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SPECIAL ELECTRONICS RESEARCH AND DEVELOPMENT DIVISION

APPLICATION RESEARCH SECTION

30 November 1945

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DEVELOPMENT OF MODEL XCX BOAT TYPE SONO RADIO BUOY

BY

F.J. HOLLWECK

- Report R-2685

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Preliminary Pages...........a-d
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BuShips Problem S303R-C

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ABSTRACT

This report describes the development of a boat type, anchored Sono Radio Buoy for use in harbor defense in the detection of underwater sound. The problem was essentially a redesign of the JM equipment, now in service, on the basis of operation information obtained from this service. Tests of the completed equipment verified the original proposition that a single unit buoy of boat design simplified servicing and permitted operation in sea states that would cause failures in JM equipment. Lowering the carrier output with consequent reduction of battery dimensions, to approximately one-half, was found to give satisfactory field strength. The inclusion of audio AVC has improved the quality and sensitivity of listening in the judgment of qualified personnel. The potential danger of the confined hydrogen generated by chemical action in the dry batteries was considered and a means of preventing uncontrolled reaction is presented. The ground plane type antenna, now used on the JM equipment, was deleted to effect further maintenance reduction, and the simple sleeve type antenna is considered to have an improved radiation pattern. Low drain minature tubes are used and a single dial controlled oscillator-doubler circuit with little frequency shift due to ambient changes and antenna reactance shifts has been used. Extensive tests were made at Portland, Maine, for comparison with installed JM-3 units and an operational life of approximately 30 days has been reported from subsequent tests at that activity in addition to comment as to the ability of the equipment to operate in extremely abnormal sea states.

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TABLE OF CONTENTS

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INTRODUCTION

1. Under authority of reference (1) development of an improved type Sono Radio Buoy was begun June 1943.

2. Sono Radio Buoys are essentially anchored flotation gear, comprising a low powered radio transmitter modulated by underwater sound as received by a hydrophone suspended some depth below the water surface. The buoys are generally spaced across any waterway as a means of detecting the passage of any surface or under surface craft.

3. The assigned frequency spectrum for this equipment is 70 to 90 Mc and, due to the line-of-sight characteristics of this spectrum, the receiving equipment is normally within a ten mile radius of any buoy. The transmission is frequency modulated to obtain the increased signal-to-noise ratio inherent in FM and for the economy of battery life and size obtained by the saving in modulator power required in amplitude modulation.

4. The original development of Sono Radio Buoys was begun at the Naval Research Laboratory in 1940 and resulted in the type JM equipment. After tests and some field experience, a redesign was begun in May 1941 and, upon completion of extensive tests in September, 1941, production was authorized on this equipment. This was the JM-1 Sono Radio Buoy, a two unit arrangement, one unit including the transmitter and suspended hydrophone and connected by tie and battery cable to the second unit, a large toroidal-shaped float which is anchored and contains the battery power supply. Though this equipment has been in extensive service at numerous activities, field reports have indicated that a new design was possible to reduce various recurring failures.

5. The major factors used as a basis for redesign are, briefly:

(a) A single unit equipment is preferred as it immediately reduces the service load.

(b) Some trouble had been reported from the fact that in slack tides, the tie and battery cables became fouled as the units came together and frequent replacement of these cables was necessary.

(c) Because of inefficient hydrodynamic form, the transmitter buoy had poor stability in high currents and, in excessive tides, had been reported to entirely submerge.

(d) The antenna ground plane has been found to be a serious service problem due to breaking and loosening, with resultant noise on the carrier and accumulation of ice on the ground plane has frequently caused the transmitter

[redacted]

buoy to lay down on the water surface, completely shutting off the carrier.

(e) For the required radio range, the power output of the JM units - approximately 4 watts - is excessive and uneconomical.

(f) The present optimum spacing between carriers has been found to limit excessively the number of buoys in one installation. This spacing is determined by the maximum frequency deviations which occurs from loud underwater sounds and carrier frequency shift due to varying ambient conditions. Frequency deviation due to modulation is relatively unlimited in the JM units.

(g) The presence of hydrogen, a product of battery chemical action, has been found to be a personnel hazard in the JM units. Though a relief valve is provided to release this gas above a certain pressure, the presence of any concentration constitutes a dangerous condition due to the possibility of sparking as circuits are disturbed.

(h) Several other design factors to be included are: single dial tuning of the r-f oscillator - doubler and standard RMA pre-emphasis for improvement of signal-to-noise ratio.

BOAT DESIGN

6. Design of the boat was initiated with several basic propositions in mind; namely, it was to be a single unit with less horizontal resistance and capable of sustaining heavier anchor loading than the JM type and for use in the higher currents sometimes encountered at sono buoy locations.

7. In reference (2), Lt. E. B. Roberts of United States Coast and Geodetic Survey describes the development of a buoy to accomplish the results required in the present problem. In the reference report Lt. Roberts mentions repeated failures of the drum type buoy, similar to the JM units, under circumstances pointing to their inability to withstand currents of abnormal magnitude. Observations are reported in which such buoys wobbled badly, took water over their tops and submerged in currents of five knots. It is also reported that under extreme conditions, drum type buoys have been known to collapse upon sinking.

8. Reduction of horizontal resistance is the main factor to consider as this force can be translated into anchor line loading and therefore, into downward component to the degree depending on the resistance and dip angle of the anchor line at the bouy. Some improvement can be achieved by lengthening the scope, or ratio of anchor line to depth, but

[redacted]

such a gain is slight with any practicable scope. It, therefore, appears that the horizontal resistance must be reduced.

