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The Marine Laboratory
University of Miami

TECHNICAL REPORT

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Ambient Noise Measurements at Bimini

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by

R. Dann and M. Kronengold

Miami, Florida 33149
B8839
ML 64357

F. G. Walton Smith
Director

ABSTRACT

Long term investigation of undersea ambient noise is in progress near Bimini, Bahamas. One of the major problems encountered in this investigation has been in the aspects of ocean engineering, i.e., the establishment of buoys and environmental sensors which are capable of continuous service. Design and construction of sensors and equipment have been necessitated by the lack of commercially available units. Preliminary analysis of the characteristics of sound pressure spectrum levels were obtained by autocorrelation and by analysis of variance calculations. The autocorrelation analysis indicated possible periodicities in the noise at 25 cps and 16 cps. Analysis of variance of limited data showed that above 200 cps the highest percentage of variability was associated with weeks (or months) and the variability of levels between 40-200 cps were equally divided between hours and minutes. Mathematical relationships were derived for the statistics between a force-per-unit area measure of pressure and a dB measure of pressure.

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INTRODUCTION

The Institute of Marine Science is now engaged in a long term investigation of undersea ambient noise, particularly in relation to the significant environmental factors of wind speed and direction, wave height, tide height, current magnitude and direction and temperature vs. depth profile. The site of this investigation is off Bimini, Bahamas.

Some of the more difficult problems encountered in this program are involved in the design and installation of the environmental sensors. Difficulties range from sensor failure to damage caused by hurricane CLEO. The major effort during the interim of this report was devoted to equipment repair and redesign.

During this period, effort was continued on the theoretical aspects of the program to prepare for the data analysis that will be required when all equipment is functioning properly.

The apparent normality of the distribution of the logarithms of sound pressures has indicated that a decibel measure of pressure be used for most of the statistical calculations. For other uses, a pressure-per unit-area measure is needed. Relationships between the statistics of these measures, which should be of considerable utility, have been derived.

Autocorrelation and an Analysis of Variance have been carried out on samples of the limited data available in an effort to generate preliminary information on time variability and periodicities in the noise. Preparations are being made for the use of power spectrum analysis as an analytical tool, but at this time, no results are available for reporting,

A continuous data acquisition system of the kind being installed for this study presents the possibility that too much data will be collected. Beyond a certain point, analysis cost increases while the yield of useful information remains constant, With the purpose of avoiding this pitfall, while still obtaining sufficient data for proposed analysis, a sampling schedule spanning a full year of automatic data acquisition is presented.

FIGURES

I. AUTOCORRELATION OF BIMINI PRESSURE LEVELS

Acoustic measurements obtained during the period of 10-12 December 1963 were selected for autocorrelation analysis in a preliminary attempt to detect periodicities. This period provided approximately 68 hours of data when the winds were light and the sea state low. Autocorrelation of the data was performed at three frequencies: 25 cps, 250 cps, and 1600 cps.

The time series used had a length of 68.2 hours and consisted of 247 data points spaced 0.276 hours apart. A data point is the mean of two 10-second average readings which the instrumentation produced in 30 seconds. In addition, occasional gaps in the original record were filled by interpolating values representing the mean of the data points or either side of the gap.

The 23 cps autocorrelation analysis was performed in a preliminary attempt to determine periodicities associated with tidal effects. Selection of this frequency was based on the assumption that noise due to tidal current would occur at relatively low frequencies, and that the 25 cps data was the lowest analyzed frequency which was believed to be free from system noise limitations. If there is periodicity in the noise levels associated with tides, a period of approximately 12.5 hours should be evident. From the autocorrelation of this data (Figure 1), a tidal periodicity is not apparent. A fairly strong negative correlation appears to occur at about the 10-hour period indicating a possible periodicity much greater than that related to the tide.

Chronological plots of the higher frequency data, 250-2000 cps indicated a sharp rise in level each evening at approximately 1/30 hours and lasting for about 3 hours. This phenomenon was probably caused by the monthly marine animal chorus categorized "clicks" as described by Cummings *et al,* (1964). An autocorrelation was performed on 1/3 octave data centered at 1600 cps which was the frequency band showing the strongest cyclic pattern of this phenomenon, A record length of less than three days can yield only very uncertain information concerning diurnal periodicities. The autocorrelation function of this frequency band does, however, suggest the presence of a 24-hour periodicity (Figure 2). This autocorrelation also indicates a periodicity having an interval of about 3.9 hours.

The autocorrelation functions for data at an intermediate frequency 250 cps contains no obvious periodicities (Figure 3).

Although very little can be said of periodicities which may exist in the ambient noise spectrum based upon this single relatively short record. There are indications that analysis of this type applied to several longer records would provide valuable information on the nature of ambient noise,

II. PRELIMINARY ANALYSIS OF VARIANCE

To obtain preliminary information on the time variability of the ambient noise spectrum, an analysis of variance (ANOV) was performed on short periods of Bimini noise data. A series of measurements was made during each of four months with a series lasting from one to three days. A series consisted of two-10 second average levels spaced 20 seconds apart and repeated at approximately 0.28 hour intervals during the series.

The ANOV analysis and the interpretation of the results which follow were reported by F. T. Dietz (1964).

These data were subjected to a nested analysis of variance which computed the components of variance associated with the various levels of the nested hierarchy: months or weeks, days, hours, minutes, and the error term. The total variance is expressed as follows:

$$\sigma_T^2 = \sigma_w^2 + \sigma_d^2 + \sigma_h^2 + \sigma_m^2 + \sigma^2$$

The variance associated with a particular sound pressure was expressed as a percentage of the total variance. A plot of the percentage of the total variance attributable to the various levels as a function of frequency was obtained (Figure 4). It is noted that week-to-week (or month-to-month) variability is less than 20 percent of the total below 200 cps. However, close to 40 percent of the variability above 200 cps is associated with weeks (or months). The remaining 60 percent appears to be equally divided among days, hours, and minutes. The error term accounts for approximately 5 percent of the total.

Between 40-200 cps, 70 percent of the variability is equally divided between hours and minutes. The remaining 30 percent is shared by weeks, days, and the error term.

Below 40 cps, the primary factors are the hour and error terms. The trend is for the error term to increase with decreasing frequency. At 16 cps the component of variance associated with the error term is over 50 percent of the total variance. The interpretation offered is that this variability is mainly associated with short-term fluctuations occurring at intervals of less than one minute. If this conclusion is valid, 16 cps data must be sampled on a different basis from that at higher frequencies.

The magnitude of the error component decreases rapidly with increasing frequency and the hour and minute terms become predominant in the region where shipping and animal sounds are expected.

The predominant role of the component associated with weeks (or months) above 200 cps is apparently related to the local weather picture since each of the sampling periods included different types of weather.

