NORTHEASTERN UNIVERSITY
DAY DIVISION
DEPARTMENT OF CO-OPERATIVE EDUCATION

Title

Using a Bombshot Analysis Technique to Determine Underwater Acoustic Transmission Characteristics

Submitted by

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(Name) (Class) (Div.) (College) (Curriculum or Major)

Due on

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(Date)

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(Name of Student's Co-ordinator)

Employed by

U. S. Navy Underwater Sound Laboratory
(Name of Firm)

Inspected and passed by ______________________
(Signature of Firm's Supervisor)

Co-ordinator's Record	
Title Approved by	Date
Date Received	
Grade	

Fort Trumbull
New London, Connecticut
April 7, 1965

Professor P. W. Dunphy
360 Huntington Avenue
Boston 15, Massachusetts

Dear Professor Dunphy:

In accordance with the requirements of the Department of Co-operative Education, I am submitting this report entitled, "Using A BombShot Analysis Technique To Determine Underwater Acoustic Transmission Characteristics" covering my activities as a Student Aid from February to April 1965 in the Systems Development Branch at the U. S. Navy Underwater Sound Laboratory.

This report represents an attempt to determine acoustic path characteristics by means of correlating known, underwater acoustical data with that obtained experimentally. In doing this, it was found that, for certain area of ocean, the transmission characteristics were "normal" and therefore satisfactory.

Sincerely,

JEROME A. SCHWELL

OUTLINE

The Systems Development Branch of the U. S. Navy Underwater Sound Laboratory has undertaken the project of installing a permanent acoustic projector in the Atlantic ocean in order to facilitate future underwater acoustic research.

Data from previous tests held in the area of interest have seemed to indicate that the acoustical characteristics in the immediate area of the projector are not suitable for Laboratory use. There seemed to be a sensitivity to high frequencies; that is, an unusually rapid rolloff. In order to verify this supposition, a detailed study of underwater explosions in the area of interest was conducted. These explosions were recorded on magnetic tape several hundred miles away. These recordings were analyzed for frequency content and compared to other explosions detonated out of the area in question, but of negligible distance when compared to the total range of transmission. Bombs were dropped at 4 stations, henceforth labled as A-1, A-4, A-5 and A-6 respectively. Stations A-1 and A-4 were within the area under scrutiny; the remaining two were to be used as standards. Figure 11 is a diagram of the stations locations.

In order to properly interpret the results of this analysis, several factors must be known, such as the mechanics and spectrum of an underwater bomb shot, the absorbtion characteristics of the ocean and the ambient noise levels of the sea.

When an explosion is detonated underwater, a spherically symmetrical bubble is formed by the high-pressure incandescent gasses of the explosion. This bubble appears almost instantly and expands outward until a point is reached where a slightly negative radial pressure occurs. Due to the inertia of the water, the bubble's radius slightly overshoots its

