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ST. CROIX REVISITED: FURTHER MEASUREMENTS OF THE AMBIENT ACOUSTIC BACKGROUND AT DIFFERENT DEPTH AT A DEEP SEA LOCATION

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Naval Ordnance Laboratory

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13. ABSTRACT

A series of simultaneous hourly measurements of ambient noise at a number of depths between 100 and 12,000 feet shows a gradual reduction of noise level with depth. This decrease is most rapid at shallow depths and is less rapid at great depths. Individual noise profiles show considerable variability, some depths being at times more noisy, and at other times more quiet, than others.

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St. Croix Revisited: Further Measurements of the Ambient Acoustic Background at Different Depths at a Deep Sea Location

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NAVAL ORDNANCE LABORATORY
Silver Spring, Maryland 20910

20 February 1973

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ST. CROIX REVISITED: FURTHER MEASUREMENTS OF THE AMBIENT ACOUSTIC BACKGROUND AT DIFFERENT DEPTH AT A DEEP SEA LOCATION.

This is a continuation of NOL Project MARLIN concerning variation of the ambient noise background with depth in the deep sea. It will be of interest to those concerned with the problem of the optimum depth for long range listening in the deep ocean.

The work was done under AIRTASK A370-370A/WF11-121-701, Problem 202, for the Air Systems Command.

ROBERT WILLIAMSON II
Captain, USN
Commander

Z.I. Slawsky

Z.I. SLAWSKY
By direction

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INTRODUCTION

1. This is a sequel to an earlier report * which presented measurements of the ambient noise profile down to 8000 feet at a location off St. Croix, Virgin Islands. The present report is an extension of these measurements to a depth of 12,000 feet in deeper water some 5 miles from the previous location. The methods of calibration and analysis of the data are identical to those used previously. The results show that the level of the ambient noise background at both sites falls off with depth, rapidly at first and then more slowly as the bottom is approached.

MEASUREMENT METHOD

2. The measurements were made with a string of hydrophones spaced 2000 feet apart along a common coaxial cable. Figure 1 shows the experimental geometry. Each hydrophone fed its own frequency-modulated carrier up the cable to the anchored platform, where the signals were de-modulated and recorded. In addition, a separate hydrophone from an A/N-SSQ-57 sonobuoy was floated away from the anchored barge to record noise at a depth of 100 feet. Noise samples 1 1/2 minutes long were obtained at hourly intervals during an overnight period. A total of 18 such samples were recorded; however, only 14 noise samples were obtained with the 100-foot hydrophone, which was found to have broken off toward the end of the overnight period.

3. An in-situ calibration of the system was obtained with a standard J-9 sound source. Playback of the field recordings was done later in 1/3-octave filter bands, and the band levels were reduced to spectrum levels in the conventional way by subtracting 10 times the log of the bandwidth, and have been referred to 1 dyne/cm^2, rather than to 1μPa, so as to enable easy comparison with the earlier results.

4. Figure 2 shows the test site, located at the cross in 13,600 feet of water north of the island of St. Croix. The earlier site in 10,000 feet of water is indicated by the dot located to the east. Notice that both measurement locations are on the side of a deep basin bounded by islands to the north and south and by bottom ridges to the east and west.

*Same authors, "The Depth Profile of Ambient Noise in the Deep Sea North of St. Croix, Virgin Islands", NOLTR 72-176, Aug 1972

RESULTS

5. Figure 3 gives the distribution of the hourly levels plotted on normal probability paper. The indicated standard deviations (σ) are the slopes of the straight lines drawn by eye through the data points. They are seen to vary from about 7 db at low frequencies to 2 to 3 db at high frequencies.

6. Figure 4 shows profiles of the mean noise level at the different measurement depths in the various analysis bands. The standard deviation of the mean level, equal to the value of σ from the previous figure divided by the square root of the number of samples, is shown by the horizontal bars. At 5000 Hz only median levels are plotted, since at this frequency electronic noise tended to mask sea noise under quiet conditions.

7. Figure 5 is a complete third-octave analysis of a single 8-second simultaneous sample at 4 depths, as made by a General Radio Type 1921 Real Time Analyzer using an 8-second integration time. We may note in this data the typical depth variation shown by the averaged data. In addition, there is a steep increase in level toward the low frequency end of the spectrum apparently caused by a distant ship, or ships, that were evident on listening to the sample. The level of electronic noise shown by the lower dashed curve is satisfactorily below that of sea noise except in the highest two 1/3-octave bands.

8. Figure 6 illustrates the variability of the noise profile from hour to hour by means of hourly profiles at frequencies of 125 and 2000 Hz. We observe from these profiles that while their general shape tends to be maintained, there are variations in detail such that for the 1 1/2 minute samples taken at hourly intervals, some depths are more noisy and others more quiet than they are on the average.

9. Finally, Fig. 7 shows the mean levels of Fig. 4 plotted against frequency, along with the Knudsen-Wenz spectrum for conditions of moderate shipping and a 11-16 knot wind. At 2000 feet and below, the levels at the test site are seen to be some 3-7 db lower than expected or predicted, whil the levels at 100 feet are considerable higher.