III. STATISTICS OF LOG NORMAL DISTRIBUTED SOUND PRESSURES

In the study of ambient noise, it is sometimes useful to work with a force-per-unit area measure of pressure, and sometimes it is useful to work with a dB measure of pressure. Generally the statistics (probability density function, mean, variance, etc.) of the sound pressure levels are reported in terms of a dB measure, but they are calculated using a force-per-unit area measure of pressure. For many calculations of these statistics, it would be easier to use the dB measure of pressure. Jacobson (1964) investigated the relationship between these statistics and reported the following:

Relationship Between Variables

In the following, we shall let

X = pressure of dynes per square centimeter per cycle

Y = pressure in dE relative to one dyne per square centimeter per cycle

f(x) = probability density function (P.d.f.) of X

$g(y) =$ probability density function (P.d.f.) of Y

$m_x\ \sigma_x^2$ = mean and variance of X

$m_y\ \sigma_y^2$ = mean and variance of Y

We shall suppose that the statistics of Y are known, and wish to determine statistics of X directly.

The continuous random variables X and Y are simply related by the equations

$$Y = 20 \log_{10} X = 8.686 \log X$$

$$X = e^{\frac{\log 10}{20} Y} = e^{0.1151y} \qquad (1)$$

where log denotes the natural logarithm.

Relationship Between Power Density Functions

The P.d.f. for X can be written in terms of the P.d.f. for Y as follows *.

$$f(x) = g(y) \frac{dy}{dx} \qquad (2)$$

From (1),

$$\frac{dy}{dx} = \frac{8.686}{x} = 8.686\, e^{-0.1151y} \qquad (3)$$

so that (2) becomes

$$f(x) = 8.686\, e^{-0.1151y}\, g(y) = \frac{8.686}{x}\, g\,(8.686 \log x) \qquad (4)$$

Eq. (4) gives the P.d.f. for X when the P.d.f. for Y is known. In general, (4) holds for $0 \le x < \infty$ and for $-\infty < y < \infty$. In actuality, however, the range of y is expected to be between -10 and -60 dB.

Moments of X

By definition, the k'th moment of X about the origin is giver by :

$$\mu_k(x) = \int_0^\infty x^k f(x)\, dx \qquad (5)$$

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* Cramer, (1946), p. 294.
Cramer, (1946), p. 174.

In terms of the μ_k, the mean and variance of x are given by

$$m_x = \mu_1(x) = \int_0^\infty x\, f(x)\, dx$$

$$\sigma_x^2 = \mu_2(x) - \mu_1^2(x) = \int_0^\infty x^2\, f(x)\, dx - m_x^2 \quad (6)$$

where f(x) can be found from g(y) by (4). The moments of X can be determined directly from the. of y. Using (1), (3), (4), and (5),

$$\mu_k(x) = \int_{-\infty}^\infty e^{0.1151ky}\, g(y)\, dy \quad (7)$$

Also, (6) may be written as

$$m_x = \int_{-\infty}^\infty e^{0.1151y}\, g(y)\, dy$$

$$\sigma_x^2 = \int_{-\infty}^\infty e^{0.2302y}\, g(y)\, dy - m_x^2 \quad (8)$$

Y Normally Distributed

In several investigations of ambient noise, it has been found that Y is approximately normally distributed. That is

$$g(y) = \frac{1}{\sqrt{2\pi}\, \sigma_y}\, e^{-(y - m_y)^2/2\sigma_y^2} \quad (9)$$

In this case, from (4) and (9), the. of x is

$$f(x) = \frac{8.686}{\sqrt{2\pi}\, \sigma_y\, x}\, e^{-(8.686 \log x - m_y)^2/2\sigma_y^2} \quad (10)$$

The random variable X, with the P.d.f. (10) , is said to have a log normal distribution.

The mean and variance of X can now be found from (8) and (9) or from (6) and (10). However, it is simpler to use existing results in this case. Suppose that

$$Z = \frac{y}{8.686} = \log x \quad (11)$$

Then Z is normally distributed with mean and variance

$$m_z = \frac{1}{8.686}\, m_y$$

$$\sigma_x^2 = \frac{1}{(8.686)^2}\, \sigma_y^2 \quad (12)$$

It can be shown from a problem in Cramer[◊] that the mean and variance of X are given in terms of m_z and σ_z^2 by the equations

$$m_x = e^{m_z + \sigma_z^2/2}$$

$$\sigma_x^2 = e^{2m_z + \sigma_z^2}\left(e^{\sigma_z^2} - 1\right) = 2e^{2m_z + \frac{3}{2}\sigma_z^2} \sinh\left(\frac{1}{2}\sigma_z^2\right) \tag{13}$$

From (12) and (13),

$$m_x = e^{\frac{m_y}{8.686} + \frac{1}{2}\left(\frac{\sigma_y}{8.686}\right)^2} \tag{14}$$

$$\sigma_x^2 = e^{\frac{m_y}{4.343} + \left(\frac{\sigma_y}{8.686}\right)^2}\left[e^{\left(\frac{\sigma_y}{8.686}\right)^2} - 1\right]$$

$$= 2e^{\frac{m_y}{4.343} + \frac{3}{2}\left(\frac{\sigma_y}{8.686}\right)^2} \sinh \frac{1}{2}\left(\frac{\sigma_y}{8.686}\right)^2$$

These equations give the mean and variance of X in terms of the mean and variance of Y when Y is normally distributed. When $(\sigma_y/8.686)^2 << 1$, which is the case in a recent study by Kronengold *et al.* (1964), (14) simplifies to

$$m_x \sim e^{m_y/8.686} \tag{15}$$

$$\sigma_x^2 \sim \left(\frac{\sigma_y}{8.686} e^{m_y/8.686}\right)^2 = \left(\frac{m_y\,\sigma_y}{8.686}\right)^2$$

Kronengold *et al.* (1964) showed that y is approximately normally distributed for sufficient low and sufficiently high frequencies. For a one-third octave band centered at 16 cps and with 1057 samples, he found the following sample mean and sample standard deviation:

$$m_y \text{ (sample)} = -17.2$$

$$\sigma_y \text{ (sample)} = 1.7 \tag{16}$$

The computations were repeated for sample values of X, giving

$$m_x \text{ (sample)} = 0.143$$

Cramer, (1946), p. 258, problem 17.

$$\sigma^{x} \text{ (sample)} = 024 \tag{17}$$

If the values of m_y and σ_y in (16) are substituted into (14) or (15), it is found that

$$m_x = 0.141$$

$$\sigma_x = 0.027 \tag{18}$$

These results are in reasonable agreement with (17). Greater accuracy could be obtained by increasing the sample size and by selecting a better estimate of the P.d.f. of y than that provided by the assumption of normality.

IV. ANTICIPATED DATA COLLECTION AND ANALYSIS

In planning a year's sampling program of ambient noise and various environmental conditions, it became evident that continuous collection of data would not be feasible. Studies indicate that the total number of sampling periods should be held to about 12,000 to 15,000 for the first year. This is a manageable amount of data and should be of sufficient quantity to provide significant information. In planning a sampling program, the type of data analysis to be performed must be considered.

Data Analysis

In describing ambient noise characteristics some consideration should be given to the detection of periodic sound level changes which may be present. In this area, the sampling rates and consecutive record lengths will determine the frequency bounds of the cyclic phenomena which are detectable. Possible periodicities associated with weather, tidal, and biological cycles have large periods: half days, days, etc. and the sampling design must consider them.

