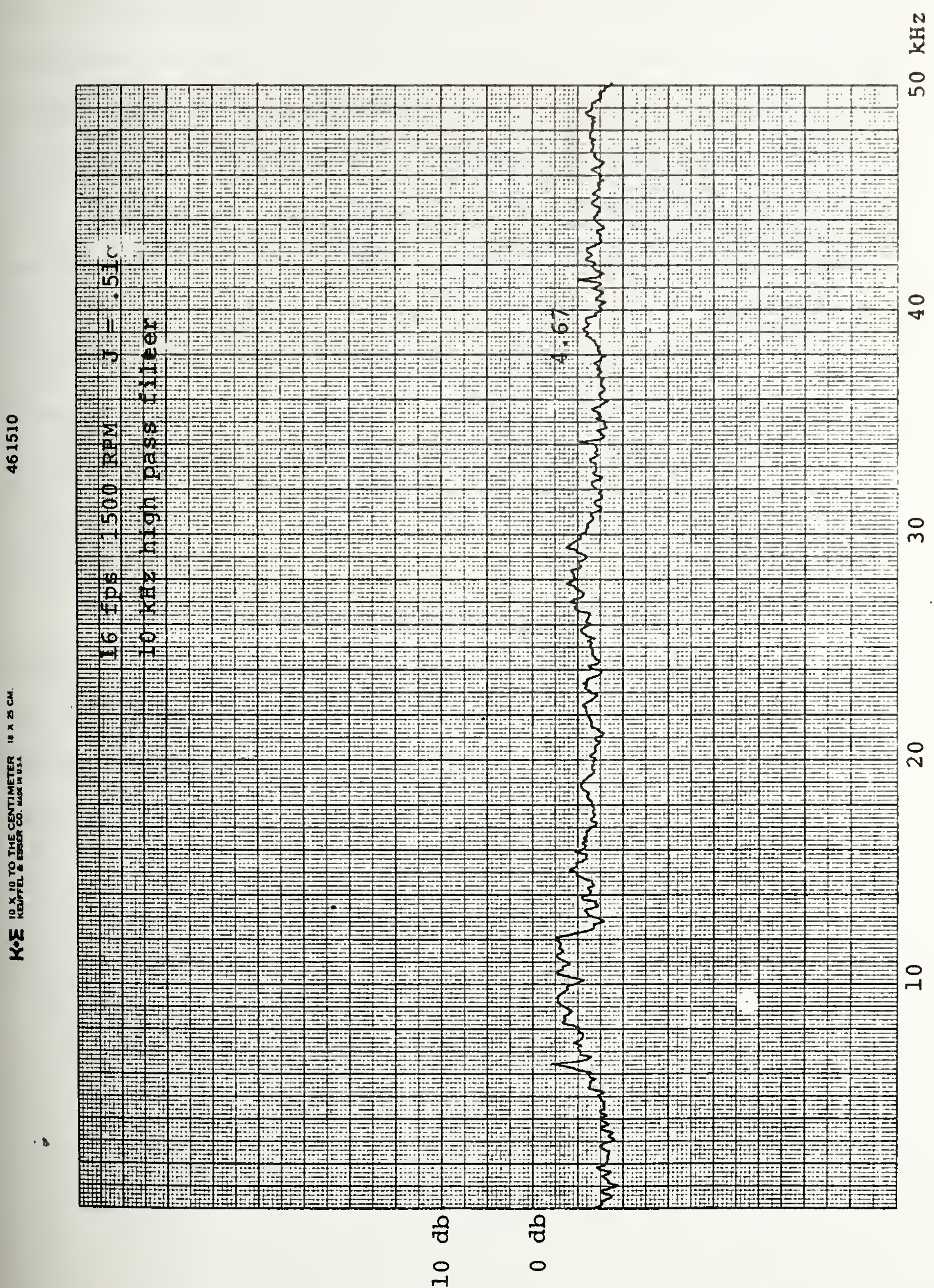

16 fps 1500 RPM J = .51
10 kHz high pass filter
4.67
10
20
30
40
50 kHz
10 db
0 db

Figure 11

line at blade rate (number of blades times shaft rate) indicated all blades were cavitating (despite the possibility of the blade rate line merely being a harmonic of the shaft rate line). The inception criteria for this analysis was first taken to be the presence of lines at both shaft rate and blade rate which were at least 3 db above the general trend of the noise. A subsequent and less stringent criteria finally adopted was to require the presence of a line 3 db above the noise at blade rate frequency, with other lines present at shaft rate spacing to verify that cavitation was causing the line. Typical demodulated spectra are shown in figures 12 and 13.

For each test, the value of σ_i obtained was plotted against J to produce the cavitation inception curve. The two different inception criteria for the demodulated signal analysis were plotted on the same graph, but with contrasting symbols and curves.

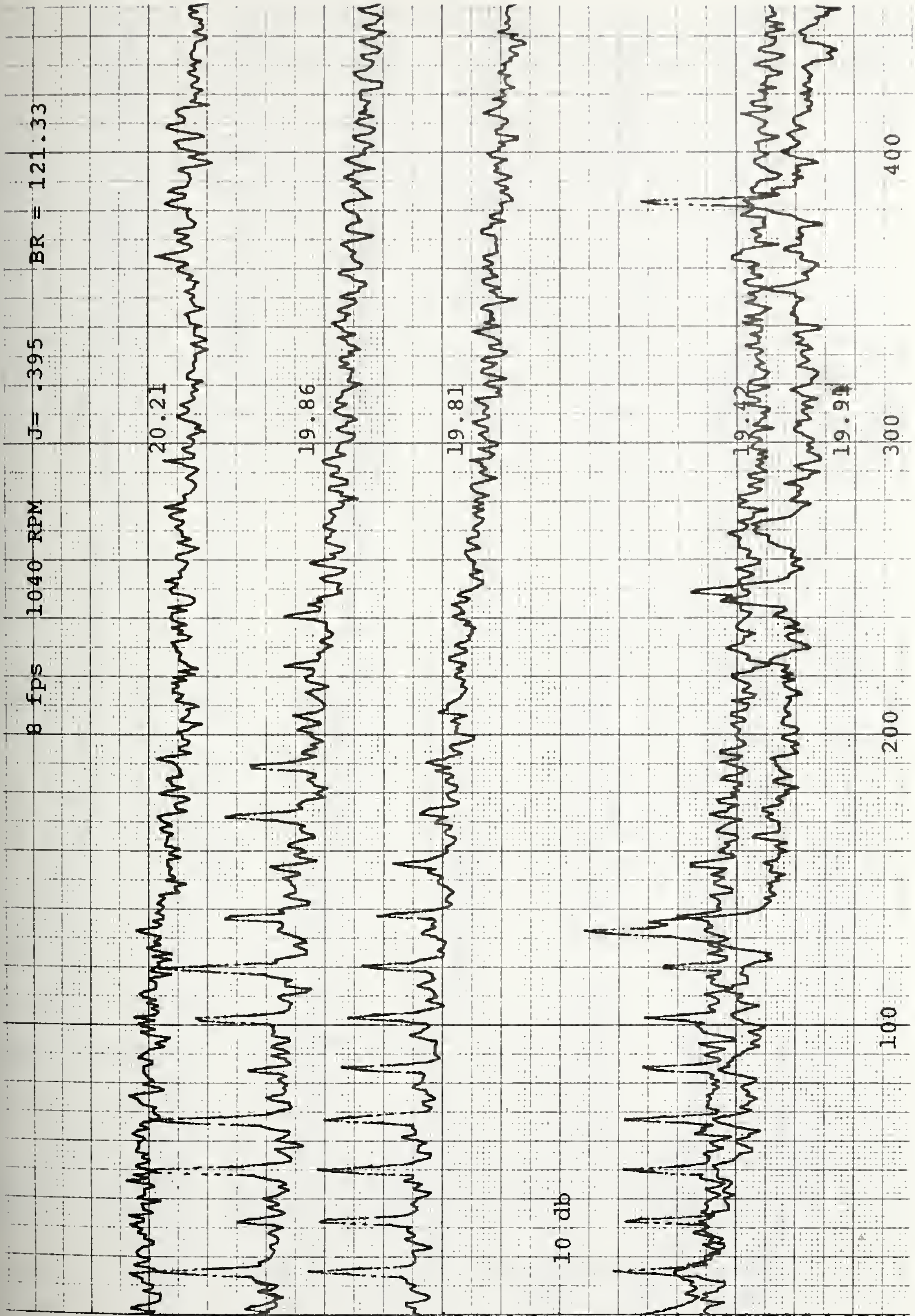

8 fps 1040 RPM J= .395 BR = 121.33
20.21
19.86
19.81
19.42
19.91
10 db
100
200
300
400

Figure 12

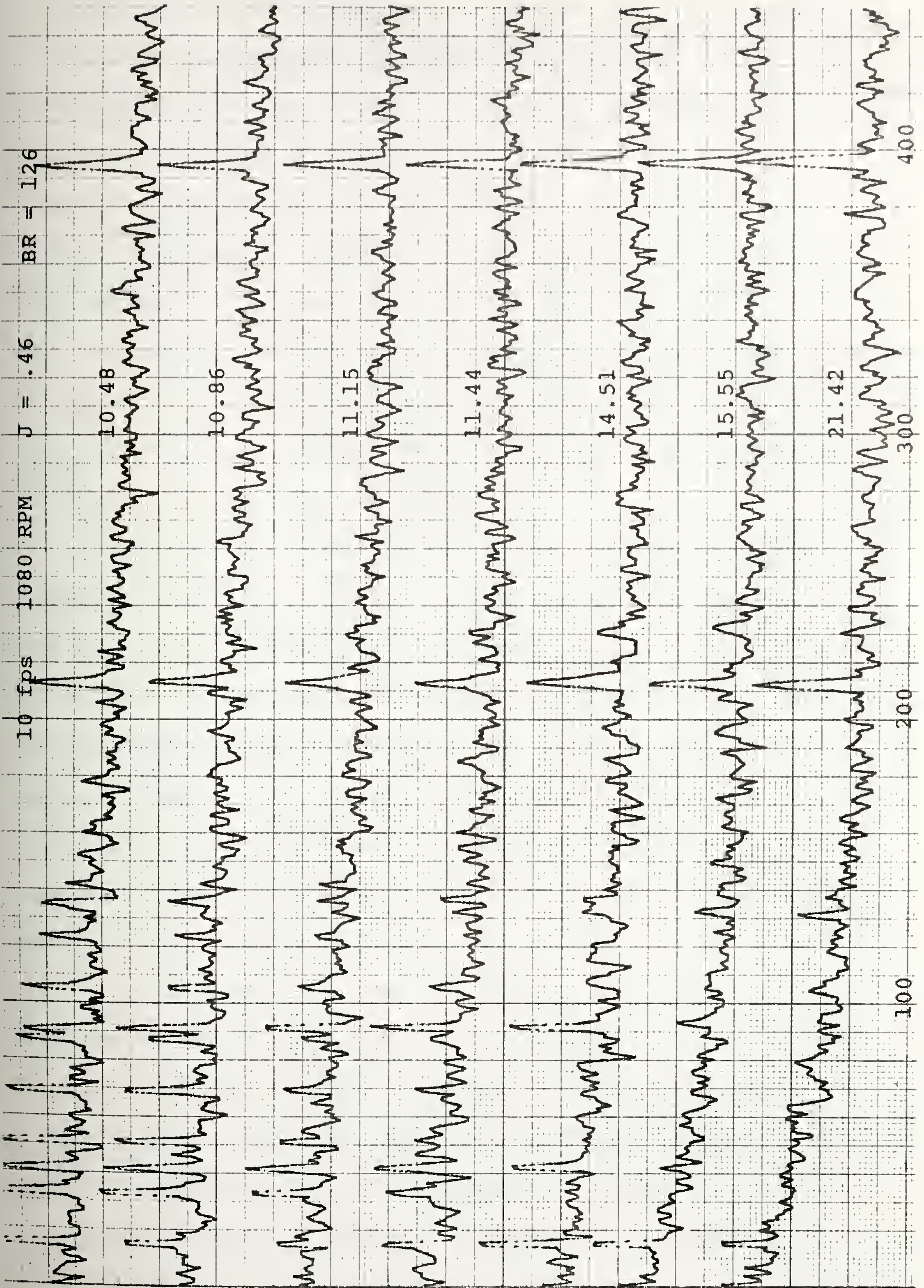

10 fps 1080 RPM J = .46 BR = 126
10.48
10.86
11.15
11.44
14.51
15.55
21.42
100
200
300
400

Figure 13

V. RESULTS AND DISCUSSION

Curves of σ_i versus J for the visual and acoustic cavitation inception determinations are presented in figures 14 through 18. The comparison of acoustic and visual determinations for the one-third octave acoustic level measurements (figures 14 and 15) show a reasonably good agreement between the acoustically determined curve and the portion of the visually determined curve corresponding to the back bubble cavitation. However, tip vortex and leading edge face cavitation do not appear to be detected acoustically with the setup used.

Comparing the acoustic and visual results for the demodulated analysis of the acoustic signal figures 16, 17 and 18 shows a much better agreement for all types of cavitation, except for hub vortex cavitation. The results of the demodulated analysis of the 50-63 kHz band (figure 17) agrees almost exactly with the visually determined results for both of the inception criteria used with the acoustic analysis. The demodulated analysis of the acoustic signal above 20 kHz (figure 18) shows cavitation inception occurring at a higher value of σ for tip vortex cavitation than for the visual results, and at about equivalent values of σ for leading edge cavitation. The less stringent criteria for acoustically determined inception shows cavitation occurring at a higher value of σ than the more stringent criteria.

The two sets of results presented use different acoustic sensors. For the one-third octave level measurements,

Figure 14

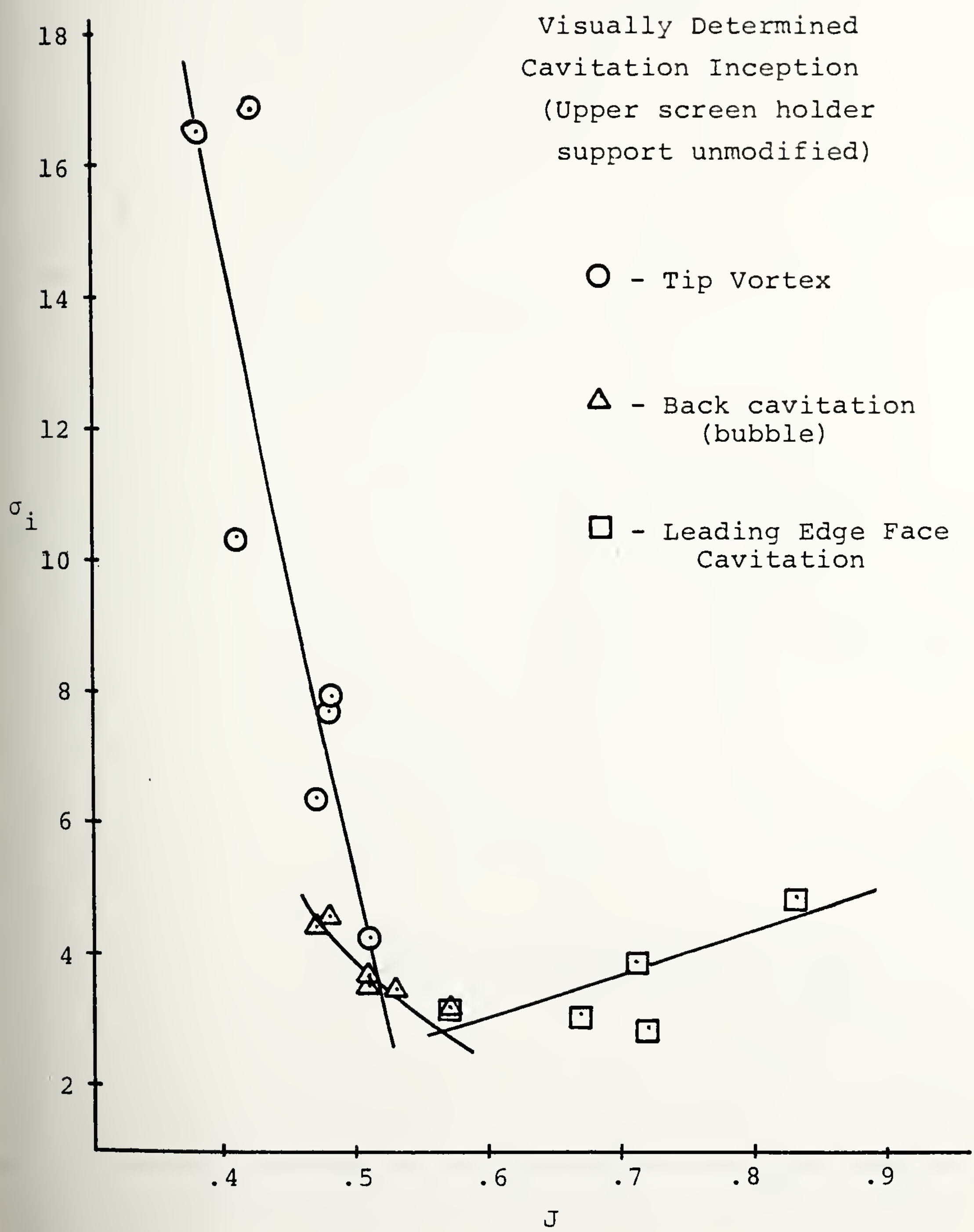

Visually Determined
Cavitation Inception
(Upper screen holder
support unmodified)
○ - Tip Vortex
△ - Back cavitation
(bubble)
□ - Leading Edge Face
Cavitation
σ_i
18
16
14
12
10
8
6
4
2
.4
.5
.6
.7
.8
.9
J

Figure 15

Acoustically Determined
Cavitation Inception
(Inception based upon one-third octave band level.
Data point is average over
three bands - 30 to 60 KHz)

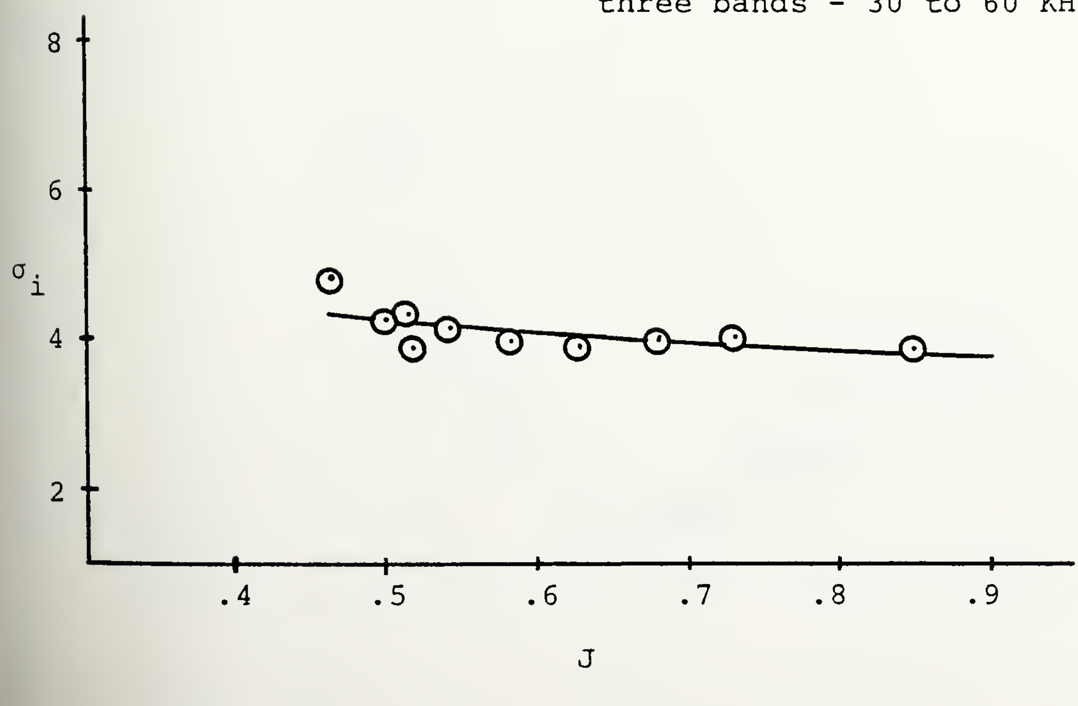


Figure 16

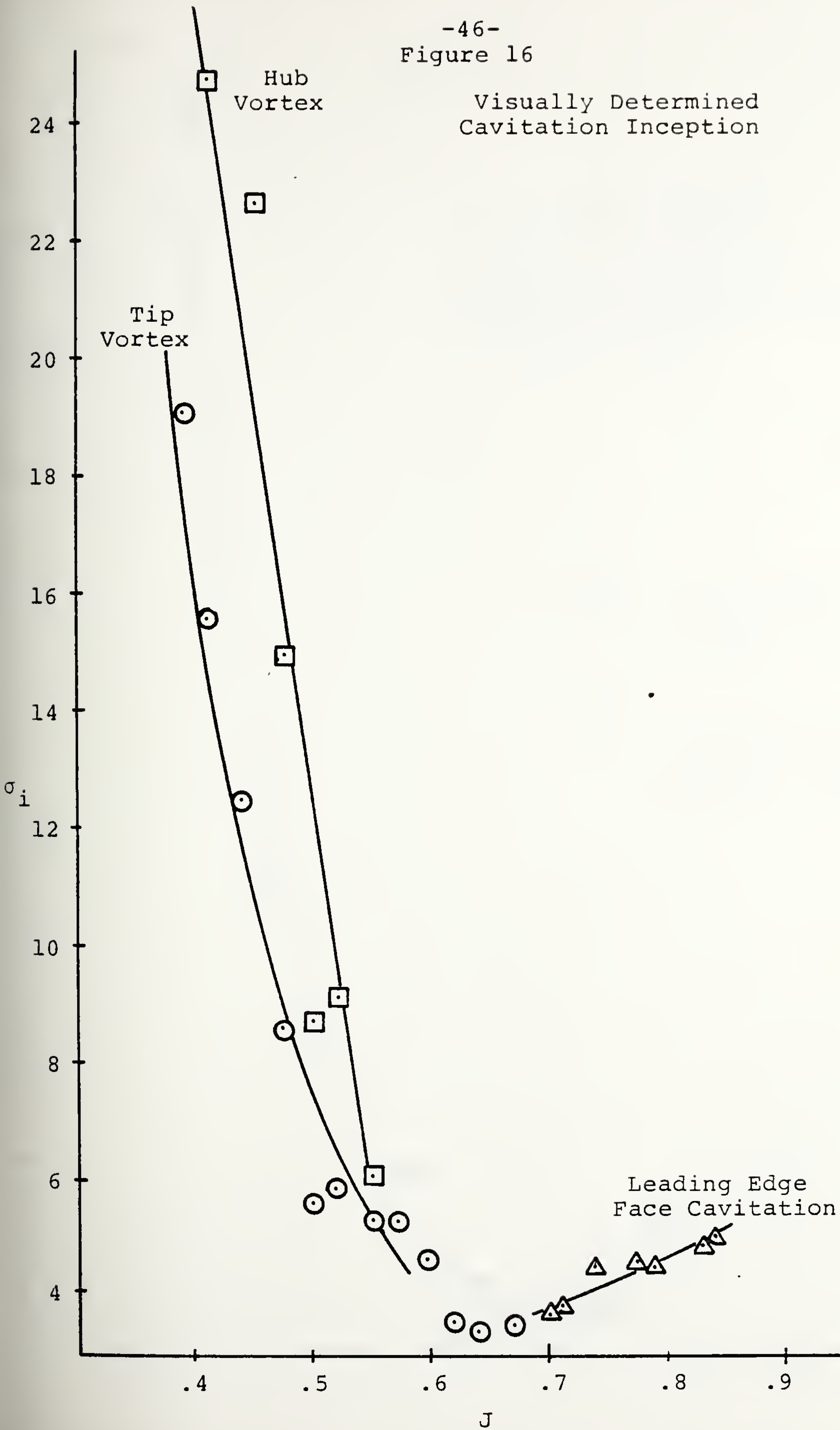

Hub
Vortex
Visually Determined
Cavitation Inception
Tip
Vortex
Leading Edge
Face Cavitation
24
22
20
18
16
14
12
10
8
6
4
σ_i
.4
.5
.6
.7
.8
.9
J

Figure 17

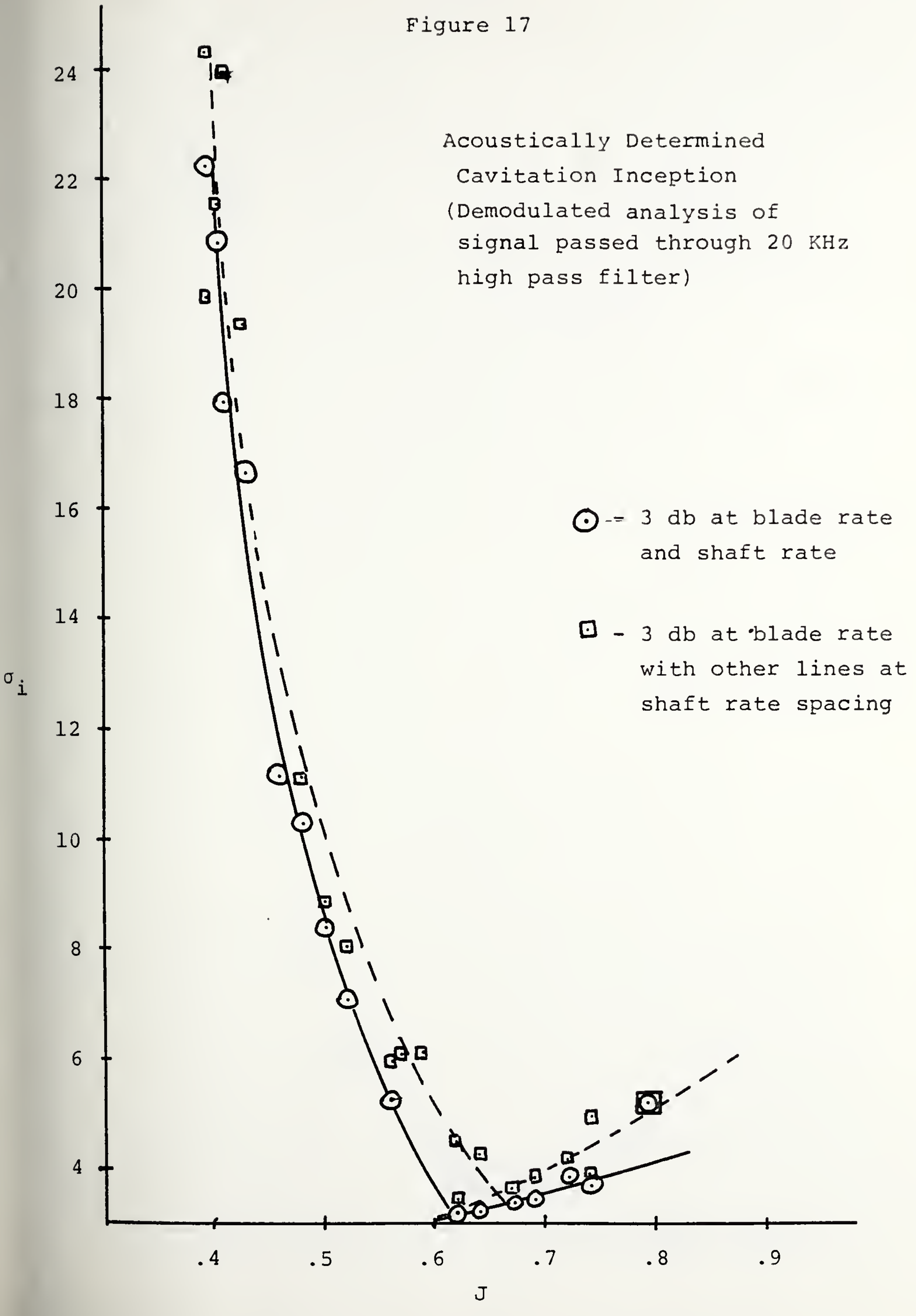
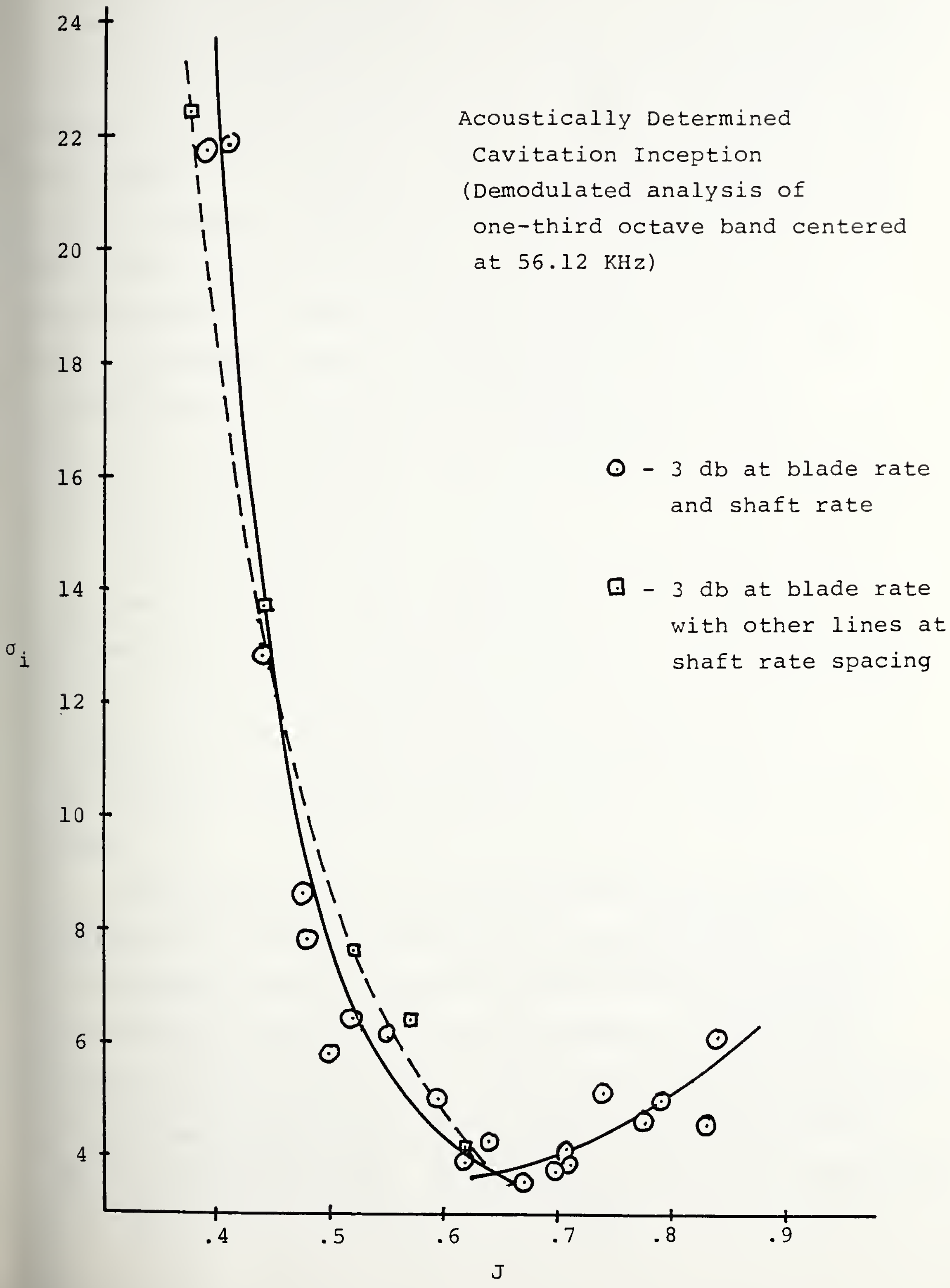

Acoustically Determined
Cavitation Inception
(Demodulated analysis of
signal passed through 20 KHz
high pass filter)
- 3 db at blade rate
and shaft rate
- 3 db at blade rate
with other lines at
shaft rate spacing
24
22
20
18
16
14
12
10
8
6
4
σi
.4
.5
.6
.7
.8
.9
J

Figure 18



24
22
20
18
16
14
12
10
8
6
4
σ_i
.4
.5
.6
.7
.8
.9
J
Acoustically Determined Cavitation Inception (Demodulated analysis of one-third octave band centered at 56.12 KHz)
⊙ - 3 db at blade rate and shaft rate
⊡ - 3 db at blade rate with other lines at shaft rate spacing

the accelerometer was used; but the demodulated analysis presented used the hydrophone, since it was felt that the higher usable frequency for the hydrophone was necessary. However, a test run at J=0.62 (run number 2 of 4 March) was performed to compare the acoustic information obtained from the two sensors. Examples of the demodulated spectra from the two sensors for a given σ are shown in figures 19 (hydrophone) and 20 (accelerometer). Except for the equipment gain adjustments needed to accomodate the different sensitivities of the sensors, the spectra are almost identical, indicating that either sensor was usable for an acoustic detection method.

It was expected that the curves of σ_i versus J would show good agreement between the acoustic and visually determined cavitation inception, and these results confirm this. It was also expected that the acoustically determined inception would anticipate (occur at a higher value of σ) the visually determined inception. This, in general, did not occur.

The higher value of σ at acoustically determined inception is based upon bubble size considerations. It was first assumed that the minimum bubble diameter which could be detected visually under the conditions of a propeller cavitation test was 0.001 in. This size was then taken to be the maximum diameter ($2R_1$) of a bubble in the calculation shown by Strasberg (1977) for the total lifetime of the cavity,

$$T = 2.7\ R_1 \sqrt{\rho/P_o}$$

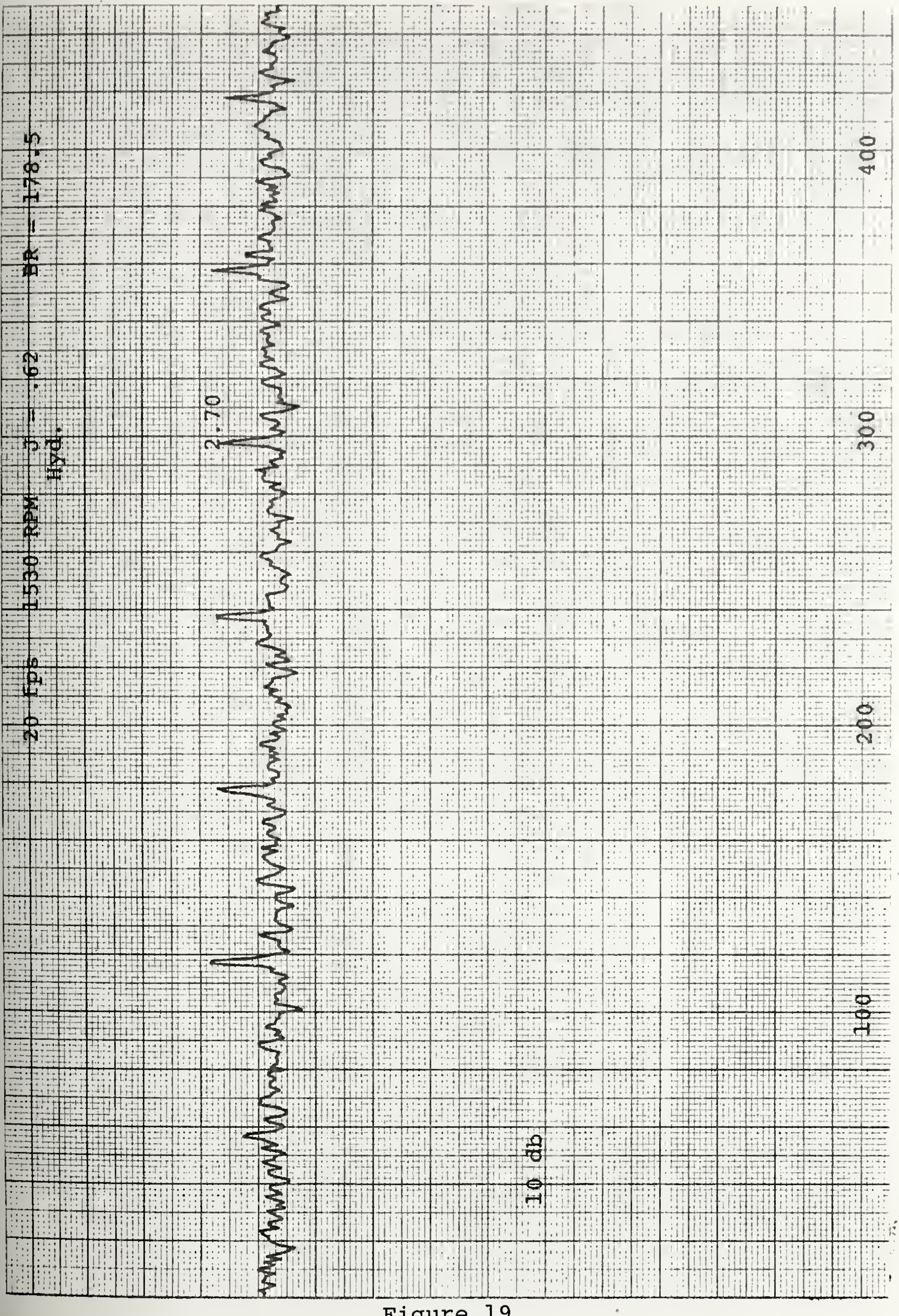


Figure 19

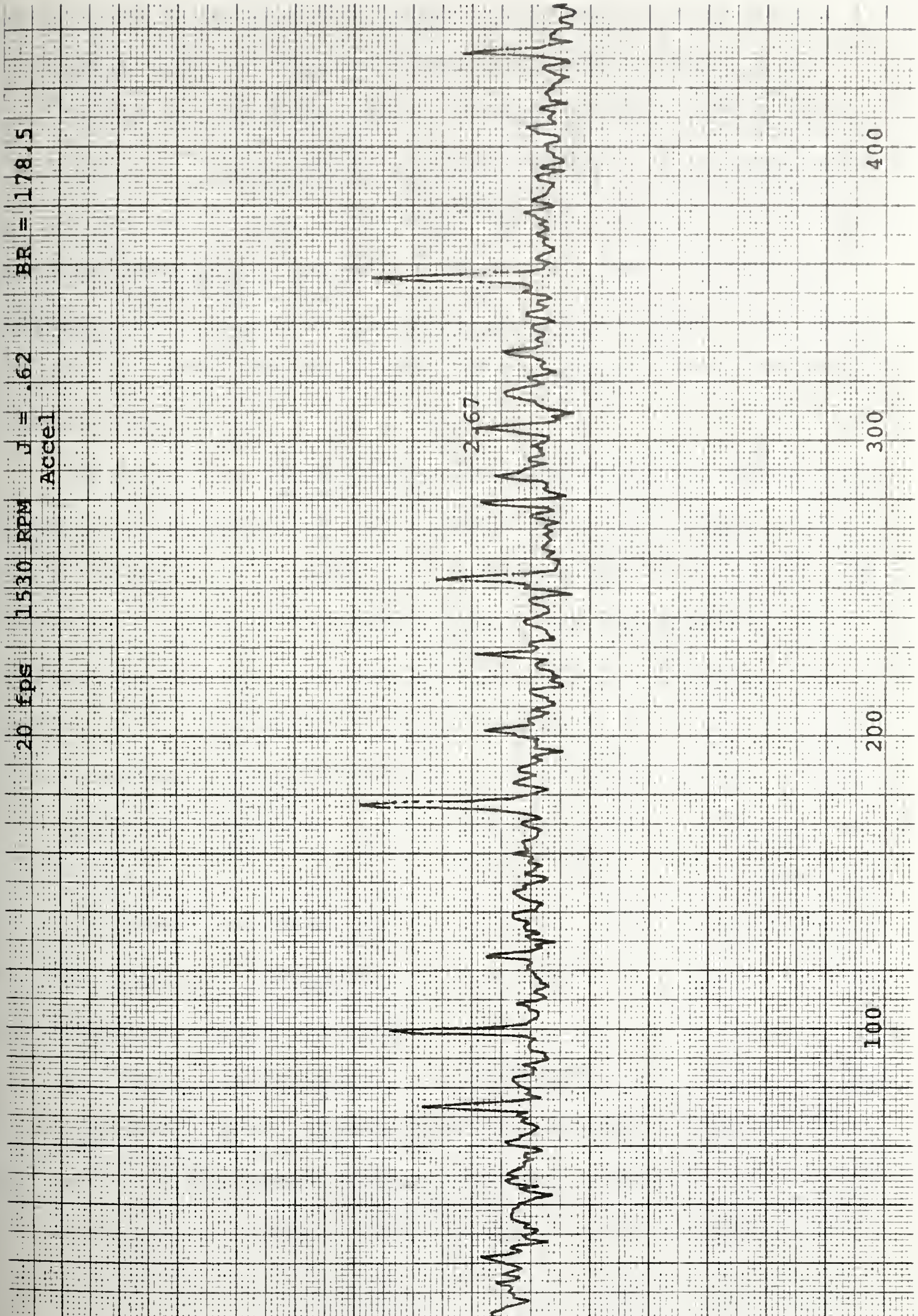


Figure 20

where ρ and P_o were taken to be representative of the conditions in a cavitation test, $\rho = 1.93$ lb-sec^2/ft^4, $P_o = 400$ mm Hg, or 1114 lb/ft^2. Under these conditions, $T = 5.62 \times 10^{-4}$ sec, which corresponds to a frequency peak, f_p, in the cavitation noise spectrum of 17 kHz. With P_o equal to atmospheric pressure, $f_p = 24.5$ kHz. Since the frequency used for this analysis was much higher than these, it was felt that the detection of inception would occur at a higher value of σ.

Two possible explanations for the observed result not being in agreement with the prediction come to mind. The first is that the existence of scale effects (affecting the frequency scaling), due particularly to compressibility, surface tension and viscous effects, were not taken into account. If this caused the discrepancy, the use of high frequency acoustic information to anticipate visual inception determination would not be a workable scheme. However, if the expected acoustic signal was present, but was not detectable with the method or equipment used here, then anticipating the visual inception determination is possible, so long as the appropriate changes are made.

If the 0.001 in diameter bubble mentioned above is used with Strasberg's non-dimensionalization for acoustic power, the ratio of the power output with the spectral peak at 56 kHz to that with the just barely visible bubble are given by,

$$\frac{\tilde{P}_{acoustic}}{\tilde{P}_{visual}} = \frac{D_a}{D_v} = \frac{f_v}{f_a} = \frac{17}{56} = 0.304$$

or about 10 db. Thus, without considering the noise present or the increased absorption of the high frequency signal, 10 db of gain are required to have an equal acoustic signal with the two conditions. When these other considerations are included, it becomes obvious that increasing the gain of the signal or decreasing the level of noise, or both, is needed. The dramatic change between the inception information obtainable with a one-third octave analysis and that obtainable with the demodulated analysis tends to verify this.

By using an acoustic sensor which had some degree of directivity, either by using an array of hydrophones or by using some sort of reflector, an increase in the signal to noise ratio could be expected. Problems encountered with the instrumentation used could be corrected:

(1) There was no account taken of the changes in absorption that occurs as air bubbles grow when the pressure is reduced in the test section. The use of a calibrated reference signal in the frequency range of interest would enable correction of the acoustic signal levels for absorption.

(2) The combination of spectrum analyzer and X-Y plotter used required about three minutes to produce a paper copy of the demodulated spectrum, and the concurrent acoustic and visual cavitation inception determination extended this time span to the range of four to five minutes. Thus, for each value of static pressure for a given J, about four minutes were required, and the time required to produce each data point on the σ_i versus J curve was about thirty minutes.

Because of time constraints on the availability of the test facilities and equipment, and the time required for each data point, two factors added to the inaccuracies in the results. First, each data point represented only one test at that value of J. Second, the steps in tunnel static pressure used were on the order of 25 mm Hg. This represents an error of 2 units of cavitation index at a tunnel flow speed of 6 feet per second or 0.3 units at 16 feet per second.

A more rapid analysis of the demodulated spectrum would make the method less time-consuming.

(3) During the time required for the spectrum analysis and averaging, tunnel flow speed and static pressure and propeller RPM would tend to drift on the order of one to five percent. The cumulative effects of these changes would also affect the accuracy of the analysis by causing variations (although slight) in the frequency of interest and by affecting the values of σ and J for the test run.

VI. CONCLUSIONS

Strasberg (1977) points out that "it is not possible to estimate the inception cavitation number of the prototype from model measurements without using empirically or theoretically determined scale factors." However, the results here show that it is possible to determine the cavitation inception performance of a model propeller by acoustic means at least as accurately as by visual means, as long as an adequate system for detecting the noise from all types of cavitation was available. And although the acoustically determined inception would require the same scale factors mentioned by Strasberg to predict full scale inception, the use of an acoustic inception determination technique for model tests does have advantages.

First, where full scale inception measurements are made acoustically, an acoustic measurement technique for the model would eliminate any scale effect that would occur between model and full scale measurements caused by visual observation on the model and acoustic determination on the full scale propeller. Although the results indicate that for the propeller tested here this scale effect would be small, the test of a different propeller, with a different length scale might show a greater difference between acoustic and visual results.

Second, displaying the spectrum of the demodulated cavitation noise signal gives a more definitive criteria for inception than visual methods, as expected.

VII. REFERENCES

Fitzpatrick, H.M. Strasberg, M.	1959	"Hydrodynamic Sources of Sound," David Taylor Model Basin (DTMB) Report 1269 (Reprinted from the First Symposium on Naval Hydrodynamics
Lehman, A.F.	1964	"Some Cavitation Observation Techniques for Water Tunnels and a Description of the Oceanics Tunnel," Proc. of Symposium on Cavitation Research Facilities and Techniques, American Society of Mechanical Engineers.
McCarthy, J.H.	1963	"A Method of Wake Production in Water Tunnels," DTMB Report 1785.
Pope, A Harper, J.J.	1966	Low Speed Wind Tunnel Testing, John Wiley & Sons, Inc., New York.
Rose, J.D., Jr.	1969	"IBM-7090 Computer Program for Design Calculations of Wake Screens," David Taylor Naval Ship Research and Development Center Hydrodynamics Laboratory Technical Note 59.
Ross, D.	1976	Mechanics of Underwater Noise, Pergamon Press, Elmsford, New York.
Strasberg, M.	1946	"The Development of Cavitation Noise by Model Propellers," DTMB Report 543.
Strasberg, M.	1977	"Propeller Cavitation Noise: Thirty Years of Research," in Noise and Fluids Engineering, presented at the ASME Winter Meeting.

Appendix A

Details of the Wake Screen Design

The method developed by McCarthy (1963) and adapted into a FORTRAN program by Rose (1969) attempts to determine the value of the non-dimensional resistance coefficient for a grid,

$$K = \frac{\Delta p}{\frac{1}{2}\rho w_o^2} \qquad (1)$$

where Δp is the local static pressure drop across the screen grid and w_o is the local velocity normal to the grid. McCarthy points out that an empirical estimate for K for a given screen laid over a support screen is given by

$$K = 0.78 \frac{s}{(1-s)^2} + K_s \qquad (2)$$

where: s, the solidity ratio for the screen = MD(2-MD)

M is the number of wires per inch in the mesh

D is the diameter of the wire in inches

K_s is the resistance coefficient for the support screen

The program written by Rose requires that the test section area be subdivided into smaller areas, A_i, with a flow velocity, V_i, associated with each area, which is the average velocity for the subdivision. The overall velocity average is then calculated,

$$V_{avg} = \frac{\Sigma A_i V_i}{\Sigma A_i} \qquad (3)$$

Then, for each area, the resistance coefficient, K_i, is calculated as follows:

(1) The integration constant, γ_o, from McCarthy's solution is determined from the area having the maximum average velocity, V_{max}, which is assumed to have the resistance coefficient, K_s, for the support screen only:

$$\gamma_o = \frac{1}{N}\left[\frac{(2+K_s-\chi_s)^2}{\chi_s+1}\right]^{1/3}\left[\frac{V_{max}}{V_{avg}} - 1\right] + \chi_s - \frac{1}{6(K_s+1)} \qquad (4)$$

where $\chi_s = (1+K_s)^{1/2}$

$N = 1.02$

(2) For each area, A_i, with its associated V_i, K_i is determined by solving the following equation for K_i:

$$\frac{V_i}{V_{avg}} = 1 + \left[\gamma_o - \chi_i - \frac{1}{6(K_i+1)}\right] N \left[\frac{\chi_i+1}{(2+K_i+\chi_i)^2}\right]^{1/3} \qquad (5)$$

where $\chi_i = (1+K_i)^{1/2}$

$N = 1.02$

(3) Once K_i is determined for each area, the last step is to account for the deflections of the streamlines by the changes in velocity caused by the wake screen. This is done by an iterative procedure which adjusts the areas, A_i, until the volume flow rate at the screen is equal to the volume flow rate at the propeller (this assumes that the screen is within

one tunnel diameter of the propeller, and it uses an empirical constant, α). The result is a correction to the actual screen area for each subdivision.

For this experiment, this program was adapted for use with a TI-59 programmable hand calculator. The test section was divided into four areas, each with its associated velocity, as shown in Table A-1. These areas and velocities were based upon the desired circumferential mean wake information provided for the velocities over the propeller disk, and an estimate for the average velocity outside that area. For each area, K_i and the area correction, ΔA_i, were determined from the program.

At this point Rose's method and the one used here become different. When a large number of screens with different meshes and wire diameters are available, having a screen available with the proper resistance coefficient enables the final wake screen to be assembled by piecing together the correct screens on the support screen. But here, the desired screens were not all available, so an alternative had to be developed.

The alternative was based on an interpretation of information given in Pope and Harper (1966) on turburlence generation by screens in wind tunnels. This text indicates that the cumulative effect of several layers of screens was additive. This seemed to be supported by the empirical formula for K in equation (2), where the effect of the support screen and the wake producing screen are added. It was

Table A-1

Wake Characteristics

Area Designation	Range of r/R	A_i	V_i	$A_{i\ cor}$	r/R corr	K_{req}
1	∞ - 1.0	308.39	.97	317.86	∞ -.946	0.4612
2	1.0-0.7	46.72	.817	44.51	.946-.641	0.9462
3	.7-.5	21.99	.636	18.78	.641-.454	1.756
4	.5-.23	18.06	.510	14.01	.454-.23	2.531

felt that, even though Pope and Harper note that the effect of the screens was additive only if they did not touch, assuming that the effect was additive would be satisfactory for a first approximation.

Thus, the desired initial K_i values were obtained by using several layers of two different screens. The characteristics of these screens are listed in Table A-2, and the actual K_i for the screens used is listed in Table A-1. The was screen was then assembled, with the pieces of screen wired onto the support screen with pieces of 0.020 in stainless steel wire. A wake survey conducted with the Laser Doppler Anemometer was performed along the diagonal line shown in figure 3 previously.

The determination of velocities in the wake was done with the propeller removed from the shaft. The longitudinal flow speeds were determined in the plane 2.5 in downstream of the propeller blade leading edges. The results of this and all other wake surveys performed are contained in Appendix B.1. The results for this initial screen are plotted in figure A-1.

From the plot of non-dimensional velocity versus non-dimensional radius, r/R, it was possible to determine the average velocities actually obtained for each of the subdivided areas used, since the wake was to be axisymmetric. From the actual values of V_i, equations (4) and (5) were then used to determine the actual K_i obtained from the screen used for each area, shown in Table A-3. At this point it was

Table A-2

Screen Characteristics

Mesh, M	Wire Diameter, D	Solidity ratio, s	$K-K_s$
8×8	0.020 in	.2944	.4612
18×18	0.012 in	.3853	.7956

Table A-3

Comparison of Installed and Measured K Values

Area	K_{req}	K_{inst}	ΔK_{inst}	K_{meas}	ΔK_{meas}	ΔK ratio
1	0.4612	0.4612	-	0.4612	-	-
2	0.9462	0.9224	0.4612	1.1813	0.7201	1.560
3	1.756	1.7179	0.7954	2.4197	1.2384	1.557
4	2.531	2.5134	0.7954	4.106	1.6863	2.120

assumed that the calculated drag associated with the support screen was correct, and the remaining screen layers could be adjusted to develop the desired wake.

Still assuming that the effect of multiple layers of screen material was additive, the measured increase in K_i for each increment of screen material was determined (ΔK_i in Table A-3). In each case, the ratio of measured ΔK_i to installed ΔK_i was determined. The results of these calculations were interpreted as follows:

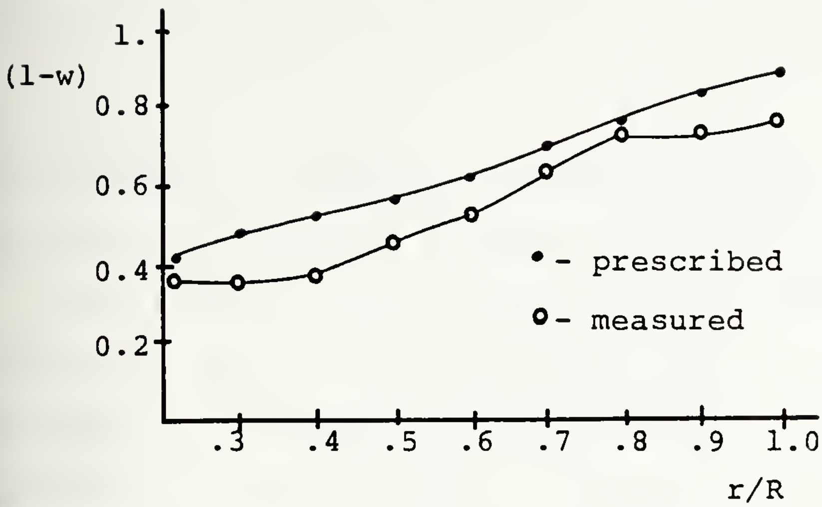
(1) In area 2, the same material as that found in 1 was added, and the increase in K was 1.56 times greater than that expected from the simple addition of resistance coefficients.

(2) Comparing measured results for areas 3 and 4, the increase from adding another layer of the same material was 1.36 ($\frac{1.6863}{1.2384} = 1.36$) times greater than the expected result.

(3) The apparent effect of adding the screen of area 3 onto that of area 2 was 1.56 greater than expected.

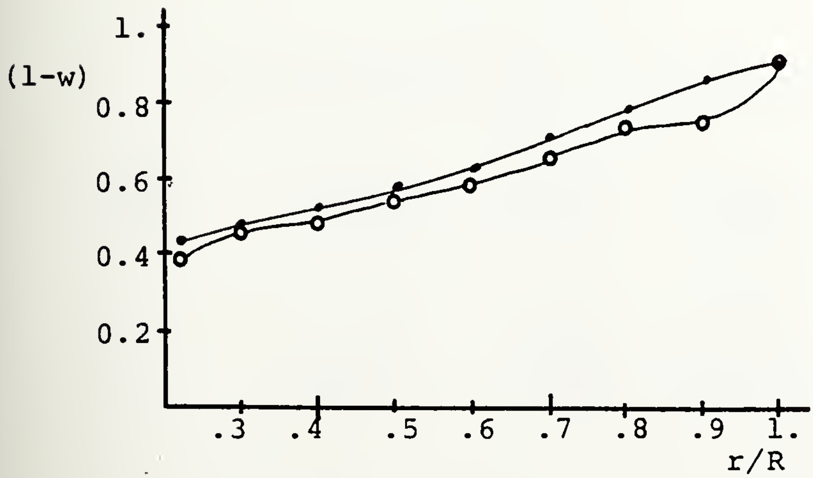
(4) Thus, an average increase in the resistance coefficient from adding layers of screen material was felt to be on the order of 1.5 times the expected result.

In terms of the screen material available, this meant that the 8×8×.020" screen material would be used for all screen layers, with each added layer having 1.5 times the resistance coefficient of the single layer. Table A-4 shows the



Wake Survey - Initial Wake Screen

Figure A-1



Wake Survey - Final Wake Screen

Figure A-2

calculated $K_{installed}$ values for the four wake screen areas compared to the required K values, where

$$K_{calc} = K_s + 1.5K_{screen}$$

This screen was assembled as noted previously, and another wake survey was made at the same points as before.

The results of this survey are shown graphically in figure A-2. The low velocity seen at the outer radii correspond to the use of a screen giving higher than the required value of K in area 2. Lacking a screen with a small enough K to correct this discrepancy, this wake was considered to be acceptable.

Table A-4

Final Screen Resistance Coefficients

Area	K_{req}	K added	K_{calc}
1	0.4612		0.4612
2	0.9462	0.4612	1.148
3	1.756	0.4612	1.836
4	2.531	0.4612	2.523

APPENDIX B

Raw Data

The following pages of this section contain the propeller operating conditions data sheets, the graphs of sound level versus cavitation index for one-third octave level measurements, and the X-Y plotter outputs for the demodulated spectra and for the analysis of the complete spectrum. Since, in some cases, the recorded data may not be completely clear as to what is being presented, some clarifying explanations are presented here.

Wake survey data - For tables B-1 and B-2, the velocity used to obtain (1-w) is the $V_{\infty avg}$ calculated from the 6,7,and 8 inch radial positions. For table B-3, the velocity used is the velocity from the manometer height, 12.0 fps.