DISCUSSION

10. The present data show a gradual decrease of mean level from 2000 feet to 12,000 feet. In the earlier data, there was a suggestion of a reversal below 6000 feet; the mean levels at 8000 feet were 2 to 3 db higher than those at 6000 feet. The present data do not substantiate this reversal, which may have merely represented the uncertainly of 1 to 2 db or so in the system calibration.

11. Another item of difference is the low value of σ at high frequencies in the present data. This must be the result of

the small variation of wind speed in the present overnight series. During this period of 17 hours the wind speed was 9-10 knots during the first half of the period and rose gradually to 16-17 knots toward the end.

12. The rapid decrease of noise below the surface continues to be a puzzling and apparently valid characteristic of the noise background at the test location. In addition to the evidence for its validity that was presented in the earlier report, the effect was verified anew by lowering and raising a hydrophone between 50 and 300 feet, with pauses of 5 to 10 seconds at 100 and 200 feet for a steady noise reading at these intermediate depths. This was done from both the barge and a small craft lying to some 400 feet away. The results are plotted in Fig. 8 as noise profiles in a number of 1/3 octave bands, normalized to a common value at 100 feet at each frequency. They show a decrease of about 3 db between 50 and 300 feet, with no clear dependence on frequency. This decrease evidently continues at a lesser rate down to the sea bottom, as shown by the mean noise profiles given previously in Fig. 4. The cause of this behavior is not clear. On the one hand, the rapid decrease at shallow depths may be thought to be the effect of the surface duct, which must act to channel the noise produced by near-surface sources and, by surface scattering, produce a decreasing sound field in the water below. Evidence for this interpretation lies in the fact that the difference in level between 100 feet and 2000 feet is greater at frequencies above a few hundred Hertz than below, a frequency region that corresponds to the lower limit of trapping by the 150 foot surface duct. This frequency difference is evident in Fig. 5 and was noted in Fig. 8 of the earlier report. On the other hand, an alternative explanation is that the rapid decrease of level with depth is the result of the over-all velocity profile, since the decrease occurs in ray-trace intensity computations and appears in the observed data at frequencies as low as 125 Hz. However, there is no convincing or exclusive evidence for either of these possibilities. Indeed, both of these hypotheses may be correct; the surface duct may merely intensify or enhance a variation of noise level with depth caused by the velocity profile. In any event, an understanding of why the noise profile is the way it is, at this location as well as at others where computed or observed profiles may become available, is an important problem for future solution.

SUMMARY

13. The results of this short field trial may be summarized by the following statements:

a. Based on an overnight series of hourly noise samples, the mean noise level at all frequencies from 50 to 5000 Hz is found to decrease with depth, with a rapid decrease down to 2000 feet and a smaller decrease below (Fig. 4).

b. Individual 1 1/2 minute noise samples taken at hourly intervals fluctuate in level with a standard deviation of 6-7 db at low frequencies and 2-3 db at high (Fig. 3). The latter value is smaller than that found previously because of the smaller variation in wind-speed during the shorter time duration of the observation period.

c. Because of this variability, the noise profile existing at any one time is itself variable, some depths being at times more noisy than others (Fig. 6).

d. Below 2000 feet, the sea at the test site averages about 5 db more quiet than an estimate based on the Kundsen-Wenz noise spectra (Fig. 7).

e. Lowering and raising a hydrophone shows a decrease of level of about 3 db at all frequencies between 50 and 300 feet (Fig. 8). This rapid near-surface decrease of noise has been observed in other ways on other occasions at the test site, and appears to represent the uppermost small segment of the noise profile as determined by the fixed hydrophones at deeper depths.

f. The origin of the noise profile remains uncertain, but must be understood before the validity of the present results for other locations and other environmental conditions can be assessed.

ACKNOWLEDGEMENT

14. The writers are again indebted to Mr. J. F. Kennedy and other personnel of TRACOR-MAS, Inc. for their invaluable assistance during the field work.