9. The drum, heretofore used, is in the opinion of Lt. Roberts, "nearly as inefficient an object, hydrostatically, as can be imagined". This, he further states, can be attributed to its square ends with chines and cylindrical tailing surface which causes great turbulence and consequent resistance.

10. The discussions in reference (2) thereafter cover the courses and results of the investigation of various shapes of buoys, boat-shaped or similar to sea-sleds, hydroplanes or pontoons. The final form evolved, though not the most perfect, was most acceptable when considering manufacturing simplicity in conjunction with quality of performances.

11. From basic sketches supplied this laboratory, a two-foot scaled model of the Roberts buoy was designed, constructed and given preliminary tests to establish maximum permissable loading. These tests indicated that an increase in displacement was required. As the problem specifications permitted a maximum length of 10 feet, an exact proportional increase of the Roberts design, to gain required displacement, would necessitate an overall length of 12 feet which was prohibitive. For this reason it was decided to maintain all other proportions with the exception of height which was increased. This did not affect the general contours which are the inherent value of the so called Roberts buoy.

12. A second two-foot scaled model was therefore constructed on this basis and a problem established under reference (6) at the David Taylor Model Basin for complete and comprehensive studies of the two models. The true scaled Roberts buoy was designated Model "A" and the revised unit was Model "B".

13. The principal results of the model tests are reported under reference (3) which states that both buoys possessvery stable towing and mooring characteristics under load. It was further determined that the directional stability as well as rolling characteristics are generally satisfactory. As was assumed, Model "B" is stated as being capable of carrying greater loads than Model "A" and is recommended for field installation.

14. Further information is included in reference (3) on mooring line lengths where this length is twice the depth of water at the anchorage. Data includes various depths, lengths or anchor line, proportion of chain and cable recommended, diameters of chain and cable and maximum permissable current for each condition. This information is included as Plate 8 and taken from enclosures in reference (3). Table III of Plate 8 is pertinent to the subject buoy, Table II, covering conditions for buoy "A", the exact Roberts design. This information, summarized

[redacted]

for buoy "B" for ready reference that may be issued to various activities concerned with sono buoys, is included as Plate 9 and, too, is a copy of an enclosure to reference (3).

15. Plate 10 shows, in graphic form, the towline tensions developed and horsepower required for towing the buoys over a large range of speeds. Satisfactory agreement was found between these model curves and data taken during field test of the completed buoy. Using a 40 HP buoy tender boat the following speeds were averaged in two directions over a one mile course:

Without tow	7.7 knots
With XCX in tow	5.85 knots.

1.85

The power required to tow the XCX under these conditions is therefore approximately 9 HP. Assuming that speed vs horsepower over this small range is approximately linear; inspection of the horsepower curve "Buoy B" of Plate 10 will indicate close agreement.

16. From the very complete analysis supplied in reference (3), a simplification has been made of numerous curves to show the safe anchoring currents for various depths of water using a scope of 2. These curves, shown on Plate 11, are predicated on one-half the total anchor line being 3/8 inches diameter plow steel cable and the remainder 11/32 inch chain. The various curves show the downward load imposed on buoy "B" by a mooring line of the size indicated for various depths and speeds. The intersection of the curves of Plate 11 with the "maximum allowable buoy load" curve represents the loading limit for the buoy and Plate 12 is included as a plot of these intersections. The absolute limit at 9.9 knots, shown on Plate 12, is based on the breaking strength of the cable and tension developed if the buoy should inadvertently become completely submerged.

17. From data made available in reference (3) it was confirmed that a boat designed similar to model "B" would satisfactorily fill the requirements as set forth in the original problem; namely, a unit that would have satisfactory operational characteristics in currents in excess of 4 knots and anchoring depths up to 200 fathoms.

18. Drawings were prepared by the Design and Drafting Section of the Laboratory with valuable assistance contributed by the Small Boats Division of the Bureau of Ships who offered professional opinions on the design. The final full size test model, as constructed in the Naval Research Laboratory shops to drawings RA54F216A, is shown on Plates 1 through 7, and has the following general parameters;

Length	10 feet
Beam	5 feet
Height	5 feet
Weight	1500 pounds
Displacement	4600 pounds
Volume	73 cu. feet

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19. The outer skin of the boat is 1/8 inch C.R. steel formed to the required contours and welded to the frame members which are made of 2" x 2" x 1/8" angle iron. All transverse frame members are secured to a keel.

20. The hull is divided by two bulkheads into three watertight compartments. The middle section houses the battery and radio equipment which are removable through a 30 inch round hatch opening into the center compartment. The hatch cover is sealed against water by a semi-confined rubber gasket and secured to the coaming by 8 swivel hold-down bolts. The coaming is required to secure additional height for housing the battery and transmitter due to the decreased available height near the stern. The forward compartments is reached by removal of two inspection plates; a feature that was planned only for the experimental model for making preliminary stability tests with sand ballast. Both forward and stern compartments have a removable screw plug on the deck surface for inserting a hose to remove accumulated bilge.

21. In operation the boat is anchored from a V-shaped bridle, approximately six feet in length made of channel iron and hinged for longitudinal movement. Plate 7 best shows this bridle folded upward toward the prow as it would be during towing or shipment. Four beckets as shown on Plate 2 are welded around the deck edge and used for hoisting and to tie the unit to the tender boat during servicing. As shown on Plate 7, a towing eye is welded to the prow, passing through the main frame for strength. A similar eye, but smaller, is welded to the rear transom to provide a means for tandem towing. As shown on Plate 1, two wheels are provided at the hinge point of the bridle assembly for shore-side handling of the boat. These wheels and the connecting axle are easily removable previous to launching, as is a single swivel wheel, not shown in the photographs, located at the rear of the keel.