RELATIVE LOCATIONS

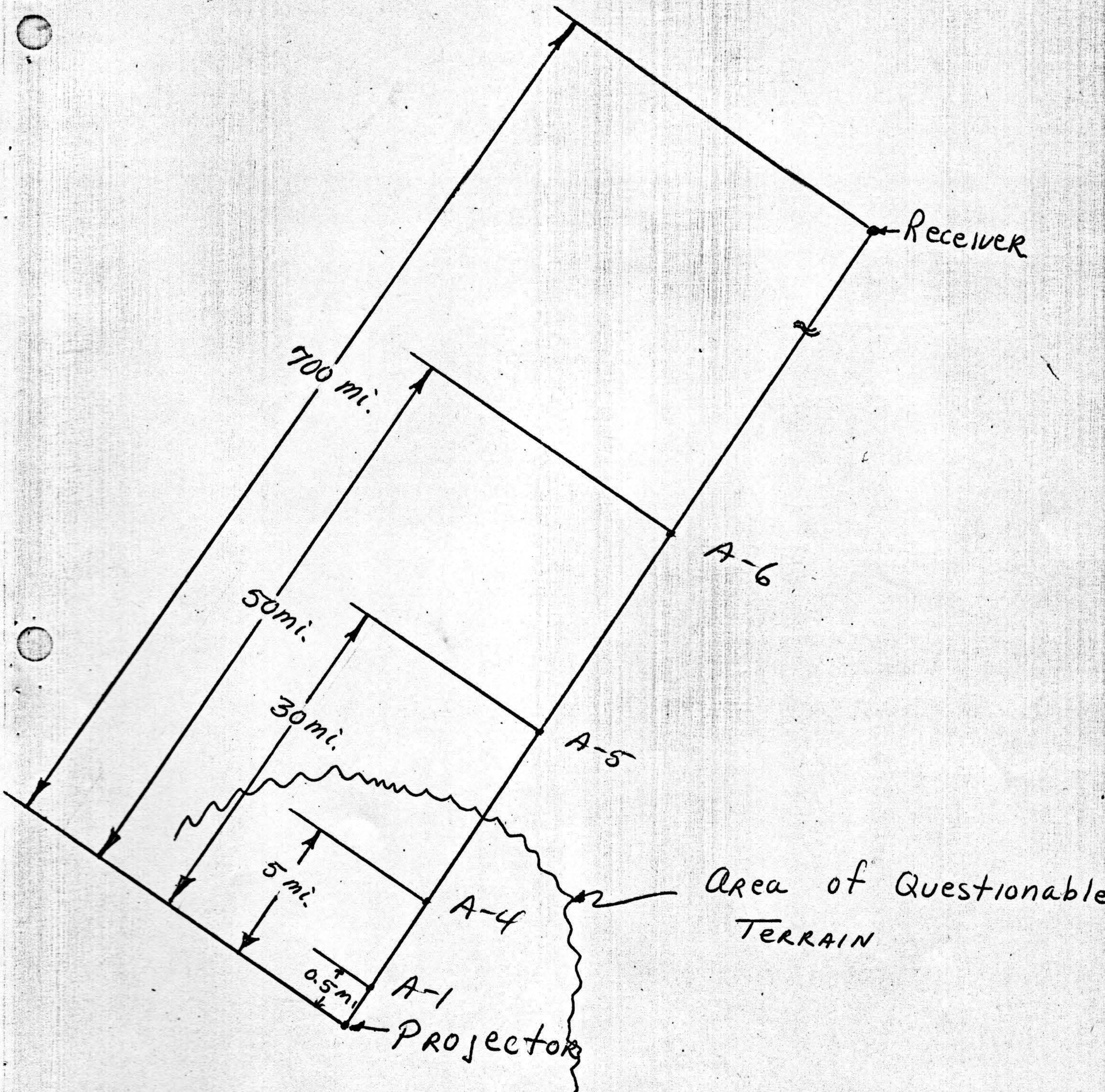


Fig. 11

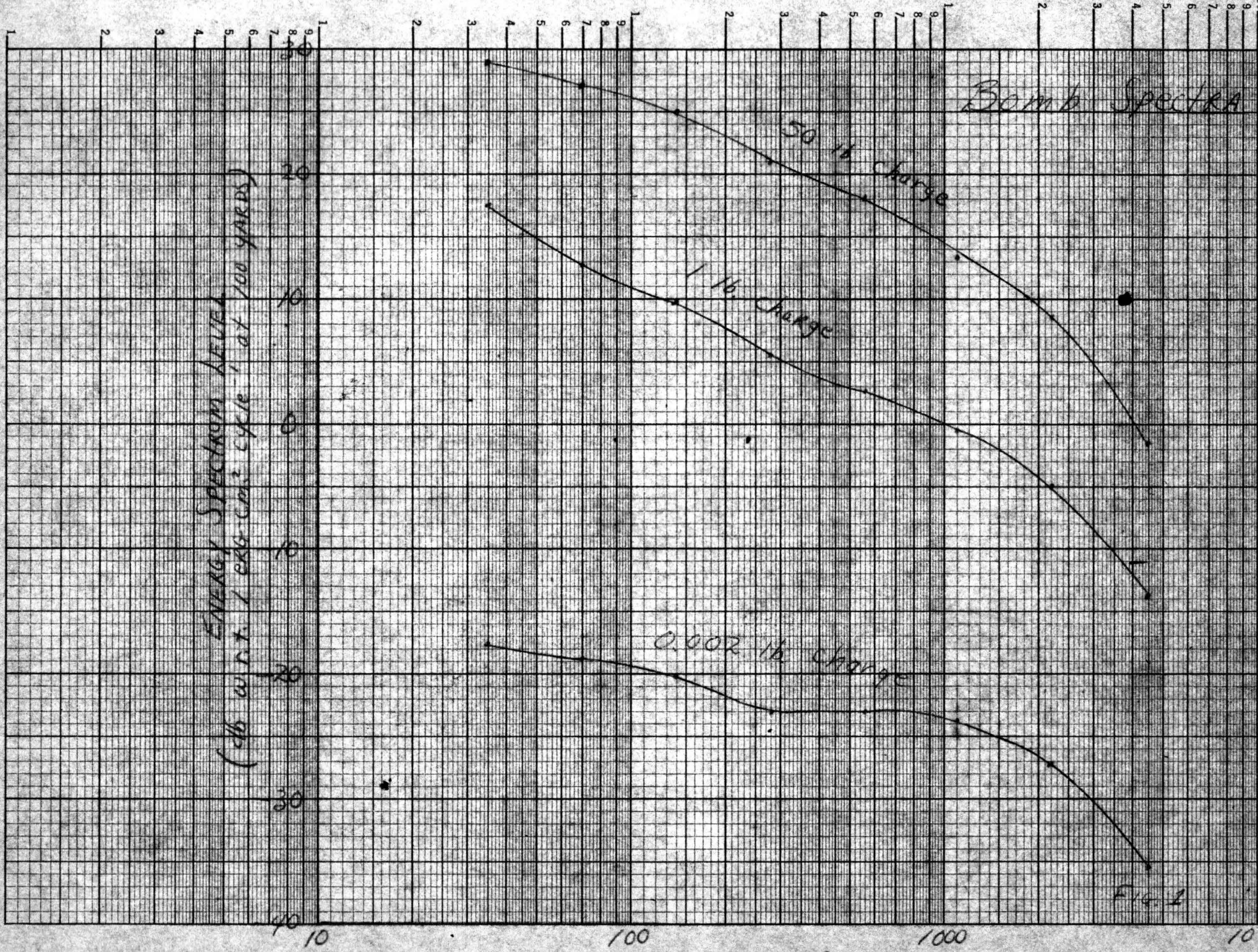
equilibrium point, and a slight damped oscillation occurs, with the large initial bubble breaking into several smaller ones. Each of these smaller bubbles now contributes its own pressure pulse whose amplitude is much smaller than that of the initial pulse but whose duration is longer. According to Fourier Analysis, the large initial pulse contains a wider band of frequencies than any of the smaller secondary pulses. When all the contributions are summed, the spectrum of the bomb is obtained. As might be expected, the bulk of the energy lies in the lower frequencies. An actual bomb spectrum is shown in figure 1.[1] The graph shows an approximate slope of -4.5 db/octave. The data for this plot was obtained experimentally at a distance of 100 yards from the detonation point so that transmission losses may be safely neglected.

Other factors which must be known are characteristics of the medium. The first of these is the absorbtion of sound in seawater as a function of frequency. Figure 2.

Since the distances from the various points of detonation to the point of reception are essentially the same for all cases, this factor reduces to a function of frequency.

Large deviations from this absorbtion curve would be functions of the ocean bottom, since this curve was derived under conditions of a normal ocean terrain.

The third and final condition of the medium which must be known is the ambient noise level. Figure 3[3] shows the normal curve of ambient underwater noise for various sea states. Meterological data taken at the time of the bomb shots showed that the sea states were constant for each station and the curves of ambient noise as obtained in the present analysis verifies this.


Bomb Spectra
50 lb charge
1 lb charge
0.002 lb charge
ENERGY SPECTRUM LEVEL
(db w.r.t. 1 erg/cm² cycle⁻¹ at 100 yards)
30
20
10
0
10
20
30
40
10
100
1000
10⁴
FREQUENCY (c/s)
Fig 1