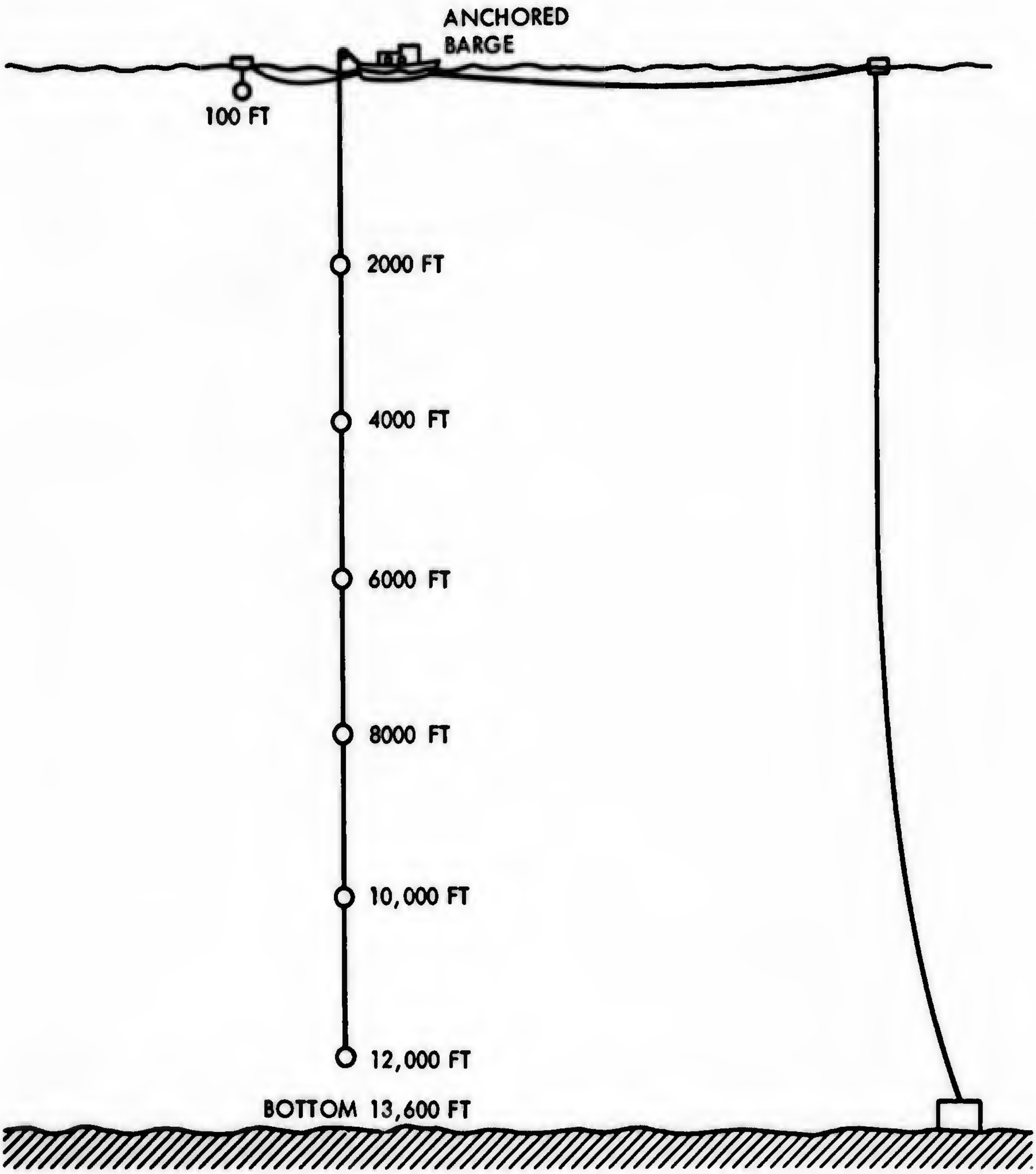

FIG. 1 EXPERIMENTAL ARRANGEMENT.