22. Referring to Plate 6, there will be seen a forked stanchion located forward of the main hatch and used to receive the antenna when the hatch assembly is tilted forward for servicing. A kelcotter, secured by a light chain to the stanchion, can be used to secure the antenna against leaving its position in the fork. A trough is provided just forward up the main hatch to secure the hatch cover against rolling when it is in the servicing position.

23. Previous to field tests it was recommended that additional towing eyes be welded to the prow in order to determine the most favorable tow point. Two additional loops, not shown in the photographs, were added below the original one. Towing tests made in average and rough seas demonstrated that the middle towing loop caused a reduction in drag over the upper loop and still had improved stability and freedom from yaw experienced when towing from the lowest loop. The center of this middle loop is approximately 12 1/2" from the deck and is welded directly into center longitudinal angle.

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24. Details of the main hatch assembly are shown on Plates 5 and 6. The hatch cover is a standard 30 inch flanged dome modified by additional hold-down lugs. Appearing on the top of this hatch (see Plate 6) is the transmitter control grouping which comprises the main turning knob and dial, a vernier tuning knob, dial lock, and rotary power switch; the antenna mast reinforced by an angle iron tripod; and the hydrophone input connector, a watertight assembly including a hinged cover to close off this opening when not in use. The hood, shown at the apex of the antenna tripod members, is a cover for the battery exhaust valve on the end of the hydrogen bleeder tube. This copper tube passes down one of the tripod angles and through the hatch cover at which point it is connected internally by means of a rubber tube to the battery hydrogen bleeder tube. Two guide pins are located approximately 150 degrees apart around the coaming for accurate positioning of the dome cover on assembly. A cover over the transmitter control grouping is shown on Plate 4. As designed, this does not constitute a watertight enclosure but is merely for mechanical protection. Later considerations indicate that such a watertight housing would be a desirable added protection. During field tests it was determined that the main tuning knob was of little value; the vernier tuning giving satisfactory control. The tuning dial is calibrated 270 degrees for the 80 to 85 Mc range. The vernier tuning acting on the periphery of the main dial gives a 2:1 ratio which is completely satisfactory for accurate frequency adjustment.

25. Plate 5 is an interior view of the main hatch with the cover in servicing position. The radio transmitter is mounted on two brackets welded to the underside of the cover. Shock mounting by means of 4 Lord type mounts is provided for the transmitter chassis and a latching arrangement allows for easy removal of the chassis from the hangers. As the transmitter tuning shaft is extended up through the hatch cover it was necessary to provide a flexible link someplace in the system to maintain the integrity of the shock mounts for the chassis. Toward this end, a flexible metal bellows was used to link two portions of the shaft to permit independent movement of the chassis from the upper shaft. This bellows also permits easy removal of the chassis with the added advantage of introducing a minimum of backlash into the system. The battery, as seen in position on Plate 5, fits into the well with a minimum of tolerance and is held snugly against movement by two channel irons bolted at each corner. Rounded guides are placed around the well to assist in locating the battery squarely upon loading. A wrench is secured to one of the channels for removing the battery bolts.

26. Other details of the deck structure include four chocks for securing the bridle line around the deck when under tow and a hinged clamp mounted at the stern to secure the hydrophone cable as it passes over the rear transom. Also mounted on this transom is a heavy eye for towing boats in tandem. A design change would locate this eye parallel to the deck and be enlarged so that the hydrophone and cable could pass through it to protect the cable and simplify hydrophone re-

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moval. It will be noted that pipe sections are added to the rear transom and forward deck edges to protect these edges against injury in collison. Improved design would include these pipes as scuffing surfaces along the two side deck edges. An addition, not shown, was made in the form of two reinforcing members from the lowest point on the stern end of the keel upward to the knuckle line on the rear transom. It was noted that severe strain was applied to the keel extension during shore handling and these reinforcements were added as a result.

27. All external hull surfaces were given two coats of zinc chromate primer. The sides below the water line were then given one coat of anti-fouling plastic paint, Navy formula 15HP. The top deck, after application of primer coats, was given one coat of phenolic varnish, formula 80, immediately followed by sprinkled sand and two coats of deck paint. This gave a roughened surface which was satisfactorily anti-skid for servicing in wet weather. All freeboard surfaces were given two coats of haze gray lead paint. Brass and bronze fittings were lightly sand blasted and all galvanized fittings given a phosporic acid cleaning previous to painting. Inside hull surfaces were given a zinc chromate primer, followed by a surfacing of expanded Vermiculite over a varnish binder. Vermiculite is a flaked micaceous substance having sound absorbing properties to reduce noises caused by wave action on the hull. As a final finish, a fire resistant varnish was applied over the Vermiculite.

TRANSMITTER

28. The following are some general characteristics of the transmitter:

Type of Modulation	Frequency
Carrier Frequency	80 to 85 Mc
Power Output	1.5 watts
Maximum Deviation	75 kc
Input for 75kc Deviation	10 microvolts
Tube Complement	
2-9001	Audio Amplifier
1-6AK5	Reactance Modulator
1-6C4	Oscillator - Doubler
1-6C4	Automatic Gain Limiter
SD-818	Ballast Tube
Power Supply	Dry Batteries
Nominal Plate Voltage	270 V.
Nominal Heater Voltage	7.5 V.
Battery Life at 25 degrees C	500 hours

29. The transmitter for this equipment is a conventional type reactance tube, frequency modulated unit, comprising two resistance coupled audio amplifier stages, reactance modulator, automatic audio gain limiter

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and a high frequency oscillator-doubler feeding a skirt type half-wave dipole antenna, both elements of which are adjustable over the required frequency range.