Periodicities may be elicited from equal interval samples of data by autocorrelation analysis. Additional information from these data can be obtained using power spectrum analysis which gives quantitative information on the periodicities as well as the relative power density of these occurrences.

Additional ambient noise characteristics may be obtained from the results of an analysis of variance (ANOV). This technique is a process for partitioning the total sum of squares into components associated with recognized or assumed intervals of variation. A natural method of partitioning could be in terms of months, weeks, days, hours, and minutes. An ANOV based on this type of model can exhibit the mean squares and components of variance assignable to each interval. The ratios between mean squares permit conclusions about hypotheses concerned with variability at each interval. For an ANOV, the data is not required to be sampled at equal intervals.

Simple and partial correlation and regression analysis will be used to investigate the ambient noise relationship to various environmental conditions. Given an adequate sample of data including the pressure variable and representative spreads of wind speed, wave height, current, etc., it should be possible to locate the important associations and arrive all a prediction equation.

Computer Processing

Data acquired from hydrophones and oceanographic sensors are recorded on magnetic tape at the Bimini field station (Kronengold *et al.*, 1964). The information on the tape is then digitized and punched cards by a semi-automatic data processor located in Miami. The information on these cards is in coded form and computer processing is required to present the data in understandable units. Preliminary data has been processed by an IBM type 1620 computer using a combination SPS and Fortran compiler. In November 1964, the Institute of Marine Science is acquiring an IBM type 1401 computer which will handle the data faster than our present computer. In December of this year, the University of Miami is expected to have an IBM type 7040 computer in operation at its new computing center. This larger computer will be utilized for the more complicated statistical calculations which are anticipated.

For time series and multivariate statistical analysis of the data, assistance will be obtained from the Biometric research group of the University of Miami. This group is directed by Dr. Dean J. Clyde who is also acting director of the University's computing center.

Sampling Schedule

In order to provide sufficient data to perform the above analysis, a combination of fixed and random sampling is proposed (Figure 5).

Specifically, the sampling program was set up to include:

A. 120 random. days of information for use in simple and partial correlation and regression analysis and ANOV.

B. Monthly series of 5 or 6 consecutive days from which auto and cross correlations can be calculated.

C. Regular sampling at 8-day intervals for investigating lunar and seasonal periodicities.

By optimizing part B and C to coincide with part A, a total of 157 sampling days are required. A basic sampling rate of four samples per hour will be used. This will produce 15,072 regularly scheduled data periods for the year which should be a manageable quantity. In addition to the regular schedule, when special or infrequently occurring events are noticed during a non-sampling period, additional samples at the basic rate may be taken.

V. BUOY AND SENSOR INSTALLATION

The spar and submerged buoys were first installed off Bimini during the spring of 1964. The spar buoy was equipped with an anemometer, wind direction indicator, a wave staff, magnetic reference compass and an inclinometer, all with telemetering transducers (Figure 6). The submerged buoy supported a riser with a current direction vane which is referenced to a magnetic compass, and a series of thermistors all suitable for remote readout.

The above sensors were connected to a submerged instrument package which housed a sequential scanner and an instrument which converted the electrical output of each sensor to a pulse train having a frequency proportional to the variable being measured (Dann *et al.*, 1963). In addition a hydrophone was placed approximately 150-ft from the spar buoy for the purpose of transmitting ambient noise levels to the laboratory ashore.

After installation, problems arose in the mechanical and electrical systems. The following is an account of these troubles and what has been accomplished to date toward solving them.

Buoys

Spar buoy - When the spar buoy was originally installed, it had approximately 1000 lbs. of positive buoyancy and was tethered with a taut mooring line. Since the currents occasionally were quite strong, the buoy was occasionally pulled under for short periods. At other times, it listed at an angle of 15' to 30', a tolerable condition. The vertical motion seemed negligible, a condition essential for proper operation of the wave staff.

Corrosion developed at the junction of the guy wire ring bolts and the top supporting plate. This junction was further weakened during hurricane CLEO, we believe, causing the top 10 foot section of the spar to break at its flange-connection when a man was climbing up to inspect it.

The spar was taken ashore and is being refitted with stainless steel spreaders instead of aluminum, and heavier stainless steel ring bolts. The top section was fitted with a metal collar and flange similar to that existing on the lower sections so it will have the required strength.

The mooring has been redesigned (Figure 7). This configuration was tested for several months on our 30 ft. spar buoy off Bimini and was successful. This in effect increases the virtual length of the spar buoy, moors at its center of pressure, and exerts a horizontal restraining force on the buoy so that in high currents it will not tilt appreciably nor sink. Redesign is complete and all parts ordered.

Submerged buoy - The submerged "plank-on-edge" buoy performs exactly as designed. It is stable, maintains a taut moor and aligns itself with the current at all times. It is still moored in place.

The only problem encountered was with the mooring cable supplied by the vendor. The armor which was to have been capable of bearing the buoy load was quite light and evidently not pre stressed. It pulled apart before full load was applied and it was necessary to substitute 8H10 cable, using the armor as the strength member. This has proven to be satisfactory.

Sensors

Anemometer - The anemometer originally supplied by the vendor developed corroded bearings after a short period and was returned for repair.

A new bearing assembly and housing was designed for a cup anemometer and we have used this for several months. We believe that this design will last for at least 6 months and we will have a second unit standing by for immediate replacement in the event of failure.

Wind direction readout - The wind direction readout potentiometer failed after a period of three months. This potentiometer has been replaced with a recently developed Model No. 6213-13-0 6 which has a plastic based resistance element and has a life rated at twenty times that of the wire wound unit previously used.

In addition, we have designed a new direction sensor which employs long-life-magnetic-reed switches and fixed resistors as the transducer. The vane rides on teflon ball bearings in a

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* Braincon Corporation, Type 189.
Braincon Corporation, Type 257.

teflon race and we should expect trouble-free operation from this device. The first unit has been assembled and after suitable tests, will be substituted for the potentiometer type unit. Both types are electrically and mechanically interchangeable.

Wave staff - The wave staff originally installed was electrically sound and in our opinion converted the surface fluctuations accurately; however, it was deficient in mechanical strength and was broken twice, once by accidental collision with a boat and once by vandalism (Figure 8).

A new wave staff was designed and is near completion (Figure 9). This will be electrically interchangeable with the original unit. but will be housed in an aluminum cylinder 20 ft. long with a 1/4 in. wall thickness. The operating mechanism is a float containing a magnet which will close reed switches as it rises and falls in the aforementioned cylinder. The reed switches short out sections of a series resistor chain in the way the sea water shorted the platinum ring sections on the original wave staff. It will readout in 3 in. increments of wave height.

Magnetic reference compass - The magnetic reference compass has been operative since installation,

Inclinometer - The inclinometer used for measuring the tilt of the spar buoy has been operative since the installation.

Current meter - The rotor and reed switches of the Savonius rotor current meter were still operational after several months of continuous submergence. As a precaution we removed the device to replace the lower rotor bearing. The factory wiring of the reed switches was faulty and it was necessary for us to rewire and reinsulate the switches completely. The unit is now ready for reinstallation.

Current direction - A commercially available current direction instrument which references the current direction directly against a magnetic compass heading is being used. The readout transducer is a wire-wound potentiometer having an extremely light torque requirement (0.005 in/oz). The potentiometer wiper fatigued after several months of operation and is being replaced.

