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U.S. Naval Air Development Center

Johnsville, Pennsylvania

AERONAUTICAL COMPUTER LABORATORY

NADC-AC-6411 **10 NOVEMBER 1964**

TECHNICAL REPORT

ANALOG POWER SPECTRAL DENSITY ANALYSIS OF ELECTRORETINOGRAM DATA

WEPTASK RAE13C005/2001/R005-0101

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A technique for performing power spectral density analyses on physiological data is presented in this report. Electroretinograms were made and recorded on magnetic tape at the Air Crew Equipment Laboratory. Analog techniques were employed to analyze the electroretinogram data at the Naval Air Development Center.

Prepared by: A. Futterweit
A. FUTTERWEIT

J. G. Dahms
J. G. DAHMS

Approved by: H G Tremblay
H. G. TREMBLAY
Director

INTRODUCTION

The possible toxic effect of a 100 percent oxygen atmosphere at ambient pressures less than that at sea level is of concern in connection with the manned space flight program. It has been planned to maintain the internal pressure of the Gemini capsule at 258 millimeters of mercury with a 100 percent oxygen atmosphere. This plan was made on the assumption that at this pressure the pure oxygen environment would have no significant toxic effects.

The National Aeronautics and Space Administration (NASA) supported an experiment conducted at the Air Crew Equipment Laboratory (ACEL) in which the effects of several oxygen pressures on various visual functions were examined. As part of this experiment, electroretinograms (ERG) were made in which the change in voltage between the corneal surface of the eye and a reference location on the head were measured continuously in response to visual stimulation by means of a contact lens electrode on the eye. The visual stimulation was provided by a regularly flashing light. These ERG's provide a means to measure visual deficit and could provide indications of changes in physiological functions which may underlie visual deficit.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDIXES

BACKGROUND

The Air Crew Equipment Laboratory (ACEL) has been conducting experiments to ascertain the physiological effects on human subjects of exposing them to a 100 percent oxygen atmosphere at various pressure altitudes for prolonged periods of time. As part of these experiments electroretinograms (ERG) were recorded on magnetic tape to be analyzed by the Aeronautical Computer Laboratory (ACL) at the Naval Air Development Center (NAVAIRDEVCEN). Subjects were placed in a 100 percent oxygen atmosphere at pressures equivalent to 18,000 and 27,000 feet altitude for 72 hours, a series of ERG's being recorded at 6, 24, 48, and 72 hours. They were placed in a 100 percent oxygen atmosphere at sea level pressure for 24 hours, a series of ERG's being recorded at 6, 15, and 24 hours. Initially and between each change of pressure, a series of baseline ERG's were recorded under normal atmospheric conditions of air and sea level pressure. Two types of ERG runs were recorded: one with a red light flashing in the subject's eye every second for 2 minutes and one with a blue light flashing every second for 1 minute. A series of runs consisted of three red-light runs, followed by four blue, and then a fourth red.

SCOPE

The ERG records generated during the ACEL experiment were processed by the ACL by various methods to determine whether significant changes occurred in the signal as a function of the controlled parameters. This report addresses itself specifically to the analog power spectral density analysis of these records, and refers to the digital spectral analysis of the same data for method validation. The method of digital analysis was the same as that described in reference (a).

The analog power spectral density analysis of the ERG records was implemented in two stages:

a. transcription of original tape record to magnetic tape loops, each containing data for a single red or blue run,

b. analysis of this loop data through an analog power spectral density analyzer with automatic plotting of power spectral density curves.

Only third red and third blue runs were analyzed. Appendix A lists all experimental runs made and indicates which runs were analyzed.

METHOD

To produce a plot of power spectral density versus frequency over a spectral band of interest for a finite length data signal, the data is impressed on a series of spectral apertures of a width determined by the required frequency resolution, and the transmitted power is measured for each aperture. To preclude the necessity of using multiple apertures, a single fixed spectral aperture is used and successive spectral increments of the data are translated to the fixed aperture frequency, and the power contained in those increments is measured. In practice the frequency translation is slowly and continuously swept over the frequency band of interest at a rate commensurate with the chosen aperture width, to provide spectral sampling of the data at all frequencies of interest.

The technique employed for the analog power spectral density analysis is illustrated in the block diagram in figure 1. The data signal, f(t), is passed through a high-pass filter to remove d.c. offset and is then impressed on two linear heterodyners where the signal component frequencies are translated along the spectrum by a frequency equal to the local sweep oscillator frequency, ω_o. Applying the Fourier postulate the data signal can be represented by a series in the frequency domain:

$$f(t) = A_1 \cos(\omega_1 t+\beta_1) + A_2 \cos(\omega_2 t+\beta_2)+....+ A_k \cos(\omega_k t+\beta_k)+...$$

$$= \sum_{k=1}^{n} A_k \cos(\omega_k t+\beta_k)$$

After heterodyning with the unity-amplitude in-quadrature sinusoids from the local oscillator, two functions, termed real, $f_r(t)$, and imaginary, $f_i(t)$ result:

$$f_r(t) = \cos \omega_o t \sum_{k=1}^{n} A_k \cos(\omega_k t+\beta_k)$$

$$= \sum_{k=1}^{n} \frac{A_k}{2} \cos[(\omega_k-\omega_o)t+\beta_k] + \cos[(\omega_k+\omega_o)t+\beta_k]$$

$$f_i(t) = \sin \omega_o t \sum_{k=1}^{n} A_k \cos(\omega_k t+\beta_k)$$

$$= \sum_{k=1}^{n} \frac{A_k}{2} \sin[(\omega_k-\omega_o)t+\beta_k] -\sin[(\omega_k+\omega_o)t+\beta_k]$$

From the above equations it can be seen that in each path, real and imaginary, each Fourier frequency component, ω_k, present in the input signal, f(t) has been transformed into two new frequency components, $\omega_k-\omega_o$ and $\omega_k+\omega_o$, representing the sum and difference frequencies of the original frequency component and the local oscillator frequency.

The heterodyned signal is applied to the narrow-bandwidth, sharp-cutoff, low-pass filters which transmit only those difference components in the translated signals which are of low enough frequency to pass through the filter. This low-pass filter is selectively transmitting those Fourier signal components from the original input signal, that lie within a spectral aperture centered at ω_o and having a width equal to twice the low-pass filter bandpass. The outputs from the two low-pass filters, $f_r'(t)$ and $f_i'(t)$ can be expressed by the approximations:

$$f_r'(t) \approx \sum_k \frac{A_k}{2} \cos\left[(\omega_k-\omega_o)t+\beta_k\right], \text{ for all values of k where:}$$

$$\omega_o - \frac{0.490}{\tau_2} < \omega_k < \omega_o + \frac{0.490}{\tau_2}$$

$$f_i'(t) \approx \sum_k \frac{A_k}{2} \sin\left[(\omega_k-\omega_o)t+\beta_k\right], \text{ for all values of k where:}$$

$$\omega_o - \frac{0.490}{\tau_2} < \omega_k < \omega_o + \frac{0.490}{\tau_2}$$

The coefficient 0.490 and τ_2 are derived from the selected low-pass filter design, as explained later in the text.

By squaring and adding the real and imaginary filtered signal paths, the quadrature sinusoidal components of the resulting signals are eliminated, leaving only the summation of the square of amplitude components falling within the spectral window, the instantaneous power spectral density, PSD (t,ω_o).

$$PSD(t,\omega_o) \approx [f_r'(t)]^2 + [f_i'(t)]^2$$

$$\sum_k \frac{A_k^2}{4}, \text{ for all values of k where:}$$

$$\omega_o - \frac{0.490}{\tau_2} < \omega_k < \omega_o + \frac{0.490}{\tau_2}$$

To remove the time variable from the power spectral density analysis the instantaneous power spectral density, PSD(t,ω_o) is averaged over several data sample time periods, and the logarithm of the final power spectral density output, PSD(ω_o), is plotted against local oscillator frequency, ω_o.

Spectral window width (controlled by τ_2), sweep rate ($\dot{\omega}_o$), output averaging filter (determined by τ_3), and input high-pass filter roll-off (determined by τ_1) are interrelated parameters, and each must be carefully chosen as a function of basic data and analysis parameters. The desired spectral resolution determines the design and bandwidth of the filter used as the spectral window. For this analysis a straightforward compound lag filter of four stages was selected. The relationship between and the calculation of corner frequency and spectral window width, are discussed in appendix B. The sweep rate, $\dot{\omega}_o$, must be slow enough to permit the spectral filter to operate on an adequate data sample at each spectral segment. In order to smooth data irregularities during a run, the complete data loop should pass through the filter several times while the spectral window is swept through an increment equal to its width. The output averaging filter time constant is selected to compute the average spectral power over the complete data loop.

The time required for this analysis is reduced by employing a time compression technique. This technique involves processing data at a faster rate than real time. All functions having time relationships, such as sweep rates and filter widths were time-scaled appropriately for analyzer operation. In listing the results and labeling the final curves, however, real time equivalents have been employed.

IMPLEMENTATION

Preparation of Loop Data. The original raw data was recorded on 1/2-inch, 7-track magnetic tape at a tape speed of 3.75 inches per second. Tracks 1, 2, and 4 contain photocell pulses, compensation, and ERG's respectively, recorded in wide-band FM at a center frequency of 3.375KC. Track 7 contains voice cues recorded in AM, and tracks 3, 5, and 6 are blank.

The raw data was transcribed from the 1/2-inch original tape to 1-inch analog tape loops. The 1/2-inch transport operated at 7.5 inches per second, and the 1-inch transport operated at 1.875 inches per second. The ERG signal was recorded on track 4 and a ground signal for compensation on track 6, both on wide-band FM at a center frequency of 1.6875KC. An AM recording of a 400 cps signal was made on channel 14. All other channels were blank.

Loops were transcribed containing run data only, with a negligible blank portion of tape between the end and the beginning of a data run. The technique used to transcribe such loops was to connect the signals to be transcribed on the normally open poles of a relay, a ground signal on the normally closed, with the arm connection routed to the record amplifiers of the loop tape transport, and to perform the following operation:

a. start the 1/2-inch original tape transport,

b. just before the desired run, start the loop transport and close the relay,

c. release the relay a second or two before end of run,

d. stop the loop transport soon after relay release.

The resulting loop can be cut and respliced to exclude any transients due to tape transport starting and stopping and to relay closure and release.

The tape loops were reproduced for input to the analyzer at 15 inches per second (13.5KC FM demodulation center frequency) when a 16:1 time compression was required, and at 1.875 inches per second (1.6875KC FM demodulation center frequency) when a 2:1 time compression was required. As the initial data was recorded at 3.75 inches per second and reproduced at twice that speed (7.5 inches per second) during the loop-making process, an initial time compression of 2:1 was obtained. By reproducing the loops at eight times loop recording speed an additional time compression of 8:1 was obtained for a total compression of 16:1 between original recording and analysis. It should be noted that time compression increases all data frequency components by the compression ratio with no change in the amplitude.

Analog Design. The total analog program is represented in figures 2 and 3. The voltage-controlled local oscillator which provides the in-quadrature, unity-amplitude sinusoids is diagrammed in figure 2. The two integrators 4 and 5 in conjunction with inverter 10 provide the basic oscillating loop. Multipliers 1 and 2 each represent a variable coefficient proportional to ω_0, controlled by the other inputs to the multipliers. The frequency ω_0 is swept over the desired range by integrator 1 which drives the frequency-control multipliers. The remaining circuitry provides automatic amplitude and quadrature control to the oscillator.

Figure 3 illustrates the main analyzer program. Amplifier A1 is the input high-pass filter; multipliers 5 and 6 perform the linear heterodyning; amplifiers A5 through A12 are the two low-pass spectral filters; and the remaining circuitry performs the squaring, summing, filtering, and log conversion required in the power spectral density calculation. Analyzer calibration is controlled by ganged potentiometer X1. Passive component values shown are for the analysis over the band of real time data frequencies from 0.7 cps to 10 cps.

Selection of Dynamic Coefficients. The sweep oscillator and heterodyning multipliers were designed to operate over a band of frequencies between 10 cps and 200 cps. The data to be analyzed was brought within this range by the time compression technique. Frequencies of interest between 0.7 cps and 10 cps were shifted by a 16:1 factor to a band between 11.2 cps to 160 cps, and frequencies of interest between 5 cps and 50 cps were shifted by a 2:1 factor to a band between 10 cps and 100 cps.

The spectral window width was empirically selected after a series of preliminary runs, on the basis of combining a reasonable maximum sweep rate with good peak-to-valley resolution of the resulting spectral signatures. To make this selection, data samples were analyzed using a series of sequentially narrower apertures combined with commensurate slower frequency sweep rates until no noticeable improvements in the spectral signatures could be observed. The usable data loop length varied between 45 and 120 real-time seconds. The sweep rate was designed to allow a minimum of 1.5 loop lengths of data to be analyzed for a sweep frequency change equal to the spectral window width in the 0.7 cps to 10 cps band and 0.5 loop length in the 5 cps to 50 cps band. The following table lists all pertinent analog program parameters used in the two-part analysis.

	ANALYZER	REAL TIME	ANALYZER	REAL TIME
Spectral Band	11 - 160 cps	0.7 - 10 cps	10 - 100 cps	5 - 50 cps
Spectral Filter Width	-	0.066 cps	-	0.066 cps
τ_1	1.0 sec	16 sec	2.5 sec	5 sec
τ_2	0.15 sec	2.4 sec	1.2 sec	2.4 sec
τ_3	10 sec	160 sec	20 sec	40 sec
Time Scale	16 X	1	2 X	1
Loop Time	3-8 sec	45-120 sec	22-60 sec	45-120 sec
Sweep Rate	0.1 cps/s	0.0004 cps/s	0.25 cps/s	0.065 cps/s

<u>Bookkeeping</u>. Each data run was identified by a 10-digit run number coded according to specifications listed below beginning with the high-order digit. Because these numbers were also used on digital tape for runs that were digitized, the numbers on the analog records were preceded by the letter A. Runs that were repeated for different settings of the analog analyzer carried an eleventh digit starting with 2 for the first repeat and advancing sequentially for subsequent repeats.

DIGIT	SIGNIFICANCE			
1, 2, 3	ACL Problem No. (412)			
4, 5	Human Subject			
	01 - Hreno			
	02 - Parris			
	03 -			
	04 -			
	05 - Mlynek			
	06 - Christoph			
	07 - Conser			
	08 -			
6	Photocell			
	1	1st Red	5	1st Blue
	2	2nd Red	6	2nd Blue
	3	3rd Red	7	3rd Blue
	4	4th Red	8	4th Blue
7	Pressure and O_2 Content of Atmosphere			
	1.	27,000 ft 100% O_2	4.	Baseline #3
	2.	Baseline #2	5.	Sea Level 100% O_2
	3.	18,000 ft 100% O_2	6.	Baseline #4

DIGIT	SIGNIFICANCE
8	Time of Exposure
	0. Baseline
	1. 6 hours
	2. 24 hours
	3. 48 hours
	4. 72 hours
9 and 10	Run sequence in analyzer

The primary data tapes and the intermediate tape loops are stored in the analog tape storage cabinet.

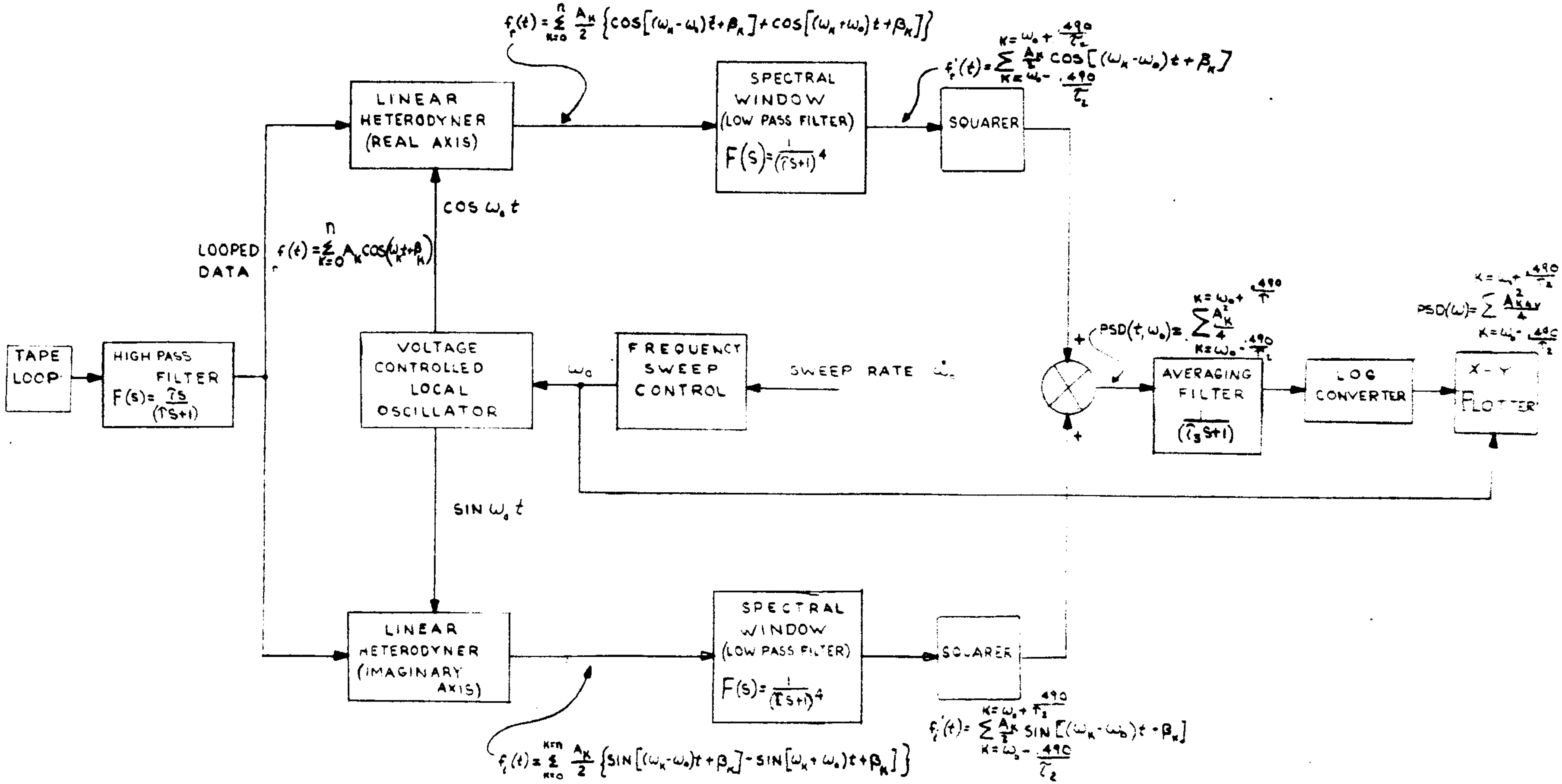
RESULTS

Appendix A catalogs which of the original recorded runs were analyzed for each frequency band of analysis. A resulting power spectral density plot for each analyzed run is contained in appendix C. Appendix C also contains a number of power spectral density plots obtained by digital computation, and these are included to demonstrate the close comparison between solutions obtained using analog and digital methods. A further test of the validity of the analog method was made by subjecting a pulse wave of known spectral content to the analysis.

It is not the intent of this report to analyze spectral signatures or physical significance but only to document the method of analysis. The consistency of results obtained, and the close correlations of results with the more complex digital analysis demonstrates the versatility, accuracy, and dynamic range of this method of analog spectral density analysis.

REFERENCES

(a) Tremblay, H.G., J.L. Brown, and A. Futterweit, "Application of Harmonic Analysis in a Study of Tracking Performance in the TV-2 Aircraft and in Centrifuge and Stationary Simulations of that Aircraft," NADC Rpt. NADC-AC-6406, 30 April 1964



FUNCTIONAL
BLOCK DIAGRAM

FIG. 1

VP 9/18/64

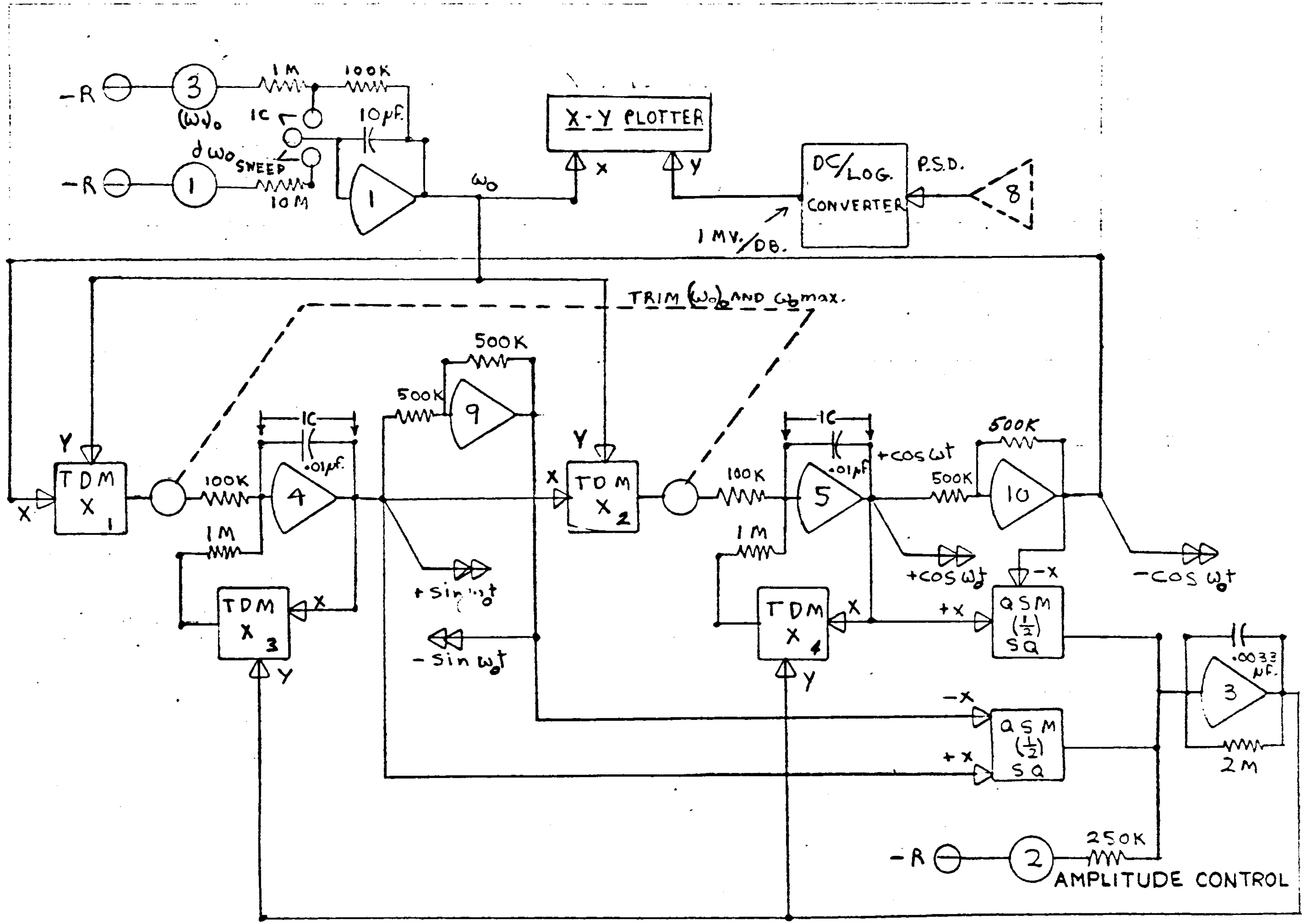


Fig.2

LOCAL OSCILLATOR FOR SPECTRAL ANALYZE

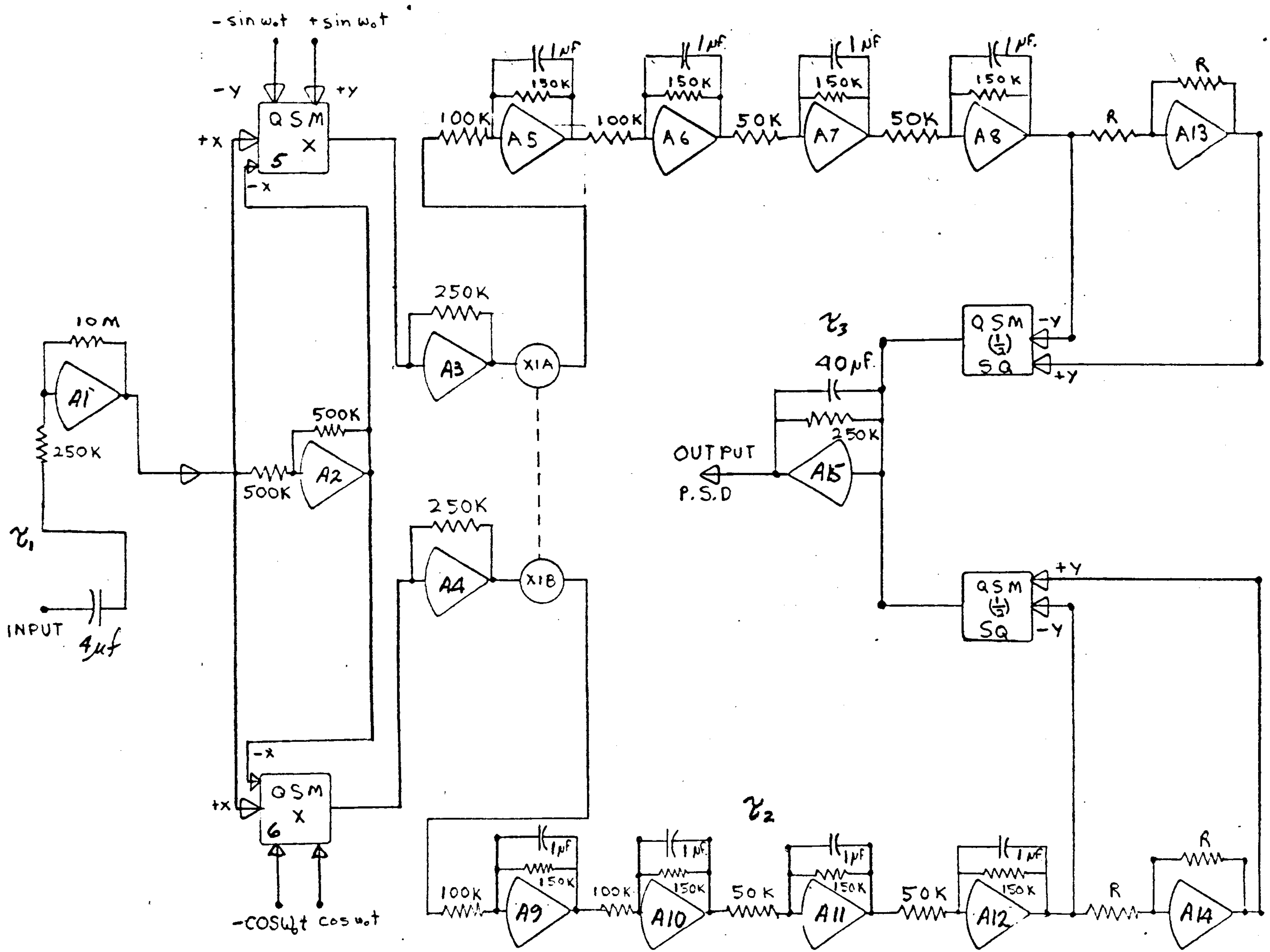


FIG. 3

SPECTRAL ANALYZER FILTER

APPENDIX A
ERG RUN SUMMARY

	Base Line #1	27,000' 24 hours	27,000' 48 hours	27,000' 72 hours	Base Line #2	18,000' 6 hours	18,000' 24 hours	18,000' 48 hours	18,000' 72 hours	Base Line #3	Sea Level 6 hours	Sea Level 15 hours	Sea Level 24 hours	Base Line #4	27,000' 6 hours	27,000' 24 hours	27,000' 48 hours	27,000' 72 hours
1. Hreno	Tapes 1,2,3	Tape 4	Tape 4	Tape 4										Tape 11	Tape 11	Tape 11		
2. Parris	Tapes 1,2,3	Tape 4	Tape 4	Tape 4	Tape 6	Tape 7	Tape 7	Tape 8	Tape 8	Tape 9	Tape 9	Tape 10	Tape 10	Tape 11	Tape 11			
3. Conser	Tapes 1,2	Tape 4	Tape 4	Tape 5	Tape 6 *	Tape 7	Tape 7	Tape 8	Tape 8 *	Tape 9 *	Tape 9	Tape 10	Tape 10 *	Tape 11	Tape 11	Tape 12	Tape 12	Tape 12 *
4. Rossi	Tapes 1,3																	
5. Hutchinson	Tapes 1,3					Tape 7	Tape 7	Tape 8	Tape 8	Tape 9	Tape 9	Tape 10						
6. Mylnek	Tapes 1,2,3	Tape 4	Tape 4	Tape 5	Tape 6 **/	Tape 7	Tape 7	Tape 8	Tape 8 **/	Tape 9 **	Tape 9	Tape 10	Tape 10 **/	Tape 11	Tape 11	Tape 12	Tape 12	Tape 12 **/
7. Calciotti	Tapes 2,3				Tape 6	Tape 7	Tape 7	Tape 8	Tape 8	Tape 9	Tape 9	Tape 10	Tape 10	Tape 11				
8. Lilley	Tapes 2,3																	
9. Christoph	Tapes 2,3	Tape 4	Tape 4	Tape 5	Tape 6 *	Tape 7	Tape 7	Tape 8	Tape 8 *	Tape 9 *	Tape 9	Tape 10	Tape 10 *	Tape 11	Tape 11	Tape 12	Tape 12	Tape 12 *
10. Kelley					Tape 6 (twice)													