30. In reference to the circuit diagram, Plate 13 shows the hydrophone output transformer-coupled to the first audio amplifier. The rectified voltage supplied by V-104 is applied through the secondary of transformer T-101 to the grid of V-101, effectively maintaining the gain of this stage constant. To improve this control, the screen potential of V-101 is taken from a voltage divider, rather than the more general series resistor, to provide better stability under varying AVC voltage.

31. A preemphasis network is inserted between the first and following amplifier stage to provide a rising characteristic of approximately 2 db per octave above 600 cps. The second amplifier stage uses a 9001 tube, the cathode of this stage being returned to ground through a resistance network R-108-109. The voltage drop across the latter resistor provides a delay voltage to the cathode of V-104, the a-v-c rectifier. This delay voltage is so chosen that the gain of the amplifier is a maximum until it reaches a value equivalent to a 60 kc carrier deviation, at which point the a-v-c tube conducts and maintains the gain relatively constant for increased audio input.

32. The output of the second amplifier drives the 6AK5 reactance modulator but due to the shunting capacities in the grid circuit of V-103, a second pre-emphasis network is inserted giving an overall response rise of 2.5 db per octave from 600 cps to 12 kc.

33. The 6AK5 reactance tube circuit is conventional except that the r-f input to the phase shifting network in the grid circuit is taken from a low impedance point on the oscillator grid coil. This provides a better impedance match between these two circuits so that loading of the oscillator by the reactance tube is kept at a low value. The cathode bias resistor, R-114, is shunted by a 500 micromicrofarad capacitor to by-pass the r-f frequencies but offers a high impedance to audio frequencies resulting in a measure of negative feedback which reduces distortion at high signal levels. Audio voltage for the a-v-c tube, V-104, is supplied by the drop across R-116 in the plate circuit of the reactance tube V-103. The a-v-c tube is a 6C4 triode used as a diode to provide a negative voltage, varying as the amplifier gain, to the grid of V-101 in order to maintain its gain constant above a given value determined by the delay voltage previously discussed.

34. The r-f portion of the transmitter uses a 6C4 triode in an oscillator-doubler circuit. A conventional grounded plate Hartley circuit generates frequencies over the range of 40 to 42.5 Mc. The plate is effectively by-passed to ground for these frequencies by the 80 to 85 Mc tuned circuit which presents a low impedance to the lower fundamental frequencies at which the tube oscillates. By tapping the

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cathode onto the oscillator coil close to the ground end of L-101, to increase the feedback, and by using a high value of grid leak resistance, the lower frequency oscillations are made to have a high harmonic content. The second harmonic in the plate current then appears across the 80 to 85 Mc tank which is tuned simultaneously with the grid tank by ganged variable capacitors C-105a and C-105b. The plate of V-105 is parallel fed through choke L-103 and the output tank is isolated from the dc plate voltage by C-113 to prevent dangerous high voltages from appearing on the antenna. The antenna is fed by a coaxial line tapped to the plate coil L-102 at the correct impedance.

35. Several advantages are considered to be obtained by the use of a single tube oscillator-doubler circuit, most important being the saving of battery power by using one tube. Added to this, the isolation between the antenna and frequency determining circuits is vitally important in sono buoys due to the reactance shifts in the antenna caused by motion in rough seas. In the JM units, this reactance shift caused objectionable frequency variation, which condition was noted at Portland, Maine, during the field test of the subject unit.

36. Plates 14 and 15 show the r-f power output to be expected over the life of the battery. It is estimated that at the end of 500 hours operation at nominal temperatures, the battery voltage will have dropped to 6 volts and 220 volts, heater and plate supply respectively. This is approximately at the half-power point giving 3 db drop in signal level. On the basis of field test data, a field strength of 15 microvolts was measured at 10 miles from the transmitter with fresh batteries. A 3db drop in power, anticipated at the battery end point, should therefore put the signal level at 10.5 microvolts under that condition.

37. The complete data on field intensity measurements made at Portland, Maine, are shown in Plate 16. Curve "E" is a plot of the signal voltage from presently used JM-3 units in service at that activity. Curve "A" is the initial results on the XCX using the 88 inch antenna mast, measured from the water surface to the antenna feed point. It is apparent that the voltage decreases more rapidly than the square law should indicate and this condition was attributed to reflections from the boat and water surfaces shifting the vertical pattern upward. To investigate this assumption the antenna mast was extended upward 37 inches to a total height of 125 inches and the test repeated with no adjustment of the antenna lengths. Curve "C" is a plot of this test and is seen to approximate square law calculations. The antenna elements were then adjusted to the new condition and the final results plotted as Curve "D" of Plate 16, indicating a signal intensity of 15 microvolts at 10 miles, against a problem objective of 10 microvolts. Inspection of Curves B, C, D and E, which approximate square law response, indicates that the vertical lobe is very favorable for the heights and distances involved.

38. Under no anchor loading the boat deck slopes downward toward the stern at an angle of 15 degrees, which angle will decrease under varying loading to where the deck will be parallel to the water surface under maximum loading. In consequence the rigidly mounted antenna will pass through a vertical angle of 15 degrees from no load to maximum. To accomodate this change, the antenna is therefore mounted at such an initial angle so as to pass through approximately ± 8 degrees from the the vertical depending on the anchor line loading. During tests at maximum ranges, measurements indicated that no appreciable difference in field intensity could be expected over this range of antenna tilt. That a more favorable vertical pattern was obtainable from the XCX sleeve type antenna as compared with the ground plane type used on the JM-3 units was apparent during the tests discussed. It was then noted that signals received during rough sea states, when buoys were rolling excessively were markedly more stable and readable from the XCX than from the latter units.