One-third octave band level - The conversion factors for T to thrust and Q to torque for this series of tests and for the data of sections B.5, B.6 and B.7 are on the data sheet for run number 1. In these and all subsequent data sheets the first number in the "GAIN CHANGE" column refers to the code number for the amplifier shown in the upper section, the second number gives the setting to which the selector was changed. In the "REMARKS" column for this section only are three numbers which refer to the displayed

level on the measuring amplifier meter for the 31.5-40 kHz band, the 40-50 kHz band, and the 50-63 kHz band,respectively. For all sections of the appendix this column also contains the visual inception determinations as follows: any visual inception determination will have a * , together with a TV for tip vortex cavitation, HV for hub vortex cavitation, LEPF for leading edge pressure face cavitation, LESF for leading edge suction face cavitation, BB or BACK for back bubble or back cavitation. The points plotted on the plots of db versus σ are the arbitrary level from the measuring amp meter. The top plot is the 31.5-40 kHz level, the middle is the 40-50 kHz level, and the bottom is the 50-63 kHz level.

Demodulated Analysis - The conversion factors for thrust and torque for these two sections are on the first data sheet for the 20 kHz high pass signal. On these and all plots from the X-Y plotter, 10 db is represented by 20 of the smallest divisions (2 cm total). For the plots in these two sections, the first plot made was the one at the bottom of the page. For each subsequent plot, the zero setting for the X-Y plotter was placed 2 cm higher (10 db). Unless noted on the associated data sheet, no gain adjustments were made. On these and all subsequent

plots the number typed in beside a particular curve is the value of the cavitation index associated with that plot.

Table B-1

Wake Survey Data -

Initial Wake Screen

R	θ	Scale		Volts	(1-w)
		Hor.	Vert.		
8	135	11.74	91.60	.831,.831,.831	-
7	135	13.08	89.80	.837,.837,.837	-
6	135	14.43	88.01	.827,.827,.827	-
5.4	135	15.24	86.93	.690,.693,.692	.827
4.86	135	15.97	85.96	.637,.638,.637	.762
4.32	135	16.69	84.99	.622,.623,.623	.745
3.78	135	17.42	84.02	.546,.546,.547	.653
3.24	135	18.15	83.05	.443,.440,.443	.528
2.70	135	18.87	82.08	.361,.366,.365	.436
2.16	135	19.60	81.11	.280,.284,.283	.338
1.62	135	20.33	80.14	.269,.268,.270	.321
1.24	135	20.84	79.46	.298,.294,.296	.354
1.24	315	24.18	75.00	.328,.331,.330	.394
1.62	315	24.69	74.32	.339,.341,.343	.408
2.16	315	25.42	73.35	.365,.362,.360	.433
2.70	315	26.15	72.38	.408,.407,.407	.487
3.24	315	26.87	71.41	.443,.443,.443	.530
3.78	315	27.60	70.44	.540,.539,.540	.645
4.32	315	28.33	69.47	.623,.622,.622	.744
4.86	315	29.05	68.50	.633,.634,.632	.757
5.4	315	29.78	67.53	.759,.771,.770	.917
6	315	30.59	66.45	.844,.844,.844	-
7	315	31.94	64.66	.839,.841,.838	-
0	0	22.51	77.28	-	-

1 Volt = 20.805 ft/sec

$V_{\infty avg}$ = .836 V = 17.4 ft/sec

Table B-1 (Continued)

Comparison With Prescribed Wake
Initial Wake Screen

r/R	$(1-w)_{avg}$	$(1-w)_{req}$	Error
1.	.872	.903	-.03
0.9	.759	.846	-.10
0.8	.745	.784	-.05
0.7	.649	.710	-.09
0.6	.529	.636	-.17
0.5	.461	.573	-.19
0.4	.385	.528	-.27
0.3	.365	.488	-.25
0.23	.374	.431	-.13

Table B-2

Wake Survey Data -
Final Wake Screen
(Unmodified upper support)

R	θ	Scale Hor.	Scale Vert.	Volts	(1-w)
8	135	11.74	91.60	.836,.837,.837	-
7	135	13.08	89.80	.838,.835,.838	-
6	135	14.43	88.01	.836,.836,.837	-
5.40	135	15.24	86.93	.741,.739,.739	.883
4.86	135	15.97	85.96	.617,.617,.618	.737
4.32	135	16.69	84.99	.603,.602,.601	.718
3.78	135	17.42	84.02	.529,.526,.523	.625
3.24	135	18.15	83.05	.477,.476,.477	.567
2.70	135	18.87	82.08	.441,.441,.443	.525
2.16	135	19.60	81.11	.406,.407,.406	.485
1.62	135	20.33	80.14	.391,.390,.395	.468
1.24	135	20.84	79.46	.272,.288,.287	.332
1.24	315	24.18	75.00	.378,.379,.379	.459
1.62	315	24.69	74.32	.404,.404,.400	.483
2.16	315	25.42	73.35	.418,.416,.415	.499
2.70	315	26.15	72.38	.480,.478,.479	.574
3.24	315	26.87	71.41	.514,.516,.517	.618
3.78	315	27.60	70.44	.575,.579,.578	.693
4.32	315	28.33	69.47	.621,.623,.623	.745
4.86	315	29.05	68.50	.630,.629,.631	.754
5.40	315	29.78	67.53	.762,.769,.769	.919
0	0	22.51	77.28		

$V_{\infty avg}$ = .836 V = 17.4 ft/sec

Table B-2 (Continued)

Comparison With Prescribed Wake
Final Wake Screen
(Unmodified upper support)

r/R	$(1-w)_{avg}$	$(1-w)_{req}$	Error
1.0	.901	.903	-.003
0.9	.746	.846	-.118
0.8	.732	.784	-.066
0.7	.659	.710	-.072
0.6	.593	.636	-.068
0.5	.550	.573	-.040
0.4	.491	.528	-.070
0.3	.475	.488	-.027
0.23	.395	.431	-.083

Table B-3

Wake Survey Data -

Final Wake Screen
(Modified upper support)

y	z	Scale Hor.	Scale Vert.	Volts	Speed	(1-w)
6	1	37.91	75.84	.646	13.44	1.12
	0		78.38	.687	14.29	1.19
	-1		80.92	.656	13.65	1.14
5	-3	36.00	86.00	.633	13.17	1.10
	-2		83.46	.546	11.36	.95
	-1		80.92	.513	10.67	.89
	0		78.38	.597	12.42	1.04
	1		75.84	.578	12.03	1.0
	2		73.30	.601	12.50	1.04
	3		70.76	.648	13.48	1.12
4	4	34.10	68.22	.655	13.63	1.14
	3		70.76	.505	10.51	.88
	2		73.30	.470	9.78	.81
	1		75.84	.462	9.61	.80
	0		78.38	.543	11.30	.94
	-1		80.92	.501	10.42	.87
	-2		83.46	.478	9.94	.83
	-3		86.00	.506	10.53	.88
	-4		88.54	.556	11.57	.96
3	-4	32.19	88.54	.516	10.74	.89
	-3		86.00	.507	10.55	.88
	-2		83.46	.438	9.11	.76
	-1		80.92	.407	8.47	.71
	0		78.38	.483	10.05	.84
	1		75.84	.411	8.55	.71
	2		73.30	.410	8.53	.71
	3		70.76	.460	9.57	.80
	4		68.22	.549	11.42	.95

Table B-3 (Continued)

y	z	Scale Hor.	Scale Vert.	Volts	Speed	(1-w)
2	5	30.29	65.68	.656	13.65	1.14
	4		68.22	.476	9.90	.83
	3		70.76	.455	9.47	.79
	2		73.30	.363	7.55	.63
	1		75.84	.287	5.97	.50
	0		78.38	.355	7.39	.62
	-1		80.92	.334	6.95	.58
	-2		83.46	.369	7.68	.64
	-3		86.00	.469	9.76	.81
	-4		88.54	.434	9.03	.75
	-5		91.08	.430	8.95	.75
1	-6	28.38	93.62	.459	9.55	.80
	-5		91.08	.340	7.07	.59
	-4		88.54	.370	7.70	.64
	-3		86.00	.370	7.70	.64
	-2		83.46	.269	5.60	.47
	-1		80.92	.259	5.39	.45
	1		75.84	.266	5.53	.46
	2		73.30	.357	7.43	.62
	3		70.76	.450	9.36	.78
	4		68.22	.480	9.99	.83
	5		65.68	.645	13.42	1.12
	6		63.14	.657	13.67	1.14
0	6	26.48	63.14	.690	14.36	1.20
	5		65.68	.673	14.00	1.17
	4		68.22	.556	11.57	.96
	3		70.76	.480	9.99	.83
	2		73.30	.394	8.20	.68
	-2		83.46	.257	5.35	.45
	-3		86.00	.289	6.01	.50
	-4		88.54	.297	6.18	.51
	-5		91.08	.290	6.03	.50
	-6		93.62	.400	8.32	.69

Table B-3 (Continued)

y	z	Scale Hor.	Scale Vert.	Volts	Speed	(1-w)
-1	-6	24.58	93.62	.491	10.22	.85
	-5		91.08	.360	7.49	.62
	-4		88.54	.354	7.36	.61
	-3		86.00	.355	7.39	.62
	-2		83.46	.329	6.84	.57
	-1		80.92	.273	5.68	.47
	1		75.84	.308	6.41	.53
	2		73.30	.359	7.47	.62
	3		70.76	.401	8.34	.70
	4		68.22	.484	10.07	.84
	5		65.68	.638	13.27	1.11
	6		63.14	.659	13.71	1.14
-2	5	22.67	65.68	.646	13.44	1.12
	4		68.22	.486	10.11	.84
	3		70.76	.444	9.24	.77
	2		73.30	.317	6.60	.55
	1		75.84	.329	6.84	.57
	0		78.38	.346	7.20	.60
	-1		80.92	.377	7.84	.65
	-2		83.46	.366	7.61	.63
	-3		86.00	.438	9.11	.76
	-4		88.54	.438	9.11	.76
	-5		91.08	.483	10.05	.84
-3	-4	20.77	88.54	.500	10.40	.87
	-3		86.00	.476	9.90	.83
	-2		83.46	.430	8.95	.75
	-1		80.92	.405	8.43	.70
	0		78.38	.504	10.49	.87
	1		75.84	.447	9.30	.77
	2		73.30	.455	9.47	.79
	3		70.76	.457	9.51	.79
	4		68.22	.517	10.76	.90

Table B-3 (Continued)

y	z	Scale Hor.	Scale Vert.	Volts	Speed	(1-w)
-4	4	18.86	68.22	.629	13.09	1.09
	3		70.76	.495	10.30	.86
	2		73.30	.459	9.55	.80
	1		75.84	.492	10.24	.85
	0		78.38	.481	10.01	.83
	-1		80.92	.438	9.11	.76
	-2		83.46	.501	10.42	.87
	-3		86.00	.507	10.55	.88
	-4		88.54	.602	12.52	1.04
-5	-3	16.96	86.00	.648	13.48	1.12
	-2		83.46	.572	11.90	.99
	-1		80.92	.523	10.88	.91
	0		78.38	.552	11.48	.96
	1		75.84	.632	13.15	1.10
	2		73.30	.618	12.86	1.07
	3		70.76	.648	13.48	1.12
-6	1	15.05	75.84	.648	13.48	1.12
	0		78.38	.686	14.27	1.19
	-1		80.92	.651	13.54	1.13
-6.5	-6.5	14.10	94.89	.651	13.54	1.13
-6	-6	15.05	93.62	.653	13.59	1.13
-5.5	-5.5	16.01	92.35	.666	13.86	1.15
-5	-5	16.96	91.08	.657	13.67	1.14

$U_{nominal}$ = 12 fps   1 Volt = 20.805 fps

Coordinates are in inches.   (1-w) is based on 12 fps

DATA SHEET

RUN NO 1/9

DATE 2/25/79

U_{nom} 10 RPM 950 J_{nom} .51 Shaft rate ______

(Taps: 6/5 blue) Blade rate ______

Ithaco amp① +60 db; Filter: Hi pass ______ Trans Anal

Lo pass ______ ② ______ db

Measuring Equipment: Input atten③ 0.1 V ~~db~~ Meas amp x (# of
Output gain④ x 1 ~~db~~ Spect anal. ___ spectra ___)

Temperature: (Start) water 78 air 75 Reynolds number:

(End) 78 75 ______

Thrust in lbs = T x 0.200 Torque in ft-lbs = $\frac{Q}{12}$

MAN	STAT	RPM	T	Q	GAIN CHANGE	K_T	J	σ	REMARKS
11	BAR 769.5	1006	-2	10.5					TARE
									db
									31.5-40 40-50 50-63
371	399	951	260	101					15 11 8.5
370	365	954	258	101.5					15 10.8 8
370	343	952	254	101.5					15 9.5 6
369	325	953	252	101.5					13 7 5
372	300	953	248	101.5					10.5 5 4
371	272	953	242	101.5					5 4 9.2
370	238	955	230	100					16.3 11.5 10.8

DATA SHEET

RUN NO 219

DATE 2/25

U_{nom} 10 (Taps: 6/5 blue) RPM 1200 J_{nom} .458 Shaft rate ____ Blade rate ____

Ithaco amp ① +80 db; Filter: Hi pass ____ Lo pass ____ Trans Anal ② ____ db

Measuring Equipment: Input atten ③ 0.3V ~~db~~ Output gain ④ x 1 ~~db~~ Meas amp x Spect anal. ____ (# of spectra ____)

Temperature: (Start) water 78 air 75 (End) 78 75 Reynolds number: 7.6x105

MAN	STAT	RPM	T	Q	GAIN CHANGE	K_T	J	σ	REMARKS
370	787	1202	616	182.5		.24	.41	22.52	17.5 13.2 10
372	620	1205	596	183		.243		17.62	17 12 9
370	592	1202	596	183.5				16.92	16.6 12 9
370	564	1203	590	183				16.11	16.4 11.6 8.5
371	538	1203	588	183.5				15.32	15.7 11.0 7.8
369	578	1203	586	183.5				14.83	15.6 11.0 7.8
370	484	1204	582	183				13.81	15.6 11.2 7.5
370	460	1204	580	184				13.12	15.6 11 7.5
371	425	1204	576	184				12.07	16 11 7.8
369	396	1205	572	184				11.31	17 12 9
369	363	1205	568	183.5				10.35	16.2 12.2 6 *
369	353	1205	566	183.5				10.07	15.6 11.2 9.5
370	340	1205	566	184				9.72	14.6 10.5 9
370	319	1205	562	183.5					10 6 7
370	291	1206	556	183					1 1 5

DATA SHEET

RUN NO 3/9

DATE 2/25

U_{nom} 10 RPM 1300 J_{nom} .378 Shaft rate ______
(Taps: 6/5 blue)

Blade rate ______

Ithaco amp① +80 db; Filter: Hi pass ______ Trans Anal

Lo pass ______ ② ______ db

Measuring Equipment: Input atten③ 0.3V ~~db~~ Meas amp X (# of
Output gain④ x1 db Spect anal. ___ spectra ___)

Temperature: (Start) water 78 air 75 Reynolds number:

(End) 78 75 8.19x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS		
370	783	1300	762	221			.255	.38	22.42	19	15	12
371	665	1300	744	220.5	1	+70				13.2	9	6.5
371	606	1297	734	219.5						13	9	6.5
370	578	1299	734	220						13	9.2	7 TL ✗
371	559	1299	730	220						13.2	9	6.8
370	535	1300	732	221						13.4	9.1	7
371	509	1301	730	221						13.5	9	6.2
371	482	1302	728	221.5						13	8.6	6
371	460	1302	724	221.5						13.5	8	5.4
371	436	1300	718	221						12.6	8.2	6
370	409	1300	714	220.5						11.9	7.6	5.8

DATA SHEET

RUN NO 4/9

DATE 2/25

U_{nom} 16 RPM 1050 J_{nom} .746 Shaft rate ______

(Taps: 6/5 blue)

Blade rate ______

Ithaco amp① +60 db; Filter: Hi pass ______ Trans Anal

Lo pass ______ ② ______ db

Measuring Equipment: Input atten③ .3V ~~db~~ Meas amp X (# of spectra ___)

Output gain④ x 1 ~~db~~ Spect anal. ___

Temperature: (Start) water 78 air 75 Reynolds number:

(End) 78 75 6.86 x 10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
917	747	1050	174	72			0.09	0.72	8.30	13.4 8.1 6
909	699	1050	170	72.5					7.84	13.6 8.1 6.1
909	650	1050	160	71.5					7.29	13.1 8.8 6.2
912	611	1050	156	72					6.82	13 8.8 6.2
911	577	1050	154	71.5					6.45	13.5 9 6.6
911	546	1050	150	72.5					6.10	13.4 9 6.8
912	521	1050	144	71.5					5.81	13.7 9.2 7
912	488	1050	140	72					5.44	13.5 9.1 7.0
~~912~~	~~488~~	~~1050~~	~~1~~							
912	455	1050	138	72.5					5.07	13.8 9.2 7.1
911	415	1050	132	72.0					4.62	14.2 10 7.2
912	389	1050	128	72.0					4.33	15 10.7 7.9
912	364	1050	124	71.5					4.05	17 13 10.5
913	321	1050	114	70.5	1	+50			3.56	14 11.6 10
913	300	1050	106	70.0					3.32	15.4 12 8.4 T
906	260	1050	100	69.5	1	+60				8 2 20 * test
				Observed big bubbles						

DATA SHEET

RUN NO 5/9

DATE 2/25

U_{nom} 16 RPM 1150 J_{nom} .681 Shaft rate ______

(Taps: 6/5 blue) Blade rate ______

Ithaco amp ① ~~+80~~ +60 db; Filter: Hi pass ______ Trans Anal

Lo pass ______ ② ______ db

Measuring Equipment: Input atten ③ 0.3V ~~db~~ Meas amp ∝ (# of

Output gain ④ x1 ~~db~~ Spect anal. ___ spectra ___)

Temperature: (Start) water 78 air 75 Reynolds number:

(End) 78 75 7.46×10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS		
912	747	1150	290	104.5			0.125	0.67	8.35	14.2	10	7.9
912	680	1150	278	104.5						144	10.1	7.5
913	616	1150	270	104.0						14.5	10.3	7.7
913	571	1150	262	103.5					5.94	14.6	9.9	7.2
912	532	1150	262	104.5						14.5	10	7.8
911	491	1150	260	105					5.48	14.5	10.2	7.8
911	460	1150	252	105						14.5	10	7.6
911	425	1150	246	104.5					4.74	144	10	7.5
912	375	1150	238	104					4.17	14.9	10.6	8
915	346	1150	236	104.5					3.83	18-20	17	14-11.5
912	324	1150	230	103.5	1	+50			3.60	14.9	12.5	9.9
912	303	1150	222	103					3.36	14.9	11.5	9 —
912	285	1150	218	102.5					3.16	12.4	6	0 *
911	256	1151	204	101.5	1	+80				14	9	5.5
							observed by bubbles					

DATA SHEET

RUN NO 6/9

DATE 2/25

U_{nom} 16 RPM 1250 J_{nom} 0.627 Shaft rate ______

(Taps: 6/5 blue) Blade rate ______

Ithaco amp ① +60 db; Filter: Hi pass ______ Trans Anal

Lo pass ______ ② ______ db

Measuring Equipment: Input atten ③ 0.3 db Meas amp X (# of

Output gain ④ X1 db Spect anal. ___ spectra ___)

Temperature: (Start) water 78 air 75 Reynolds number:

(End) 78 75 8.05×10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
913	749	1250	414	139			0.151	0.605	8.37	15.0 11.0 8.9
913	669	1250	400	138.5					7.47	14.8 10.6 8.9
912	587	1250	390	139.5						15 10.9 8.6
910	530	1250	384	139.0					5.93	14.8 10.7 8.7
912	493	1250	380	140						14.8 10.7 8.1
913	459	1250	372	139					5.11	14.4 10.6 8.5
913	415	1250	364	138						14.9 10.8 8.8
913	384	1250	360	138.5					4.27	15.0 11.0 8.5
912	335	1250	354	138.5	1	+50			3.72	13.2 10 8.5
913	300	1250	346	137.5					3.39	13.8 10 8.2
912	274	1250	334	136					3.03	7.3 <0 <0

obscured by bubbles

DATA SHEET

RUN NO 7/9

DATE 2/25

U_{nom} 16 (Taps: 6/5 blue) RPM 1350 J_{nom} 0.580 Shaft rate ______

Blade rate ______

Ithaco amp ① +60 db; Filter: Hi pass ______ Trans Anal

Lo pass ______ ② ______ db

Measuring Equipment: Input atten ③ 0.3V ~~db~~ Meas amp X (# of

Output gain ④ X1 ~~db~~ Spect anal. ___ spectra ___)

Temperature: (Start) water 78 air 75 Reynolds number:

(End) 78 75 8.66x10⁵

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
912	748	1350	548	176.5			0.171	0.57	8.37	15 11.1 9.0
911	652	1350	530	176						15 11.1 9.0
912	575	1350	522	176.5						14.9 11.0 9.0
913	525	1350	514	176					5.85	14.9 11.1 9.0
911	482	1350	510	176						14.9 11.0 8.7
911	448	1350	500	175.5						14.8 10.8 8.8
911	406	1350	498	176					4.53	14.6 10.5 8.3
910	373	1350	494	176					4.16	15.2 11.5 9.0
913	356	1350	488	175.5					3.95	18.5 14.4 11.7 EU
912	332	1350	482	175	1	+50			3.69	12.4 9 7.2
912	310	1350	478	174.5					3.44	12.9 9 7.5
913	289	1350	466	172.5					3.20	10.6 4.9 4.0

DATA SHEET

RUN NO 8/9

DATE 2/25

U_{nom} 16 RPM 1510 J_{nom} 0.519 Shaft rate ________
(Taps: 6/5 blue)

Blade rate ________

Ithaco amp① +60 db; Filter: Hi pass ______ Trans Anal

Lo pass ______ ② ________ db

Measuring Equipment: Input atten③ 0.3V ~~db~~ Meas amp X (# of
Output gain④ x1 ~~db~~ Spect anal. ___ spectra___)

Temperature: (Start) water 78 air 75 Reynolds number:

(End) 78 75 9.62×10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
912	749	1510	784	242			0.195	0.51	8.38	14.9 10.9 8.7
911	658	1509	770	242						14.8 10.9 8.6
912	614	1510	766	242						14.7 10.9 8.5
911	567	1510	754	241						14.7 10.6 8.7
911	519	1510	750	241					5.80	14.7 10.8 8.4
913	486	1510	744	241						14.7 10.5 8.4
913	451	1510	738	241						14.5 10.4 8.0
912	422	1510	736	241.5					4.70	14.4 10.1 7.8
911	378	1510	730	241.5					4.21	15.4 11.0 8.2
913	345	1510	718	240					3.83	19 14.6 11.8
912	320	1510	712	239	1	+50			3.55	12 7 3.6 * BACK
912	287	1510	698	242.5					3.18	10.5 5 1
910	267	1510	662	240	1	+60				1 20 20
							Obscured by bubbles			

DATA SHEET

RUN NO 9/9

DATE 2/25

U_{nom} 16 (Taps: 6/5 blue) RPM 1710 J_{nom} 0.458 Shaft rate ______

Blade rate ______

Ithaco amp ① +60 db; Filter: Hi pass ______ Trans Anal

Lo pass ______ ② ______ db

Measuring Equipment: Input atten ③ 0.3V ~~db~~ Meas amp X (# of

Output gain ④ x1 ~~db~~ Spect anal. ___ spectra___)

Temperature: (Start) water 78 air 75 Reynolds number:

(End) 78 75 1.085×10^6

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
911	750	1710	1128	337			0.219	0.47	8.40	15 10.9 8.5
912	690	1710	1118	337						15 10.9 9.0
910	618	1710	1110	337					6.92	14.9 10.6 8.5
911	577	1710	1104	336					6.45	14.6 10.5 8
911	542	1710	1100	336.5					6.06	14.5 10.4 8
912	509	1710	1096	336.0						14.5 10.0 7.8 TV *
909	478	1710	1088	336.5					5.35	14.0 9.4 7.0
912	439	1710	1080	334.5					4.89	14.4 9.8 6.6 Bad
911	400	1710	1070	335	1	+50			4.46	20 15 14 *
12	BAR 762.7		-2	11.5						TARE

DATA SHEET

RUN NO 1

DATE 2/26

U_{nom} 16 RPM 1710 J_{nom} .458 Shaft rate ______

(Taps: 6/5 blue) Blade rate ______

Ithaco amp ① +60 db; Filter: Hi pass ______ Trans Anal

Lo pass ______ ② ______ db

Measuring Equipment: Input atten ③ 0.3V ~~db~~ Meas amp X (# of spectra ___)

Output gain ④ X1 ~~db~~ Spect anal. ___

Temperature: (Start) water 82 air 75 Reynolds number:

(End) 83 75 1.10×10^6

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
12	BAR 962.7		-2	11.5			~~0.216~~	~~0.48~~	~~8~~	TARE
912	747	1710	1112	338.0			0.216	0.48	8.31	12.7 8.6 7.1
913	713	1710	1108	338						B 9.1 7.5
912	674	1710	1104	338.5						13.4 9.2 7.4 Tc *
912	645	1710	1100	337.5					7.16	13.2 9.1 7.1
912	624	1710	1096	337.5						13.1 9.1 7.1
912	597	1710	1092	335.5						13.4 9.3 7.2
911	565	1710	1090	335.0						13.0 9.0 7.0
912	530	1710	1086	335.0					5.87	12.9 8.9 6.8
912	501	1710	1086	335.5						12.8 8.3 6.1
912	470	1710	1078	334.5					5.19	12.4 7.0 4.5
912	440	1710	1070	333.0						11.8 6.9 3
910	412	1710	1066	333.5	1	+50			4.55	13.8 8.5 5.2 BAC *
912	382	1710	1060	334.0	1	+40			4.20	11.4 7.0 4.0
911	351	1710	1046	338.0					3.86	12.6 7 5

DATA SHEET

RUN NO 2

DATE 2/26

U_{nom} 30 RPM 1900 J_{nom} .515 Shaft rate ______
(Taps: 6/5 blue)

Blade rate ______

Ithaco amp① +50 db; Filter: Hi pass — Trans Anal

Lo pass — ② — db

Measuring Equipment: Input atten③ 0.3V ~~db~~ Meas amp X (# of

Output gain④ X 1 ~~db~~ Spect anal. ___ spectra ___)

Temperature: (Start) water 83 air 75 Reynolds number:

(End) 85 75 1.23×10^6

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
1465	715	1900	1220	378			.255	.38	~~22.49~~ 5.09	8.2 4.2 1.9
1405	685	1900	1220	378.5						8.8 4.2 2
1406	650	1900	1210	378.0					4.63	8.9 4.9 2.1
1404	626	1900	1208	377.0					4.45	9.3 5.0 2
1405	602	1900	1204	377.0					4.27	12.0 6.3 3.8
1403	572	1900	1200	378.5					4.06	16 12.2 8.8
1404	542	1900	1192	376.0	1	+40			3.84	9.6 6.5 6.5 TV*
1405	519	1900	1190	377.5					3.68	11.0 8.5 7.2
1404	496	1900	1188	377.0					3.51	13 10.1 8.5 BB*
1402	471	1900	1178	378.0					3.34	14 10.5 8.8
1403	442	1900	1158	385					3.13	13.2 9.2 7

DATA SHEET

RUN NO 3

DATE 2/26

U_{nom} 30 RPM 1800 J_{nom} .543 Shaft rate —
(Taps: 6/5 blue)

Blade rate —

Ithaco amp① +50 db; Filter: Hi pass ______ Trans Anal

Lo pass ______ ②______ db

Measuring Equipment: Input atten③ 0.3V ~~db~~ Meas amp α (# of
Output gain④ ×1 ~~db~~ Spect anal. ___ spectra___)

Temperature: (Start) water 83 air 75 Reynolds number:

(End) 85 75 1.16×10^6

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
1403	715	1800	1040	325.0			.183	.53	5.09	7.4 3.0 0.5
1402	691	1800	1036	328.5						7.6 3.1 0.5
1402	643	1800	1028	325.5					4.58	7.9 3.0 0.5
1400	607	1800	1024	326.0					4.32	7.5 3.1 0.2
1401	568	1800	1016	326.0					4.04	12.6 7.1 3.8
1404	543	1800	1010	325.0					3.85	18.8 15.2 14.6
1404	527	1800	1004	324.5	1	+40			3.73	9.6 7.0 5.9
1403	506	1800	1006	325.0					3.59	10.5 8.0 6.8
1405	489	1800	1000	324.0					3.46	11.4 8.5 7.7 *
1406	469	1800	970	330.5					3.31	11.7 9.0 7.9 BB *
1404	445	1800	978	323.0					3.14	12.1 8.9 7.0
1406	426	1800	966	322.5					3.00	12.1 7.9 5.0 TV *

DATA SHEET

RUN NO 4

DATE 2/26

U_{nom} 20 RPM 1340 J_{nom} 0.73 Shaft rate ______

(Taps: 6/5 blue) Blade rate ______

Ithaco amp ① +50 db; Filter: Hi pass ______ Trans Anal

Lo pass ______ ② ______ db

Measuring Equipment: Input atten ③ 0.3 V ~~db~~ Meas amp × (# of

Output gain ④ ×1 ~~db~~ Spect anal. ___ spectra ___)

Temperature: (Start) water 85 air 75 Reynolds number:

(End) 88 76 8.84×10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
1410	714	1340	302	118.0			.095	.71	5.06	10.0 6.0 36
1402	688	1339	304	118.5						10.1 6.0 3.7
1401	662	1339	304	120.0					4.72	10.0 6.0 3.9
1401	632	1340	296	118.5					4.50	10.3 6.5 3.9
1410	593	1340	286	118.0					4.19	11.4 7.1 4.8
1406	569	1340	286	119.0					4.03	12.9 9.2 7.0
1402	546	1340	284	119.0					3.88	17.5 14 12.5 * LEP.
1407	536	1340	282	118.0					3.72	20 17.0 15.7
1409	500	1340	270	116.5	1	+40			3.53	11.7 8.9 7.6
1403	472	1340	278	120.0					3.34	12.0 9.1 8.2
1409	442	1340	254	115.0					3.11	11.5 8.7 7
1408	425	1340	258	117						10.9 7.7 5.3

DATA SHEET

RUN NO 5

DATE 2/26

U_{nom} 20 RPM 1150 J_{nom} .851 Shaft rate ______

(Taps: 6/5 blue) Blade rate ______

Ithaco amp ① +50 db; Filter: Hi pass — Trans Anal

Lo pass — ② — db

Measuring Equipment: Input atten ③ 0.3V ~~db~~ Meas amp X (# of

Output gain ④ x1 ~~db~~ Spect anal. ___ spectra ___)

Temperature: (Start) water 88 air 76 Reynolds number:

(End) 90 78 7.72×10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE	K_T	J	σ	REMARKS
1407	722	1150	58	51.0		.024	.83	5.13	12.5 7.3 5.9
1408	685	1150	50	49.5				4.86	12.8 88 6.6 *
1413	655	1151	40	48.5				4.63	13.1 9.1 6.6
1405	618	1150	34	46.5				4.39	13.7 9.6 7.1
1406	579	1150	32	46.5				4.10	15.4 10.9 8.1
1407	550	1150	24	45.0				3.89	~~18.9~~ 18.8 14.5 15.4
1399	521	1151	26	46.5	1 +40			3.70	10.6 7.2 6.5
1403	491	1151	16	44.5				3.48	12.2 7.2 7.5
1409	474	1150	12	45				3.34	12.4 9.2 7.9
1405	441	1150	8	45					11.2 8.1 6
11	BAR 760.0		8	12.5					TARE

DATA SHEET

RUN NO 1

DATE 2/27

U_{nom} 10 (Taps: 6/5 blue) RPM 1200 J_{nom} .41 Shaft rate —

Blade rate —

Ithaco amp ① +70 db; Filter: Hi pass — Trans Anal

Lo pass — ② ____ db

Measuring Equipment: Input atten ③ 0.3V ~~db~~ Meas amp X (# of

Output gain ④ x1 ~~db~~ Spect anal. ___ spectra ___)

Temperature: (Start) water 87 air 77 Reynolds number:

(End) 87 77 8.32×10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
17	BAR 757.1		2	9.5						TARE
373	770	1200	610	181			0.238	0.42	22.08	7.1 3.6 0.2
374	736	1200	602	180						8.0 3.1 0.1
373	657	1200	596	180.5						8.0 3.5 0
374	615	1200	590	180.5					17.53	8.3 3.7 0.1
374	592	1200	586	180						8.1 3.0 0
374	566	1200	582	180						7.9 3.1 0
373	543	1200	580	180					15.49	7.9 3.1 <0
373	520	1200	578	180						7.6 2.8 <0
373	501	1200	576	180	1	+80			14.27	18.4 13.3 10.2
373	477	1200	572	180					13.58	15.2 12.5 9.2 * TV
371	458	1200	570	180						16.1 12.2 9.8
372	433	1200	568	180						15.8 12.2 9.6
372	405	1200	562	179.5					11.52	14.1 11.5 10.5
374	376	1200	558	179.5						10 6 7.5
372	345	1200	552	178.5						<0 <0 6
373	321	1200	548	178.5						<0 <0 2

DATA SHEET

RUN NO 2

DATE 2/27

U_{nom} 16 RPM 1710 J_{nom} .458 Shaft rate —

(Taps: 6/5 blue) Blade rate —

Ithaco amp① +60 db; Filter: Hi pass ______ Trans Anal

Lo pass ______ ② ______ db

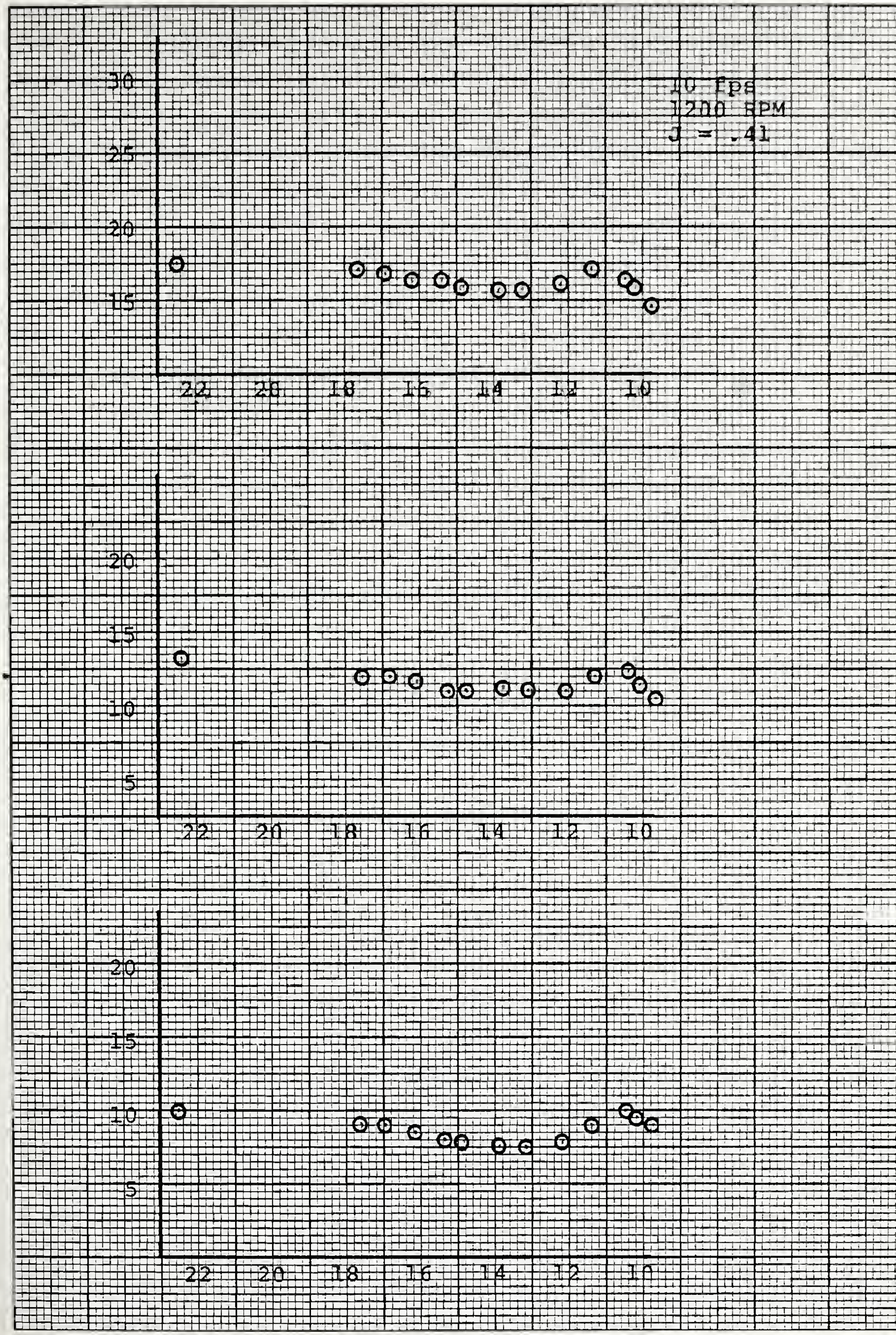
Measuring Equipment: Input atten③ 0.3 V ~~db~~ Meas amp X (# of

Output gain④ X 1 ~~db~~ Spect anal. ___ spectra ___)

Temperature: (Start) water 87 air 77 Reynolds number:

(End) 87 77 1.19×10^6

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS			
914	736	1710	1112	331.5			.213	.48	8.17	13.9	9.4	7.9	
912	699	1710	1106	331.5						13.7	9.2	6.9	
914	661	1710	1098	331						13.6	9.0	6.3	
914	630	1710	1092	331						13.4	8.9	6.0	TV *
912	595	1710	1092	331						12.8	8.6	6.0	
~~915~~	~~552~~	~~1710~~								1			
914	578	1710	1086	331						12.6	8.2	5.5	
915	552	1710	1084	331.5						11.9	7.3	4.6	
914	534	1710	1082	331.5						12.4	7.9	5.1	
915	505	1710	1078	331						11.9	6.8	3.2	
912	476	1710	1074	331						10.6	5.6	2	
914	451	1710	1070	330.5						10.6	5.9	2	
915	441	1710	1068	330.5						13.2	8.8	6	
914	430	1710	1066	330	1	+50				7.1	3.5	0	BAD *
914	410	1710	1062	330						18	13.2	12.5	
914	739	1710	1114	332.5	1	+60				12.4	8.1	6.0	
13	BAR 756.4		14	11						TARE			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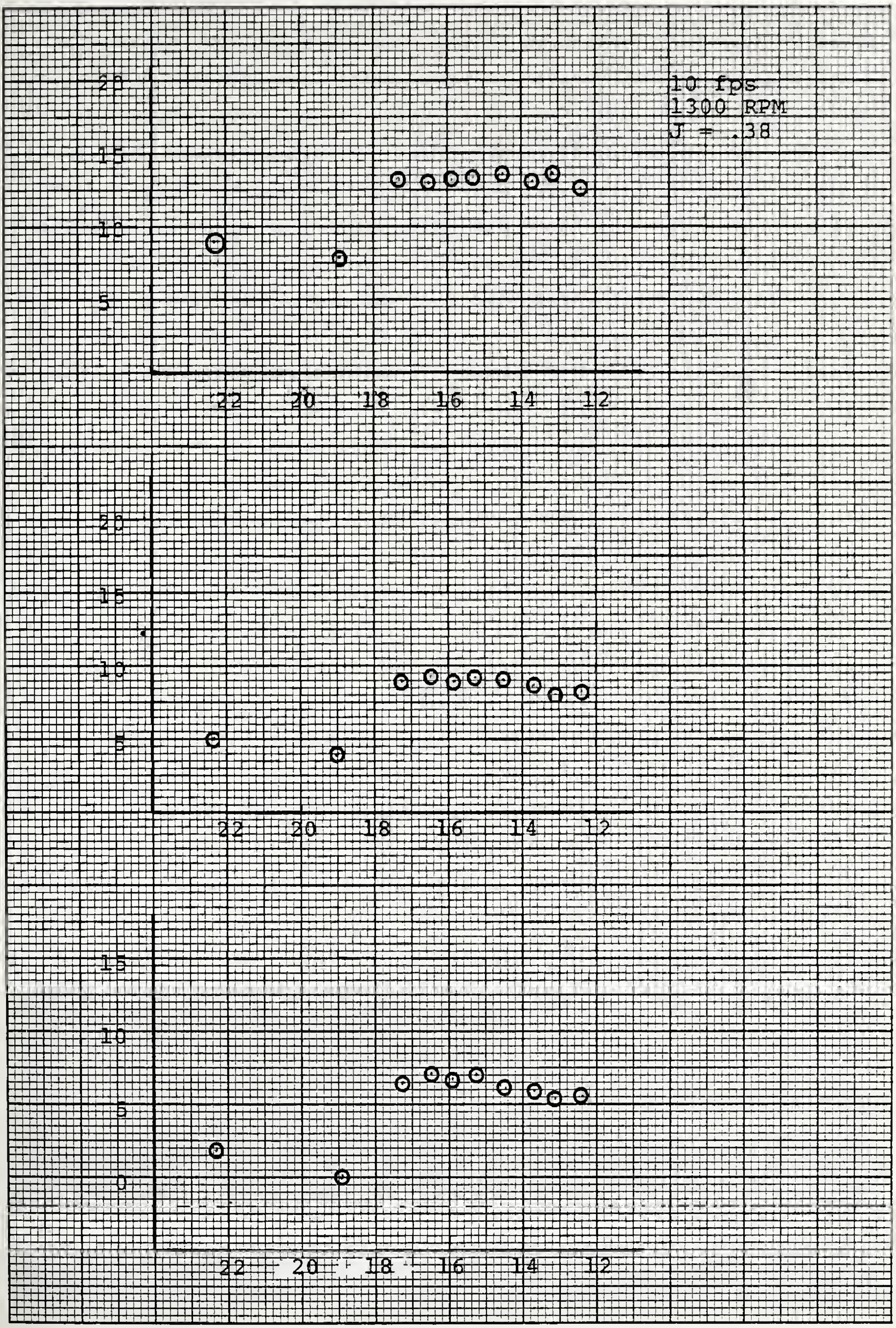
1200 RPM
J = .41
30
25
20
15
22
20
18
16
14
12
10
20
15
10
5
22
20
18
16
14
12
10
20
15
10
5
22
20
18
16
14
12
10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1300 RPM
J = .38
20
15
10
5
22
20
18
16
14
12
20
15
10
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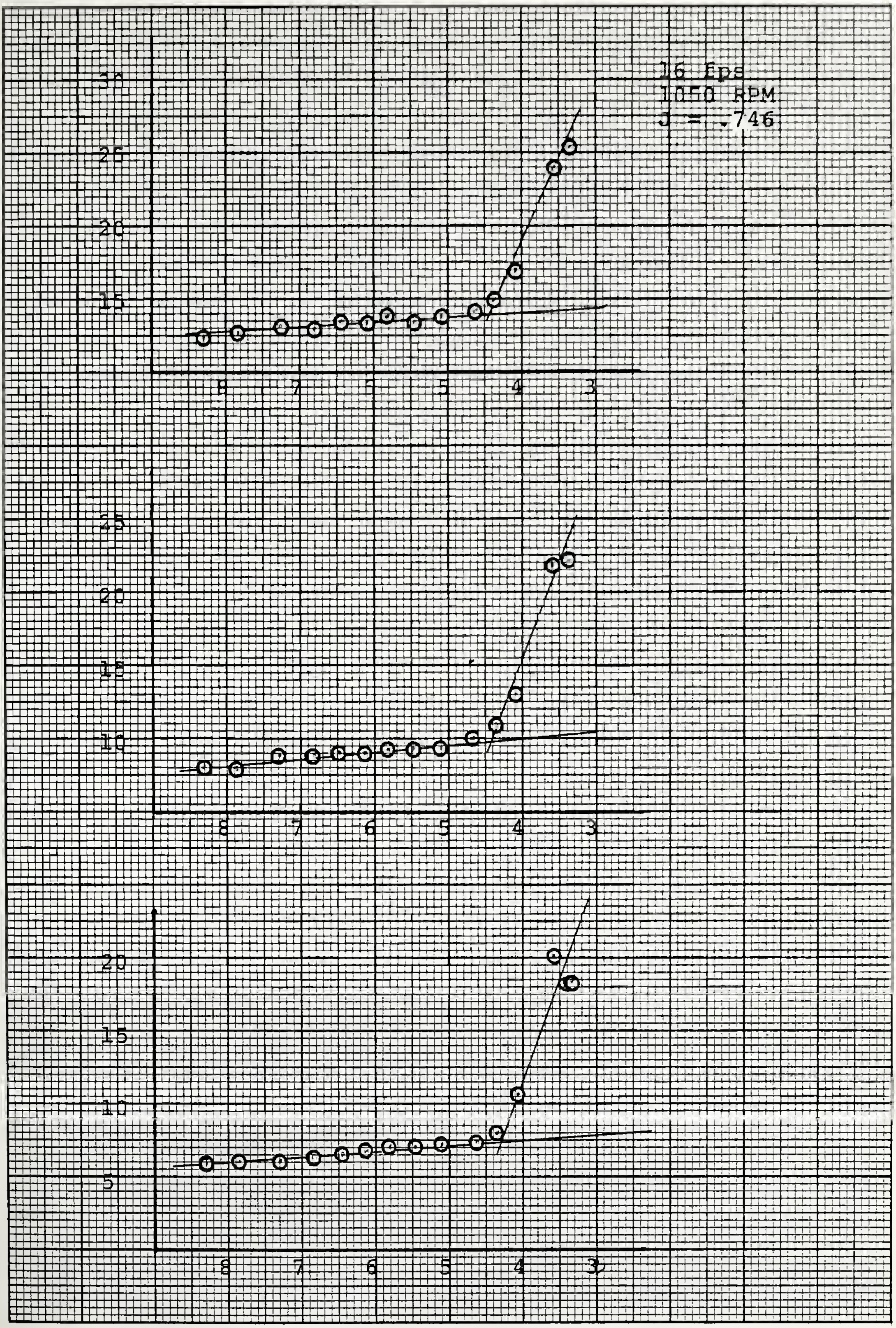
22
20
18
16
14
12
15
10
5
0
22
20
18
16
14
12


16 Eps
1050 RPM
J = .746
30
25
20
15
8
7
6
5
4
3
25
20
15
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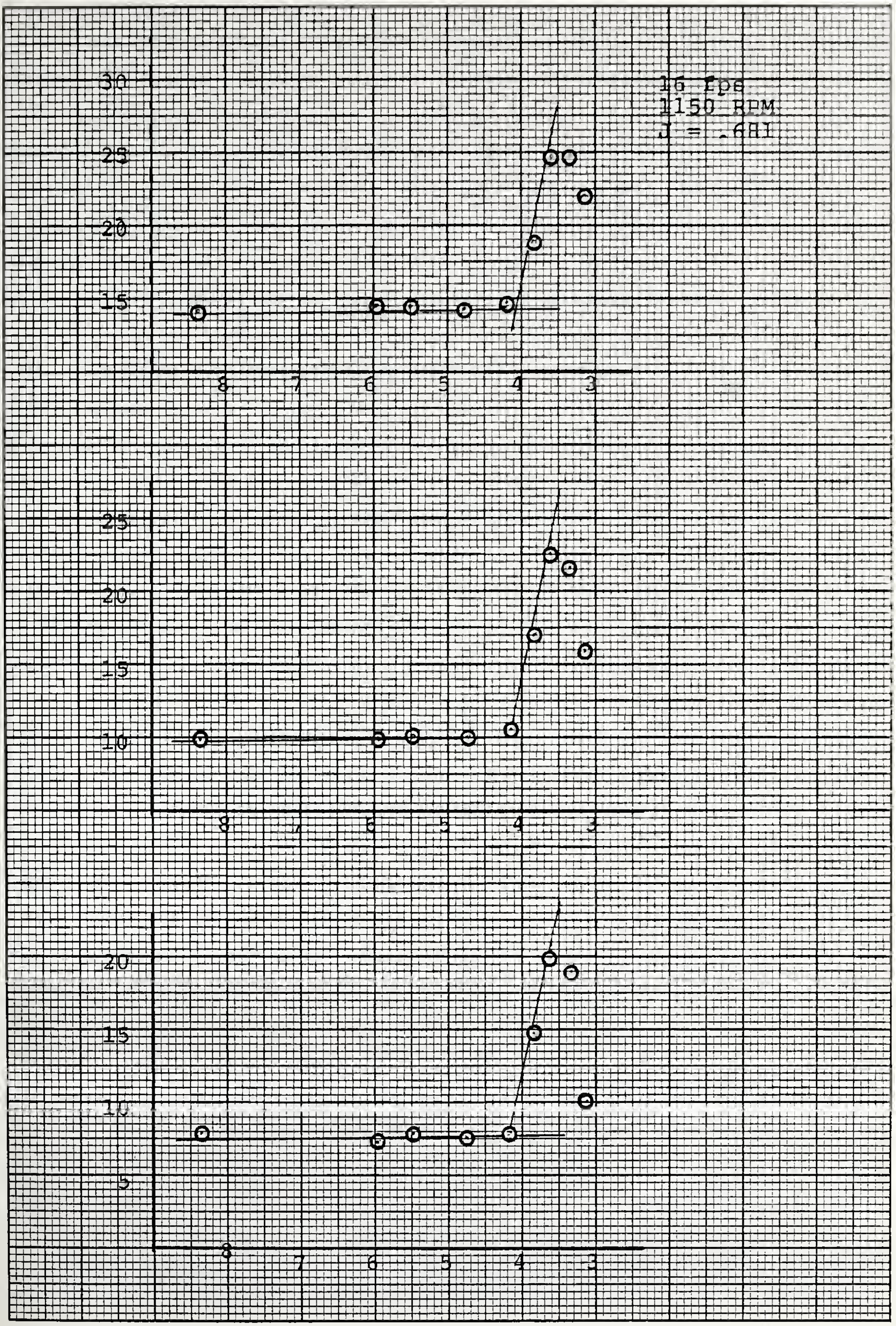
7
6
5
4
3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1150 RPM
J = .681
30
25
20
15
8
7
6
5
4
3
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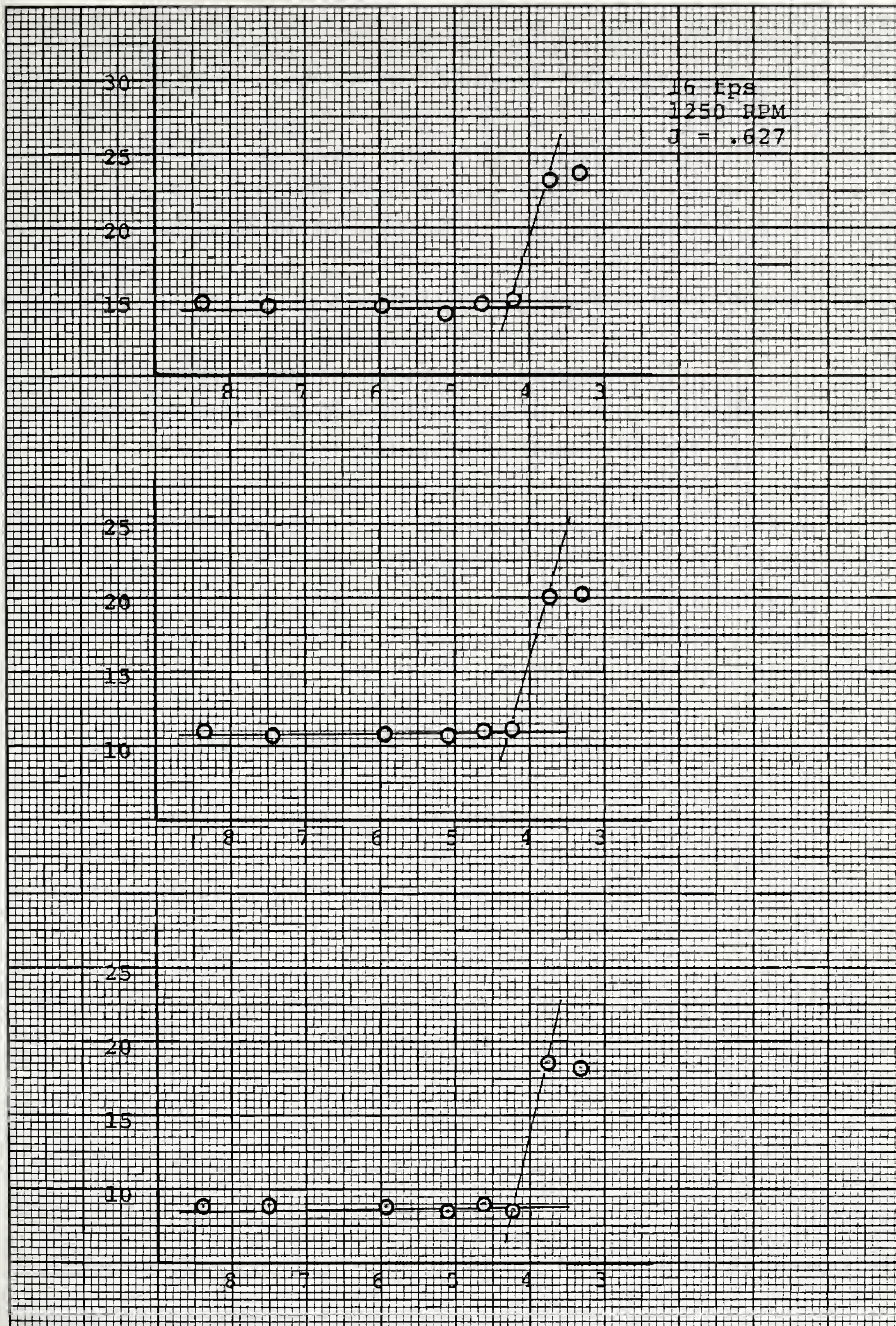
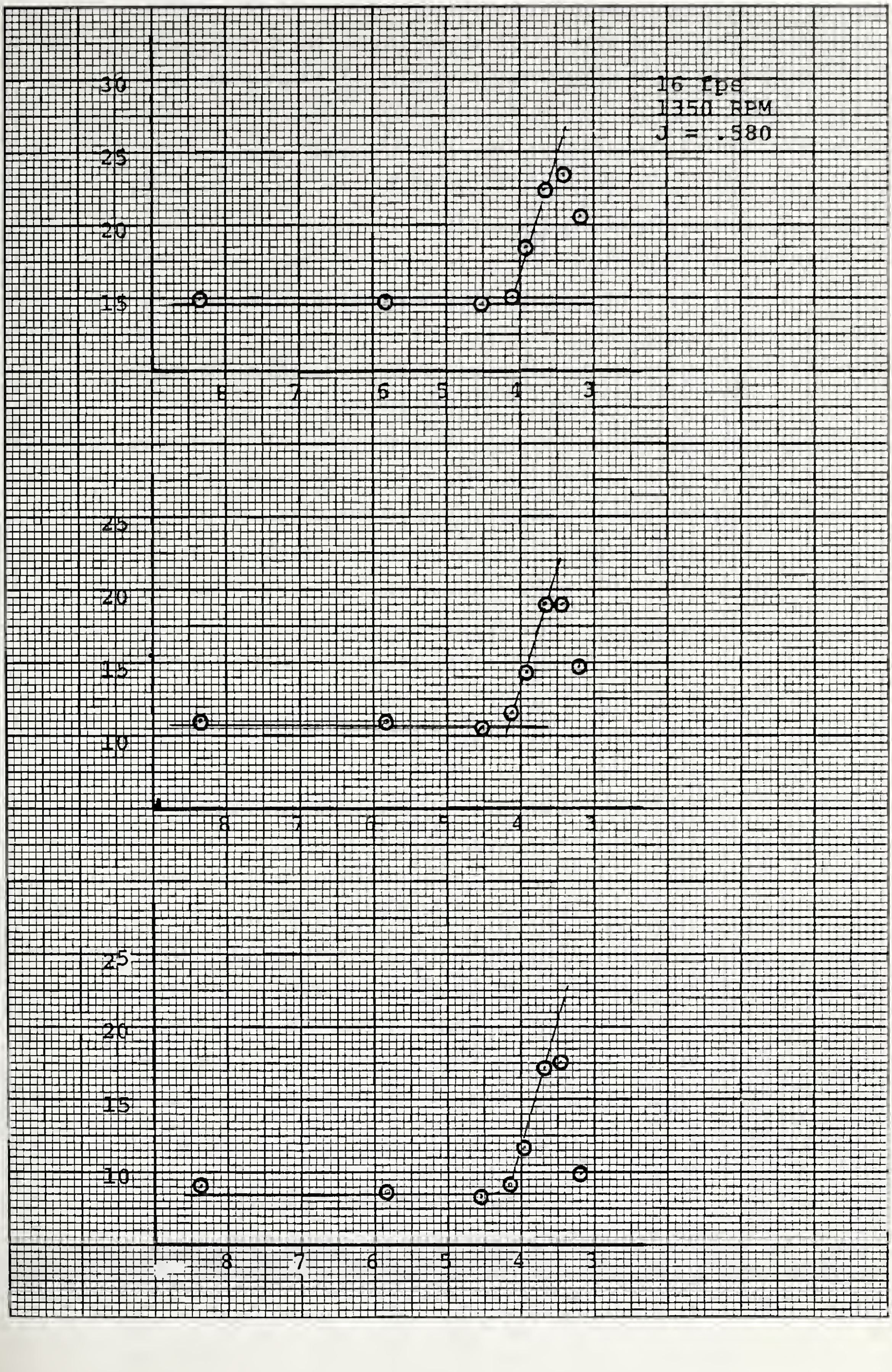
7
6
5
4
3