The direction indicator will probably be vulnerable to failure because of its potentiometer, but is at present the only available transducer which will meet our reeds. We are now studying the application of a "Hall Effect" generator for this purpose.

Thermistor chain - We have experienced no difficulty with the thermistors themselves, but due to the cable failure previously discussed on the submerged buoy, the thermistor housing became unusable. A new thermistor chain was fabricated and will be part of the new installation.

Inverted fathometer - The inverted fathometer has been assembled and calibrated, This unit is scheduled for installation at the same time as the other sensors.

Hydrophones - Several times in the past our hydrophones have been rendered inoperative y boats dragging their anchors across the connecting cables. Therefore, all existing lightly armored cables are being replaced by heavily armored quad cables which were received from Navy surplus stocks. In addition two hydrophones and preamplifiers will be placed at each site.

Braincon Corporation, Marion, Massachusetts, Model 252.

Data Acquisition System

Commutator-selector - The commutator-selector functions in accordance with design expectations. We do not anticipate difficulty here.

Acquisition console - The laboratory data acquisition console is operational.

Processing console - The semi-automatic data processing console requires further debugging and final checkout. This system should be in operation by the time the buoy and sensor system are reinstalled.

Emergency power - A large bank of nickel cadmium storage cells has been acquired from surplus stores and will form the nucleus of a standby Power system. A battery charger and voltage converter are Yet to be acquired for this system.

VI. CONCLUSION

In spite of our expectations, there was very little equipment commercially available to use "off the shelf" which was suitable for prolonged submergence in an ocean environment. This necessitated a development program in the field of ocean engineering, which we feel has resulted in much improved instrumentation. However, this must be proven in the field under conditions of continuous usage and will probably require continued development activity.

Wherever possible, such as in the case of the anemometer, interchangeable spares are on a standby basis so that immediate replacement is available in the event if failure.

Two hydrophones will be installed at both the shallow and deep locations using heavily armored cable to insure continuous service. Standby hydrophones, and pre-amplifiers are available.

Computer programs are being prepared for data reduction and analyses. It is expected that date acquisition, reduction, and analyses will begin as soon as the installation is operational. It is expected that the reinstallation and complete restoration of the acquisition function will be accomplished within the next two months.

VII. ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance of J. Loewenstein and R. Murciano for the design and construction of the electrical and electronic equipment and the assistance of L. de Villeneuve for electromechanical design and W. Green for cable and buoy installations. The efforts of the above personnel and the other members of the acoustic group of the Institute of Marine Science of the University of Miami are greatly appreciated.

For the advice and invaluable assistance in setting up this acoustical program and in obtaining preliminary results, the authors express their gratitude to Dr. F. T. Dietz (Visiting Professor from the University of Rhode Island) and Dr. M. J. Jacobson (Visiting Professor from Rensselaer Polytechnic Institute). Acknowledgment is also made of the cooperation of D. Eger and the IMSUM computer group for their computer programming.

VIII. LITERATURE CITED

Cramer, H. Mathematical Methods of Statistics (Princeton University Press, Princeton, 1946).

Cummings, W. C., B. D. Brahy, and W. F. Herrnkind. 164. The occurrence of underwater sounds of biological origin off the west coast of Bimini, Bahamas. pp. 27-43 in Tavolga, W. N. (ed.), Marine Bio-Acoustics. Pergamon Press, New York, xii + 413 pp.

Dann, R., and M. Kronengold. 1963. Ambient Noise Studies Off Bimini, Bahamas, Institute of Marine Science, Tech. Report, ML 63582.

Dietz, F. T. 1964. Comments Relative to Ambient Noise Measurements and Analysis. Institute of Marine Science, Memorandum for File, unpublished.

Jacobson, M. J. 1964. A Note on the Statistics of Ambient Noise. Institute of Marine Science, Memorandum for File, unpublished.

Kronengold, M., R. Dann, and F. T. Dietz. 1964. Ambient Noise Measurements at Bimini: October 1963 - March 1964. Institute of Marine Science, Tech. Report, ML 64184.

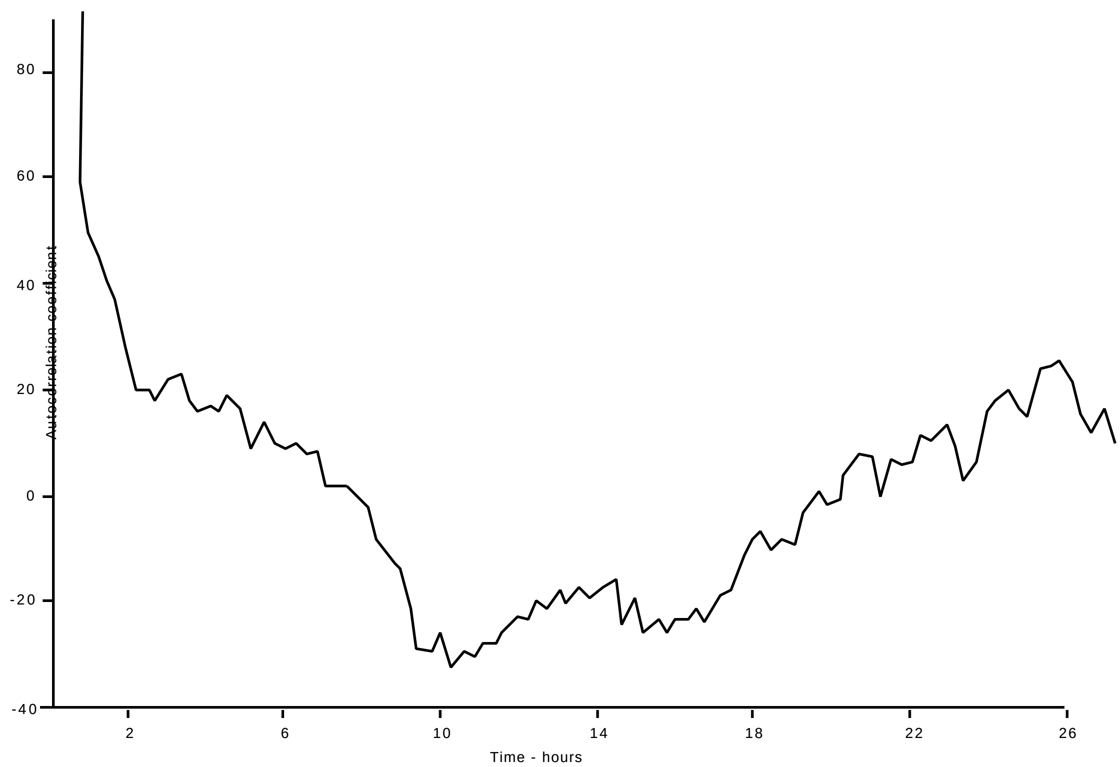

Figure 1. Autocorrelation - 1/3 octave at 25 cps.