WESTON, 1960

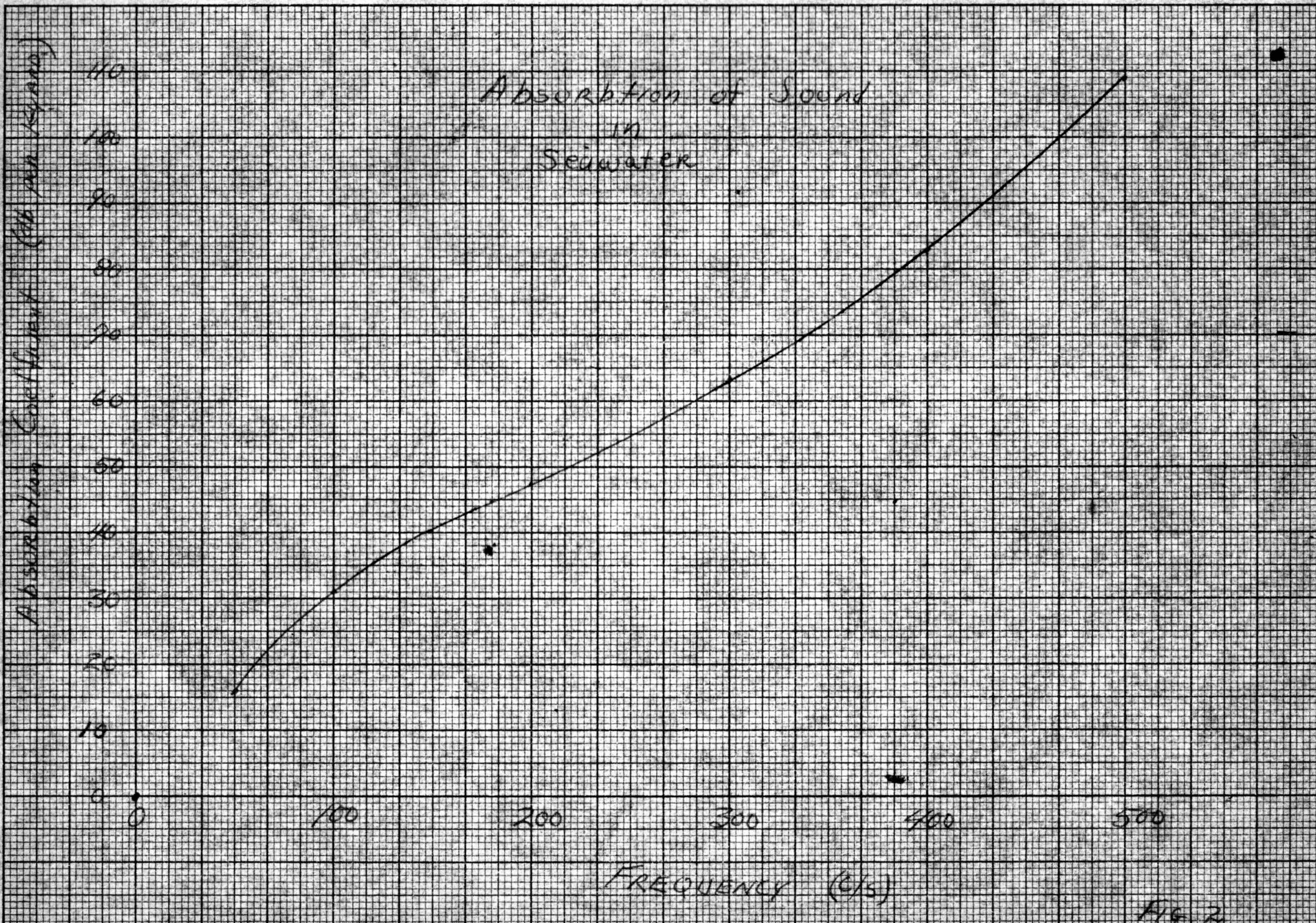
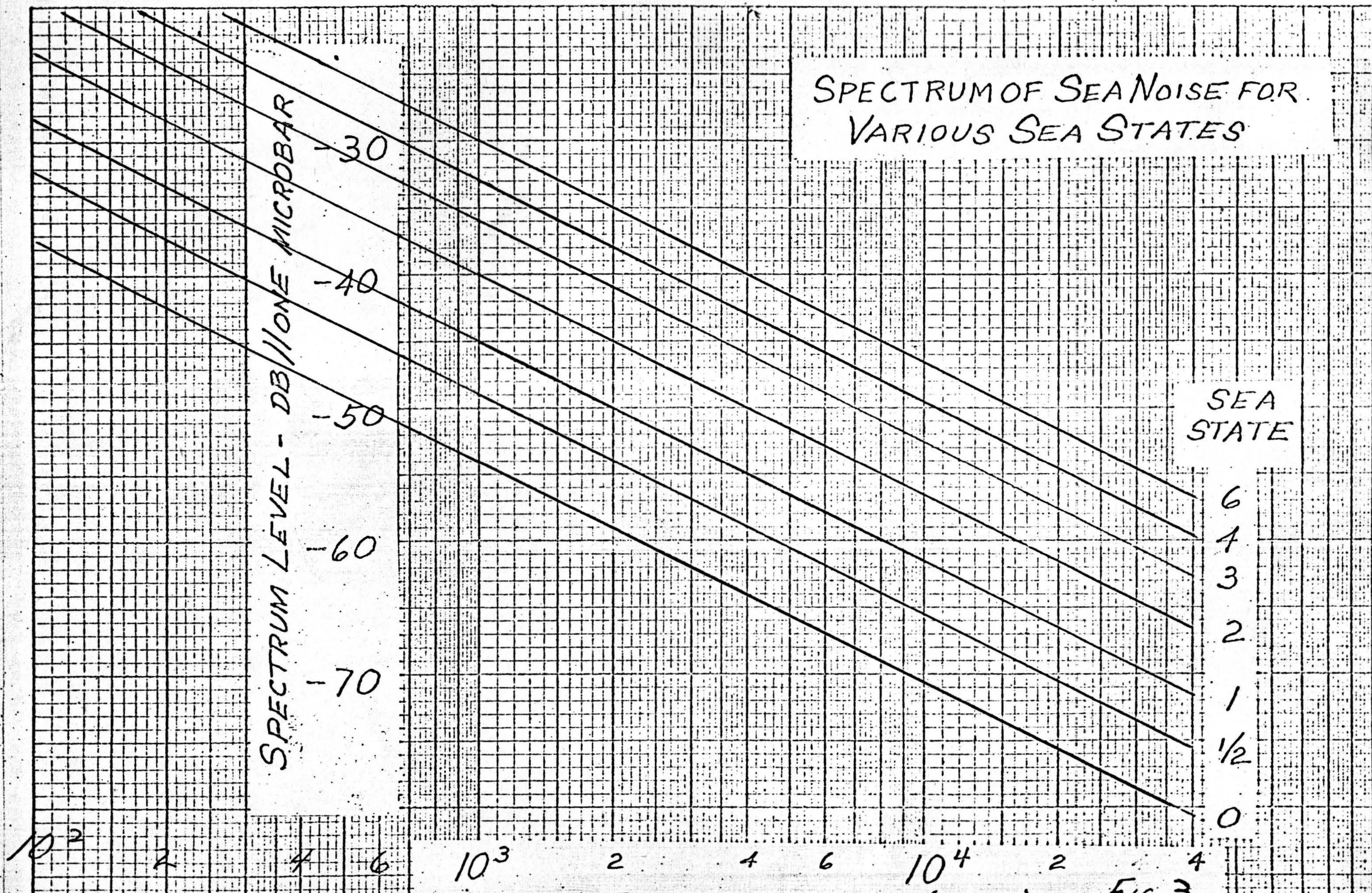


Fig 2

Horton, P. 81


SPECTRUM OF SEA NOISE FOR VARIOUS SEA STATES
SPECTRUM LEVEL - DB//ONE MICROBAR
-30
-40
-50
-60
-70
SEA STATE
6
4
3
2
1
1/2
0
10^2
2
4
6
10^3
2
4
6
10^4
2
4
FREQUENCY (CPS)
USL SPEC NO 306
FIG. 3

The analysis system consisted of a magnecord tape recorder to facilitate repetition of the raw data, feeding a variable filter of 50 cycle bandwidth (General Radio #1900-A). The output of this was fed to a General Radio #1521 Graphic Level Recorder. A typical plot is shown in figure 4. The upper curve is centered at 150 cycles and the lower is the same bomb shot at 350 cycles. It can be readily seen that the level is considerably attenuated and in the third plot, which is centered at 500 cycles the bomb's energy is so low as to be "lost" in the noise.