16 fps
1250 RPM
J = .627
30
25
20
15
8
7
6
5
4
3
25
20
15
10
8
7
6
5
4
3
25
20
15
10
8
7
6
5
4
3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1350 RPM
J = .580
30
25
20
15
8
7
6
5
4
3
25
20
15
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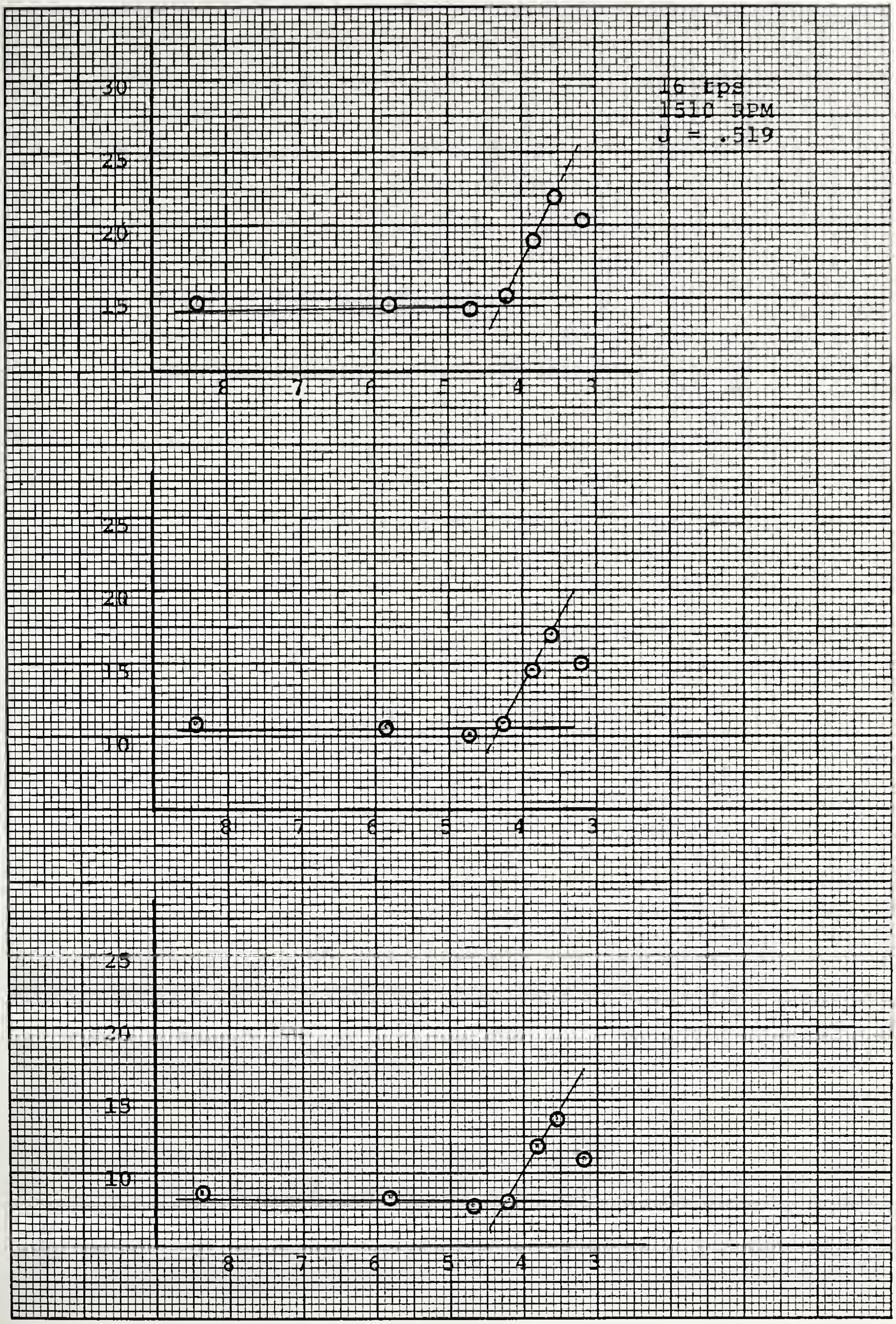
8
7
6
5
4
3
25
20
15
10
8
7
6
5
4
3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1510 RPM
J = .519
30
25
20
15
8
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6
5
4
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7
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5
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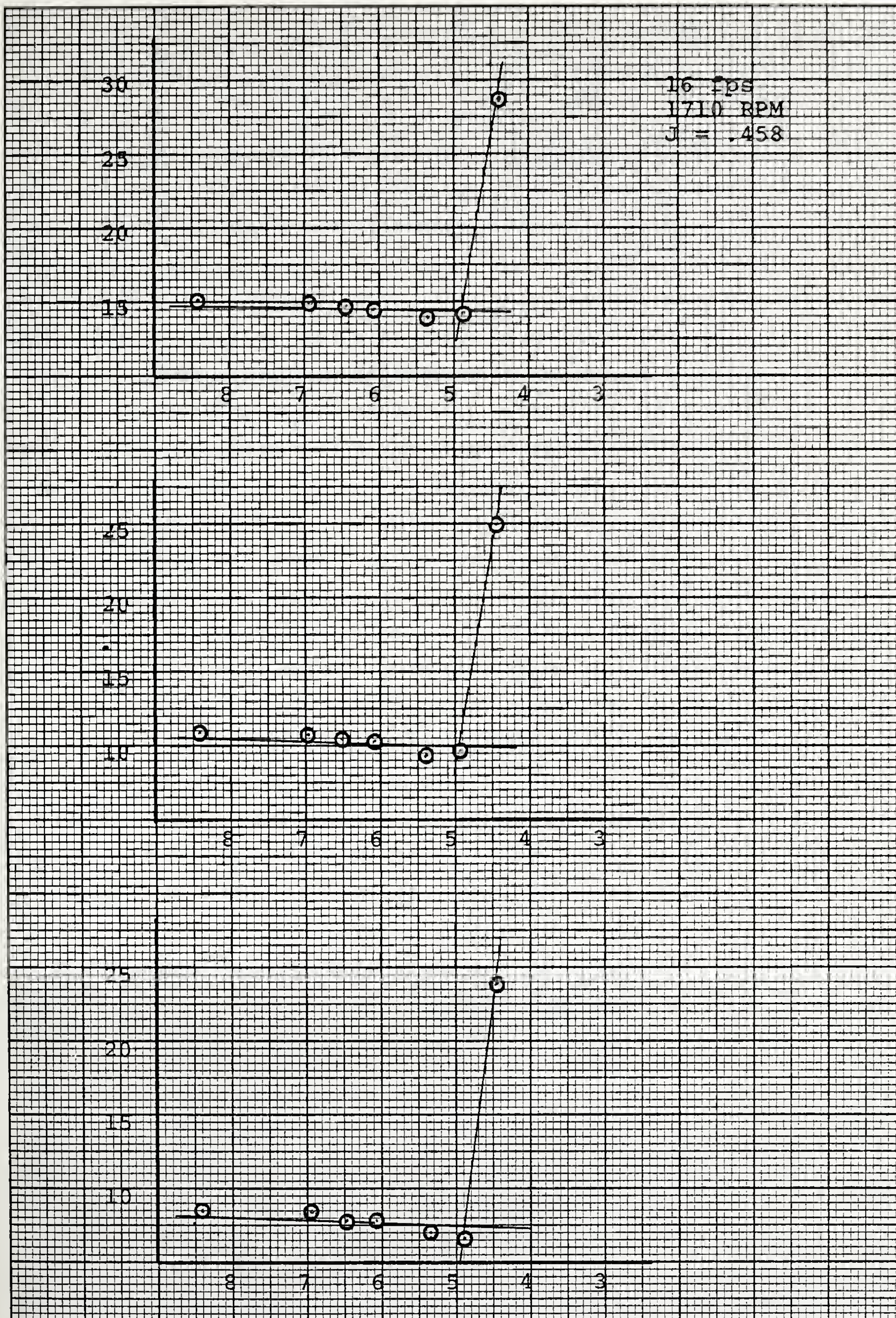
25
20
15
10
8
7
6
5
4
3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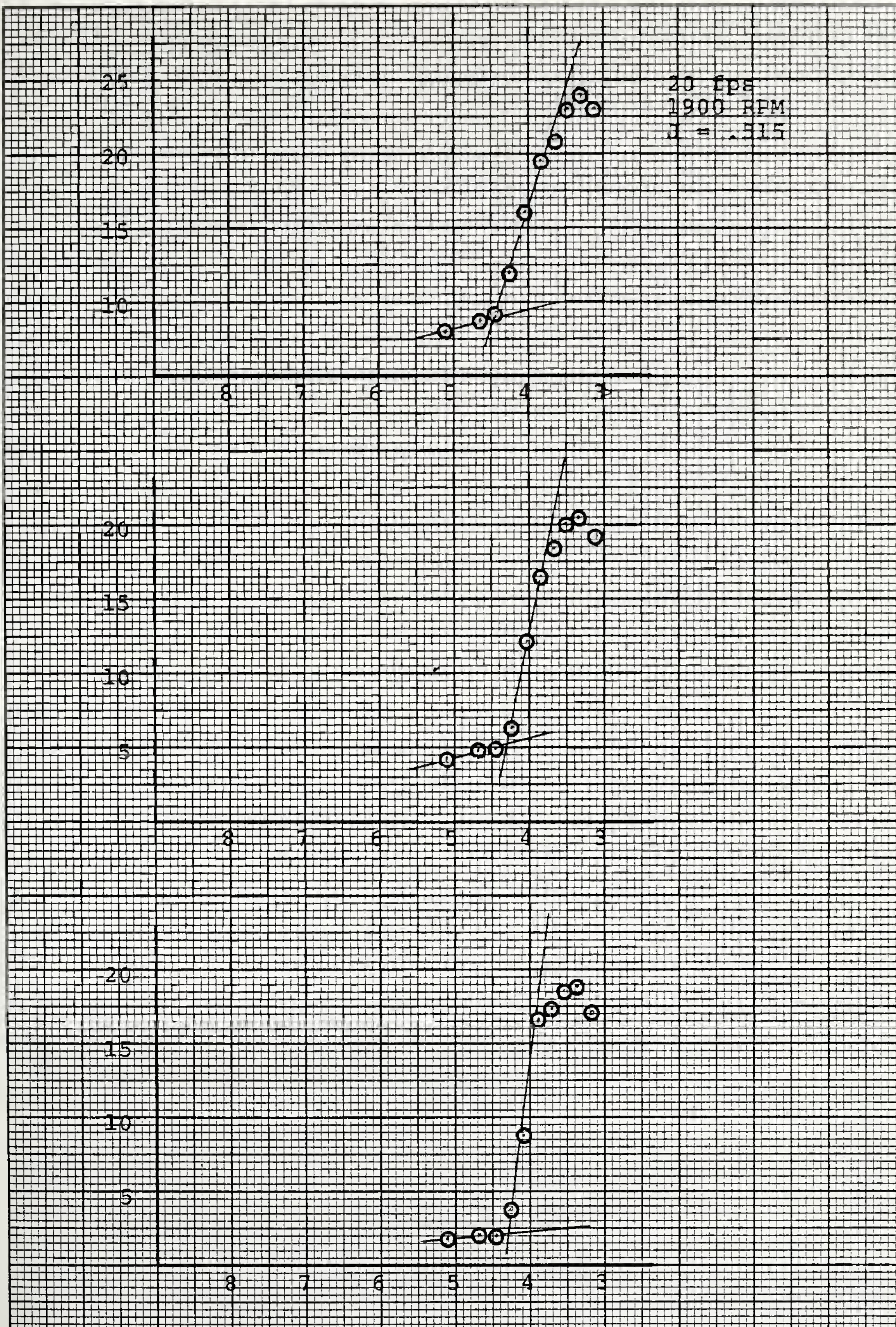
1710 RPM
J = .458
30
25
20
15
8
7
6
5
4
3
25
20
15
10
8
7
6
5
4
3
25
20
15
10
8
7
6
5
4
3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1900 RPM
J = .515
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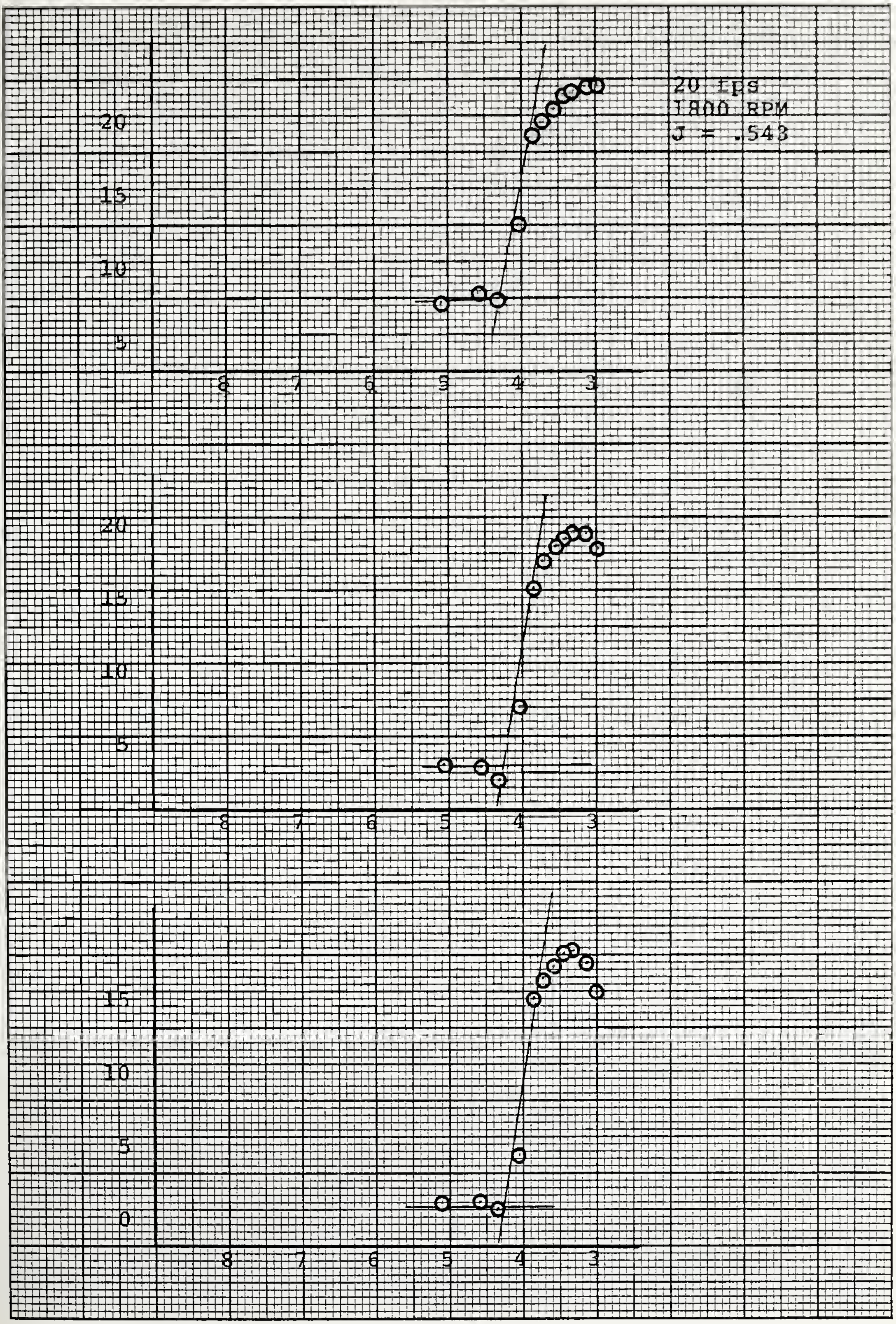
15
10
8 7 6 5 4 3
20
15
10
5
8 7 6 5 4 3
20
15
10
5
8 7 6 5 4 3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1800 RPM
J = .543
20
15
10
5
8
7
6
5
4
3
20
15
10
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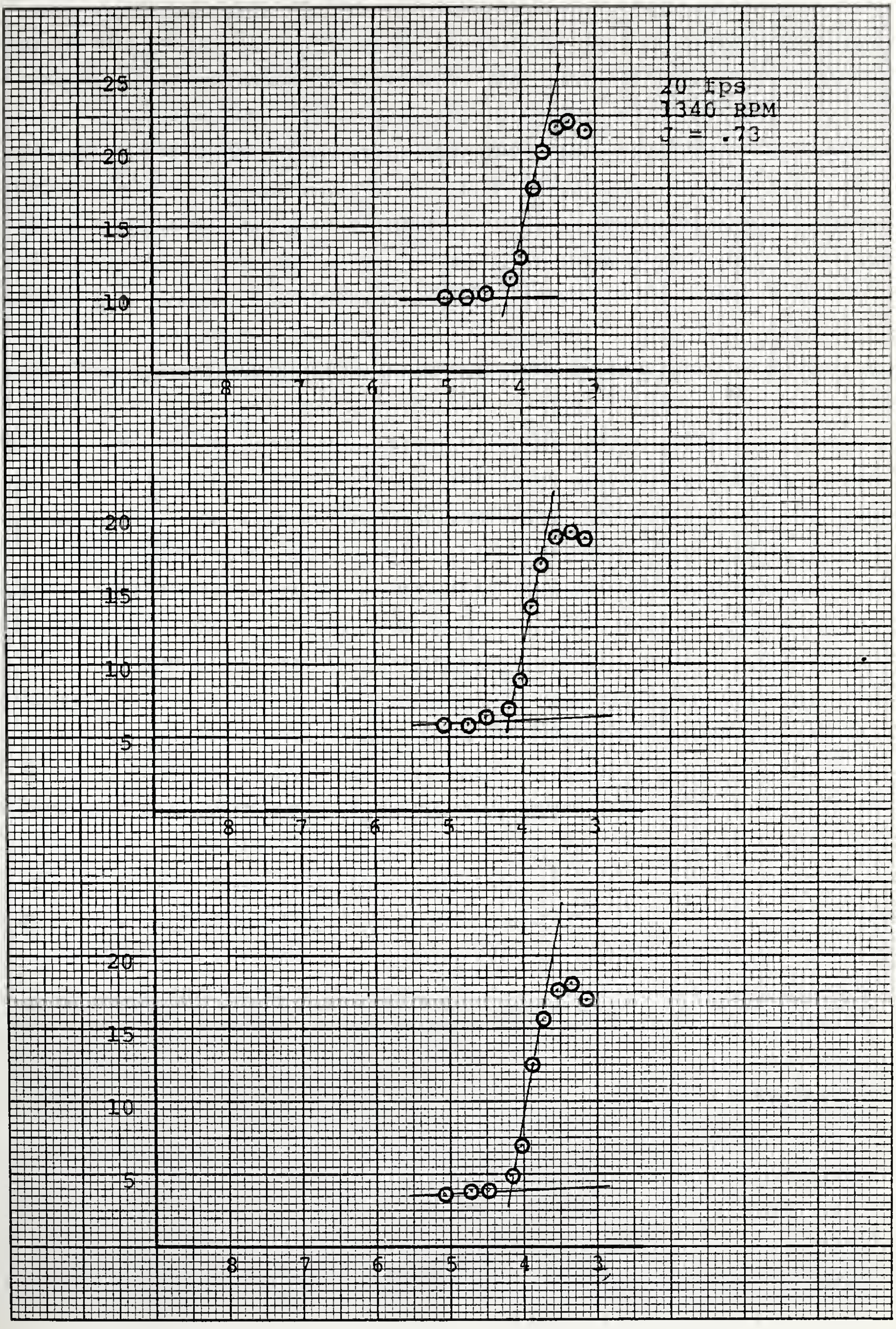
8
7
6
5
4
3
15
10
5
0
8
7
6
5
4
3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1340 RPM
J = .73
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20
15
10
8
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5
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15
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7
6
5
4
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20
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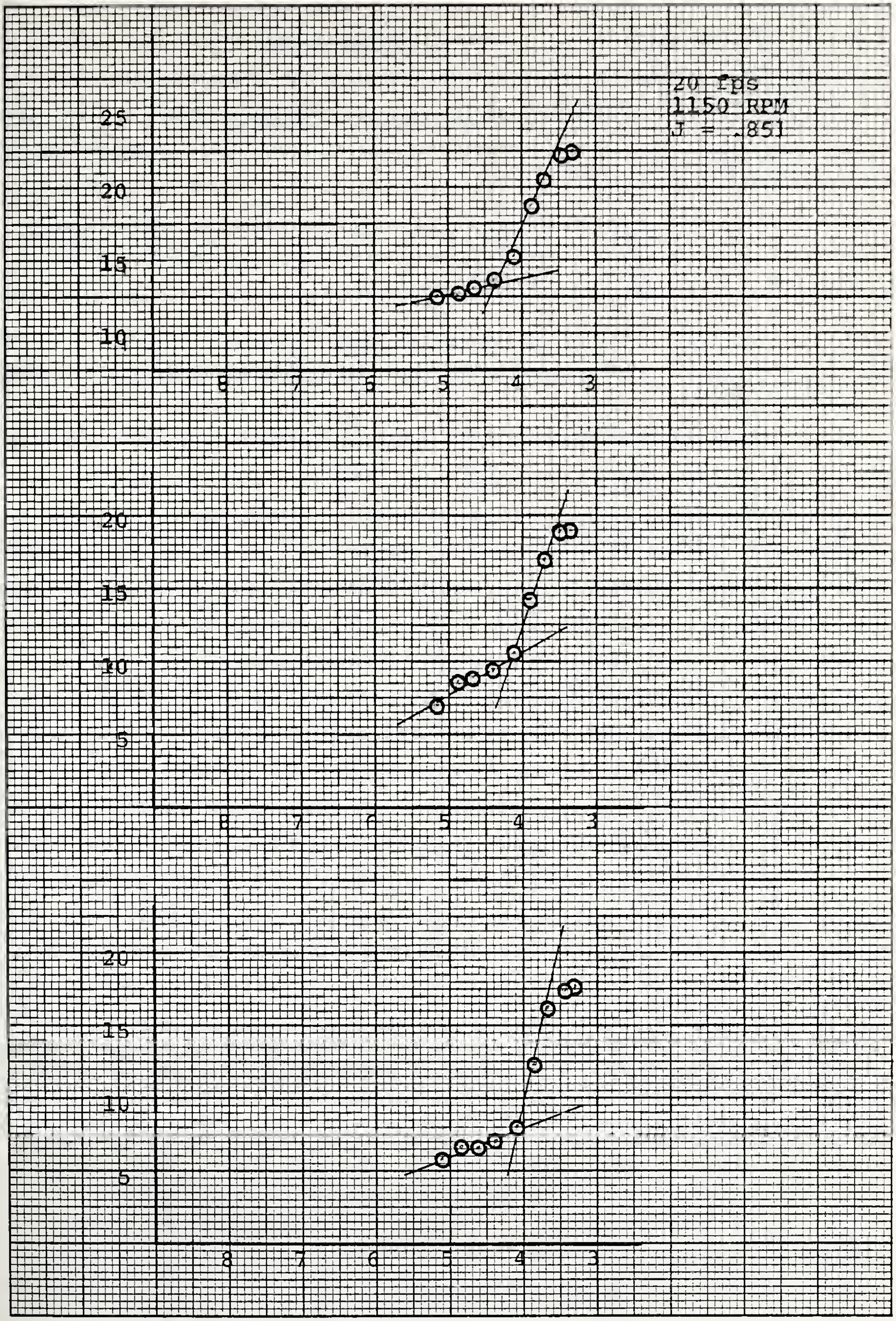
10
5
8
7
6
5
4
3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1150 RPM
J = .851
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20
15
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6
5
4
3
20
15
10
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8
7
6
5
4
3
20
15
10
5
8
7
6
5
4
3

DATA SHEET

RUN NO 5

DATE 3/25

U_{nom} 8 RPM 1040 J_{nom} .375 Shaft rate 17.33
(Taps: 6/5 blue)

Blade rate 121.33

Ithaco amp ① +50 db; Filter: Hi pass 2x10^4 Trans Anal

Lo pass 10x10^5 ② -15 db

Measuring Equipment: Input atten ③ -30 db Meas amp ___ (# of

Output gain ④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 82 air 76 Reynolds number:

(End) 82 76 7.63 x 10^5

Thrust in lbs = T x 0.1 Torque in ft lbs = Q/12

MAN	STAT BAR	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
12	753.8		-4	10						TARE
246	760	1043	978	145			.254	.395	33.70	7-1
250	683	1042	950	145					29.75	-2
252	587	1043	928	145					25.32	
251	561	1040	916	144.5					24.29	-3
248	534	1041	912	144.5					23.40	-4
248	507	1042	916	145.5					22.21	-5
249	480	1043	910	145.5					20.92	-6
249	457	1043	900	145.5	2	-25			19.91	8-1
248	429	1045	906	146.5					18.75	
248	444	1043	902	145.5					19.42	-2 P↑550 ↓
248	453	1045	908	146.5					19.81	-3 P↑550
247	452	1040	896	145					19.86	-4 P↑550
247	460	1044	908	145.5					20.21	-5 P↑550

DATA SHEET

RUN NO 6

DATE 3/25

U_{nom} 8 (Taps: 6/5 blue) RPM 975 J_{nom} 0.4 Shaft rate 16.25

Blade rate 113.75

Ithaco amp① +50 db; Filter: Hi pass 2x10⁴ Trans Anal

Lo pass 10x10⁵ ② -10 db

Measuring Equipment: Input atten③ -30 db Meas amp ___ (# of

Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 82 air 76 Reynolds number:

(End) 83 74 7.14 x10⁵

MAN	STAT	RPM	T	Q	GAIN CHANGE	K_T	J	σ	REMARKS
243	757	975	832	124.5		.247	.41	34.03	9-1
244	536	976	778	125.5				23.92	-2
243	402	973	736	124.5				17.95	-3
242	298	970	706	124				13.30	-4

DATA SHEET

RUN NO 7

DATE 3/25

U_{nom} 10 RPM 1215 J_{nom} 0.4 Shaft rate 20.25
(Taps: 6/5 blue)

Blade rate 141.75

Ithaco amp① +50 db;Filter: Hi pass 2x10^4 Trans Anal

Lo pass 10x10^5 ② -15 db

Measuring Equipment: Input atten③ -30 db Meas amp ___ (# of
Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 83 air 74 Reynolds number:

(End) 83 73 7.95x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
369	750	1215	1570	187.5			.244	.405	21.53	10-1
370	670	1215	1548	188					19.21	-2
370	700	1215	1560	188					20.08	-3
368	717	1215	1565	188					20.69	-4
369	725	1215	1562	188					20.86	-5

DATA SHEET

RUN NO 8

DATE 3/25

U_{nom} 10 RPM 1150 J_{nom} 0.42 Shaft rate 19.17
(Taps: 6/5 blue)

Blade rate 134.17

Ithaco amp① +50 db; Filter: Hi pass 2x10^4 Trans Anal

Lo pass 10x10^5 ② -15 db

Measuring Equipment: Input atten③ -30 db Meas amp ___ (# of
Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 83 air 73 Reynolds number:

(End) 83 73 7.55x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE	K_T	J	σ	REMARKS
369	758	1151	1102	165		.235	.43	21.76	11-1
370	642	1152	1080	166				18.34	-2
369	675	1151	1080	165				19.35	-3
370	612	1154	1072	166				17.47	-4 *NV
370	601	1151	1062	165				17.15	-5
370	583	1150	1056	165				16.63	-6

DATA SHEET

RUN NO 9

DATE 3/25

U_{nom} 8 RPM 915 J_{nom} .425 Shaft rate 15.25
(Taps: 6/5 blue)

Blade rate 106.75

Ithaco amp① +50 db;Filter: Hi pass 2x10⁴ Trans Anal

Lo pass 10x10⁵ ② -15 db

Measuring Equipment: Input atten③ -30 db Meas amp ___ (# of
Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 83 air 73 Reynolds number:

(End) 83 73 6.0x10⁵

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
247	766	915	706	108			.237	.43	33.59	12-1
249	470	918	632	108					20.65	-2
249	385	917	608	108					16.85	
252	334	919	596	108					14.76	-3

DATA SHEET

RUN NO 10

DATE 3/25

U_{nom} 10 (Taps: 6/5 blue) RPM 1080 J_{nom} 0.45 Shaft rate 18

Blade rate 126

Ithaco amp ① +50 db; Filter: Hi pass 2x10^4 Trans Anal

Lo pass 10x10^5 ② -20 db

Measuring Equipment: Input atten ③ -30 db Meas amp ___ (# of

Output gain ④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 83 air 73 Reynolds number:

(End) 83 73 7.08x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE	K_T	J	σ	REMARKS
371	750	1077	916	140		.224	.46	21.42	13-1
370	545	1080	872	141				15.55	-2
370	509	1080	862	141				14.51	-3
369	402	1078	836	141				11.44	-4
369	392	1080	836	141				11.15	-5
369	382	1079	832	141				10.86	-6
370	370	1081	832	141.5				10.48	-7

DATA SHEET

RUN NO 11

DATE 3/25

U_{nom} 12 RPM 1225 J_{nom} 0.475 Shaft rate 20.42
(Taps: 6/5 blue)

Blade rate 142.92

Ithaco amp ① +50 db; Filter: Hi pass 2x10⁴ Trans Anal

Lo pass 10x10⁵ ② -30 db

Measuring Equipment: Input atten ③ -20 db Meas amp ___ (# of
Output gain ④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 83 air 73 Reynolds number:

(End) 83.5 73 8.07x10⁵

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
521	740	1225	1136	172			.213	.48	14.78	14-1
521	558	1228	1086	174					11.11	-2
527	535	1224	1058	171					10.51	-3
526	523	1224	1058	171.5					10.30	-4

DATA SHEET

RUN NO 12

DATE 3/25

U_{nom} 16 RPM 1550 J_{nom} 0.5 Shaft rate 25.83

(Taps: 6/5 blue) Blade rate 180.83

Ithaco amp① +50 db;Filter: Hi pass 2×10^4 Trans Anal

Lo pass 10×10^5 ② -30 db

Measuring Equipment: Input atten③ -20 db Meas amp ___ (# of

Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 83.5 air 73 Reynolds number:

(End) 83.5 73 1.02×10^6

MAN	STAT	RPM	T	Q	GAIN CHANGE	K_T	J	σ	REMARKS
912	715	1546	1666	257.5		.199	.51	7.96	15-1

DATA SHEET

RUN NO 13

DATE 3/25

U_{nom} 12 RPM 1175 J_{nom} 0.5 Shaft rate 19.58

(Taps: 6/5 blue) Blade rate 137.08

Ithaco amp ① +50 db; Filter: Hi pass 2x10^4 Trans Anal

Lo pass 10x10^5 ② -25 db

Measuring Equipment: Input atten ③ -30 db Meas amp ___ (# of

Output gain ④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 83.5 air 73 Reynolds number:

(End) 83.5 73 7.74x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
527	739	1173	984	156			.203	.50	14.60	16-1
528	418	1174	904	154					8.17	
530	469	1175	920	154					9.15	-2 *4U
527	452	1174	910	154					8.86	-3
530	431	1175	898	153.5					8.39	-4
526	417	1175	908	154.5					8.18	-5

DATA SHEET

RUN NO 14

DATE 3/25

U_{nom} 12 RPM 1100 J_{nom} 0.525 Shaft rate 18.33

(Taps: 6/5 blue)

Blade rate 128.33

Ithaco amp① +50 db;Filter: Hi pass 2x10^4 Trans Anal

Lo pass 10x10^5 ② -25 db

Measuring Equipment: Input atten③ -30 db Meas amp ___ (# of

Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 83.5 air 73 Reynolds number:

(End) 84 73 7.28x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
529	738	1101	804	129			.188	.52	14.53	17-1
529	410	1101	716	129					8.00	-2
528	384	1101	710	129					7.49	-3
528	363	1100	700	129					7.07	-4
527	332	1101	700	129.5					6.47	-5
528	319	1101	694	129					6.20	-6

DATA SHEET

RUN NO 15

DATE 3/25

U_{nom} 12 RPM 1050 J_{nom} 0.55 Shaft rate 17.5

(Taps: 6/5 blue) Blade rate 122.5

Ithaco amp① +50 db;Filter: Hi pass 2x10⁴ Trans Anal

Lo pass 10x10⁵ ② -25 db

Measuring Equipment: Input atten③ -30 db Meas amp ___ (# of

Output gain④ +10 db Spect anal. x spectra 32)

Temperature: (Start) water 84 air 73 Reynolds number:

(End) 84 73 6.99×10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
526	739	1052	696	114			.178	.56	14.64	18-1
526	405	1051	606	114					7.95	-2
526	305	1051	580	114					5.94	-3
526	273	1051	574	114					5.30	-4
524	249	1051	568	114					4.84	-5 ←NU
523	225	1049	556	113					4.37	-6

DATA SHEET

RUN NO 16

DATE 3/25

U_{nom} 16 RPM 1350 J_{nom} 0.575 Shaft rate 22.5

(Taps: 6/5 blue) Blade rate 157.5

Ithaco amp① +50 db;Filter: Hi pass 2x10⁴ Trans Anal

Lo pass 10x10⁵ ② -25 db

Measuring Equipment: Input atten③ -30 db Meas amp ___ (# of

Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 84 air 73 Reynolds number:

(End) 84.5 73 9.09x10⁵

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
919	712	1351	1080	176.5			.169	.57	7.62	19-1
914	600	1348	1034	174					6.40	-2
911	566	1348	1030	175	2 3	-30 -30			6.04	-3
911	541	1350	1030	176					5.76	-4
907	329	1349	970	175.5	2	-40			3.55	-5

DATA SHEET

RUN NO 17

DATE 3/25

U_{nom} 16 RPM 1300 J_{nom} 0.6 Shaft rate ~~20~~ 21.67
(Taps: 6/5 blue)

Blade rate 151.67

Ithaco amp① +50 db;Filter: Hi pass 2x10^4 Trans Anal

Lo pass 10x10^5 ② -30 db

Measuring Equipment: Input atten③ -20 db Meas amp ___ (# of
Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 84.5 air 73 Reynolds number:

(End) 85 73 8.77x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
909	717	1300	938	157			.158	.59	7.76	20-1
916	577	1299	886	155					6.13	-2
916	531.	1300	8.78	156					5.62	-3
914	.504	1303	878	157					5.32	-4
911	481	1305	828	158					5.08	-5
913	452	1300	856	155.5					4.74	-6

DATA SHEET

RUN NO 18

DATE 3/25

U_{nom} 16 RPM 1250 J_{nom} 0.625 Shaft rate 20.83

(Taps: 6/5 blue) Blade rate 145.83

Ithaco amp① +50 db;Filter: Hi pass 2x10^4 Trans Anal

Lo pass 10x10^5 ② -30 db

Measuring Equipment: Input atten③ -20 db Meas amp ___ (# of

Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 85 air 73 Reynolds number:

(End) 85.5 73 8.56x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
919	713	1250	784	137.5			.143	.62	7.87	21-1
919	409	1250	706	136.5					4.47	-2
918	397	1253	716	139					4.34	~~-4~~ -3
912	386	1251	710	137.5	3	-30			4.24	-4
911	371	1250	706	138					4.08	-5
909	344	1251	704	138	2 3	-35 -20			3.78	-6
915	318	1251	698	138	1	+40			3.46	22-1
912	307	1251	690	137					3.35	-2
910	292	1251	674	137					3.19	-3
913	272	1250	660	136					2.95	-4

DATA SHEET

RUN NO 19

DATE 3/25

U_{nom} 16 RPM 1200 J_{nom} 0.65 Shaft rate 20
(Taps: 6/5 blue)

Blade rate 140

Ithaco amp① +40 db;Filter: Hi pass 2x10⁴ Trans Anal

Lo pass 10x10⁵ ② -20 db

Measuring Equipment: Input atten③ -20 db Meas amp ___ (# of
Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 85.5 air 73 Reynolds number:

(End) 86 73 8.25x10⁵

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
913	715	1202	684	122			.135	.64	7.95	23-1
913	466	1200	600	118.5					5.14	-2
914	423	1204	600	120					4.65	-3
910	385	1200	586	119.5					4.24	-4
912	370	1199	580	119.5					4.06	
916	355	1201	574	119.5					3.87	
914	346	1201	568	119.5	2 3	-30 -10			3.71	-5
917	334	1199	560	118.5	3	-20			3.63	24-1
917	318	1200	560	118.5					3.45	-2
914	293	1199	550	118					3.18	-3
913	274	1200	534	117.5					2.97	-4

DATA SHEET

RUN NO 20

DATE 3/25

U_{nom} 16 RPM 1150 J_{nom} 0.675 Shaft rate 19.17
(Taps: 6/5 blue) Blade rate 134.17

Ithaco amp ① +50 db;Filter: Hi pass 2x10⁴ Trans Anal

Lo pass 10x105 ② -30 db

Measuring Equipment: Input atten ③ -20 db Meas amp ___ (# of
Output gain ④ +10 db Spect anal. 2 spectra 32)

Temperature: (Start) water 86 air 73 Reynolds number:

(End) 87 72.7 7.98x10⁵

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
915	714	1151	556	102.5			.130	.67	7.91	25-1
918.	470	1152	480	101.5					5.15	-2
916	423	1150	468	101.5					4.63	-3
915	388	1150	460	101.5					4.24	-4
913	365	1150	454	102					3.99	-5
916	345	1149	440	101	2	-40			3.75	26-1
915	335	1149	440	101					3.64	-2
915	327	1149	438	101					3.55	-3
913	312	1150	438	101	1	+40			3.39	-4
915	300	1150	436	100.5					3.25	-5
915	282	1148	414	100					3.05	-6 (bottom line)

DATA SHEET

RUN NO 21

DATE 3/25

U_{nom} 16 RPM 1100 J_{nom} 0.7 Shaft rate 18.33
(Taps: 6/5 blue)

Blade rate 128.33

Ithaco amp ① +50 db; Filter: Hi pass 2x10^4 Trans Anal

Lo pass 10x10^5 ② -30 db

Measuring Equipment: Input atten ③ -20 db Meas amp ___ (# of
Output gain ④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 87 air 72.7 Reynolds number:

(End) 87.4 72.7 7.85x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
917	714	1100	430	84.5			.102	.69	7.86	27-1
918	394	1100	340	84.5					4.27	-2
918	353	1100	326	84	4	+40			3.81	-3
917	319	1101	326	85	2	-40			3.44	-4
921	302	1100	308	83					3.23	-5

DATA SHEET

RUN NO 22

DATE 3/25

U_{nom} 16 (Taps: 6/5 blue)   RPM 1070 J_{nom} 0.72   Shaft rate 17.83

Blade rate 124.83

Ithaco amp① +50 db; Filter: Hi pass 2x10⁴ Trans Anal

Lo pass 10x10⁵   ② -30 db

Measuring Equipment: Input atten③ -30 db Meas amp ___ (# of
Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 87.4 air 72.7 Reynolds number:

(End) 88   72.5   7.67 x10⁵

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
912	714	1071	366	75			.092	.72	7.91	28-1
913	386	1070	270	74.5					4.51	-2
911	354	1068	266	74.5	1	+40			3.85	-3
912	343	1071	264	74.5					3.73	-4 * [illegible]

DATA SHEET

RUN NO 23

DATE 3/25

U_{nom} 16 RPM 1040 J_{nom} .75 Shaft rate 17.33

(Taps: 6/5 blue) Blade rate 121.33

Ithaco amp ① +40 db; Filter: Hi pass 2x10^4 Trans Anal

Lo pass 10x10^5 ② -30 db

Measuring Equipment: Input atten ③ -20 db Meas amp ___ (# of

Output gain ④ +10 db Spect anal. x spectra 32)

Temperature: (Start) water 88 air 72.5 Reynolds number:

(End) 88 72.5 7.46x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
917	716	1039	286	64.5			.076	.74	7.87	29-1
914	463	1040	230	64.5					5.05	-2
914	397	1040	206	64.5					4.34	-3
916	366	1040	200	64.6					3.95	-4
914	341	1042	192	65					3.68	-5
916	356	1042	198	65					3.84	-6
914	454	1041	224	64.5					4.95	30-1
915	455	1041	224	64.5	2	-20			4.96	-2
16	BAR 750.3		20	12						TARE

DATA SHEET

RUN NO 2

DATE 3/26

U_{nom} 16 RPM 975 J_{nom} 0.80 Shaft rate 16.25
(Taps: 6/5 blue) Blade rate 113.75

Ithaco amp ① +40 db; Filter: Hi pass 2x10^4 Trans Anal

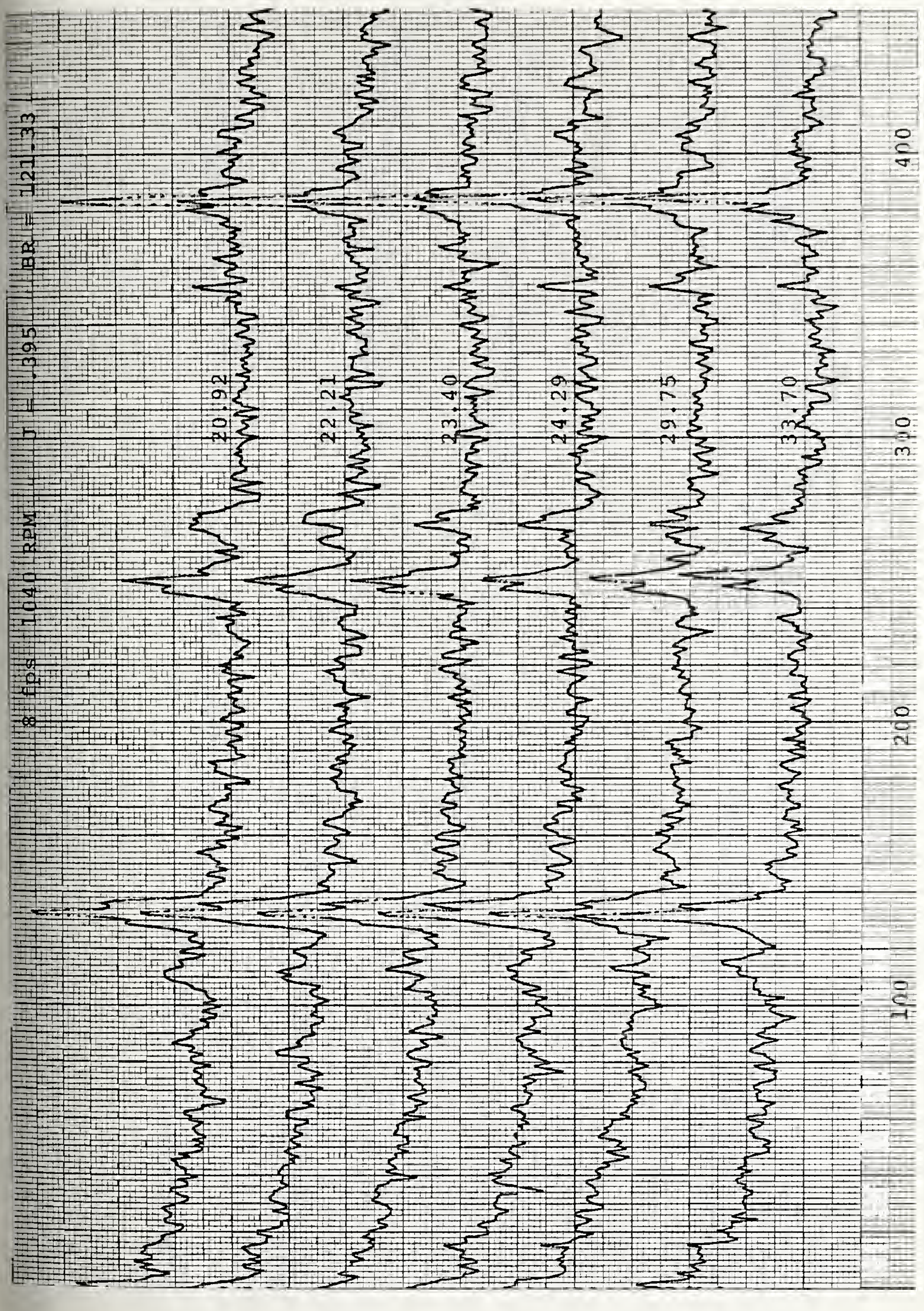
Lo pass 10x10^5 ② -20 db

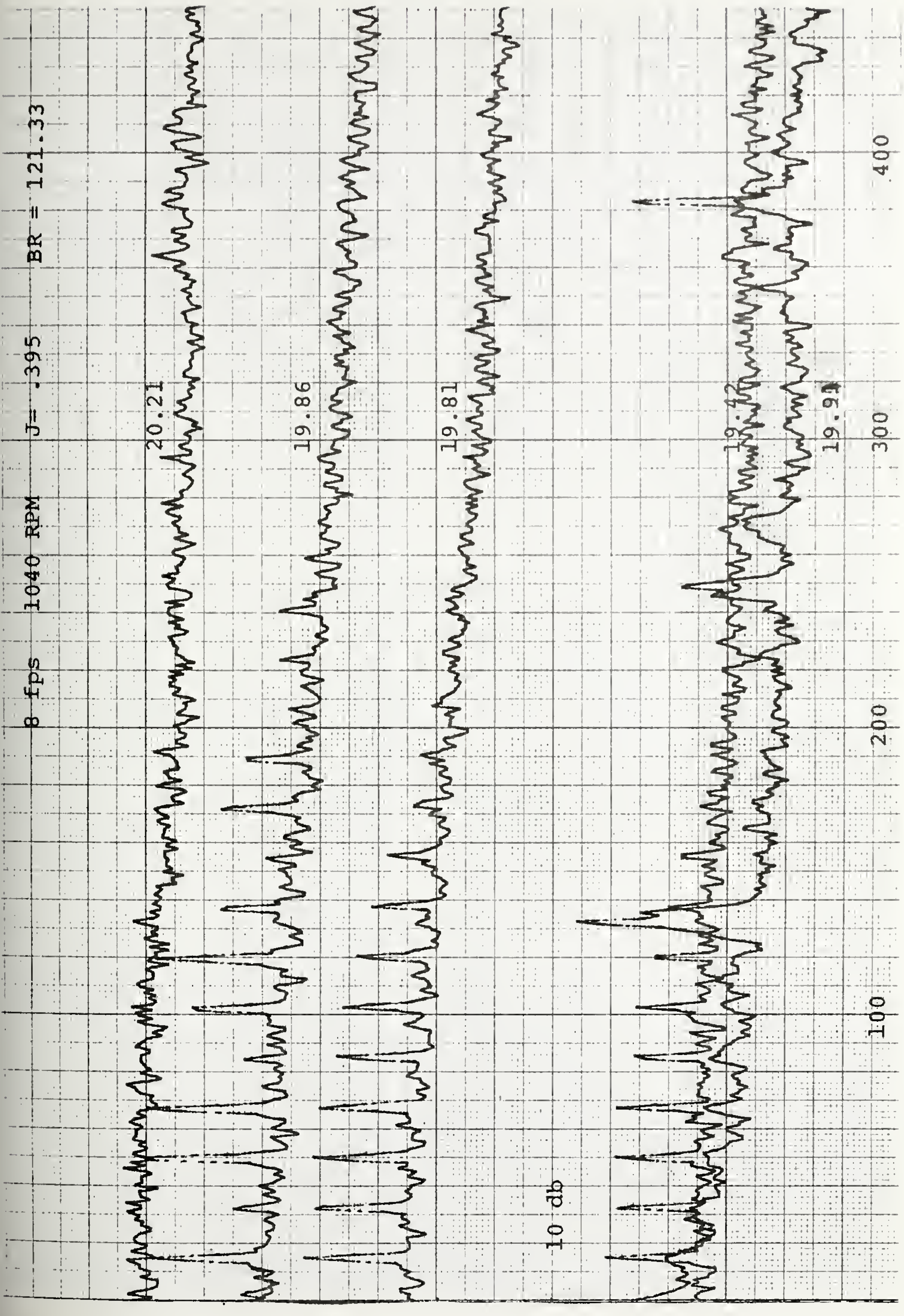
Measuring Equipment: Input atten ③ -20 db Meas amp ___ (# of
Output gain ④ +10 db Spect anal. X spectra 32)

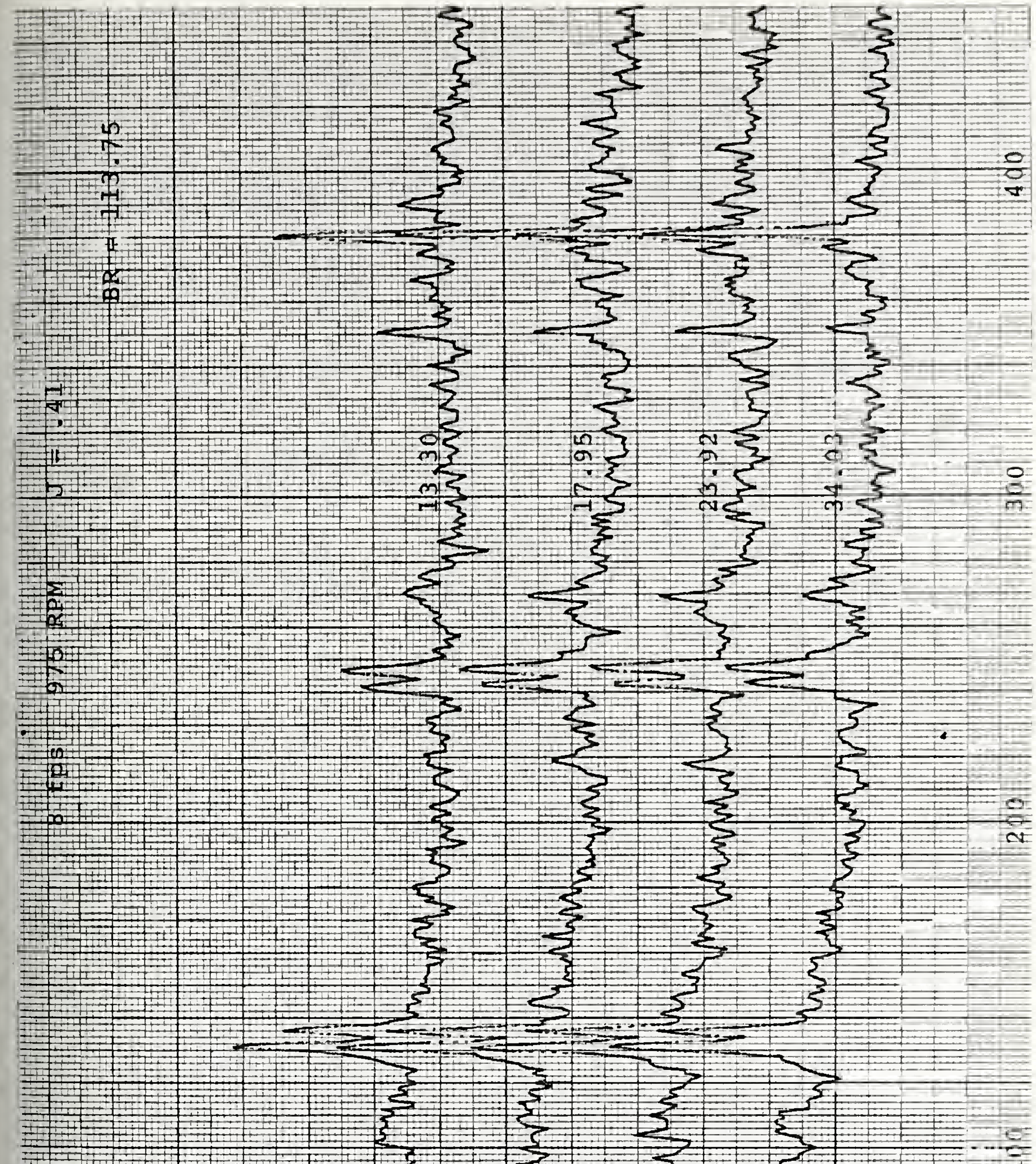
Temperature: (Start) water 87 air 77 Reynolds number:

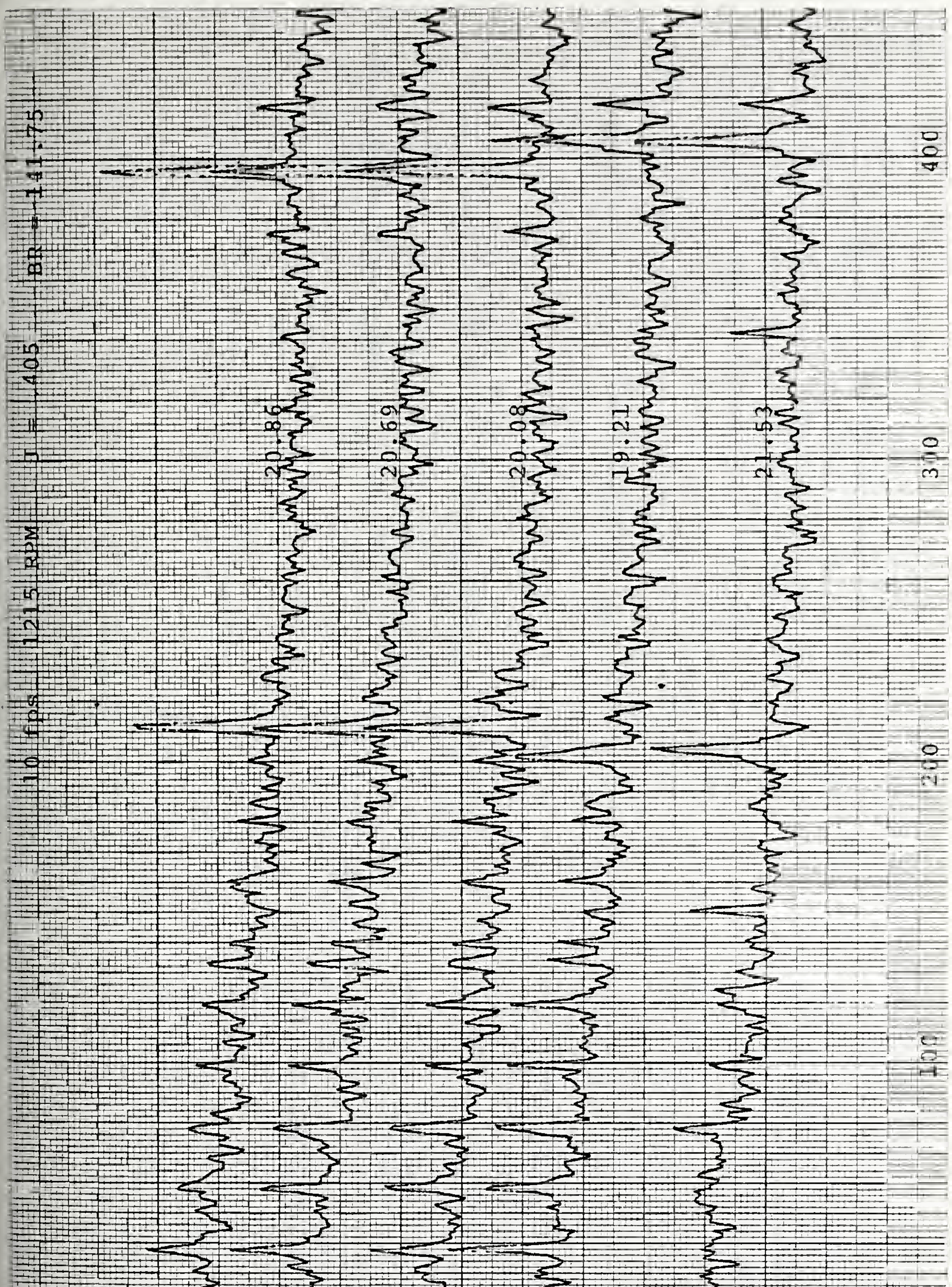
(End) 87.7 77 7.07x10^5

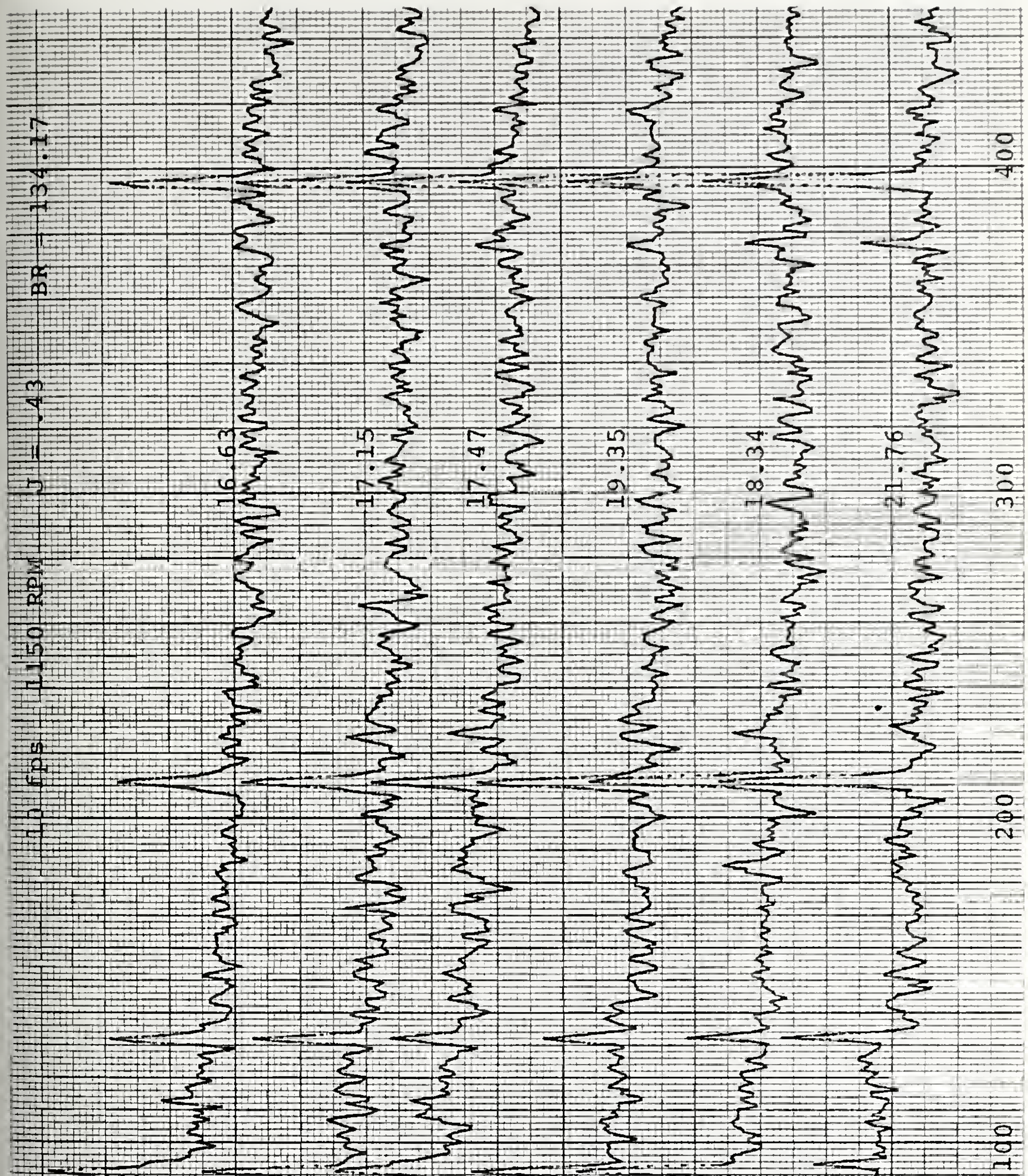
MAN	STAT	RPM	T	Q	GAIN CHANGE	K_T	J	σ	REMARKS
919	713	977	142	44.5		.043	.79	7.78	33-1
914	482	975	86	45				5.25	-2
910	475	976	86	45				5.20	-3
912	465	976	82	44.5				5.07	-4
916	453	976	86	45				4.92	-5
915	437	975	78	44				4.75	-6
915	423	974	68	44				4.59	-7 *LETPF

