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Hudson Laboratories
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PROJECT MICHAEL
Contract N6-ONR-27135

Technical Report No. 13
15 and 30 cps Sound Propagation
at a Location Near the Entrance
to New York Harbor
by
G. E. Becker and R. O. Carlson

W. A. Nierenberg
Director

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15 AND 30 CPS SOUND PROPAGATION
AT A LOCATION NEAR THE ENTRANCE
TO NEW YORK HARBOR

by

G. E. Becker and R. O. Carlson

ABSTRACT

The propagation of sound at 15 cps and 30 cps has been studied in shallow water near the entrance to New York Harbor. The operations area was 6 miles east of Ambrose Light and 8 miles south of the southern shore of Long Island. The water depth was approximately 80 feet. The water and bottom layers were sufficiently constant in thickness to be represented by a simple parallel-layer model in theoretical work. The sound source was operated at a depth of 42 feet, and most of the sound level measurements were made at this same depth.

Curves are presented which give the sound level as a function of range out to 6000 yards. The following general conclusions may be drawn:

1. The expected interference maxima and minima are observed, corresponding to changes in level of 20 db for changes in range as small as 50 yards.
2. In the range out to 6000 yards, there are approximately three times as many major dips at 15 cps as at 30 cps.

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3. At 15 cps, there is a broad minimum, or series of closely spaced minima, in the range from 300 to 900 yards. For this same range, only a gradual decrease is observed at 30 cps.
4. Azimuthal symmetry is observed at 15 cps, except for one major dip at 1400 yards which is observed to the south but not to the north. At 30 cps, insufficient data are at hand to permit a definite conclusion regarding azimuthal symmetry.
5. The average sound pressure obeys a $(1/R)$ law very closely in the range from 1000 to 6000 yards at both 30 cps and 15 cps. A $(1/\sqrt{R})$ law, corresponding to cylindrical spreading, can be definitely excluded.
6. In the range from 100 to 1000 yards, the $(1/R)$ law for pressure holds fairly well at 30 cps, but at 15 cps the sound level is much lower than would be expected with a $(1/R)$ law.

Introduction

A report has been made on the propagation of 30 cps sound in the waters of Long Island Sound.⁽¹⁾ The attempt to make a detailed comparison of theoretical and experimental results for this area was only partly successful because the bottom conditions were too irregular to be described by any reasonably simple model. Therefore, it was decided to make measurements in an area for which a parallel-layer model would be a better approximation, and for which the bottom conditions could be determined by refraction shooting. With all experimental parameters well-determined, it should be possible to check the theory, and to decide on the feasibility of using the theory to make predictions about low frequency sound fields in shallow water with various bottom conditions. Since it could not be expected that the theory would make possible detailed predictions about all areas of interest because of irregular boundary conditions, it was hoped that the experience gained in this experimental work would lead to the development of a simple and quick procedure for measuring sound fields in these areas.

The site picked for these measurements was about 6 miles east of Ambrose Lightship, and 8 miles south of Long Beach, on the southern shore of Long Island. This area is of direct interest in regard to minesweeping problems in the approaches to New York Harbor.

The analysis of the shot records which yield information about the bottom layers, and the theoretical calculations based on a suitable model, will be published in separate reports.⁽²⁾

Experimental Method

A source was maintained at constant frequency in a nearly fixed position. The listening hydrophone was moved on an approximately radial path, carried along by a small boat which was moved at slow speed by the wind and current. The path of the small boat was determined with various navigational aids. The hydrophone signal was filtered and amplified, and meter readings were recorded by an observer at intervals frequent enough to show all significant changes in sound level.

Apparatus

One ship and two small boats were used in this operation. The sound source was operated from the 140 foot USS ALLEGHENY (ATA-179), which was anchored at bow and stern to keep its position nearly fixed. The ALLEGHENY occupied her anchored position near a special buoy placed by the Coast Guard at Lat. 40°27'55" N and Long. 73°41'40" W, with a maximum error in position from day to day estimated to be in the order of magnitude of 100 yards. The hydrophones were operated from two 40 foot boats. Crude sails were improvised for these boats to produce greater speed when wind and current were weak.

The distance of each small boat from the source was determined chiefly with the radar on the ALLEGHENY. At small distances, stadiometer and sextant readings were made. The true bearing of each small boat was determined with the gyro-compass and pelorus on the ALLEGHENY.

US Navy A Mark 6(b) acoustic minesweepers were used as sound sources. The 30 cps source has been described in an earlier report.⁽³⁾ The sound power output was about 200 watts. The frequency was held to 30 cps within $\pm .005$ cps. For the 15 cps source, manual control of the field current in the DC motor was sufficient to hold the frequency constant within ± 0.05 cps for long periods of time. The amplitude of the 15 cps source was made to be 0.5 inch, four times that of the 30 cps source, so that the power outputs would be approximately the same at the two frequencies. Actual measurements close to the sources indicated that the pressure level was about 10 db lower at 15 cps.

Brush type AX-58-C hydrophones were used as detectors. Absolute levels were obtained by direct comparison of the Brush unit with a calibrated Massa hydrophone. The Brush hydrophone was suspended in the water at a constant depth for a given drift run by one of the two rigs illustrated in Fig. 1. When the hydrophone was suspended from a boom on the small boat, rocking and pitching motions caused erratic changes in the hydrophone depth, and corresponding fluctuations in meter readings. The procedure of suspending the hydrophone from a float which was towed by the small boat eliminated much of this difficulty.

The hydrophone cable itself was never allowed to become taut. As shown in Fig. 1A, a steel wire was stretched taut and held vertically by a 30 lb weight. The hydrophone was attached to this weight so that it remained at constant depth, and enough hydrophone cable was paid out so that the cable remained slack in the

water. The weighted streamlined housing for the hydrophone, shown in Figs. 1B and 2, was designed to produce a smoother motion through the water, thus reducing water noise. The actual improvement noted with this housing was not great at the towing speeds involved (one knot or less).

Fig. 3 shows a block diagram of the equipment used in the small boat. All of this equipment was battery operated. The diagram for the selective amplifier is given in Fig. 4. The circuit has strong negative feedback at all frequencies, except the one determined by the "Twin-T" section. The gain of the selective amplifier was checked frequently with the calibrating equipment shown in Fig. 3, and was found to be quite constant and reproducible from day to day. The gain of the amplifier was of the order of 50 db, and the effective Q was about 40. The corresponding band width was 0.8 cps at 30 cps and 0.4 cps at 15 cps. With this degree of filtering, it was possible to work out to ranges of several miles in spite of the noise produced by heavy shipping traffic in the area.

Procedure

The work was carried out during the month of July, 1953. The ALLEGHENY and small boats went out and returned to the base at Floyd Bennett Field each day. Seven days were devoted to work at 30 cps, and six at 15 cps. On the average, the sound source was operated for 4 1/2 hours each day.

A source depth of 42 feet was used at all times. Drift runs

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were made with the detecting hydrophone at 42 feet and also at 63 feet. In addition, a number of vertical traverses were made.

Ordinarily, the small boats started from a point near the source and moved away on a radial course determined by the wind and the current. If these changed directions during a run, the ship track was no longer on the desired radial one. On several occasions, the small boats were nearly becalmed. The diesel engines in the small boats could not be used because of the noise which they produced and also because their use would make the boat speed three knots or greater. A speed of one knot could not be exceeded without introducing excessive apparent fluctuations in level resulting from cable strumming and hydrophone motions in the water.