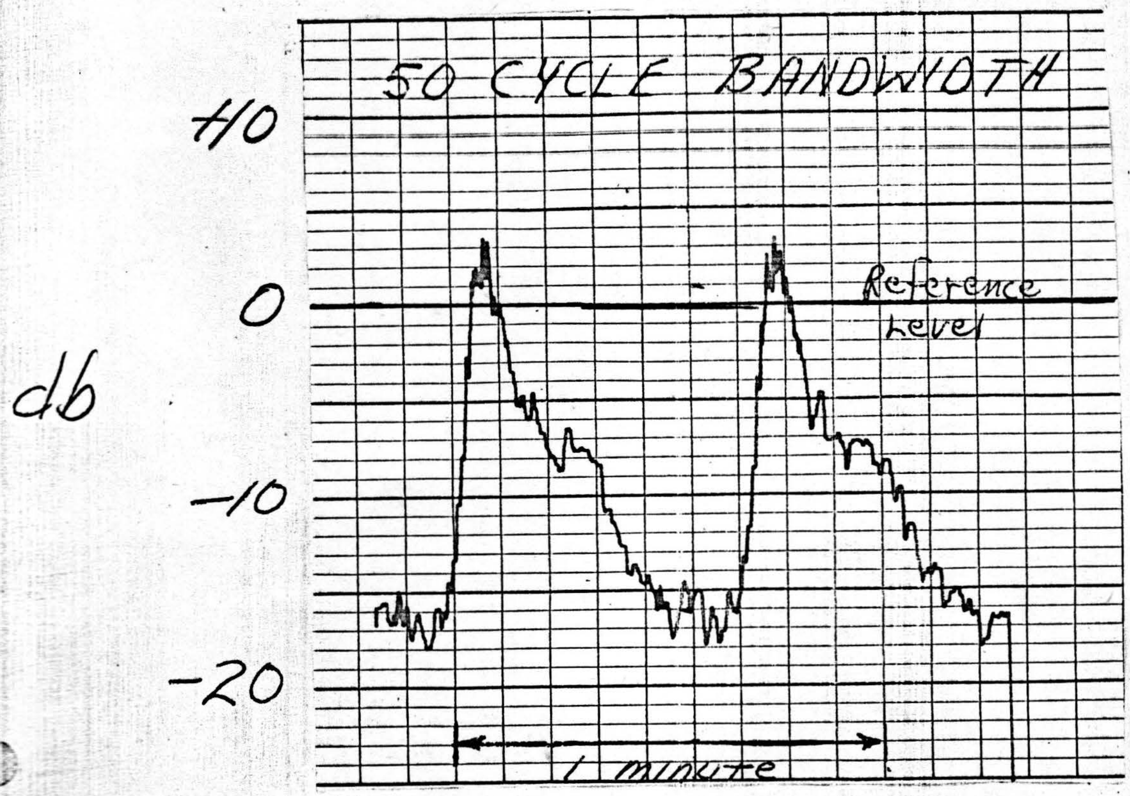
In tabulating the data from the above plots, a value of "0 db" was arbitrarily set on the center line since it is only the relative values of signal and noise that are of interest.

The value of the signal was taken to be that of the average of the peaks, since two similar bombs were dropped in each case. The value of ambient noise was similary derived as the average level. The tabulated values for all the stations are shown in figure 5. Figures 6 through 9 are of both signal and noise at each of the four stations. These plots show a definite peaking in the vicinity of 200 cycles, but since the same peaking occurs in the noise levels, it is probably due to the response of the receiving system rather than that of the transmission characteristics of the acoustic range.

Figure 10 is a summary of the above data, the various signal-to-noise ratios at each station. It can be readily seen from this plot that there is no significant difference between the reception from stations A-1 and A-4, and A-5 and A-6, therefore it can be concluded that the acoustic range under question is suitable for experimental use. Because of the expanded vertical scale apparent irregularities appear, but these deviations