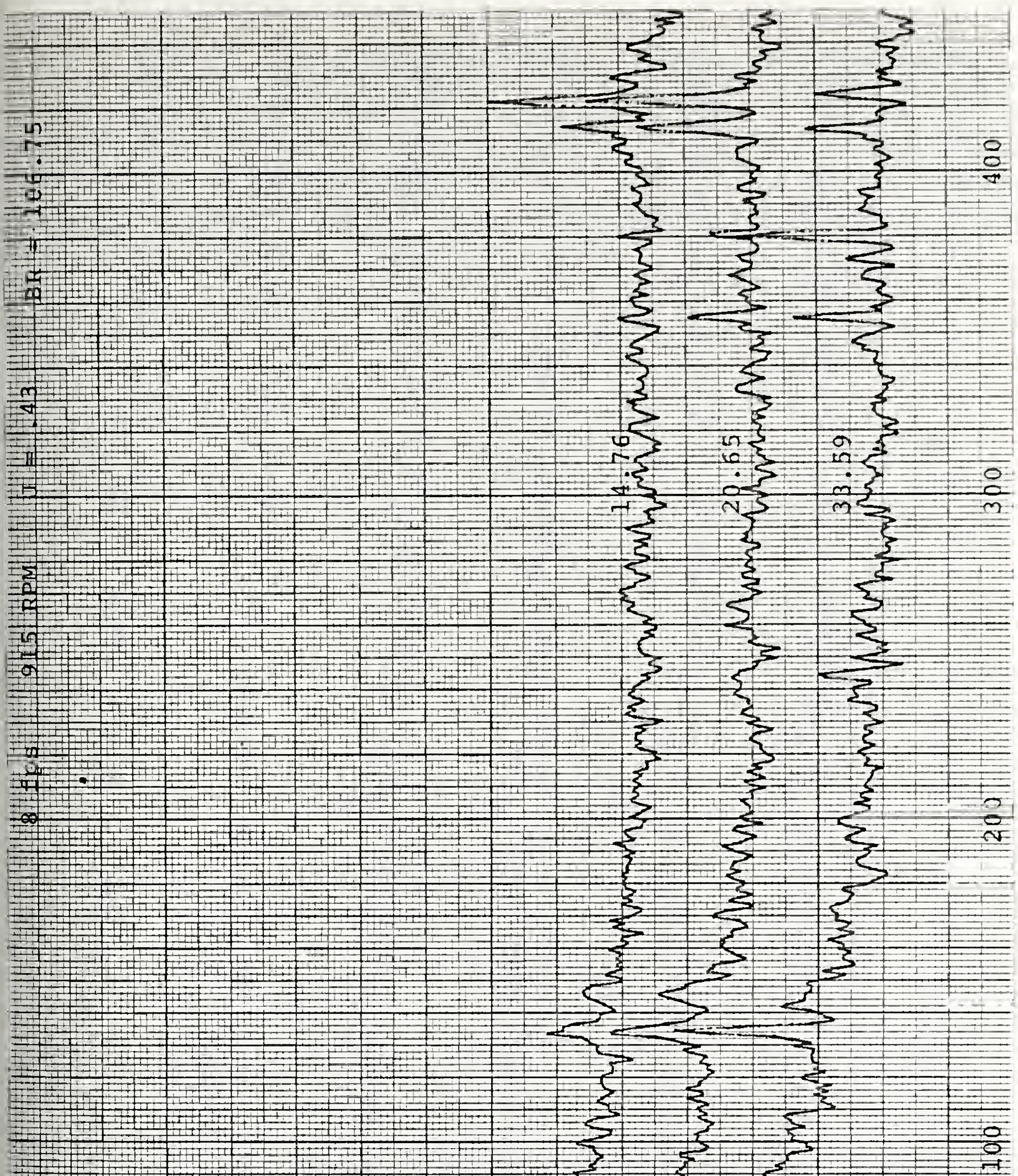

8 fps 1040 RPM J = .395 BR = 121.33
20.92
22.21
23.40
24.29
29.75
33.70
100
200
300
400

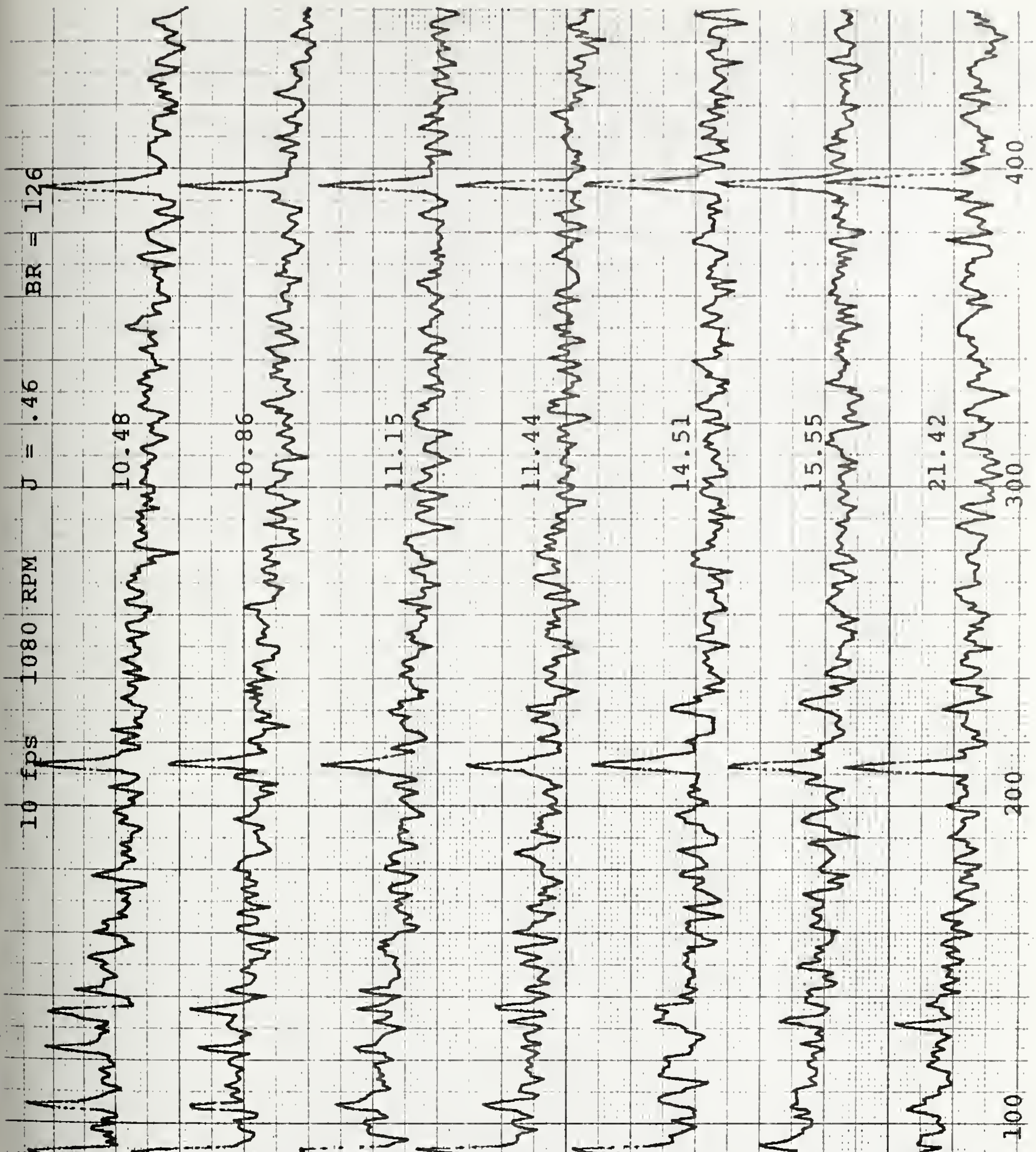

8 fps 1040 RPM J= .395 BR = 121.33
20.21
19.86
19.81
19.42
19.91
10 db
100
200
300
400

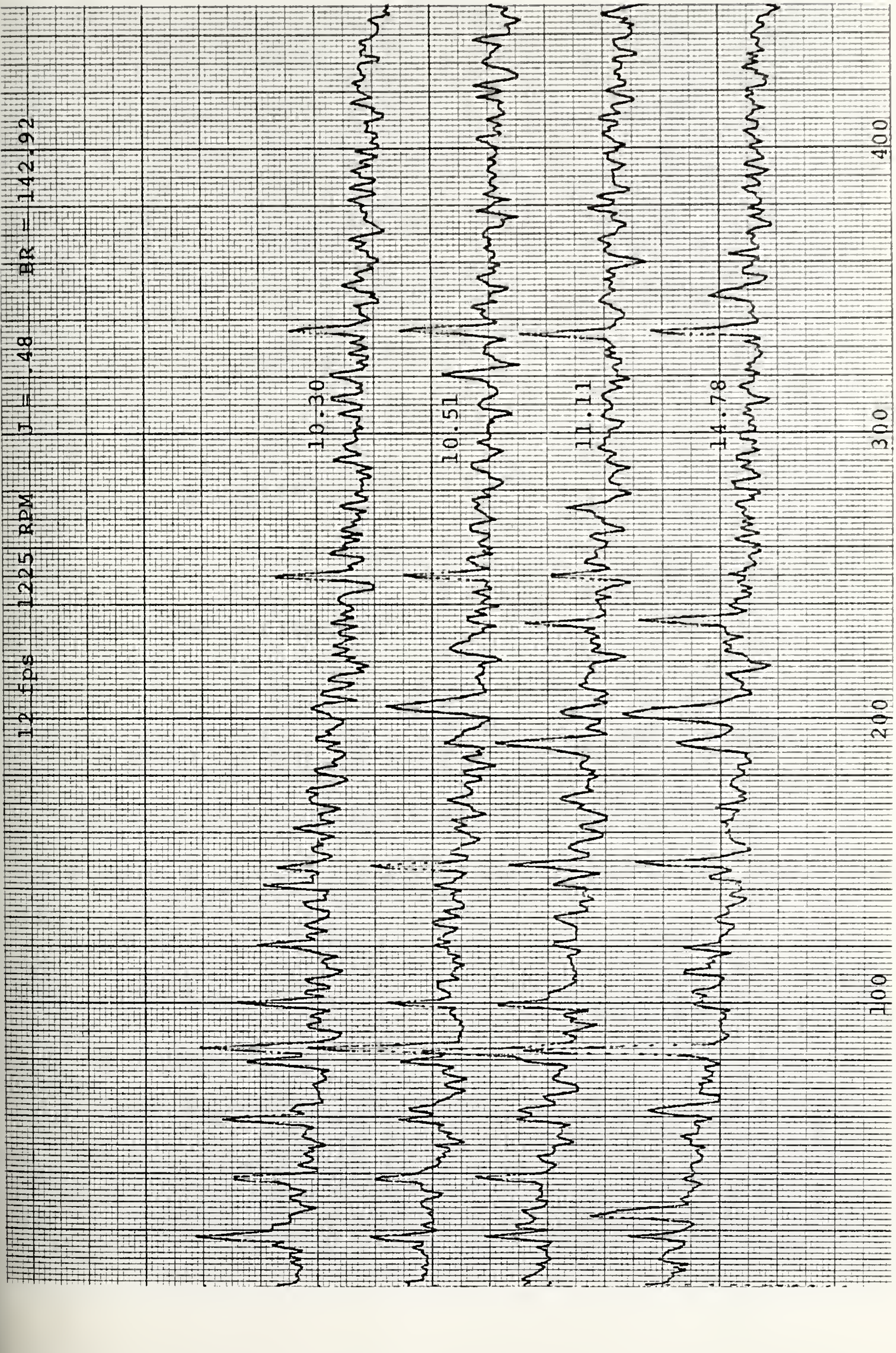

8 EDS 975 RPM J = .41 BR = 113.75
13.30
17.95
25.92
34.03
100
200
300
400

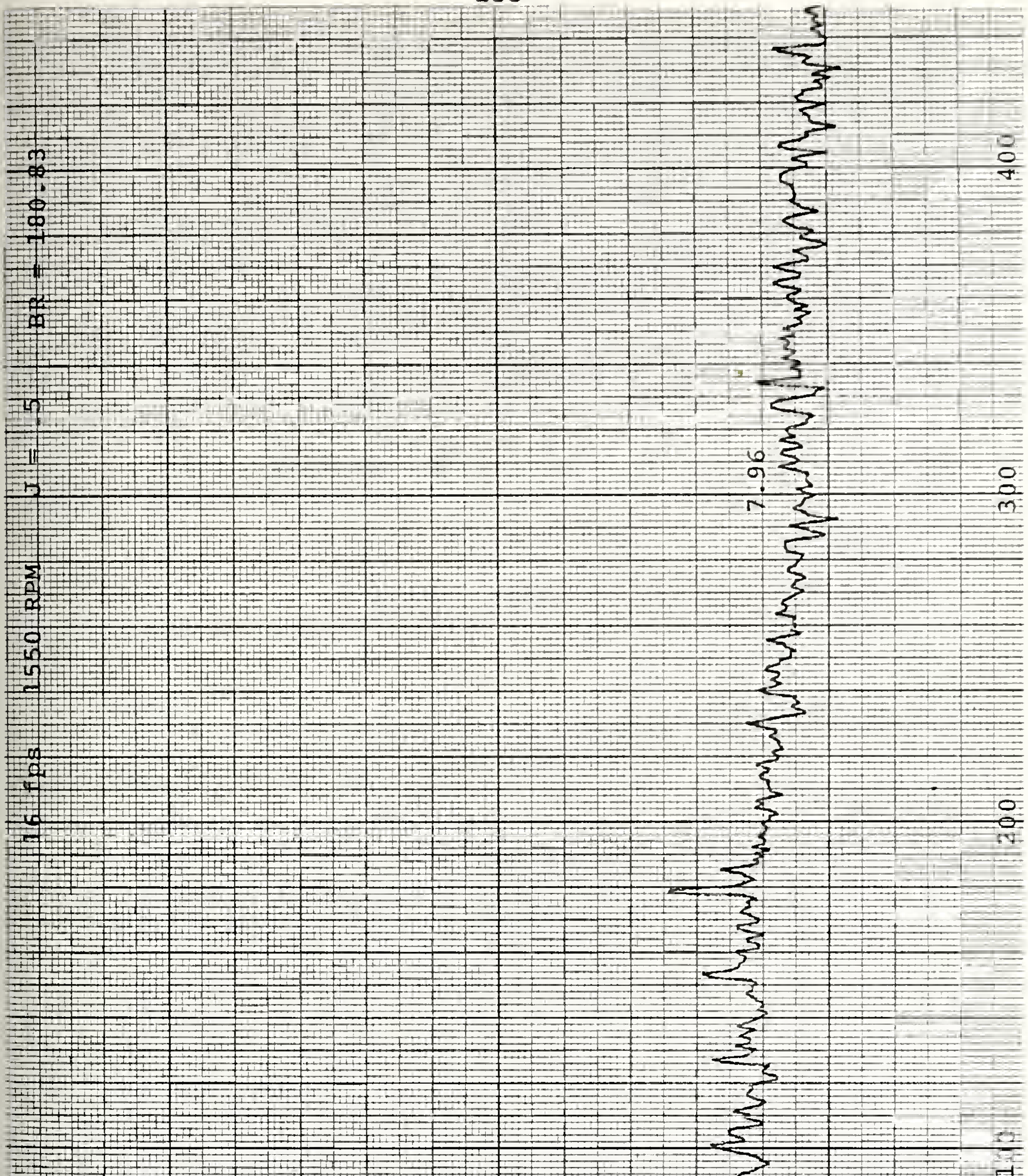

10 fps 1215 RPM J = 405 BR = 141.75
20.86
20.69
20.08
19.21
21.53
100
200
300
400

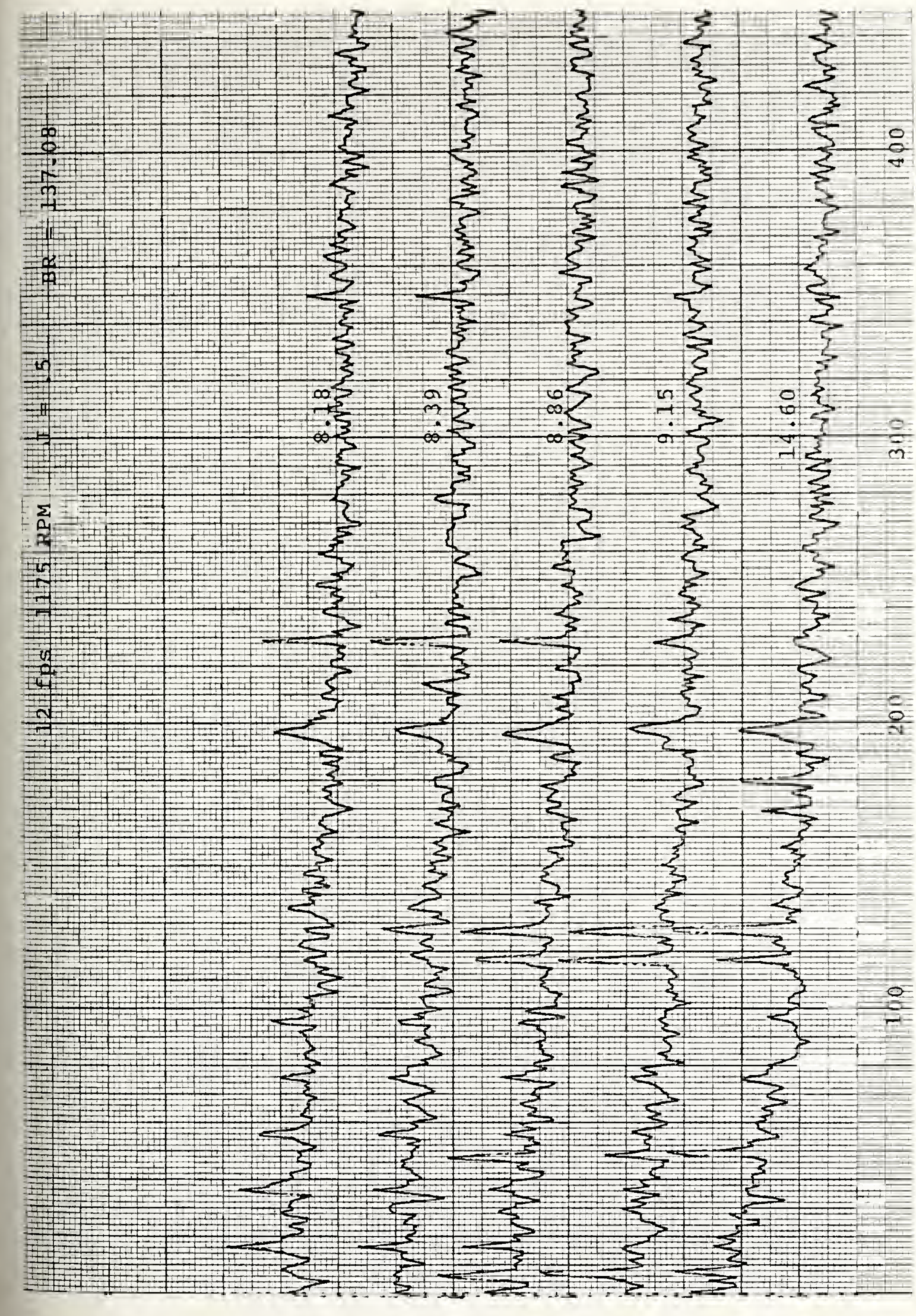

10 fps 1150 RPM J = .43 BR = 134.17
16.63
17.15
17.47
19.35
18.34
21.76
100
200
300
400

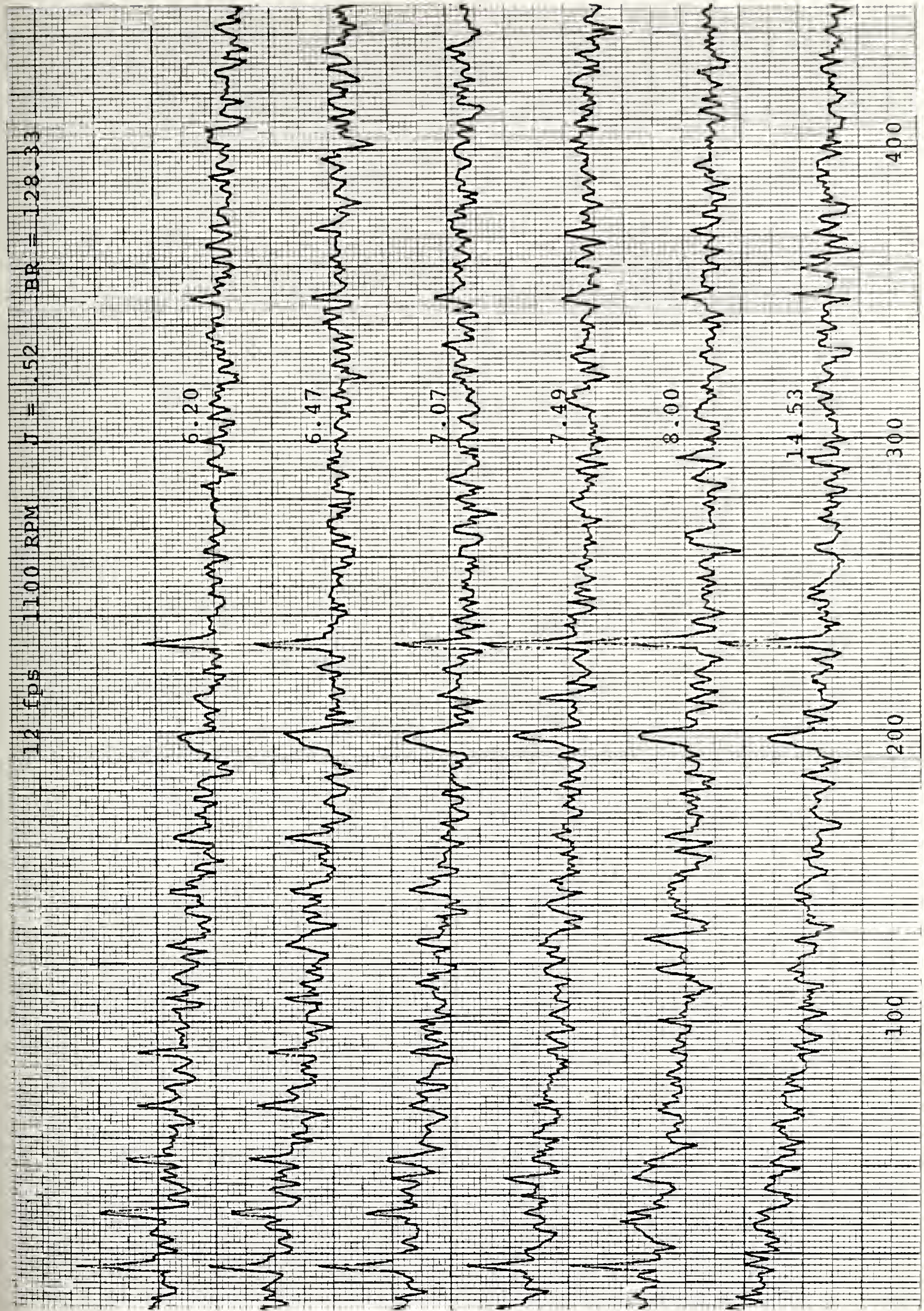

8 fps
915 RPM
J = .43
BR = 166.75
14.76
20.65
33.59
100
200
300
400

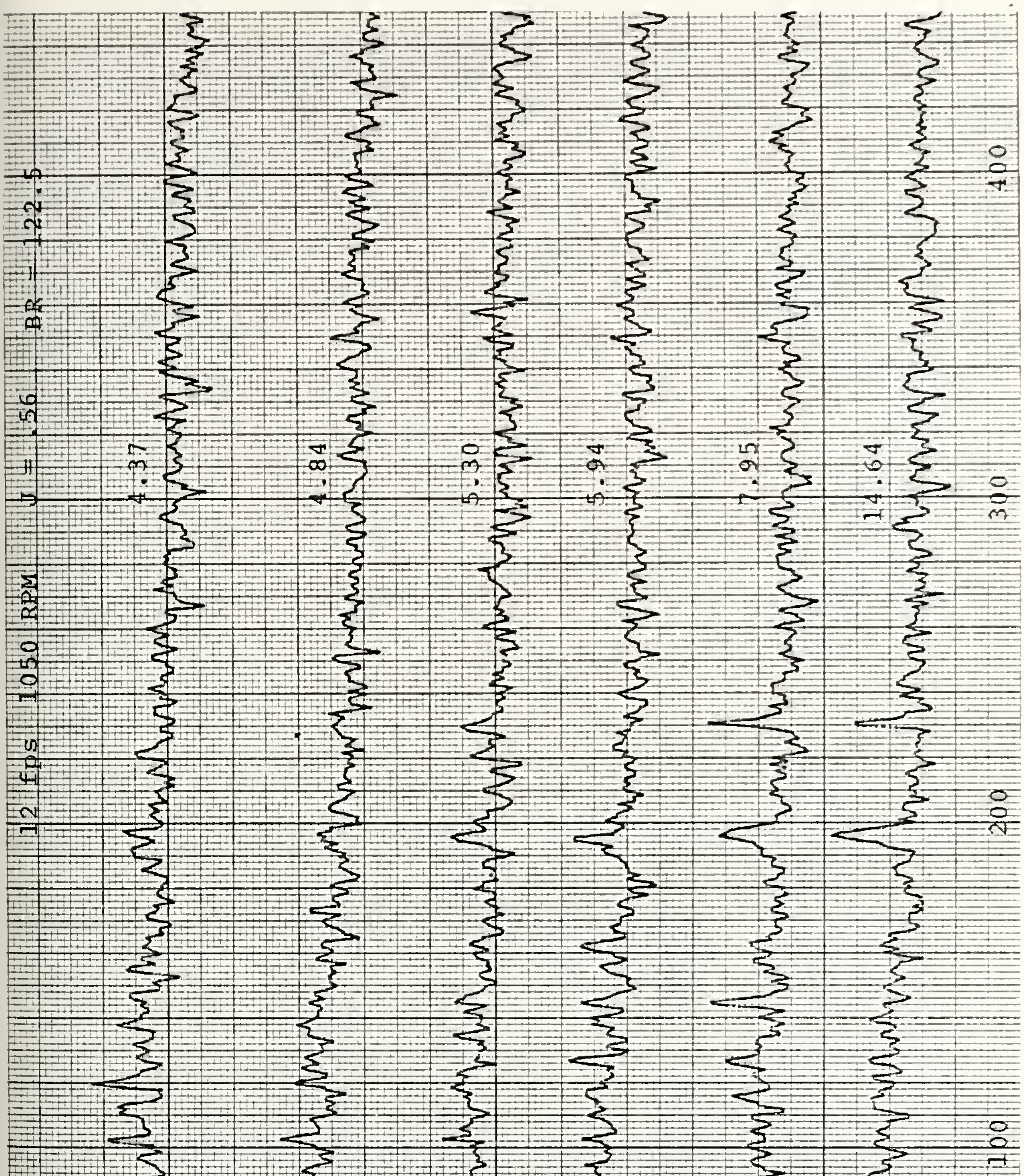

10 fps 1080 RPM J = .46 BR = 126
10.48
10.86
11.15
11.44
14.51
15.55
21.42
100
200
300
400

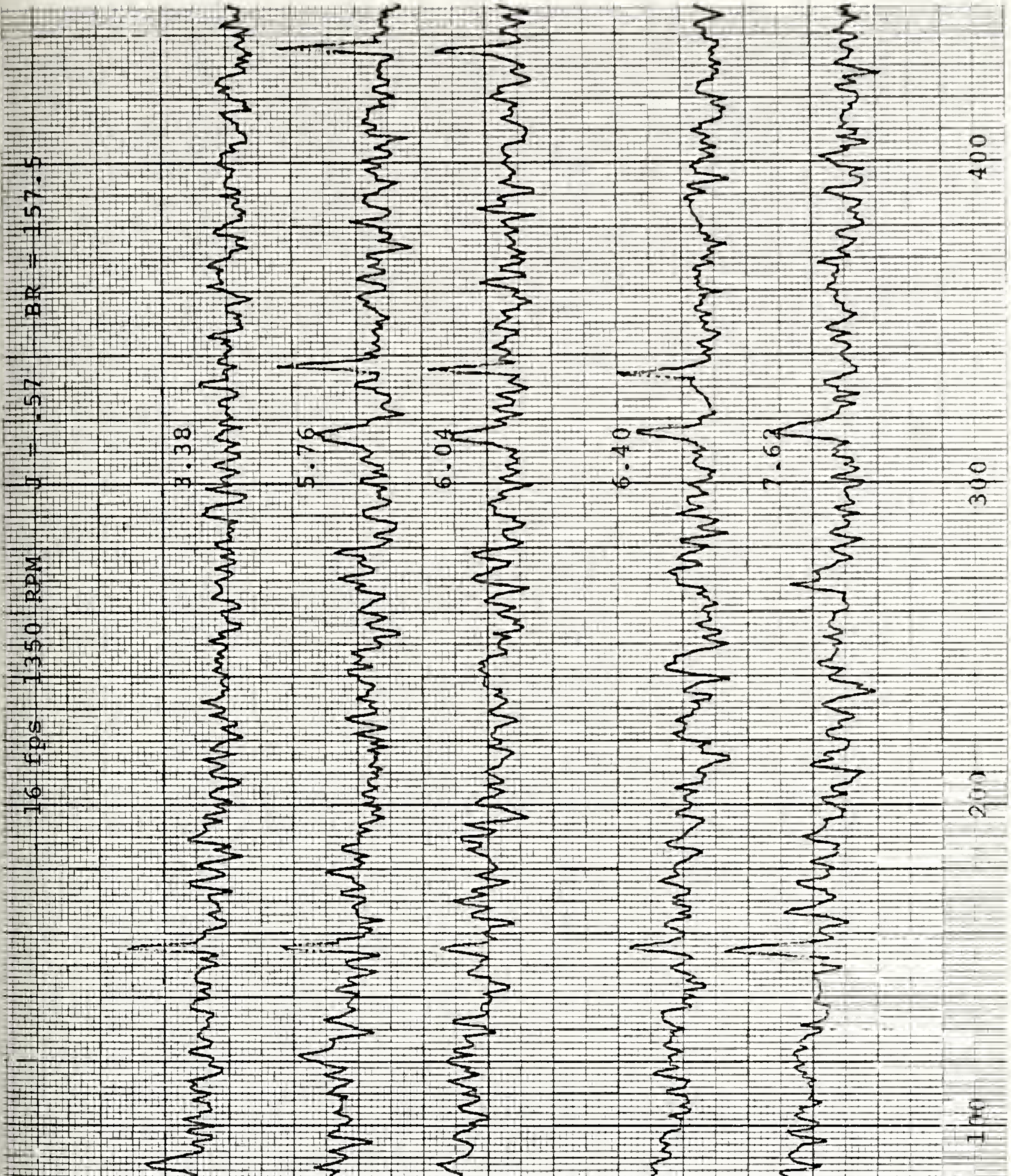

12 fps 1225 RPM J = .48 BR = 142.92
10.30
10.51
11.11
14.78
100
200
300
400

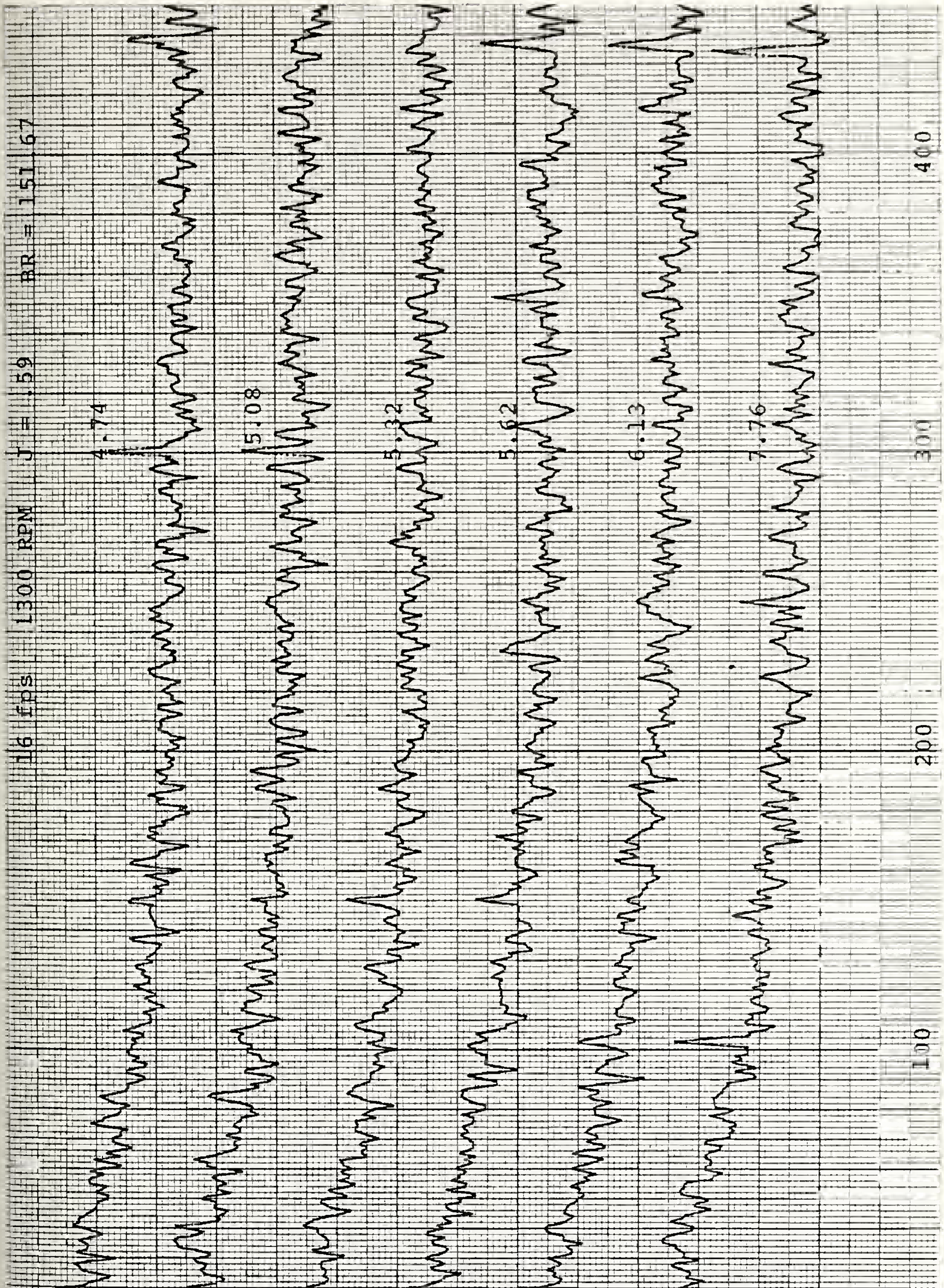

16 fps 1550 RPM J = .5 BR = 180.83
7.96
100
200
300
400

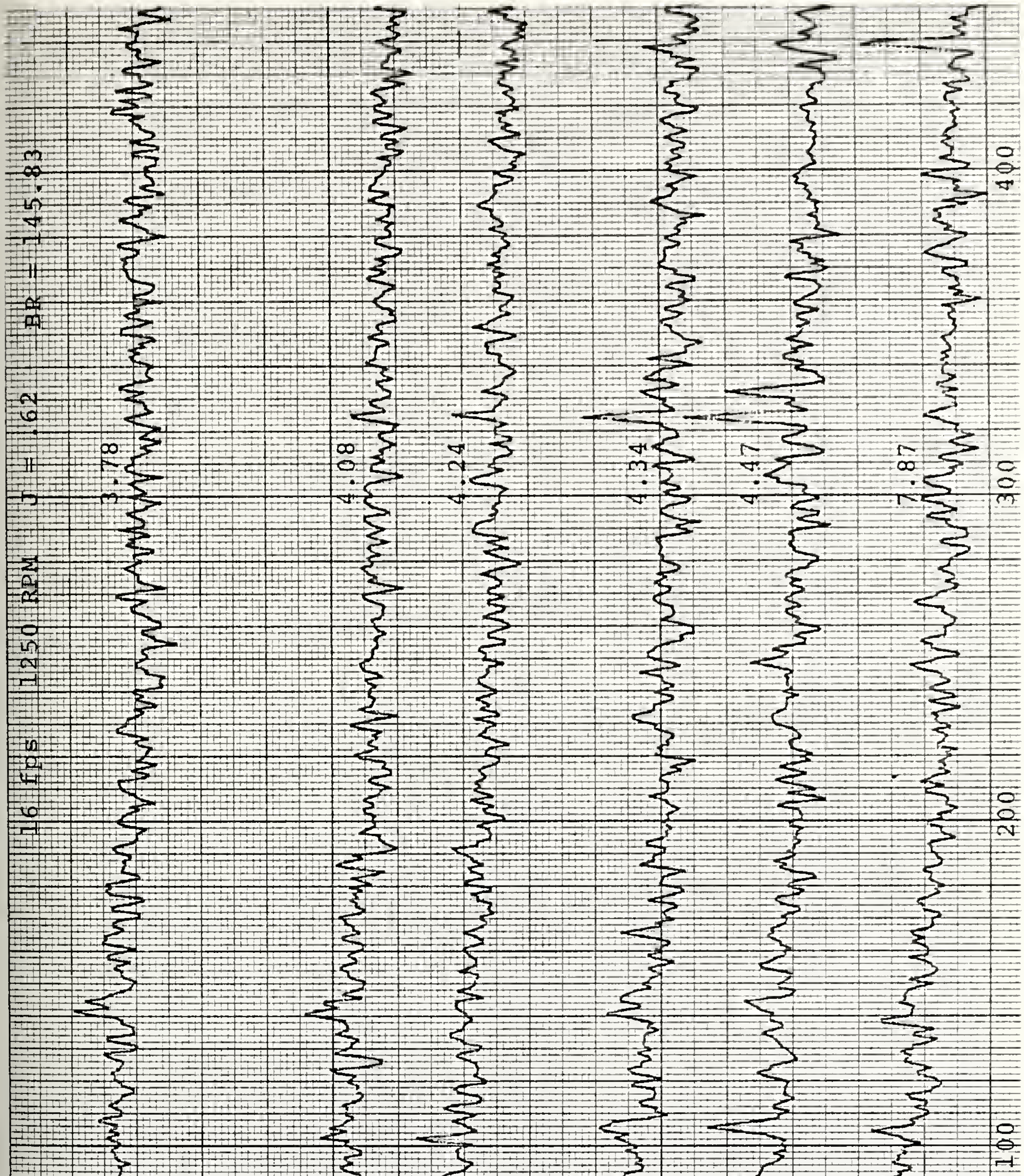

12 fps 1175 RPM J = .5 BR = 137.08
8.18
8.39
8.86
9.15
14.60
100
200
300
400

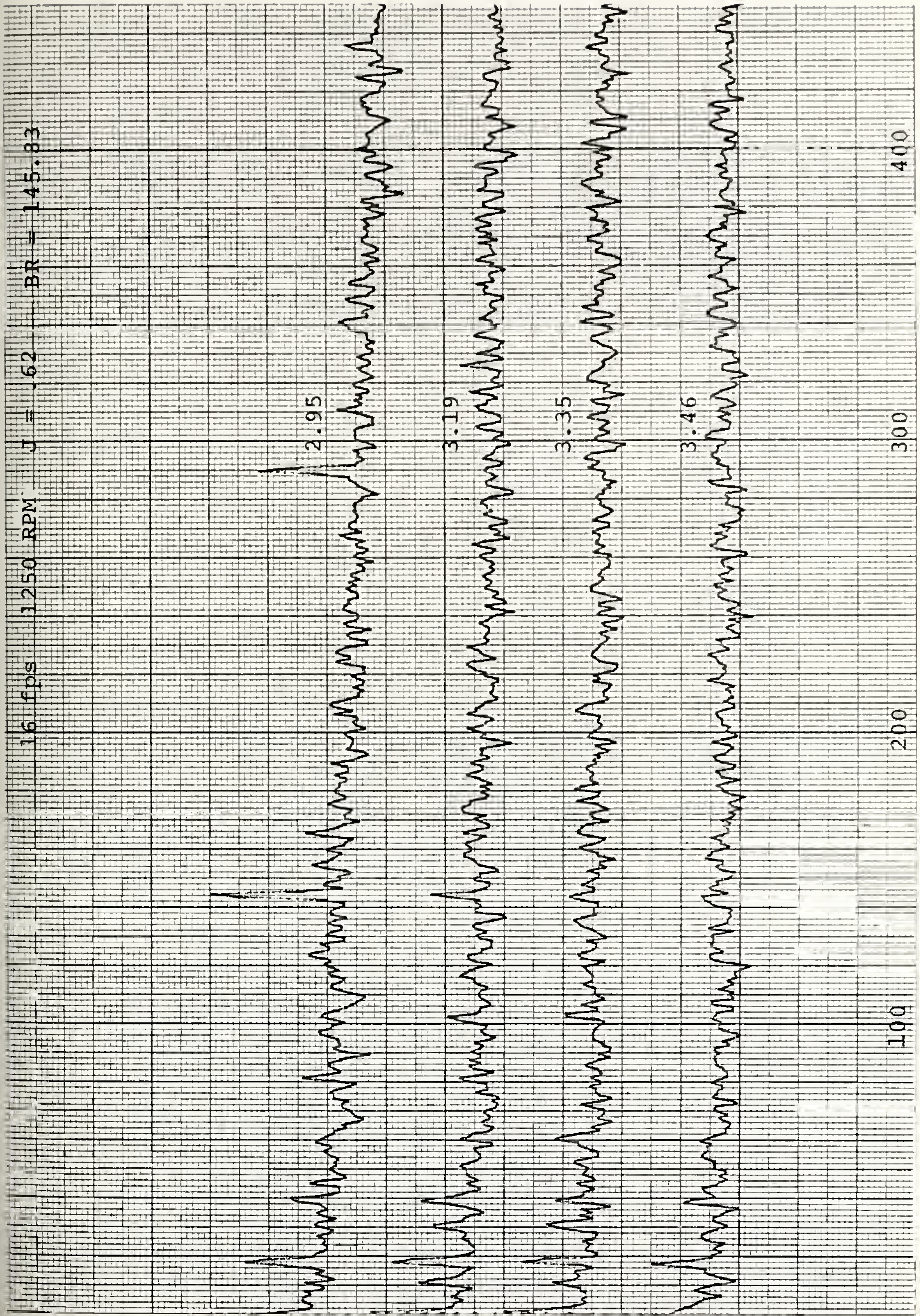

12 fps 1100 RPM J = .52 BR = 128.33
6.20
6.47
7.07
7.49
8.00
11.53
100
200
300
400

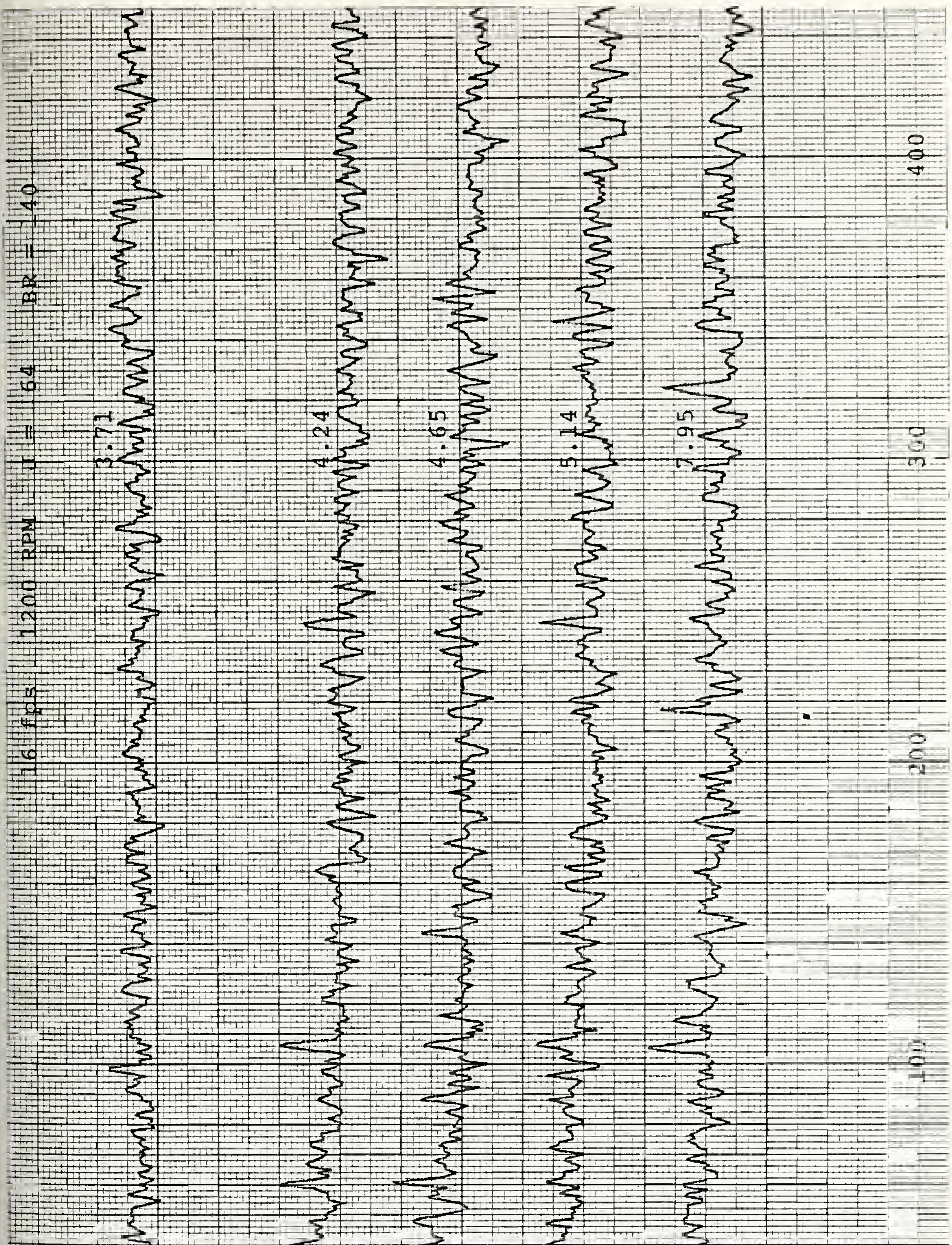

12 fps 1050 RPM J = .56 BR = 122.5
4.37
4.84
5.30
5.94
7.95
14.64
100
200
300
400


16 fps 1350 RPM J = .57 BR = 157.5
3.38
5.76
6.04
6.40
7.62
100
200
300
400

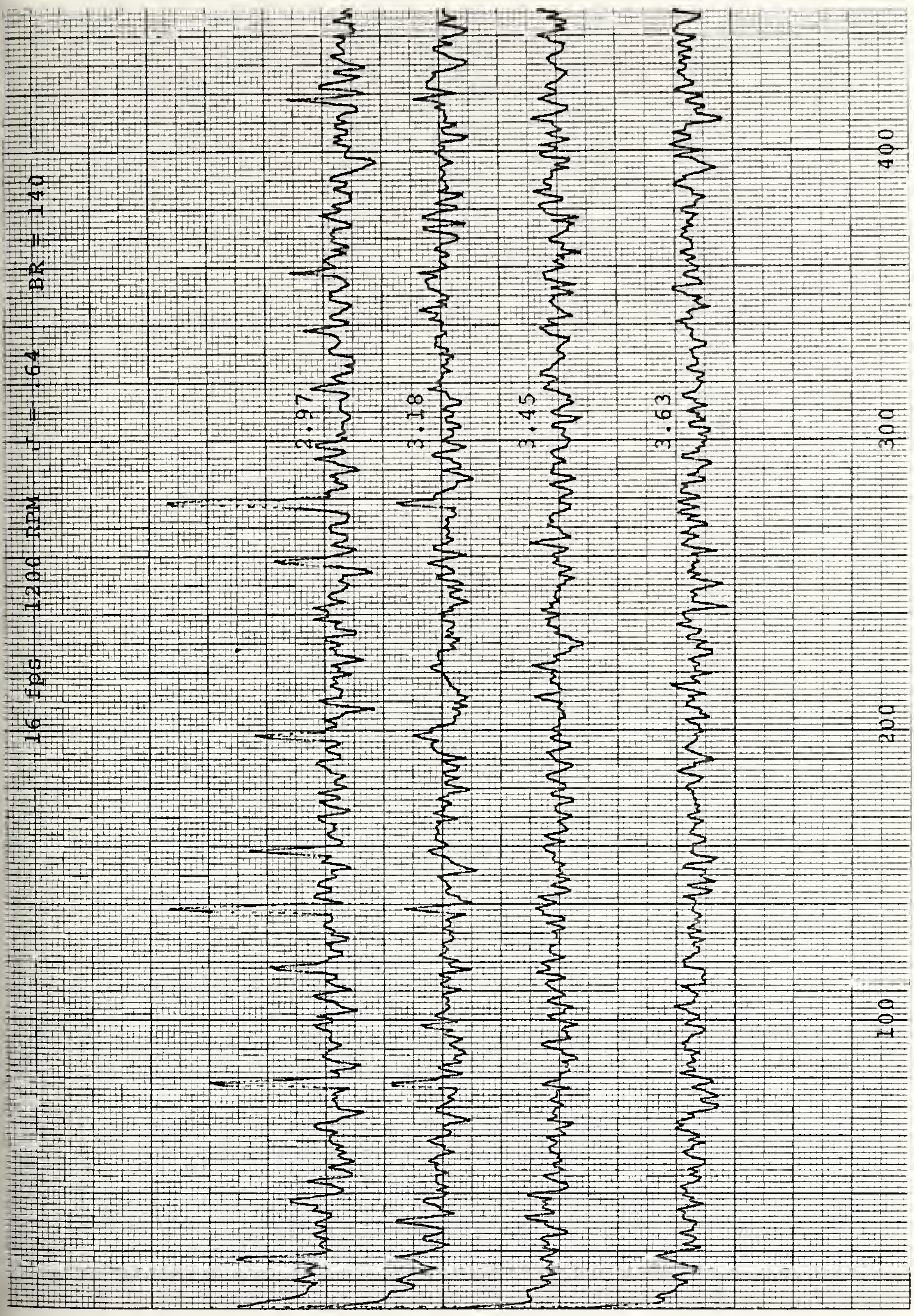

16 fps   1300 RPM   J = .59   BR = 151.67
4.74
5.08
5.32
5.62
6.13
7.76
100
200
300
400

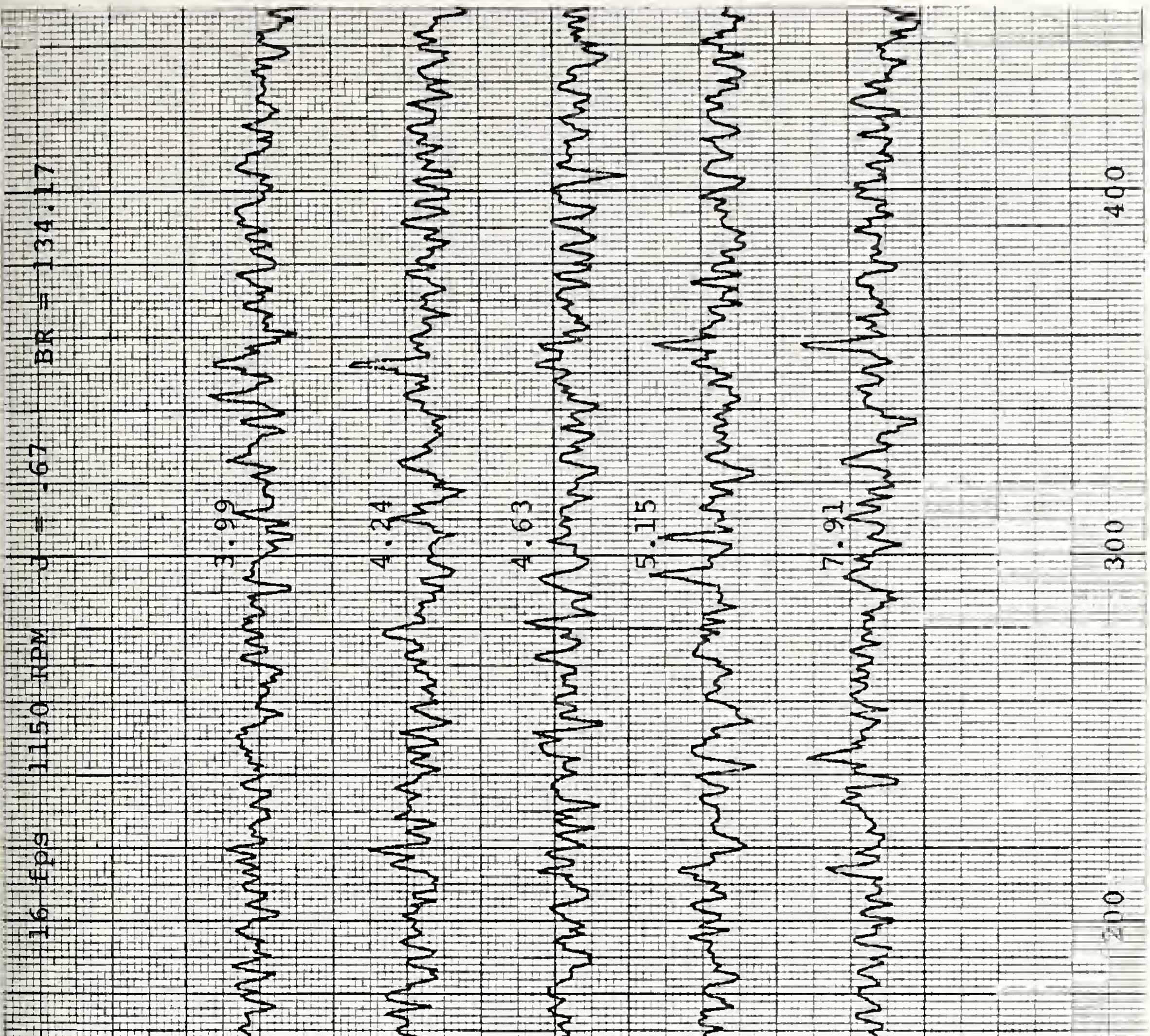

16 fps 1250 RPM J = .62 BR = 145.83
3.78
4.08
4.24
4.34
4.47
7.87
100
200
300
400