During the 30 cps work, wind and current were such that measurements were almost entirely confined to the NE and SW quadrants. At 15 cps, measurements were made in all four quadrants. The tracks of the small boats are shown in Figs. 5 and 6.

Precision of Measurements

As long as the sound level was about 20 db above background, the measurements were found to be reproducible with ± 1 db. There were a number of instances in which a measurement of sound level was made at a given point, on different days, with different hydrophones and meters. In all such cases, the measurements were found to be reproducible within the limits stated above. Meter fluctua-

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tions became greater as the signal strength decreased, because the background level fluctuated typically by ± 5 db. The observer was required to make a mental average of these readings. Hence, any one recorded level for weak signals may easily be in error by 5 db. Possible errors resulting from background fluctuations rapidly became negligible as signal strength increased.

Further evidence regarding the reproducibility of measurements is given in Fig. 7. Curves showing the sound level as a function of range are plotted for three runs made on approximately the same bearing (from 295° to 310°). The same prominent features appear on each curve. Small differences in the positions of minima may be ascribed to errors in range measurement or to real shifts because of difference in bearing.

The background levels indicated in Figs. 7 and 8 were determined when the sound source was turned off. Meter readings fluctuated in the ranges indicated, occasionally reaching the upper limit shown, but usually remaining close to the lower limit.

Absolute levels are dependent on the manufacturer's calibration of the Massa hydrophone and pre-amplifier, which was used as a standard for the calibration of the Brush AX-58-C units.

Radar ranges should be accurate to within ± 50 yards, especially after a smoothing process based on the assumption of no rapid changes in drift rate. At a range of about 600 yards, the radar range could be compared with stadimeter readings, and the two usually agreed within ± 50 yards. There was no check on the absolute accuracy of the radar at large ranges.

Results

The degree of symmetry with azimuth which was observed is illustrated by the curves in Fig. 8. The four runs were made in four different quadrants. Except for the differences near 1400 yards, the same prominent features appear on all these curves. That is, the number and position of the major dips, peaks, and plateaus are nearly the same. The differences which do appear may be attributed to local bottom irregularities and to the fact that the water and bottom layers are actually wedge-shaped, rather than of constant thickness.⁽²⁾ The only obvious clue to the differences near 1400 yards is that runs B30 and R24 were made in the southern quadrants and R30 and R22 were made in the northern quadrants. This suggests that some difference in bottom conditions may have given rise to the differences in the curves.

The high degree of similarity of the curves for all azimuths makes it possible to draw a free-hand composite curve for 15 cps, shown in Fig. 9. This appears to be the best method of presenting an average curve for a given frequency, since one can make a rather accurate mental average for the position and magnitude of each major peak or dip. The subjective element involved is not large. The curve for 15 cps given in Fig. 9 is considered to be the best single curve which can be drawn to present the experimental results at this frequency. This curve is drawn double-valued in the range near 1400 yards for the reason given in the preceding paragraph.

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At 30 cps, measurements were confined to the NE and SW quadrants. Symmetry with azimuth is not apparent from the curves which were taken. It is difficult to decide whether this is a real difference from the situation at 15 cps, which seems unlikely, or simply the result of inadequate coverage of azimuth, with a few non-typical curves produced by bottom irregularities. The composite curve given in Fig. 9 for 30 cps applies only to the NE quadrant.

Another kind of average curve may be drawn which does not involve any subjective element. All observed points at a given frequency and given range may be averaged. This was done at 50 yard intervals, with the results shown in Fig. 10. It is obvious that this straightforward averaging procedure has the effect of washing out maxima and minima. For example, there are no major dips shown on the 15 cps curve beyond 3000 yards, although such dips were actually observed on each run. It is most probable that the wedge shape of the water and bottom layers caused sufficient relative displacements of the dips at large ranges so that a fairly smooth curve was produced when data for all directions were averaged. Nevertheless, the curves in Fig. 10 are produced by a systematic averaging of all the data at each frequency, and are useful for determining the average rate of decay of the sound level.

The two curves in Fig. 10 are re-plotted separately in Figs. 11 and 12, along with curves corresponding to cylindrical (Pressure proportional to $1/R^{1/2}$) and spherical (Pressure proportional to $1/R$ decay laws.

At 30 cps, several runs were made with the hydrophone at 63 feet. Except for a generally higher sound level, no significant differences from the results at 42 feet were observed. Fig. 13 gives the results for two runs made in the same general direction (bearing 0° to 40°), one with the hydrophone at 63 feet and one at 42 feet.

A number of vertical traverses were made at distances in the range from 15 to 500 yards. In each case, a steady increase in level was observed as the hydrophone was lowered from the surface to the bottom. A typical curve is given in Fig. 14.

Discussion

A comparison of these results with those based on theory will be made in a separate report. The chief conclusions which should be explicable on a theoretical basis are the following:

1. There is a striking difference in the decay curves for 15 cps and 30 cps in the range from 100 to 1000 yards.
2. The change in sound level with range seems to obey a spherical spreading law (Pressure proportional to $1/R$) for ranges from 1000 to 6000 yards.
3. There are about three times as many major dips at 15 cps as at 30 cps in the range from 0 to 6000 yards.

REFERENCES

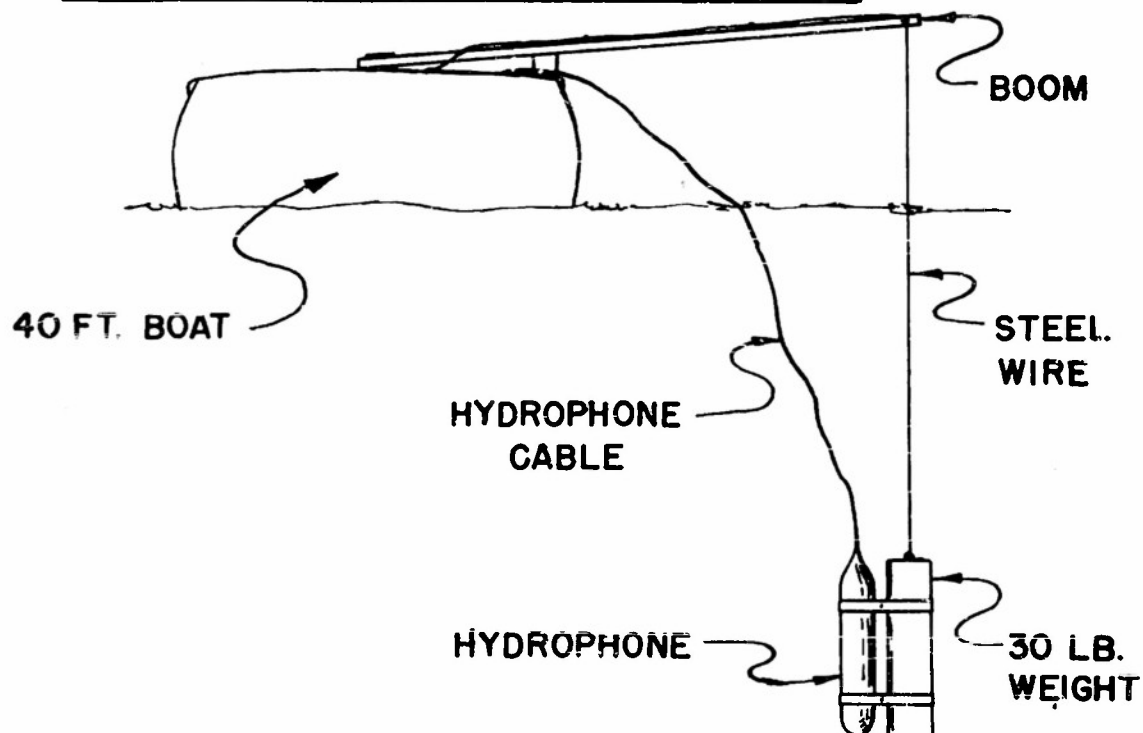
1. G. E. Becker, R. O. Carlson, R. A. Frosch, and H. L. Poss, Columbia University, Hudson Laboratories. Technical report no. 9, 30 cps sound propagation in shallow water. April 15, 1953.
2. R. O. Carlson and M. V. Brown, Columbia University, Hudson Laboratories. Technical report no. 14, Shot refraction profiles in the Atlantic Coastal Plain 6 miles east of Ambrose Lightship. November 10, 1953.
3. H. C. Beck and H. Sonnemann, Columbia University, Hudson Laboratories. Technical report no. 8, Conversion of the A Mark 6(b) minesweeping gear to a 30 cycle sound source. February 10, 1953.