39. Curve "B" of Plate 16 was intended to show the field strength at the battery end point. Series resistance was added to drop the plate and heater supply voltages to 220 volts and 6 volts respectively. This test, due to bad weather, was delayed for several days. Upon completion of the test the results as shown on Curve "B" were considered excessively low, which was found to be due to low supply voltages, 210 volts and 5.5 volts. From Plate 15 the power output with 5.5 heater supply volts and a plate voltage of 270 is found to be 1.22 watts. Selecting the point corresponding to 1.22 watts and 270 volts on Plate 14 and drawing a line through this point parallel to the other two lines, this line will intersect the 210 volt plate supply ordinate at 0.45 watts which is the output under the test conditions. Then if the field strength at 10 miles with 1.5 watts output was 15 microvolts, the voltage with 0.45 watts should be

$$S = \left[\frac{.45}{1.5}\right]^{1/2} \text{ X } 15$$

$$= 8 \text{ Microvolts.}$$

Now if Curve "B" of Plate 16 is extended, it will cut 8 microvolts at approximately 10 miles. Since this is in agreement we can assume that with half-power, the field strength at ten miles will be

$$S = \left[\frac{.75}{1.5}\right]^{1/2} \text{ X } 15$$

$$= 10.6 \text{ Microvolts}$$

This conforms to the problem objective.

40. During the field tests two types of Sono Buoy receivers were available: the RBF-1 and RBF-2. These have standard quieting sensitivities of approximately 5 microvolts; consequently, field intensities of the order of 10 microvolts were found to give satisfactory reception

under all conditions.

41. Plate 17 shows the reactance tube characteristics. It is of use mainly as a calibration chart for making tests of Plate 18 and 20. Plate 18 indicates the audio frequency response of the transmitter. The preemphasis is seen to be approximately 2.5 db per octave. The a.v.c. and overall amplifier gain at 12 kc is plotted on Plate 19. From this curve, the absolute sensitivity is given as 60 kc deviations with an audio input of 10 microvolts. Plate 20 shows the percentage distortion from the hydrophone input to the reactance tube input. The r-f power output from 80 to 85 Mc as measured with a resistive load is shown as Plate 21.

42. The carrier frequency shift between initial and calculated end point battery voltages, assuming a useful life of 500 hours, was found to be 16 kc. The temperature coefficient of frequency drift between zero and 50°C was measured and found to be .001% per degree centigrade. With constant temperature, the average change in frequency over the range of 30% to 95% relative humidity was measured at 58 kc.

43. To determine the effect of carrier frequency change on deviation, the oscillator frequency was varied over the range and the input adjusted to give 60 kc deviation at each test frequency. The following results were obtained:

Carrier Frequency Megacycles	Input Microvolts
80	15.0
81	14.8
82	14.5
83	14.3
84	13.8
85	14.0

44. The following is a summary of the transmitter design:

(a) Satisfactory and usable signals are supplied to the end point of the batteries, or 500 hours in normal temperatures.

(b) Reduced power permits large reduction in battery size with resulting reduction in service complexities.

(c) Improvement of frequency shift under varying temperature, humidity, battery voltage and antenna reactance changes, in addition to the limitation to frequency deviation by the inclusion of audio gain limiting, makes possible a reduction in carrier spacing and per-

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mits more units to be used at one location.

(d) Improved sensitivity to wanted underwater sounds by increase of signal-to-noise ratio attainable from the longer hydrophone and means for maintaining the hydrophone in a more nearly perpendicular plane under high currents. The use of minature tubes, particularly in the audio channel, has reduced microphonics to a minimum, which fact also contributes to the improved sensitivity.

(e) The heater supply ballast tube maintains the heater voltage within the rating, increasing the life of the tubes and keeping the power output more nearly constant over the life of the battery.

(f) Ganged control of the oscillator-doubler circuits simplifies frequency setting to an extreme degree as compared with the tuning problems on the JM units.

BATTERY

45. From experience with JM Sono Buoys it was realized that some measures must be taken to remove, or definitely reduce the possibility of dangerous explosions due to the accumulation of hydrogen in the battery container, in this case, the boat proper.

46. Reference (4) is a report of an investigation by the Chemistry Division of the Naval Research Laboratory to determine the cause of explosions in closed battery containers and suitable methods for preventing such explosions.

47. From these investigations it is stated that, "explosions in dry battery containers are due to the evolution of hydrogen gas by the battery and its formation of explosive mixtures with oxygen in the container". The problem of preventing such explosions was approached along the following lines:

(a) Removal of one or both explosive constituents.

(b) Causing the explosive mixture constituents to react at sub-explosive concentrations.

(c) Inhibition of reaction between hydrogen and oxygen to the extent that it is non-explosive at any concentration.

48. Removal of hydrogen can be done most easily by three methods: ventilation, purging or chemical absorption. The latter method is not feasible since there is no known agent for completely and dependably absorbing hydrogen at normal temperatures. Removal by ventilation be-

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comes extremely difficult when, as in the present instance, the case is subject to weather and sea action. In this case traps or baffles are required to prevent entrance of sea water but addition of such devices retards the loss of hydrogen. The reference report further states that consideration was given to the use of a wall composed of material permeable to gases but not to water. However no such material was known capable of handling the volume of hydrogen generated. Both the permeable membrane and open vent are subject to closure by natural conditions such as ice formation in cold weather, the report further states, "In spite of these disadvantages the open vent was given serious consideration."