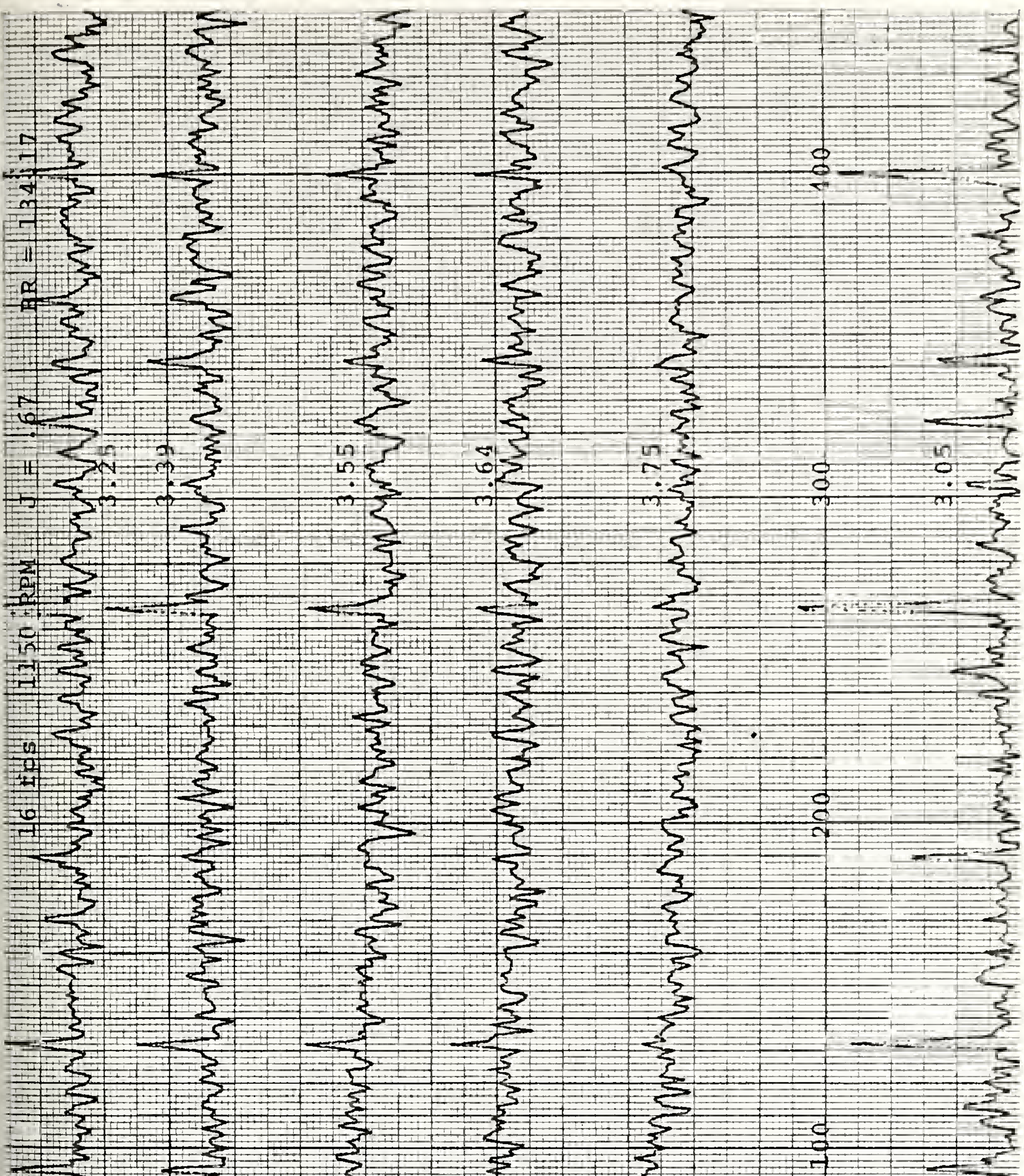

16 fps 1250 RPM J = .62 BR = 145.83
2.95
3.19
3.35
3.46
100
200
300
400

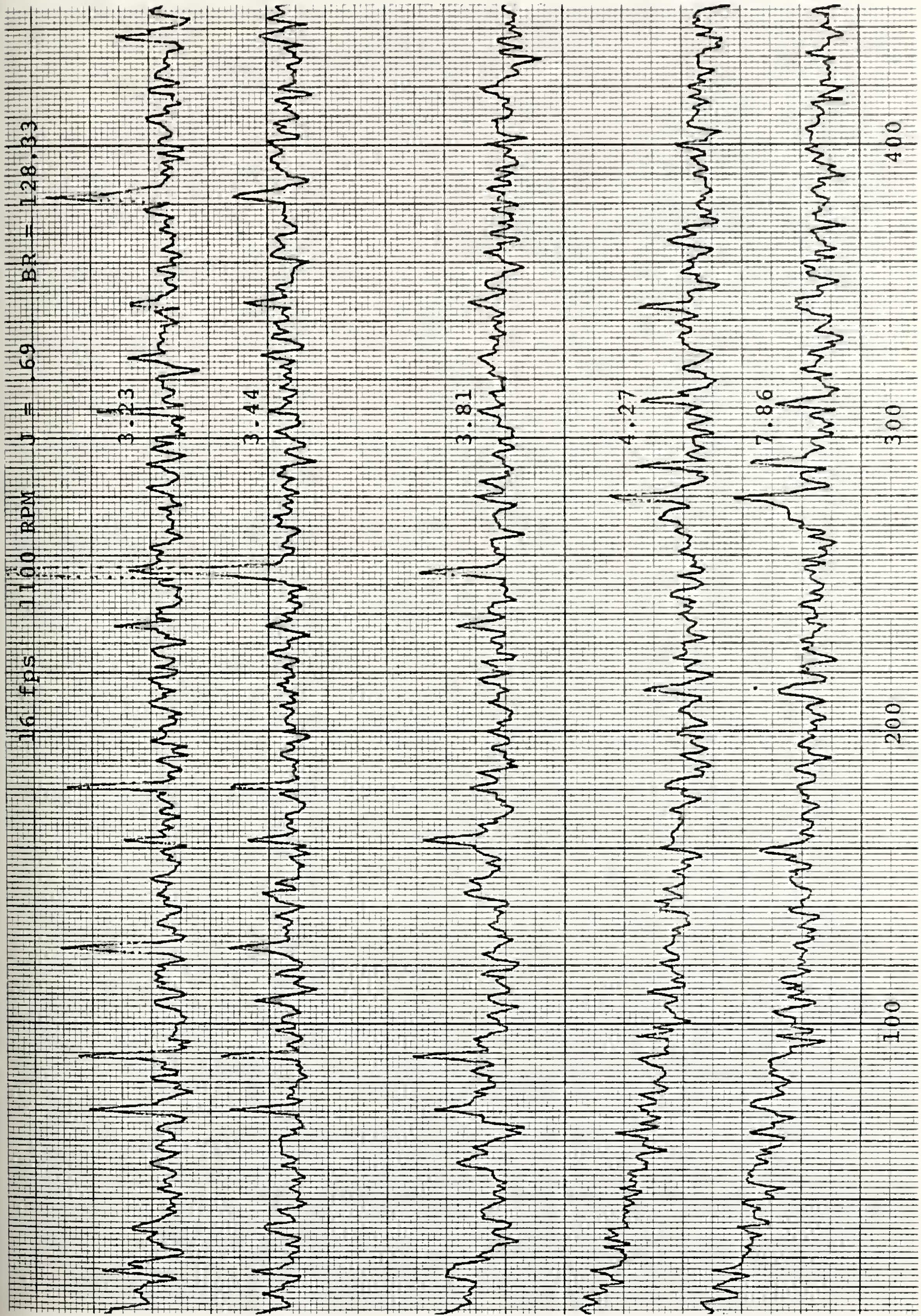


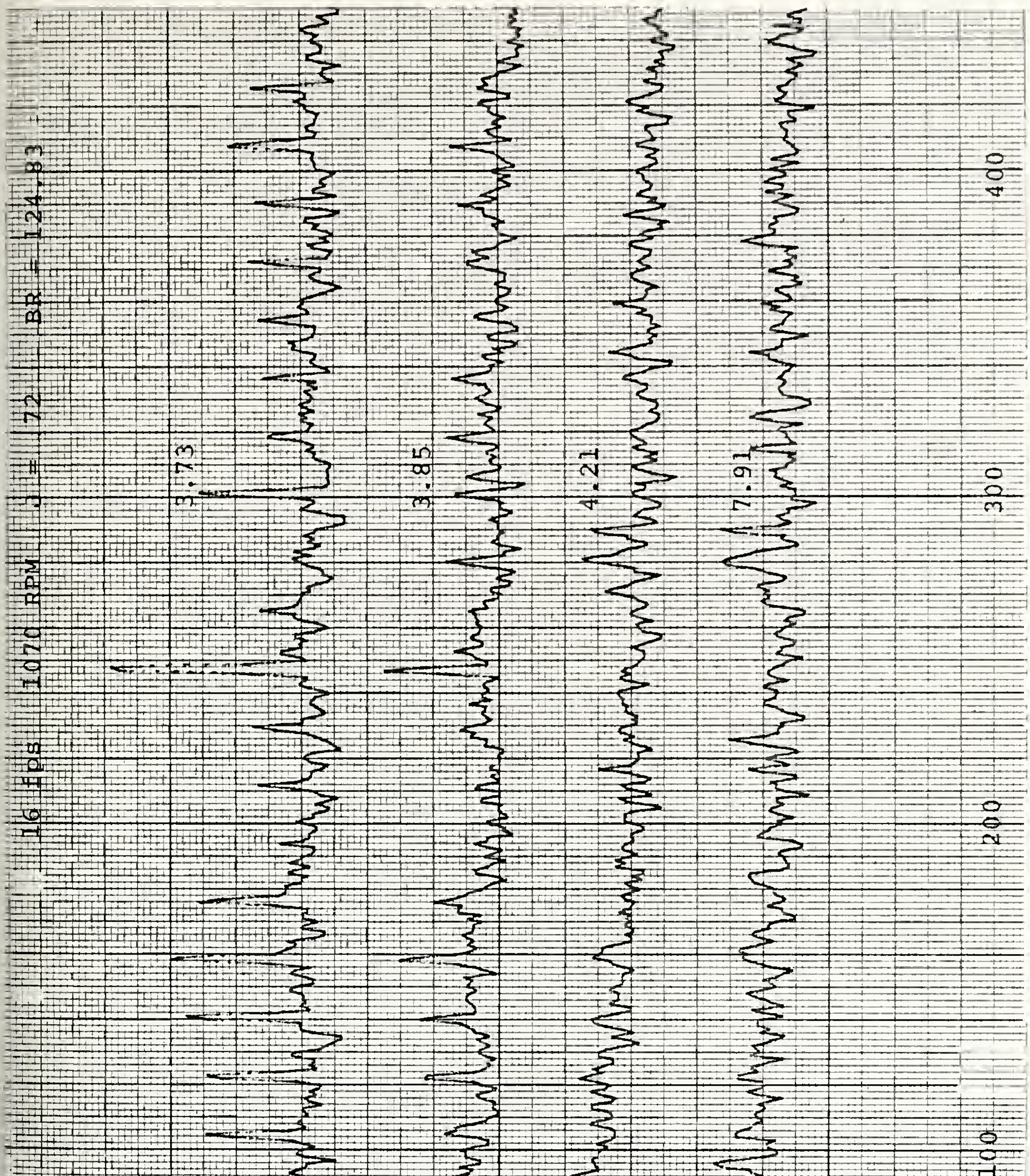
16 fps 1200 RPM J = .64 BR = .40
3.71
4.24
4.65
5.14
7.95
100
200
300
400

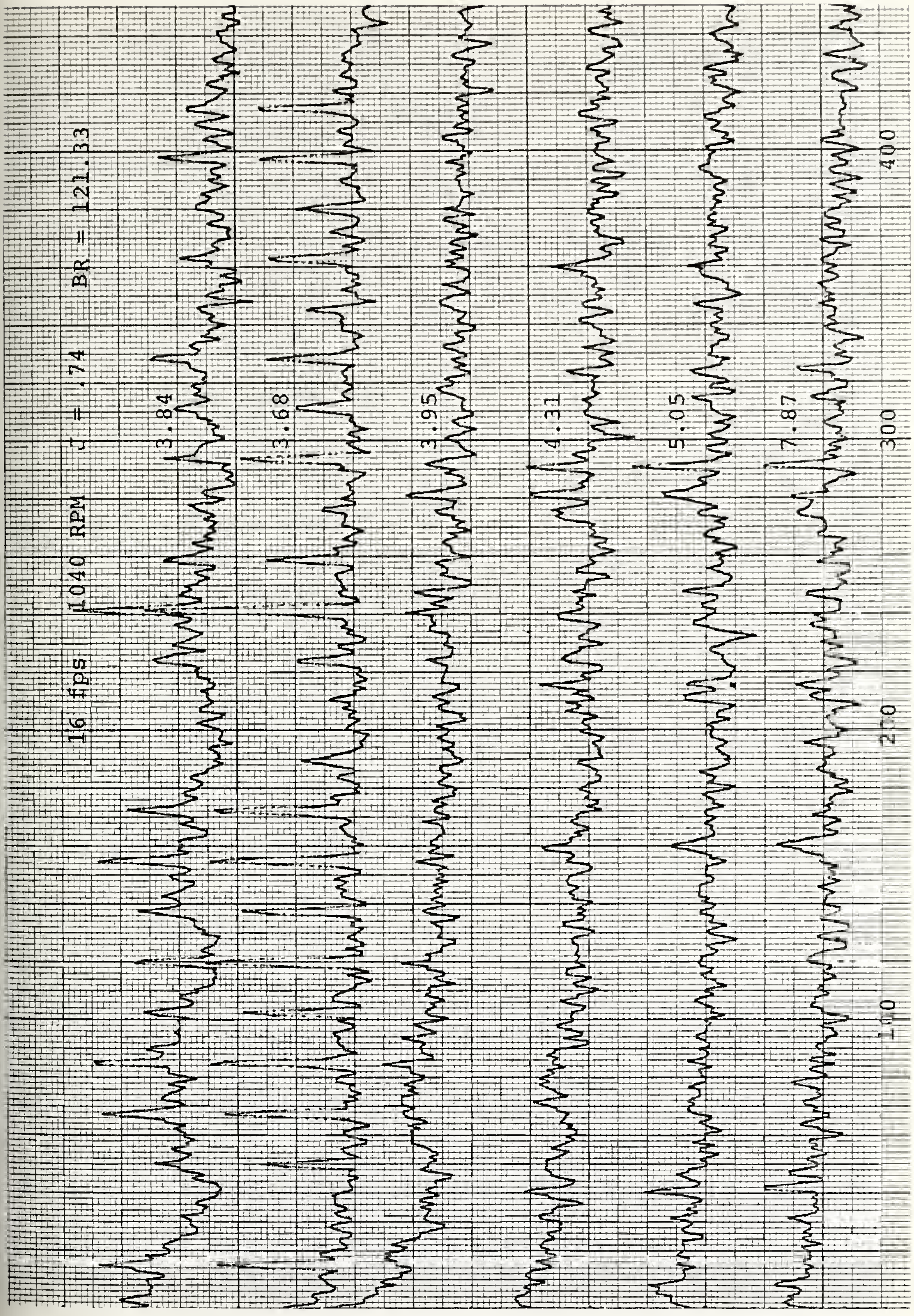

16 FPS 1200 RPM J = .64 BR = 140
2.97
3.18
3.45
3.63
100
200
300
400

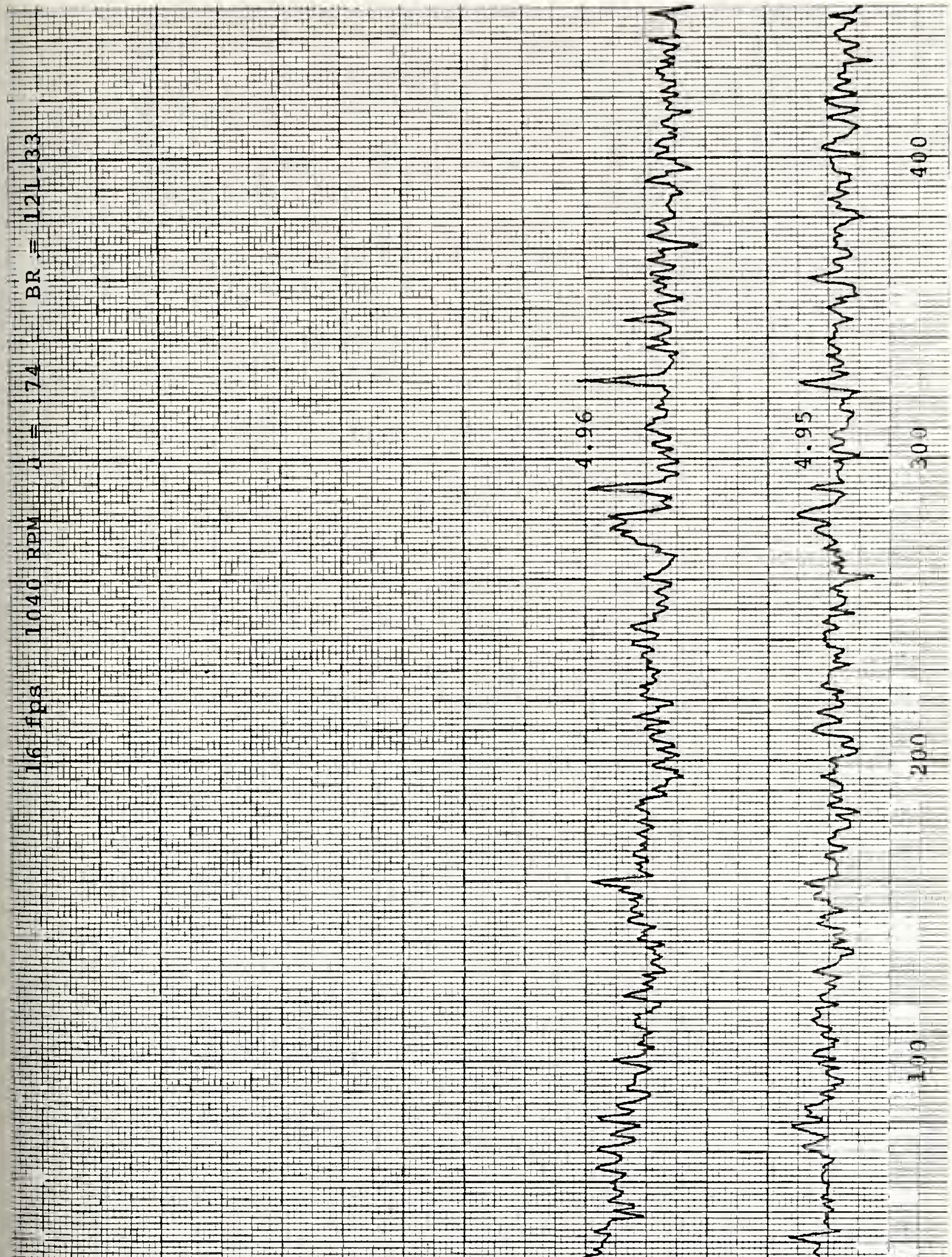

16 fps 1150 RPM J = .67 BR = 134.17
3.99
4.24
4.63
5.15
7.91
100
200
300
400

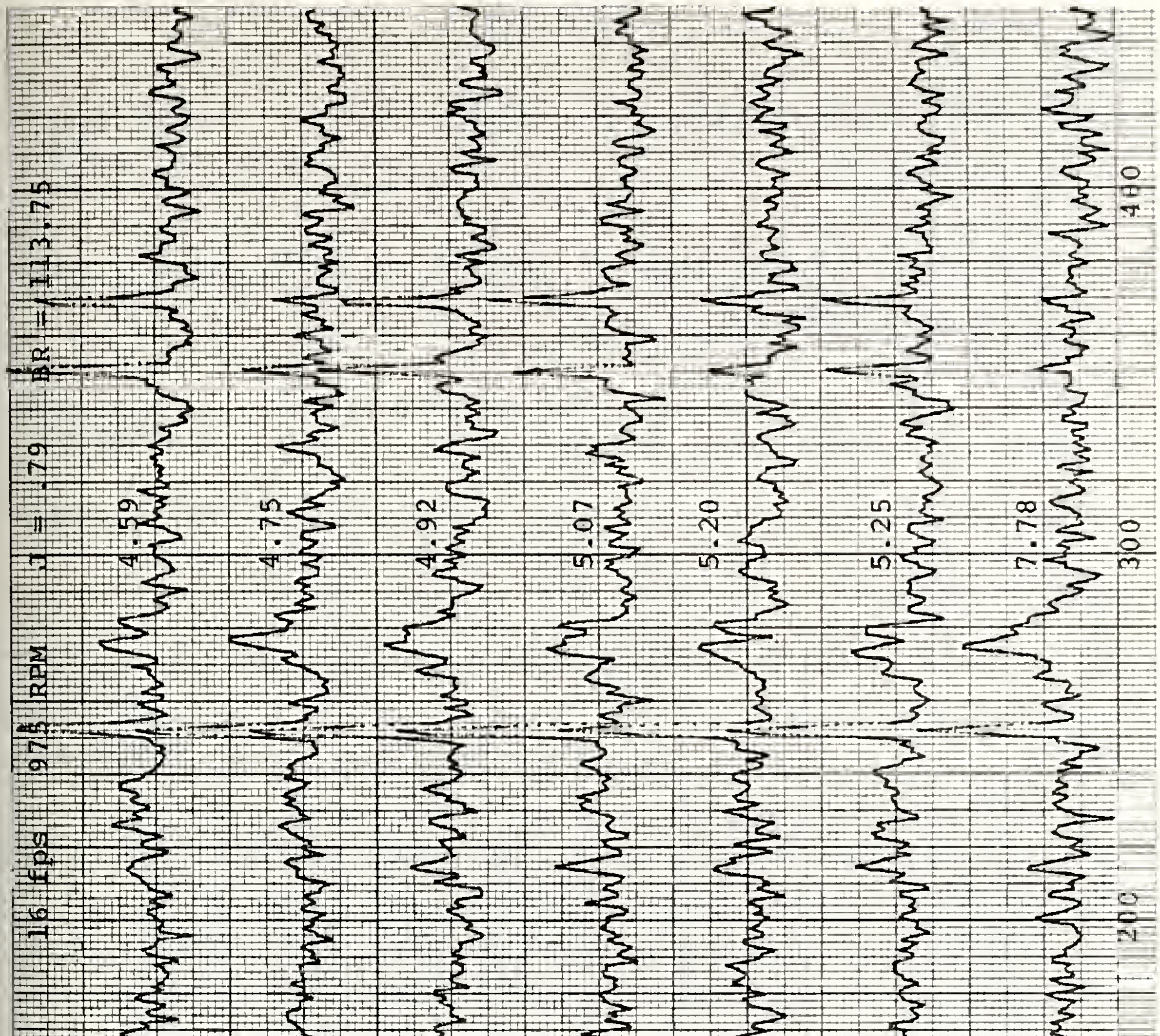

16 ECS 1150 RPM J = .67 BR = 134.17
3.25
3.39
3.55
3.64
3.75
3.05
400
300
200
100


16 fps 1100 RPM J = .69 BR = 128.33
3.23
3.44
3.81
4.27
7.86
100
200
300
400


16 fps 1070 RPM J = 72 BR = 124.83
3.73
3.85
4.21
7.91
100
200
300
400


16 fps 1040 RPM J = .74 BR = 121.33
3.84
3.68
3.95
4.31
5.05
7.87
100
200
300
400


16 fps 1040 RPM J = .74 BR = 121.33
4.96
4.95
100
200
300
400


16 fps 975 RPM J = .79 BR = 113.75
4.59
4.75
4.92
5.07
5.20
5.25
7.78
100
200
300
400

DATA SHEET

RUN NO 1

DATE 3/26

U_{nom} 16 RPM 1040 J_{nom} 0.75 Shaft rate 17.33

(Taps: 6/5 blue)

Blade rate 121.33

Ithaco amp① +40 db;Filter: Hi pass 5x10⁴ Trans Anal

Lo pass 63x10⁵ ② -15 db

Measuring Equipment: Input atten③ -20 db Meas amp ___ (# of

Output gain④ +10 db Spect anal. 2 spectra 32)

Temperature: (Start) water 85.5 air 76 Reynolds number:

(End) 87 77 7.32x10⁵

Thrust ÷ T x 0.1

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
2	BAR 750.9		0	15.0						TARE
907	471	1040	214	65			.074	.74	5.11	31-1
911	503	1043	228	66					5.51	-2
914	493	1040	224	65.5					5.38	-3
915	483	1041	222	66					5.26	-4
916	473	1040	216	65					5.14	-5
916	458	1041	216	65.5					4.98	-6
916	447	1041	214	65					4.85	32-1
919	440	1042	212	65.5					4.76	-2
919	434	1041	206	65					4.69	-3
917	426	1041	208	65					4.62	-4
918	417	1041	204	65.5					4.51	-5 + LEPBF
917	500	1041	230	65.5					5.44	-6
916	463	1042	224	66					5.03	-7

DATA SHEET

RUN NO 3

DATE 3/26

U_{nom} 16 RPM 975 J_{nom} 0.80 Shaft rate 16.25

(Taps: 6/5 blue) Blade rate 113.75

Ithaco amp① +40 db; Filter: Hi pass 5x10⁴ Trans Anal

Lo pass 6.3x10⁵ ② -15 db

Measuring Equipment: Input atten③ -20 db Meas amp ___ (# of

Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 87.7 air 77.8 Reynolds number:

(End) 88.3 76.5 7.05x10⁵

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
913	523	975	106	44			.047	.79	5.71	34-1
916	486	976	96	45					5.38	
915	473	973	86	44					5.15	
916	455	975	88	44.5					4.94	-2
913	486	974	90	44					5.30	-3
915	507	972	92	44					5.52	-4
914	495	977	100	45					5.40	-5
912	483	974	94	44					5.27	-6
914	469	975	92	44.5					5.11	-7
912	459	973	86	44					5.01	35-1
911	464	975	84	44.5					5.07	-2
914	458	974	88	44					4.99	-3
910	448	974	82	44					4.90	-4
912	434	973	80	44					4.73	-5
910	416	973	76	44					4.54	-6 *LEPF

DATA SHEET

RUN NO 4

DATE 3/26

U_{nom} 16 RPM 990 J_{nom} 0.775 Shaft rate 16.5

(Taps: 6/5 blue) Blade rate 115.5

Ithaco amp① +40 db;Filter: Hi pass 5x10⁴ Trans Anal

Lo pass 6.3x10⁵ ② -15 db

Measuring Equipment: Input atten③ -20 db Meas amp ___ (# of

Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 88.3 air 76.5 Reynolds number:

(End) 89 76 7.13x105

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
915	533	988	132	48.5			.052	.775	5.80	36-1
910	520	988	136	49					5.69	-2
915	505	992	130	49					5.49	
917	487	993	128	49.5					5.28	-3
914	471	990	116	48.5					5.12	-4
915	458	990	108	48					4.97	-5
918	441	992	108	48.5					4.76	-6
917	428	993	108	49.5					4.62	* LEPF

DATA SHEET

RUN NO 5

DATE 3/26

U_{nom} 16 RPM 930 J_{nom} 0.825 Shaft rate ____

(Taps: 6/5 blue)

Blade rate ____

Ithaco amp① +40 db;Filter: Hi pass 5x10^4 Trans Anal

Lo pass 6.3x10^5 ② -15 db

Measuring Equipment: Input atten③ -20 db Meas amp ___ (# of

Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 89 air 76 Reynolds number:

(End) 89.3 75.9 6.91x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
916	530	930	8	29.5			.018	.83	5.75	37-1
915	502	932	4	29.5					5.44	-2
915	483	931	-2	29.5					5.23	-3
916	467	933	-8	30					5.05	-4
916	451	932	-14	29.5					4.87	-5
916	423	933	-18	30					4.56	* LEPF

DATA SHEET

RUN NO 6

DATE 3/26

U_{nom} 16 RPM 915 J_{nom} 0.85 Shaft rate 15.25

(Taps: 6/5 blue) Blade rate 106.75

Ithaco amp① +40 db; Filter: Hi pass 5x10^4 Trans Anal

Lo pass 6.3x10^4 ② -15 db

Measuring Equipment: Input atten③ -20 db Meas amp ___ (# of

Output gain④ +16 db Spect anal. x spectra 32)

Temperature: (Start) water 89.3 air 75.9 Reynolds number:

(End) 90 76.2 6.82x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
911	612	917	8	26			.011	.84	6.70	38-1
910	586	919	4	26					6.42	-2
913	560	916	-8	25.5					~~5.85~~ 6.11	~~-4~~ -3
915	538	917	-12	25.5					5.85	-4
914	516	917	-22	25					5.61	-5
914	495	915	-36	24.5					5.38	-6
914	477	914	-38	24.5					5.18	
913	464	913	-42	24					5.04	
913	451	911	-44	24					4.89	-7 * LEAF

DATA SHEET

RUN NO 7

DATE 3/26

U_{nom} 16 RPM 1070 J_{nom} 0.72 Shaft rate 17.83
(Taps: 6/5 blue)

Blade rate 124.83

Ithaco amp ① +46 db; Filter: Hi pass 5x10⁴ Trans Anal

Lo pass 6.3x10⁴ ② -15 db

Measuring Equipment: Input atten ③ -20 db Meas amp ___ (# of
Output gain ④ +10 db Spect anal. X spectra 30)

Temperature: (Start) water 90 air 76.2 Reynolds number:

(End) 90.4 76.5 7.82x10⁵

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
912	393	1071	278	75			.089	.71	4.24	39-1
913	381	1070	276	74.5					4.16	-2
915	363	1070	268	74.5					3.89	-3 ALERT

DATA SHEET

RUN NO 8

DATE 3/26

U_{nom} 16 (Taps: 6/5 blue) RPM 1100 J_{nom} 0.70 Shaft rate 18.33

Blade rate 128.33

Ithaco amp ① +40 db; Filter: Hi pass 5x10^4 Trans Anal

Lo pass 6.3x10^4 ② -15 db

Measuring Equipment: Input atten ③ -20 db Meas amp ___ (# of spectra ___)

Output gain ④ +10 db Spect anal. ___

Temperature: (Start) water 90.4 air 76.5 Reynolds number:

(End) 90.6 76.7 8.01x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
914	373	1099	334	84.5			.098	.70	4.01	40-1
916	362	1100	336	84.5					3.88	-2
916	347	1100	332	84.5					3.71	* LEPF

DATA SHEET

RUN NO 9

DATE 3/26

U_{nom} 16 RPM 1150 J_{nom} 0.675 Shaft rate 19.17
(Taps: 6/5 blue)

Blade rate 134.17

Ithaco amp(1) +40 db; Filter: Hi pass 5x10[4] Trans Anal

Lo pass 6.3x10[4] (2) -15 db

Measuring Equipment: Input atten(3) -30 db Meas amp ___ (# of
Output gain(4) +10 db Spect anal. X spectra 32)

Temperature: (Start) water 90.6 air 76.7 Reynolds number:

(End) 90.7 76.5 8.33x10[5]

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
914	376	1151	466	102			.118	.67	4.05	41-1
916	359	1150	452	101.5					3.86	
914	357	1151	452	102				.	3.84	-2
916	330	1150	440	101					3.53	-3 * LEPF

DATA SHEET

RUN NO 10

DATE 3/26

U_{nom} 16 RPM 1200 J_{nom} 0.65 Shaft rate 20

(Taps: 6/5 blue) Blade rate 140

Ithaco amp① +40 db; Filter: Hi pass 5x10^4 Trans Anal

Lo pass 6.3x10^4 ② -15 db

Measuring Equipment: Input atten③ -20 db Meas amp ___ (# of

Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 90.7 air 76.5 Reynolds number:

(End) 91.1 77 8.88x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
918	405	1202	600	121			.133	.64	4.36	42-1
914	395	1199	588	119.5					4.27	-2
910	382	1204	594	121					4.14	-3
915	367	1205	584	120.5					3.95	-4
911	321	1206	576	121.5					3.45	* LEPF

DATA SHEET

RUN NO 11

DATE 3/26

U_{nom} 16 RPM 1250 J_{nom} 0.625 Shaft rate 20.83
(Taps: 6/5 blue)

Blade rate 145.83

Ithaco amp① +40 db;Filter: Hi pass 5×10^4 Trans Anal

Lo pass 6.3×10^4 ② -15 db

Measuring Equipment: Input atten③ -20 db Meas amp ___ (# of
Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 91.1 air 77 Reynolds number:

(End) 91.6 77.5 9.22×10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
917	456	1251	730	137.5			.143	.62	4.93	43-1
916	432	1251	722	137.5					4.67	-2
920	421	1250	712	137					4.53	-3
915	386	1250	706	137.5					4.16	-4
914	363	1251	704	137.5					3.91	-5
916	353	1251	706	137.5					3.79	-6
916	334	1252	700	137.5					3.58	44-1 *TV
919	316	1252	688	137.5					3.37	*4U
919	317	1253	688	137.5					3.38	-
919	309	1253	686	137					3.29	44-2

DATA SHEET

RUN NO 12
DATE 3/26

U_{nom} 16 RPM 1300 J_{nom} 0.6 Shaft rate 21.67
(Taps: 6/5 blue) Blade rate 151.67

Ithaco amp① +40 db;Filter: Hi pass 5x10⁴ Trans Anal
Lo pass 6.3x10⁴ ② -15 db

Measuring Equipment: Input atten③ -20 db Meas amp ___ (# of
Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 91.6 air 77.5 Reynolds number:
(End) 92 78 9.55x10⁵

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
916	462	1300	864	155.5			.155	.595	5.02	45-1
916	440	1299	856	155					4.78	-2
914	426	1299	850	155.5					4.63	-3 *TV

DATA SHEET

RUN NO 13

DATE 3/26

U_{nom} 16 RPM 1350 J_{nom} 0.575 Shaft rate 22.5
(Taps: 6/5 blue)

Blade rate 157.5

Ithaco amp① +40 db; Filter: Hi pass 5x10⁴ Trans Anal

Lo pass 6.3x10⁴ ② -15 db

Measuring Equipment: Input atten③ -20 db Meas amp ___ (# of
Output gain④ +10 db Spect anal. λ spectra 32)

Temperature: (Start) water 92 air 78 Reynolds number:
(End) 92.4 78.3 9.84x10⁵

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
919	714	1350	1066	175			.165	.57	7.82	46-1
918	689	1352	1060	175.5					7.55	-2
921	646	1350	1048	175					7.05	-3
918	607	1350	1040	174.5					6.64	-4
918	588	1351	1034	174.5					6.42	-5
921	559	1351	1030	175					6.08	-6
922	490	1350	1008	174.5					5.30	+33/TV

DATA SHEET

RUN NO 14

DATE 3/26

U_{nom} 12 RPM 1050 J_{nom} 0.55 Shaft rate 17.5

(Taps: 6/5 blue) Blade rate 122.5

Ithaco amp ① +50 db; Filter: Hi pass 5x10^4 Trans Anal

Lo pass 6.3x10^5 ② -30 db

Measuring Equipment: Input atten ③ ~~+30~~ -30 db Meas amp ___ (# of

Output gain ④ +20 db Spect anal. X spectra 32)

Temperature: (Start) water 92.4 air 78.3 Reynolds number:

(End) 92.6 79 7.85x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
516	488	1053	644	115			.177	.55	9.65	47-1
521	406	1054	612	114.5					7.90	~~47-2~~
526	344	1052	594	114.5					6.58	~~-3~~ -2
516	314	1051	590	114.5					6.11	-3 *HV
516	275	1050	580	114					5.31	*TV
516	274	1052	576	114.5					5.29	-4

DATA SHEET

RUN NO 15

DATE 3/26

U_{nom} 12 RPM 1100 J_{nom} 0.525 Shaft rate 18.33
(Taps: 6/5 blue)

Blade rate 128.33

Ithaco amp① +50 db;Filter: Hi pass 5×10⁴ Trans Anal

Lo pass 6.3×10⁴ ② +15 db

Measuring Equipment: Input atten③ -30 db Meas amp ___ (# of
Output gain④ +10 db Spect anal. X spectra 32

Temperature: (Start) water 92.6 air 79 Reynolds number:

(End) 92.8 79 8.17×10⁵

MAN	STAT	RPM	T	Q	GAIN CHANGE	K_T	J	σ	REMARKS
517	462	1099	740	129.5		.187	.52	9.11	*HU
517	459	1099	738	129.5				9.05	48-1
516	433	1098	726	129				8.54	-2
516	410	1098	730	130				8.07	
518	391	1099	720	129				7.65	-3
516	359	1098	714	129				7.03	-4
516	330	1100	704	129.5				6.44	-5
516	303	1100	698	129.5				5.89	-6*TV

DATA SHEET

RUN NO 16

DATE 3/26

U_{nom} 12   RPM 1175 J_{nom} 0.5   Shaft rate 19.58

(Taps: 6/5 blue)   Blade rate 137.08

Ithaco amp ① +50 db; Filter: Hi pass 5x10^4   Trans Anal

Lo pass 6.3x10^4   ② -15 db

Measuring Equipment: Input atten ③ -30 db   Meas amp ___   (# of

Output gain ④ +10 db   Spect anal. X   spectra 32)

Temperature: (Start) water 92.8 air 79   Reynolds number:

(End) 92.8   79.5   8.74x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE	K_T	J	σ	REMARKS
521	567	1178	~~955~~ 956	155		.201	.5	11.16	
520	530	1178	950	155.5				10.44	49-1
517	478	1173	928	154.5				9.44	-2
517	445	1174	918	154.5				8.77	-3 *HV
518	416	1172	908	154				8.16	-4
516	384	1173	902	154.5				7.54	-5
512	360	1172	892	154.5				7.11	-6
517	301	1173	876	154				5.84	-7
514	288	1173	876	154				5.61	*TV

DATA SHEET

RUN NO 17

DATE 3/26

U_{nom} 10/12 RPM 1025/1225 J_{nom} 0.475 Shaft rate 17.08/20.42

(Taps: 6/5 blue) Blade rate 119.58/142.92

Ithaco amp① +50 db;Filter: Hi pass 5x10^4 Trans Anal

Lo pass 6.3x10^4 ② -15 db

Measuring Equipment: Input atten③ -30 db Meas amp ___ (# of

Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 92.8 air 79.5 Reynolds number:

(End) 93 79.8 7.67x10^5/9.06x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
366	449	1036	754	158			.214	.48	12.76	~~*HU~~ HU
364	431	1033	722	124.5					12.30	50-1
520	465	1224	1048	171.5			.208	.48	9.14	
516	451	1225	1056	172.5					8.93	50-2 *HU
517	399	1226	1042	173					7.86	-3
515	367	1227	1036	173					7.23	-4
515	341	1226	1056	172.5					6.70	-5 *TV

DATA SHEET

RUN NO 18

DATE 3/26

U_{nom} 10 RPM 1080 J_{nom} 0.45 Shaft rate 18

(Taps: 6/5 blue) Blade rate 126

Ithaco amp① +50 db;Filter: Hi pass 5x10⁴ Trans Anal

Lo pass 6.3x10⁴ ②-15 db

Measuring Equipment: Input atten③ -30 db Meas amp ___ (# of

Output gain④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 93 air 79.8 Reynolds number:

(End) 93.1 79.8 8.06x10⁵

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
376	536	1089	886	143			.219	.475	14.91	*HV
364	390	1080	838	141.5				.	11.11	51-1
365	347	1076	816	140.5					9.82	-2
364	324	1077	812	140.5					9.17	
364	305	1083	822	142					8.61	-3 *TV

DATA SHEET

RUN NO 19

DATE 3/26

U_{nom} 8/10 (Taps: 6/5 blue)   RPM 915/1150 J_{nom} 0.425   Shaft rate 15.25/19.17

Blade rate 106.75/134.17

Ithaco amp ① +50 db; Filter: Hi pass 5x10^4   Trans Anal

Lo pass 6.3x10^4   ② -15 db

Measuring Equipment: Input atten ③ -30 db Meas amp ___ (# of
Output gain ④ +10 db Spect anal. X spectra 32)

Temperature: (Start) water 93.1 air 79.8 Reynolds number: 6.76x10^5

(End) 93.1 79.7 8.48x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
251	525	915	640	107			.227	.45	22.61	*HV
243	345	915	604	108					15.17	52-1
370	471	1150	1026	163.5			.230	.44	13.33	-2
367	443	1150	1024	164.5					12.62	-3
360	460	1149	1027	164					13.38	-4
364	447	1145	1012	163					12.85	-5
363	433	1151	1026	165					12.47	-6 *TV

DATA SHEET

RUN NO 20

DATE 3/26

U_{nom} 8/10 RPM 975/1215 (1015 struck out) J_{nom} 0.40 Shaft rate 16.25/20.25

(Taps: 6/5 blue) Blade rate 113.75/141.75

Ithaco amp① +50 db;Filter: Hi pass 5x10^4 Trans Anal

Lo pass 6.3x10^4 ② -15 db

Measuring Equipment: Input atten③ -30 db Meas amp ___ (# of

Output gain④ +10 db Spect anal. X spectra 33)

Temperature: (Start) water 93.1 air 79.7 Reynolds number:

(End) 93.2 79.2 7.19x10^5/8.95x10^5

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
244	555	977	792	125.5			.242	.41	24.75	*HU
364	749	1216	1280	188			.240	.41	21.83	53-1
366	539	1215	1224	187.5					15.51	-2 *TV

DATA SHEET

RUN NO 21

DATE ________

U_{nom} 8 RPM 1040 J_{nom} 0.375 Shaft rate 17.33

(Taps: 6/5 blue) Blade rate 121.33

Ithaco amp① +50 db;Filter: Hi pass 5x10⁴ Trans Anal

Lo pass 6.3x10⁵ ② -15 db

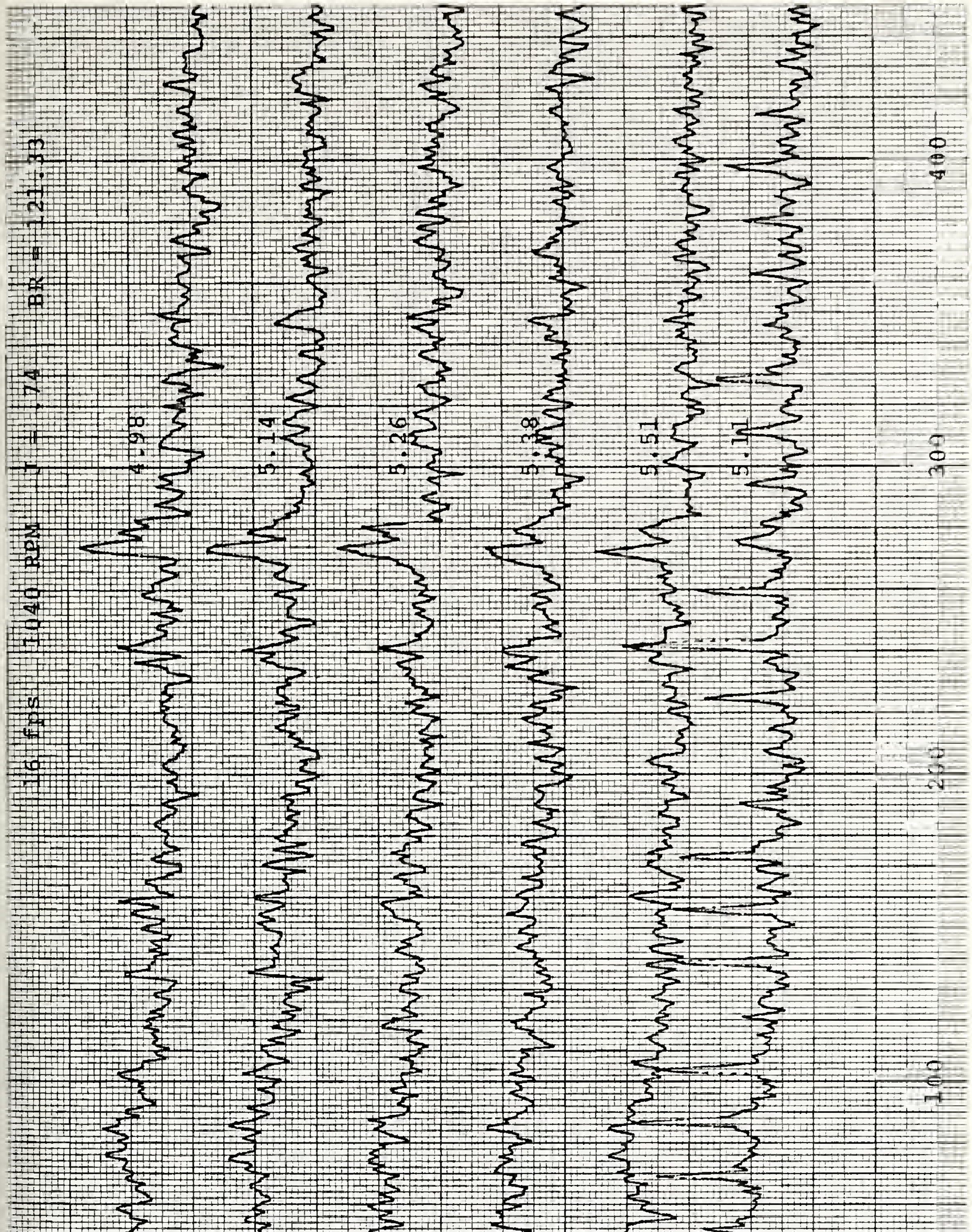
Measuring Equipment: Input atten③ -30 db Meas amp ___ (# of

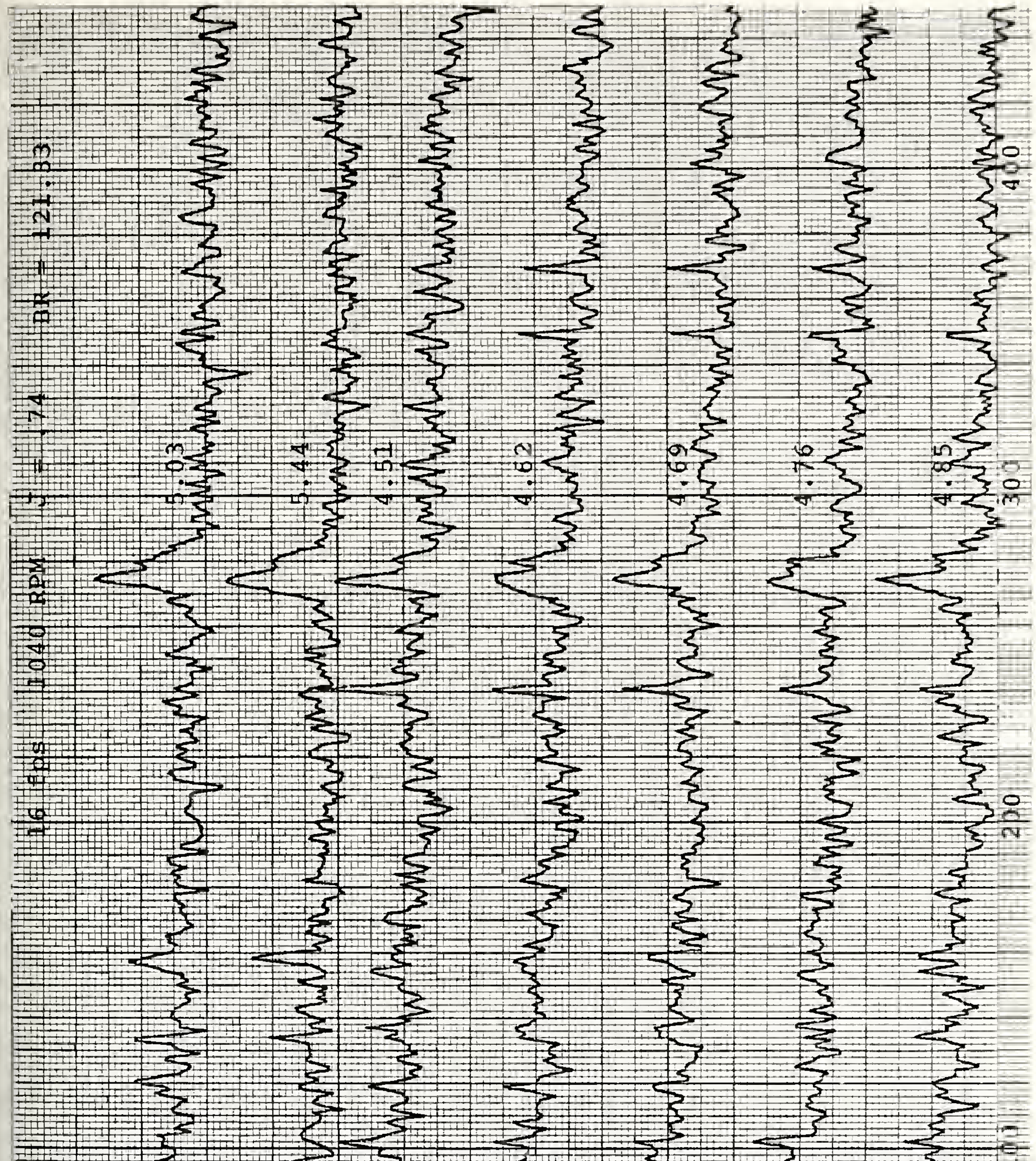
Output gain④ +10 db Spect anal. x spectra 32)

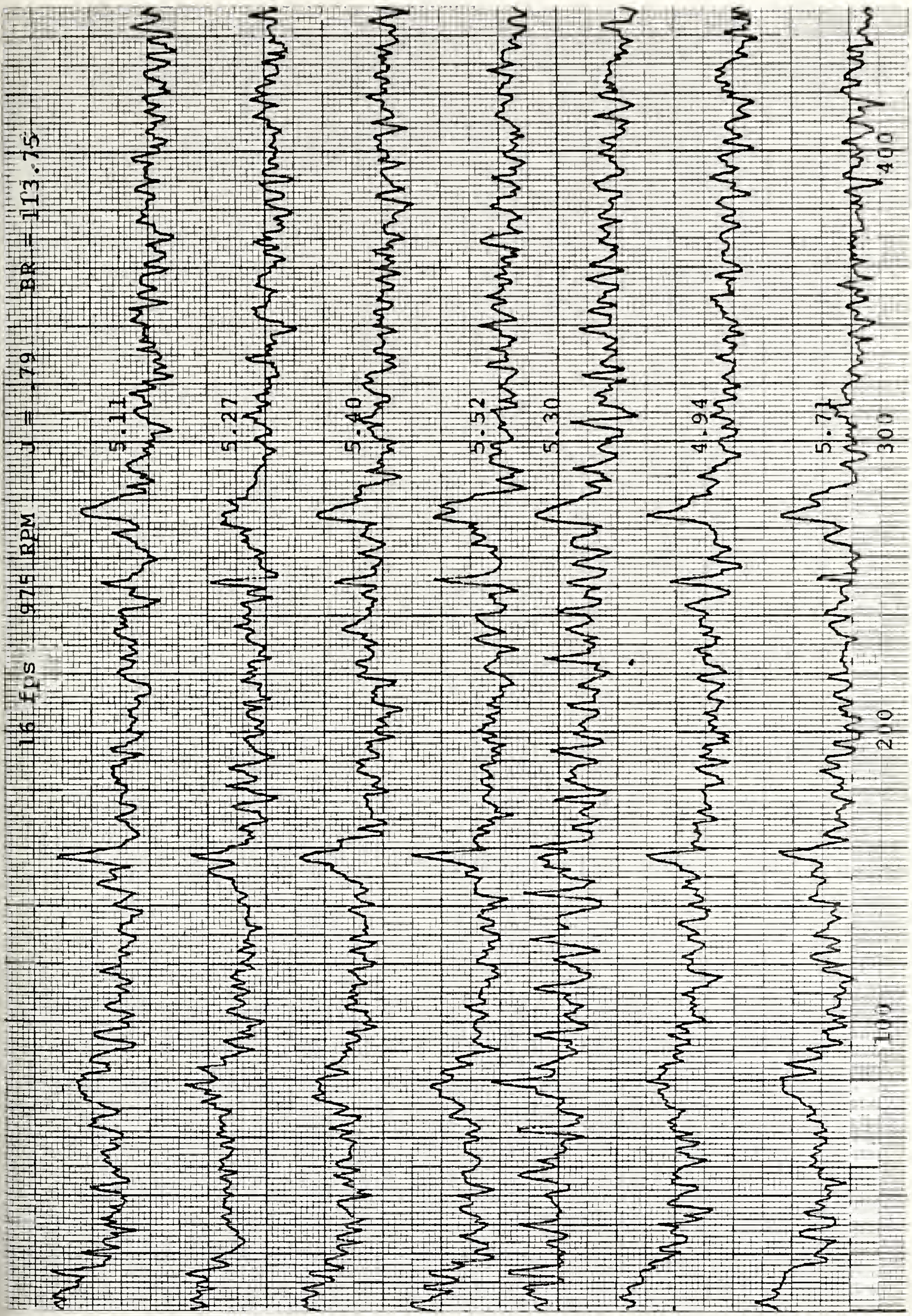
Temperature: (Start) water 93.2 air 79.2 Reynolds number:

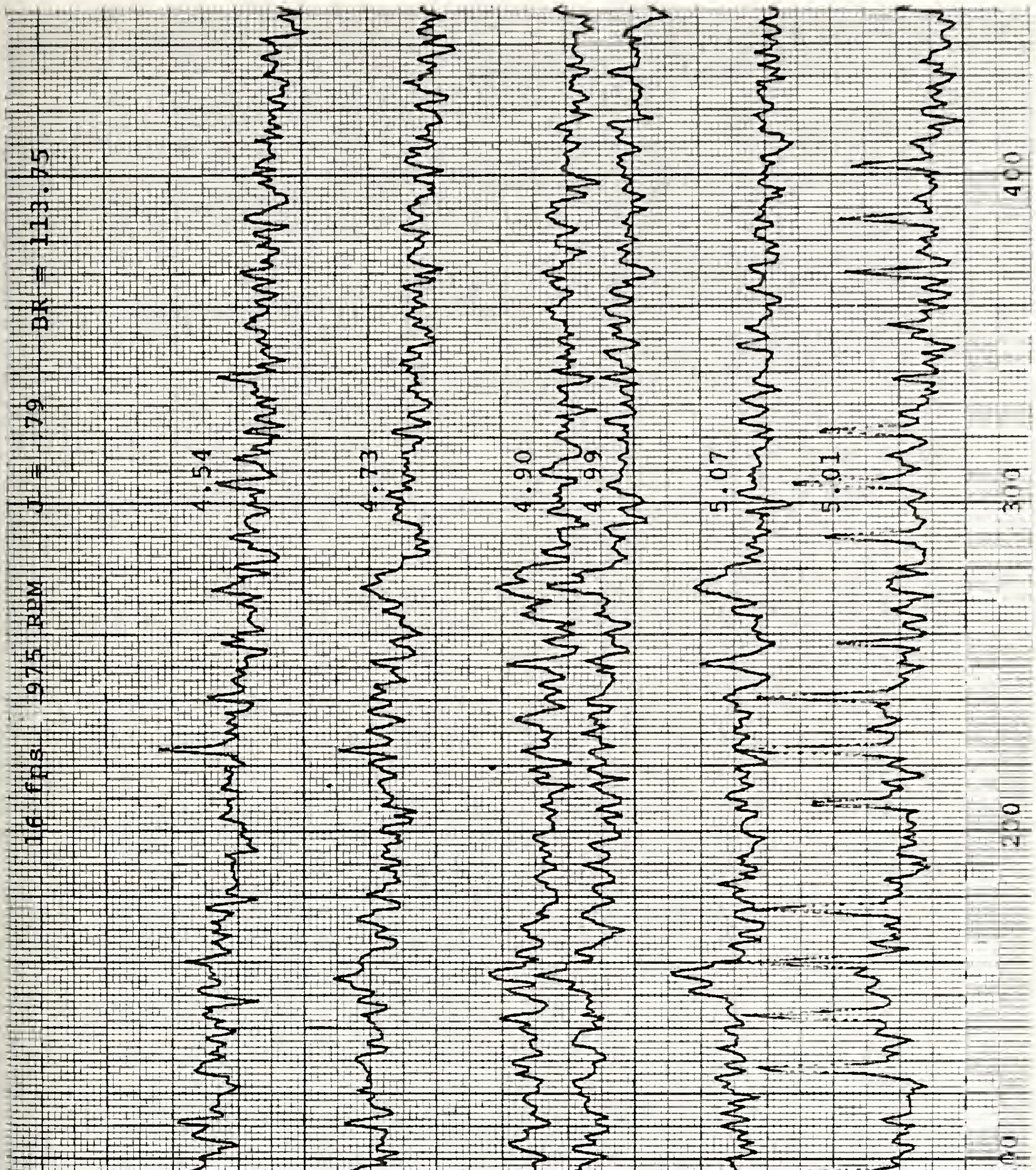
(End) 93.2 78.9 7.65x10⁵

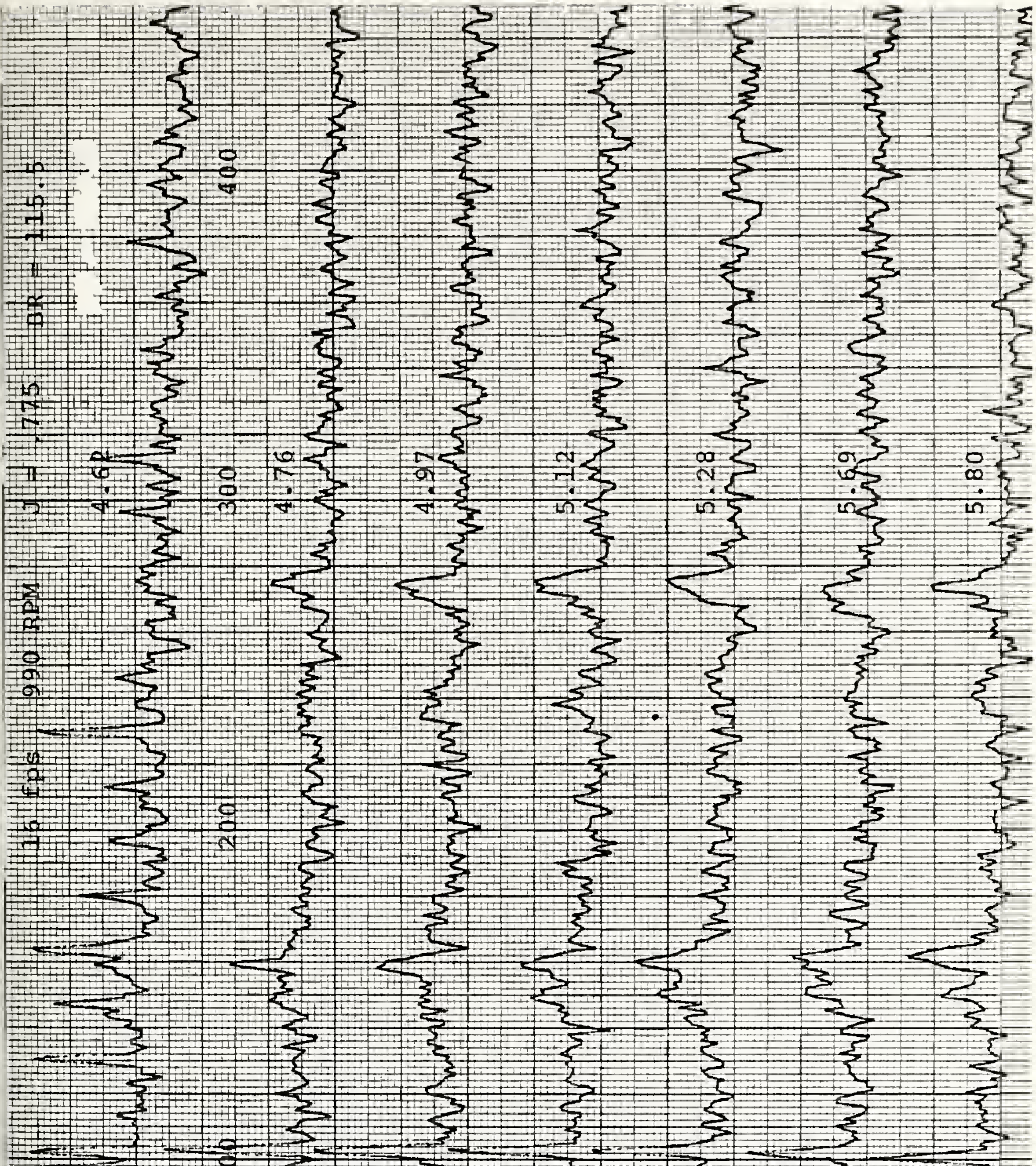
MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
244	584	1041	948	145.5			.252	.39	26.15	x HV
240	408	1043	904	146					18.41	54-1
240	388	1043	900	146					17.47	-2
241	530	1042	938	146					23.97	
241	514	1041	926	145.5					23.25	-3
240	472	1042	926	146.5					21.39	-4
239	446	1042	912	145.5					20.57	-5
243	428	1041	910	145.5					19.08	x TV
16	BAR 754.6		26	13.5						TARE