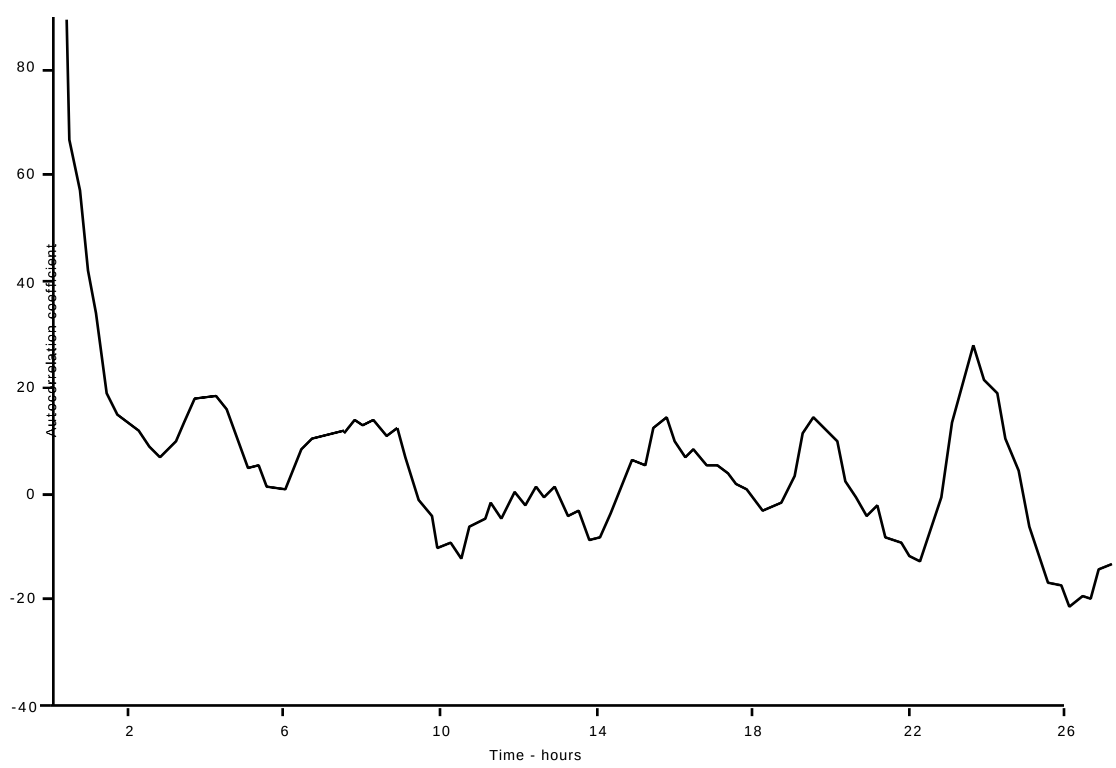

Figure 2. Autocorrelation - 1/3 octave at 1600 cps.

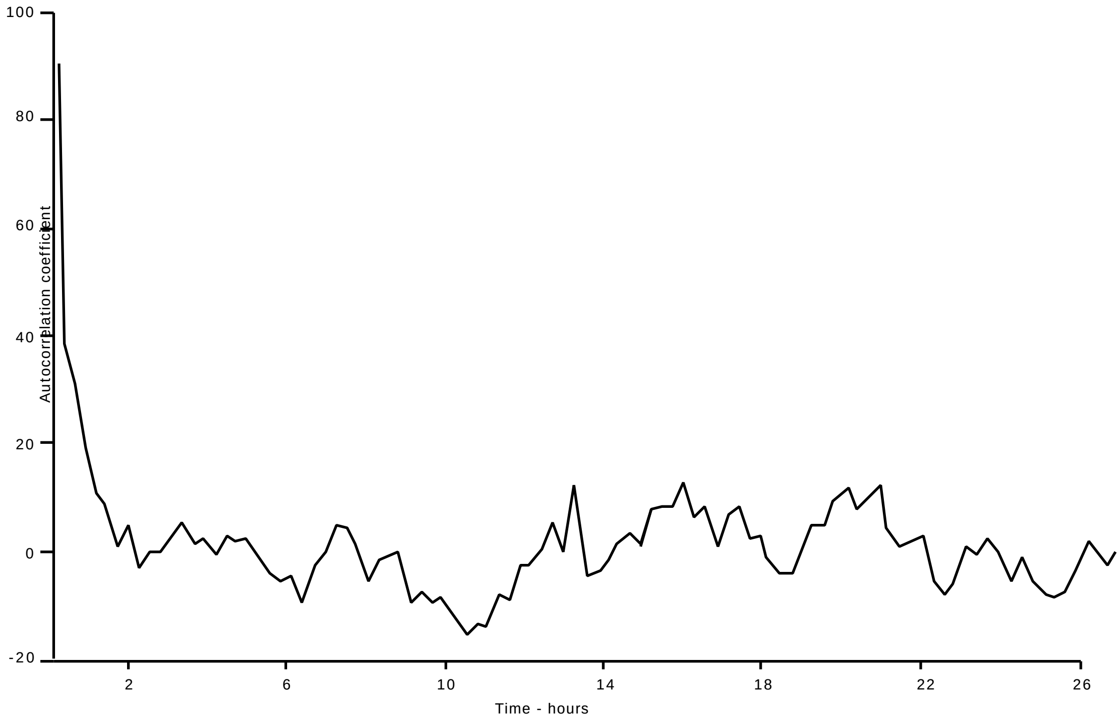

Figure 3. Autocorrelation - 1/3 octave at 250 cps.