SPECTRAL BOMB PLOTS

150 CYCLES CENTER FREQ.



350 CYCLES C. F.

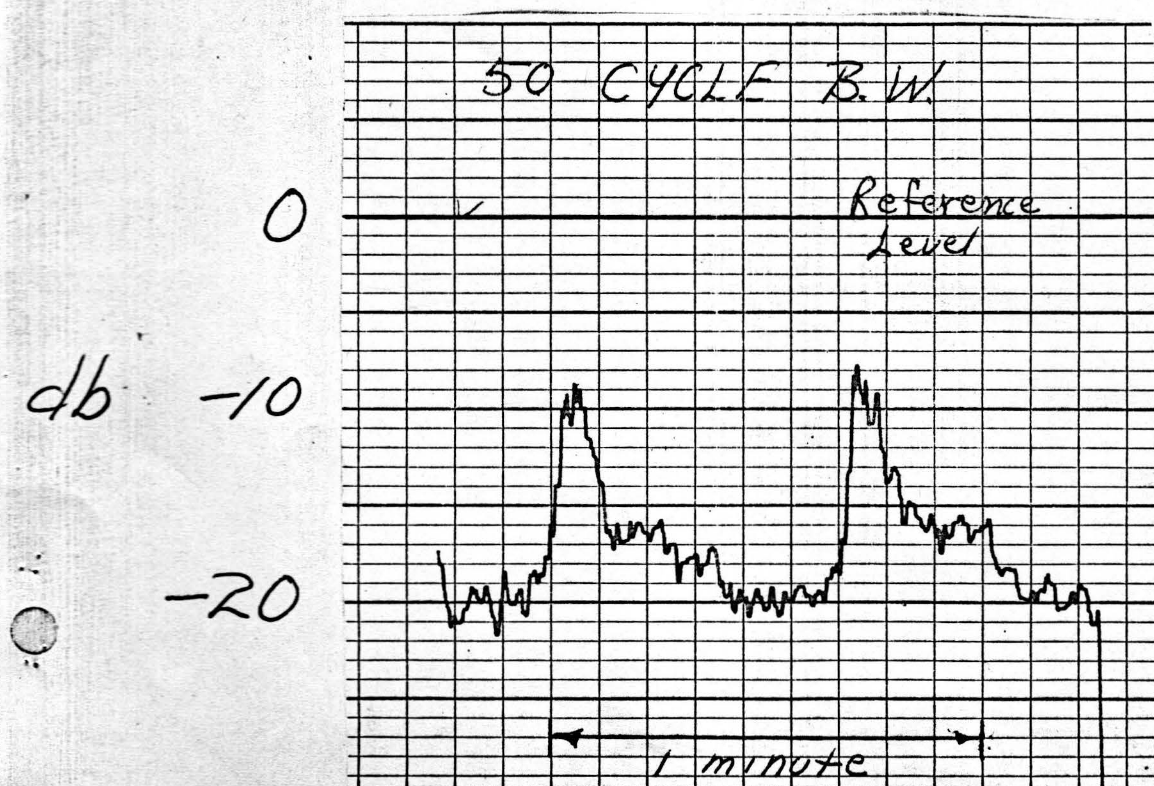
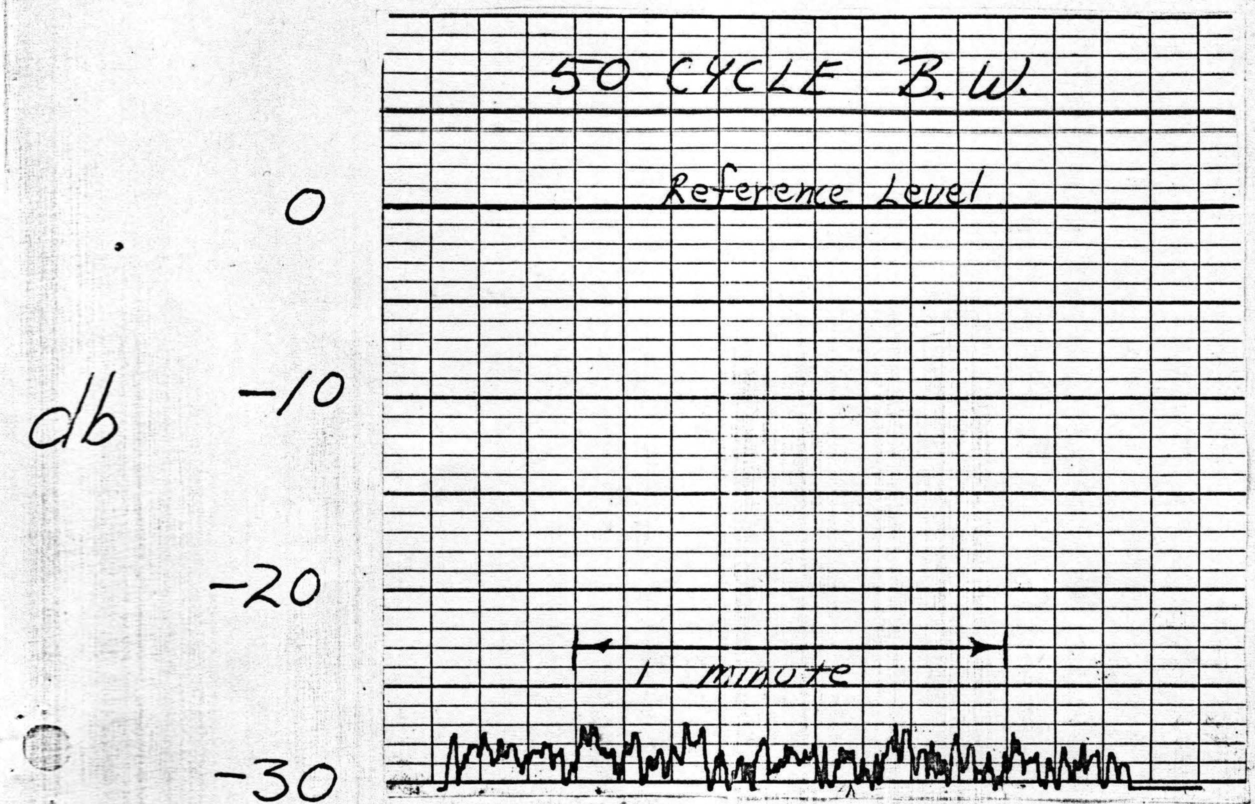


Fig. 4

500 CYCLES C. F.



Tabulated Data (db)

Station	A_1		A_4		A_5		A_6	
Frequency (c/s)	Sig.	Noise	Sig	Noise	Sig.	Noise	Sig.	Noise
50	+3	-13	+3	-12	+1	-13	+1	-13
100	+5	-13	+6	-14	+4	-14	+4	-14
150	+5	-11	+6	-11	+6	-12	+4	-11
200	+7	-10	+9	-11	+5	-12	+5	-11
250	-4	-14	-2	-15	-3	-16	-5	-14
300	-10	-18	-10	-20	-11	-20	-10	-19
350	-16	-21	-16	-22	-18	-23	-17	-21
400	-22	-24	-21	-25	-23	-25	-22	-24
450	-26	-27	-27	-26	-27	-27	-27	-26
500	≤ -28	-28	≤ -29	-29	≤ -29	-29	≤ -28	-28