1. Mylnek on tape for all 3rd Red and 3rd Blue except Base Line #1 and Sea Level, 15 hours.
2. Christoph on tape for all 3rd Red and 3rd Blue except Base Line #1 and Sea Level, 15 hours.
3. Conser on tape for all 3rd Red and 3rd Blue except Base Line #1 and Sea Level, 15 hours.

* Analog PSD's made for 3rd Red and 3rd Blue runs at 16:1 Time Compression for 0.7 to 10 cps band.

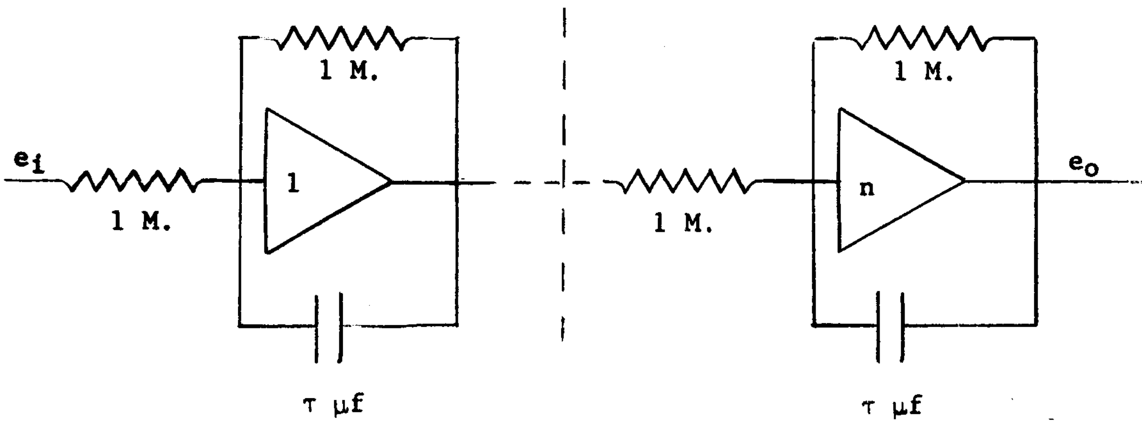
** Analog PSD's made for 3rd Red and 3rd Blue runs at 16:1 and 2:1 Time Compression for 0.7 to 10 cps band and for 5 to 50 cps band respectively.

/ Digital PSD made for 3rd Blue run.

APPENDIX B

CALCULATION OF POWER BANDWIDTH FOR A LOW PASS FILTER OF n SERIES-CONNECTED FIRST ORDER LAGS

1. It is required to design a low pass filter of n series connected equal first order lags, with the property that the total power transmission of input white noise be equal to the transmission of the same white noise through a hypothetical "perfect filter" (which allows non-attenuated power transmission of signals between zero cycles and frequency f_{BW}, and causes infinite attenuation of signals of frequency greater than f_{BW}). Figure 1 shows such a compound lag filter using analog computer techniques.

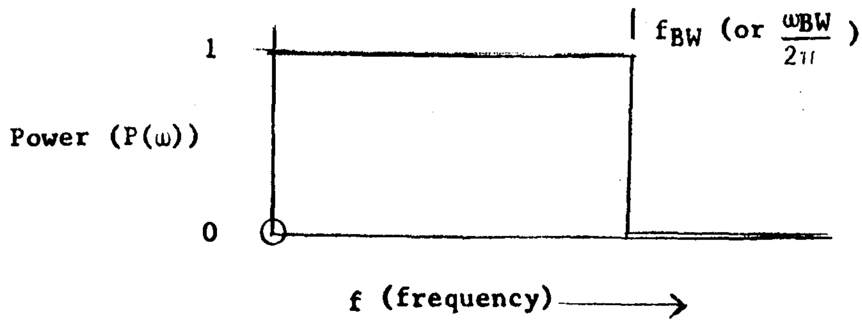


$$\frac{e_o}{e_i} = (-1)^n \quad \frac{1}{(\tau s+1)^n}$$

Figure 1

n Stage Lag Filter

2. The total power transmission of any filter is the integral of power transmission with respect to frequency from 0 to ∞ cps. The power transmission of white noise through a perfect filter is unity from 0 to $f = f_{BW}$ and then drops to 0 at values greater than f_{BW}.



The total power transmission is clearly f_{BW}. It is now necessary to determine $P(\omega)$ the power transmission function for the n^{th} order lag filter. We will then be able to let $\int_0^\infty P(\omega)d\omega = f_{BW}$ and arrive at a solution.

The amplitude/phase transmission of the n^{th} order low pass filter of series compounded first order lags is: (in Laplace notation)

$$A(\omega) = \frac{1}{(\tau s+1)^n}$$

where: τ is a filter constant in seconds

s is the Laplace operator

If the input signals are sinusoids this expression can be reduced to two non-complex expressions, one for amplitude gain and the other for phase shift.

$$\text{amplitude gain} = \frac{1}{(\tau^2\omega^2+1)^{n/2}}$$

$$\text{phase shift} = -n \text{ arc tan } \frac{1}{\tau\omega}$$

where ω is the sinusoid frequency in rad/sec.

3. Since power is proportional to amplitude squared we arrive at the power transmission function $P(\omega) = \dfrac{1}{(\tau^2\omega^2+1)^n}$

It is now only necessary to evaluate the integral $\int_0^\infty P(x)dx$ in order to obtain a value for the filter bandwidth. For the n stage filter recourse to the integral calculus shows us that:

$$\int_0^\infty \frac{dx}{(\tau^2x^2+1)^n} = \left[\left(\frac{2n-3}{2n-2}\right)\left(\frac{2n-5}{2n-4}\right)------\left(\frac{1}{2}\right)\right] \int \frac{dx}{\tau^2x^2+1}$$

$$= \left[\frac{(2n-2)!}{2^{n-1}(n-1)!\ 2^{n-1}(n-1)!} \right] \frac{\pi}{2\tau}$$

$$= \frac{\pi}{2} \frac{(2n-2)!}{2^{2n-1}[(n-1)!]^2\tau}$$

Evaluation of the resulting expression for some values of n are tabulated in the form $2\pi\ f_{BW}\tau$ versus n, for individual filters with unity DC gain.

n	1	2	3	4	5	6	10	100
$2\pi\ f_{BW}\tau$	1.57	0.785	0.589	0.490	0.429	0.386	0.292	0.089

where

n = number of compounded stages

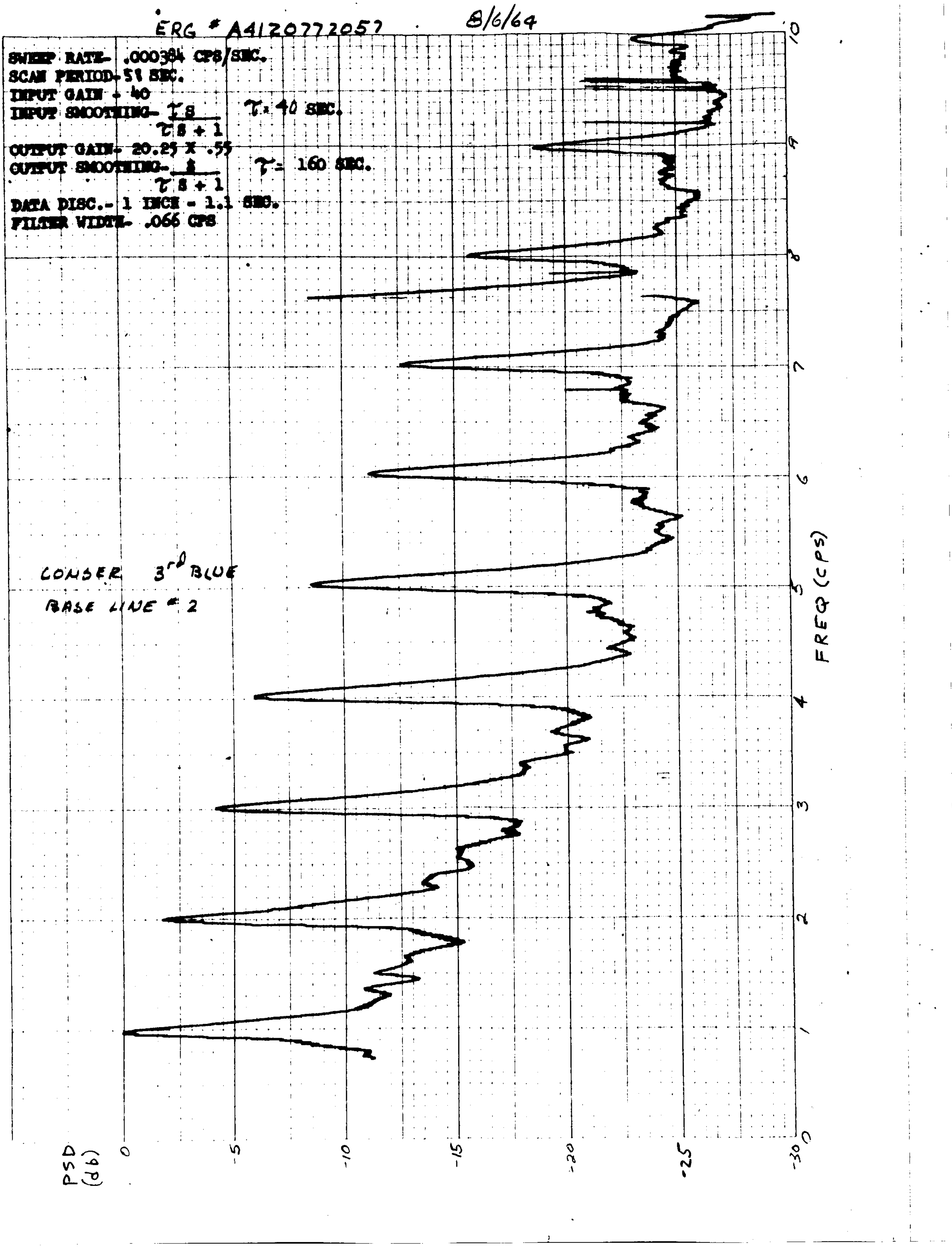
τ = single stage filter time constant in seconds

f_{BW} = bandwidth of perfect filter having equal total power transmission to white noise.

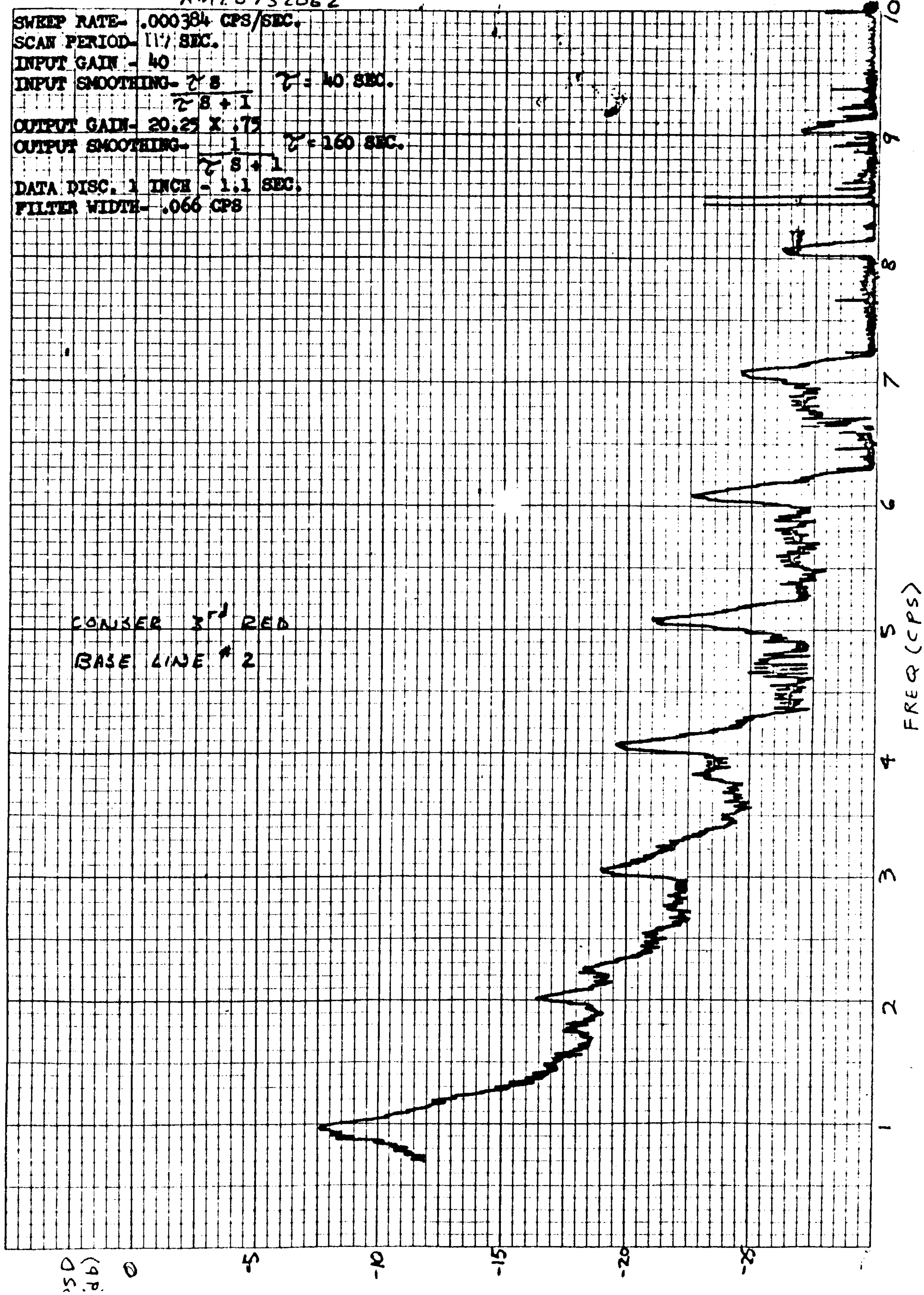
APPENDIX C

ANALOG AND DIGITAL POWER SPECTRAL DENSITY (PSD) PLOTS

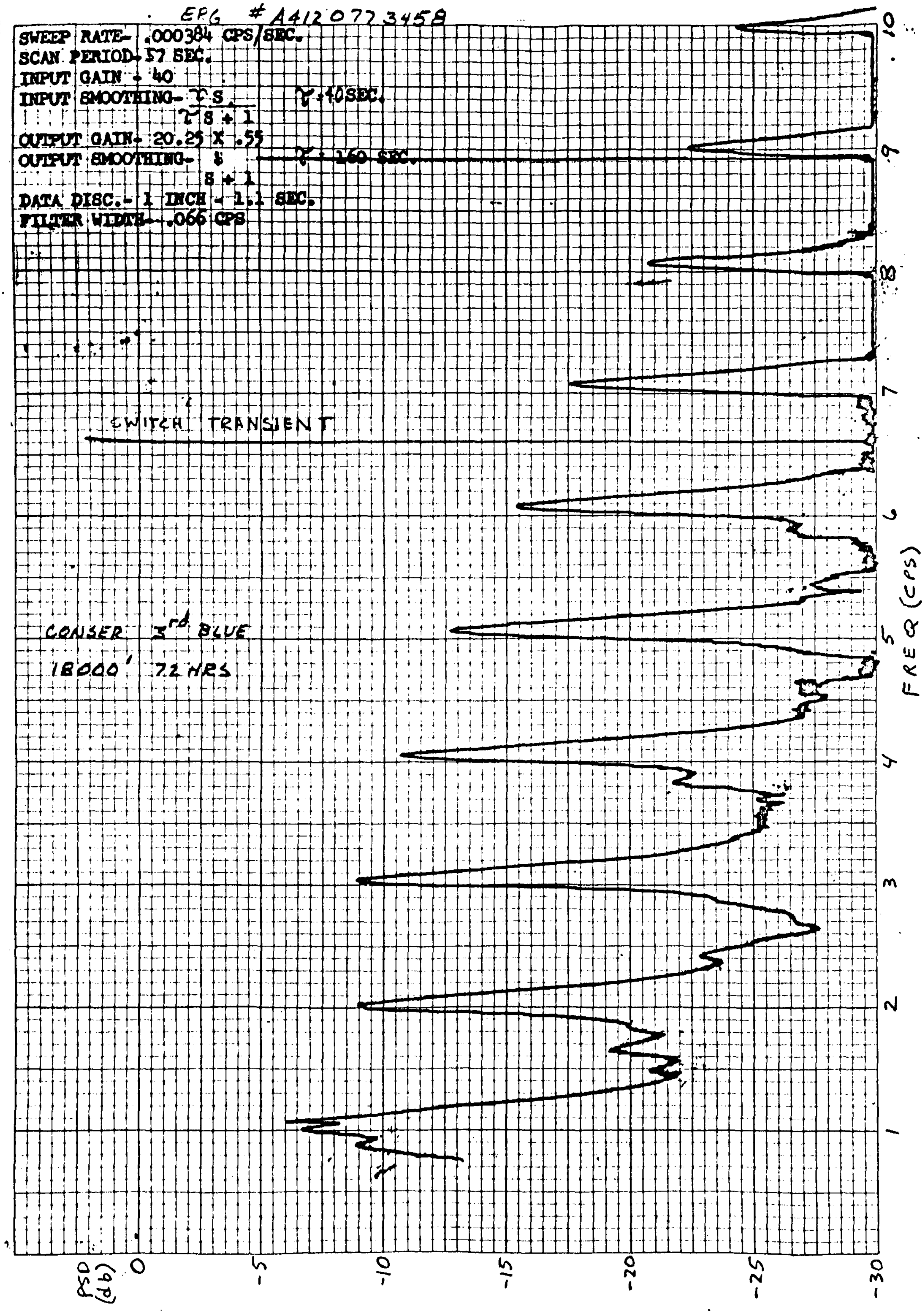
The electronretinogram run summary in appendix A indicates those runs for which there are plots in this appendix.


ERG # A4120772057
8/6/64
SWEEP RATE- .000384 CPS/SEC.
SCAN PERIOD- 5¼ SEC.
INPUT GAIN - 40
INPUT SMOOTHING- $\frac{\tau S}{\tau S + 1}$ τ = 40 SEC.
OUTPUT GAIN- 20.25 X .55
OUTPUT SMOOTHING- $\frac{S}{\tau S + 1}$ τ = 160 SEC.
DATA DISC.- 1 INCH = 1.1 SEC.
FILTER WIDTH- .066 CPS
CONSER 3rd BLUE
BASE LINE # 2
FREQ (CPS)
0
1
2
3
4
5
6
7
8
9
10
PSD (db)
0
-5
-10
-15
-20
-25
-30