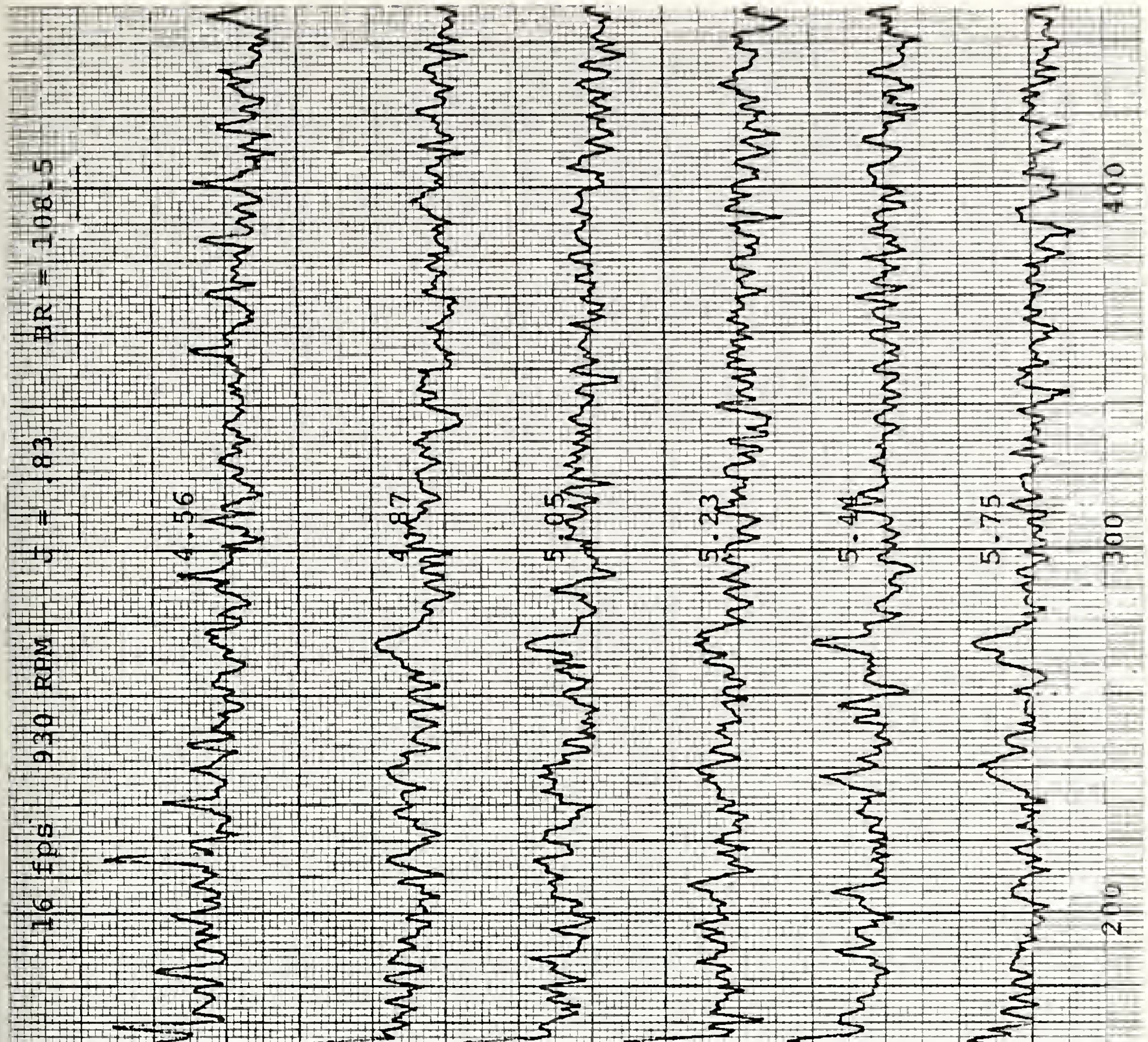

16 fps 1040 RPM J = .74 BR = 121.33
4.98
5.14
5.26
5.38
5.51
100
200
300
400

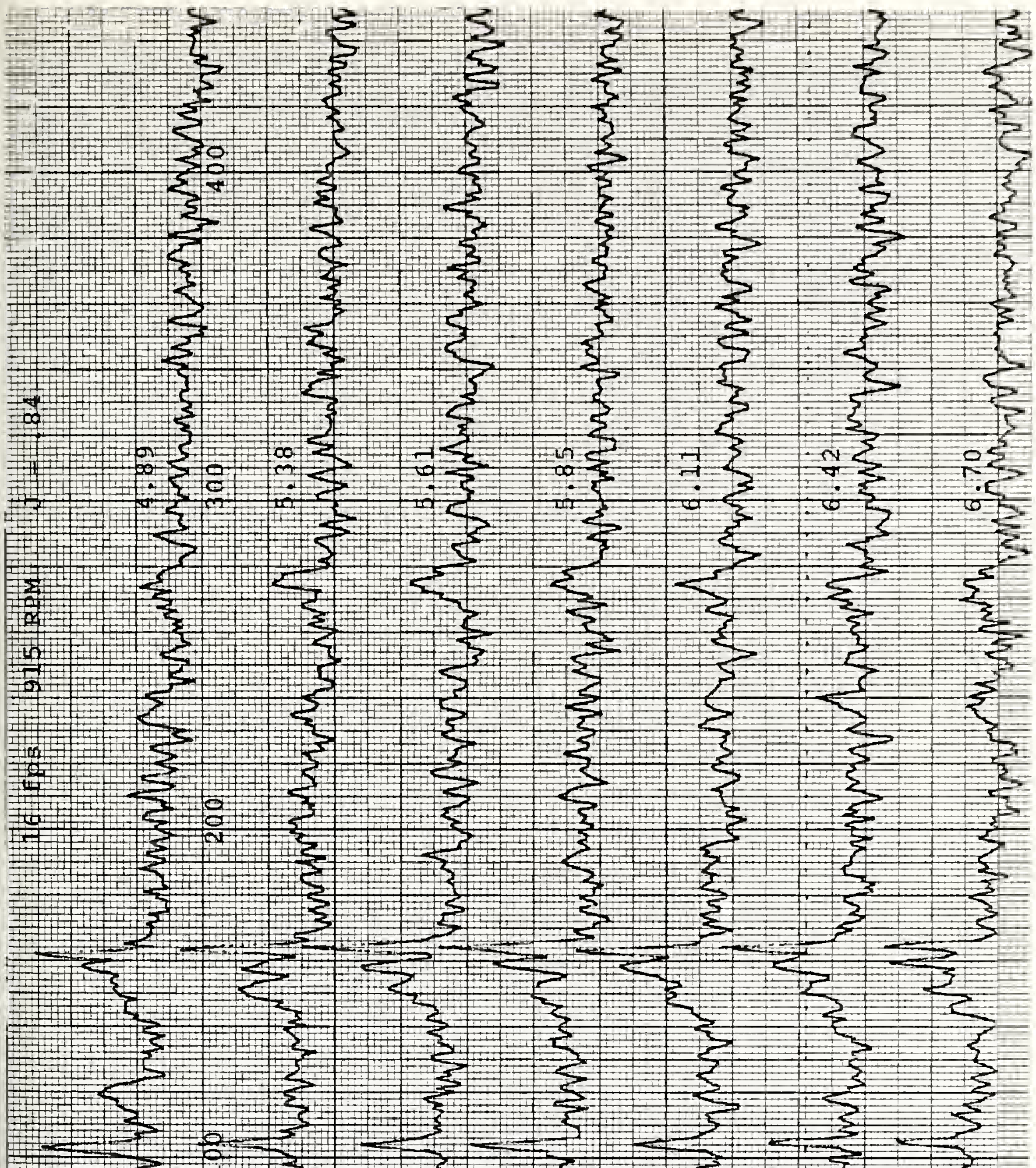

16 fps 1040 RPM J = .74 BR = 121.83
5.03
5.44
4.51
4.62
4.69
4.76
4.85
100
200
300
400

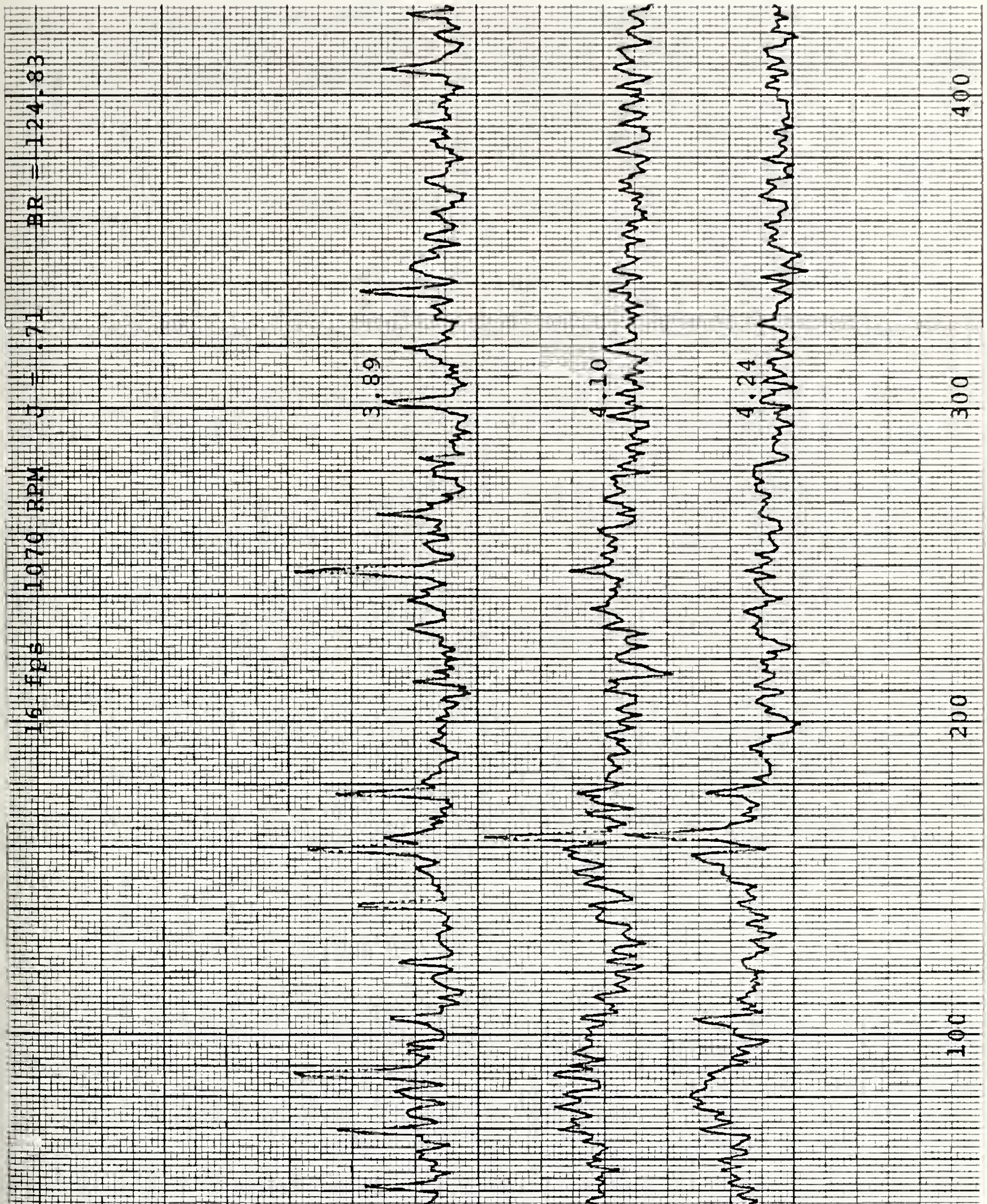

16 fps 975 RPM J = .79 BR = 113.75
5.11
5.27
5.40
5.52
5.30
4.94
5.71
100
200
300
400

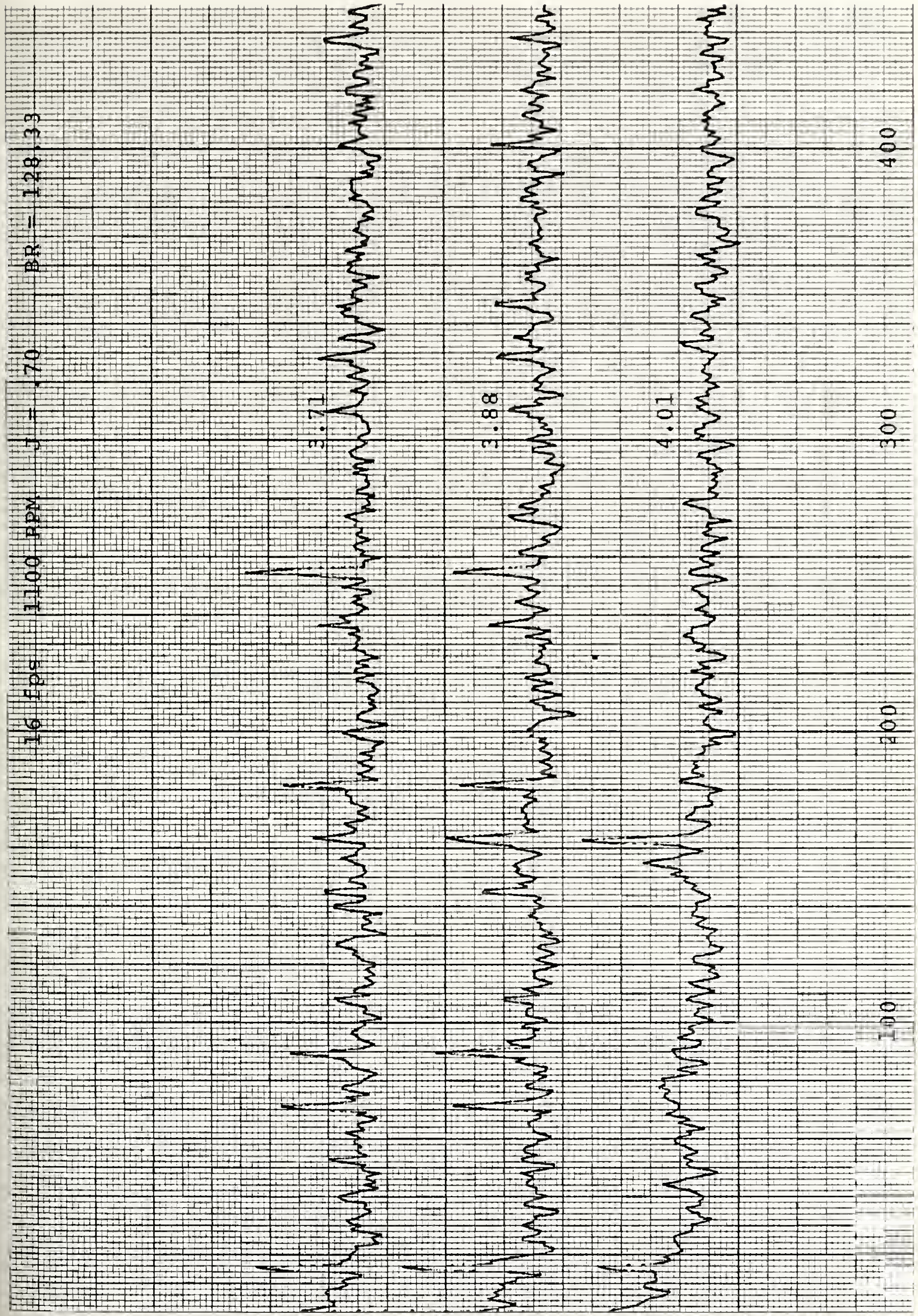

16 fps 975 RPM J = 79 BR = 113.75
4.54
4.73
4.90
4.99
5.07
100
200
300
400

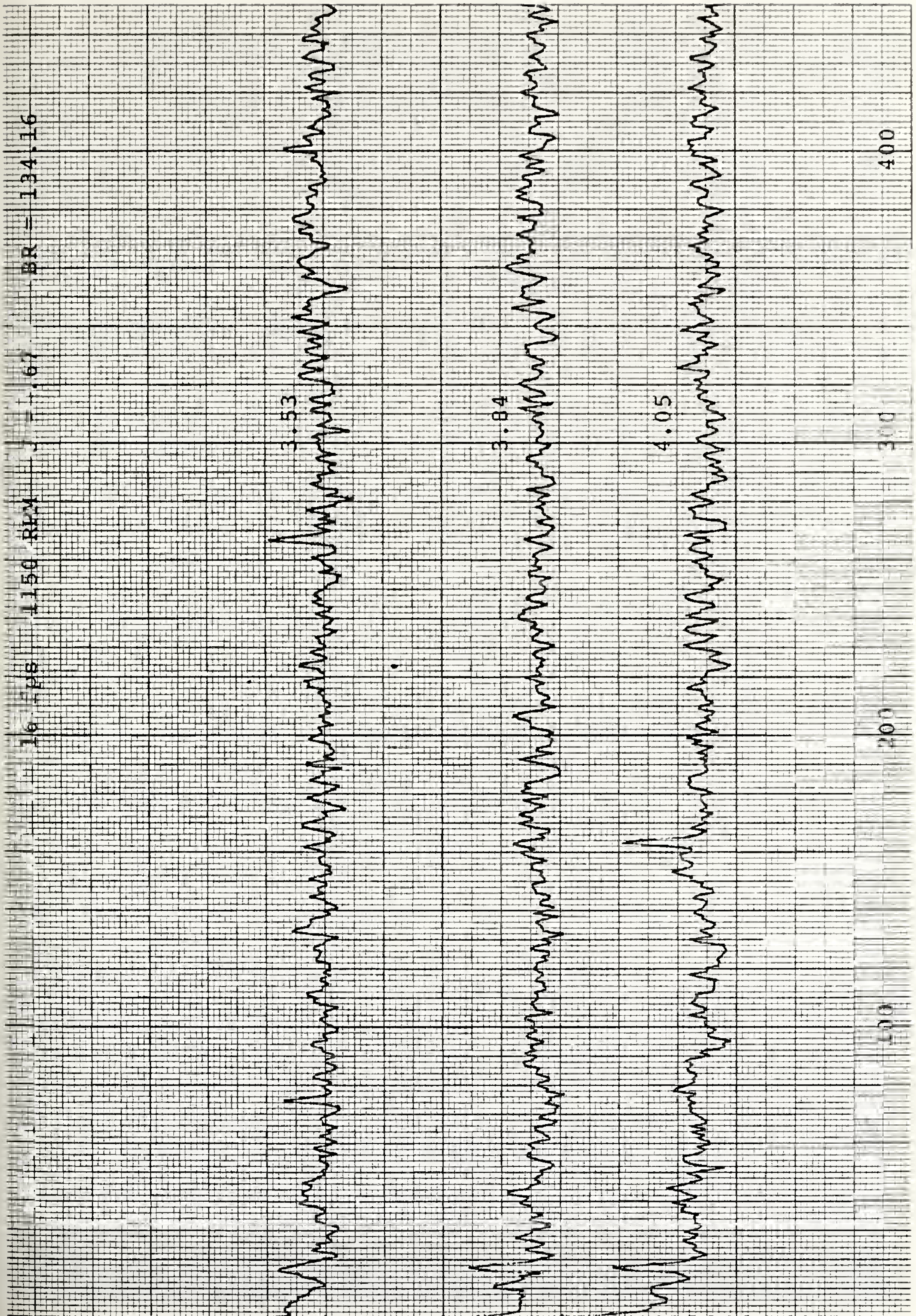

15 fps 990 RPM J = .775 BR = 115.5
100
200
300
400
4.62
4.76
4.97
5.12
5.28
5.69
5.80

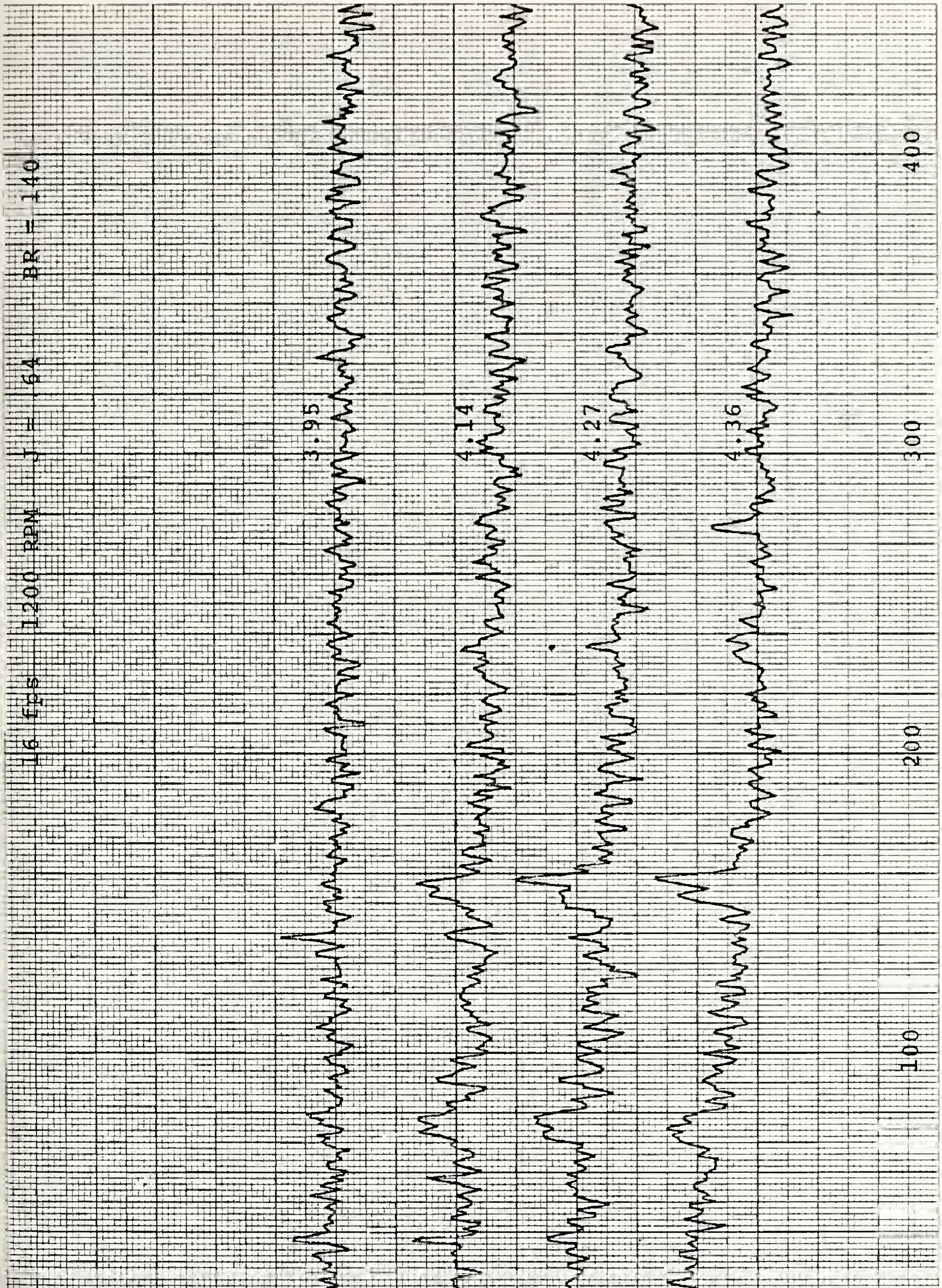

16 fps 930 RPM J = .83 BR = 108.5
4.56
4.87
5.05
5.23
5.41
5.75
100
200
300
400

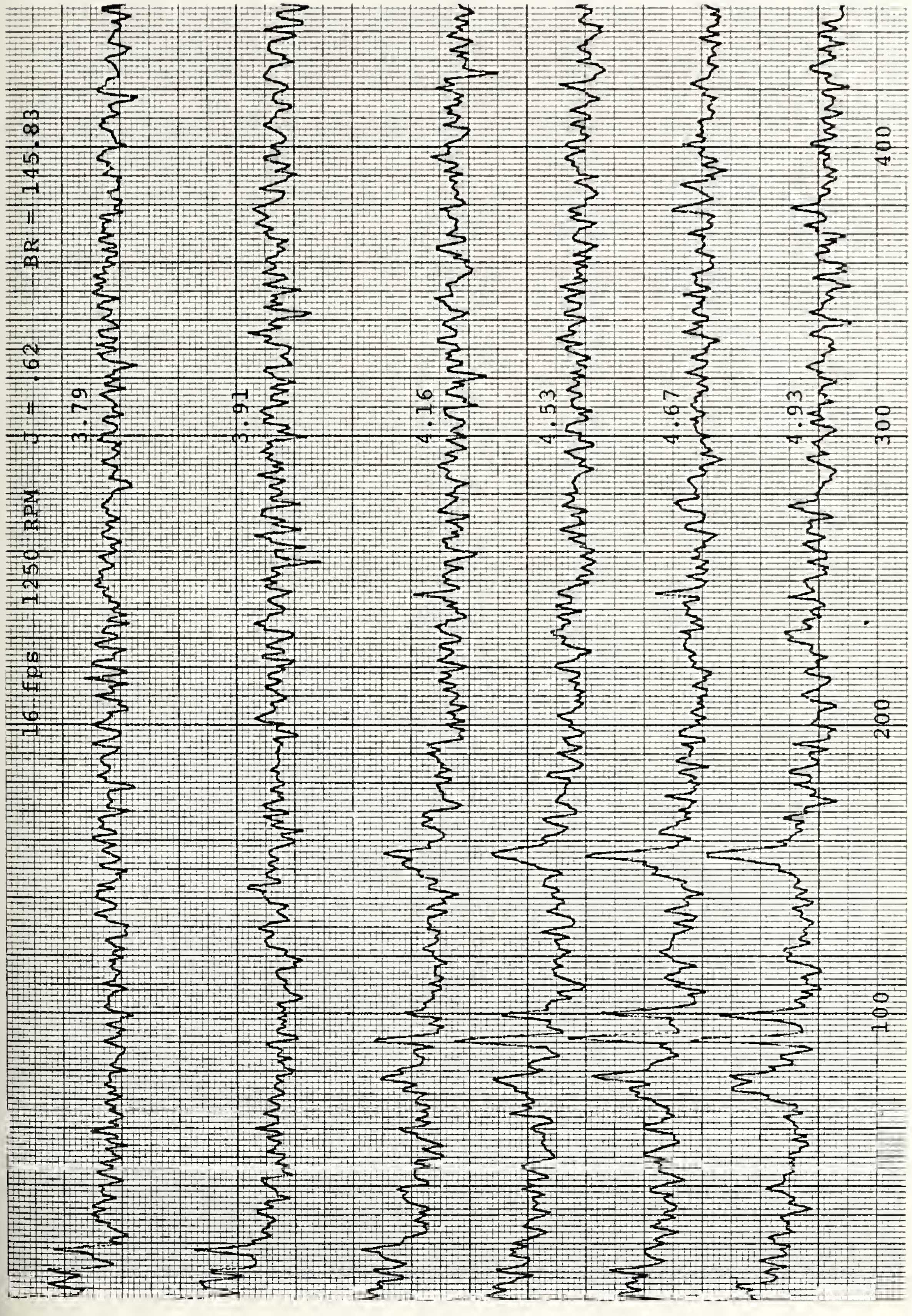

16 Fps 915 RPM J = .84
4.89
5.38
5.61
5.85
6.11
6.42
6.70
100
200
300
400

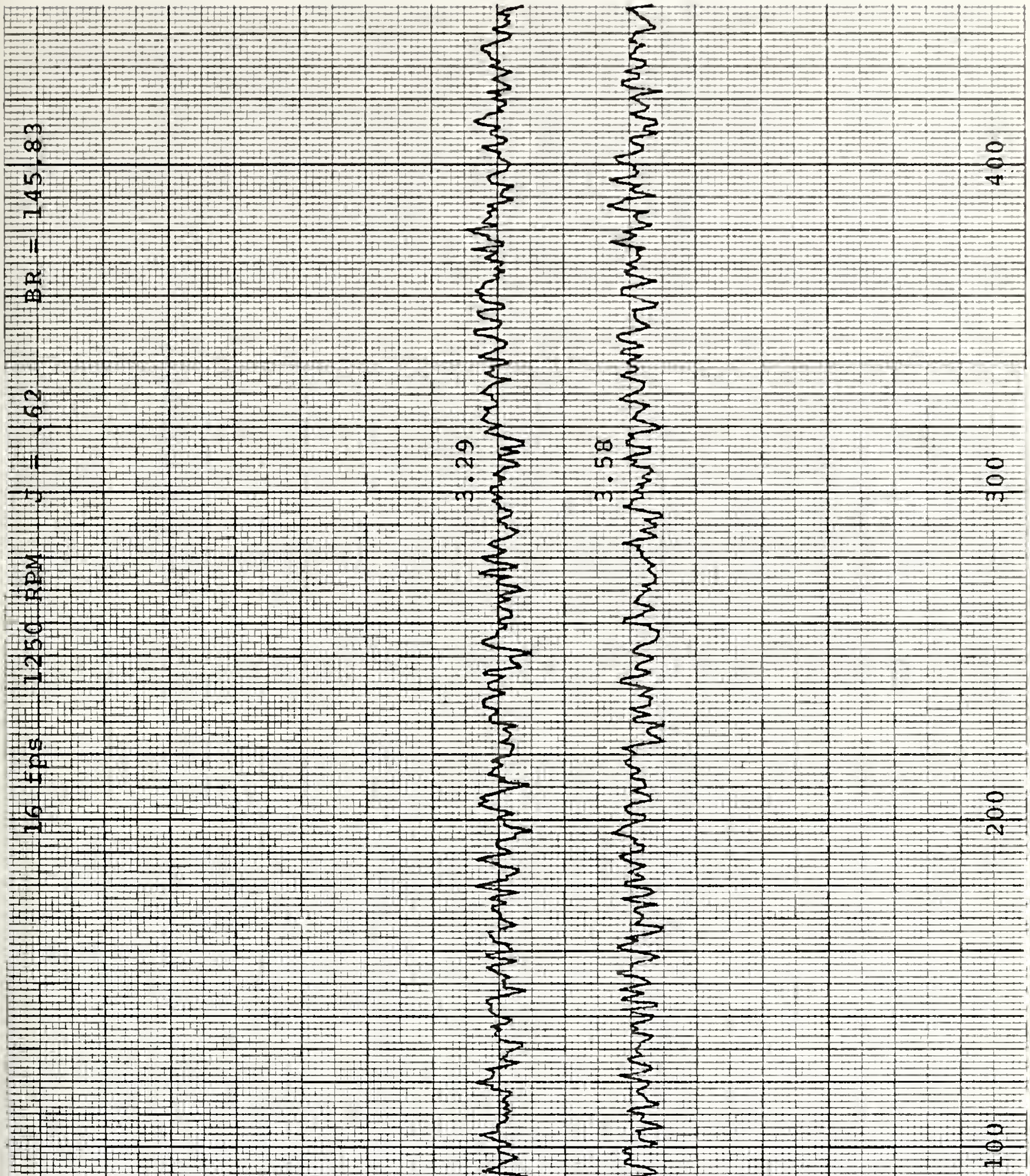

16 Fps 1070 RPM J = .71 BR = 124.83
3.89
4.10
4.24
100
200
300
400

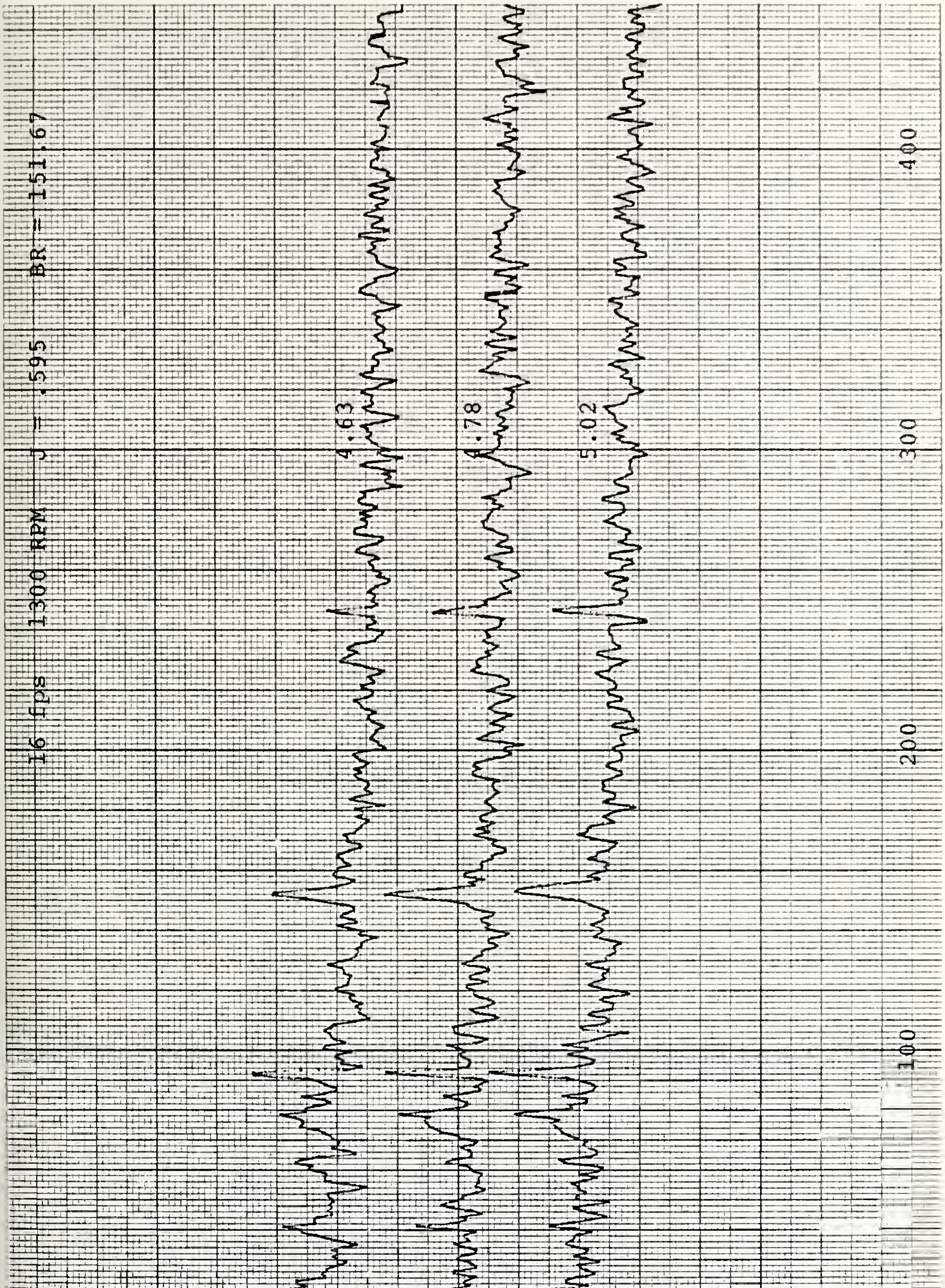

16 fps 1100 PPM J = .70 BR = 128.33
3.71
3.88
4.01
100
200
300
400

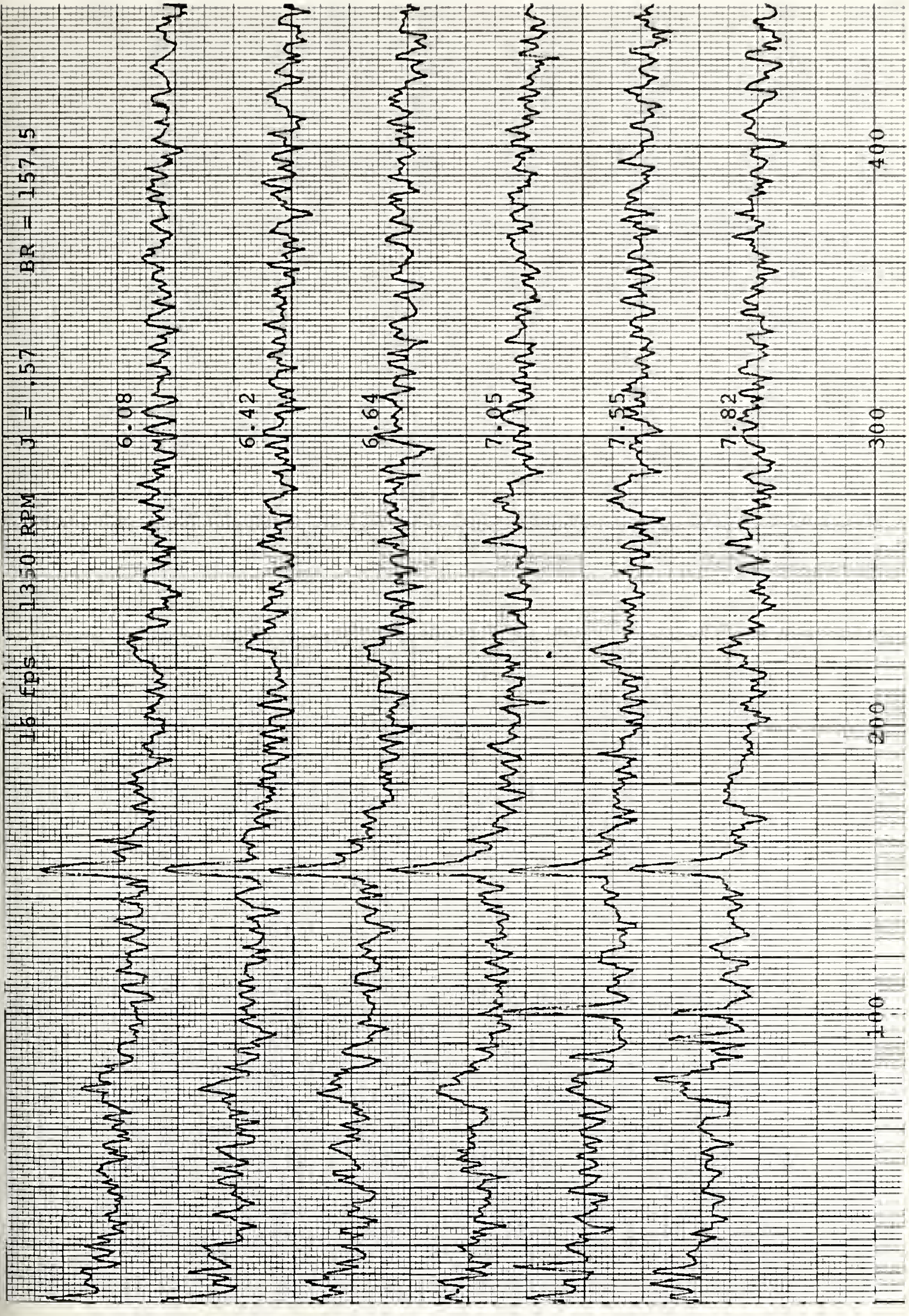

16 FPS 1150 RPM J = .67 BR = 134.16
3.53
3.84
4.05
100
200
300
400

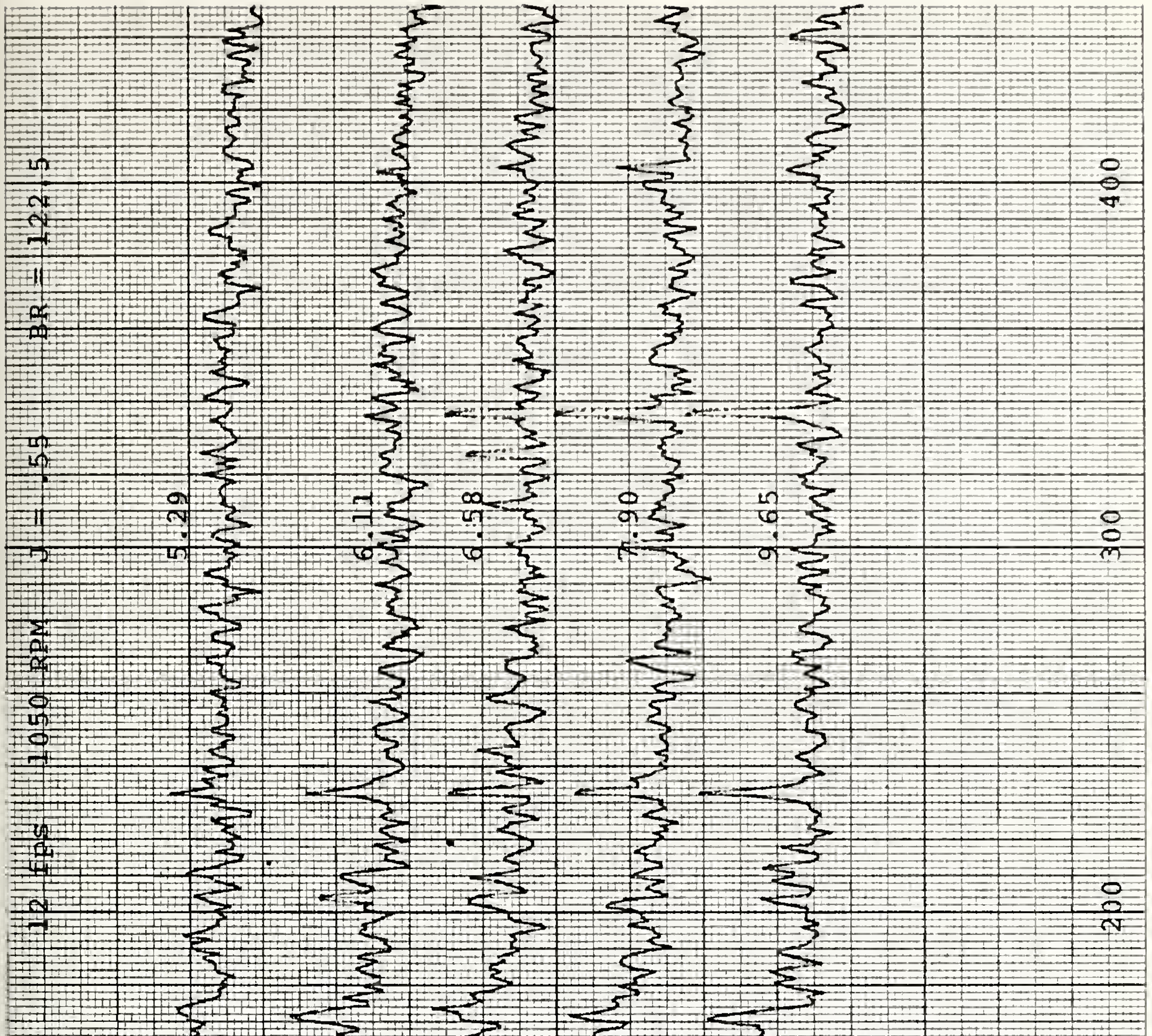

16 fps 1200 RPM J = 64 BR = 140
3.95
4.14
4.27
4.36
100
200
300
400

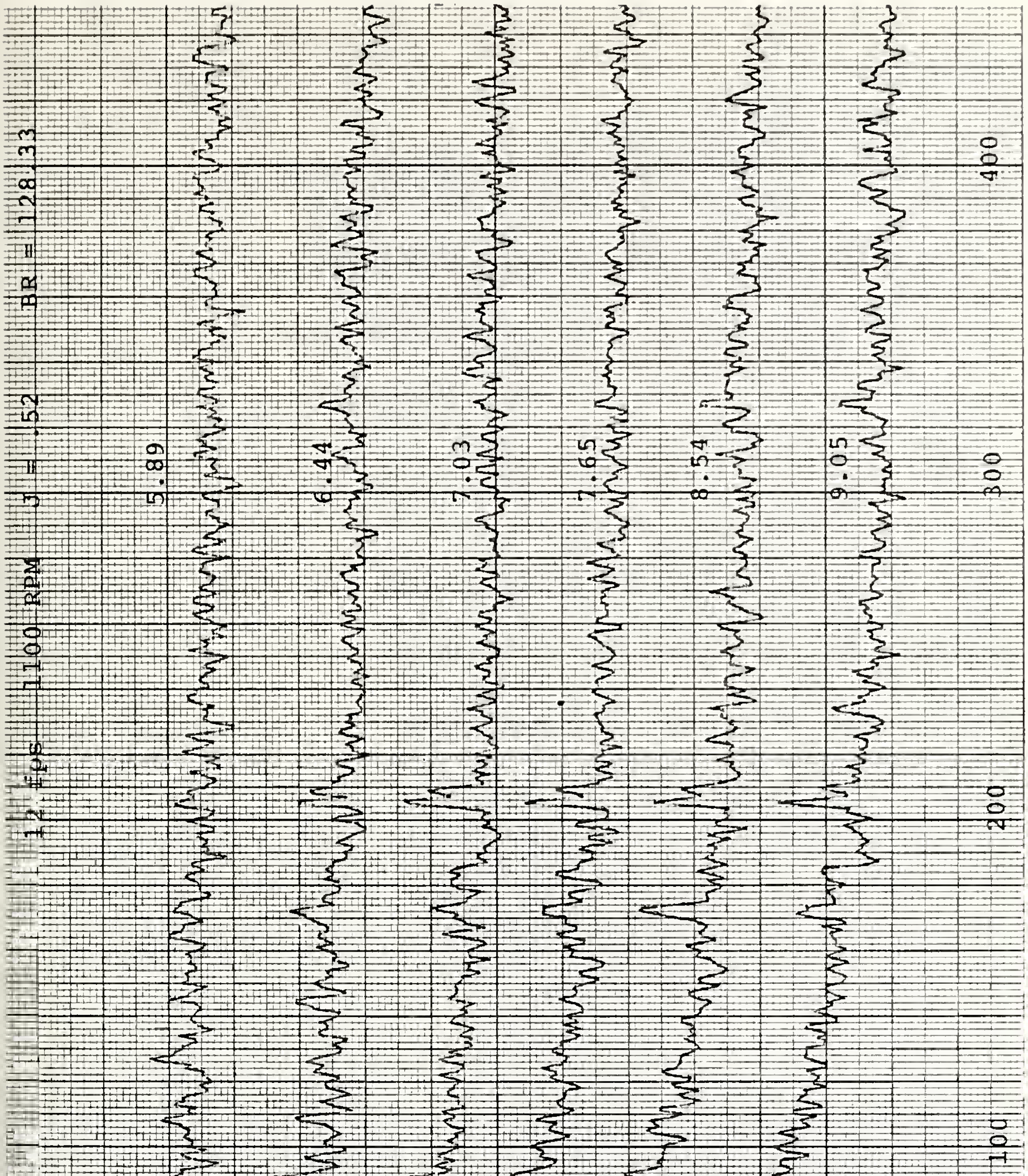

16 fps 1250 RPM J = .62 BR = 145.83
3.79
3.91
4.16
4.53
4.67
4.93
100
200
300
400