Fig. 5

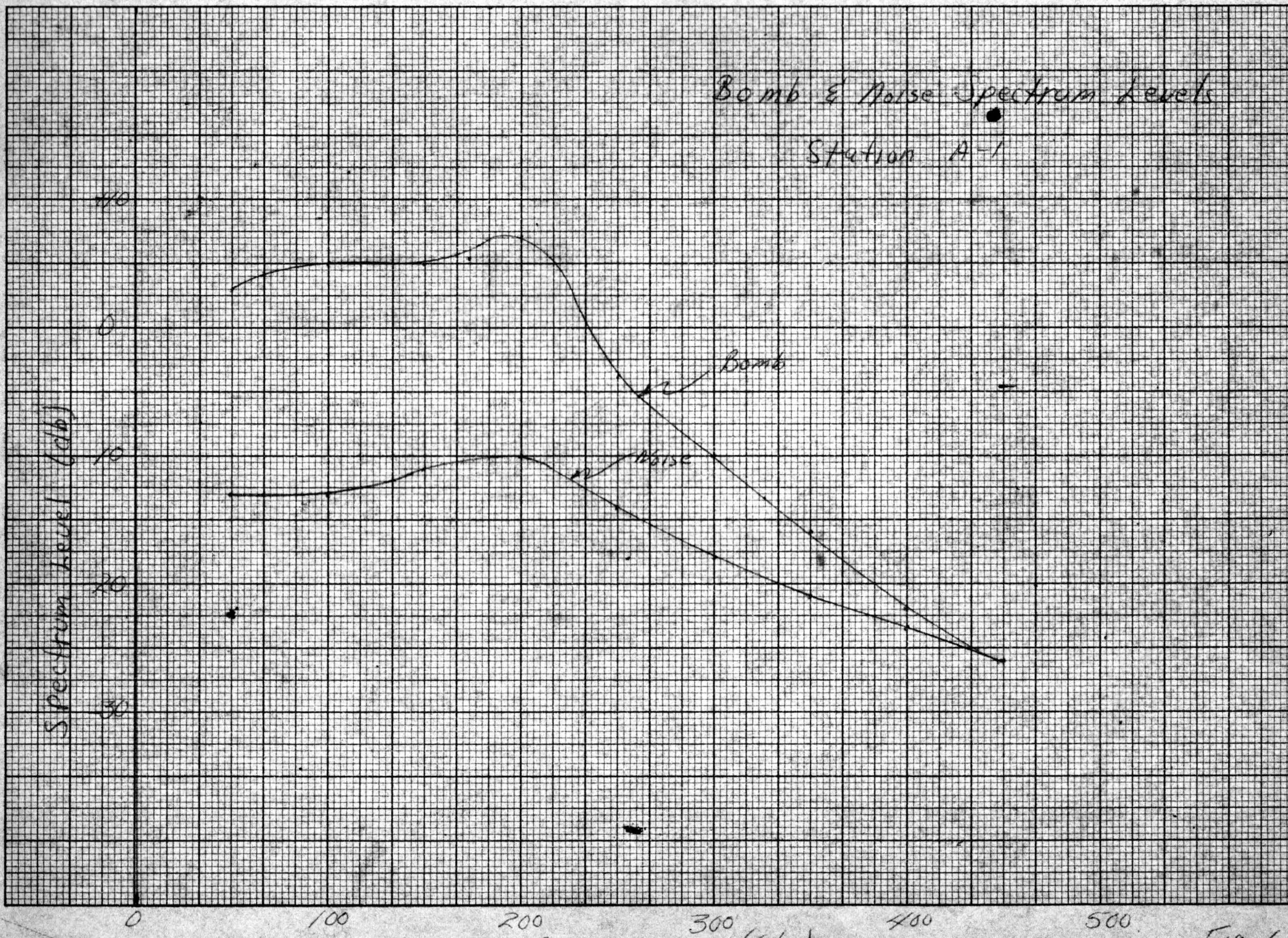
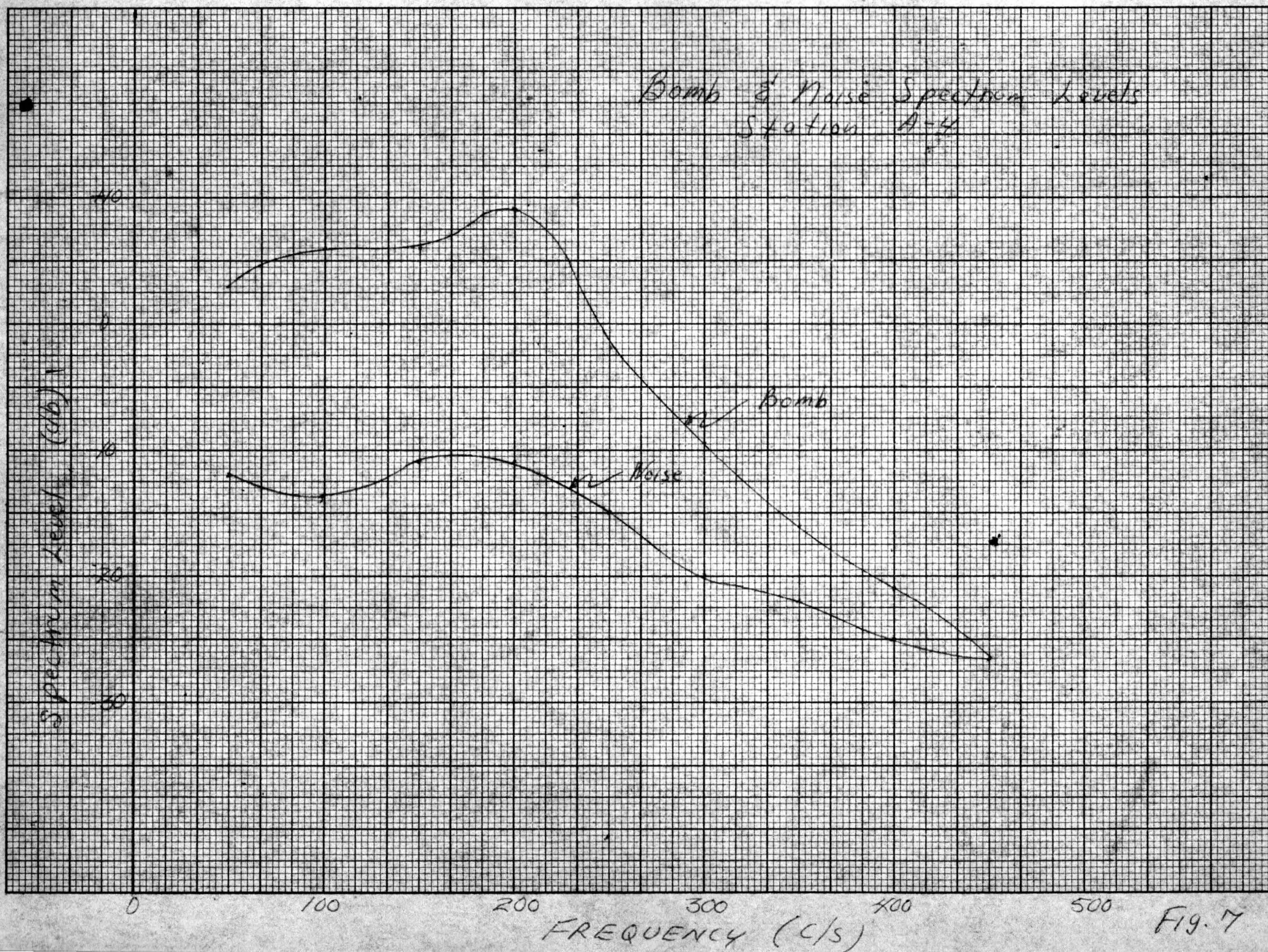

Bomb & Noise Spectrum Levels
Station A-1
Bomb
Noise
Spectrum Level (db)
40
0
10
20
30
0
100
200
300
400
500
FREQUENCY (c/s)