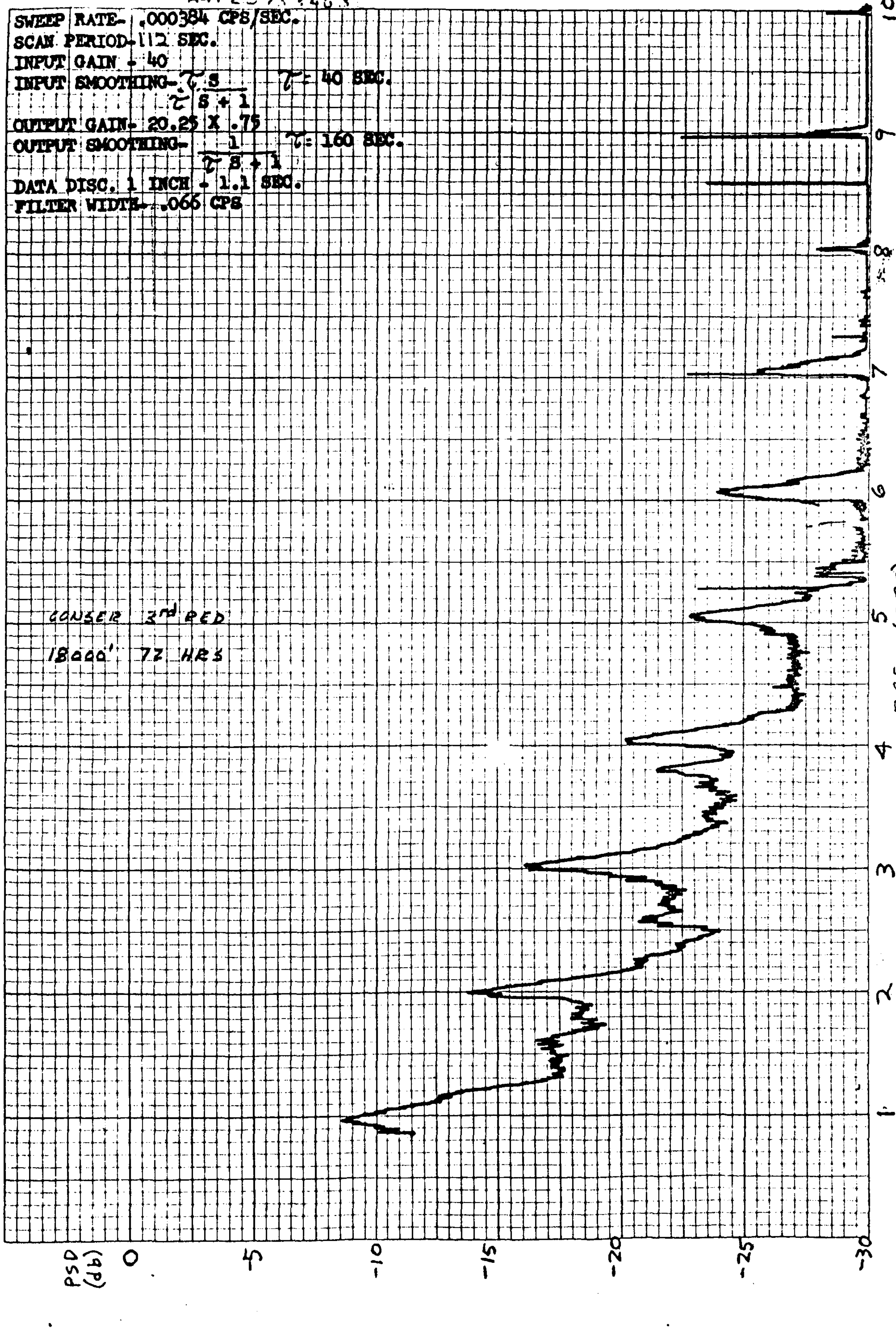
A4120732062



C3

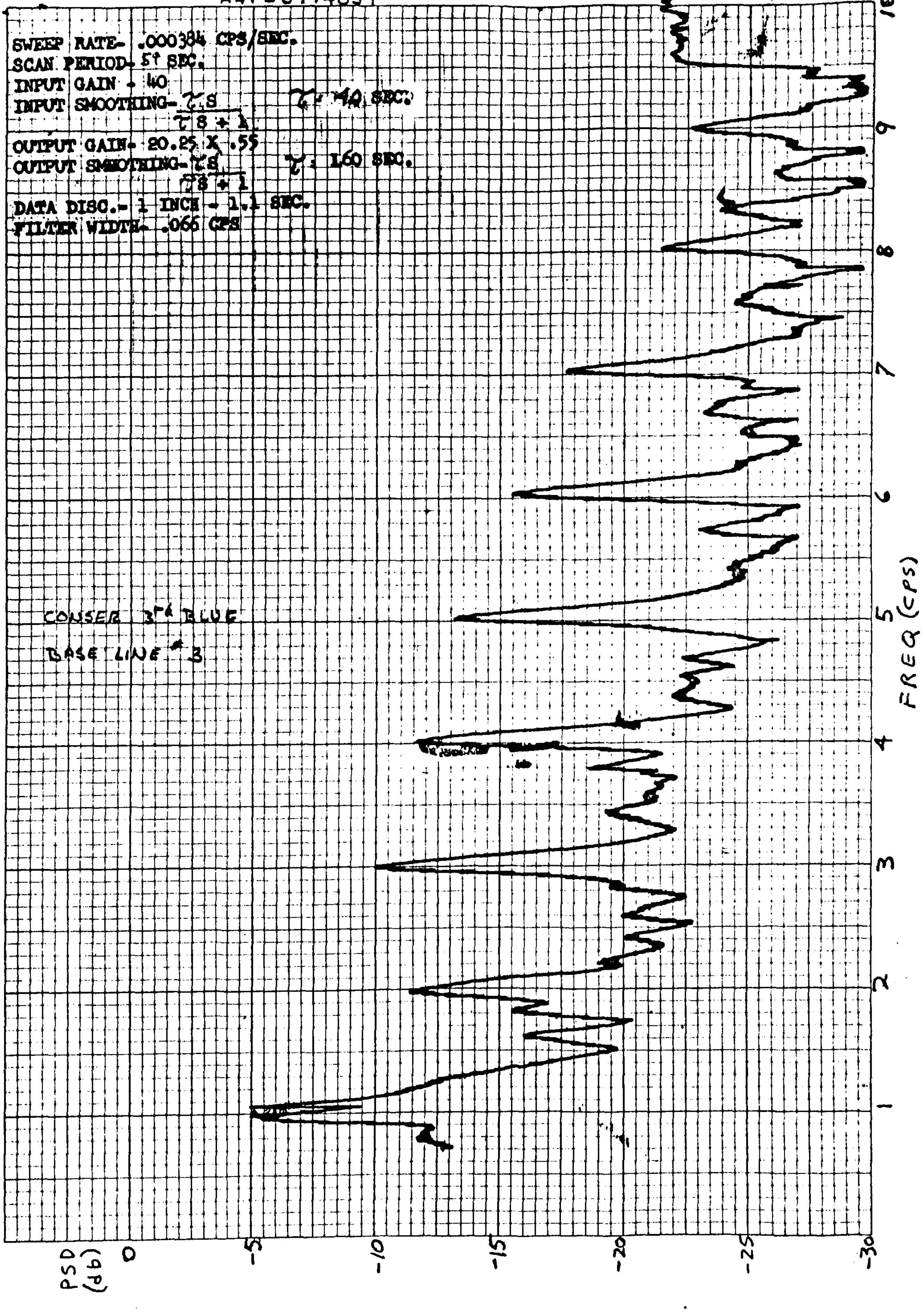

EPG #A4120773458
SWEEP RATE- .000384 CPS/SEC.
SCAN PERIOD- 57 SEC.
INPUT GAIN - 40
INPUT SMOOTHING- τS / τS + 1 τ-40SEC.
OUTPUT GAIN- 20.25 X .55
OUTPUT SMOOTHING- S / S + 1 τ - 160 SEC.
DATA DISC.- 1 INCH - 1.1 SEC.
FILTER WIDTH- .066 CPS
SWITCH TRANSIENT
CONSER 3rd BLUE
18000' 72 HRS
FREQ (CPS)
(db)

A41207?3463



C-5

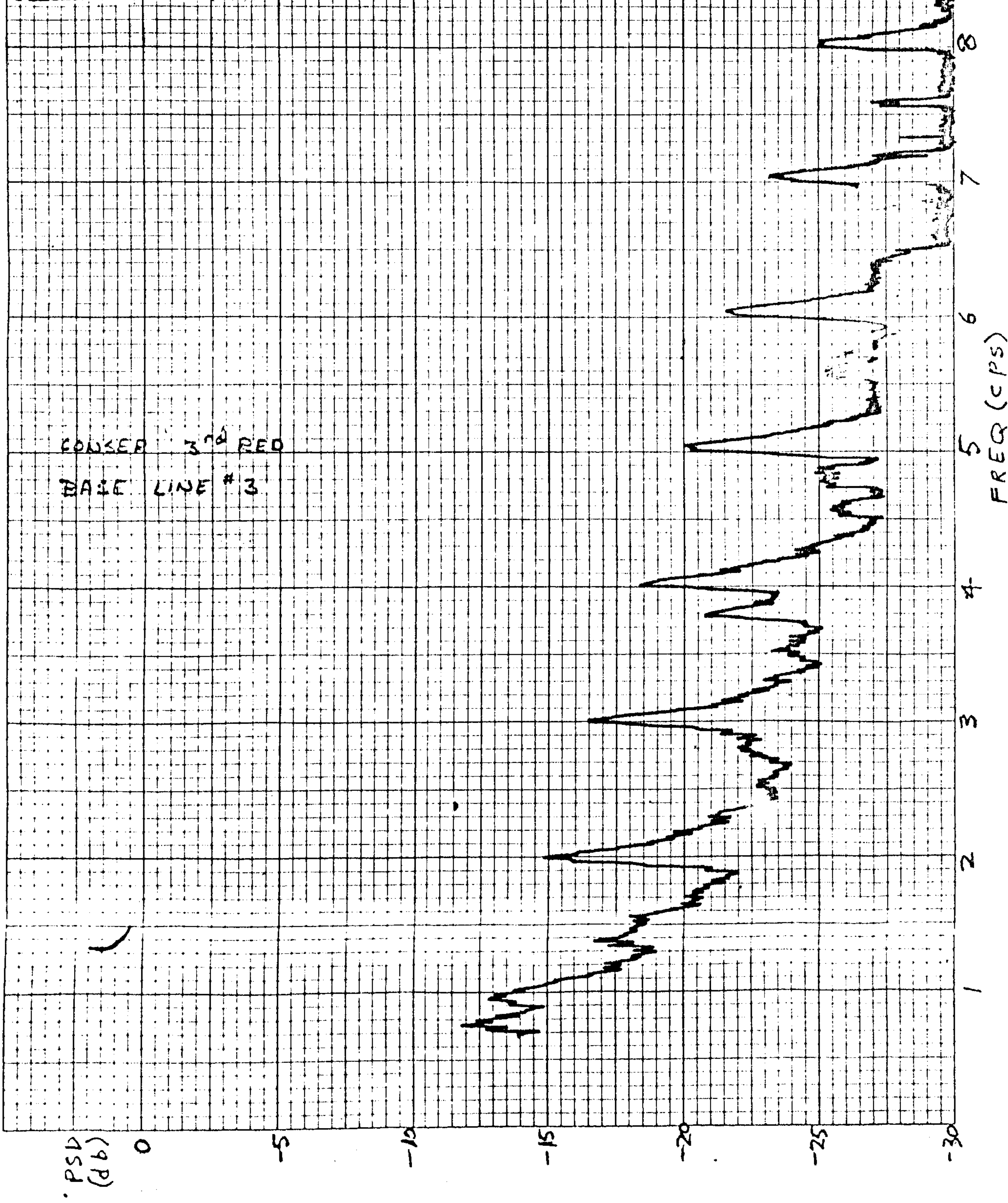
A4120774059



ERG # A412 0734064

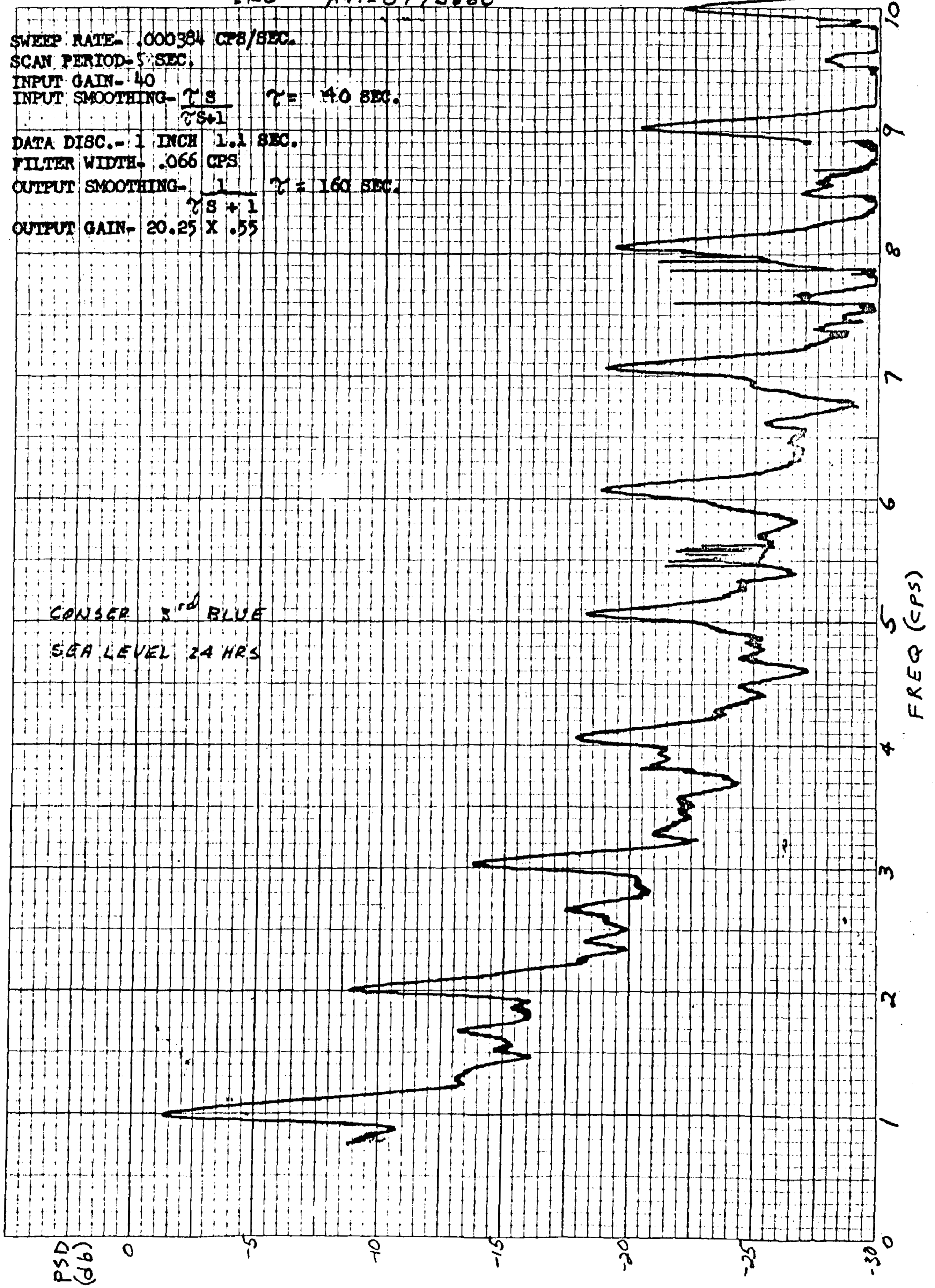
SWEEP RATE- .000384 CPS/SEC.
SCAN PERIOD- 115 SEC.
INPUT GAIN - 40
INPUT SMOOTHING- $\frac{\tau S}{\tau S + 1}$ 40 SEC.
OUTPUT GAIN- 20.25 X .75
OUTPUT SMOOTHING- $\frac{1}{\tau S + 1}$ 160 SEC.
DATA DISC. 1 INCH - 1.1 SEC.
FILTER WIDTH- .066 CPS

C-7

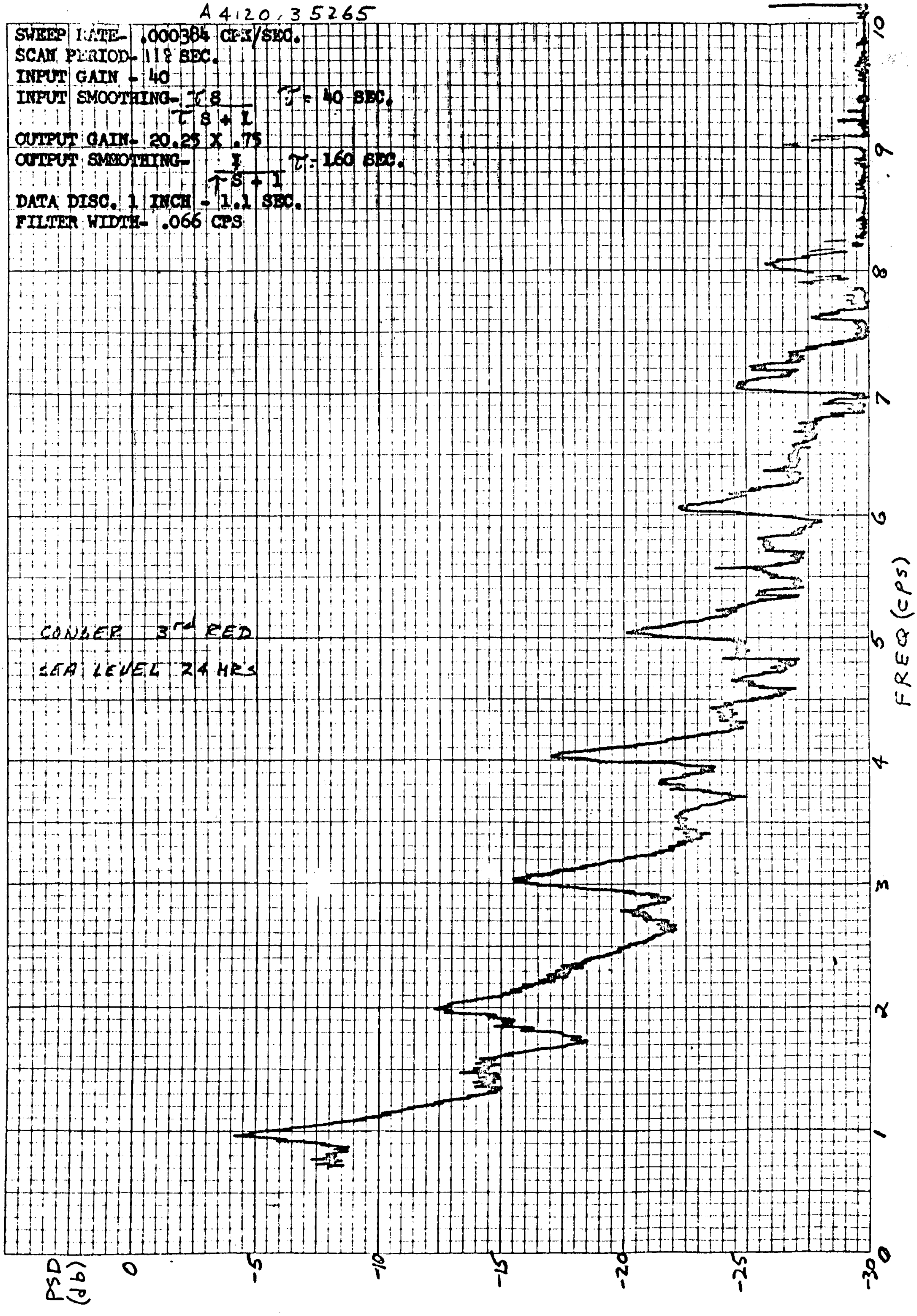


8/6/64

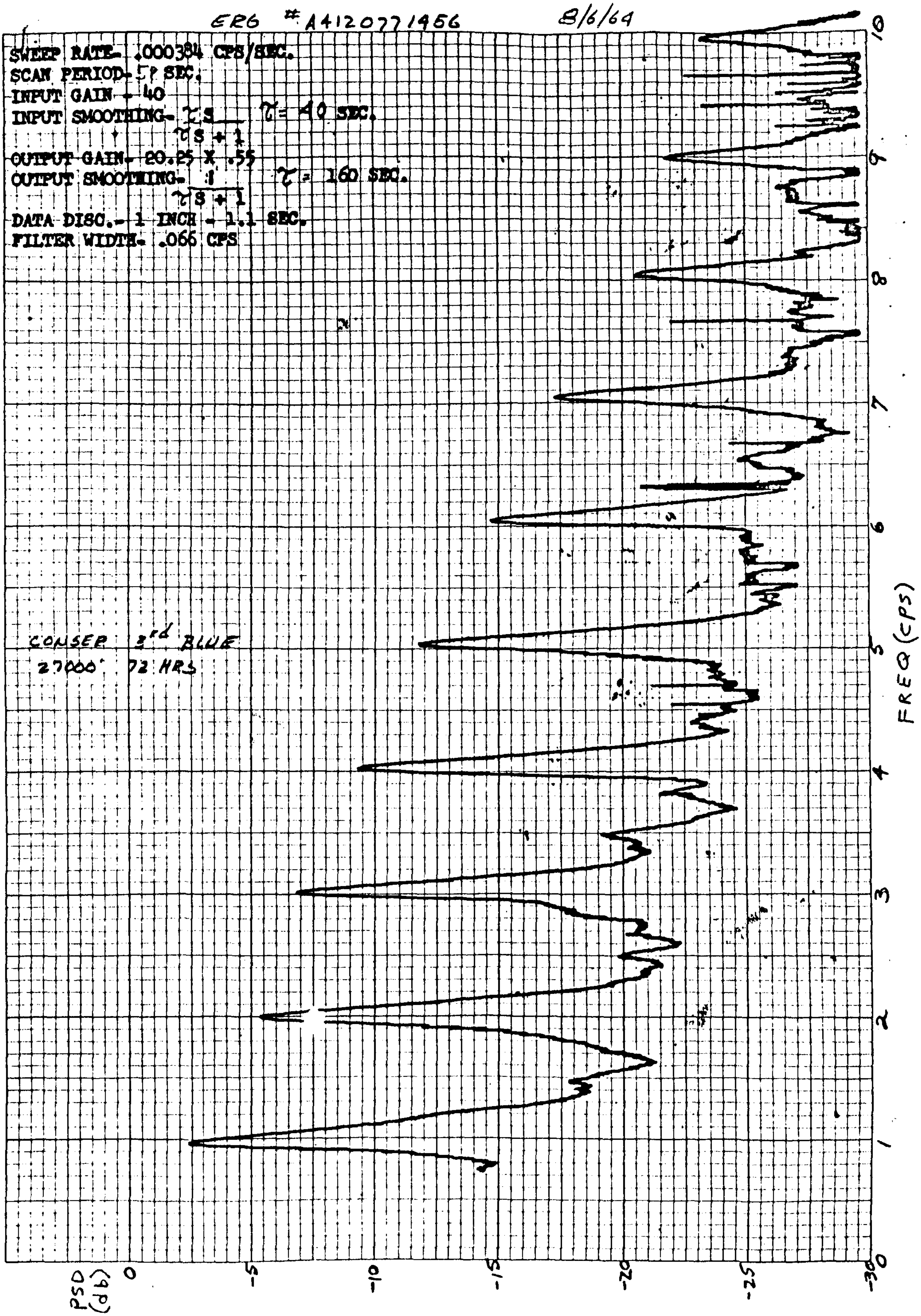
ERG # A4120775260



A 4120, 35265

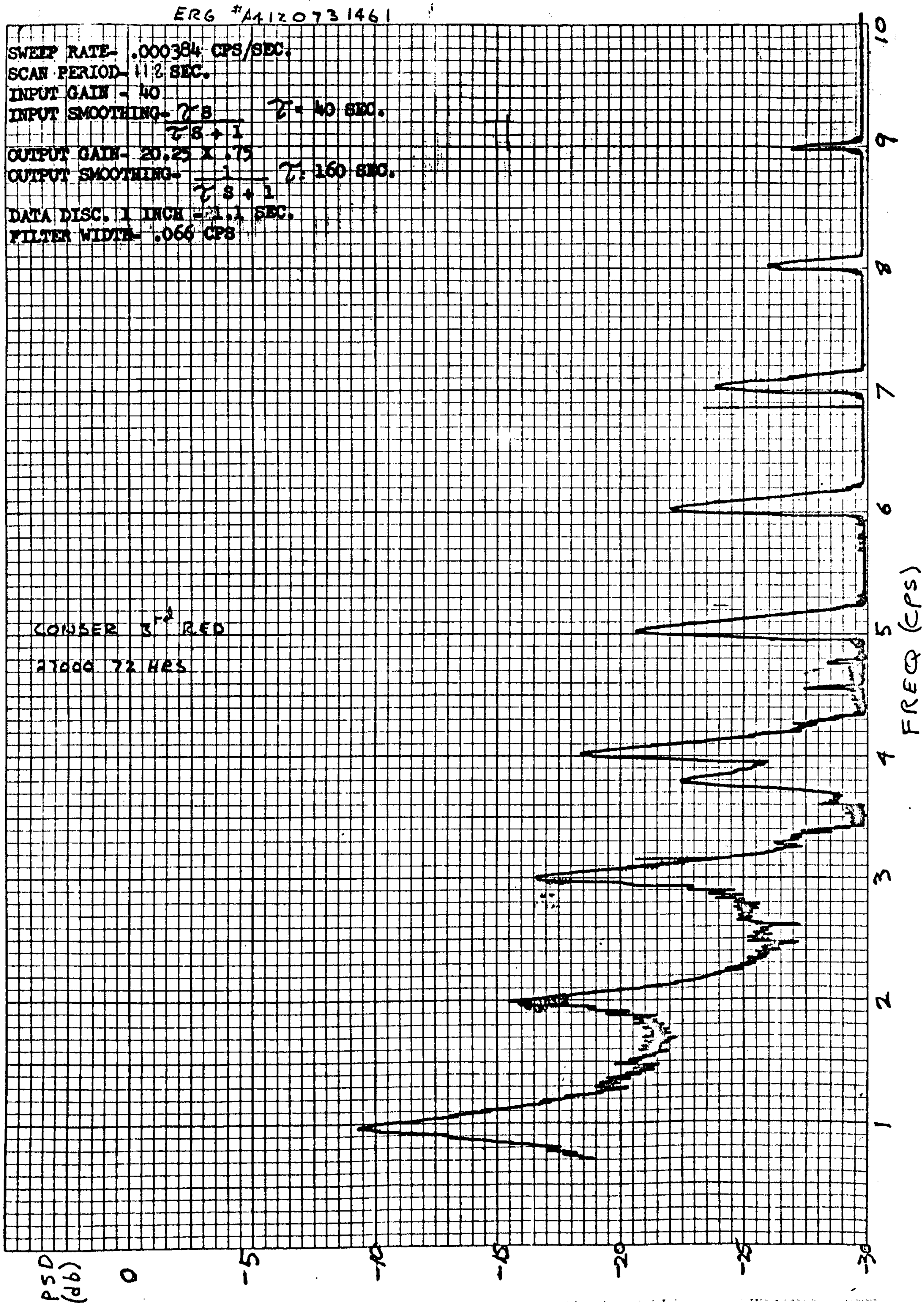


C-9



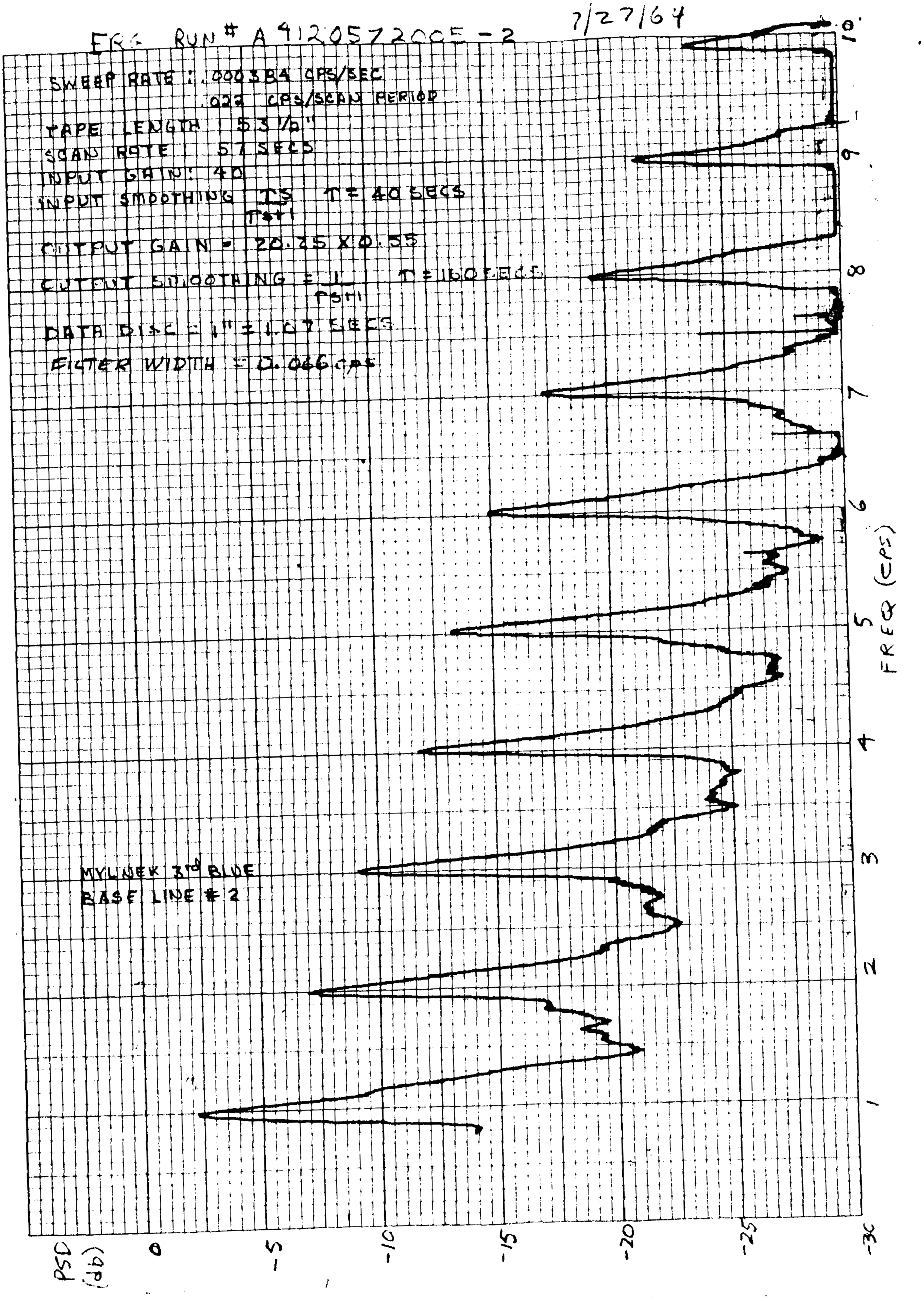
ERG #A4120771456 8/6/64
SWEEP RATE- .000384 CPS/SEC.
SCAN PERIOD- [illegible] SEC.
INPUT GAIN - 40
INPUT SMOOTHING- τS / (τS + 1) τ = 40 SEC.
OUTPUT GAIN- 20.25 X .55
OUTPUT SMOOTHING- 1 / (τS + 1) τ = 160 SEC.
DATA DISC.- 1 INCH - 1.1 SEC.
FILTER WIDTH- .066 CPS
CONSEP 3rd BLUE
27000' 72 HRS
FREQ (CPS)
1
2
3
4
5
6
7
8
9
10
PSD (db)
0
-5
-10
-15
-20
-25
-30