49. Removal of one or more constituents of explosion by purging was investigated and it is stated that a simple flushing of the container with an inert gas after closure would reduce the oxygen concentration outside the explosion region, assuming no leakage was present. If the latter event occured, a continuous flushing during service would be indicated. Reference is also made to chemical agents for absorbing oxygen, such as powdered copper, but a warning is injected that any process which removes the oxygen and not the hydrogen suffers from the disadvantage that leakage into the container will permit the entrance of atmospheric oxygen at a rate which may be sufficient to maintain an explosive mixture. The possibility of an explosion is also present when the container is opened after service and atmospheric air mixes with the high percentage of hydrogen.

50. The second method of eliminating the explosion hazard was to cause the hydrogen and oxygen to react continuously, as hydrogen was formed, thus preventing the formation of explosive concentrations. This can be done by two methods: by use of a suitable catalyst or by a hot wire. The report notes that only Palladium will cause oxygen and hydrogen to react at room temperatures, all other catalysts requiring elevated temperatures. All catalysts, it is warned, are subject to poisoning and exhaustive tests would be required before dependance could be recommended. The hot wire method places a load on the battery that would be prohibitive in the present buoy design. Perhaps a more serious disadvantage to both the catalyst or hot wire scheme is in the fact that sufficient oxygen must always be present to react with the generated hydrogen or a high concentration of hydrogen will be built up and will react, by virtue of the catalyst, when the buoy is opened, after service, and atmospheric air enters.

51. The third proposal, which seems to hold the greatest merit, was to inhibit the explosive reaction between oxygen and hydrogen. Theoretical studies, quoted in reference report, indicate that this reaction is considerably slowed down in the presence of various surfaces, glass in particular being recommended. The report continues, "Accordingly, it has developed that if the spaces of the battery container are filled with glass wool in sufficient density, the reaction between hydrogen and oxygen will not take place with sufficient activity to sus-

tain itself, and flame propagation from an ignition point will not occur."

52. Investigations were made using two types of glass wool; namely, "Pyrex Fibrous Glass #719" and "Basic Fiber #115-Corning Glass Co", the latter type proving more suitable due to its greater resilience and bulk per unit weight. It also tends to assume more uniform distribution when pressed into a void space.

53. In the studies in question, the glass wool was packed into wire frames constructed to fit into the various voids around the battery. This means was used to simplify packing and to insure even density throughout. Explosions were then carried out in the battery container with pack densities of 1, 2 and 3 pounds per cubic foot in hydrogen concentrations of 30% to 35%, the region of maximum explosibility. The report states "mild pressure rises occured resulting in a slight heave caused by the bulging of the bottom and top of the container, but did not approach dangerous values at any time". Investigation of the effects on the glass wool after these tests indicated no observable effect and it appears that under these conditions it will last indefinitely. It was observed that water appeared to have no adverse effect on the glass wool, with some indication that it may be beneficial.

54. In "Conclusions", the reference report states that the problem of prevention of dangerous explosions in closed battery containers can be most readily accomplished by filling the void spaces with "Basic Fiber #115K" at pack densities above 2 pounds per cubic foot. It is further stated that all voids need not necessarily be filled and that the ratio of unfilled to filled space can be at least 0.15 under which condition a pack density of 3 pounds per cubic foot be used in the remainder of the voids. Polystyrene foam was tested as an alternate materialbut had a tendency to burn and would require more exhaustive tests. Exfoliated mica was considered but was not tested.

55. In connection with any future design of dry battery containers reference (4) recommends that consideration should be given to the use of a container that fits the battery with a minimum of clearance. Such a design, it is believed, would prevent propagation of hydrogen flames with sufficient speed to produce appreciable pressure rise and, in consequence, the battery would tend to absorb any explosion which takes place in the space surrounding it. It is further recommended that in addition to the use of glass wool as indicated, a suitable relief value should be provided to prevent the building up of gas pressure due to evolution of hydrogen by the battery, apart from the pressure due to explosion.

56. In conformance with the recommendations covered in reference (4), consideration was given to the use of some substance to inhibit the reaction between hydrogen and oxygen. Using the standard form of battery this would require filling all the voids of the boat with inhibiting material. If glass wool were to be used at the densities re-

commended, the weight of the boat would be increased to a degree that would upset design calculations. Other deterrent factors against the use of glass wool in the entire boat are the difficulty of removing accumulated bilge and the deleterious effects of glass wool dust accumulating in the transmitter and controls. The suggested alternative material, Polystyrene, though not adding any serious weight factor, was found impractical due to the welding required on the hull after packing, the heat of that operation destroying the Polystyrene.

57. In the final development model of the XCX, taking into consideration all factors of weight, design, servicing and manufacturing, it was decided that a sealed battery, with a relief value to bleed off excess gas pressure, would be a satisfactory and reasonable solution to this complex problem. Such a battery was designed and samples were built by General Battery Co. to NRL specifications and drawing RA19F104A. The battery, designated Type 360L, is 19 1/2" x 15" x 22 1/4" high, not including the top plug assemply, and the entire unit weighs 245 pounds. The battery proper is encased in a 1/32" terne plate housing, sealed gas tight by soldering. All inside and outside terne plate surfaces are protected by a synthetic resin with good mechanical and chemical properties over the temperature range of -40 degrees to +94 degrees Centigrade. The several voltage terminals are the Sperti glass-to-metal seals, soldered directly to the terne plate case. A valve stem is soldered through the case to which a flexible tube is attached for leading developed gases to the outside atmosphere. The glass seal terminals are connected by jumpers to a standard receptacle mounted above the case and to which the connecting cable is coupled. A large folding ring is secured in the center of the battery case for lifting. The battery is encased in an outer wooden case for protection during handling.