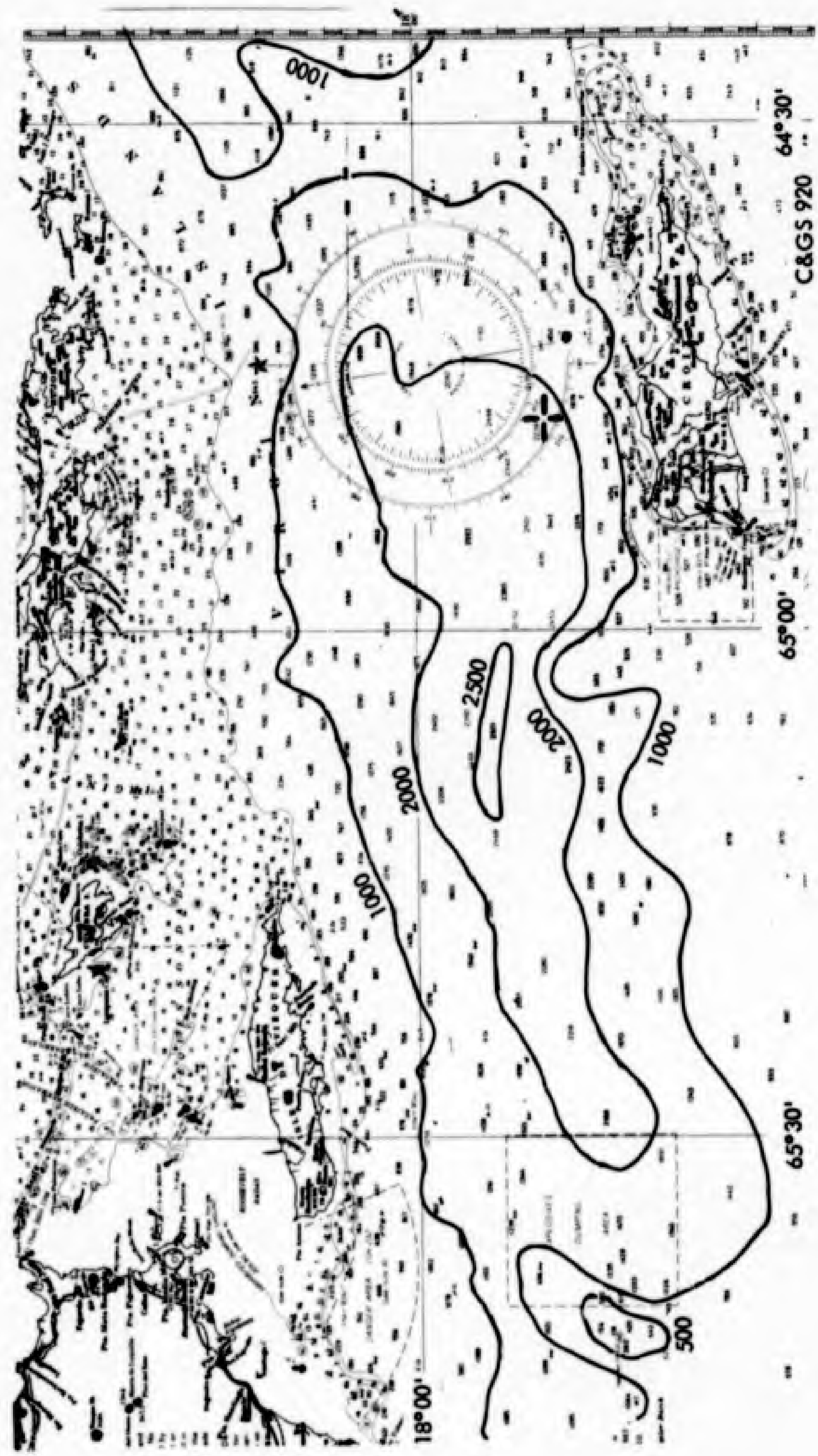

FIG. 2 CHART SHOWING MEASUREMENT SITE NORTH OF ST. CROIX. SITE IS AT THE CROSS. BOTTOM CONTOURS IN FATHOMS. EARLIER SITE WAS AT THE DOT 5 MILES TO THE EAST.