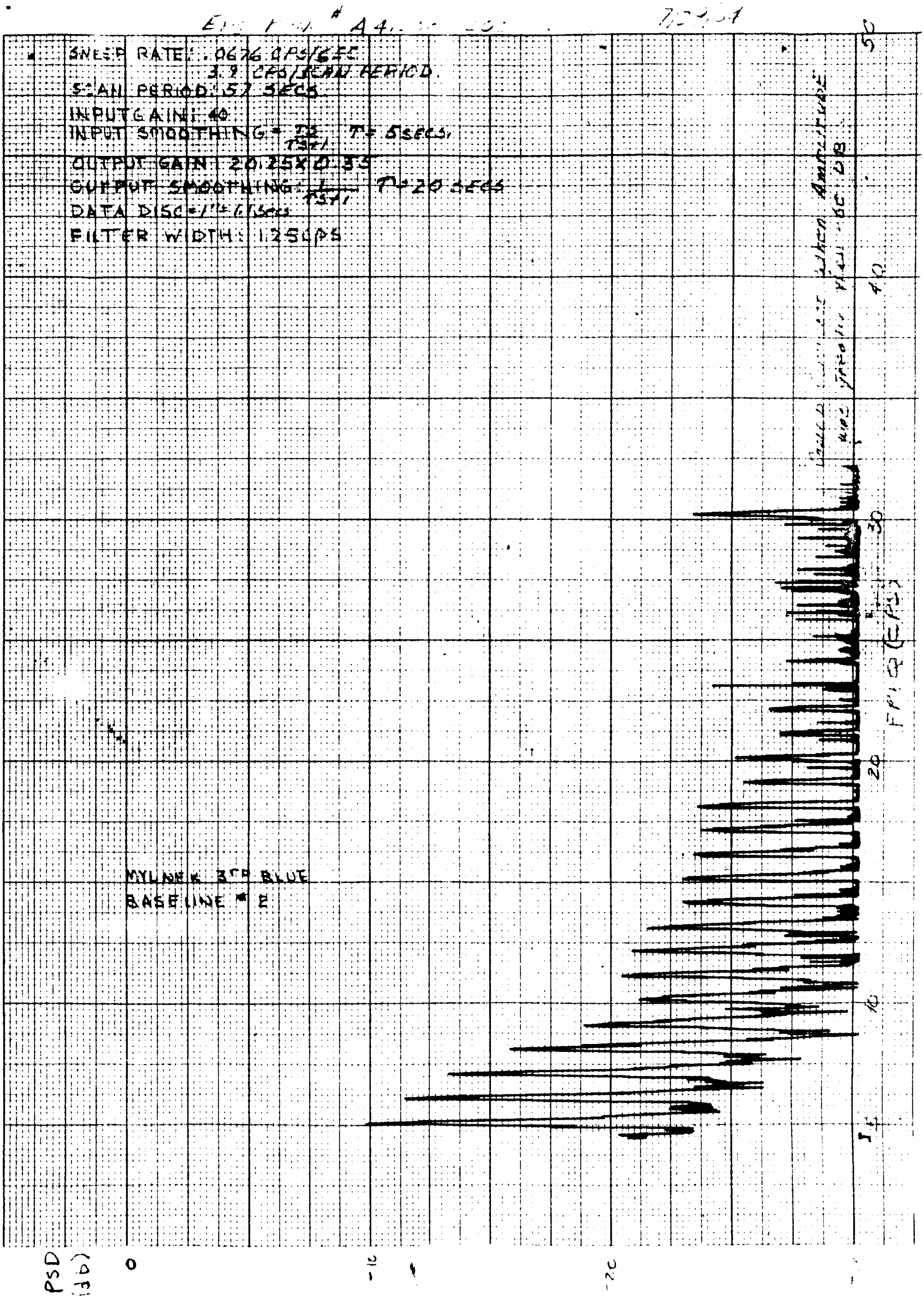
ERG #A4120731461



C-11

ERG RUN # A 4120572005-2 7/27/64

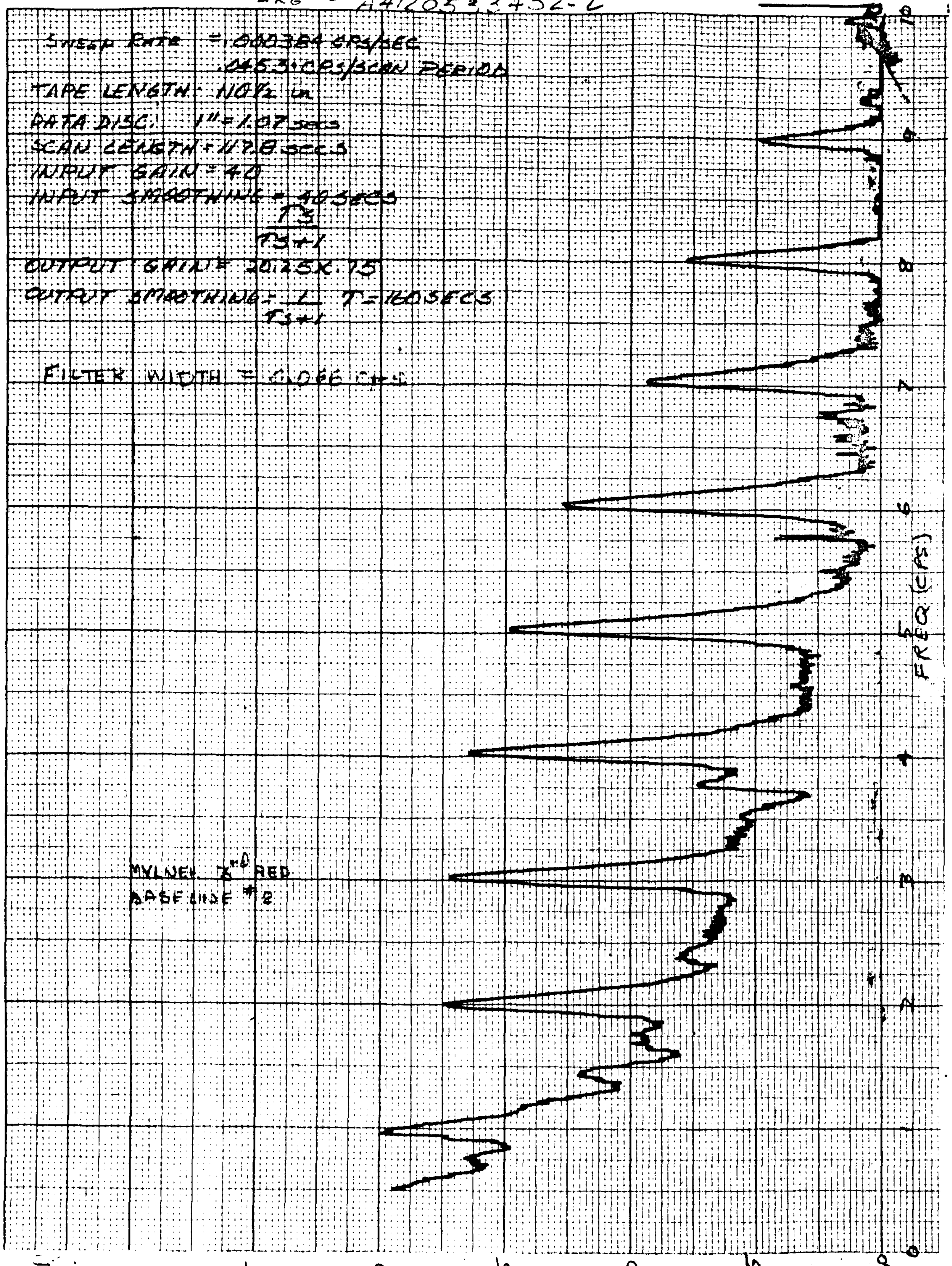



SWEEP RATE: .0676 CPS/SEC
3.9 CPS/SCAN PERIOD.
SCAN PERIOD: 57 SECS.
INPUT GAIN: 40
INPUT SMOOTHING = $\frac{T2}{TS+1}$ T = 5 SECS.
OUTPUT GAIN: 20.25 X 0.35
OUTPUT SMOOTHING: $\frac{1}{TS+1}$ T = 20 SECS
DATA DISC = 1" = 6.75 secs
FILTER WIDTH: 1.25 CPS
MYLAR = 3RD BLUE
BASELINE = E
PSD (dB)
0
-10
-20
10
20
30
40
50
FREQ (CPS)

C-13

ERG # A41205-3452-2

7/27/64



ERG # A4120533452- 7/30/64

SWEEP RATE: .0676 CPS/SEC

TAPE LENGTH: 110 ½ in

SCAN PERIOD: 117 SECS

DATA DISC = 1.1 SECS

INPUT GAIN = 40

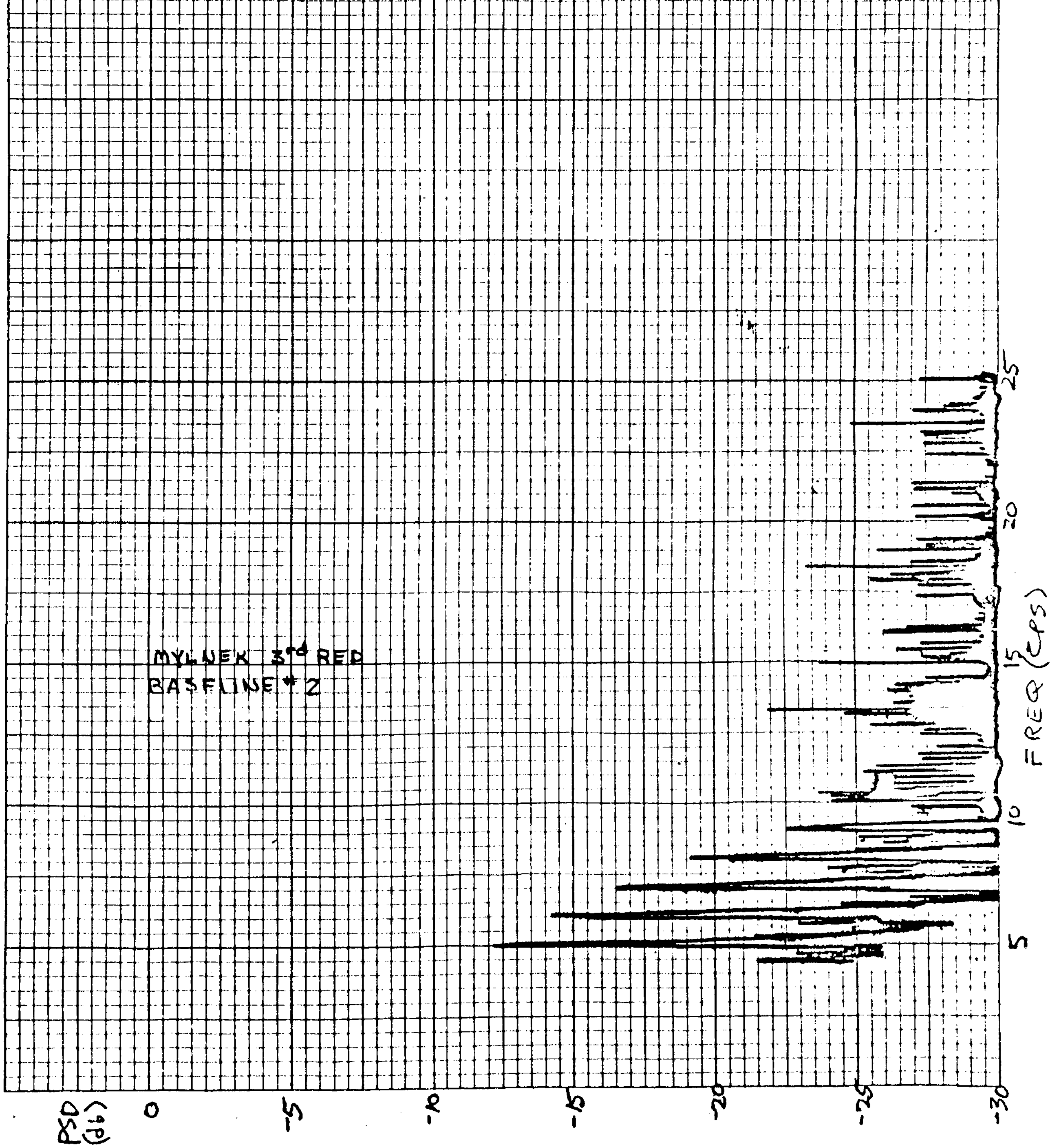
INPUT SMOOTHING = $\frac{TS}{TS+1}$ T = 5 SECS

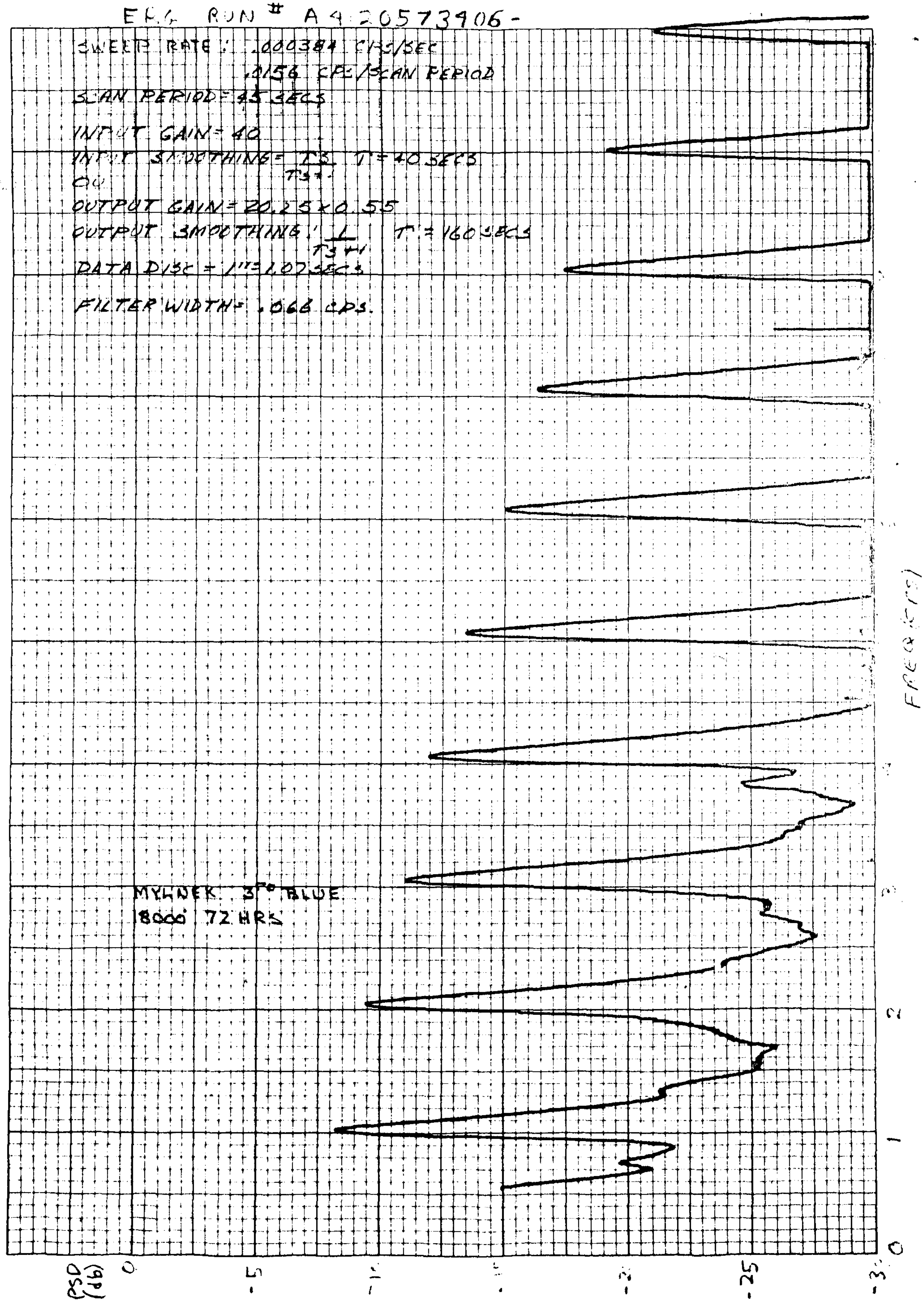
OUTPUT GAIN = 20.25 X 0.75

OUTPUT SMOOTHING = $\frac{1}{TS+1}$ T = 20 SECS

FILTER WIDTH: 1.25 CPS

2-15




EK.G RUN # A4 20573906-
SWEEP RATE: .000384 CPS/SEC
.0156 CPS/SCAN PERIOD
SCAN PERIOD = 45 SECS
INPUT GAIN = 40
INPUT SMOOTHING = TS/(TS+1) T = 40 SECS
OUTPUT GAIN = 20.25 x 0.55
OUTPUT SMOOTHING: 1/(TS+1) T = 160 SECS
DATA DISC = 1" = 1.07 SECS
FILTER WIDTH = .068 CPS.
MYLNEK 3° BLUE
18000 72 HRS
FREQ (CPS)
0
1
2
3
PSD (db)
0
-5
-10
-20
-25
-30

ERG # A4120573406-2 7/29/64

SWEEP RATE: .0676 CPS/SEC

2.74 CPS/SCAN PERIOD

SCAN PERIOD: 45 SECS

INPUT GAIN: 40

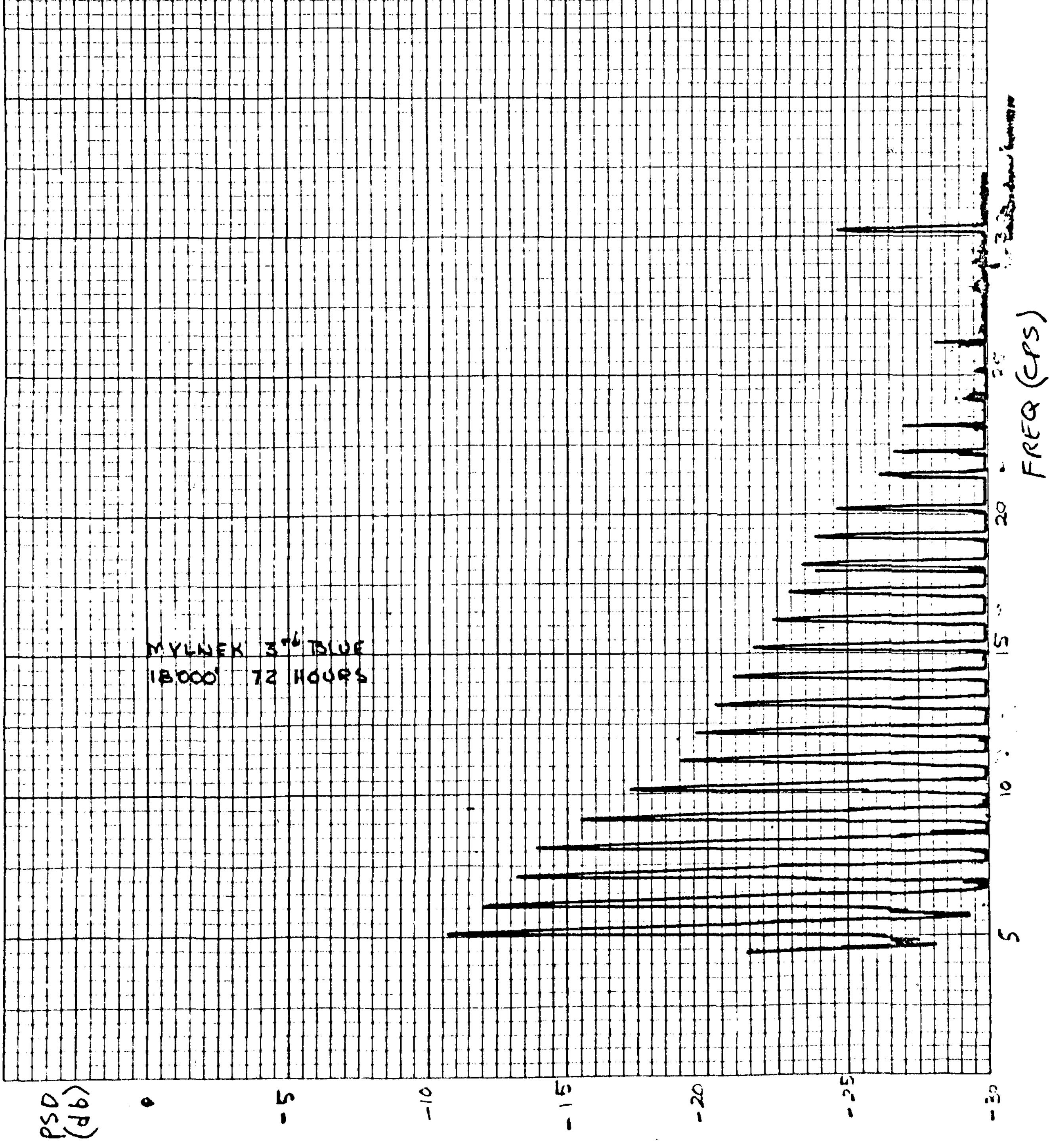
INPUT SMOOTHING = $\frac{TS}{TS+1}$ T = 5 SECS

OUTPUT GAIN: 20.26 X 0.55

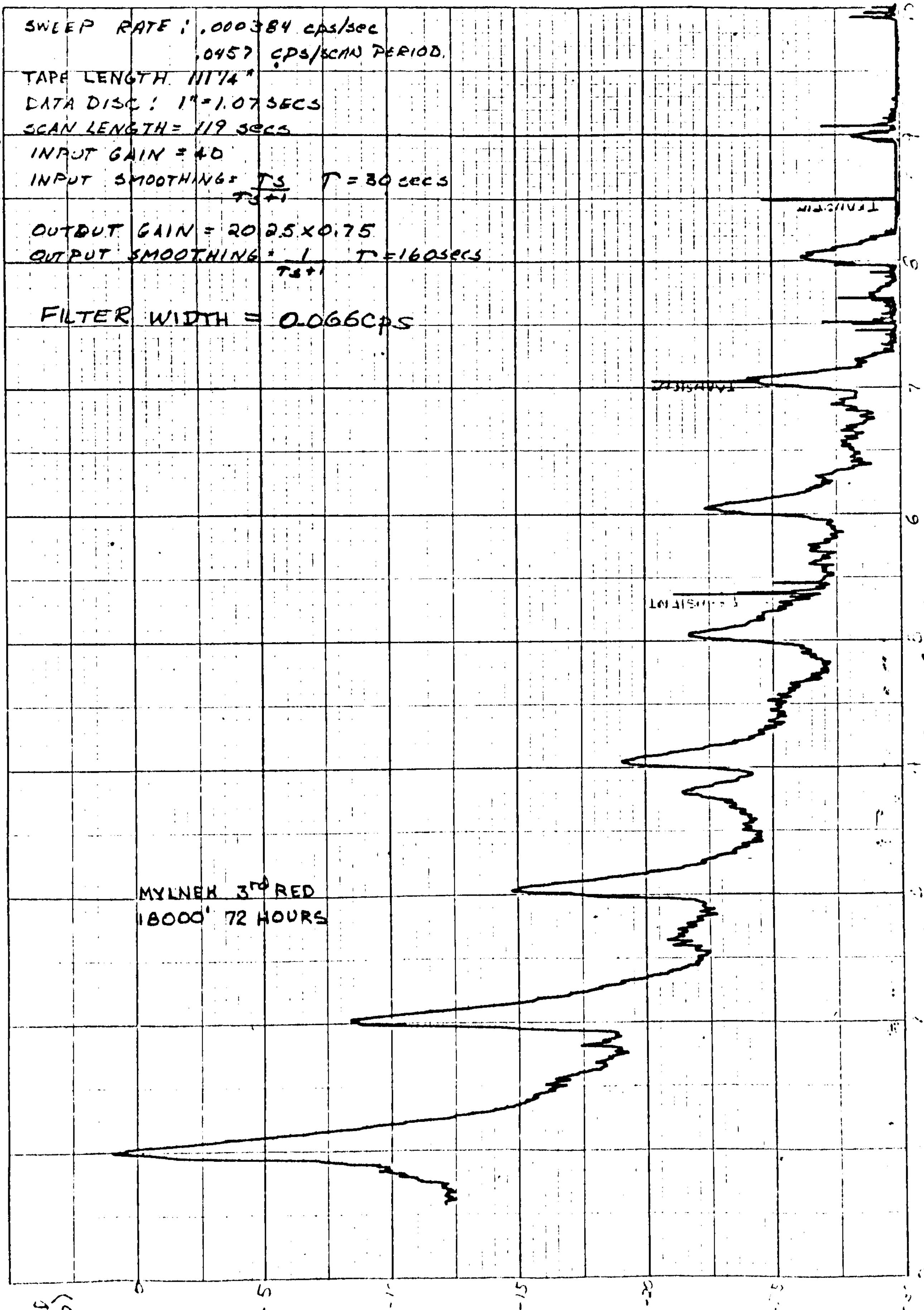
OUTPUT SMOOTHING = $\frac{1}{TS+1}$ T = 20 SECS

DATA DISC = 1" = 1.1 SECS

FILTER WIDTH = 1.25 CPS.