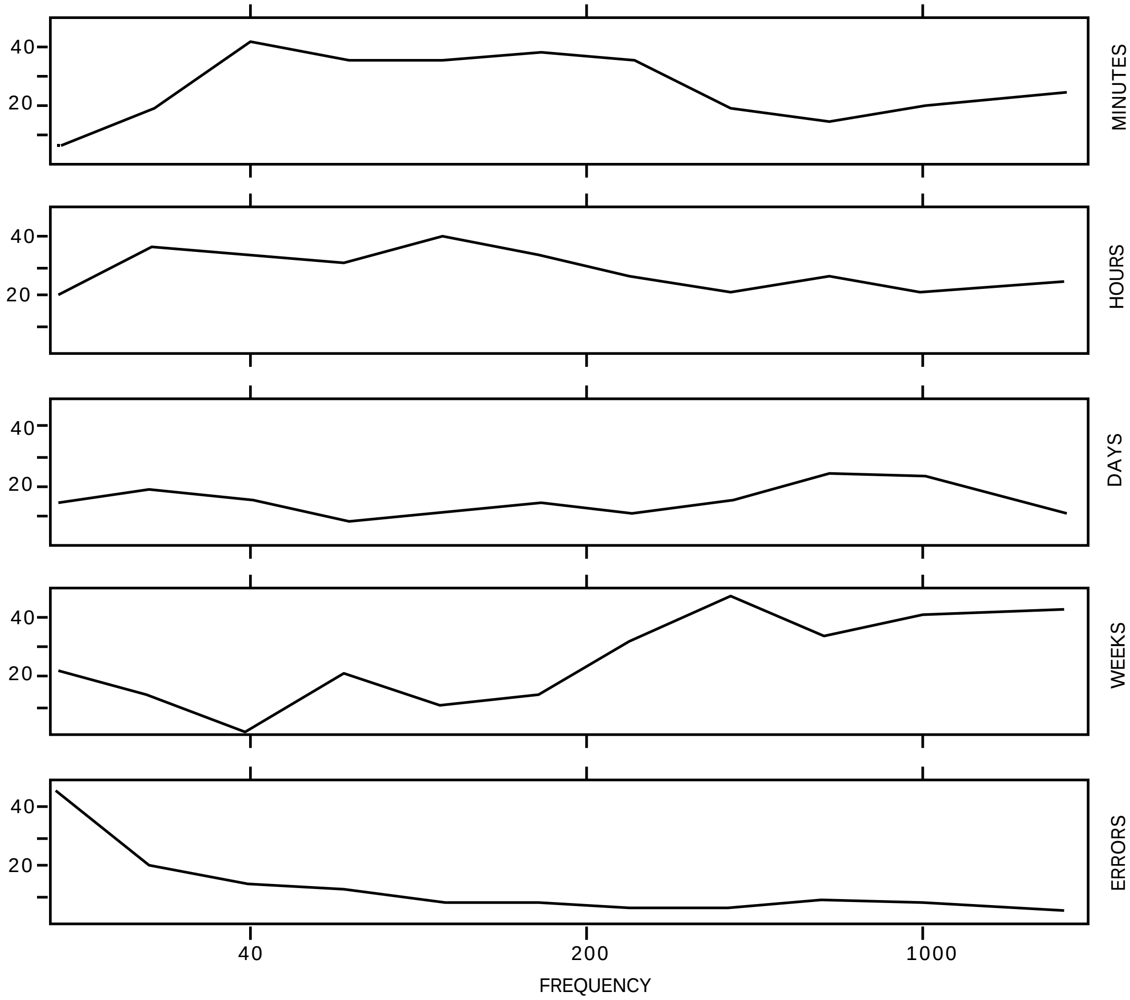

Figure 4. Analysis of variance - % of total variance vs. frequency.

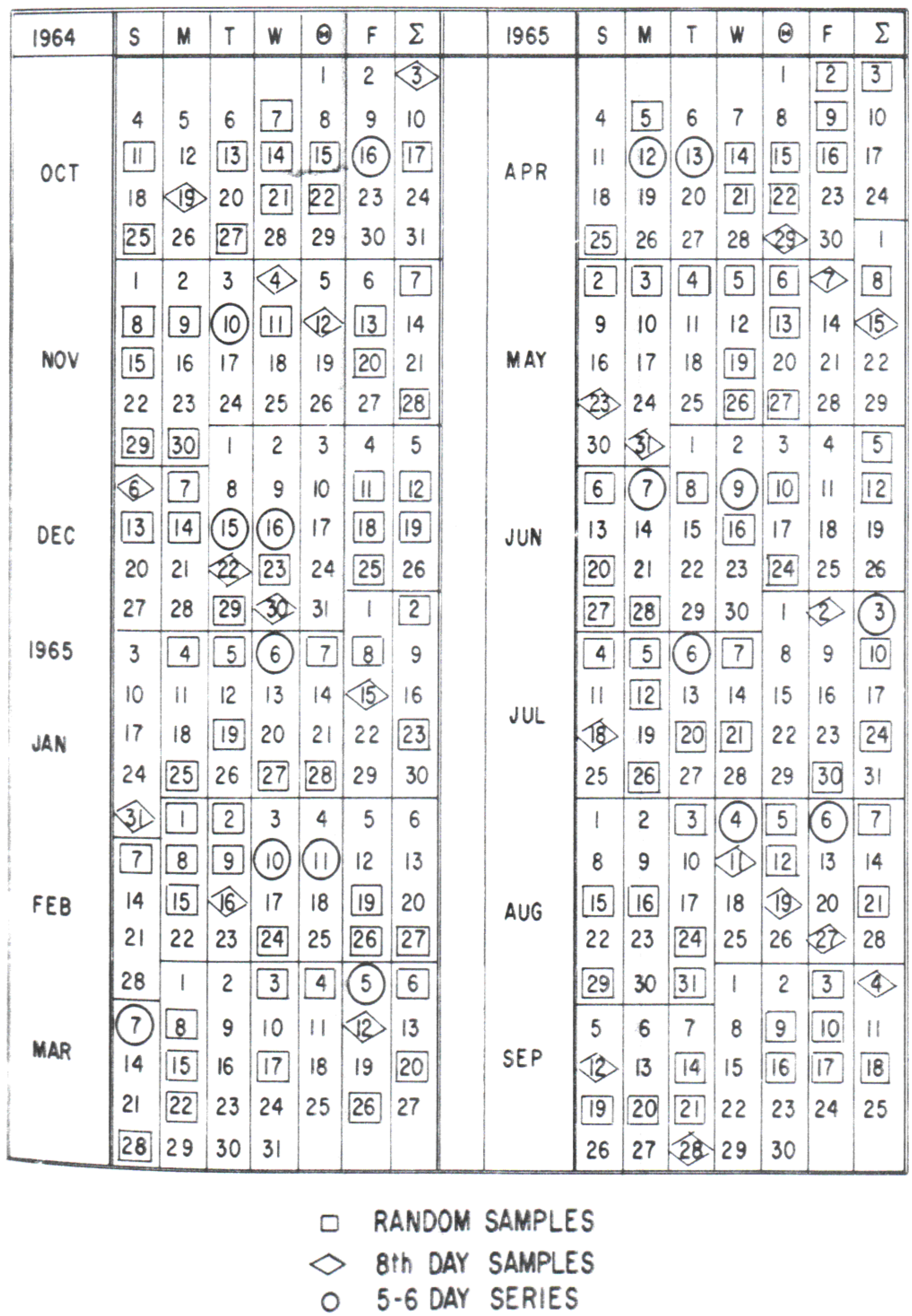

Figure 5. sampling schedule.