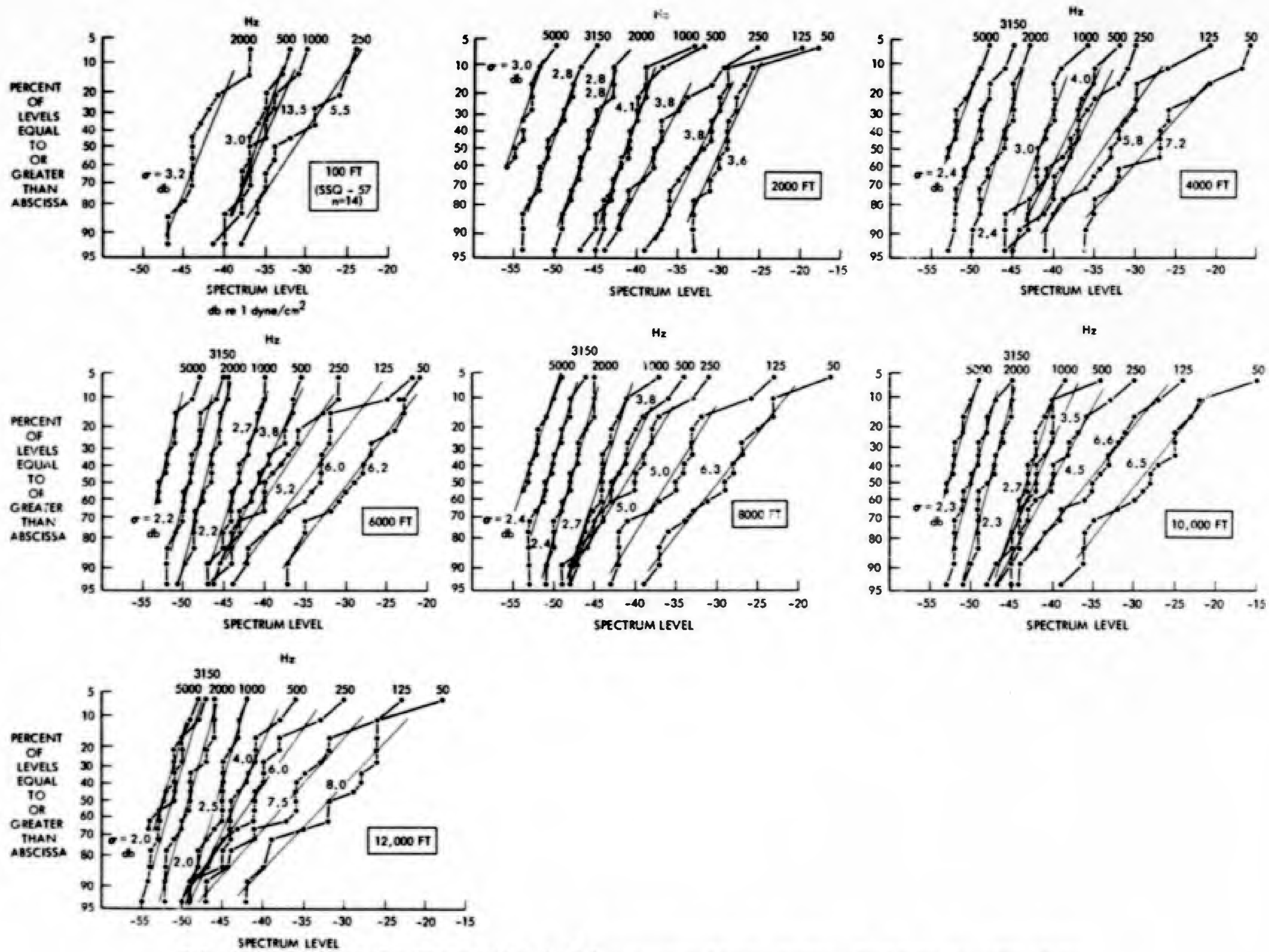

FIG. 3 CUMULATIVE DISTRIBUTION OF 1/3-OCTAVE BAND LEVELS, REDUCED TO SPECTRUM LEVELS, OF 1-1/2 MINUTE HOURLY SAMPLES.

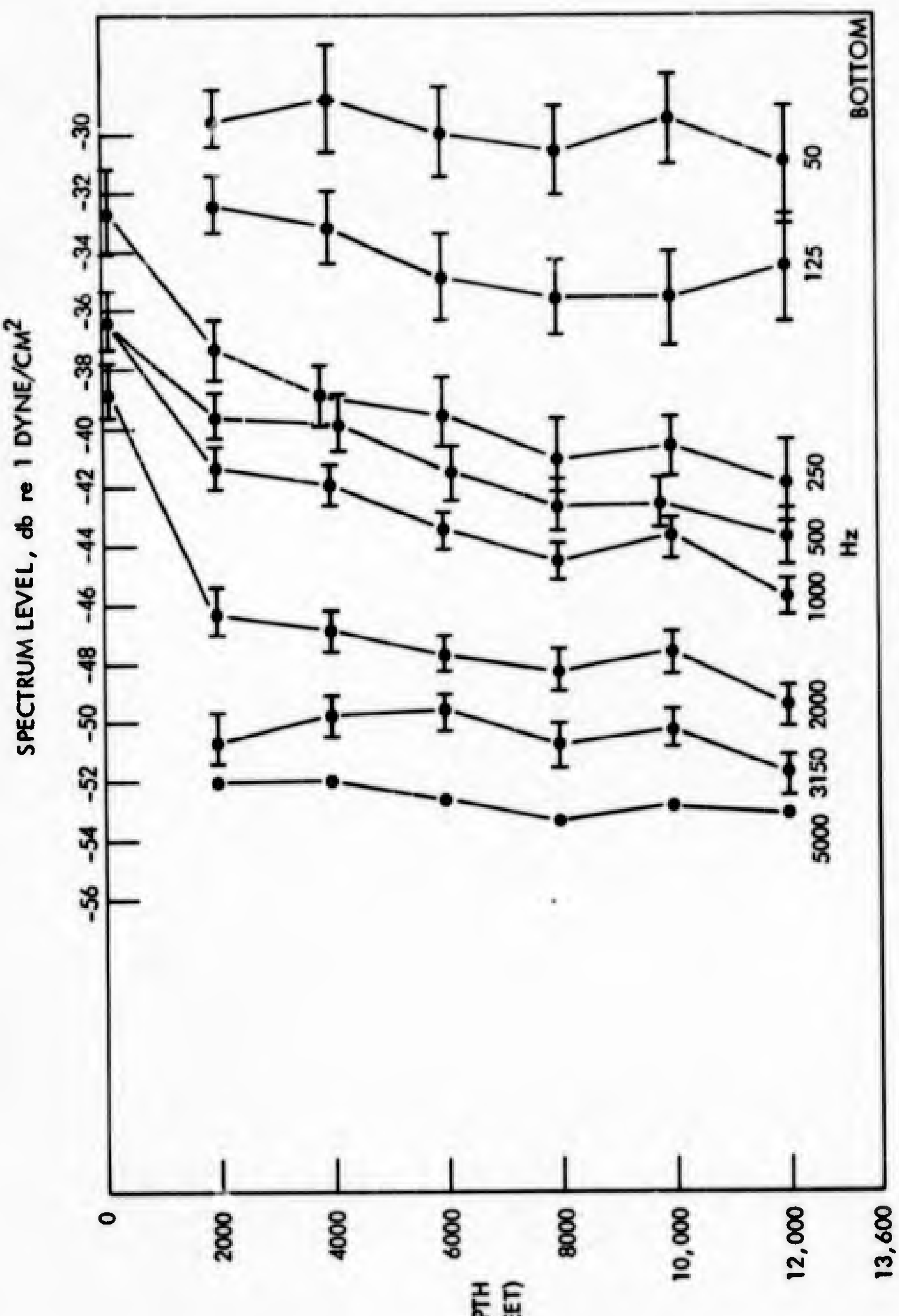

FIG. 4 NOISE PROFILES OF THE MEAN LEVEL AT THE VARIOUS DEPTHS. BARS SHOW EXTENT OF $\pm 1\sigma$.