EPG RUN # A4120535253



ERG # A412 0535253-2 7/30/64

SWEEP RATE = .0676 CPS/SEC

SCAN PERIOD = 119 SECS

DATA DISC = 1.07 SECS

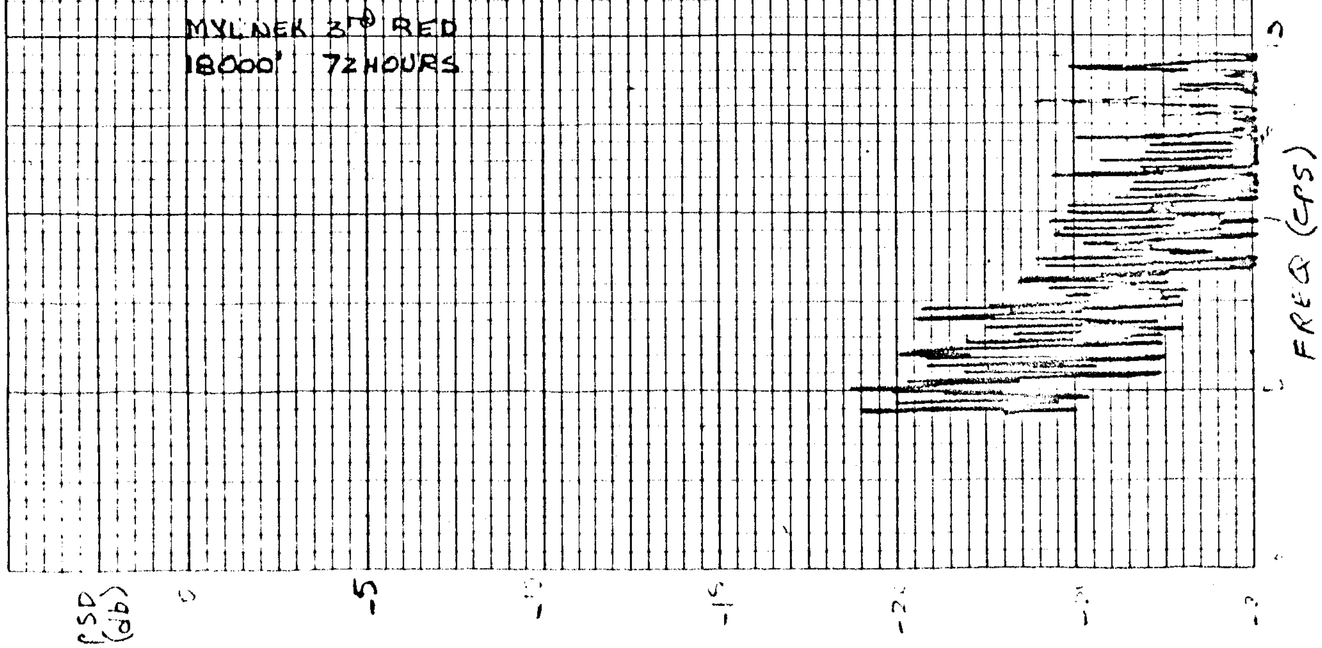
INPUT GAIN = 40

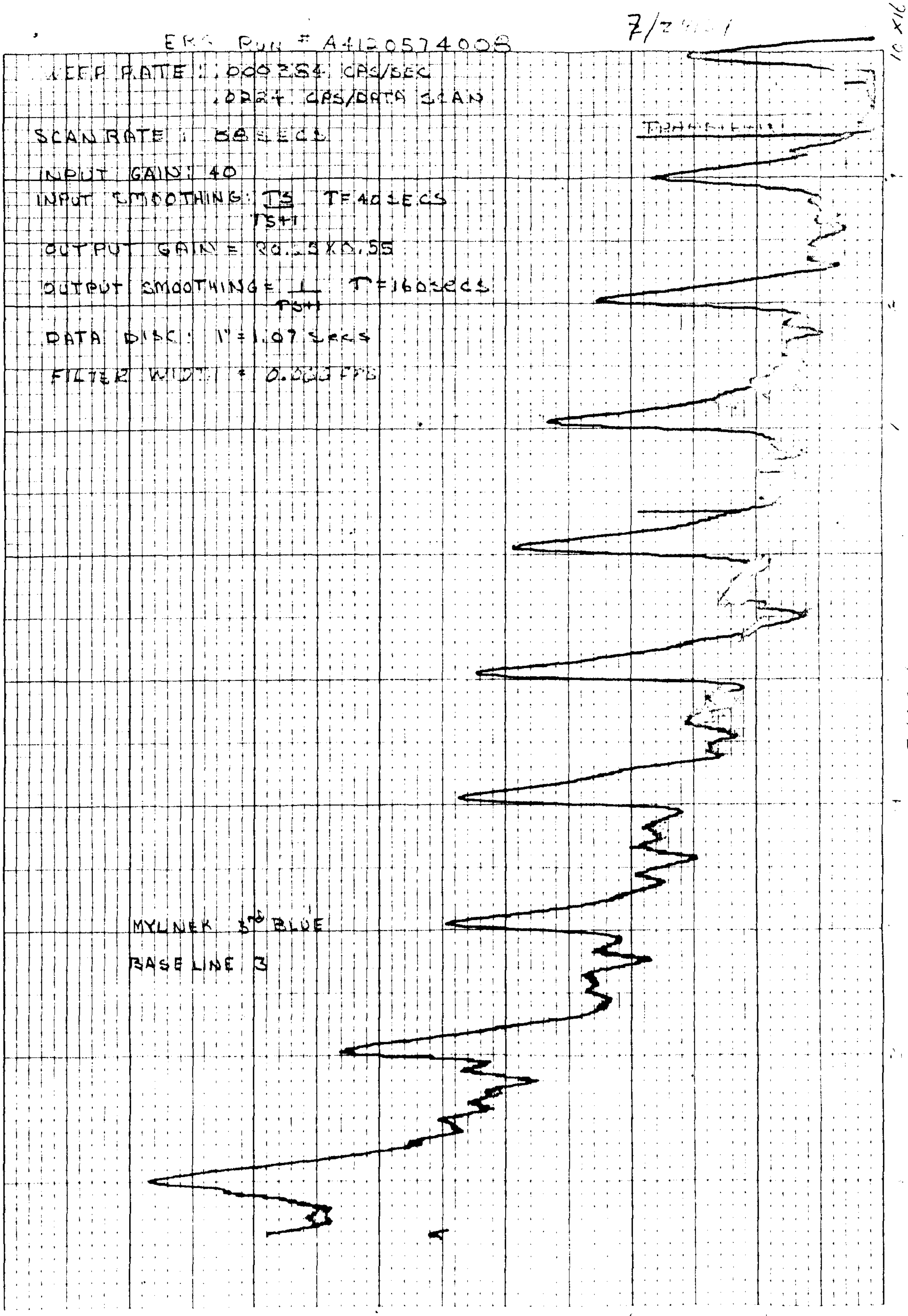
INPUT SMOOTHING = $\frac{TS}{TS+1}$ T = 5 SECS

OUTPUT GAIN = 20.25 × 0.75

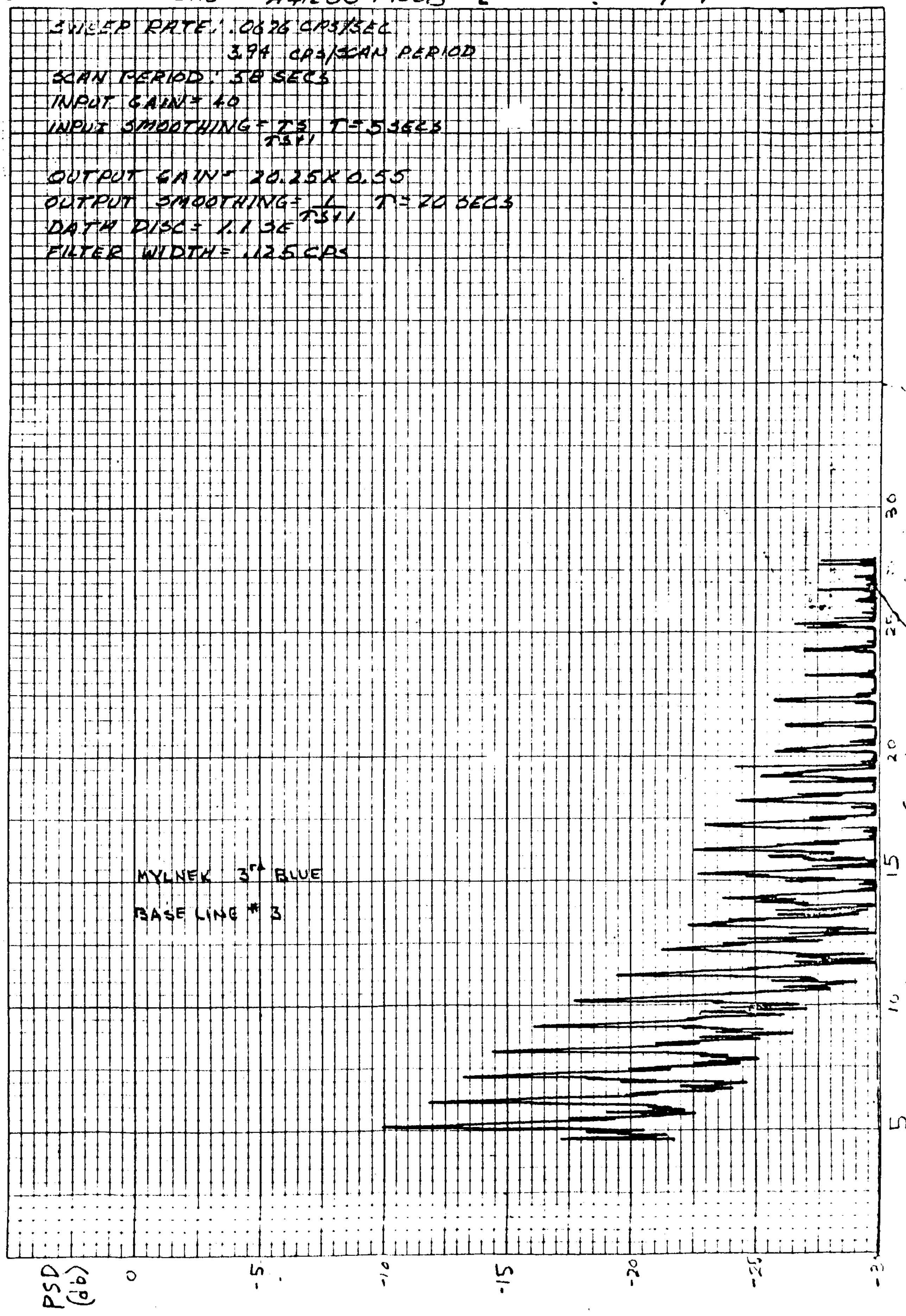
OUTPUT SMOOTHING = $\frac{1}{TS+1}$ T = 20 SECS

FILTER WIDTH = 1.25 CPS




RUN # A4120574008
RATE : .000254 CPS/SEC
.0224 CPS/DATA SCAN
SCAN RATE :
INPUT GAIN: 40
INPUT SMOOTHING: TS/TS+1 T=40 SECS
OUTPUT GAIN
OUTPUT SMOOTHING = 1/TS+1 T=160 SECS
DATA DISC: 1" = 1.07 SECS
FILTER WIDTH
MYLNER 3rd BLUE
BASE LINE 3