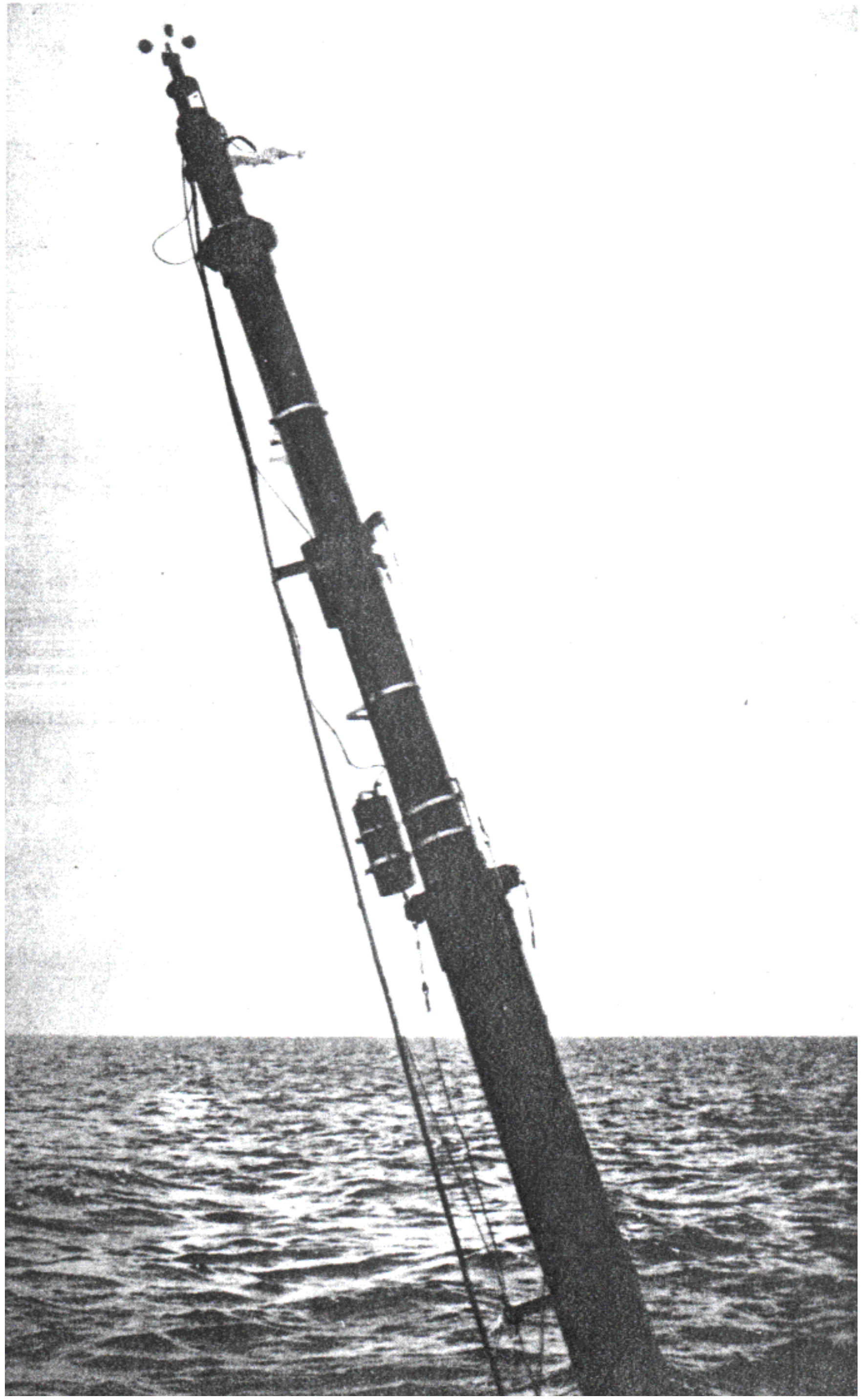

Figure 6. Spar buoy. New mooring techniques will correct buoy tilt.

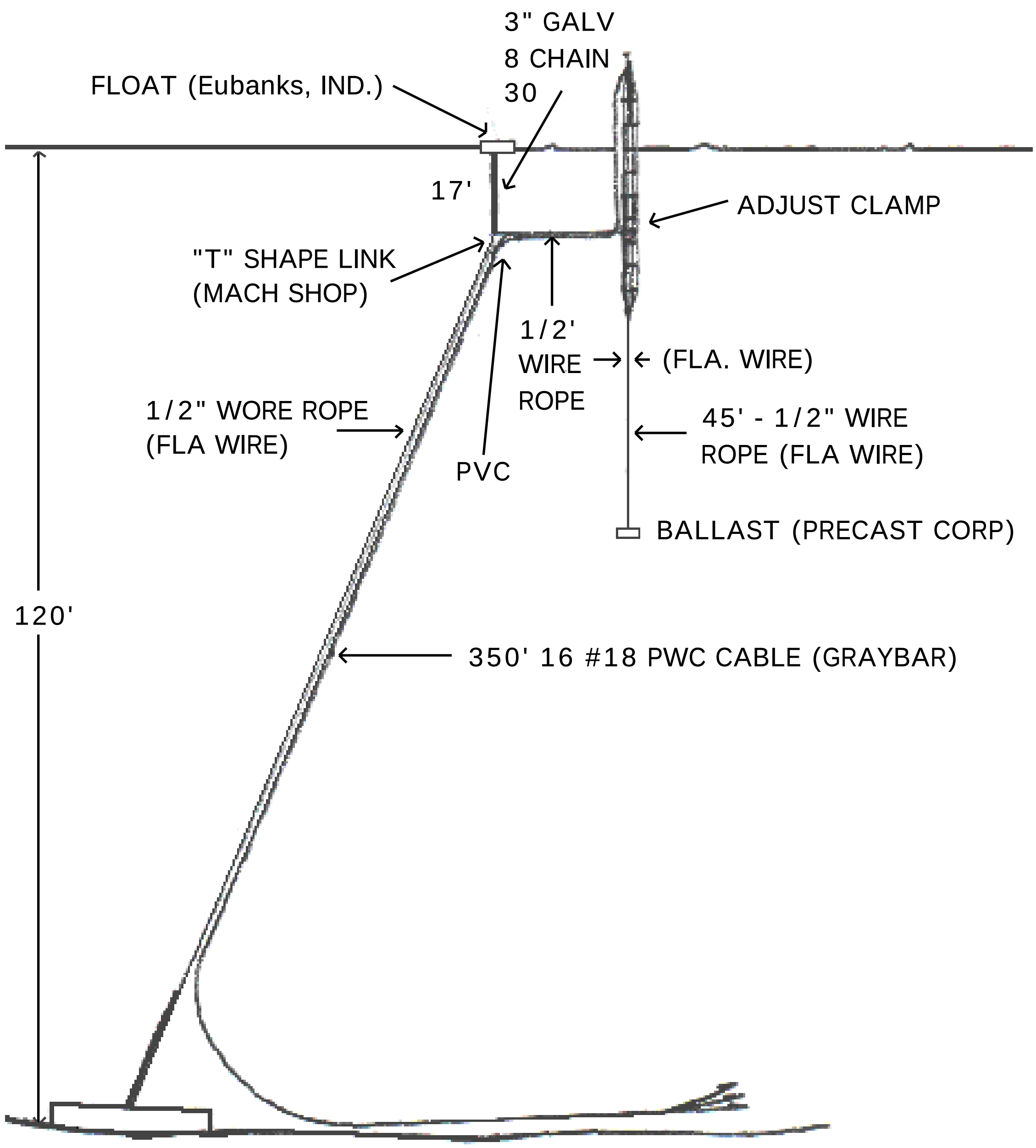

Figure 7. Spar buoy mooring.