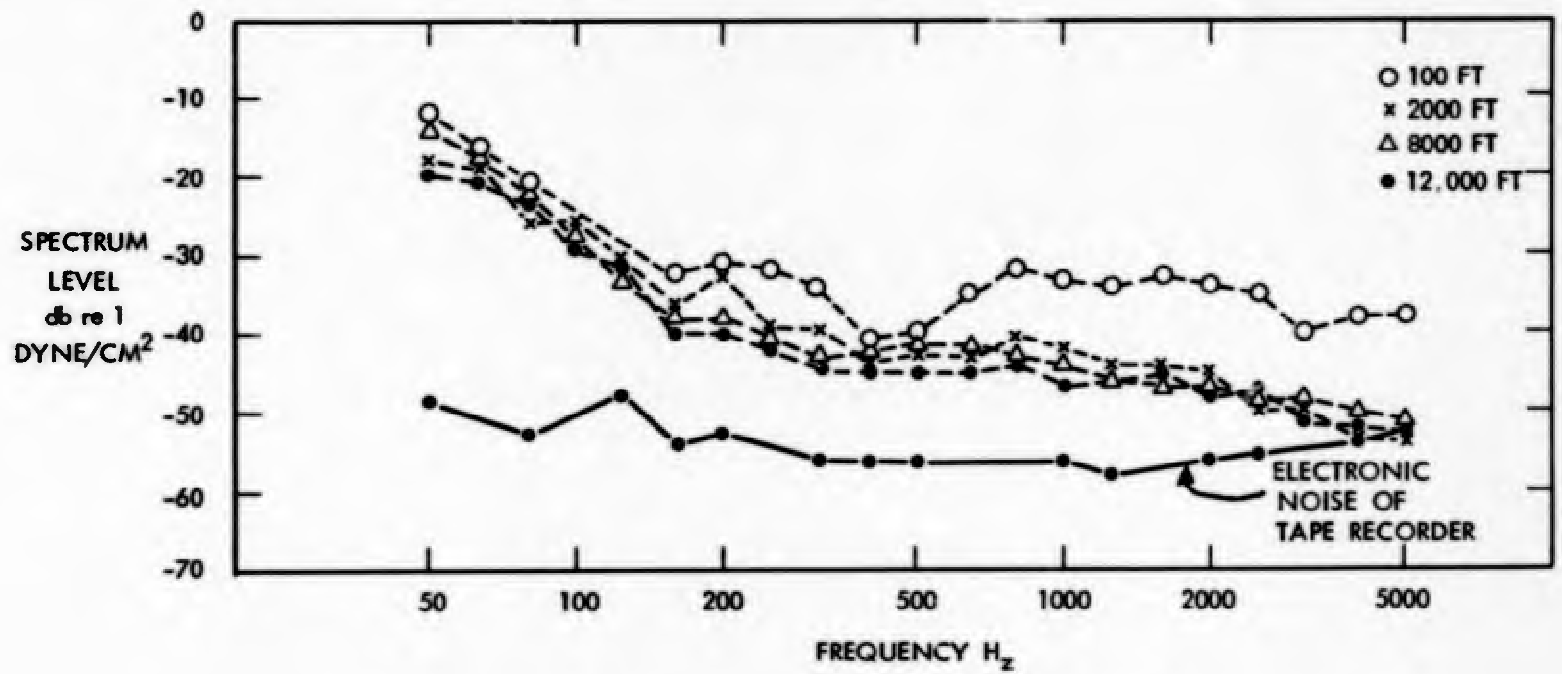

FIG. 5 1/3 OCTAVE ANALYSIS OF A SINGLE 8-SECOND NOISE SAMPLE. LOWER CURVE SHOWS THE SYSTEM ELECTRONIC NOISE LEVEL.