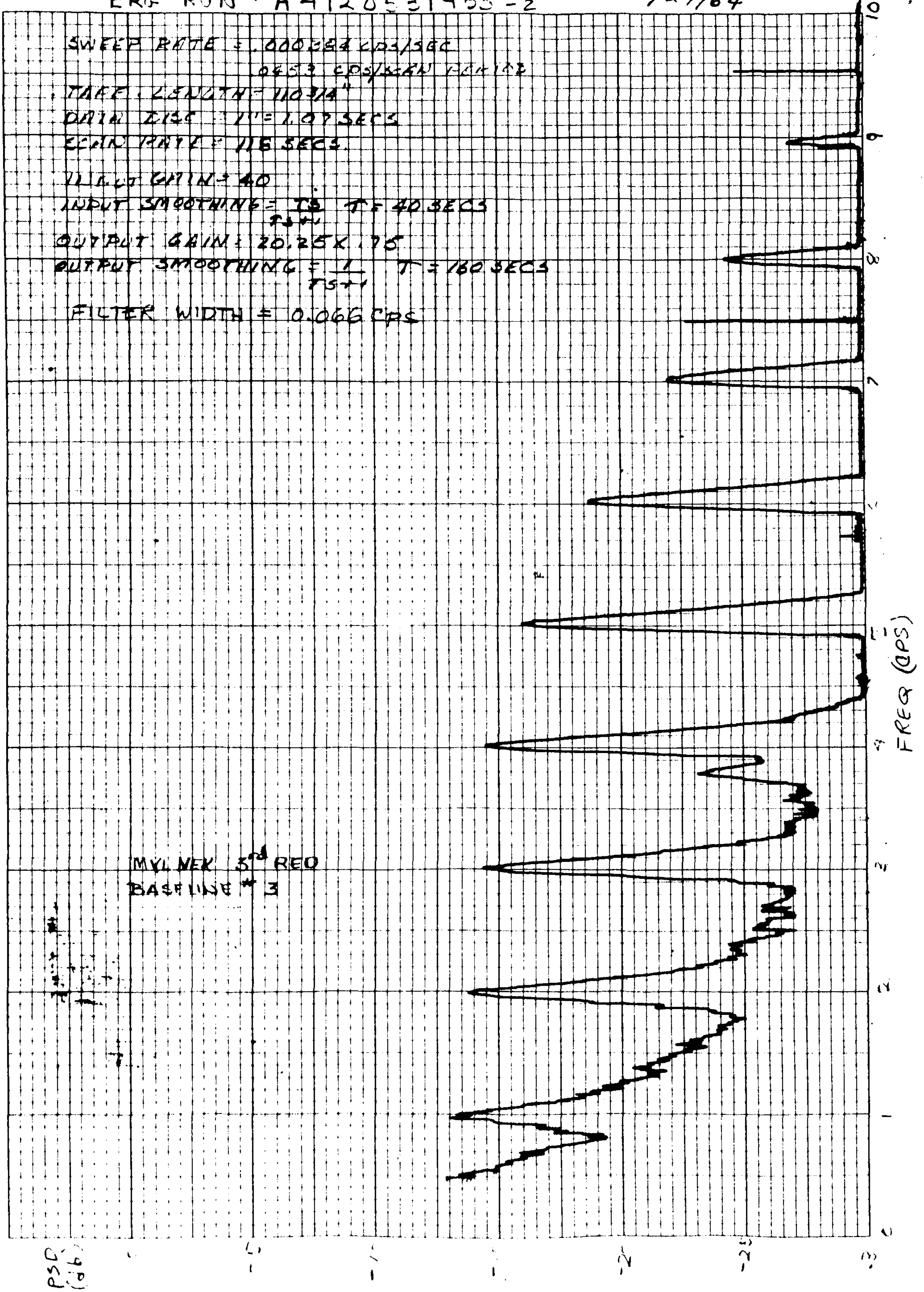
ERG * A41205 74008-2 7/29/64



RUN 04

C-21

ERG RUN # A4120531455-2 7/27/64



ERG # AA1205314 55-3 8/5/64

SWEEP RATE: .0676 CPS/SEC

SCAN RATE: 118 SECS

INPUT GAIN: 40

INPUT SMOOTHING = $\frac{TS}{TS+1}$ T = 40 SECS

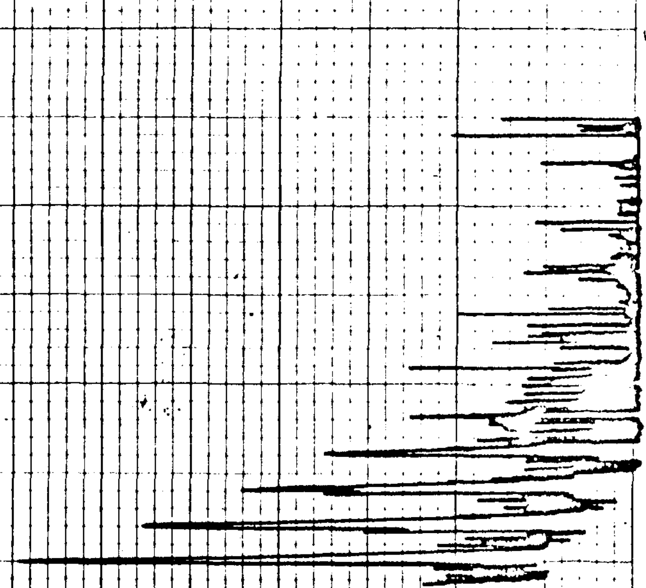
OUTPUT GAIN: 20.25 X 0.55

OUT SMOOTH $\frac{1}{TS+1}$ T = 10 SECS

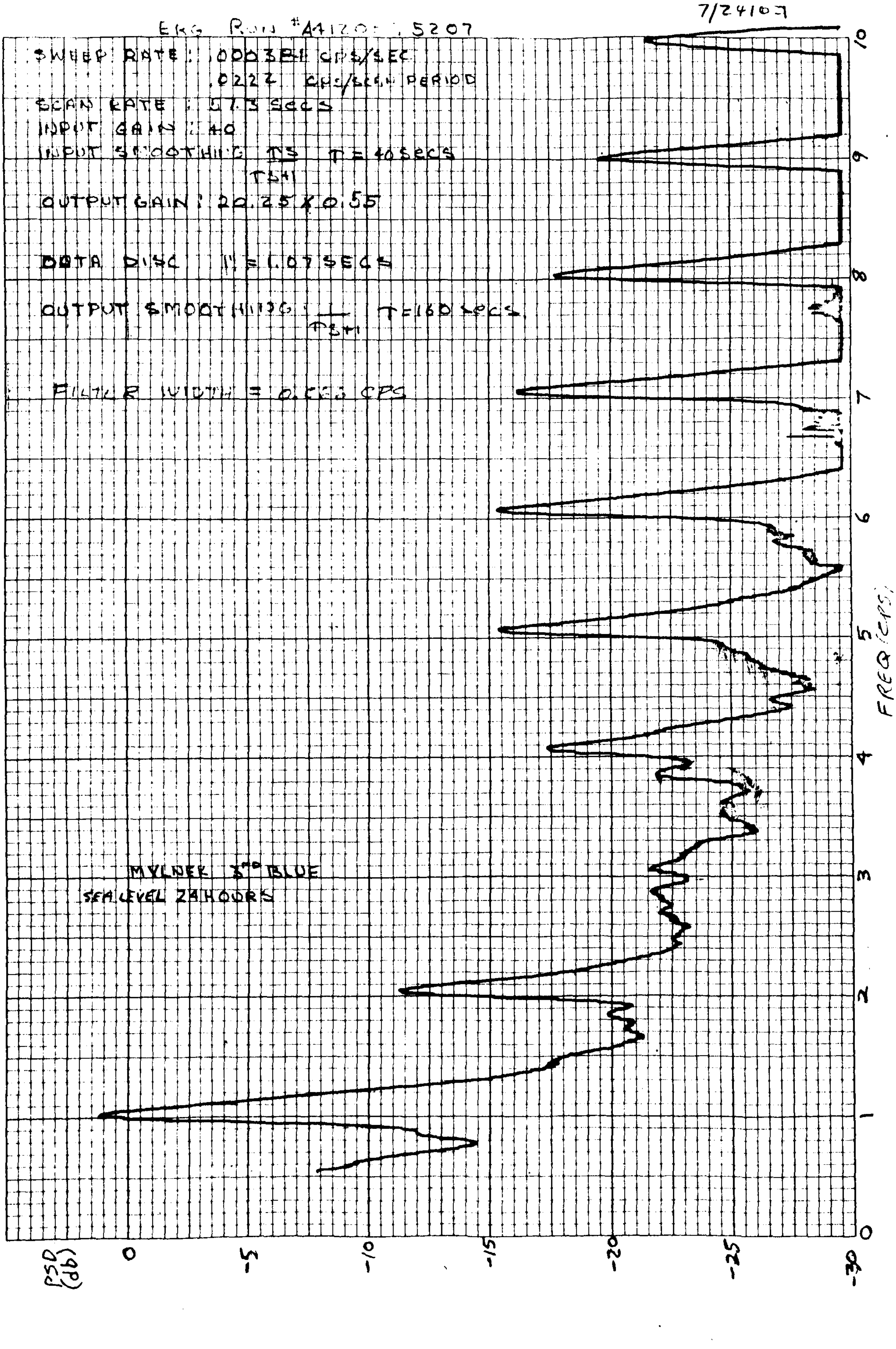
FILTER WIDTH 1.25 CPS

MYLNER 3rd RED

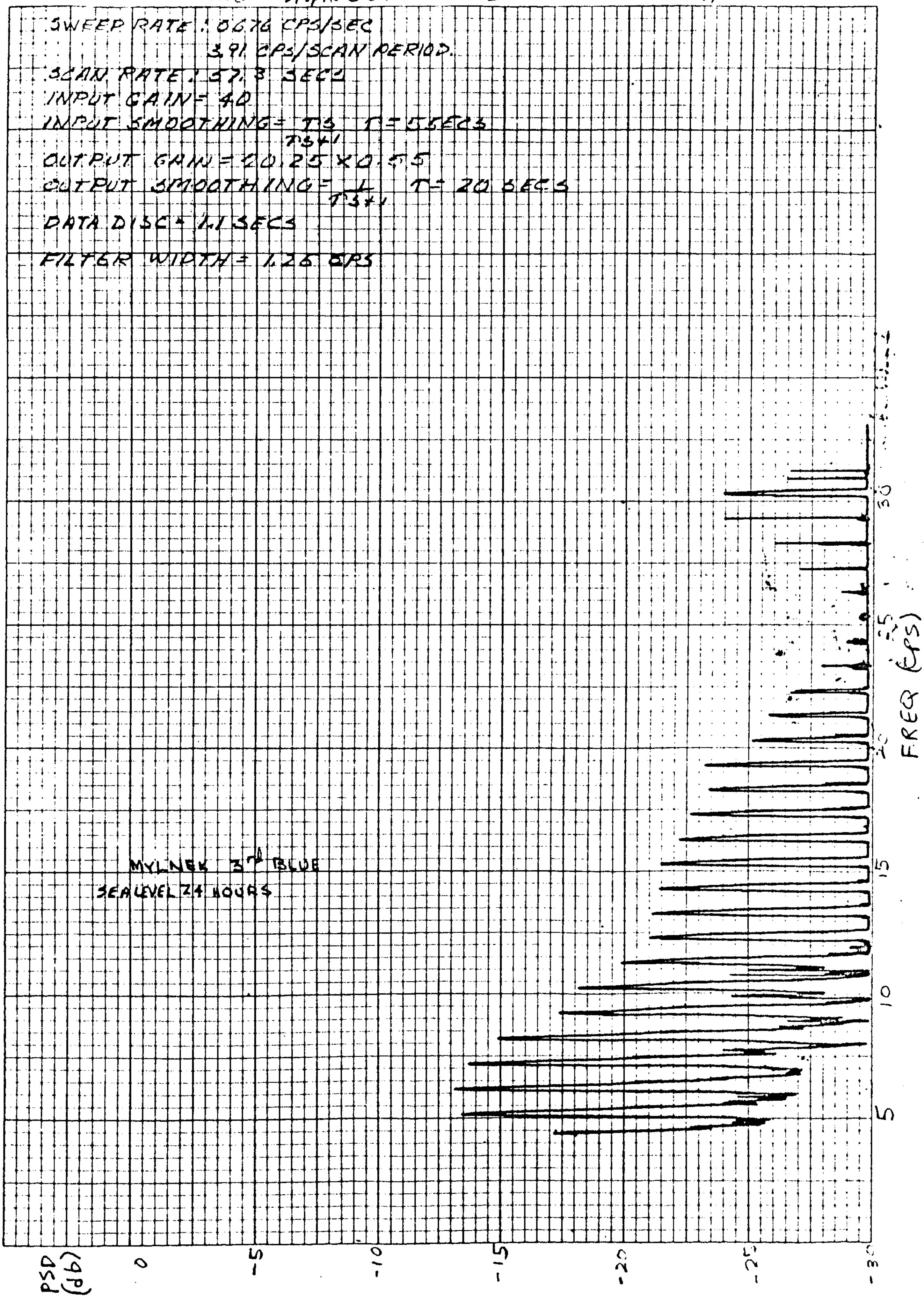
BASE LINE # 3



C-23

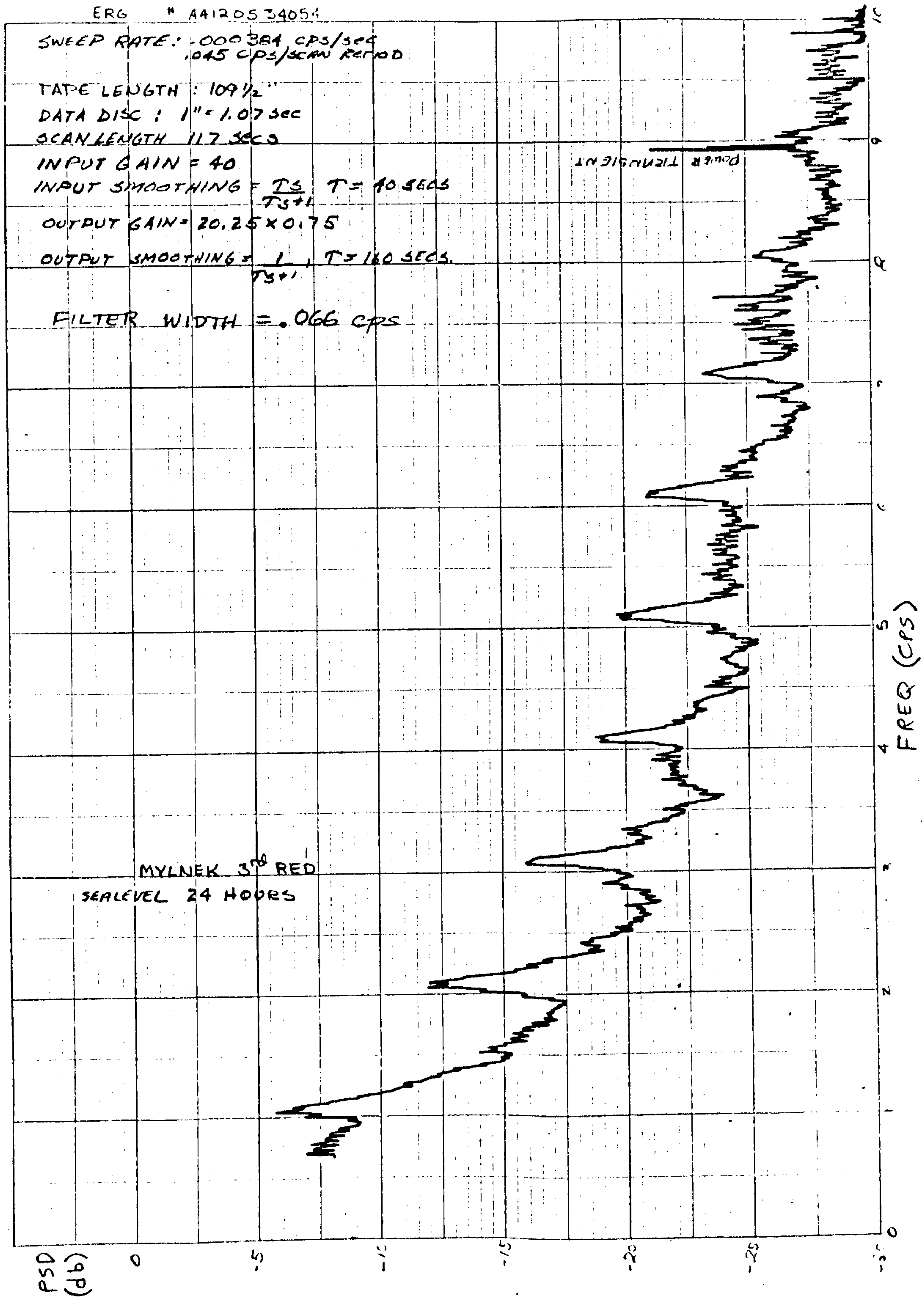

7/24/07
ERG RUN #A4120 .5207
SWEEP RATE: .00038 CPS/SEC
.0222 CPS/SCAN PERIOD
SCAN RATE: 57.3 SECS
INPUT GAIN: 40
INPUT SMOOTHING TS/TS+1 T = 40 SECS
OUTPUT GAIN: 20.25 X 0.55
DATA DISC 1" = 1.07 SECS
OUTPUT SMOOTHING 1/TS+1 T = 160 SECS
MYLNER 3RD BLUE
SEA LEVEL 24 HOURS
0
1
2
3
4
5
6
7
8
9
10
FREQ (CPS)
PSD (db)
0
-5
-10
-15
-20
-25
-30

ERG # A4120575207-2 7/20/34

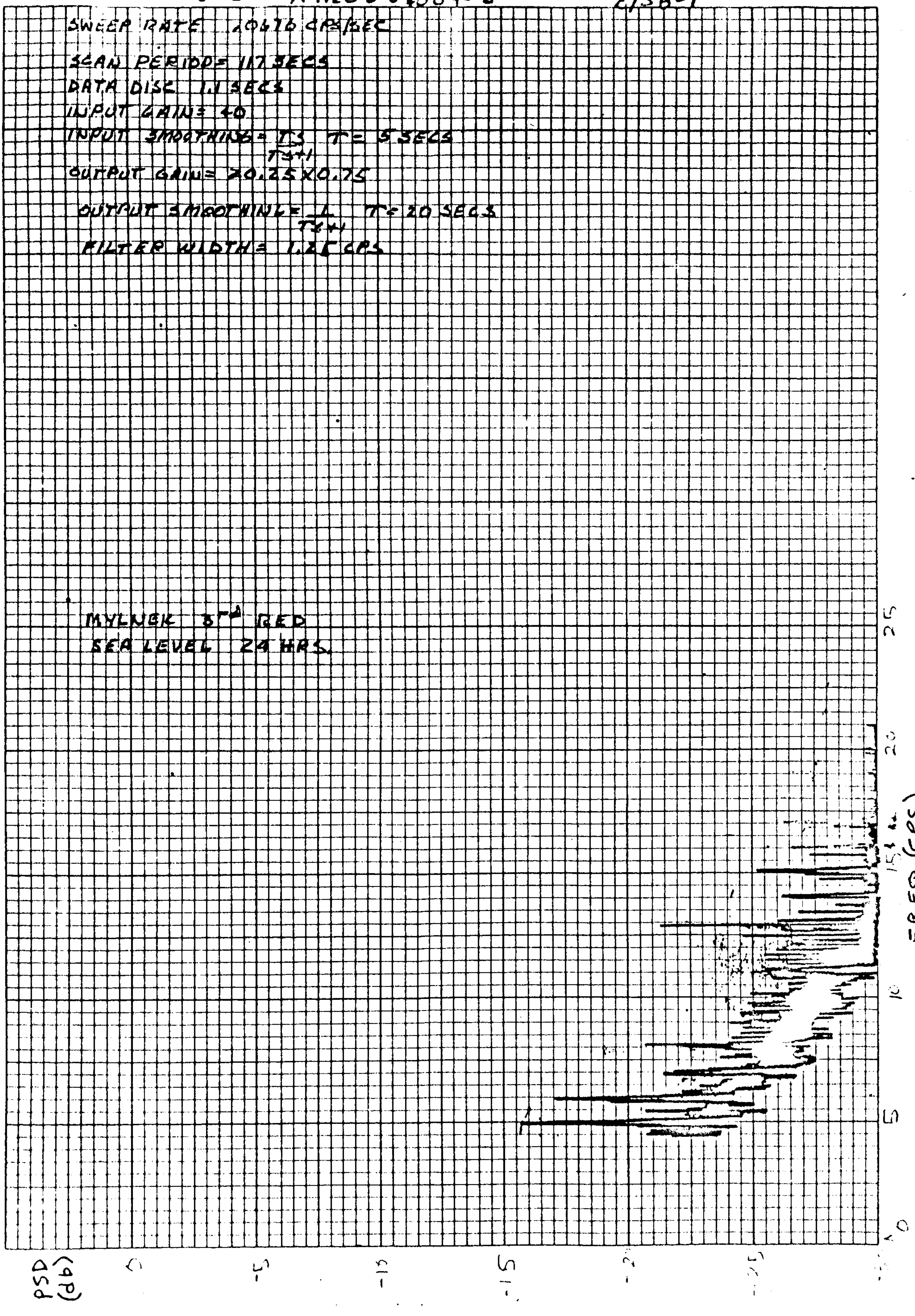


C-25

7/23/64


ERG # A41205 34054
SWEEP RATE: .000384 CPS/SEC
.045 CPS/SCAN PERIOD
TAPE LENGTH : 109½"
DATA DISC : 1" = 1.07 SEC
SCAN LENGTH 117 SECS
INPUT GAIN = 40
INPUT SMOOTHING = TS/(TS+1) T = 40 SECS
OUTPUT GAIN = 20.25 × 0.175
OUTPUT SMOOTHING = 1/(TS+1), T = 160 SECS.
FILTER WIDTH = .066 CPS
POWER TRANSIENT
MYLNEK 3RD RED
SEALEVEL 24 HOURS
FREQ (CPS)
PSD (db)
0
-5
-10
-15
-20
-25
-30
0
2
4
5
6
8
9
10

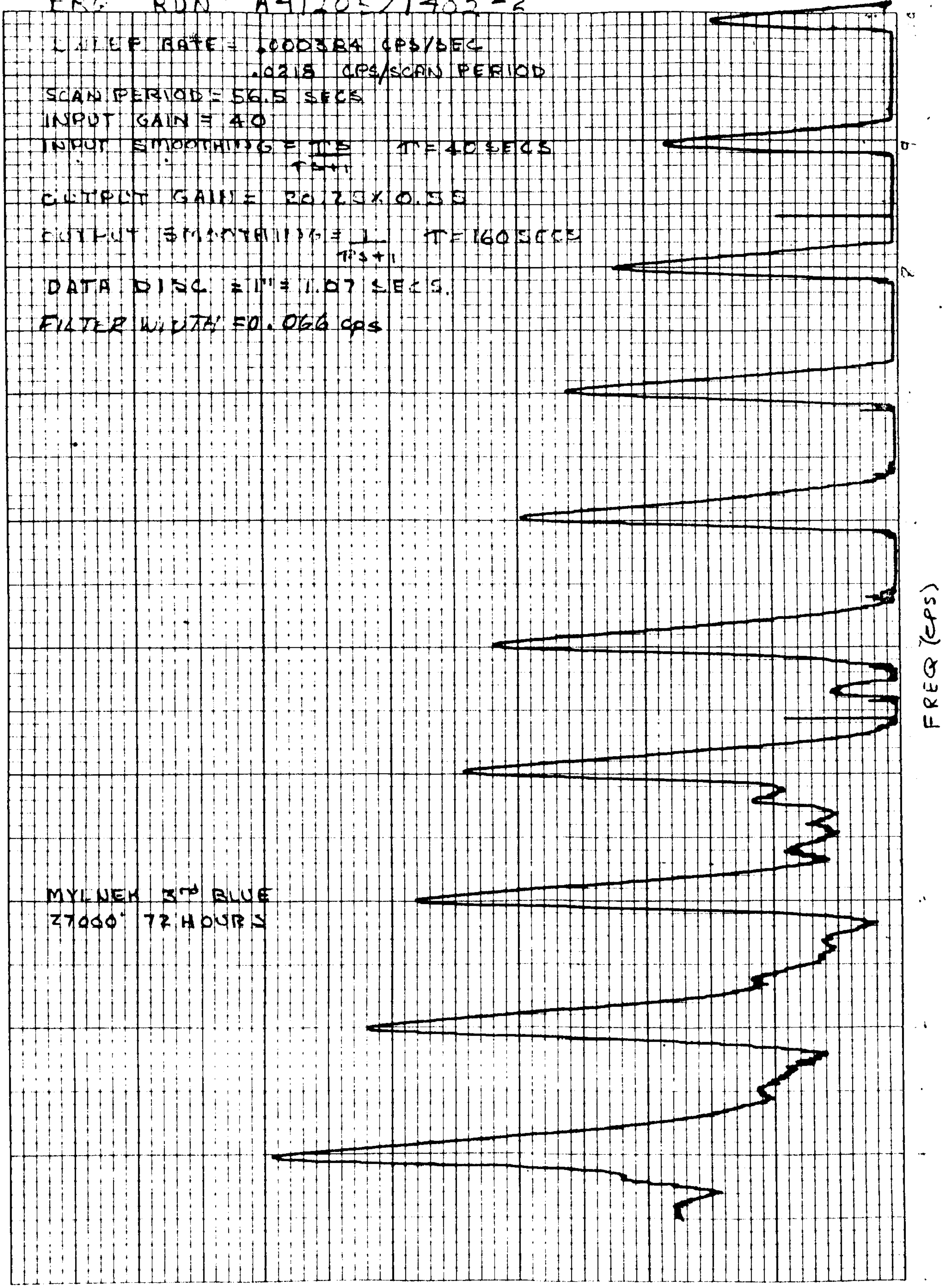
ERG # A4120534054-2 8/5/64



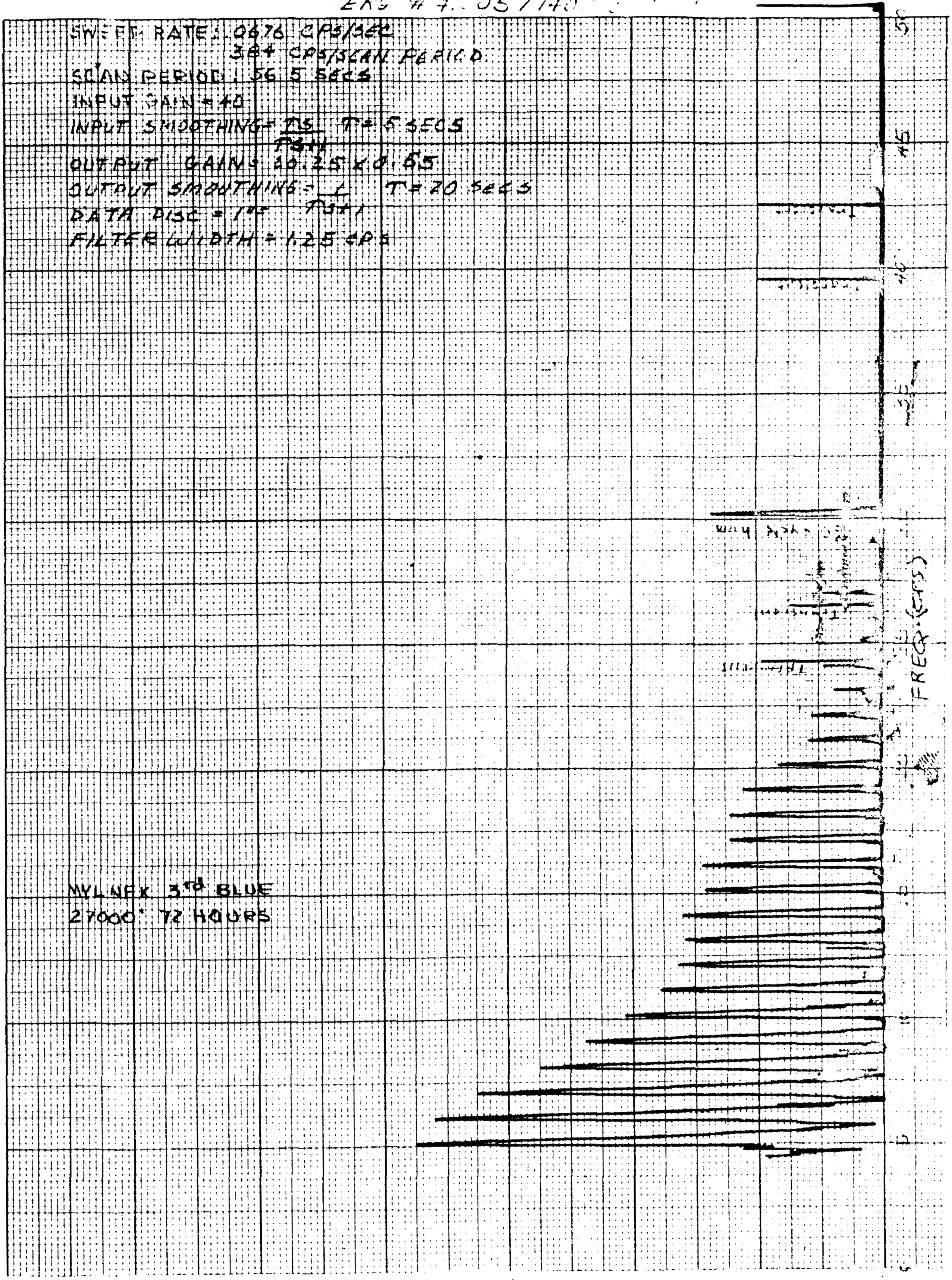
C-27

7/27/64

ERG RUN # A4120571402-2



ERS #4..05714O

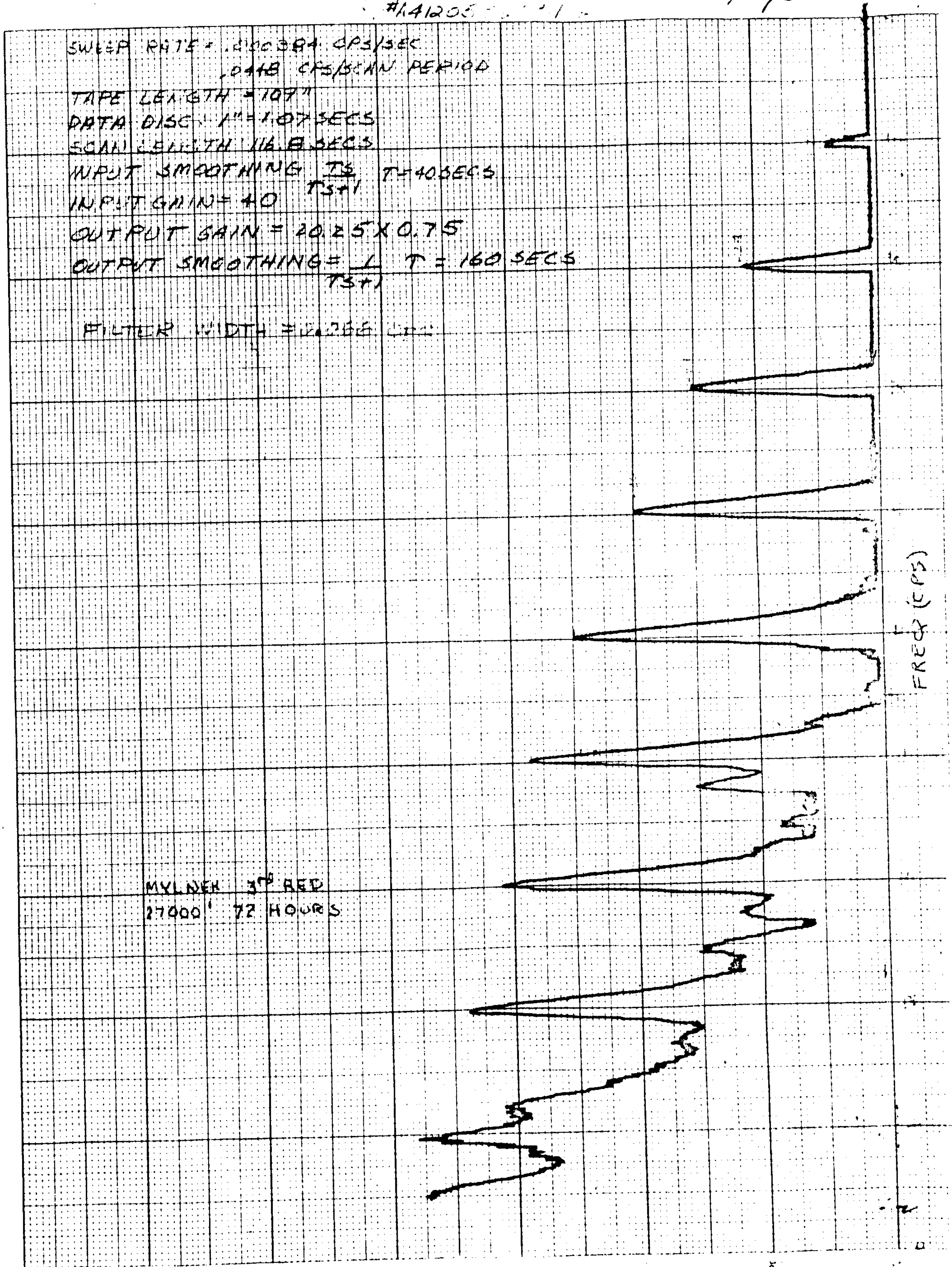


C-29

PSD (g²/cps)