* * * * *

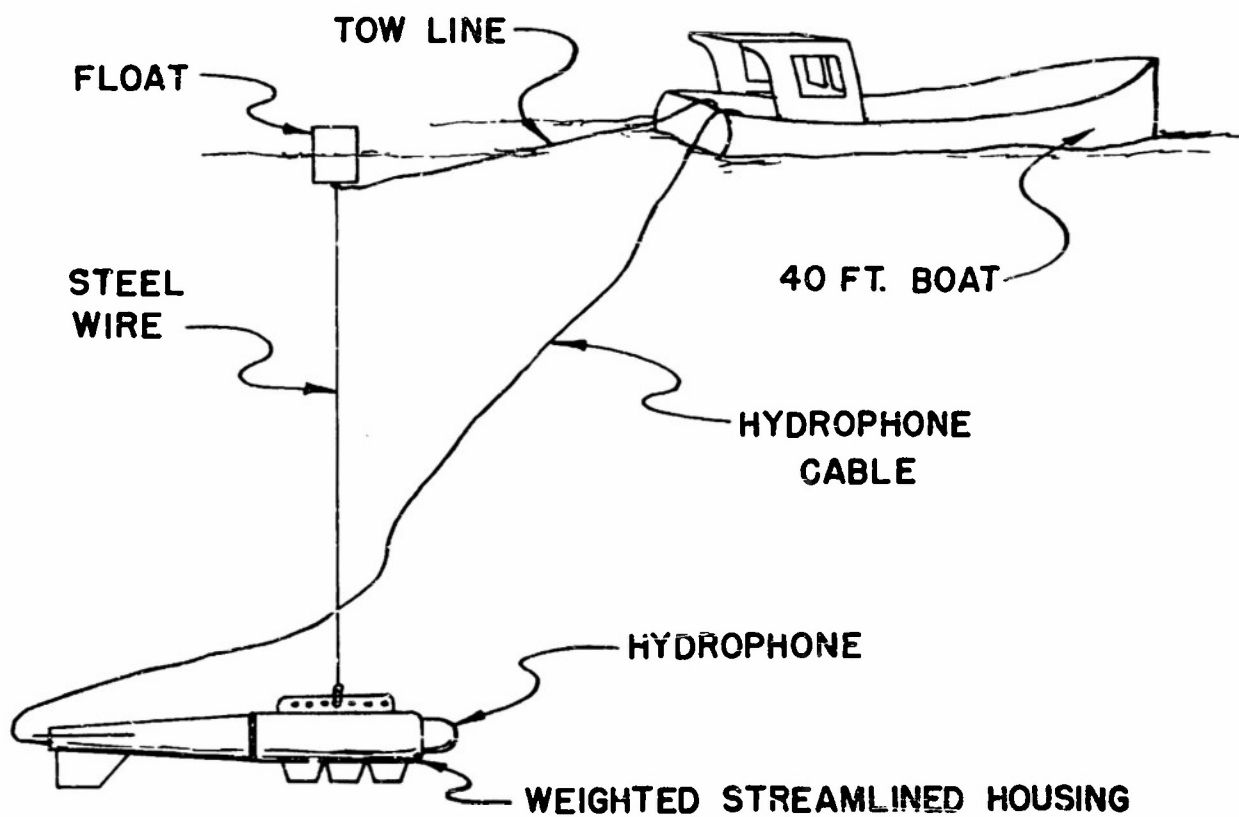
ACKNOWLEDGEMENTS

The following members of the staff of Hudson Laboratories rendered invaluable assistance in conducting the experimental work: R. Frassetto, L. P. Goldberg, M. A. Hall, G. L. Hesse, F. K. Levin, D. D. Mitchell, D. P. Mitchell, E. T. O'Neill, H. Schimmel, J. L. Smith, and J. Spira.