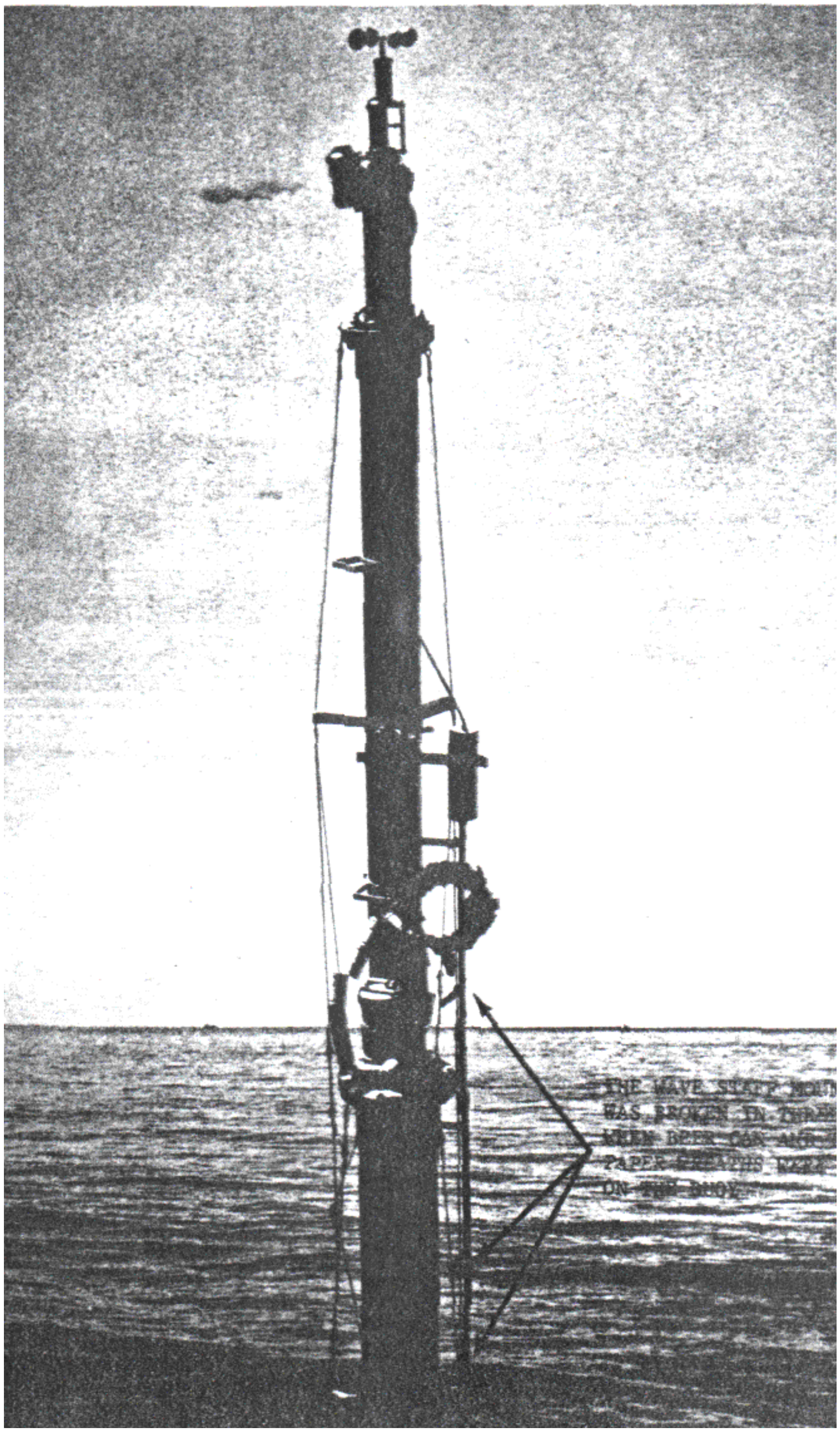

Figure 8. Vandalism to spar buoy.

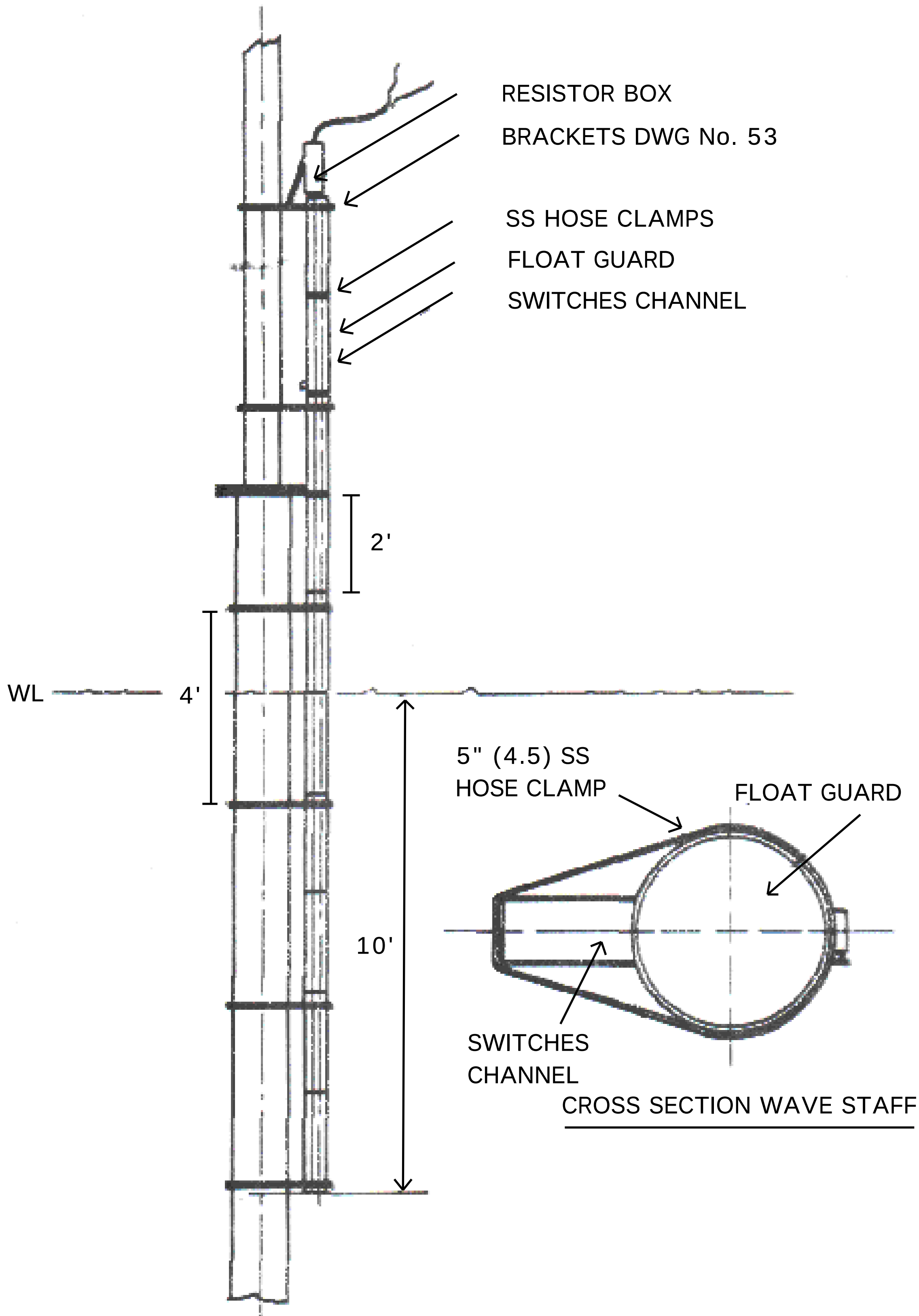

Figure 9. New wave staff mounting.

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