58. Internally the battery is constructed on the unit principle, comprising 360 "L" type cells in 8 units of 45 cells each. These units exactly fit within the terne plate case with the exception of a void where the ninth unit normally would be in a 3 x 3 arrangement. This arrangement permits a sturdy construction for the lifting ring.

59. In coincidence with the findings and recommendations of reference (3) this construction seems to conform in substance. A minimum of voids are existent and the only major void at the top can be readily filled with glass wool as recommended. This is a simple manufacturing procedure but as the findings of reference (3) were not available during design and construction of the battery, it was not included in the developmental model.

60. From the above discussion it would appear that a battery of design similar to the models, completely sealed, with all major voids packed with glass wool, Basic Fibre 115K, to a density of 3 pounds per cubic foot and with a vent to bleed off excess gas pressure, would be

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to suggest the unit was not operating normally.

65. The model C-37 hydrophone was finally accepted for use with the XCX Sono Radio Buoy. This hydrophone is 54 inches long, which is considerably longer than the C-23 unit now used on the JM-3 Buoys. This increased length improves the sensitivity and produces a degree of directivity in the vertical plane. This improves the signal-to-noise ratio by virtue of discriminatory action against surface noises in the vicinity of the Buoy.

66. The effectiveness of this vertical pattern is maximum only when the hydrophone is suspended normal to the water surface, which condition obtains only in currents of zero velocity. In effect, a sharp vertical pattern can have deleterious effects in producing a severely distorted horizontal sensitivity pattern when the hydrophone assumes any angle from the vertical in a current.

67. As no data was available on the angles from the vertical that the C-37 hydrophone would assume under varying currents, an investigation was requested of the David Taylor Model Basin to obtain such information and, in addition, methods of maintaining the subject hydrophone in essentially a vertical plane in currents to 5 knots. Reference (5) covers the findings of that activity which are discussed in subsequent paragraphs.

68. Preliminary considerations indicated that a hydrofoil type of depressor would be required to maintain the hydrophone within a few degrees of vertical in the specified current range. Such a hydrofoil would develop a dynamic lift of the order of several hundred pounds at higher speeds, but, in addition, it would necessitate a negative buoyancy of over one hundred pounds at the lower speeds. Though the hydrophone connecting cable can withstand a static load of 1500 pounds, the tensile and loading stresses developed in the hydrophone would undoubtedly be far in excess of its capabilities.

69. It was therefore decided to test depressors which are faired weights of low drag and which do not develop dynamic lift. It was thought that the use of such depressors would improve the angle over that of the hydrophone alone sufficiently to warrant their investigation.

70. A full scale model of the C-37 hydrophone was constructed of correct weight and mass distribution and tested in conjunction with the connecting cable as used on the standard hydrophone. These tests were made with 25, 50, 75 and 100 pound weights. When the several weights showed promising reduction in the hydrophone tilt angle, it was requested that a 12-pound weight be tested through the same speed range. This smaller weight was investigated as it was considered that even the 25 pound weight was perhaps overstressing the hydrophone.

71. The results of this series of tests, including that of the

[redacted]

hydrophone alone, are indicated on Plate 22, which is a copy of enclosure (b) of reference (5). Analysing these results, it appears, to quote reference (5), "that the 12 pound depressor is quite practicable since above 1 knot it decreases the hydrophone angle as much as 25 to 40 degrees depending upon the speed." Further, it is stated that, "the improvement for the heavier depressor is at a lesser rate than that of the 12 pound depressor over the hydrophone alone."

72. The additional investigation to determine the orientation of the hydrophone when suspended on a 50 foot cable and carrying the various depressors is also reported in reference (5). Plate 23 shows two sets of curves which indicate the position of the hydrophone, one set showing the depth and the other the distance astern of the buoy for each depressor and for the hydrophone unloaded. From Plates 22 and 23, therefore, the position and angle of the hydrophone under varying conditions of current can be easily determined.

73. From the results of this investigation, specifications and drawings were prepared for a hydrophone having electrical characteristics similar to the C-37 but modified mechanically to include an end fitting to which the proper depressor could be attached. This required a complete redesign of the longitudinal mechanical structure to increase the resistance to twist and deformation. Several models of such a hydrophone were produced by Brush Development Co. but discontinuance of the problem has prevented any comprehensive tests to be made of the models on hand.

74. Closing of the general problem prevented actual operational tests of this redesigned hydrophone in comparison with an unloaded unit. In particular it would be essential to investigate the background noise introduced by attaching weights as it was noted that the hydrophone with the weighted depressor had sufficient oscillation and vibration due to being held by the weight to warrant such an investigation. At higher speeds such oscillations were observed to be less than with the unloaded hydrophone which showed a very unstable oscillation in yaw.

75. As the modified hydrophone was not available during field tests, the standard C-37 unit in conjunction with the XCX Buoy, presented even to an unexperienced listener, underwater signals that were superior to those from JW units from a point of sensitivity, fidelity and intelligibility. This is in part attributable to the increased sensitivity of the longer C-37 hydrophone, but what is considered a more important factor, is the inherent directivity of this unit which affectively discriminates against surface noises in the immediate vicinity of the boat, the locus of maximum unwanted noise.