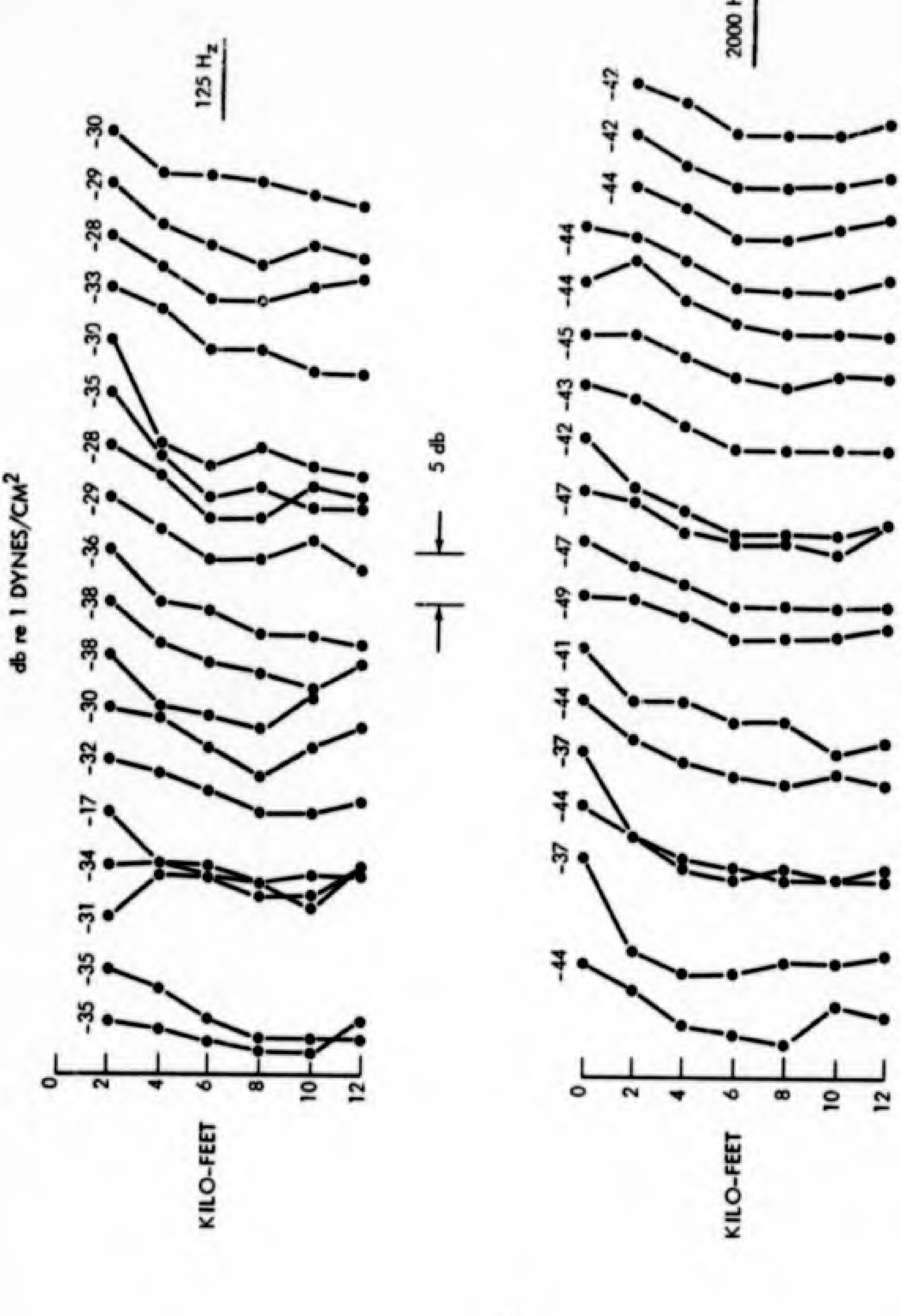

FIG. 6 INDIVIDUAL HOURLY PROFILES IN TWO FREQUENCY BANDS. FIGURES AT THE TOP OF EACH SERIES ARE THE SPECTRUM LEVELS CORRESPONDING TO THE UPPERMOST POINT IN EACH PROFILE.