HYDROPHONE SUSPENSION SYSTEMS

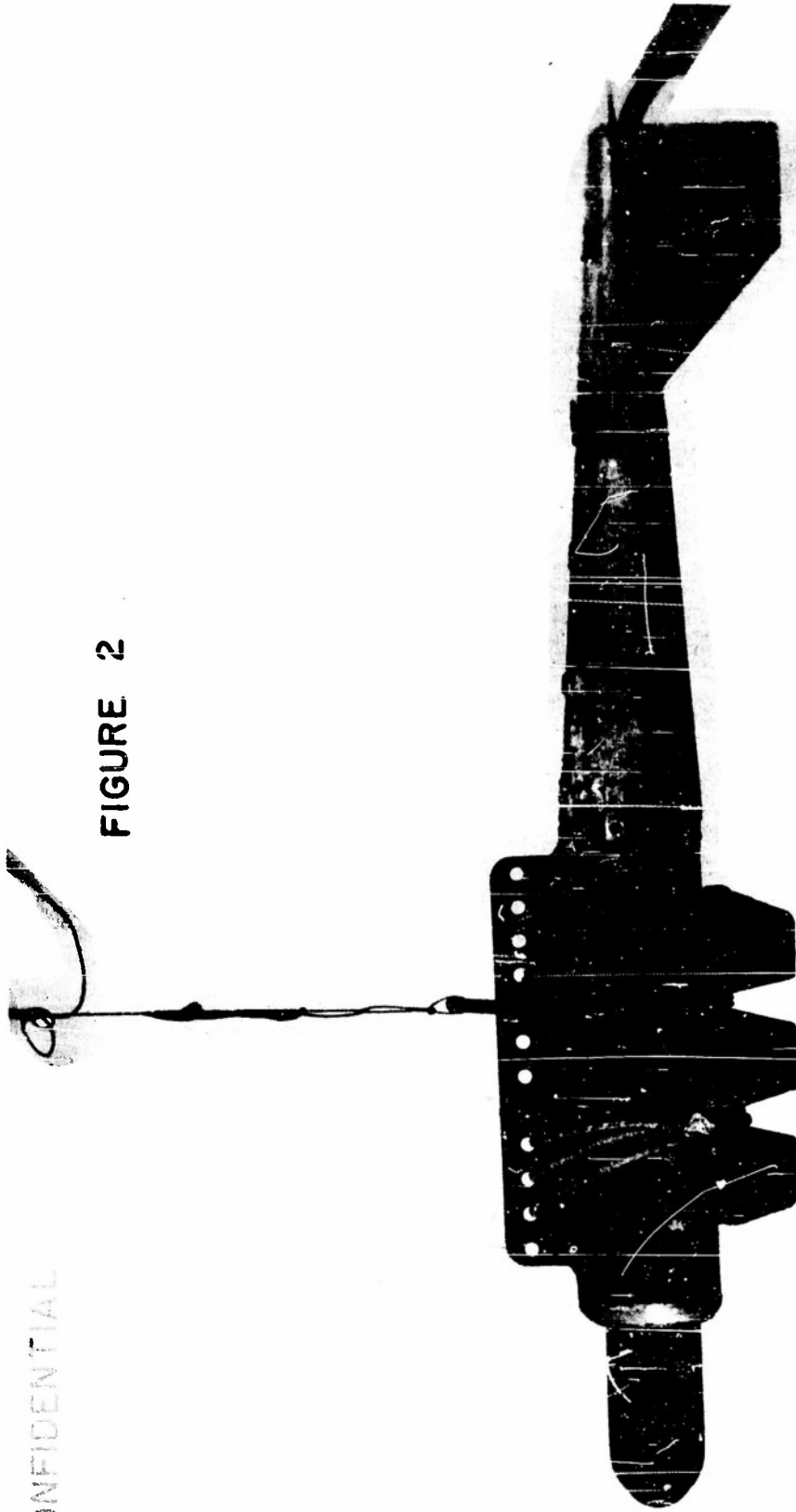


(NOTE: NOT DRAWN TO SCALE)

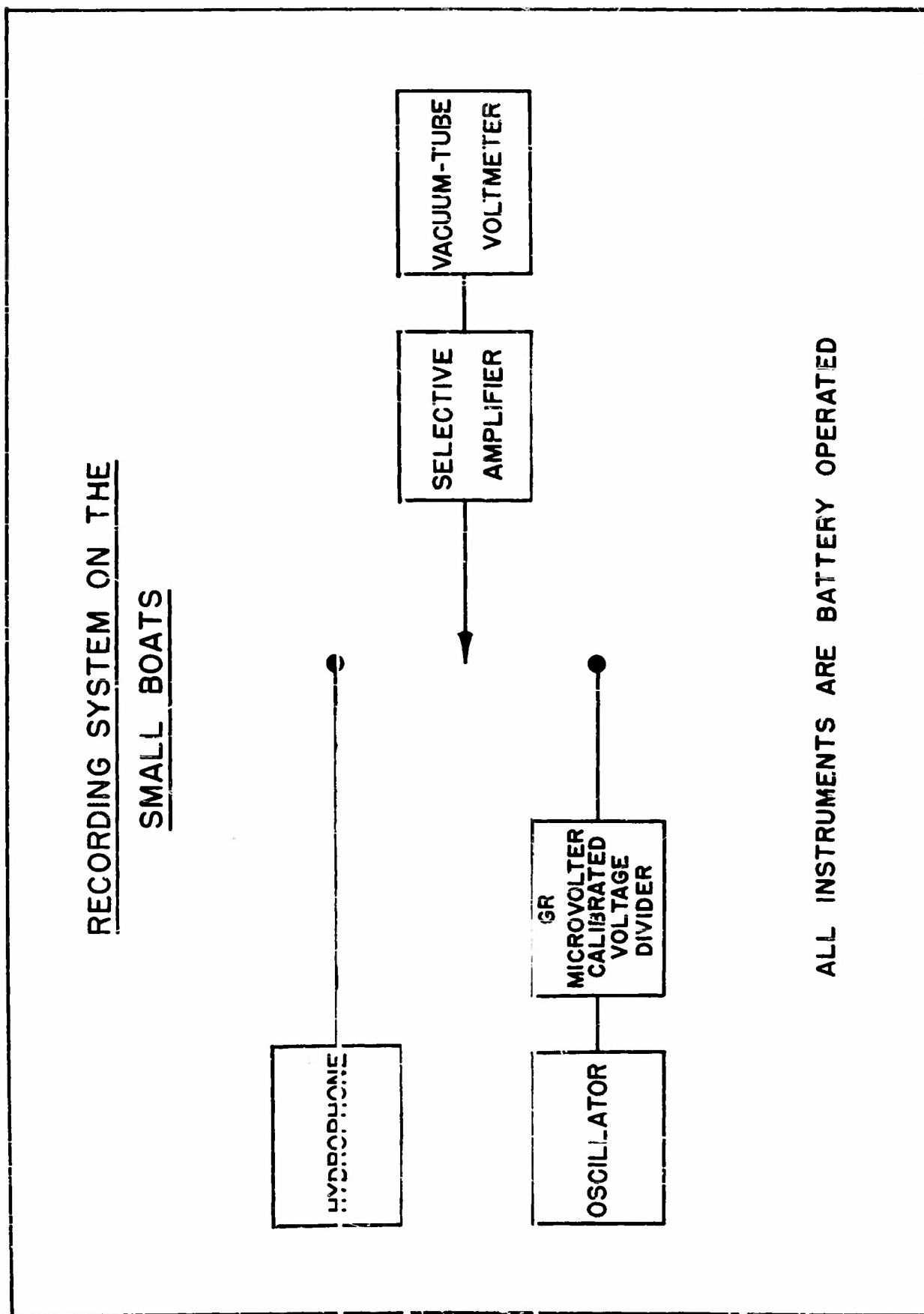


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FIGURE 2



STREAMLINED HYDROPHONE
HOUSING



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	15 CPS	30 CPS
R ₁	2.45 MEG	2.45 MEG
R ₂	2.45 MEG	2.45 MEG
R ₃	2.45 MEG	2.45 MEG
C ₁	3000 pF	1500 pF
C ₂	3000 pF	1500 pF
C ₃	0.012 μ F	6000 pF