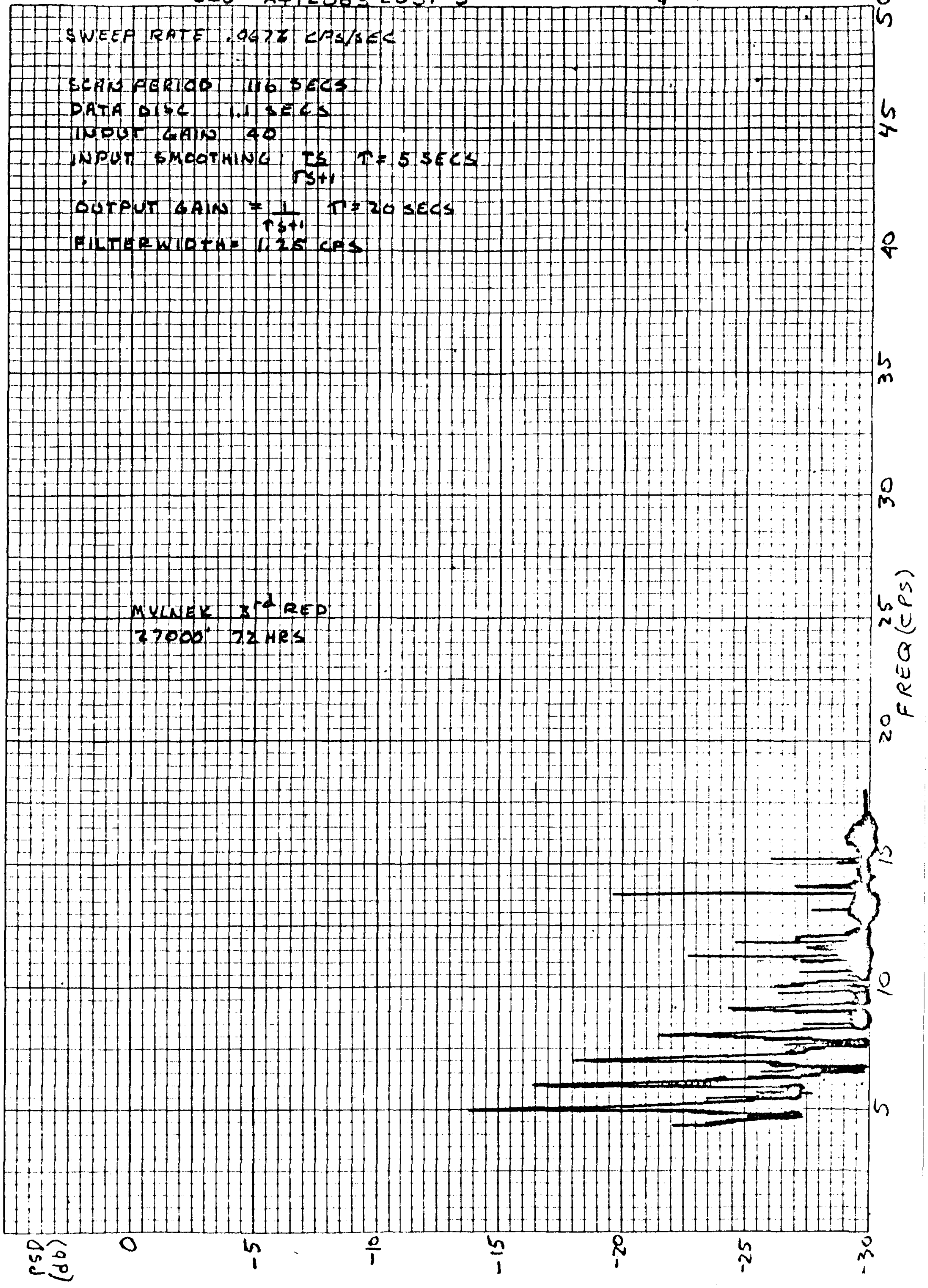
#A41205

1/27/61



(49)
Jsd

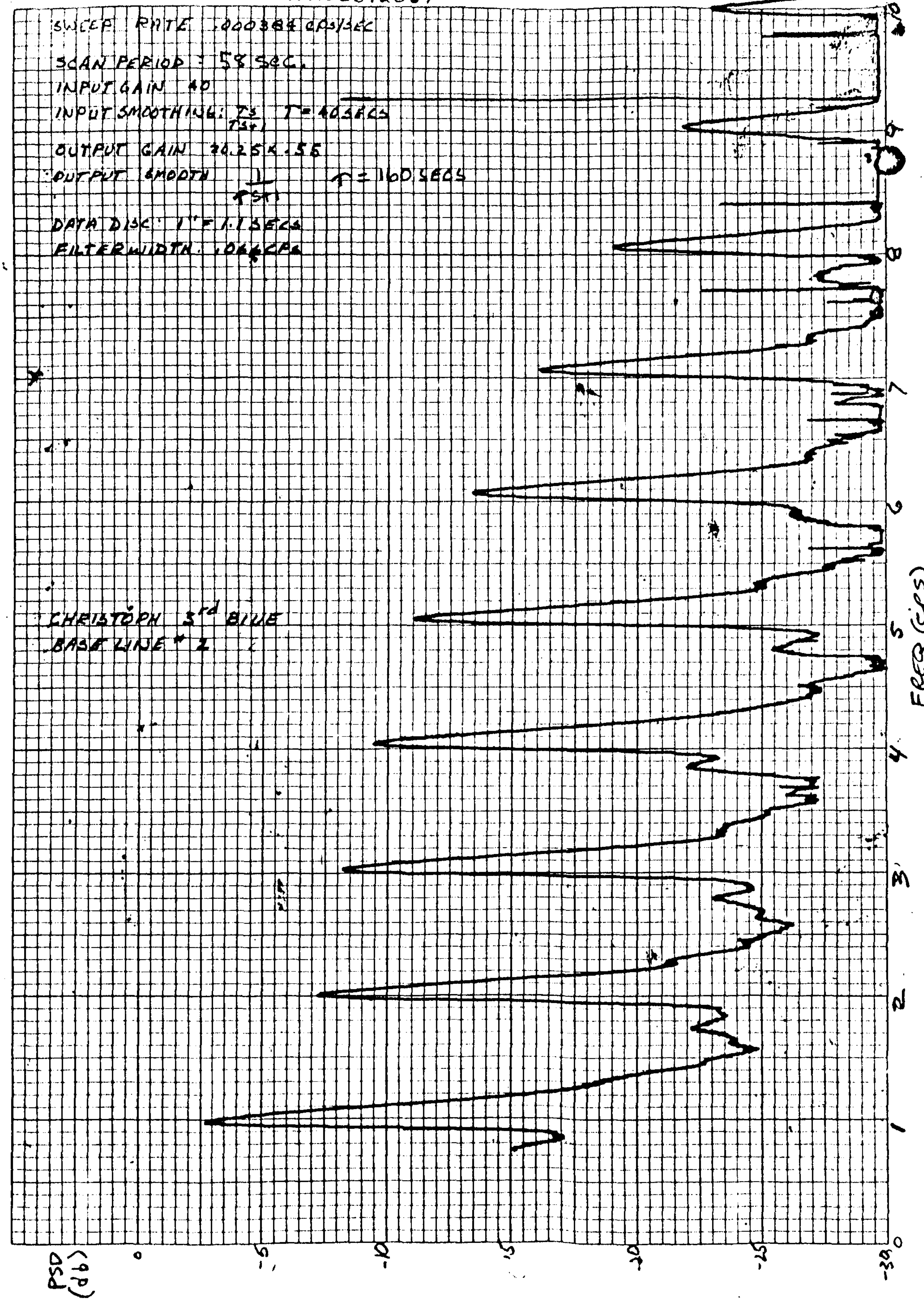
ERG #A4120632051-3 8/5/64

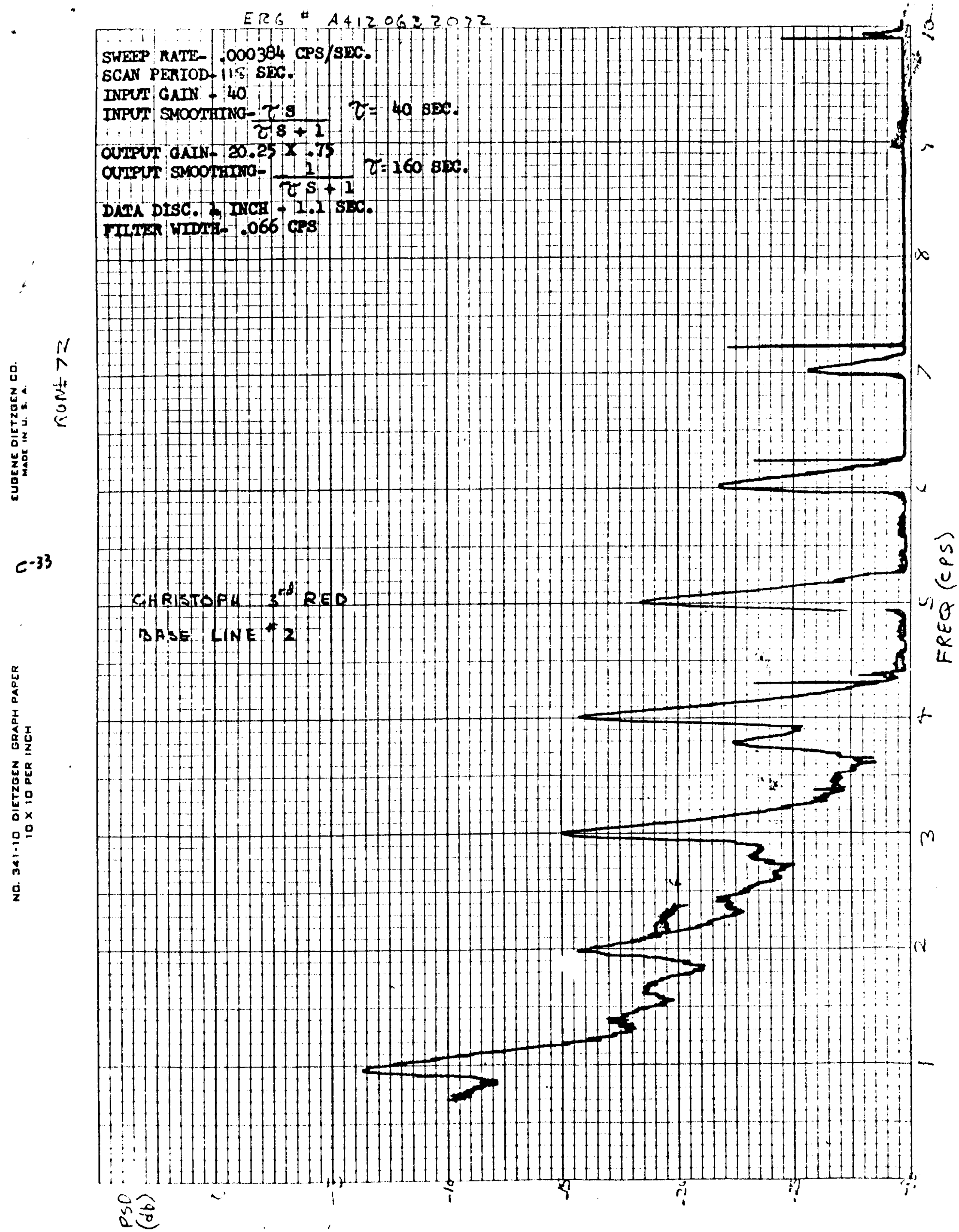


C-31

8/6/64

ERG # A4120672067





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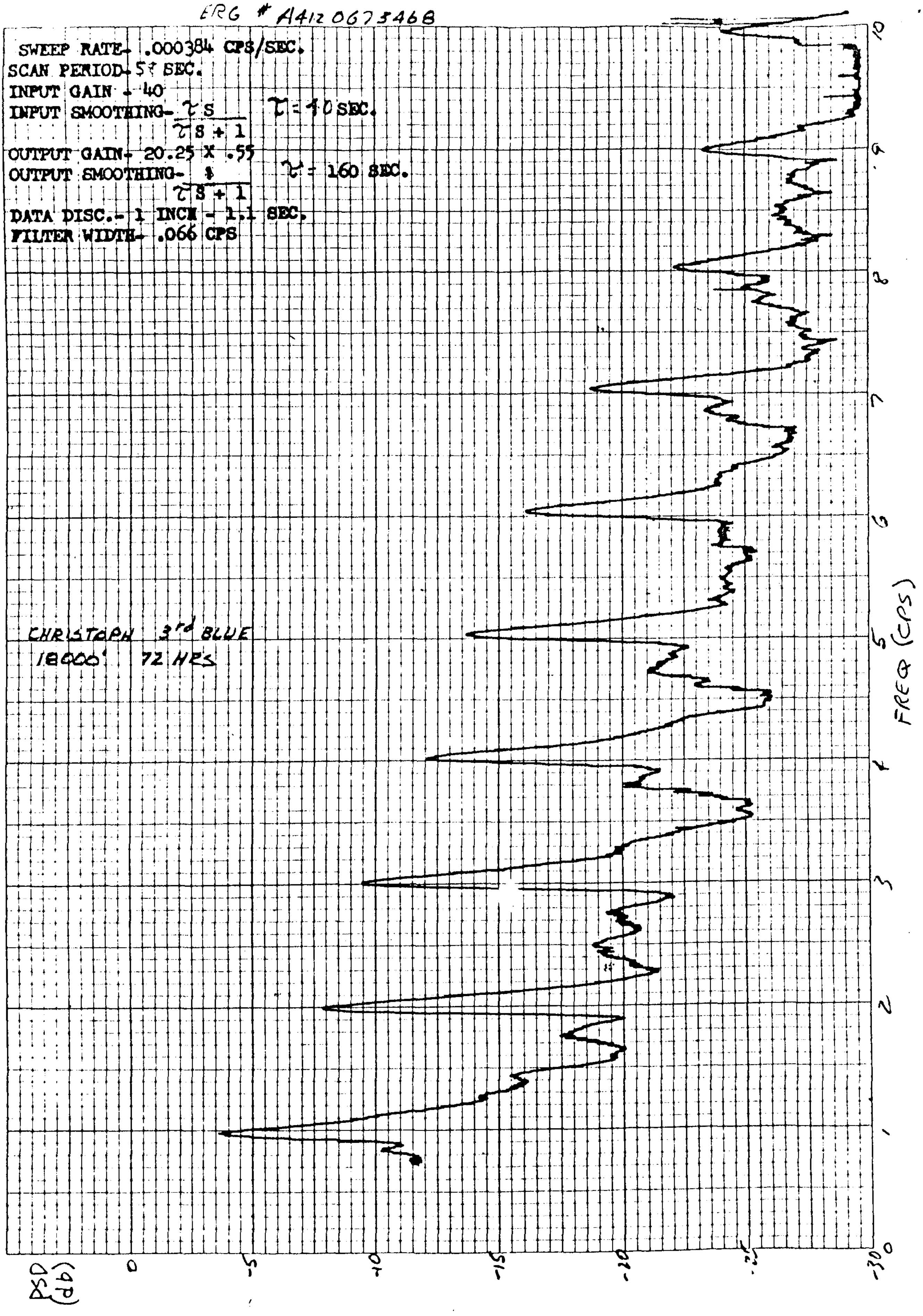
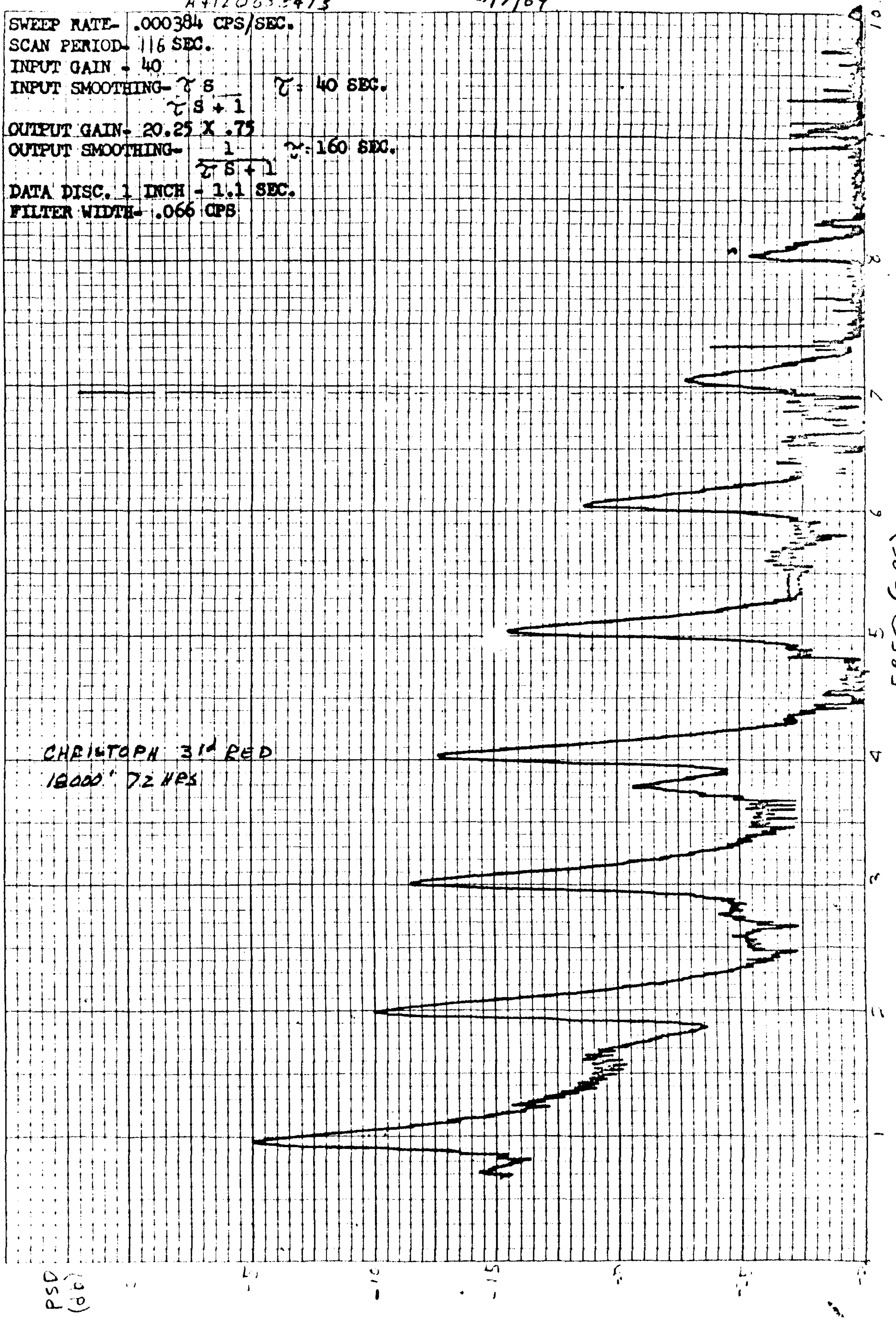
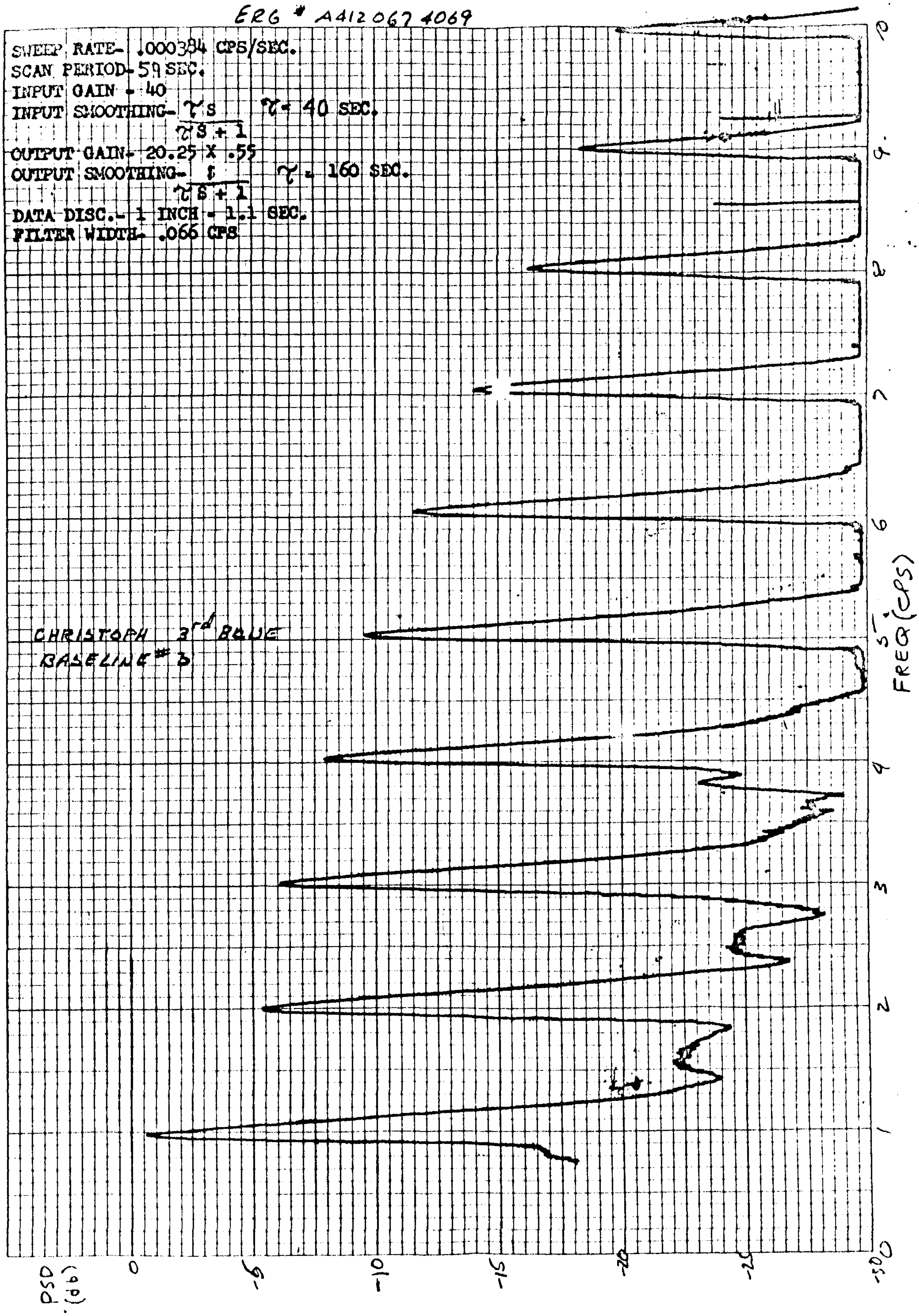
ERG # A412 067346B



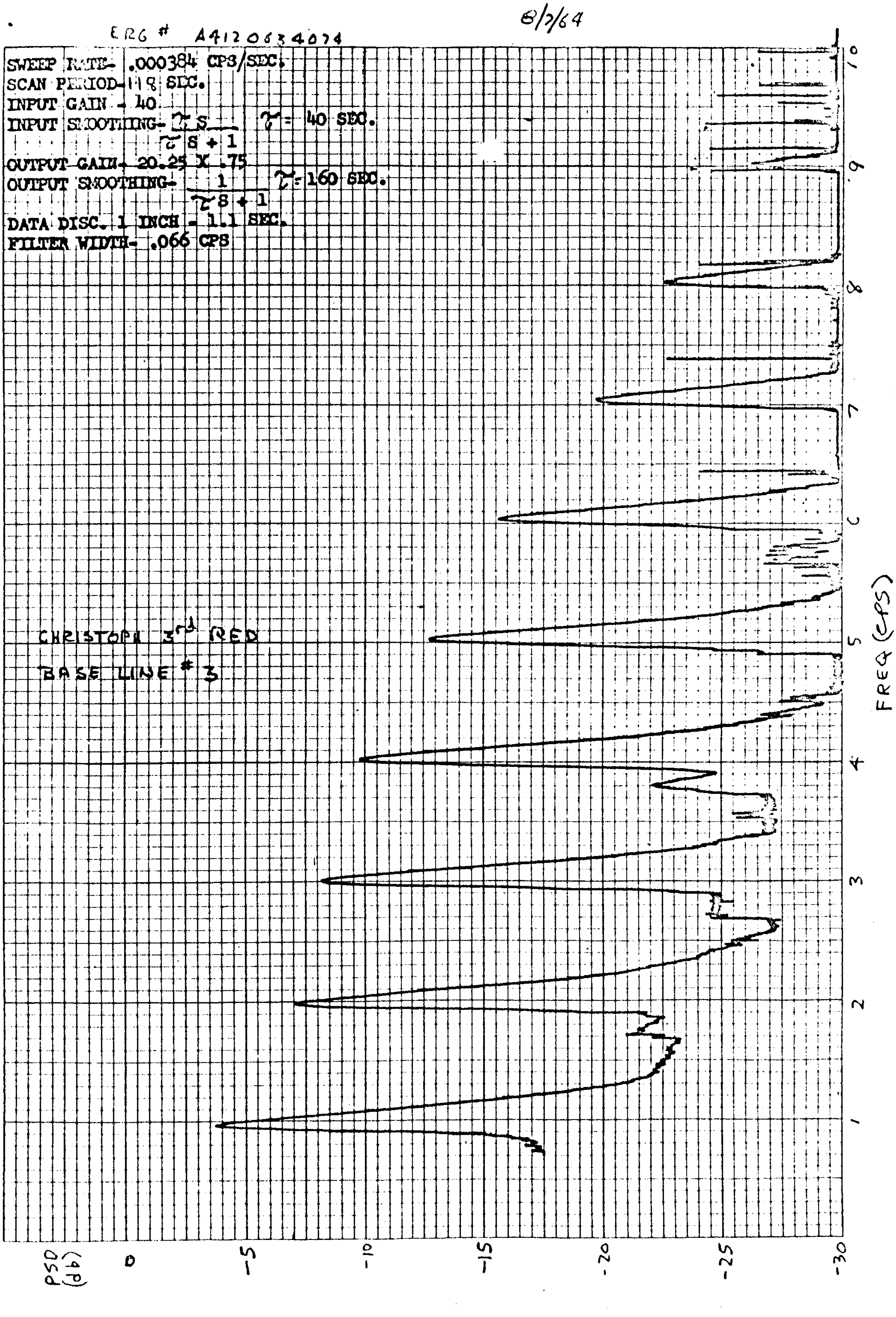
A4120633473 8/7/64

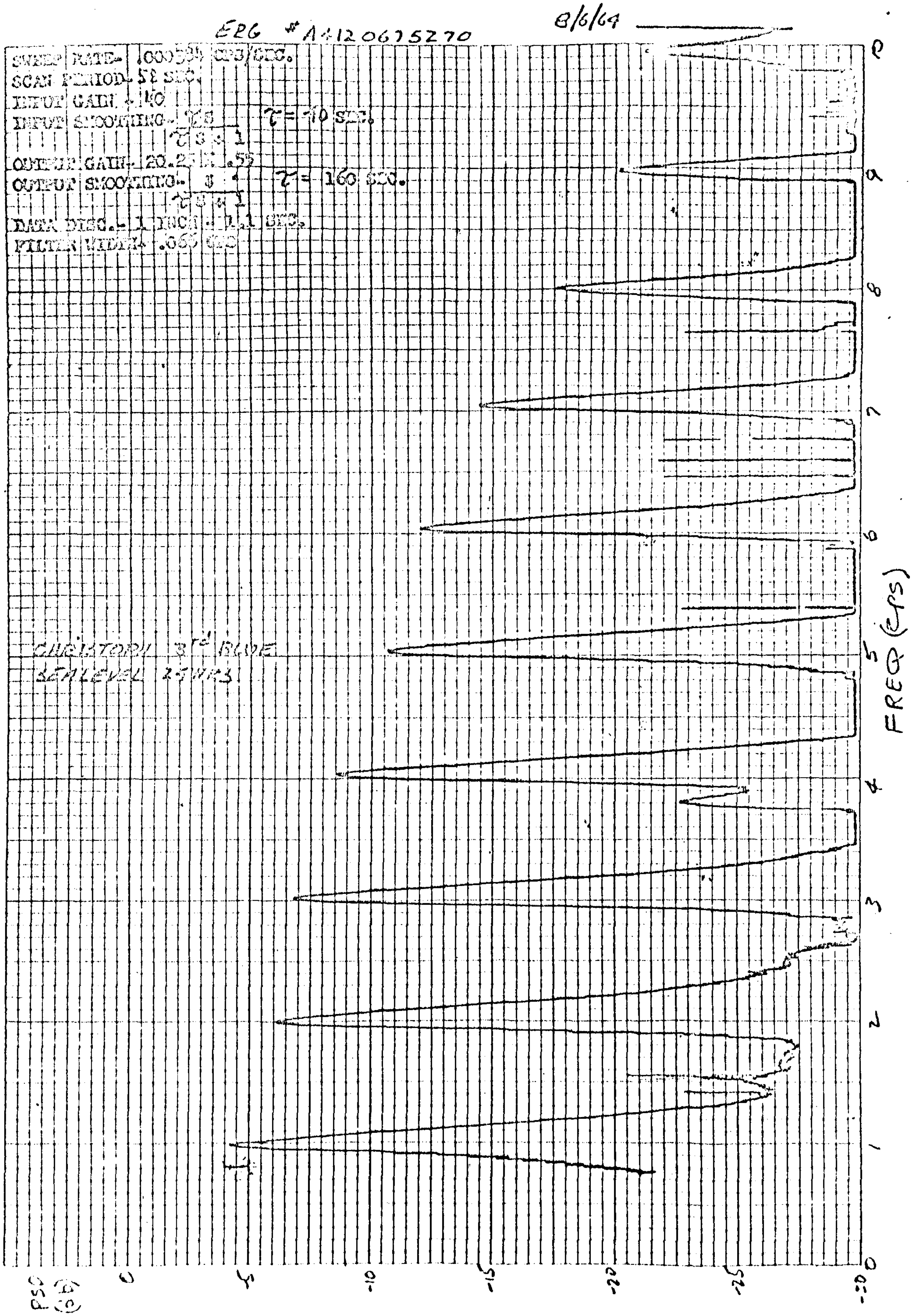


C-35


ERG # A4120674069
SWEEP RATE- .000384 CPS/SEC.
SCAN PERIOD- 59 SEC.
INPUT GAIN - 40
INPUT SMOOTHING- τs / τs + 1 τ= 40 SEC.
OUTPUT GAIN- 20.25 X .55
OUTPUT SMOOTHING- 1 / τs + 1 τ= 160 SEC.
DATA DISC.- 1 INCH = 1.1 SEC.
FILTER WIDTH- .066 CPS
CHRISTOPH 3rd BLUE
BASELINE #3
FREQ (CPS)
PSD (db)
0
-5
-10
-15
-20
-25
-30
0
1
2
3
4
5
6
7
8
9
10