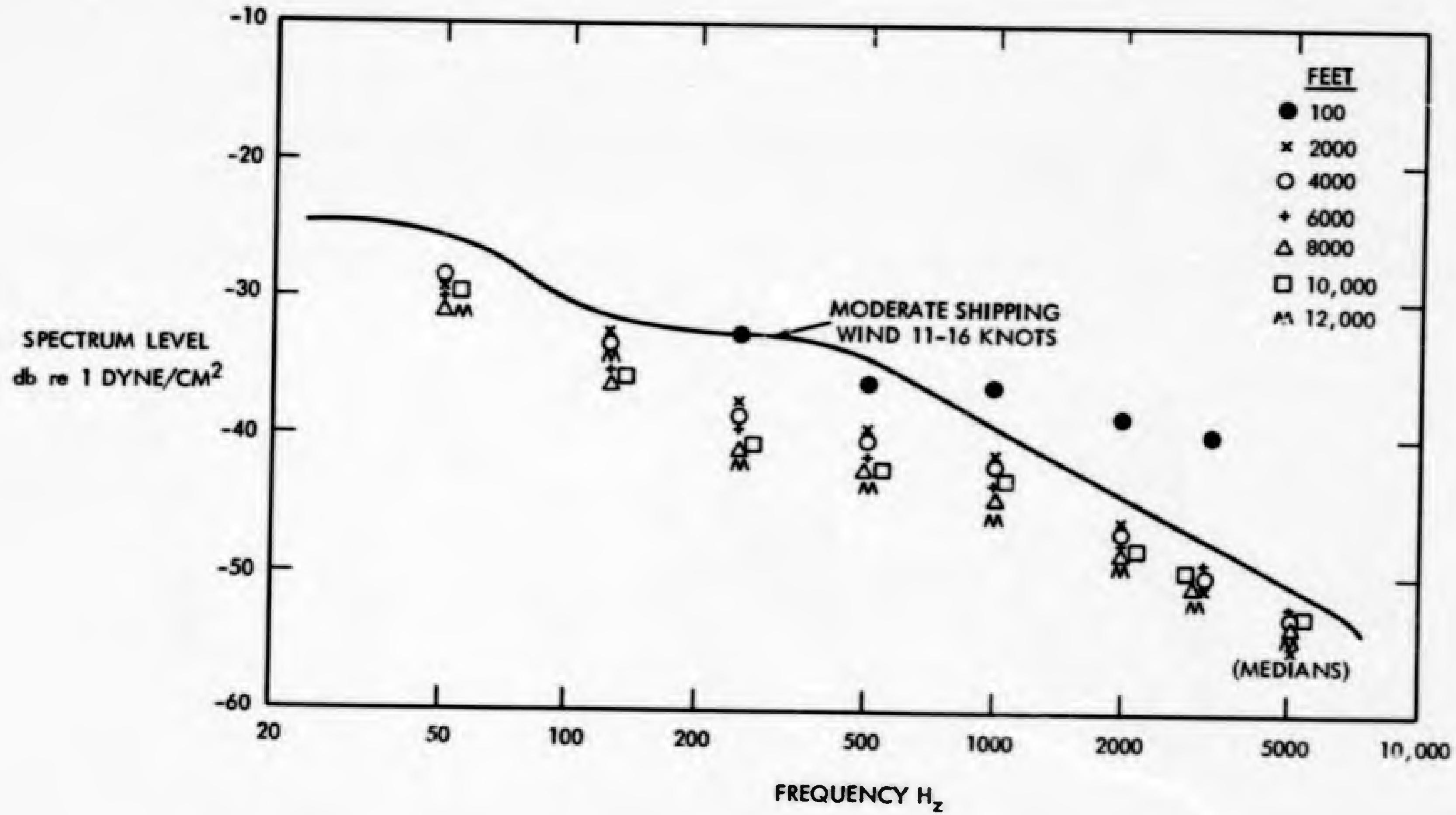

FIG. 7 MEAN LEVELS PLOTTED AGAINST FREQUENCY FOR COMPARISON WITH THE KNUDSEN-WENZ CURVE FOR MODERATE SHIPPING AND A 11-16 KNOT WIND.

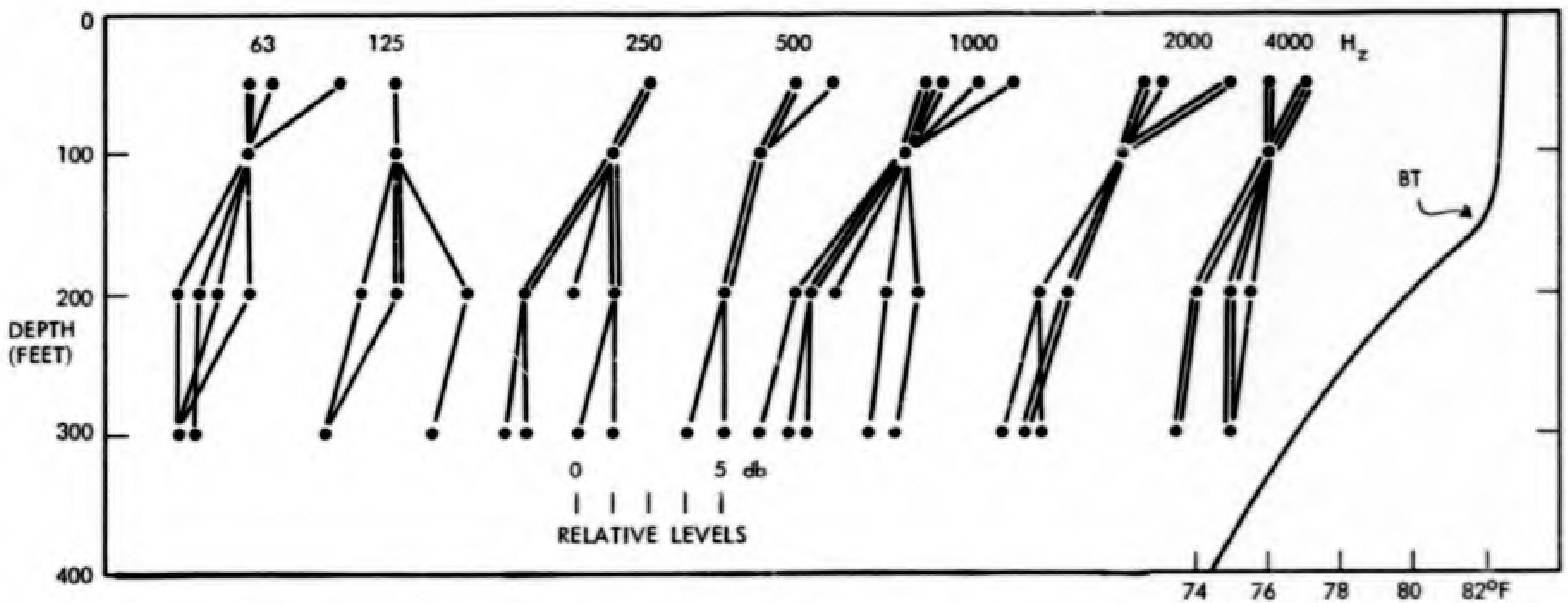

FIG. 8 NEAR-SURFACE NOISE PROFILES OBTAINED BY RAISING AND LOWERING A HYDROPHONE BETWEEN 50 AND 300 FEET. THE LEVELS ARE RELATIVE AND ARE NORMALIZED AT EACH FREQUENCY TO A COMMON VALUE AT 100 FEET.