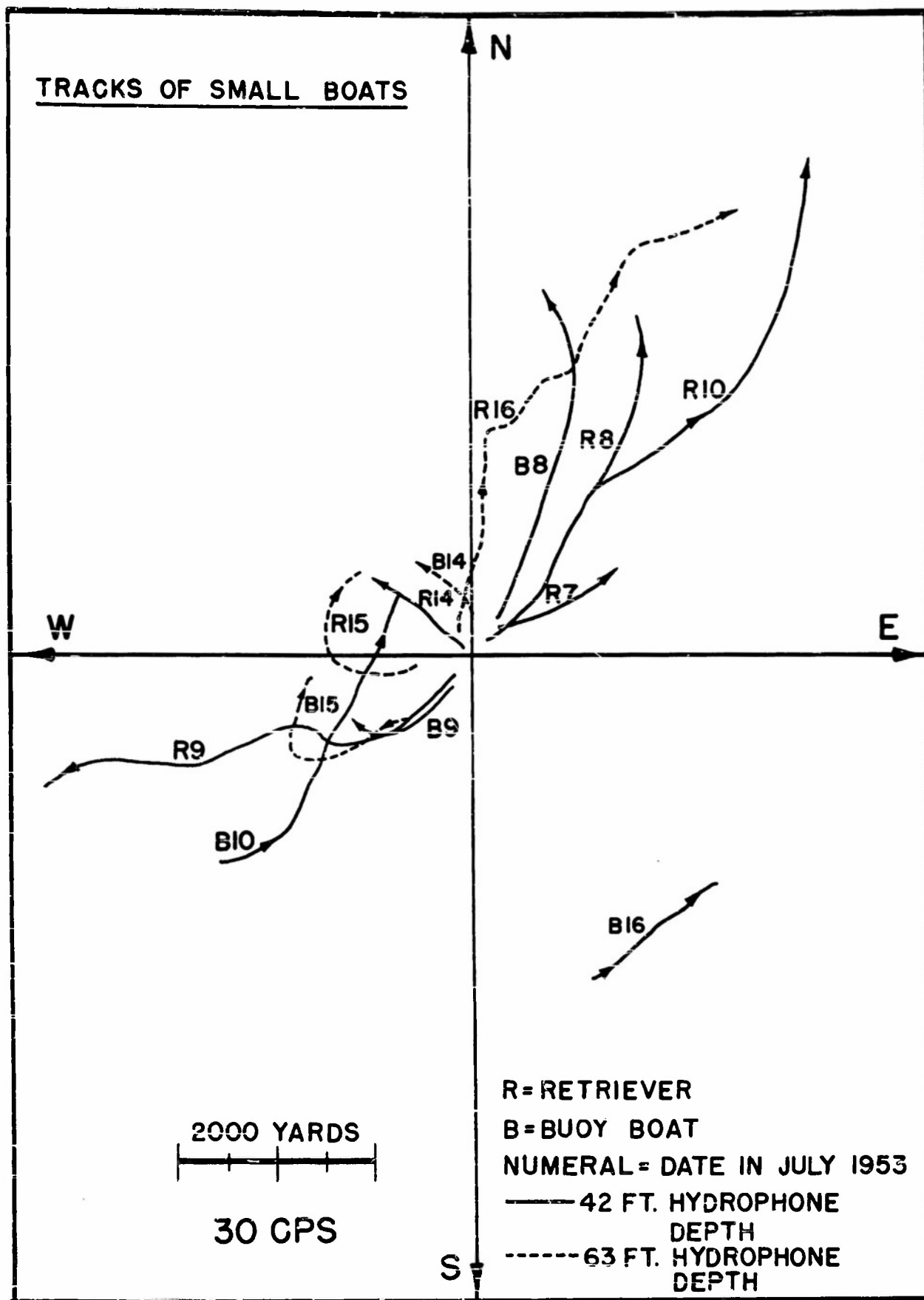
AMPLIFIER, 15 & 30 CPS.

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ALL CAPACITORS ARE IN MFD. UNLESS SPECIFIED OTHERWISE.
ALL RESISTORS ARE 1/2 W UNLESS SPECIFIED OTHERWISE.
CHASSIS - 17X7X2
PANEL - 14X8 3/4

FIGURE 4



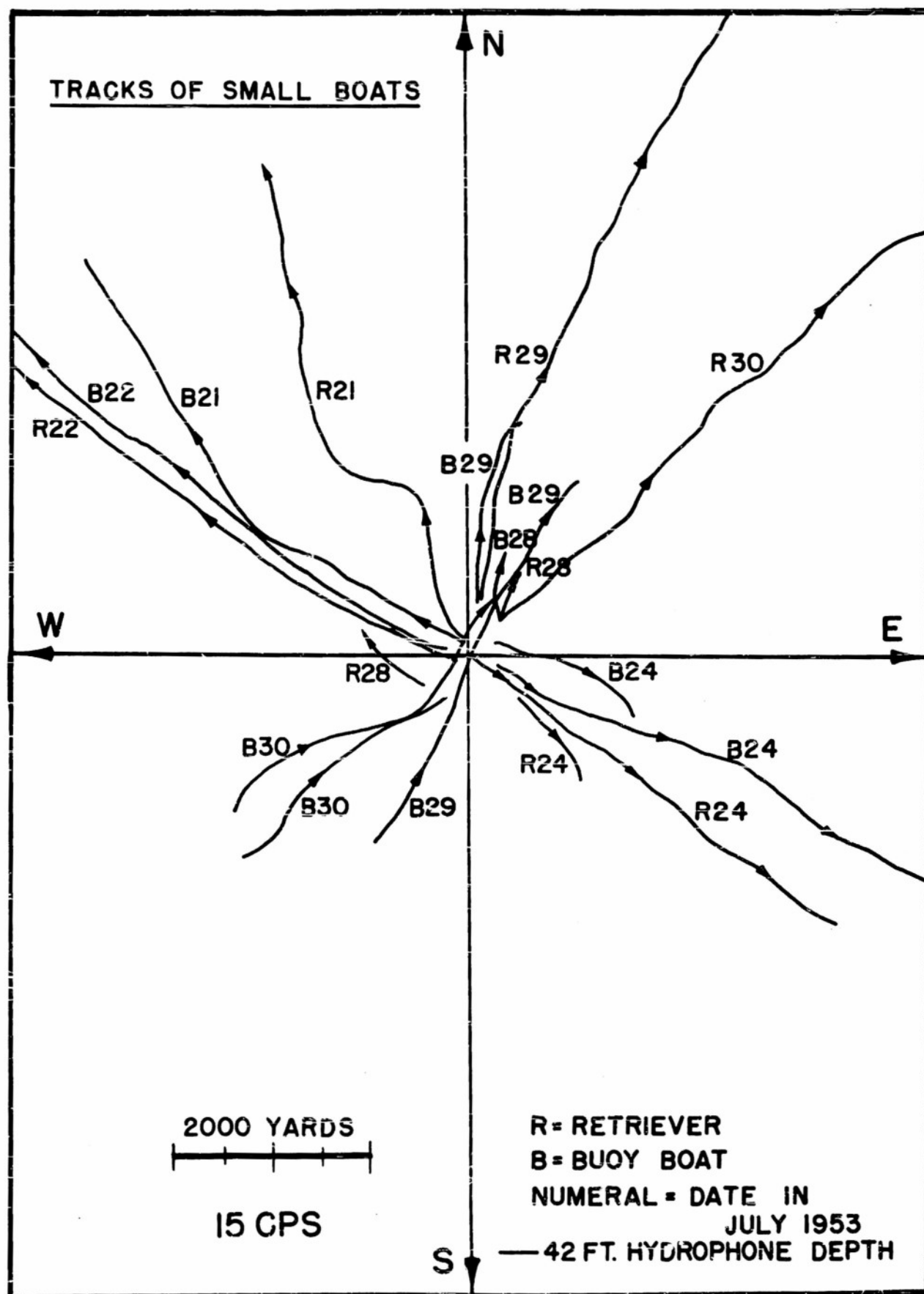
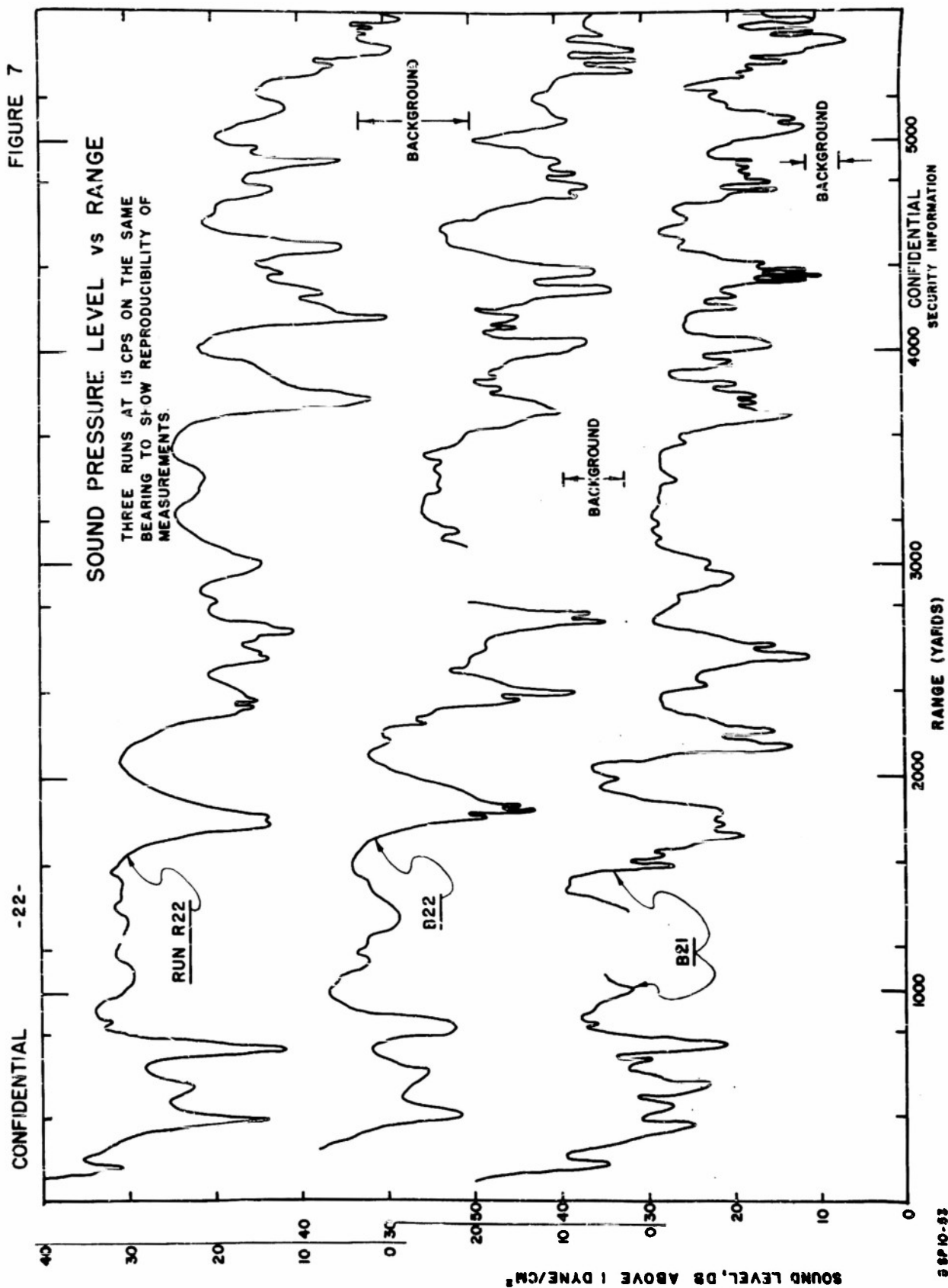