Fig. 6

5 A-4



Bomb & Noise Spectrum Levels
Station A-4
Bomb
Noise
40
0
10
20
30
Spectrum Level (db)
0
100
200
300
400
500
FREQUENCY (C/S)

Fig. 7

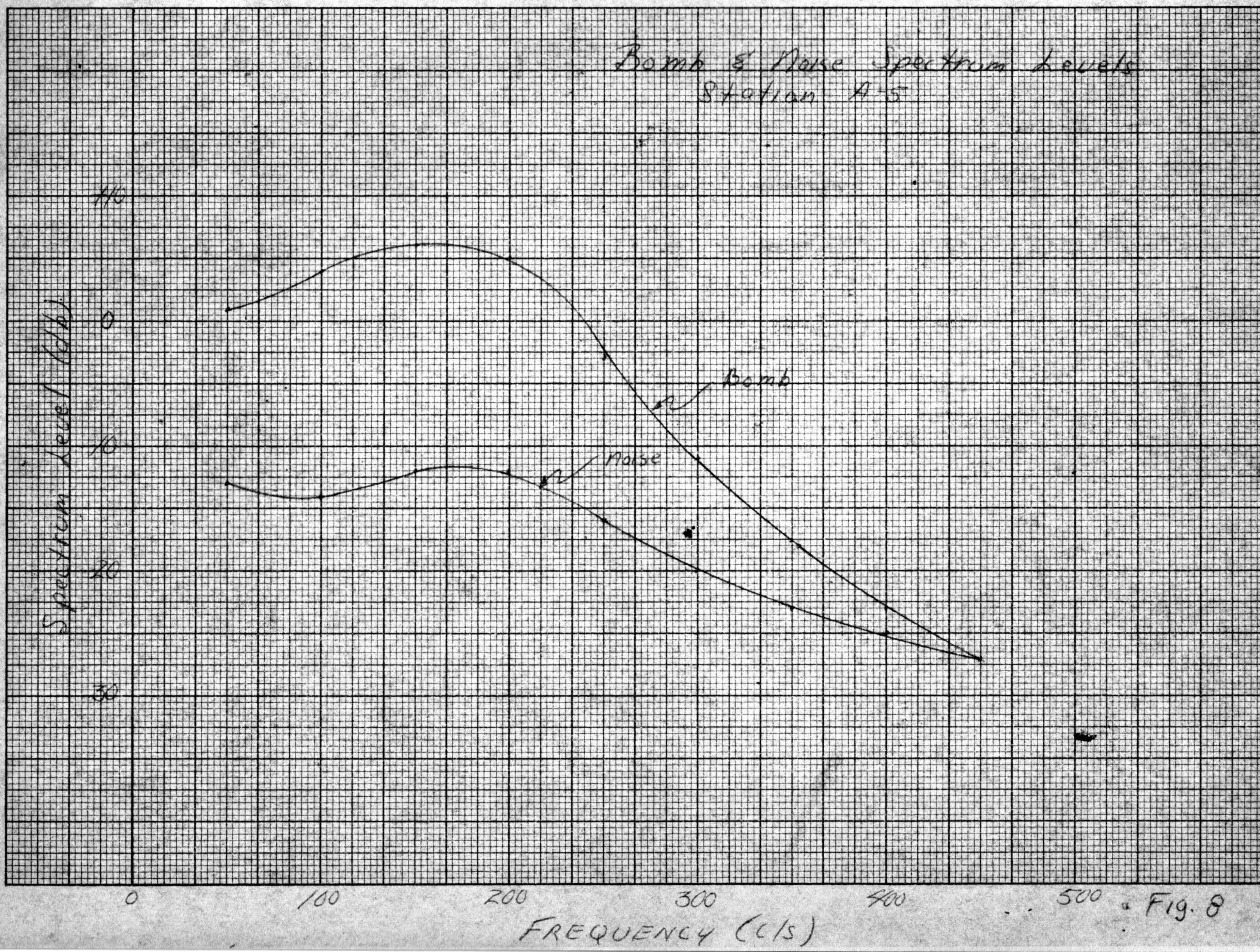

Bomb & Noise Spectrum Levels
Station A-5
Spectrum Level (db)
+10
0
10
20
30
Bomb
Noise
0
100
200
300
400
500
FREQUENCY (c/s)