16 Fps 1250 RPM J = .62 BR = 145.83
3.29
3.58
100
200
300
400

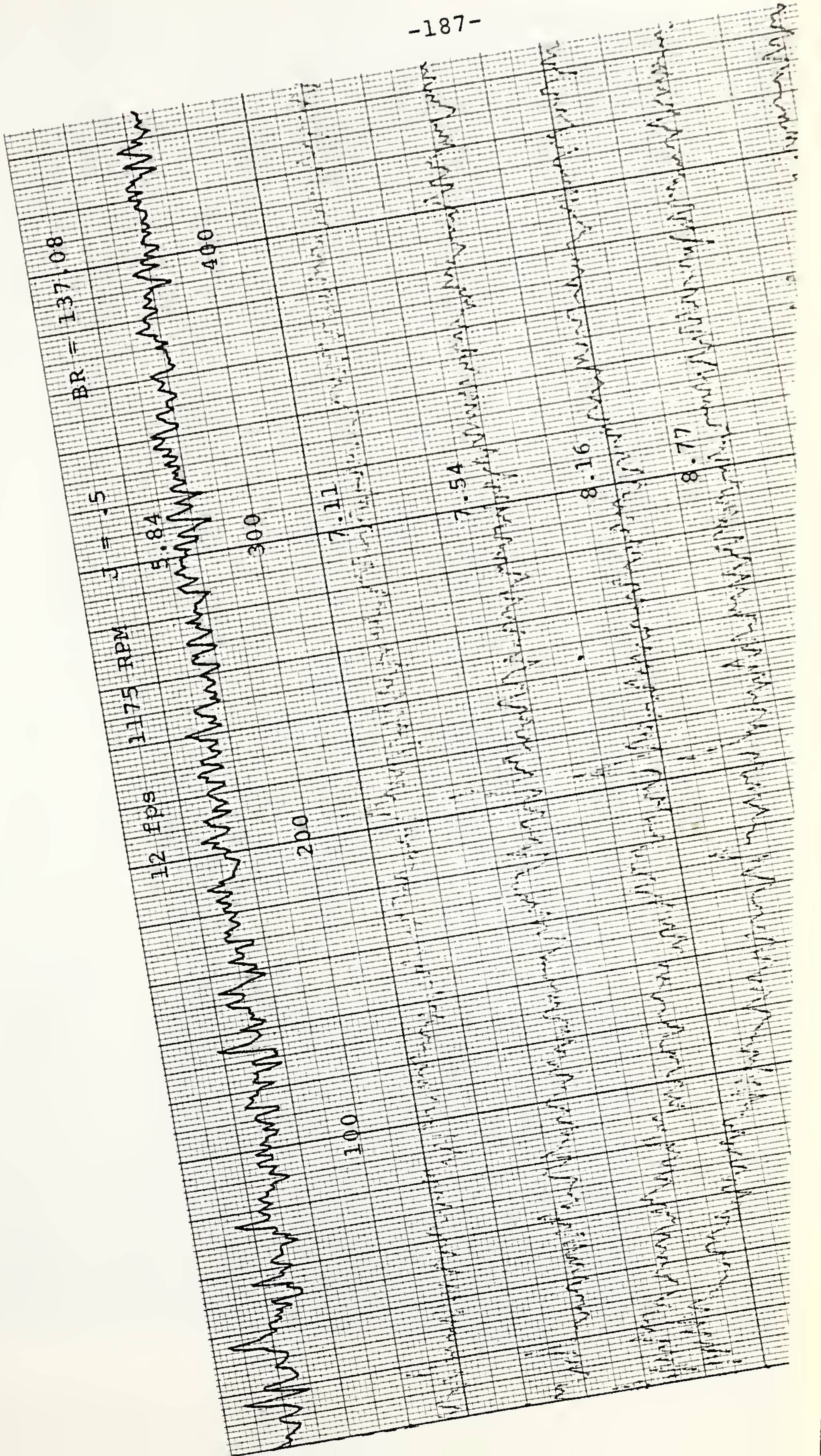

16 fps 1300 RPM J = .595 BR = 151.67
4.63
4.78
5.02
100
200
300
400

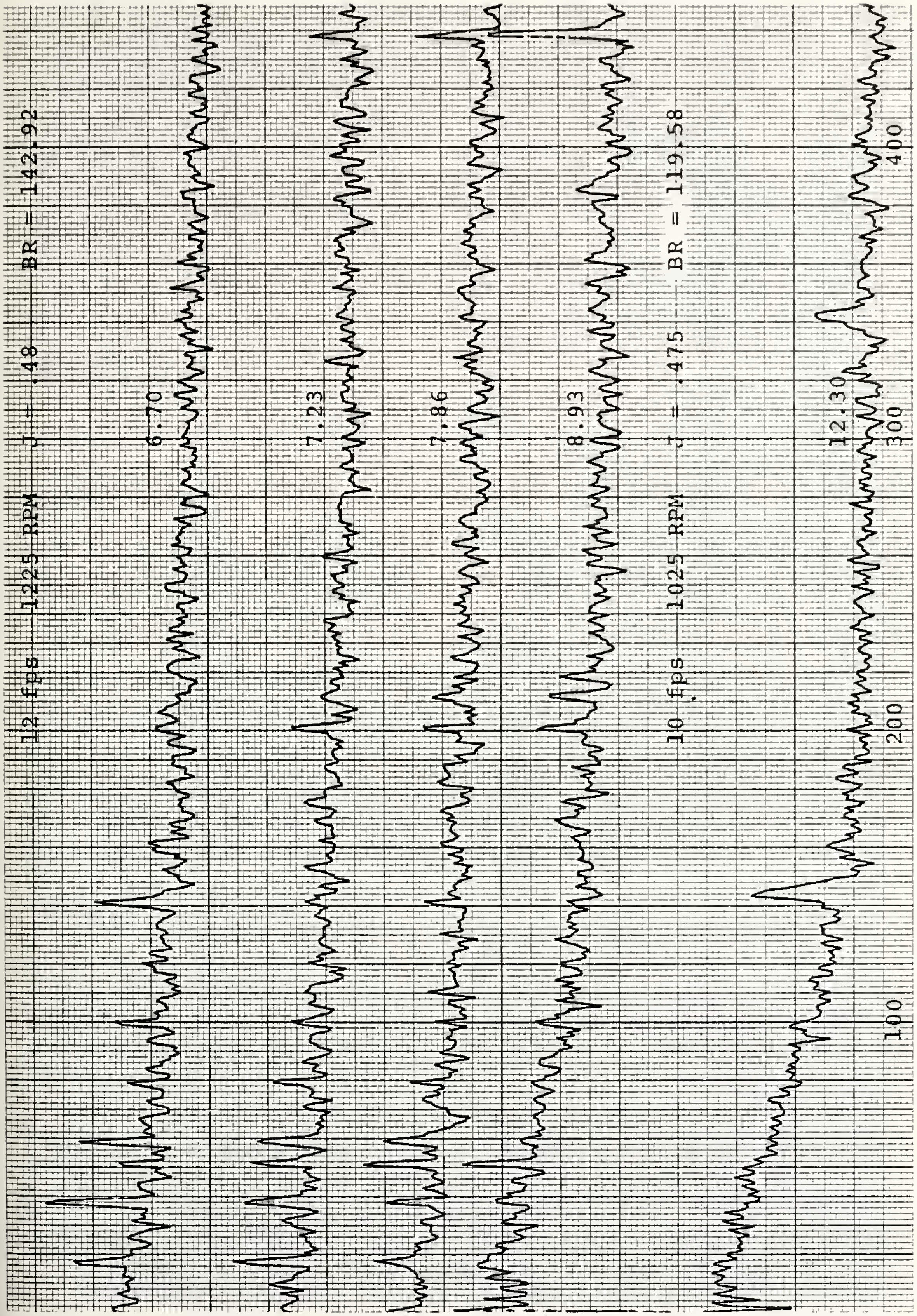

16 fps 1350 RPM J = .57 BR = 157.5
6.08
6.42
6.64
7.05
7.55
7.82
100
200
300
400

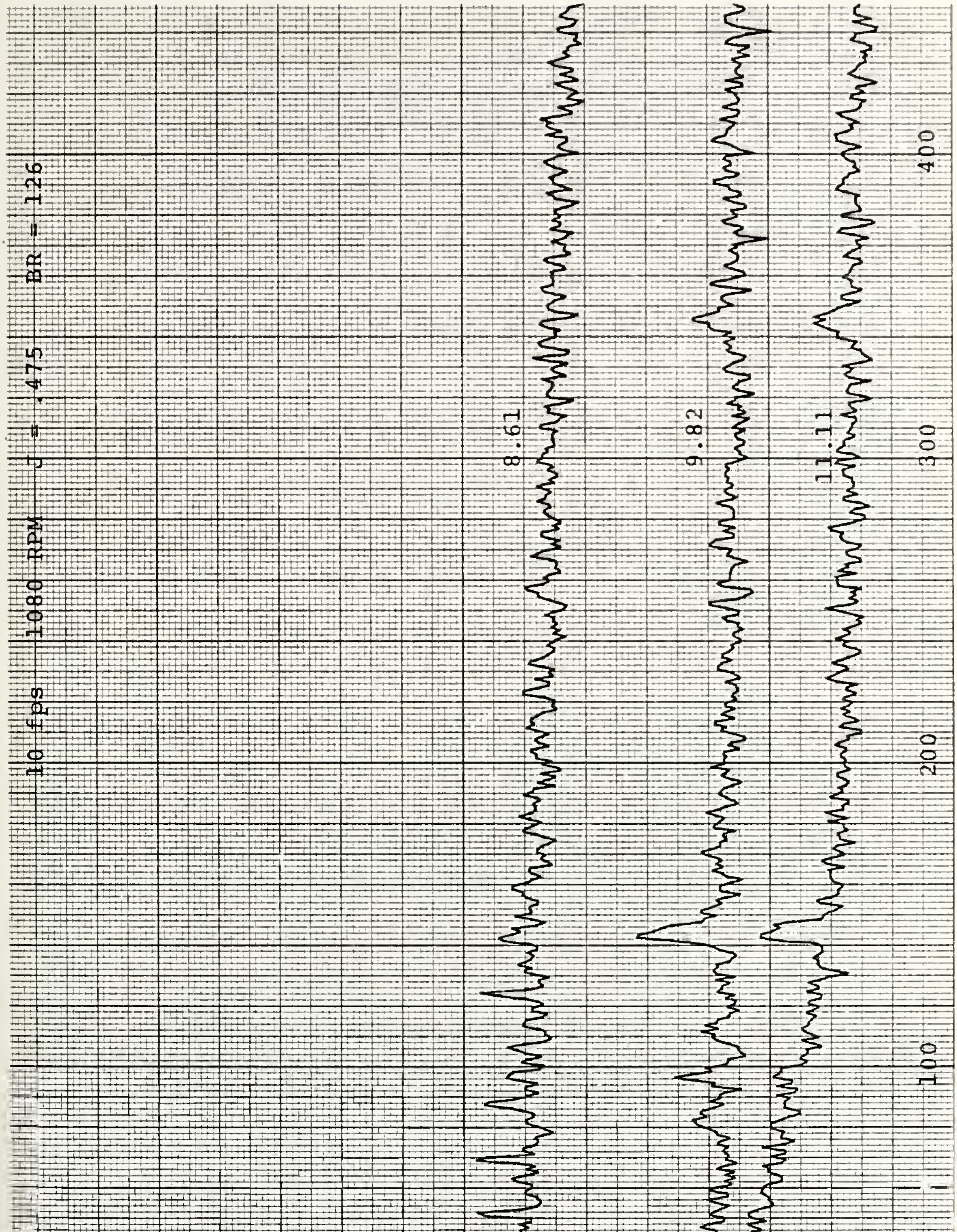

12 EPS 1050 RPM J = .55 BR = 122.5
5.29
6.11
6.58
7.90
9.65
100
200
300
400

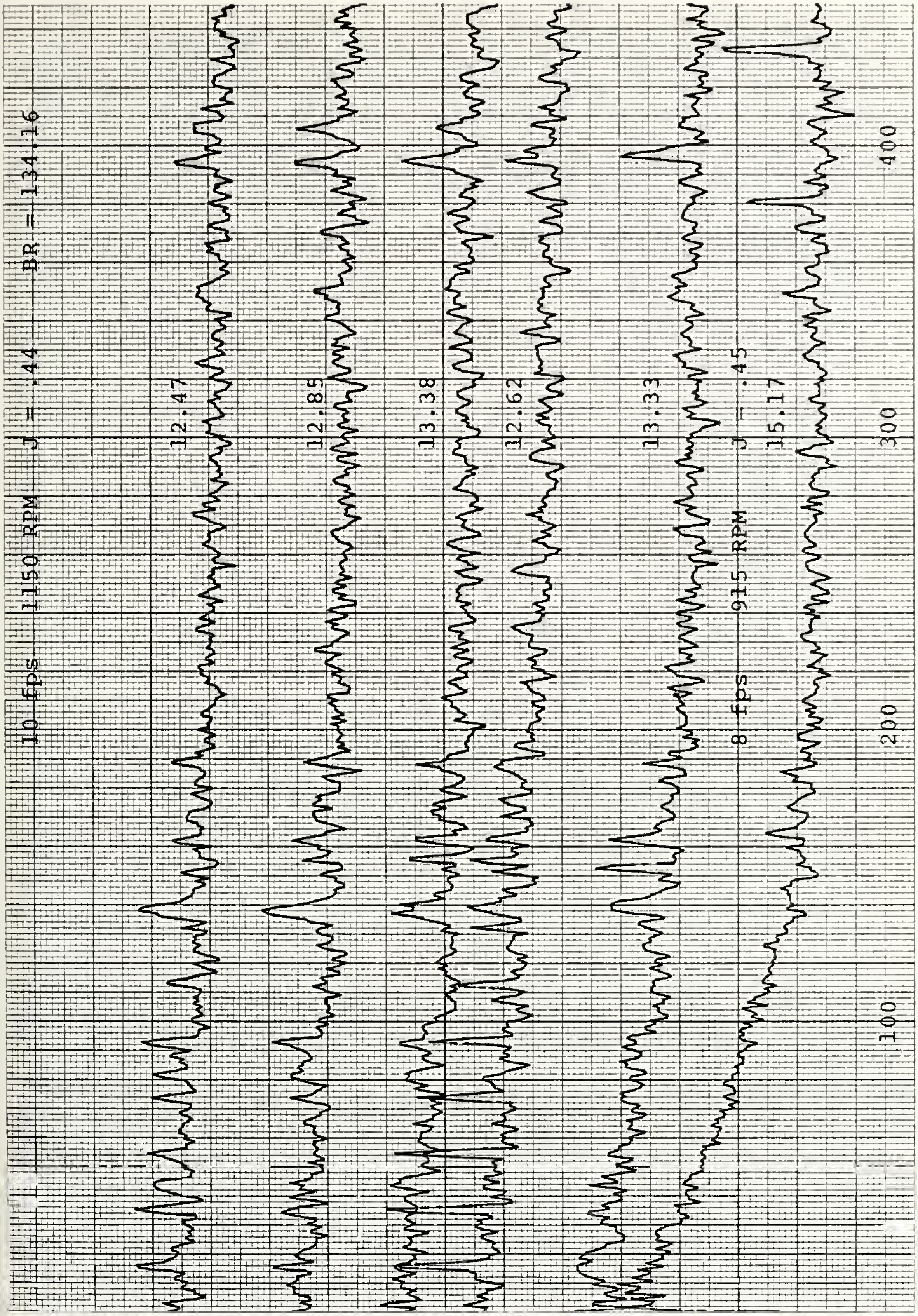

12 fps 1100 RPM J = .52 BR = 128.33
5.89
6.44
7.03
7.65
8.54
9.05
100
200
300
400

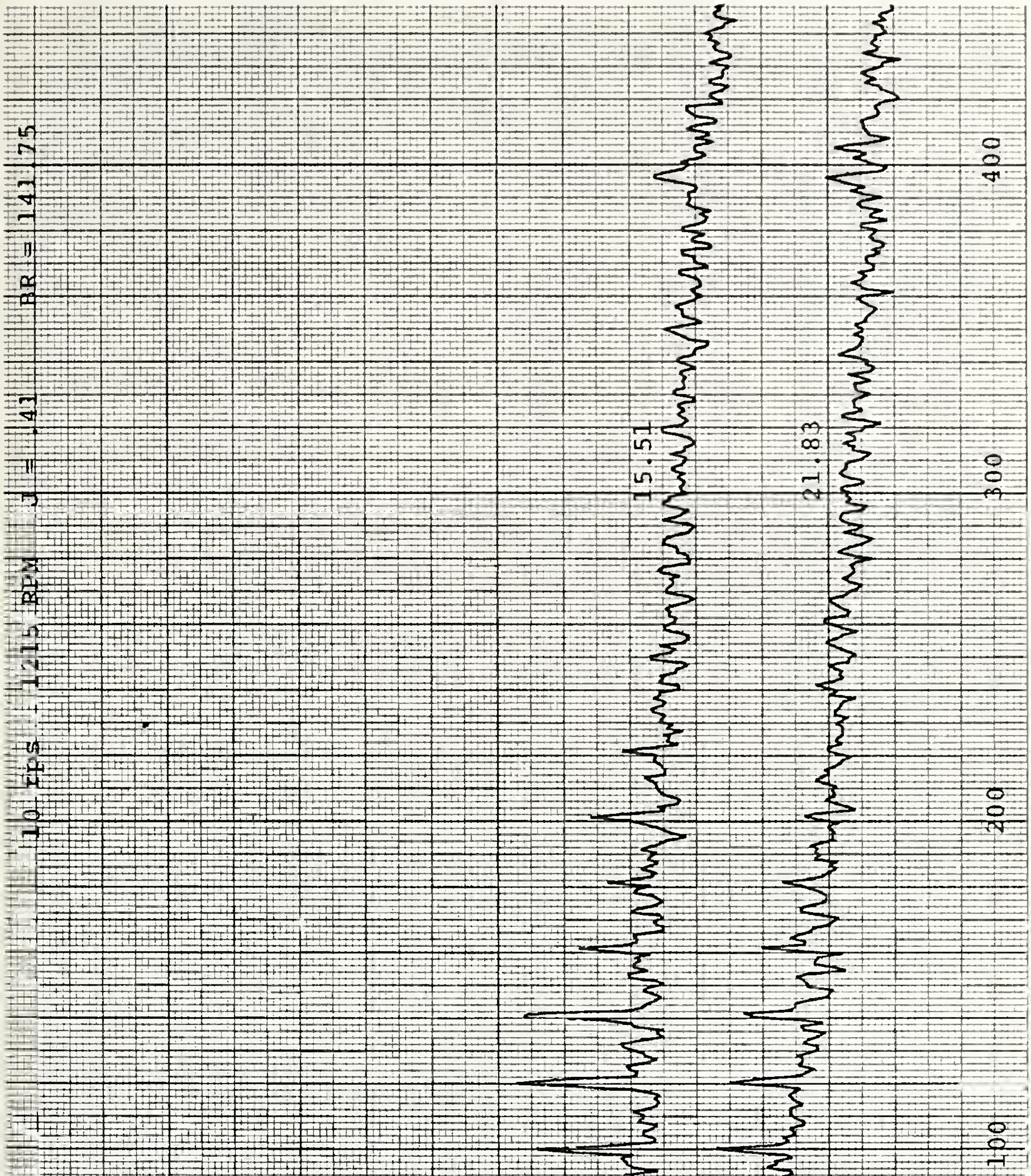
(Replacement page not available)

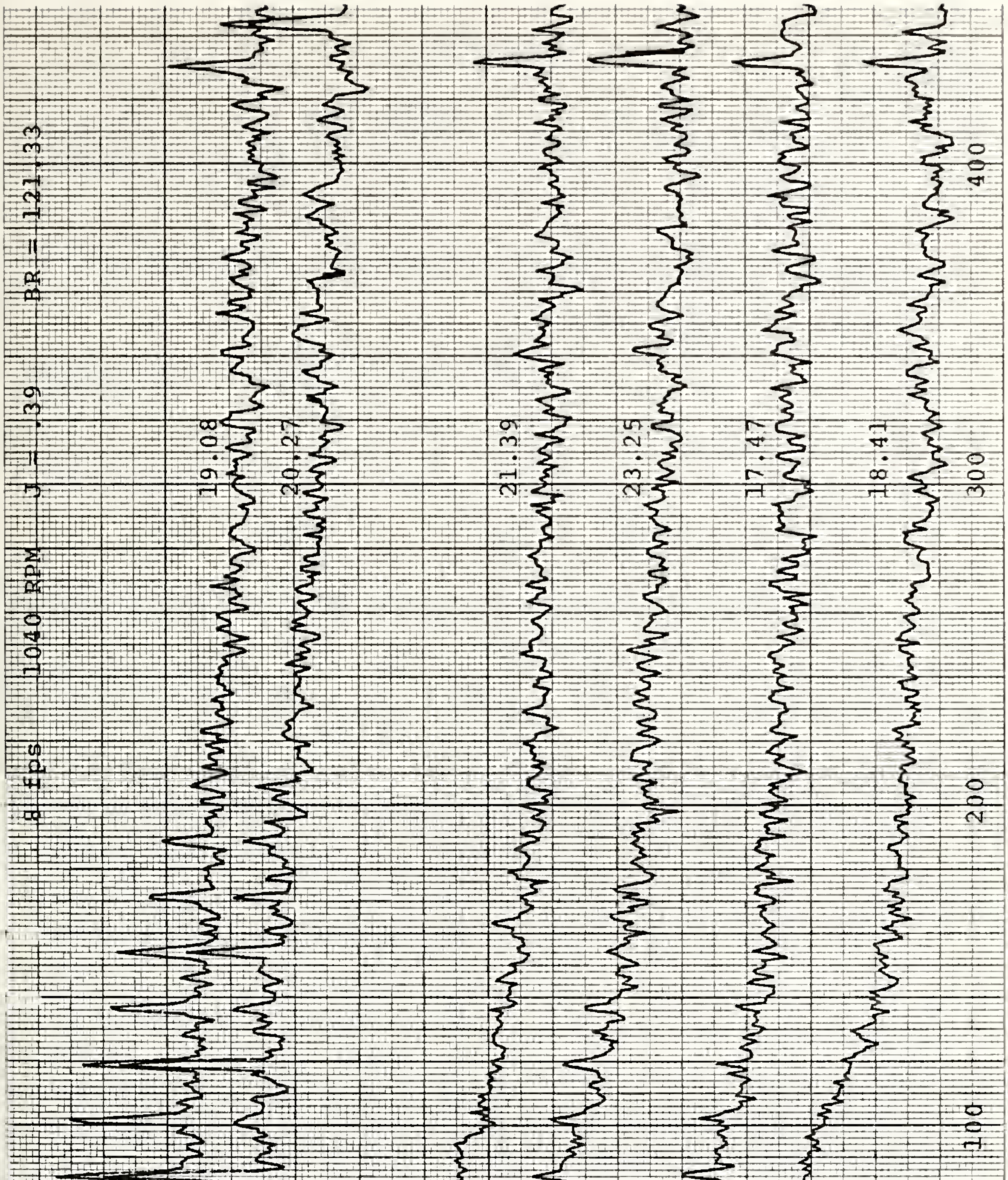



12 fps 1225 RPM J = .48 BR = 142.92
6.70
7.23
7.86
8.93
10 fps 1025 RPM J = .475 BR = 119.58
12.30
100
200
300
400


10 fps 1080 RPM J = .475 BR = 126
8.61
9.82
11.11
100
200
300
400


10 fps 1150 RPM J = .44 BR = 134.16
12.47
12.85
13.38
12.62
13.33
8 fps 915 RPM J = .45
15.17
100
200
300
400


10 FPS : 1215 RPM   J = .41   BR = 141.75
15.51
21.83
100
200
300
400


8 fps 1040 RPM J = .39 BR = 121.33
19.08
20.27
21.39
23.25
17.47
18.41
100
200
300
400

DATA SHEET

RUN NO 8

DATE 3/4

U_{nom} 16 (Taps: 6/5 blue) RPM 1200 J_{nom} 0.64 Shaft rate 20

Blade rate 140

Ithaco amp① 40 db;Filter: Hi pass 125 Trans Anal

Lo pass 10x10^5 ② — db

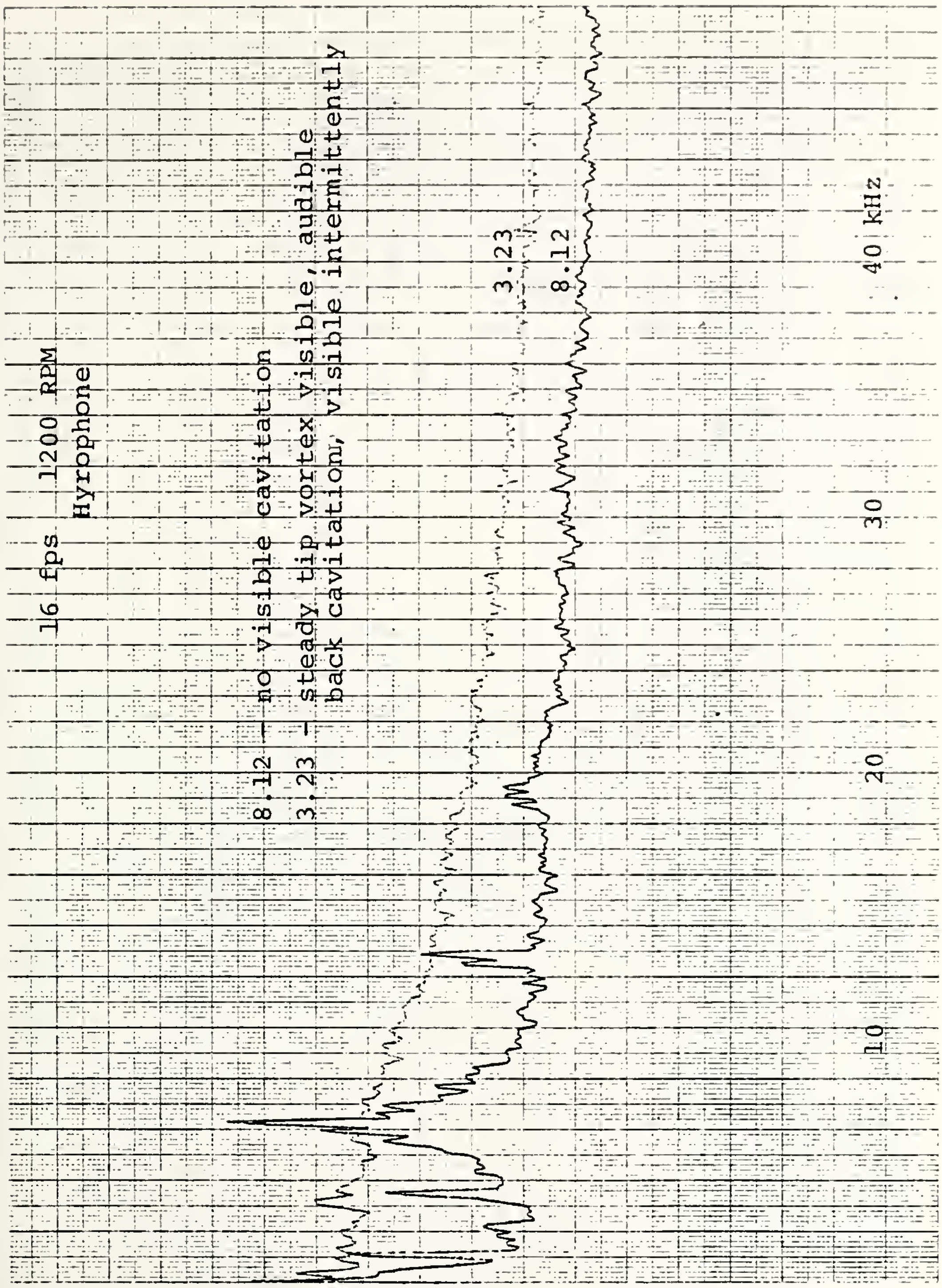
Measuring Equipment: Input atten③ -30 db Meas amp ___ (# of

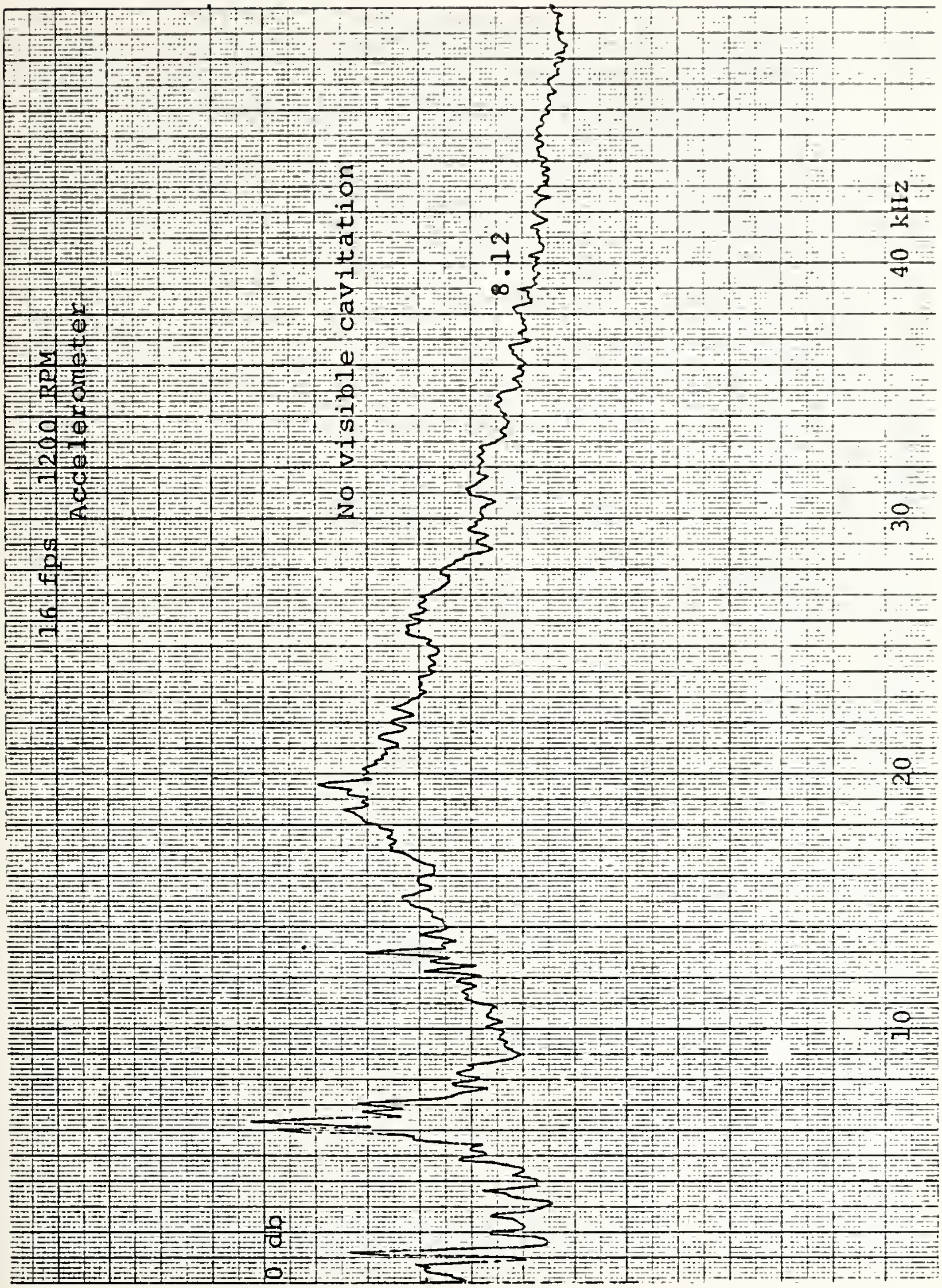
Output gain④ +20 db Spect anal. X spectra 28)

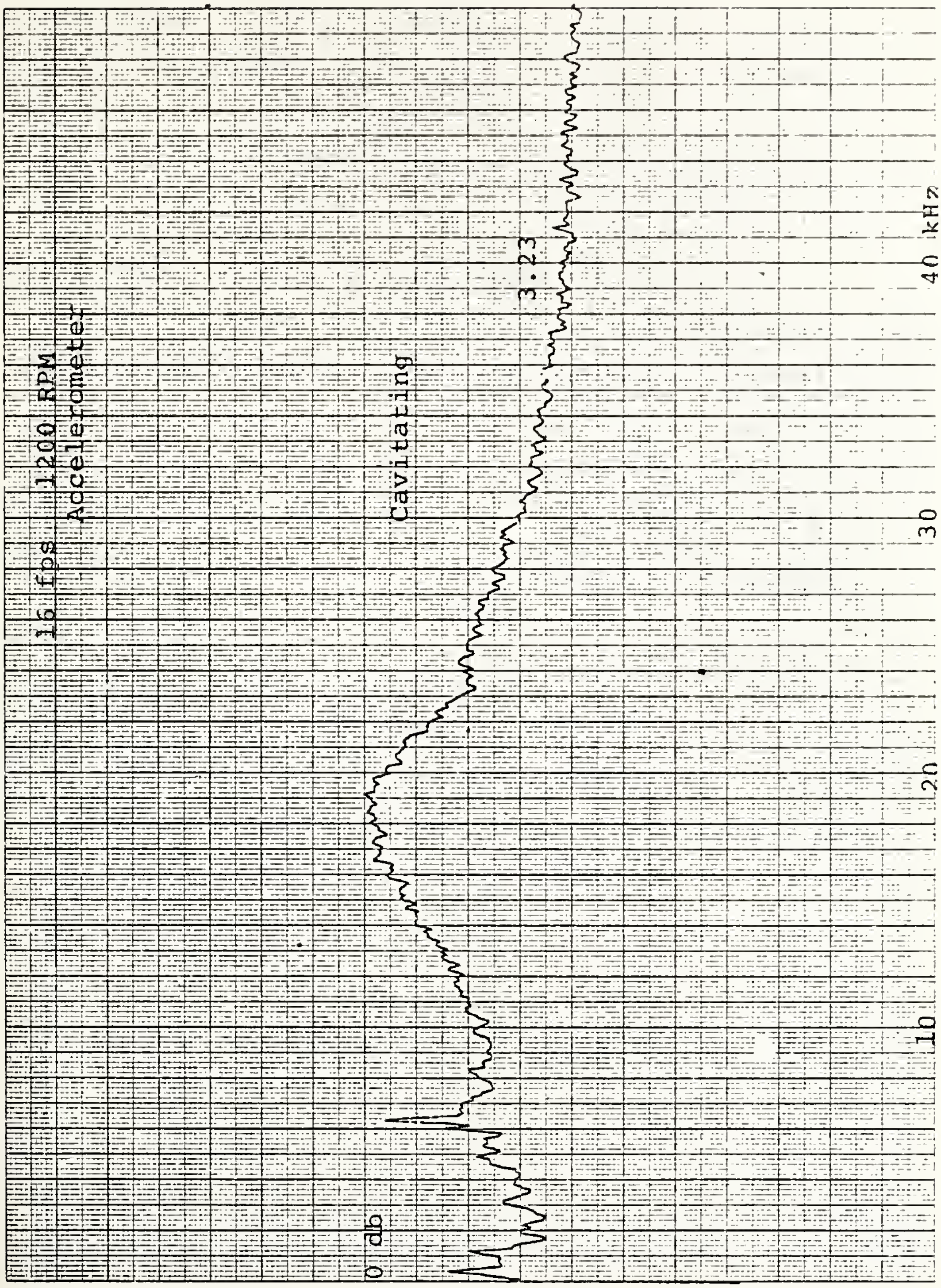
Temperature: (Start) water 102 air 81 Reynolds number:

(End) 103 82

MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
914	310	1201								
908	747	1199							3.23	7-1 Hyd
911	744	1199			1 3	+50 -20			8.12	-2 Hyd
917	308	1200			1	40			8.12	8 Accel
									3.23	9 Accel
12	BAR 771.0		2	8						
										TARE


16 fps 1200 RPM
Hyrophone
8.12 — no visible cavitation
3.23 — steady tip vortex visible, audible
back cavitation, visible intermittently
3.23
8.12
10
20
30
40 kHz


16 fps 1200 RPM
Accelerometer
No visible cavitation
8.12
0 db
10
20
30
40 kHz


16 fps 1200 RPM
Accelerometer
Cavitating
3.23
0 db
10
20
30
40 kHz

DATA SHEET

RUN NO 2A

DATE 3/4

U_{nom} 20 RPM 1530 J_{nom} 0.62 Shaft rate 25.5
(Taps: 6/5 blue)

Blade rate 178.5

Ithaco amp① +40 db; Filter: Hi pass 1x10⁴ Trans Anal

Lo pass 10x10⁵ ② -25 db

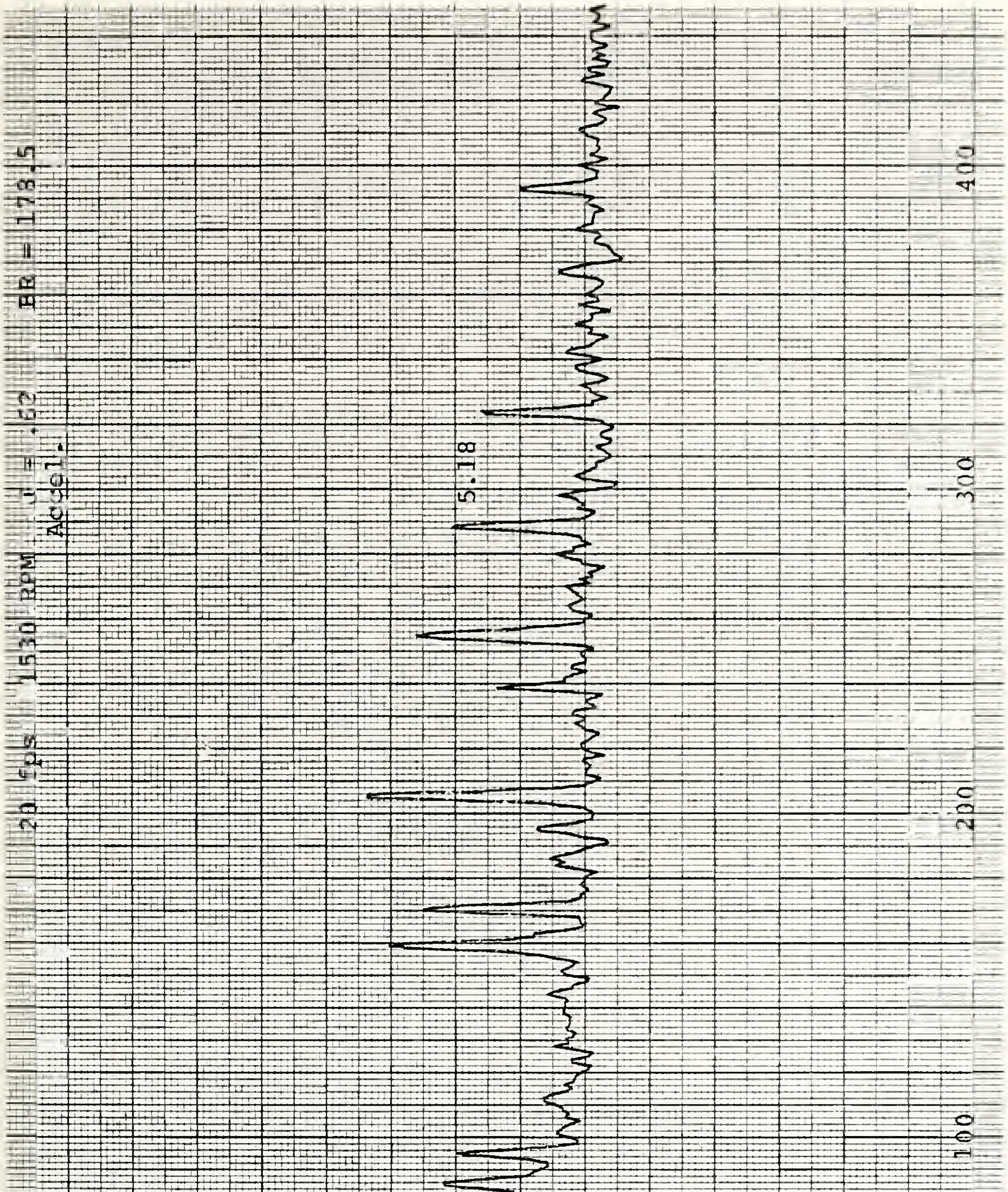
Measuring Equipment: Input atten③ -20 db Meas amp ___ (# of
Output gain④ +10 db Spect anal. X spectra 32)

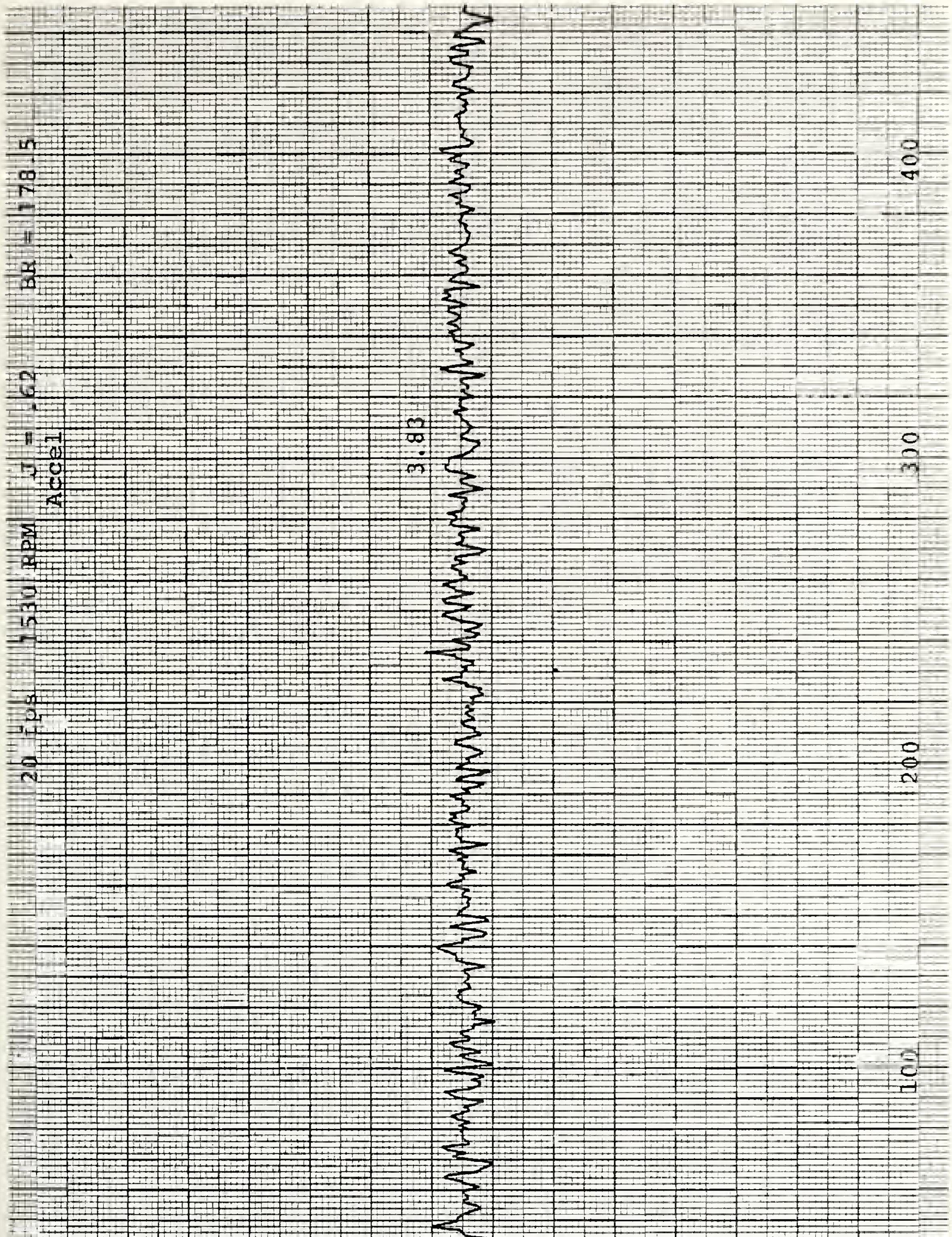
Temperature: (Start) water 94 air 77 Reynolds number:

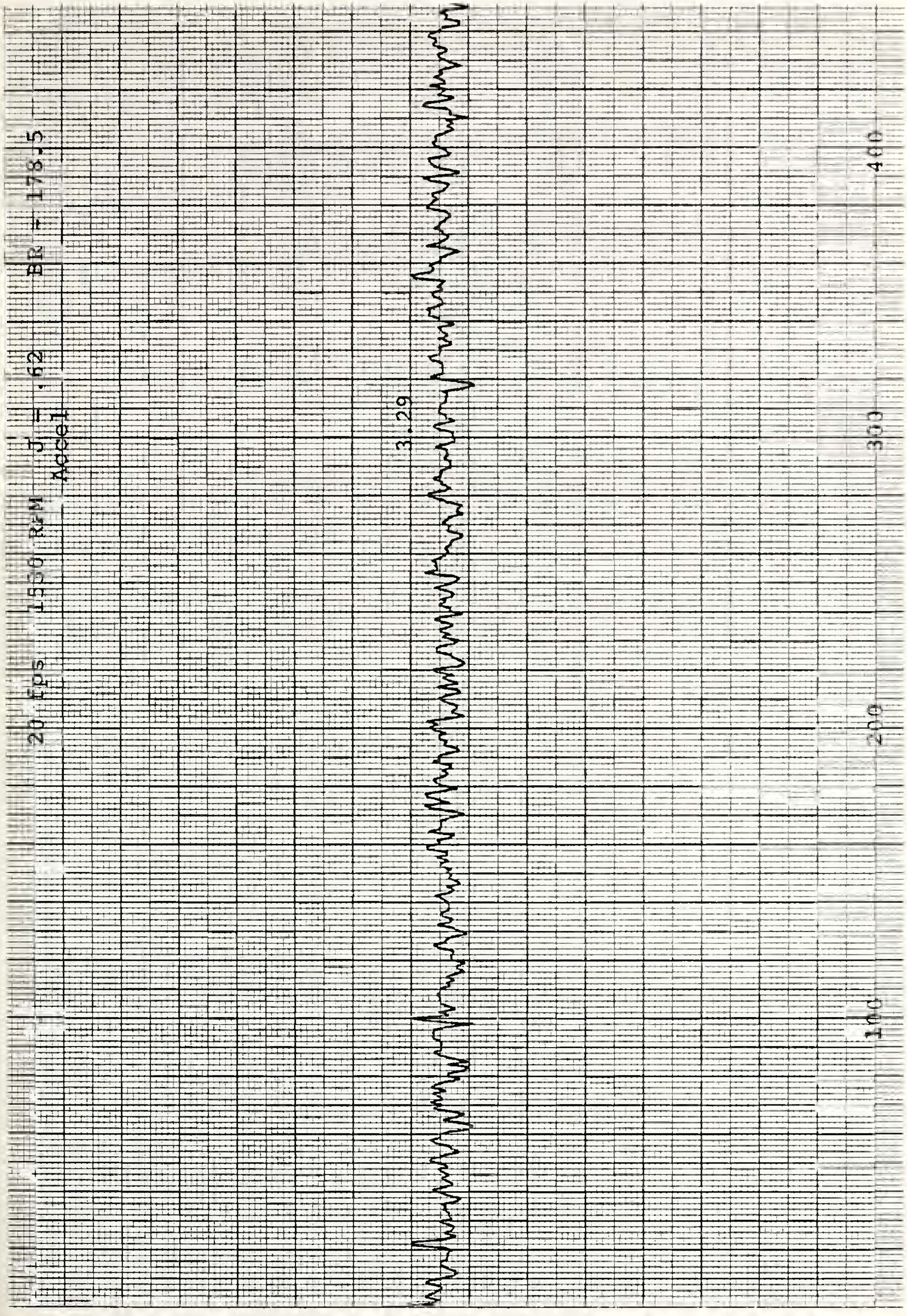
(End) 97 77 1.12 x10⁶

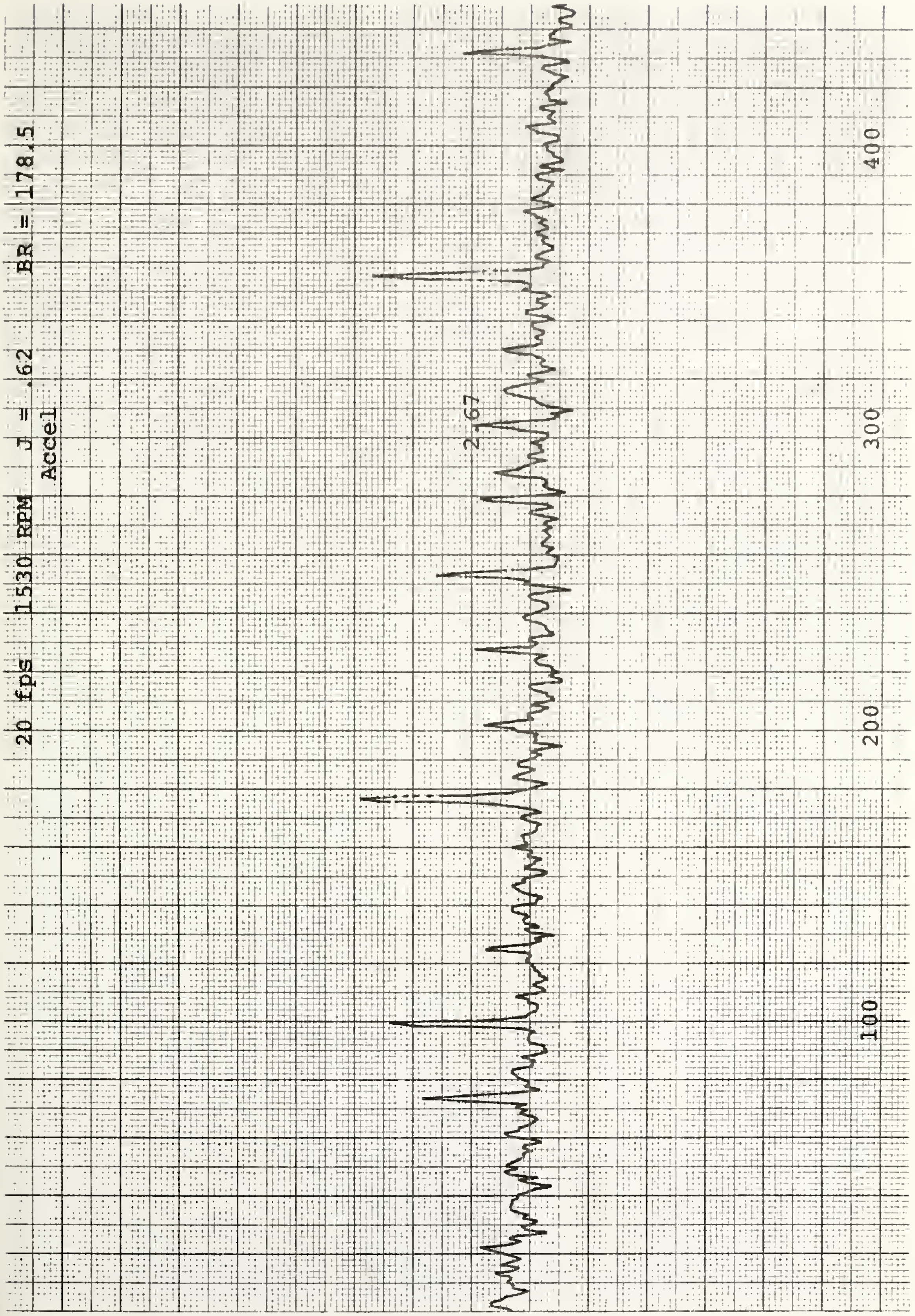
Accelerometer

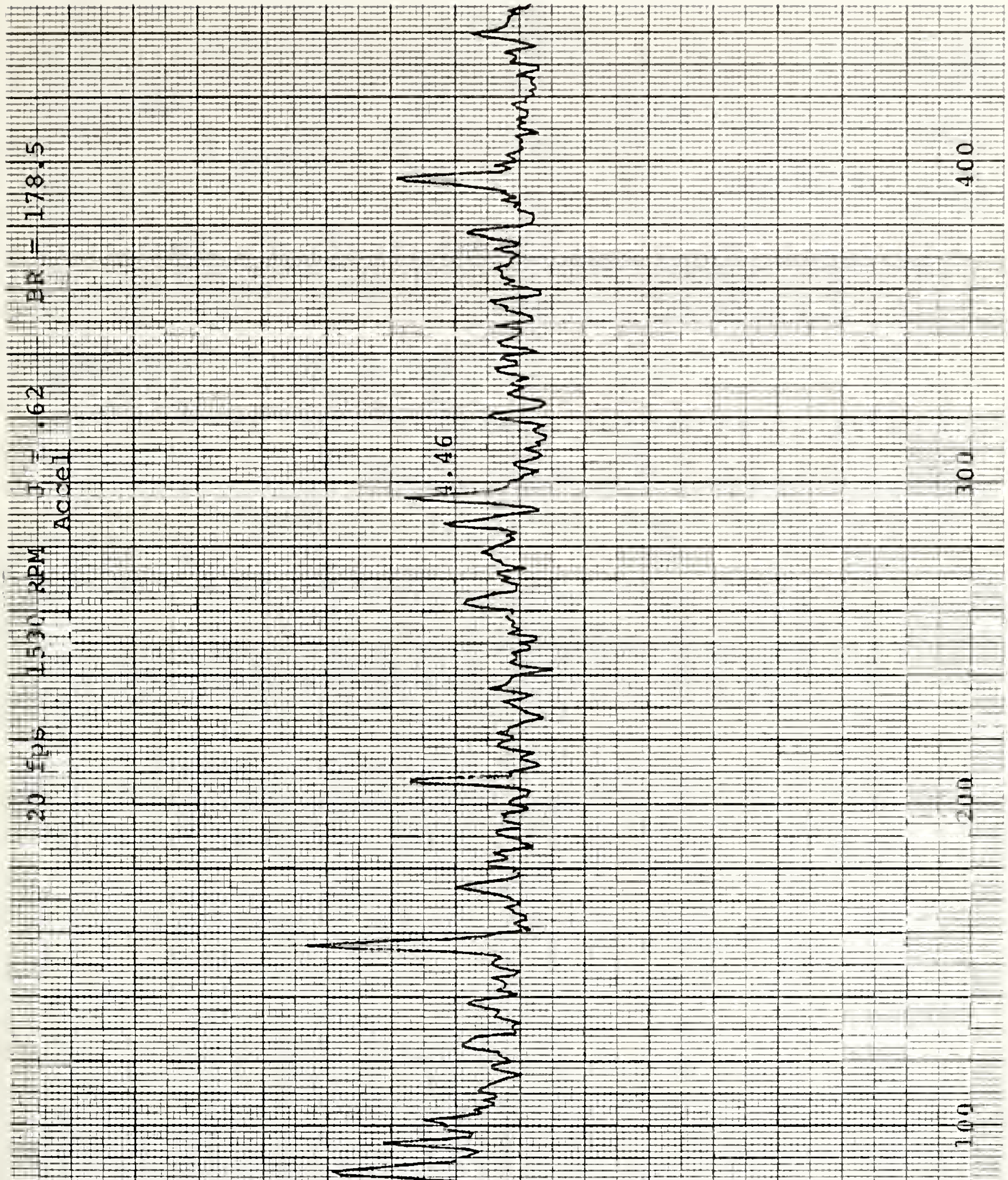
MAN	STAT BAR	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
12	775.7		0	11.5						
										TARE
1386	723	1530	594	198.5						
1368	531	1530	576	200	2 4	-30 +20	.145	.62	5.18	335
1375	460	1535	552	197.5					3.83	345
1409	386	1533	512	191.5	3	-30			3.29	375
1391	626	1532	576	198.0	2 3	-25 -20			2.67	385
									4.46	415


20 fps 1530 RPM μ = .62 BB = 178.5
Accel.
5.18
100
200
300
400


20 ips 1530 RPM J = .62 BR = 178.5
Accel
3.83
100
200
300
400


20 fps 1530 RPM J = .62 BR = 178.5
Accel
3.29
100
200
300
400


20 fps 1530 RPM J = .62 BR = 178.5
Accel
2.67
100
200
300
400


20 fps 1530 RPM J = .62 BR = 178.5
Accel
4.46
100
200
300
400

DATA SHEET

RUN NO 2H

DATE 3/4

U_{nom} 20 RPM 1530 J_{nom} 0.62 Shaft rate 25.5

(Taps: 6/5 blue)

Blade rate 178.5

Ithaco amp① +40 db;Filter: Hi pass 1x10^4 Trans Anal

Lo pass 10x10^5 ② 0 db

Measuring Equipment: Input atten③ 0 db Meas amp ___ (# of

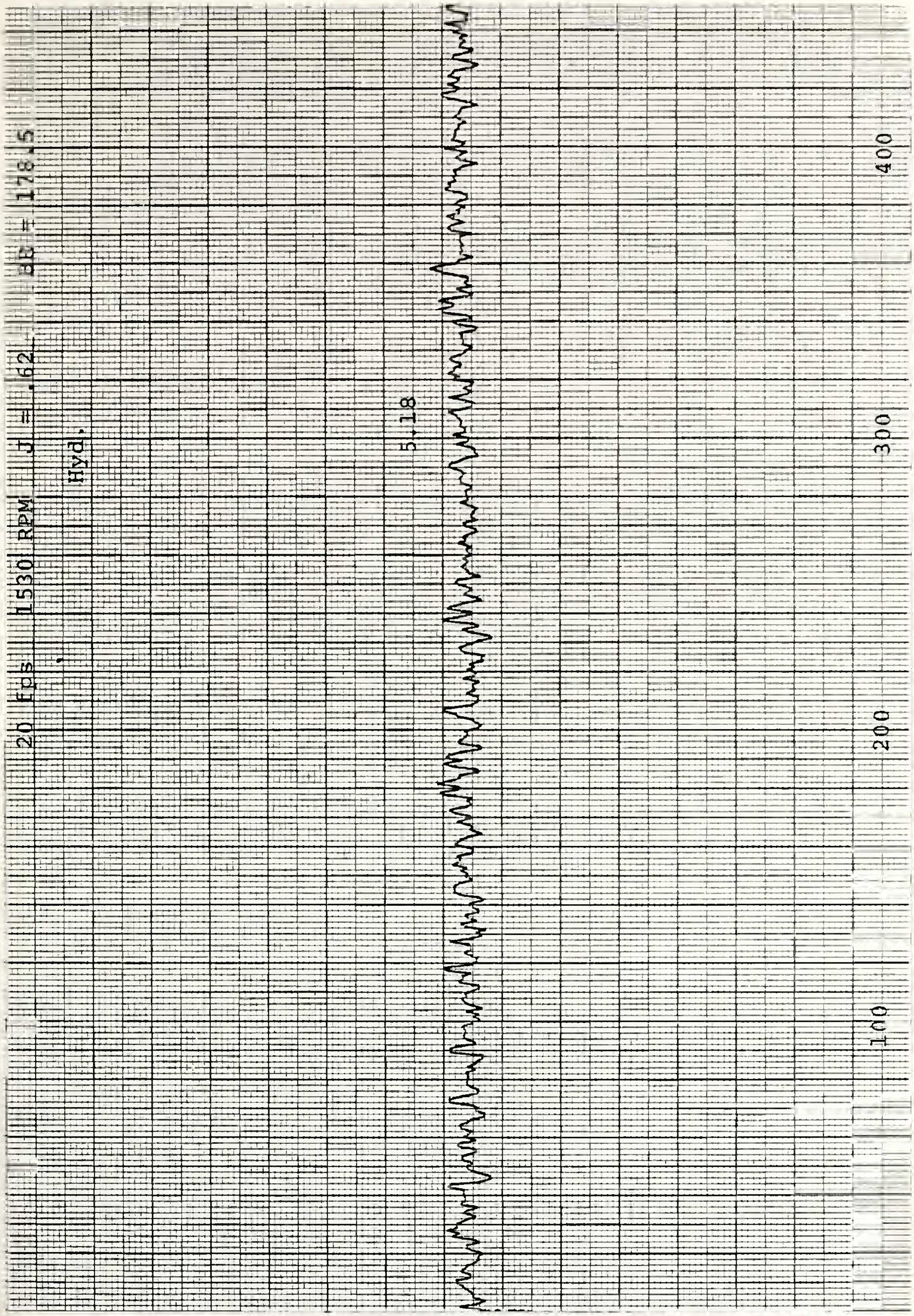
Output gain④ +20 db Spect anal. X spectra 32)

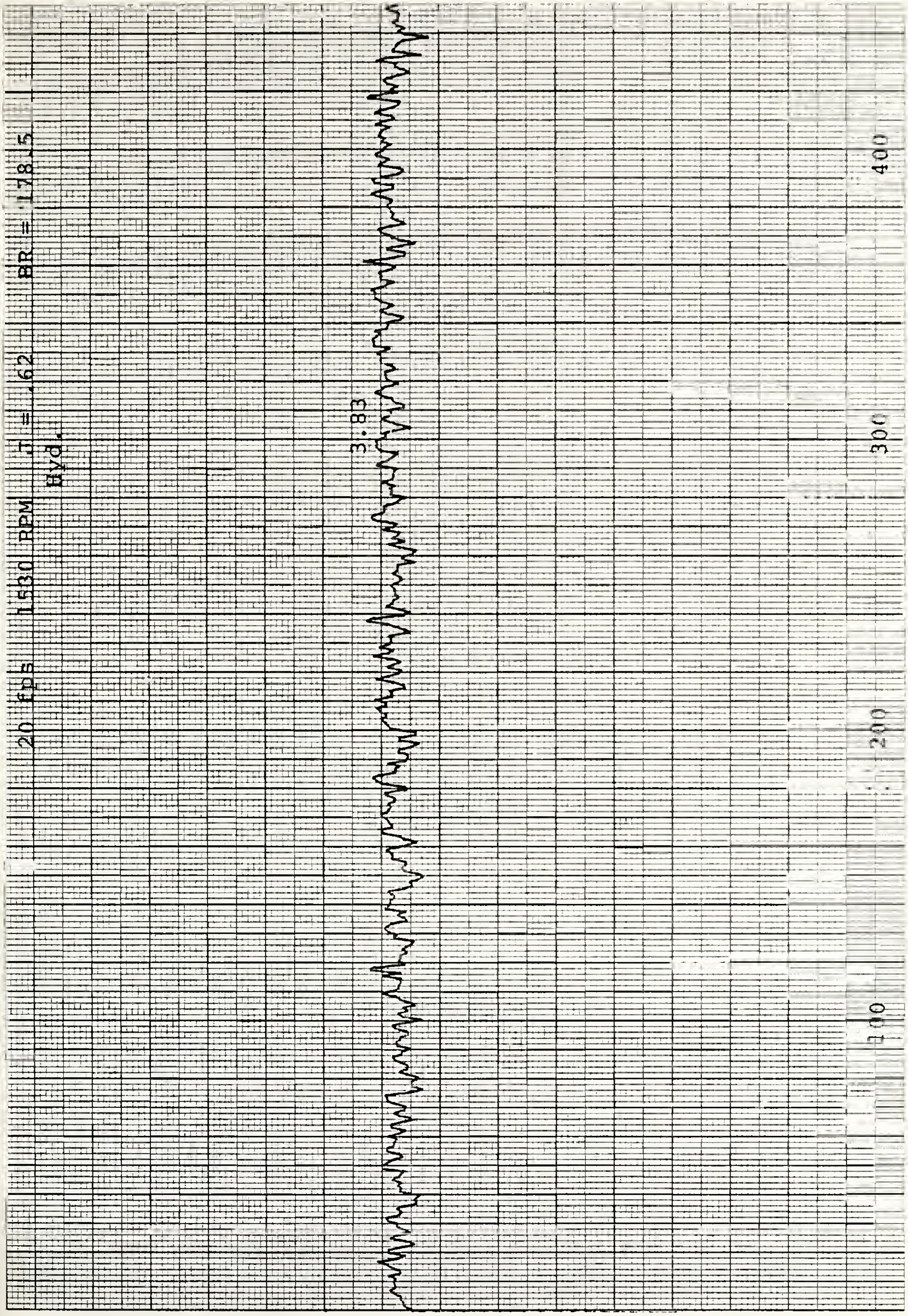
Temperature: (Start) water 94 air 77 Reynolds number:

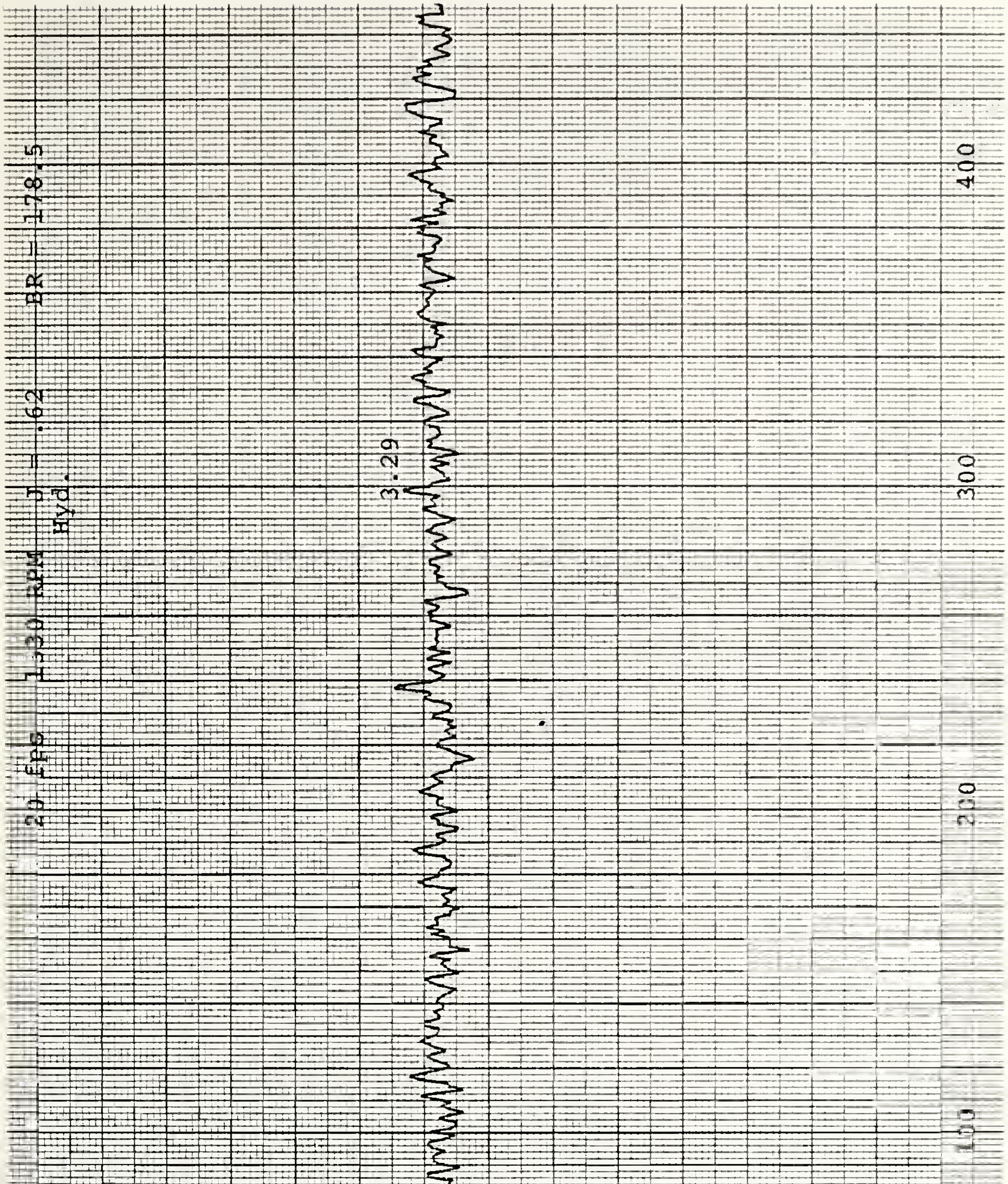
(End) 97 77 1.12x10^6

Hydrophone

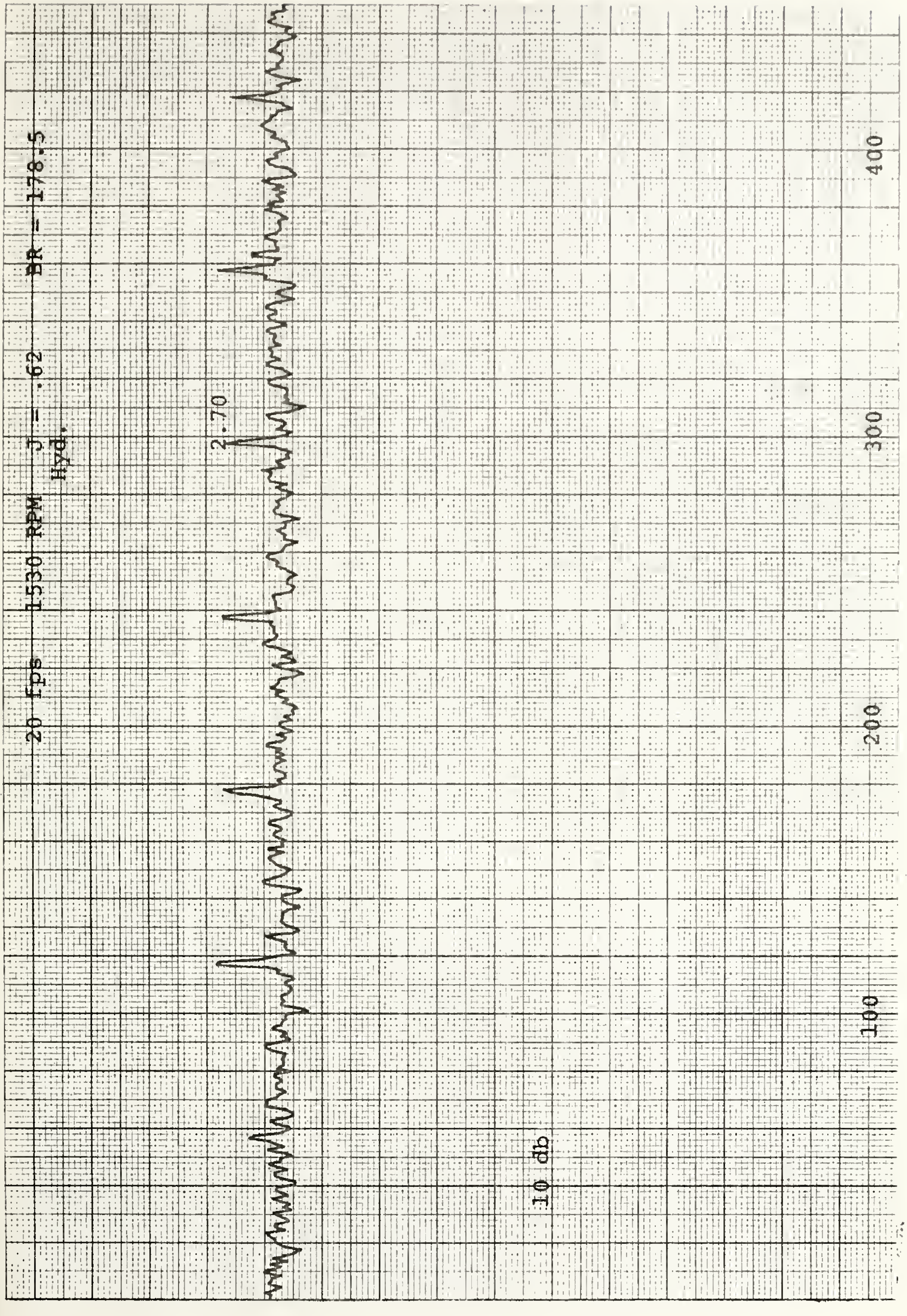
MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
1386	723	1530	594	198.5			.145	.62	5.18	32S
1388	529	1536	572	200	1/3	+50 -10			3.83	35S
1378	460	1529	526	192.5					3.29	36S
1395	386	1530	506	191	1	+60			2.70	39S
1421	634	1530	568	195.5					4.42	40S

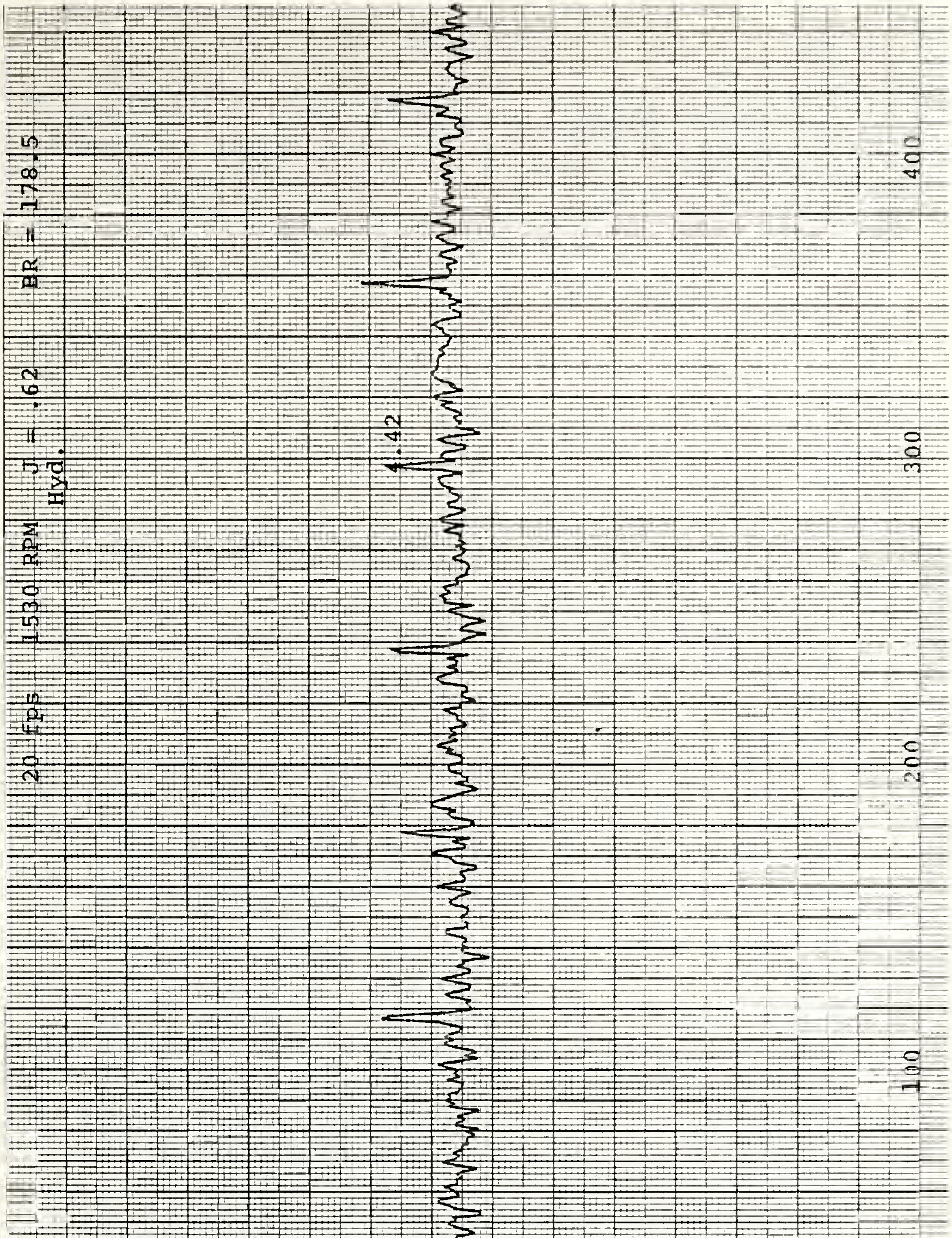

20 Eps 1530 RPM J = .62 BB = 178.5
Hyd.
5.18
100
200
300
400


20 fps 1530 RPM J = .62 BR = 178.5
Hyd.
3.83
100
200
300
400



20 fps 1530 RPM J = .62 BR = 178.5
Hyd.
3.29
100
200
300
400


20 Fps 1530 RPM J = .62 BR = 178.5
Hyd.
2.70
10 db
100
200
300
400


20 fps 1530 RPM J = .62 BR = 178.5
Hyd.
1.42
100
200
300
400

DATA SHEET

RUN NO 1

DATE 3/3

U_{nom} 16 RPM 1500 J_{nom} 0.50 Shaft rate 25

(Taps: 6/5 blue) Blade rate 175

Ithaco amp ① +40 db; Filter: Hi pass 1x10^4 Trans Anal

Lo pass 10x10^5 ② ______ db

Measuring Equipment: Input atten ③ -10 db Meas amp ___ (# of

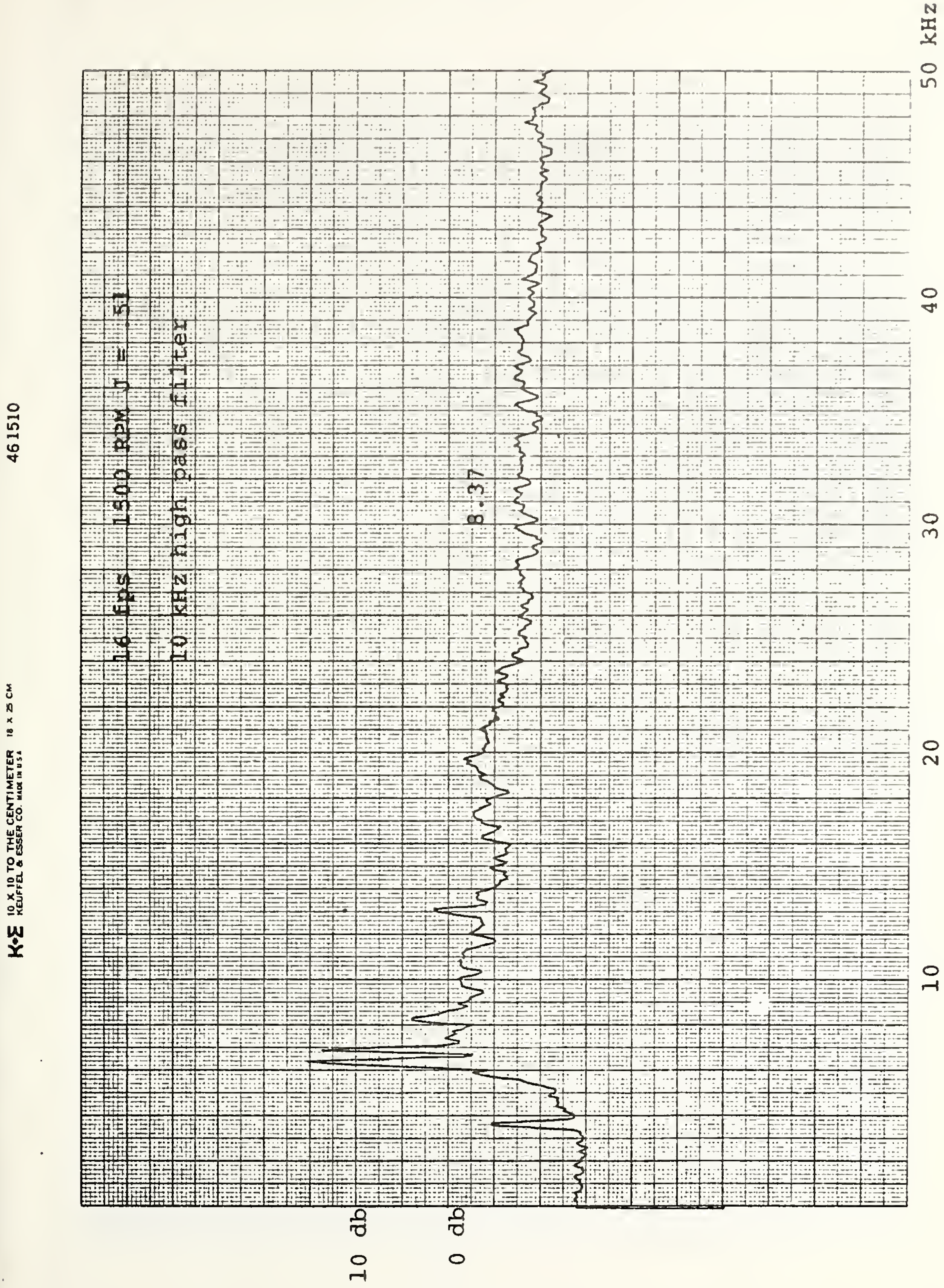
Output gain ④ +20 db Spect anal. x spectra 28)

Temperature: (Start) water 82 air 75 Reynolds number:

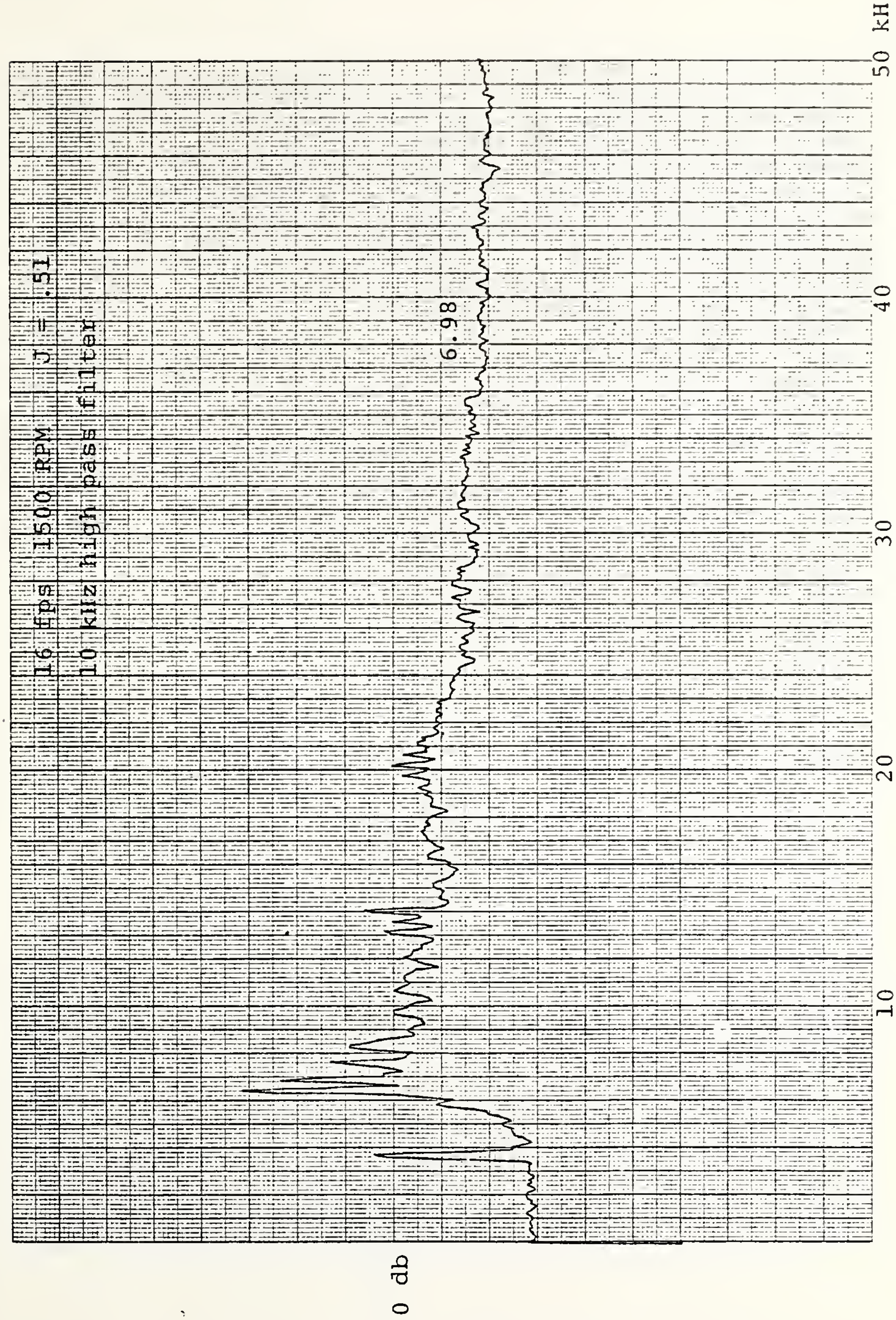
(End) 86 75 ______

Torque in pounds = T x 0,2

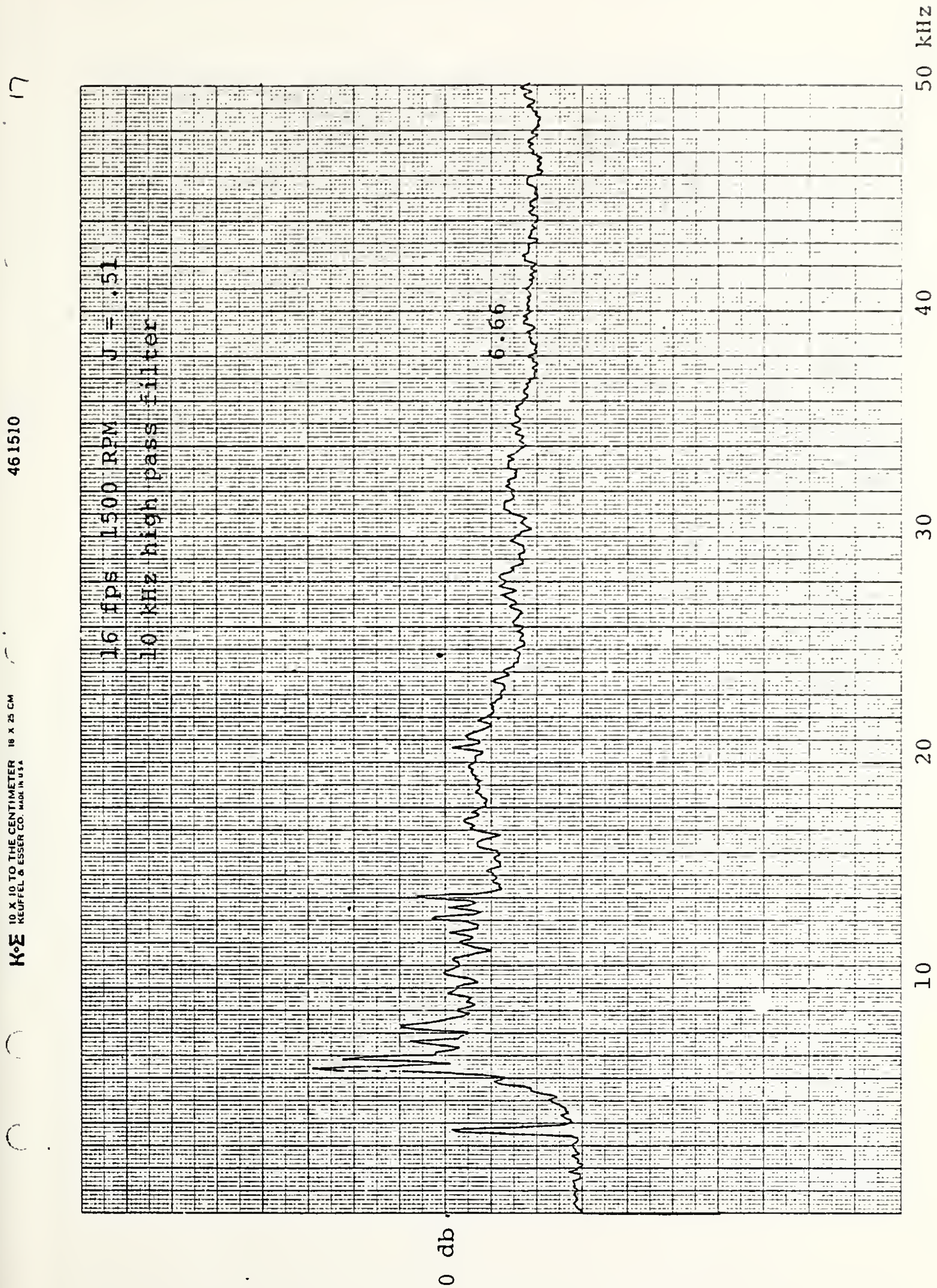
MAN	STAT	RPM	T	Q	GAIN CHANGE		K_T	J	σ	REMARKS
914	754	1500	770	236.5			.194	.51	8.37	9
916	685	1501	762	237.5					7.58	12
916	663	1501	760	237					7.33	13
916	632	1501	758	237.5					6.98	16
916	603	1501	752	237					6.66	17
914	573	1499	748	236.5					6.34	20
915	543	1500	748	237.5					5.99	21 *TV/LE...
913	513	1500	740	237					5.67	24
909	479	1497	734	236					5.31	25
909	453	1501	738	238	1	+30			5.02	28
913	424	1500	728	236.5					4.67	29
913	390	1500	722	236					4.29	32
914	338	1500	714	235.5					3.70	33 +BB
914	295	1500	702	235	1	+40			3.22	36


16 fps 1500 RPM J = .51
10 kHz high pass filter
8.37
10 db
0 db
10
20
30
40
50 kHz
461510


K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM
KEUFFEL & ESSER CO. MADE IN USA
461510
16 fps 1500 RPM J ÷ .51
10 kHz high pass filter
7.58
0 db
10
20
30
40
50 kHz



K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO MADE IN U.S.A.
461510


16 fps 1500 RPM J = .51
10 kHz high pass filter
6.66
0 db
10
20
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50 kHz
461510
K&E 10 X 10 TO THE CENTIMETER 18 X 25 CM
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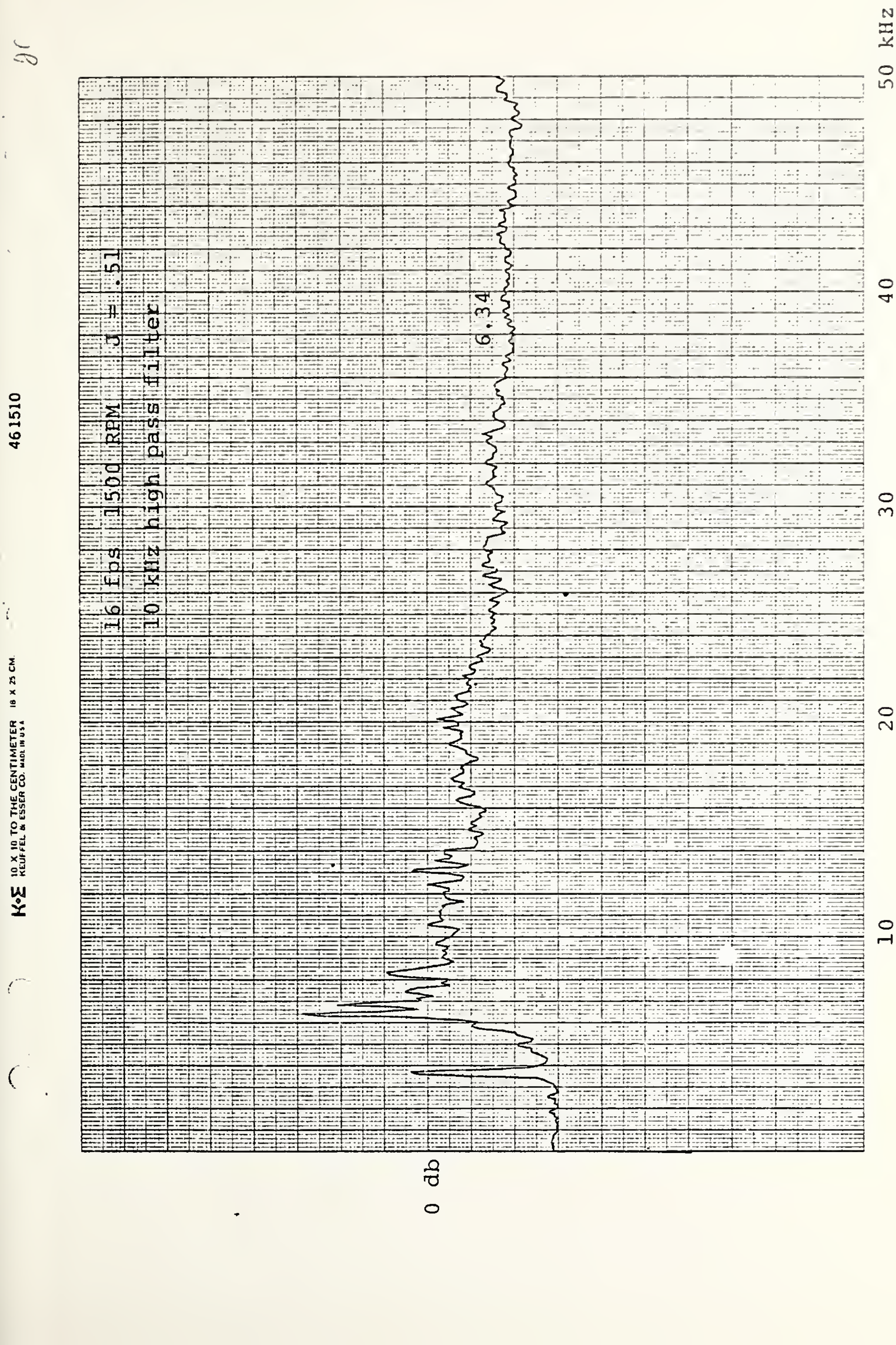
17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10 kHz high pass filter
6.34
0 db
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20
30
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50 kHz
461510
K·E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
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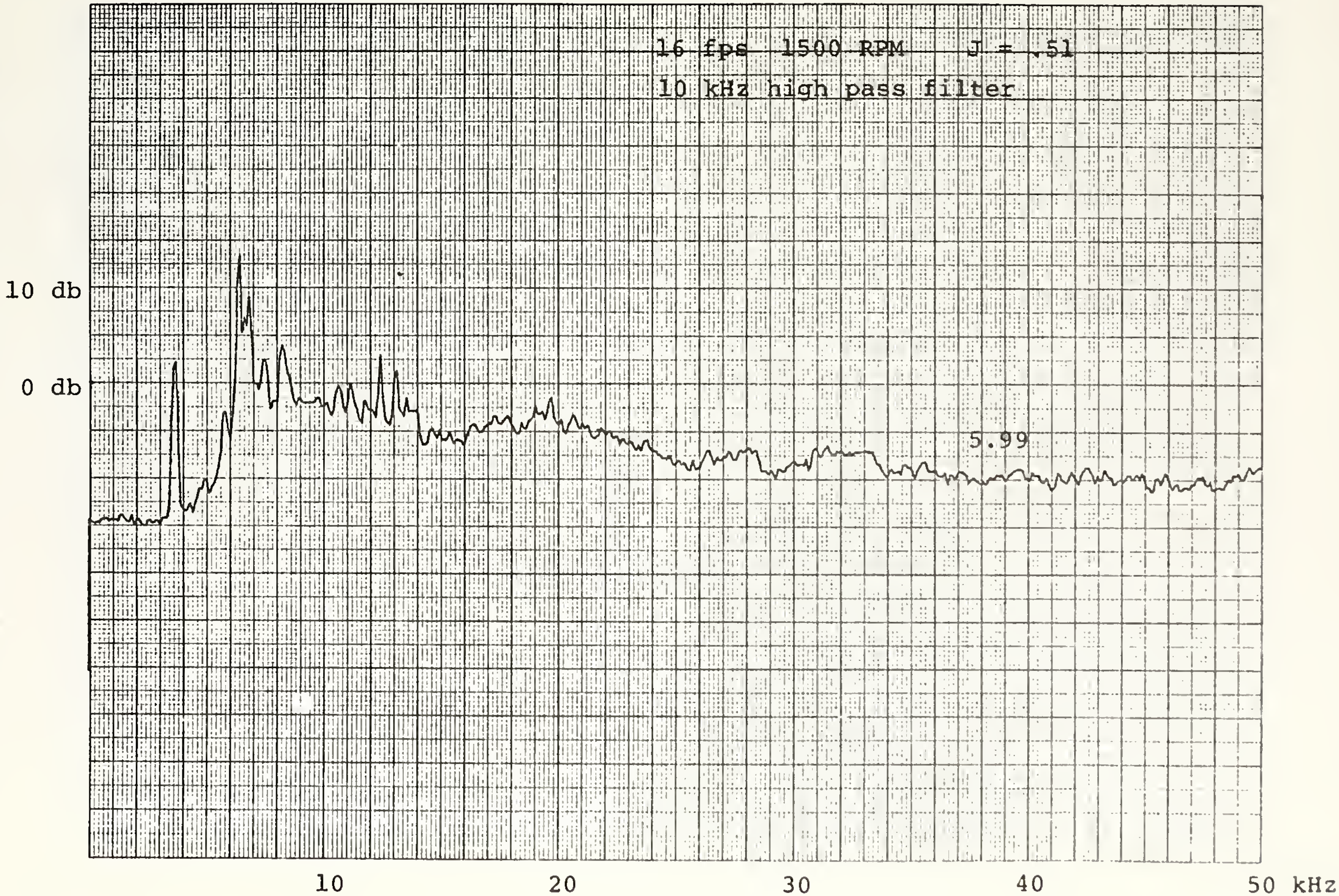
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10 kHz high pass filter
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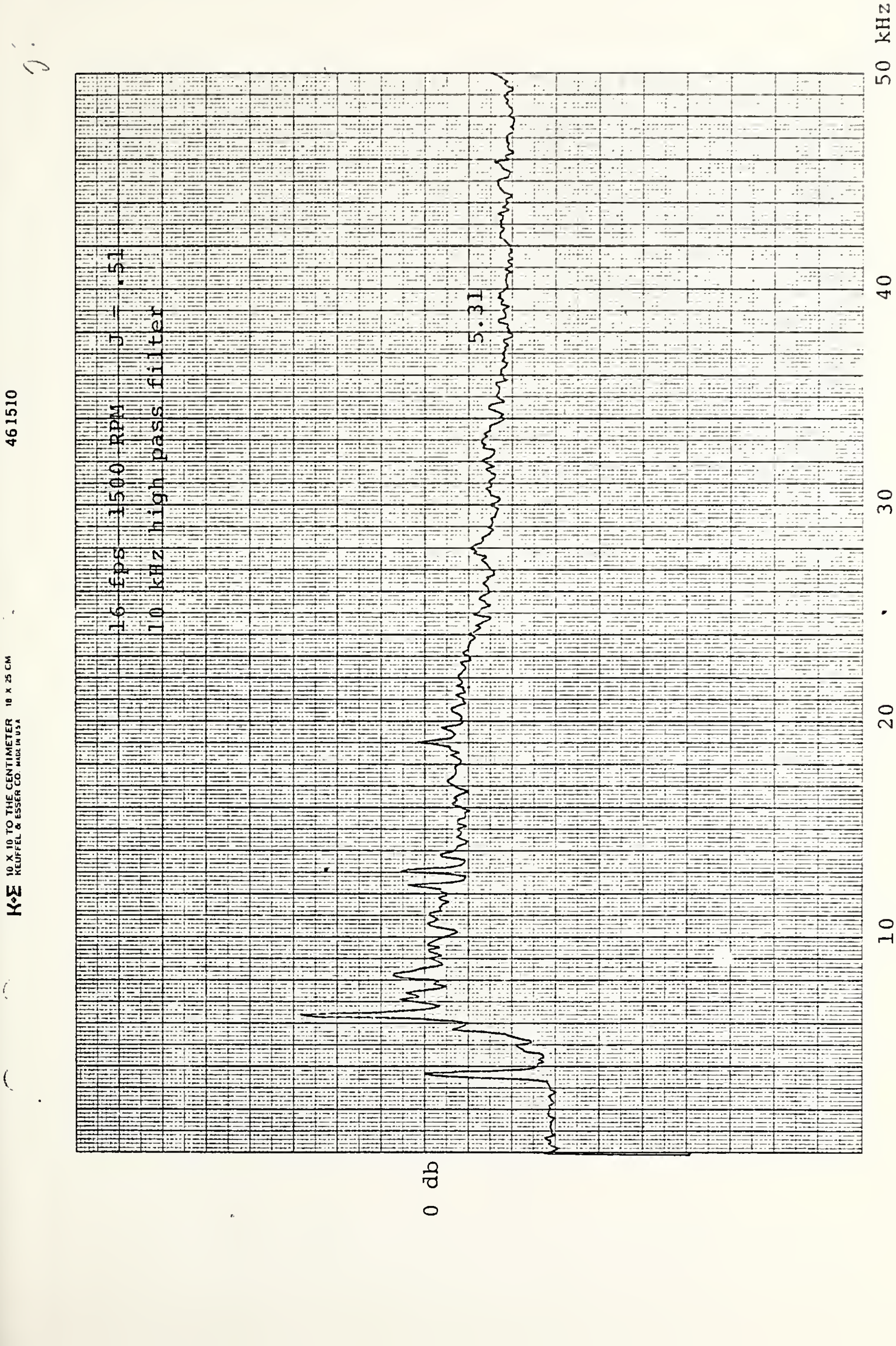
16 fps 1500 RPM J = .51
10 kHz high pass filter
5.31
0 db
10
20
30
40
50 kHz
461510
K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM
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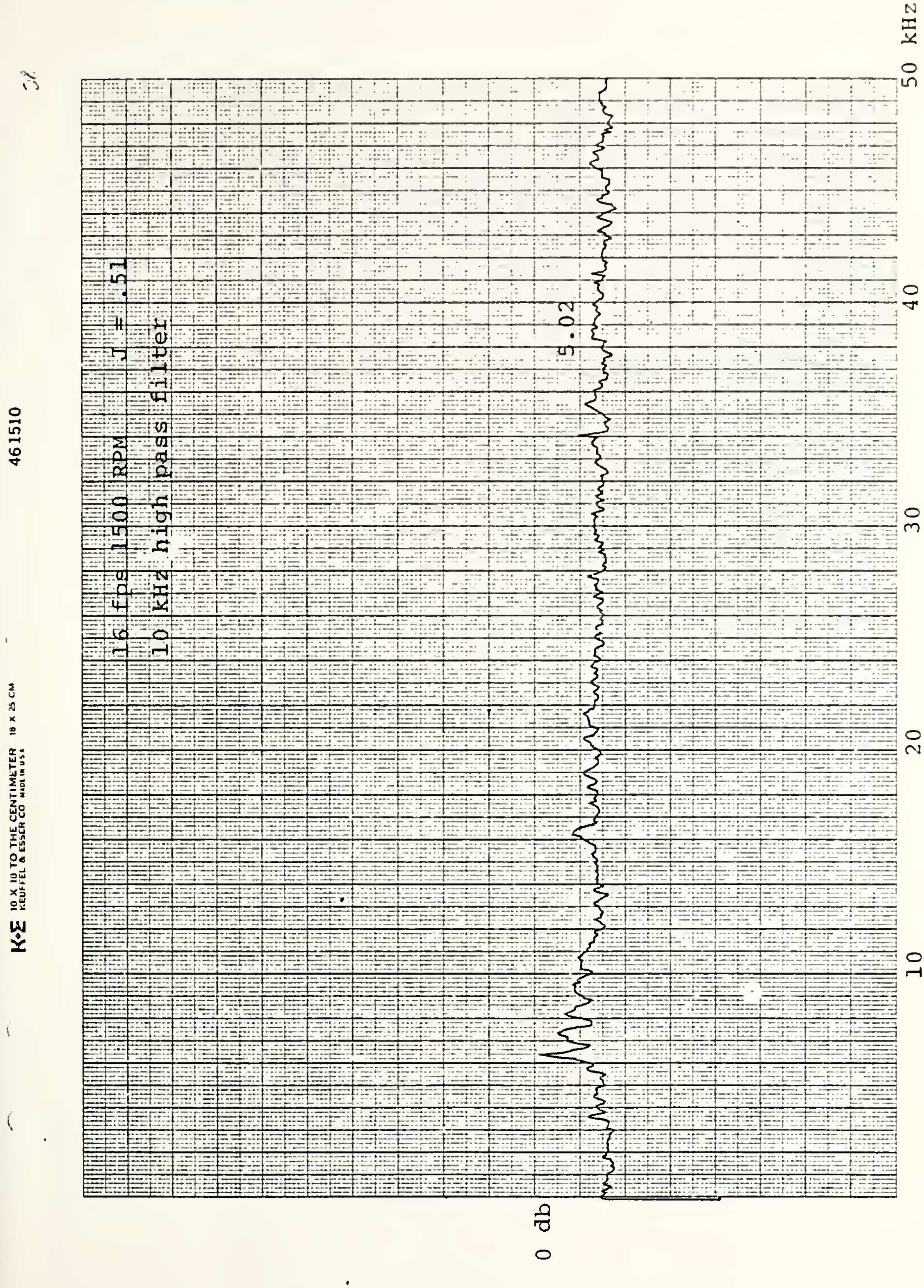

16 fps 1500 RPM J = .51
10 kHz high pass filter
5.02
0 db
10
20
30
40
50 kHz
461510
K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM
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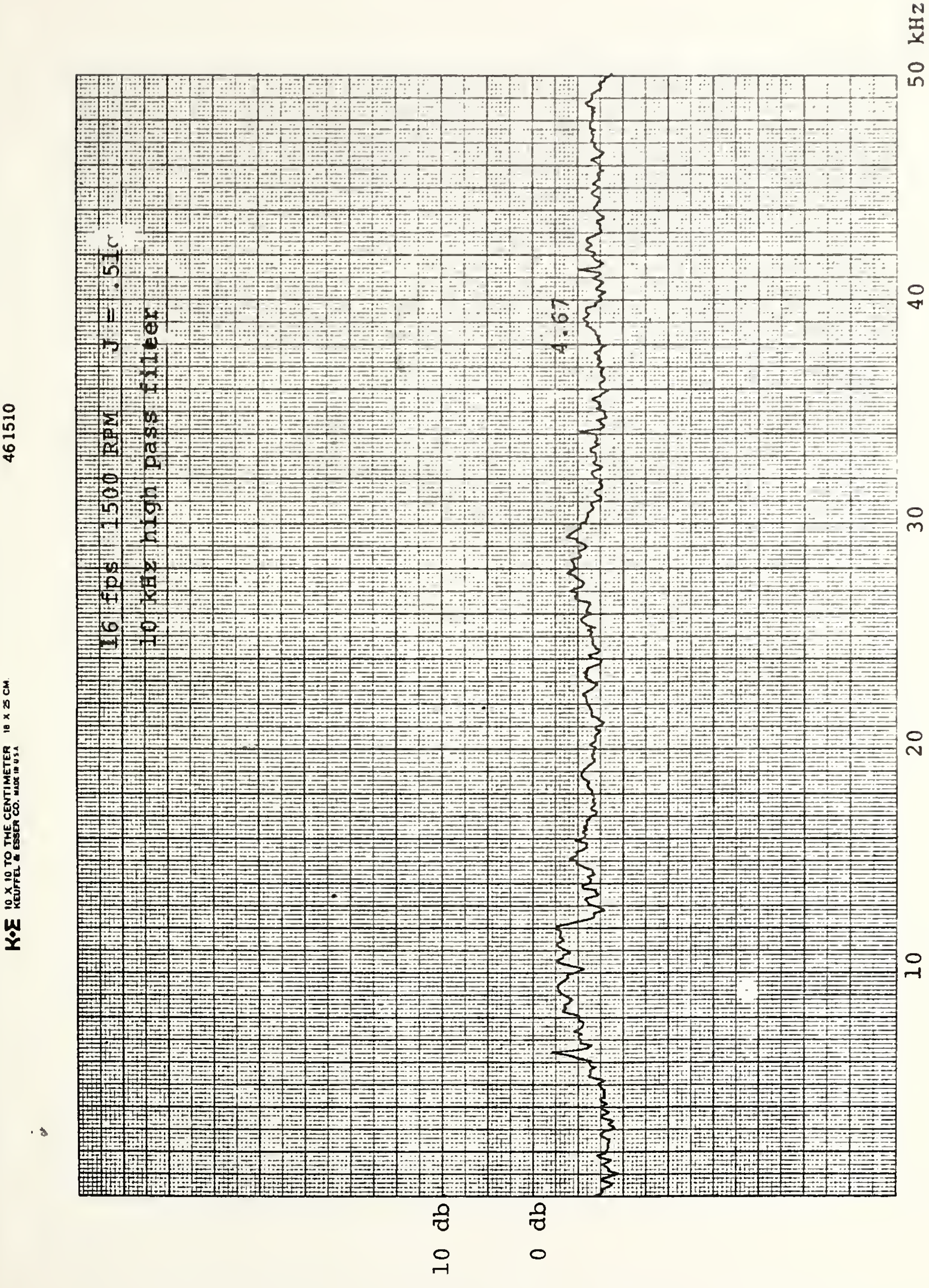
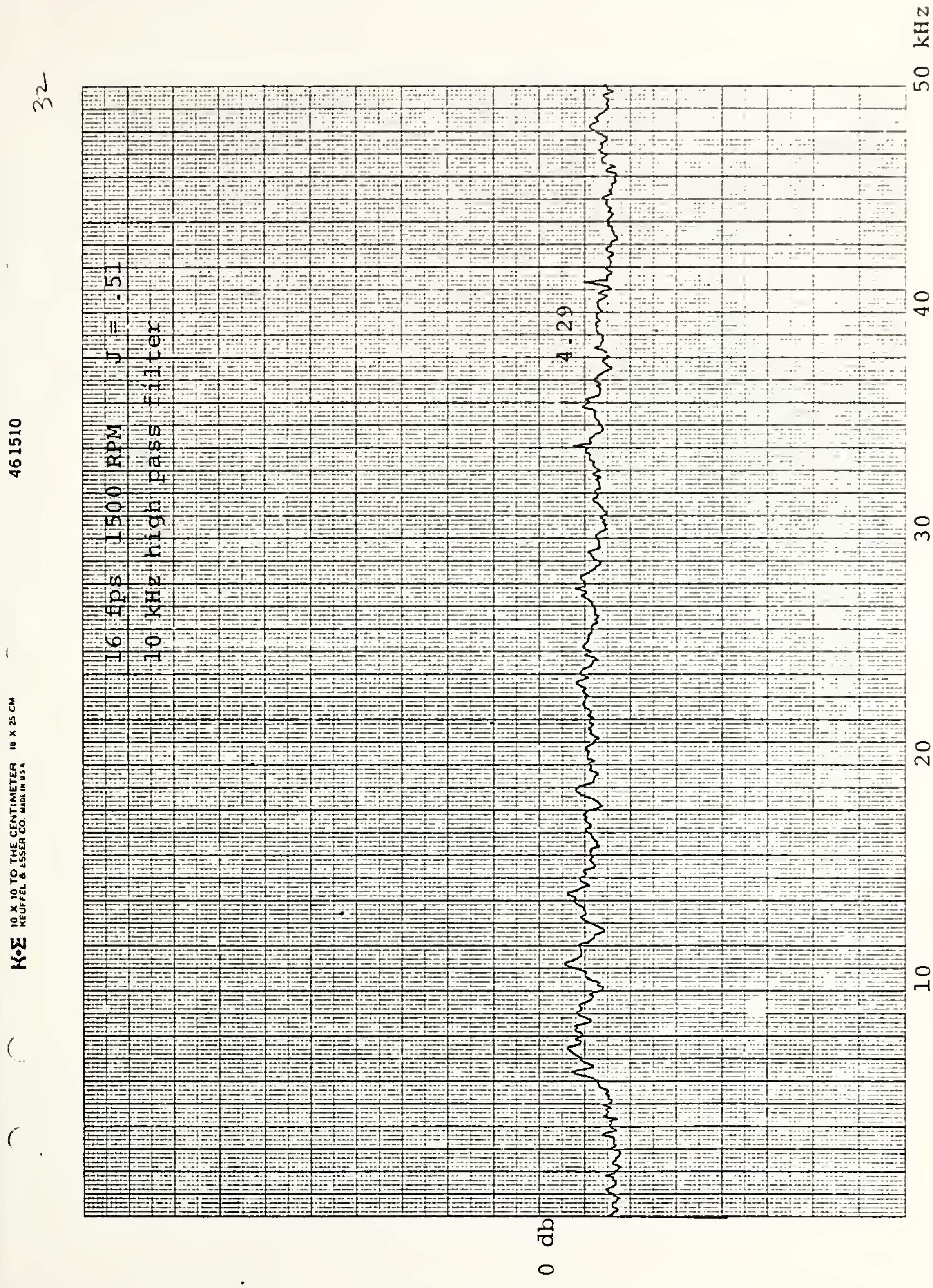

K•E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.
461510
16 fps 1500 RPM J = .51
10 kHz high pass filter
4.67
10 db
0 db
10
20
30
40
50 kHz


16 fps 1500 RPM J = .51
10 kHz high pass filter
4.29
0 db
10
20
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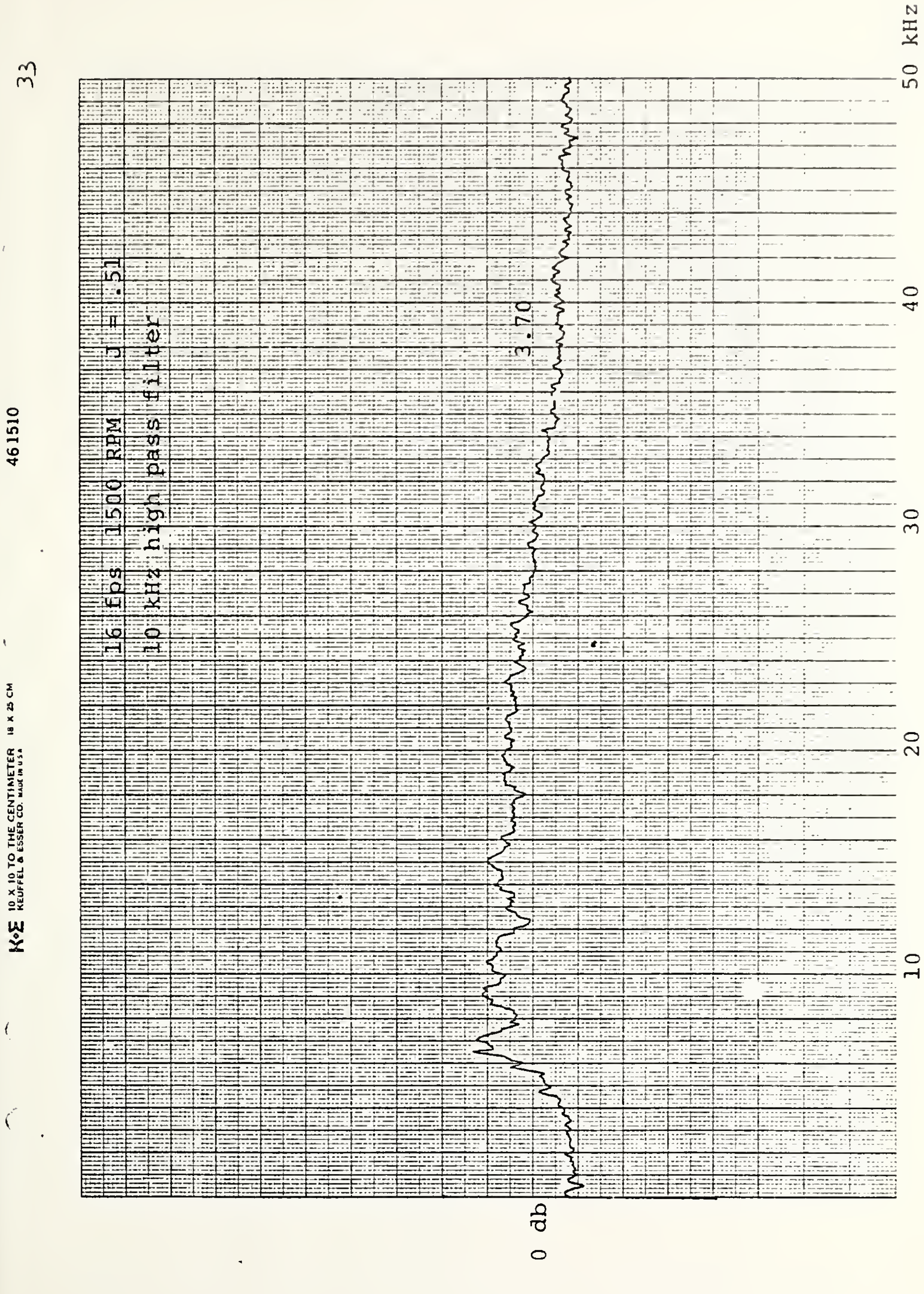
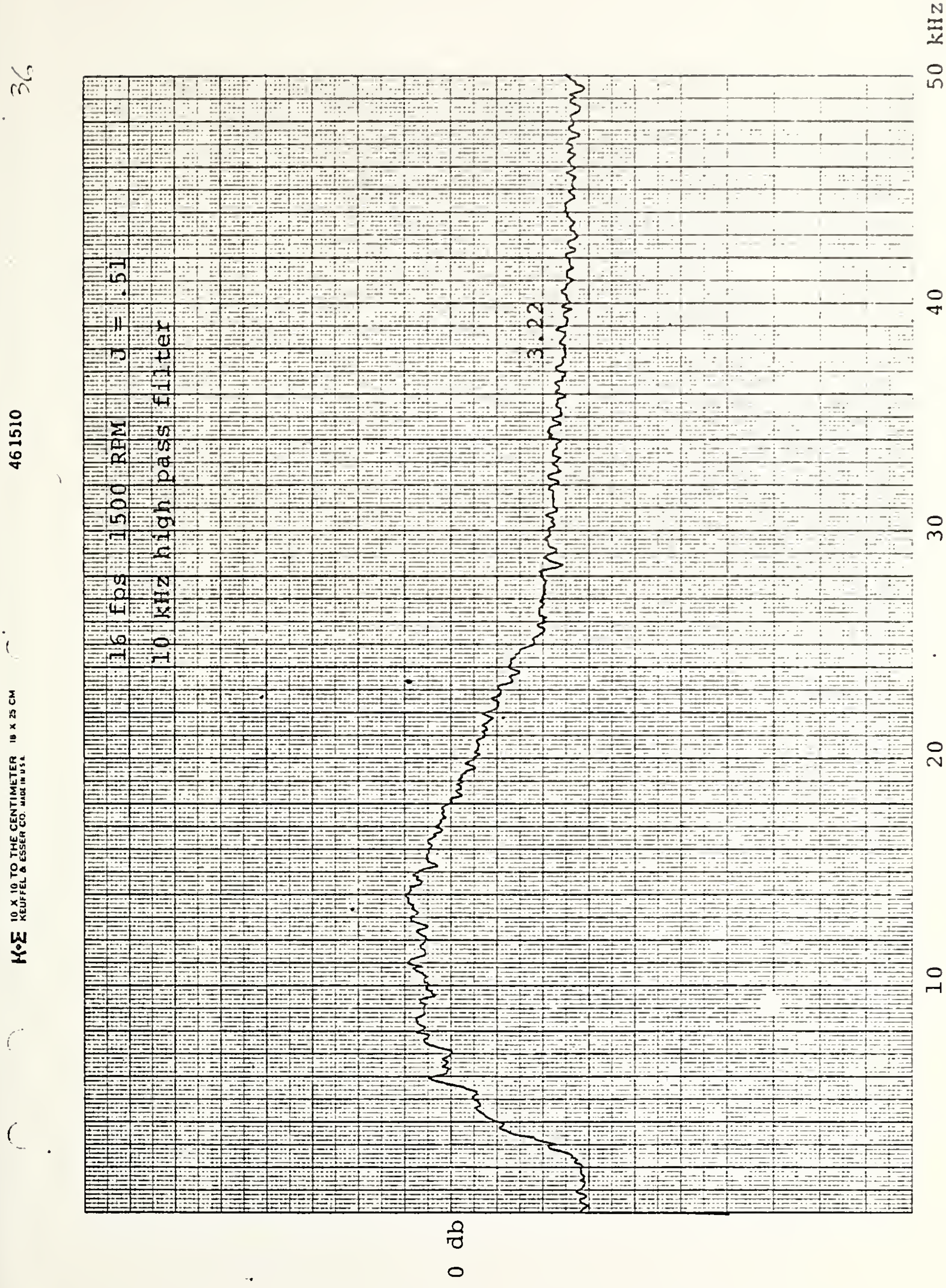
40
50 kHz
461510
K•E 10 X 10 TO THE CENTIMETER 18 X 25 CM
KEUFFEL & ESSER CO. MADE IN USA


33
16 Eps 1500 RPM J = .51
10 kHz high pass filter
3.70
0 db
10
20
30
40
50 kHz
461510
K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM
KEUFFEL & ESSER CO. MADE IN U.S.A.


16 Eps 1500 RPM J = .51
10 kHz high pass filter
3.22
0 db
10
20
30
40
50 kHz
K•E 10 X 10 TO THE CENTIMETER 18 X 25 CM
KEUFFEL & ESSER CO. MADE IN U.S.A.
461510

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A comparison of acoustic and visual determination of cavitation inception on a model propeller.