FIGURE 6

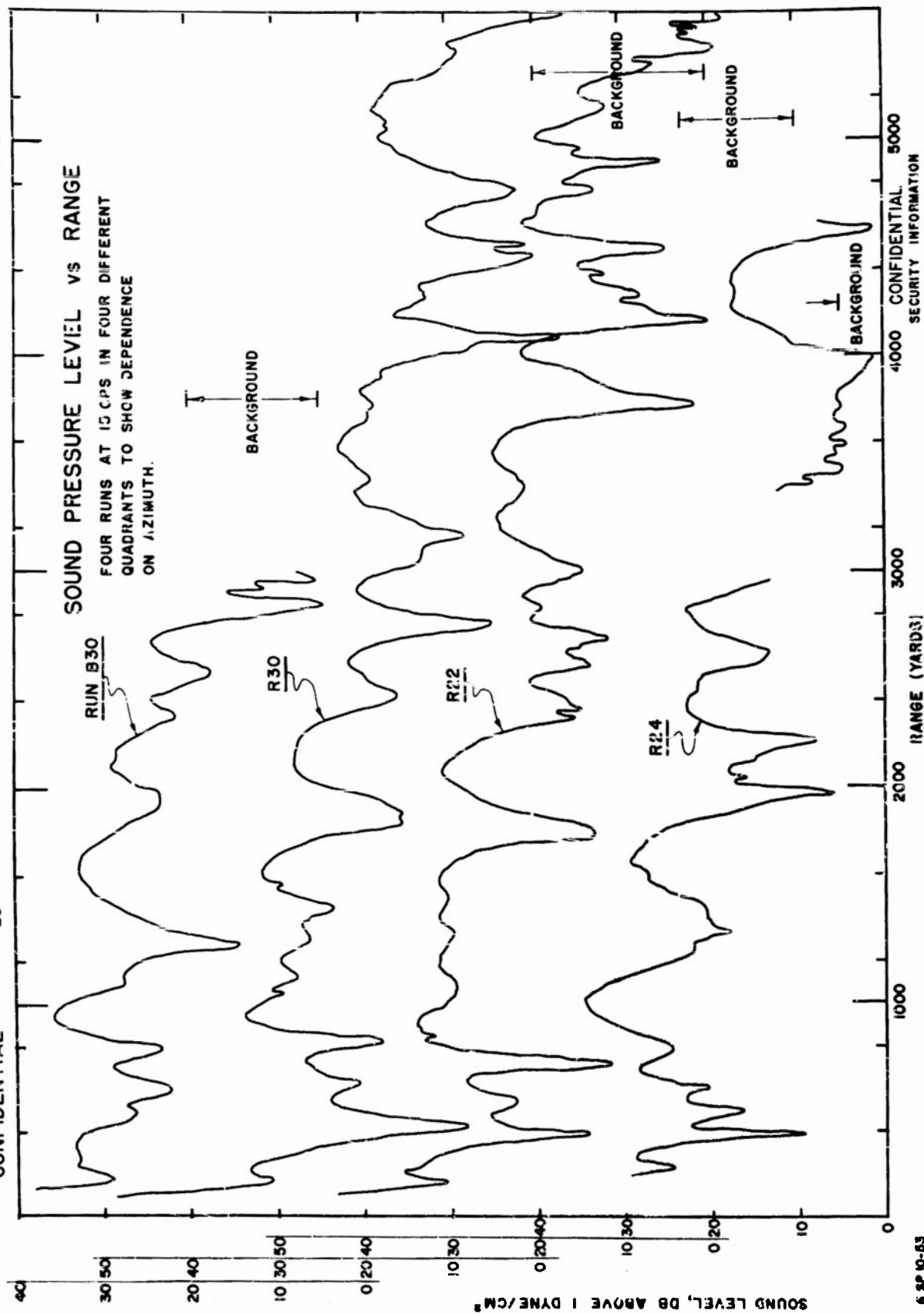
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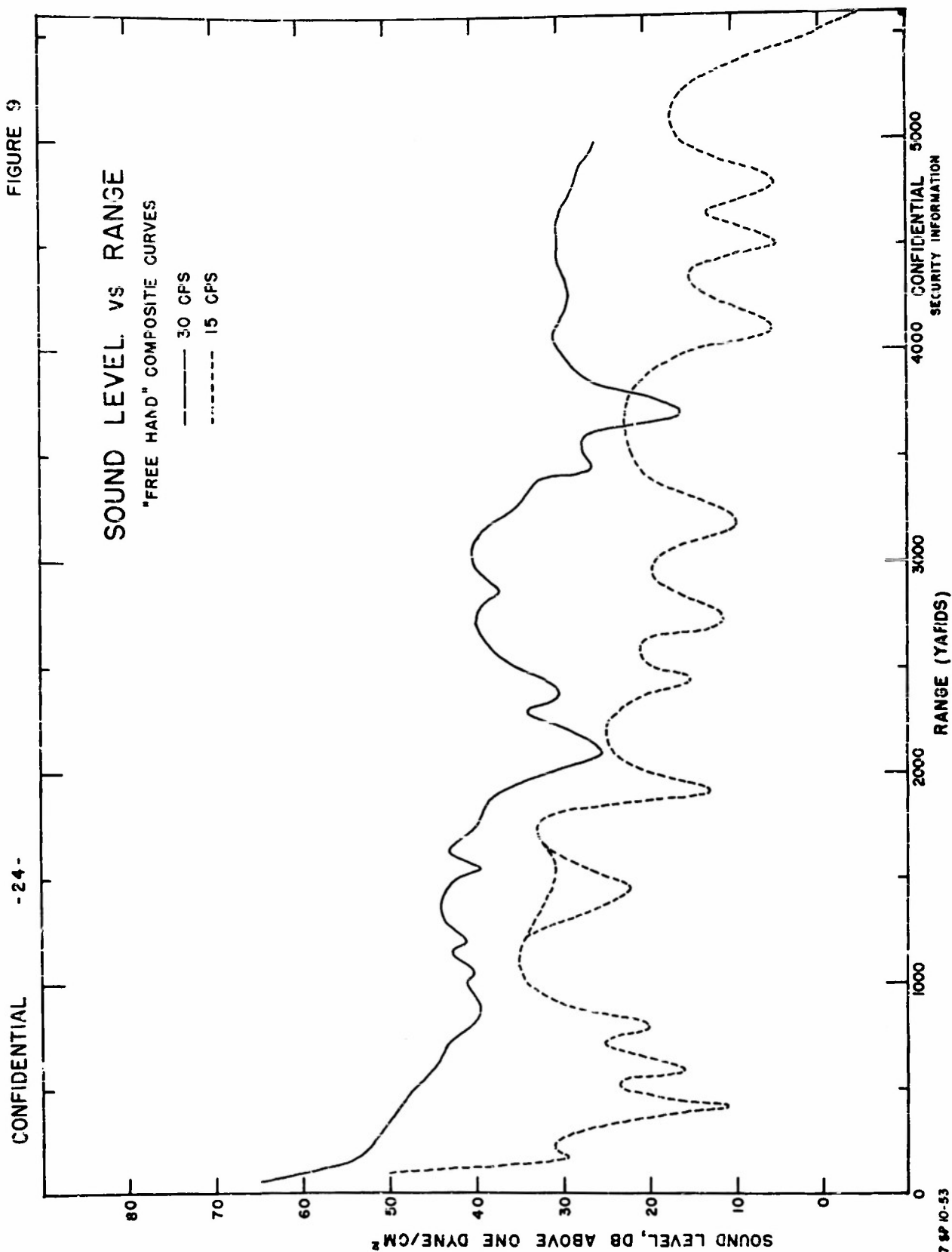