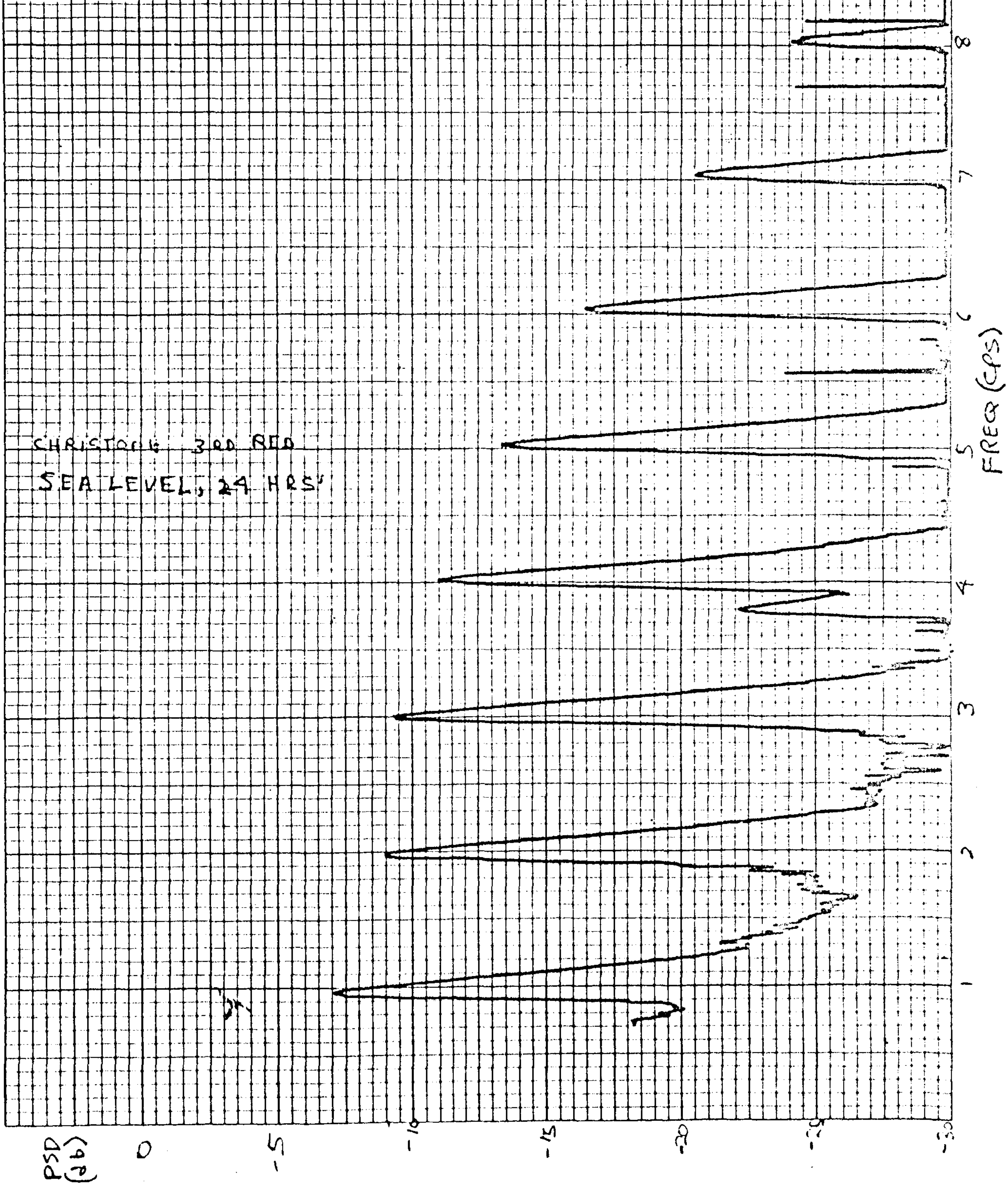
C-37


8/2/64
ERG # A41206 34074
SWEEP RATE- .000384 CPS/SEC.
SCAN PERIOD- 118 SEC.
INPUT GAIN - 40
INPUT SMOOTHING- τS / (τS + 1)   τ = 40 SEC.
OUTPUT GAIN- 20.25 X .75
OUTPUT SMOOTHING- 1 / (τS + 1)   τ = 160 SEC.
DATA DISC. 1 INCH - 1.1 SEC.
FILTER WIDTH- .066 CPS
CHRISTOPH 3rd RED
BASE LINE # 3
FREQ (CPS)
1
2
3
4
5
6
7
8
9
10
PSD (db)
0
-5
-10
-15
-20
-25
-30


ERG #A4120615270
8/6/64
SWEEP RATE- .000555 CPS/SEC.
SCAN PERIOD- 58 SEC.
INPUT GAIN - 40
INPUT SMOOTHING-
τ = 10 SEC.
OUTPUT GAIN- 20.25
OUTPUT SMOOTHING-
τ = 160 SEC.
DATA DISC.- 1 INCH - 1.1 SEC.
FILTER WIDTH- .066 CPS
FREQ (CPS)
0
1
2
3
4
5
6
7
8
9
0
-5
-10
-15
-20
-25
-30
PSD (db)

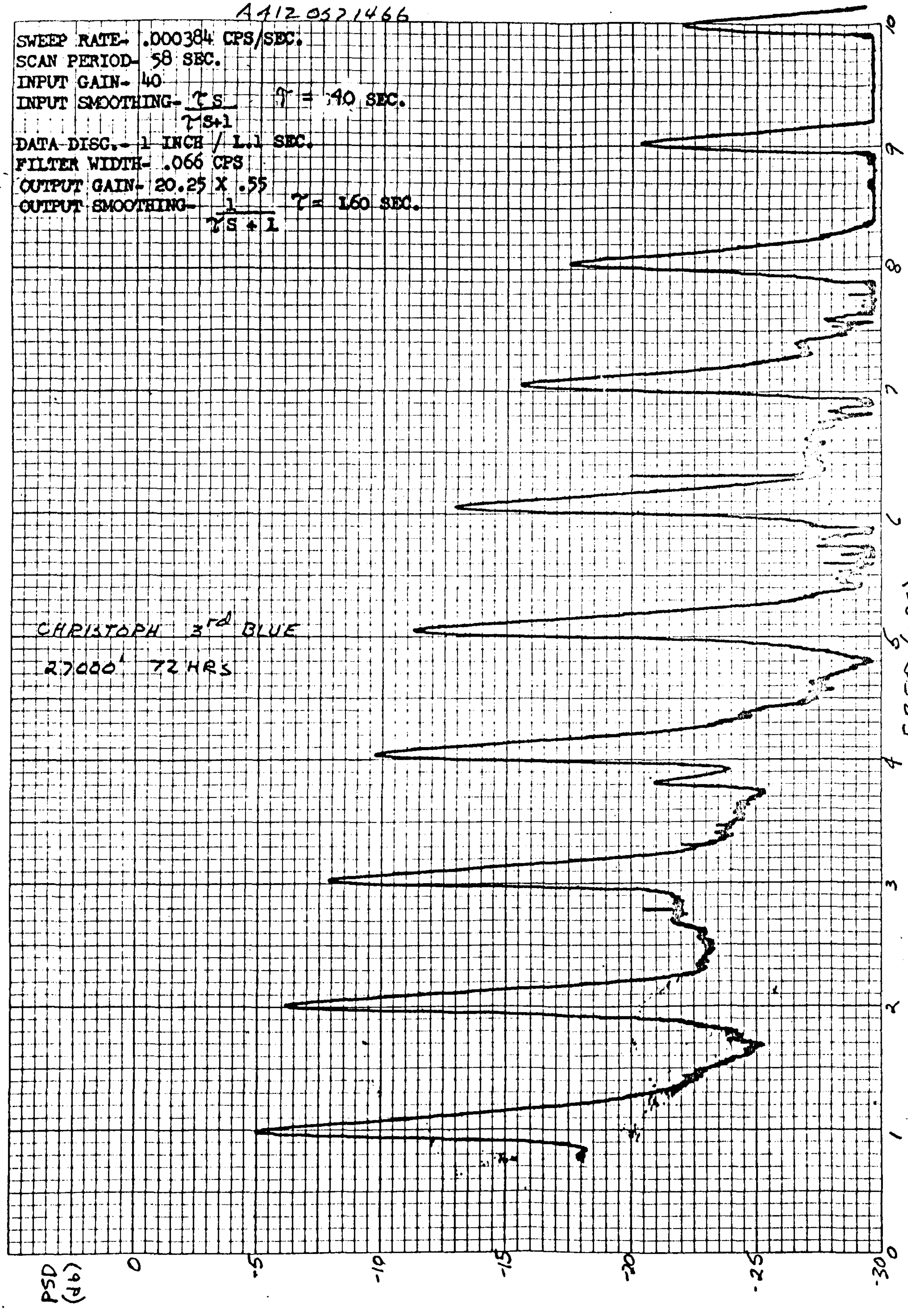
A 412 [illegible] 35275

SWEEP RATE- .000384 CPS/SEC.
SCAN PERIOD- 118 SEC.
INPUT GAIN - 40
INPUT SMOOTHING- $\frac{\tau s}{\tau s + 1}$ τ = 40 SEC.
OUTPUT GAIN- 20.25 X .75
OUTPUT SMOOTHING- $\frac{1}{\tau s + 1}$ τ = 160 SEC.
DATA DISC. 1 INCH - 1.1 SEC.
FILTER WIDTH- .066 CPS

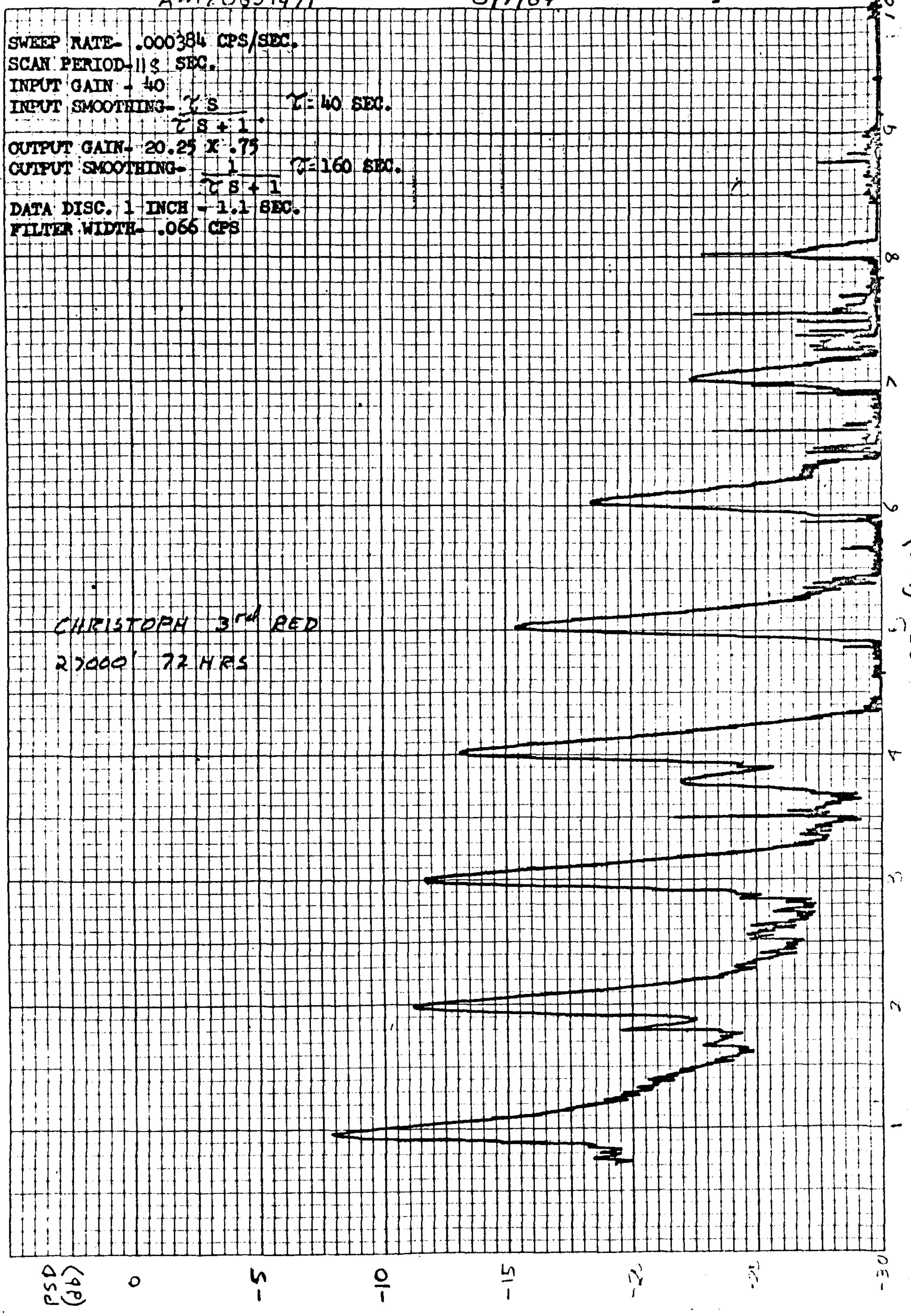


C-39

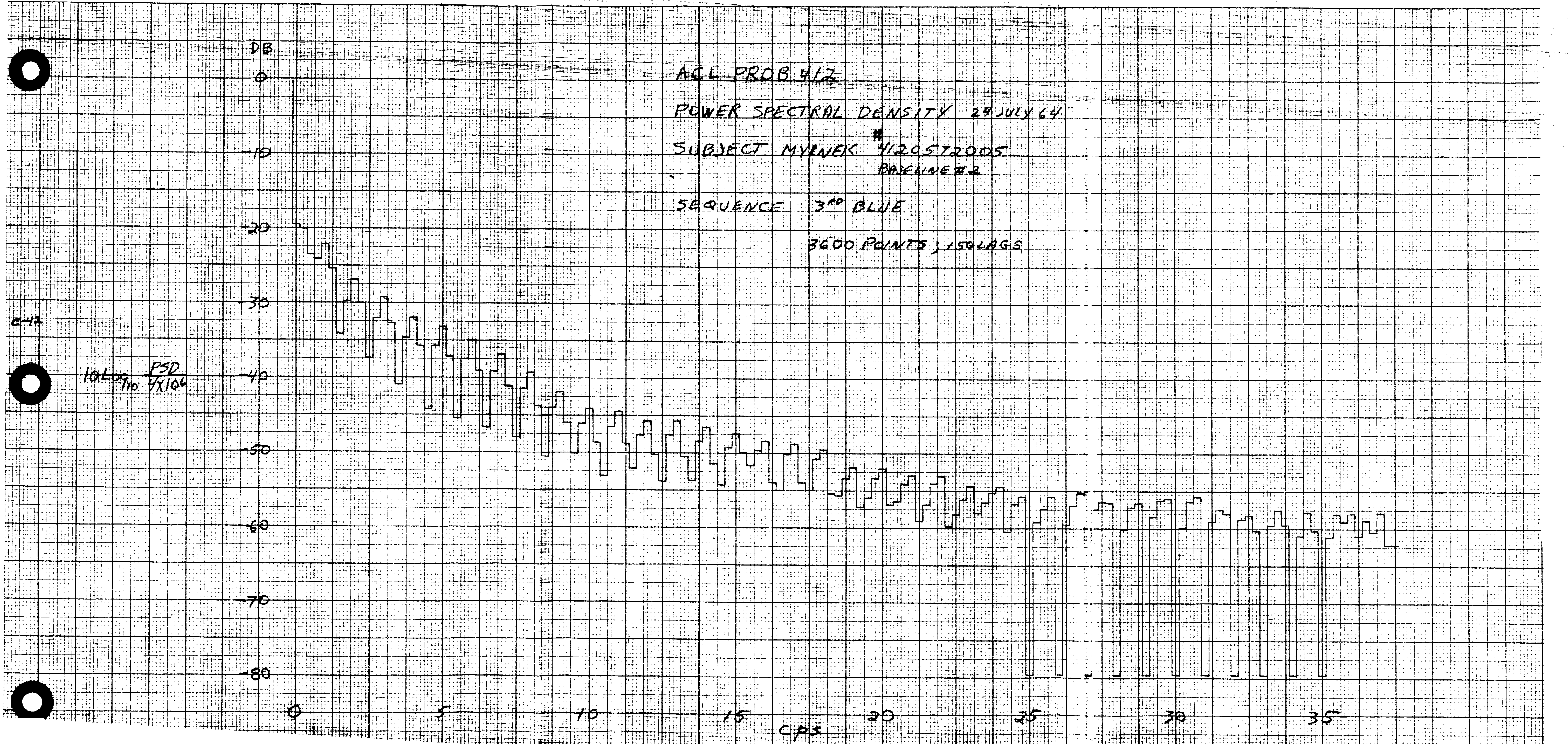
A4120521466

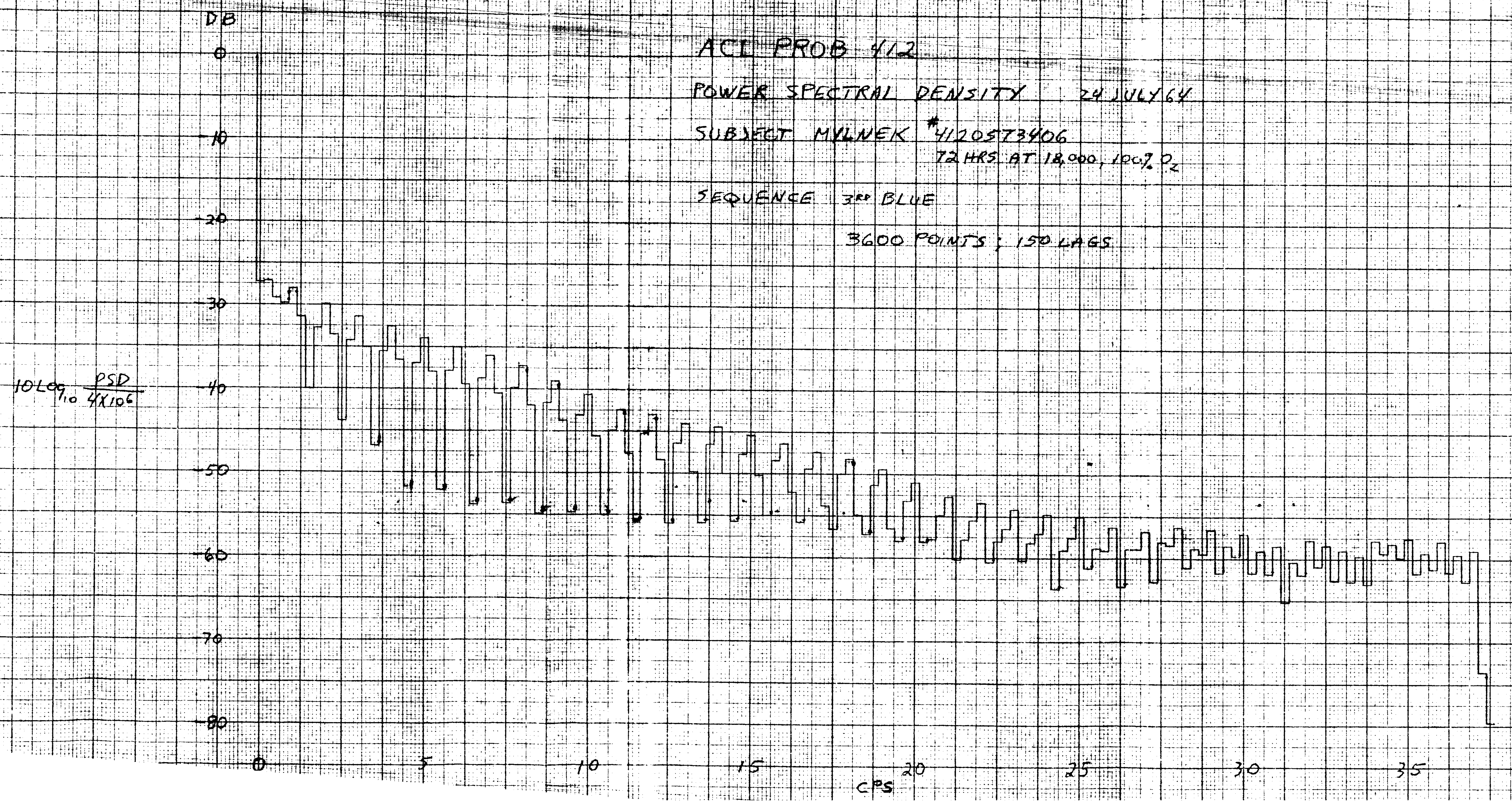


A4120631471 8/7/64



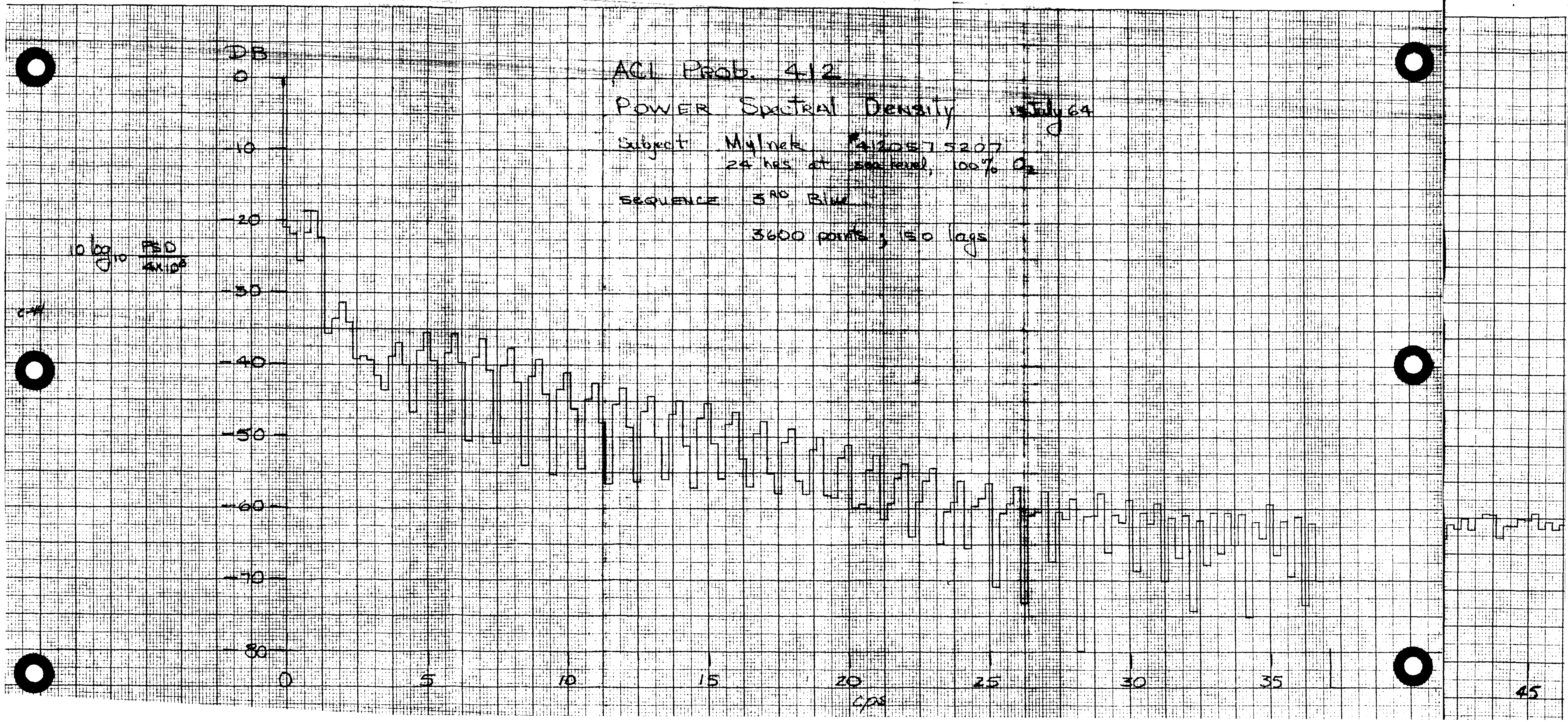
C-41


ACL PROB 412
POWER SPECTRAL DENSITY 29 JULY 64
SUBJECT MYRNEK #4120572005
BASELINE #2
SEQUENCE 3RD BLUE
3600 POINTS; 150 LAGS
DB
0
-10
-20
-30
-40
-50
-60
-70
-80
10 Log10 PSD/4x10^6
C-42
0
5
10
15
20
25
30
35
CPS



ACL PROB 412
POWER SPECTRAL DENSITY 24 JULY 64
SUBJECT MYLNEK #4120573406
72 HRS AT 18,000, 100% O2
SEQUENCE 3RD BLUE
3600 POINTS; 150 LAGS
DB
0
10
20
30
40
50
60
70
80
10 Log10 PSD/4X10^6
0
5
10
15
20
25
30
35
CPS

C-43



ACL PROB. 412
POWER SPECTRAL DENSITY July 64
Subject Mylnek
24 hrs at sea level, 100% O_2
SEQUENCE 3RD Blue
3600 points, 150 lags
DB
$10 \log_{10} \frac{PSD}{4 \times 10^{6}}$
0
-10
-20
-30
-40
-50
-60
-70
-80
0
5
10
15
20
25
30
35
45
cps

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Naval Air Development Center, Johnsville, Pa. Aeronautical Computer Laboratory	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE
Analog Power Spectral Density Analysis of Electroretinogram Data

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Technical Report

5. AUTHOR(S) *(Last name, first name, initial)*
Futterweit, A.
Dahms, J.G.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
10 November 1964	63	1

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) NADC-AC-6411
b. PROJECT NO. WEPTASK RAE13C005/2001/R005-0101	
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT

A technique for performing power spectral density analyses on physiological data is presented in this report. Electroretinograms were made and recorded on magnetic tape at the Air Crew Equipment Laboratory. Analog techniques were employed to analyze the electroretinogram data at the Naval Air Development Center.

DD FORM 1 JAN 64 1473

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
ELECTRORETINOGRAM POWER SPECTRAL DENSITY SPECTRAL ANALYZER OXYGEN ATMOSPHERE TOLERANCE						

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