Fig. 8

A-6

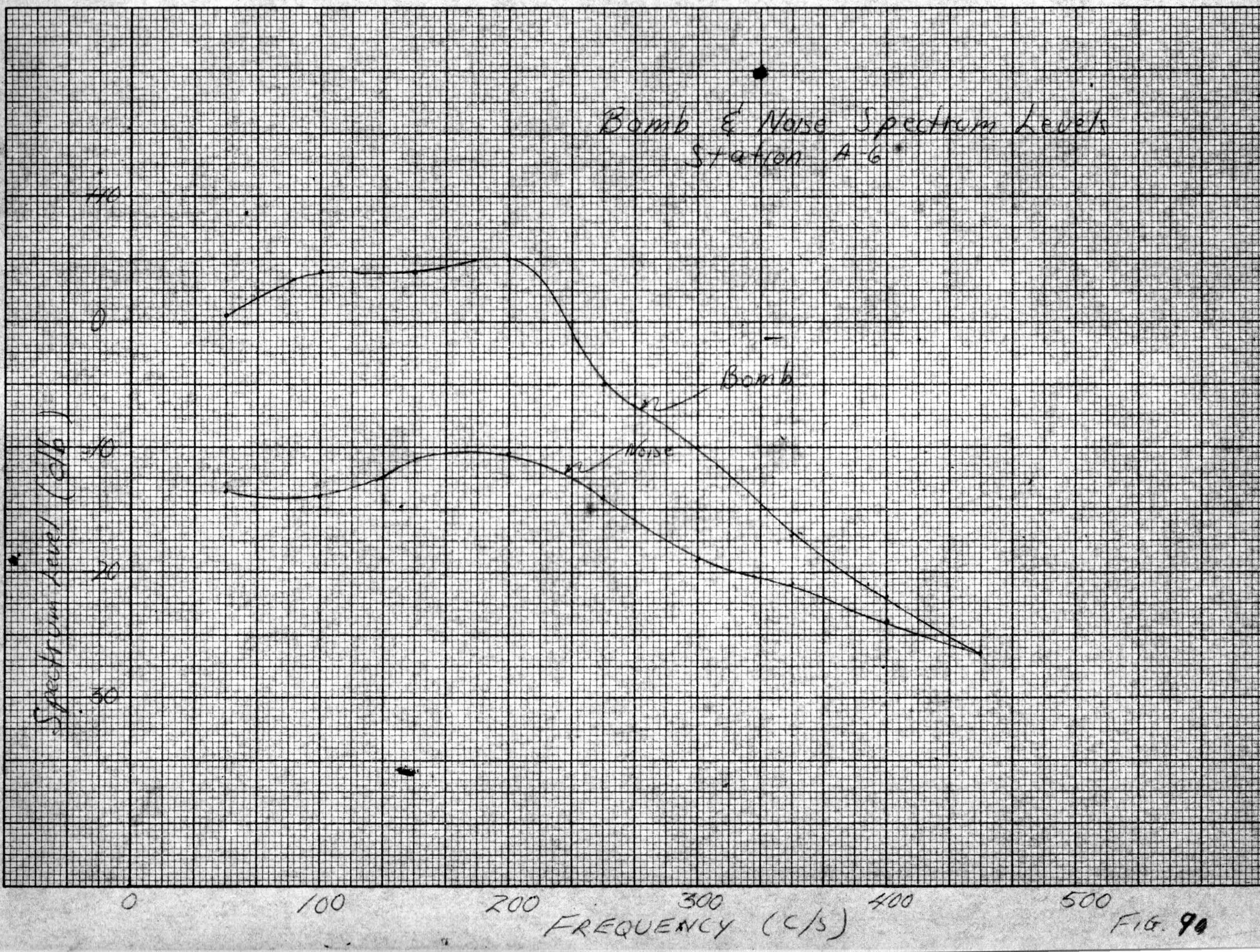

Bomb & Noise Spectrum Levels
Station A-6
+10
0
-10
-20
-30
Spectrum Level (db)
Bomb
Noise
0
100
200
300
400
500
FREQUENCY (C/S)

FIG. 9a

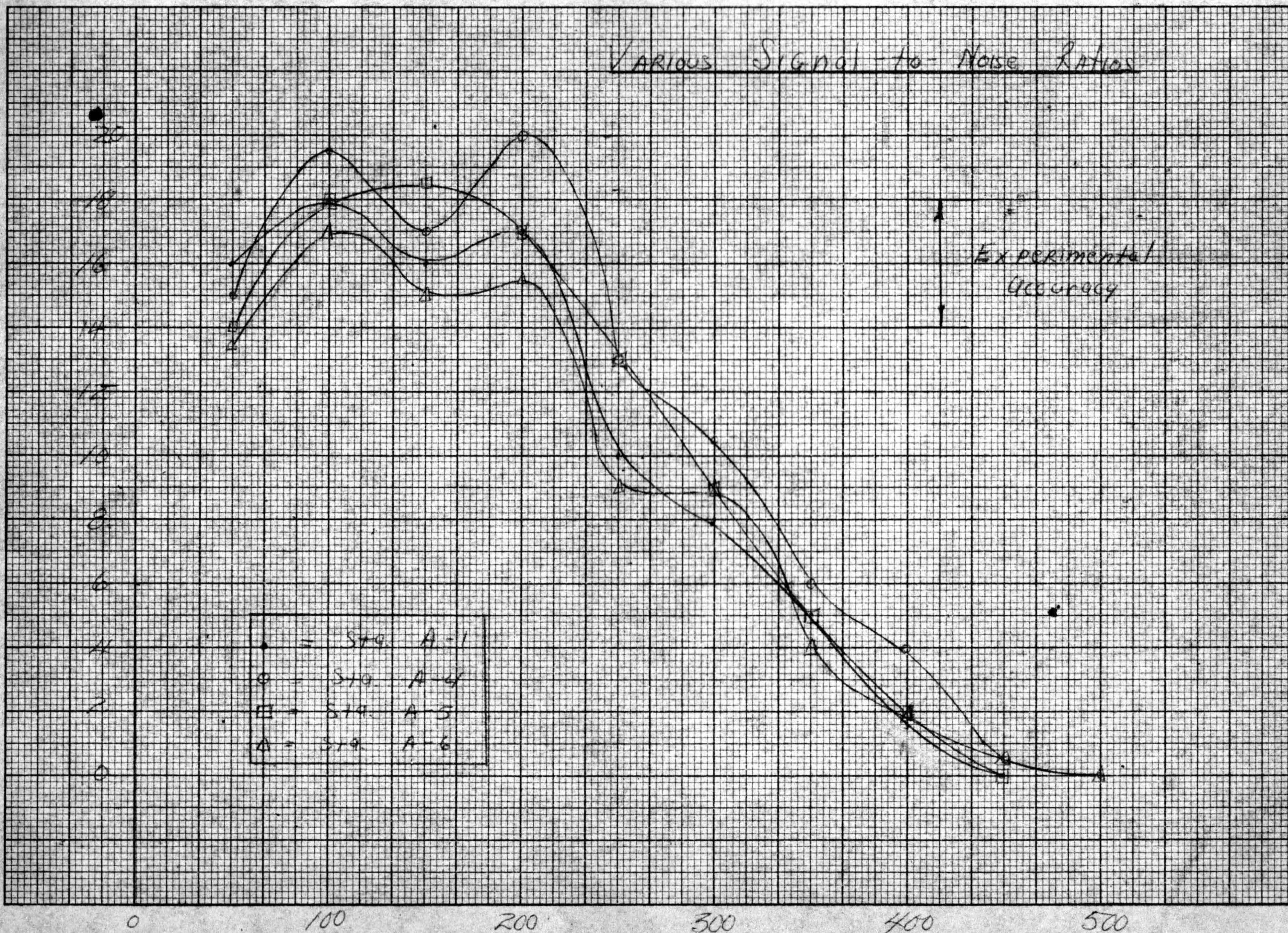

Various Signal-to-Noise Ratios
Experimental Accuracy
= S+a A-1
= S+a A-4
= S+a A-5
= S+a A-6
20
18
16
14
12
10
8
6
4
2
0
0
100
200
300
400
500

FIG. 10

are well within the limits of experimental accuracy, as indicated on the figure.

4

FOOT NOTES

1 D. E. Weston, "Underwater Explosions as Acoustic Sources," Proceedings of the Physical Society; 1960 :p. 243

2 J. W. Horton, "Fundamentals of Sonar," U. S. Naval Institute, 1961: p.81

3 Files of U. S. Navy Underwater Sound Lab, Spec. No.306

BIBLIOGRAPHY

Albers, Vernon M., Underwater Acoustic Handbook. Pennsylvania State University Press, 1960. Pp. 28-32, 95-104

Horton, J. Warren, Fundamentals of Sonar , U.S. Naval Institute. 1961. P. 81

Weston, D.E., Underwater Explosions as Acoustic Sources. Proceedings of the Physical Society, London. 1960 Pp. 233-249

A great deal of information was obtained at the U.S. Navy Underwater Sound Lab, especially in personal communication with the following people, employees of the Laboratory.

Mr. Edmund C. Gannon

Mr. William J. Jucksch