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FIGURE 8

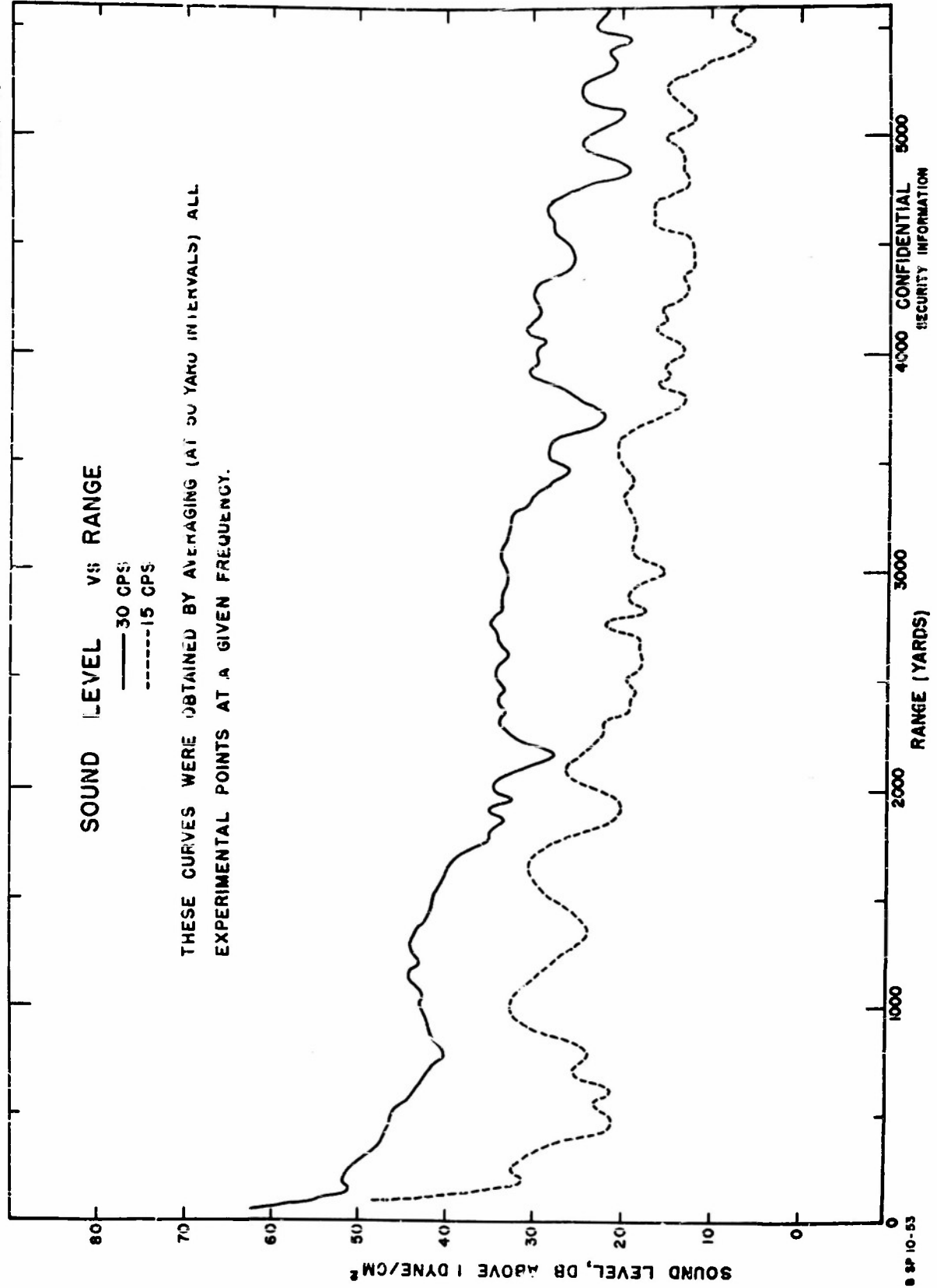




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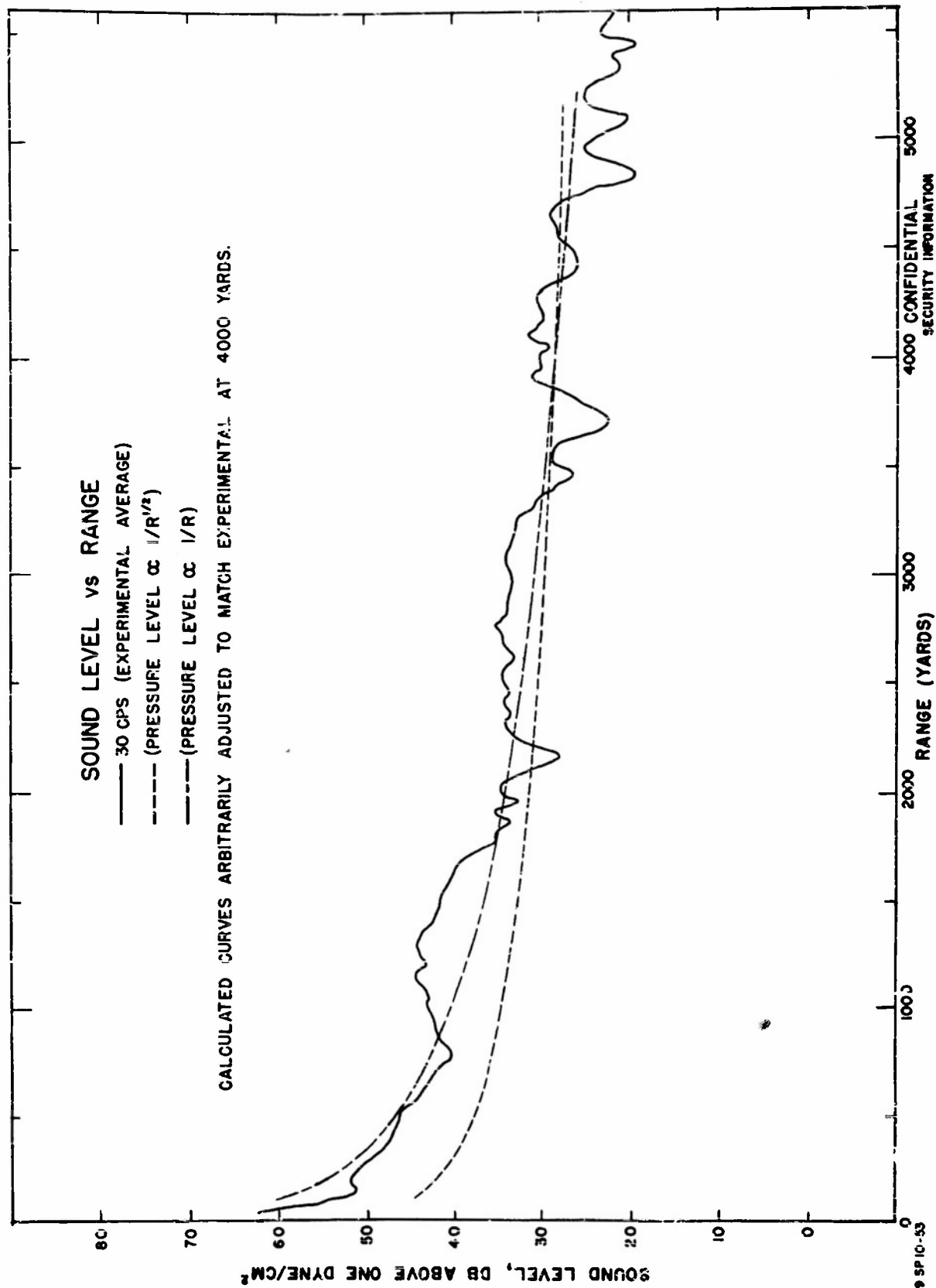
FIGURE 10



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FIGURE 11

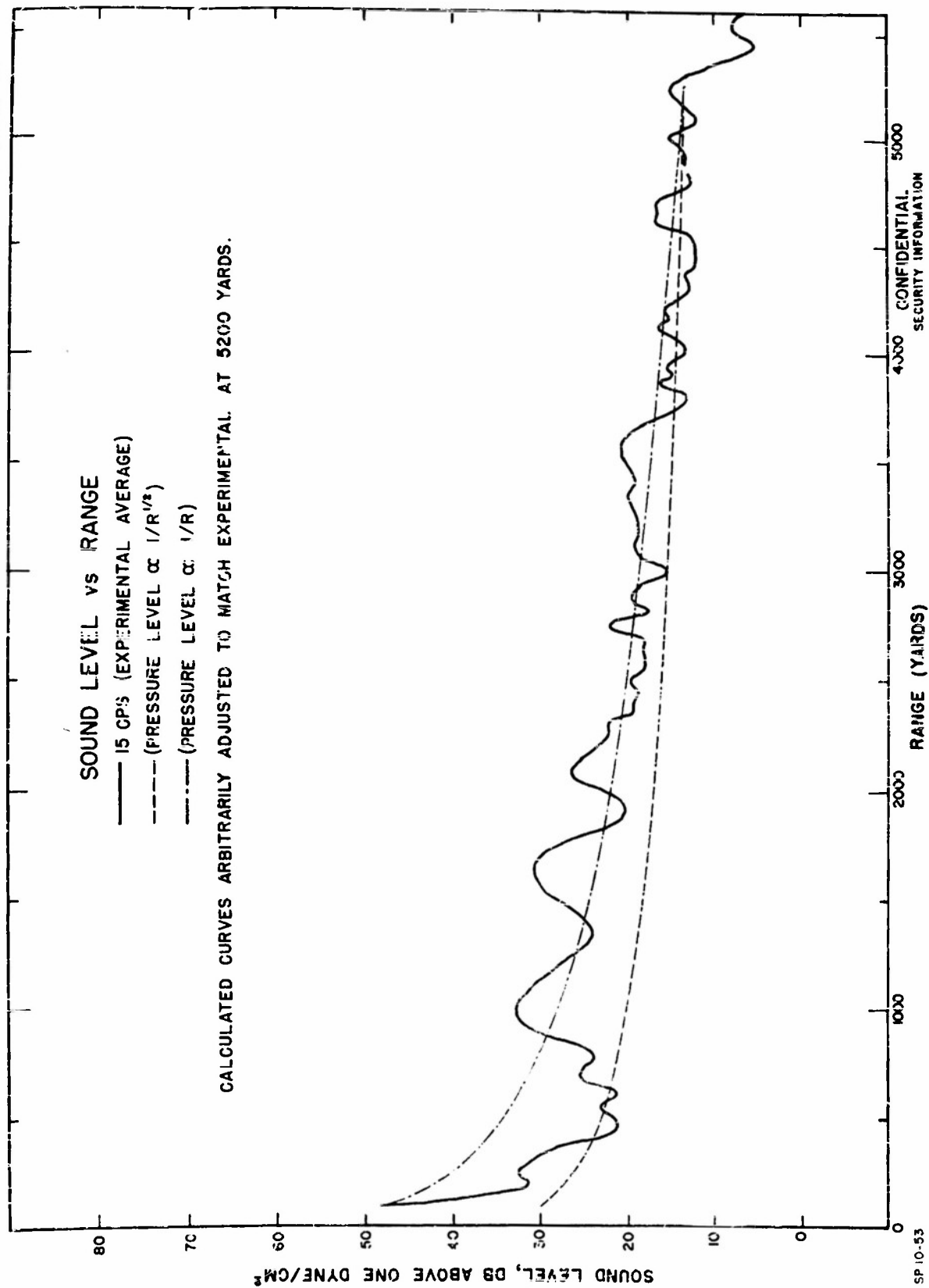


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FIGURE 12



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FIGURE 13

SOUND LEVEL vs RANGE

30 CPS

- HYDROPHONE DEPTH 63 FT. (RUN R16)
- HYDROPHONE DEPTH 42 FT. (RUN R8)

SOUND LEVEL, DB ABOVE ONE DYNE/CM²

11 SP 10-53

RANGE (YARDS)

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