76. In accordance with the findings of reference (5) concerning the angle assumed by the hydrophone in a current, the C-37 unit was suspended to a depth of 10 feet, but to maintain it in vertical orientation, a rope bridle was attached to the top and bottom, the other ends of the

bridle being tied to the lowest end of the boat anchor bridle. This maintained the hydrophone in essentially a perpendicular plane under the current experienced. A comparison was made between this hydrophone suspended to only 10 feet and a JM unit in the same area, but with its hydrophone at a depth of 40 feet. The C-37 hydrophone in perpendicular suspension gave superior listening particularly as regards the signal-to-noise ratio.

77. The results of these tests can not be completely attributable to the longer hydrophone and its more favorable orientation, but must include the intended superiority of the XCX design. The improved boat design, advanced tubes and circuits, the inclusion of audio a.v.c. and pre-emphasis; all these in conjunction with the improved hydrophone were factors in the overall excellance of results.

BALLAST TUBE

78. Operating directly from the initial 7.8 volt battery supply, the transmitter tube heaters would be severely beyond the specified limits. As a linear resistance would result in an extreme reduction of battery life, a ballast tube was definitely indicated. A standard Sylvania 1X1 filament was destroyed when the high starting current passed through it. Several methods were tried whereby a fixed resistance was introduced for several seconds to keep the current within safe limits after which the resistor was shorted out and the full voltage applied to the heaters. A mercury contactor was designed into which a time delay was introduced by controlling the flow of mercury through a small opening between two sections of the tube. An extra terminal was placed on the side of the tube which would be contacted as the level of the mercury rose. Although sound in principle, the mercury contactor was very susceptable to momentary circuit disturbances under vibration and roll.

79. After discussions with Sylvania engineers, they agreed to attempt a design of a ballast tube with correct control characteristics and with a filament that would withstand the abnormally high starting current in the heater circuit. A tube was produced with multiple parallel elements and control characteristic as shown on Plate 10.15 This tube, designated SD-818 by Sylvania, was given an accelerated starting test and showed no change in characteristics after numerous starting cycles. More complete tests indicated that the tube was satisfactory and was included in the final design.

CONCLUSIONS

80. The chief factors in evaluating the results of this development are discussed under this heading.

81. In the present design a very important consideration, which is not nullified by the modifications suggested under "Recommendations",

[redacted]

is the possibility of more nearly obtaining 100% operation. This idea is more closely approached due to the fact that periodically, when necessary battery change is made, the entire operating portion of the unit will be available on shore for a complete overhaul and inspection before being returned to service as a replacement unit. Under these conditions all tubes and circuits can be tested, corrosion removed from internal parts, frequencies accurately set and antenna adjusted for proper match. It is contemplated that such a procedure should decrease actual operational failures, exclusive of battery deterioration, to a minimum.

82. The functional design of the boat is a definite improvement over the presently used barrel-shaped units, offering a substantially more stable platform in any sea state and permitting use in deeper anchorages because of reduced horizontal resistance and resultant anchor line loading.

83. The investigation relative to the angle assumed by a long hydrophone in a current elicited surprising results when it is considered that the transducer is displaced 75 degrees from the vertical in a two-knot current. The detrimental effects of this are of course a function of the hydrophone length and resultant vertical directivity but some distortion of the receiving pattern must be expected even from the shorter C-23 hydrophone. The improvement gained by the addition of a 12-pound depressor is considered noteworthy and should be a design consideration in future work involving long freely suspended hydrophones.

84. The battery, as discussed, is considered a positive advance toward the complete removal of personnel hazards existant in the use of dry batteries in enclosed containers. The safety factor is, of course, nullified to some degree if hydrogen passes from the battery into the interior of the boat and for this reason positive gas tightness of the term plate battery enclosure must be assured in manufacture.

RECOMMENDATIONS

85. During the field trials at Portland, Maine, an investigation of prime importance was undertaken to determine the most satisfactory procedure for periodically servicing the XCX Sono Buoy.

86. The original intent was that the boat be towed from its anchorage to shore for servicing, which assumes that a second be towed out to replace the unit being withdrawn.

87. This procedure was proven to be a severe strain on the maintenance facilities for several reasons:

(a) At buoy installations 6 to 8 miles from a base, the time consumed by a standard 38-foot Buoy-Tender Boat in towing a single unit to its anchorage, changing, and returning the replaced unit to shore is quite excessive. Particularly during seasons of short daylight such a procedure could limit a single crew to two daily service changes.

(b) Towing more than one unit to a location, besides the extreme reduction in speed of the tow boat, introduces many complicated maneuvers and dangers to personnel in maintaining the several units in sufficient order to permit a transfer of units at the anchorage.

(c) The transfer of anchor line from a spent to a replacement unit was found to be a complex and dangerous procedure, requiring more operating personnel than are normally assigned to a boat crew. In sea states above 2, it is problematical that a transfer could be accomplished.

88. For the above reasons it was intended to make certain modifications to the XCX to permit a servicing procedure similar to that of the JM-3 units. Upon conclusions of the problem a simple redesign was in progress wherein the entire operating assembly including battery, transmitter and antenna would be contained in the watertight container removable from the boat. Under this plan a portion of the center of the boat could be welled to take this assembly in a manner similar to the present JM-3 battery float. A simple locking device to hold the units rigidly together would be supplied and bales for lifting the removable unit would be conveniently located.

89. It was contemplated that such a design would introduce no change in maintenance procedure over that now used with the JM-3 units. In addition, it is probable, that the reduced battery size in the XCX would permit the total weight of the entire assembly to be less than the loaded JM-3 battery container and the procedure necessary to remove the hydrophone connector is similar to the removal of the battery connector on the JM-3.

90. From a standpoint of actual service at sea it would therefore appear that both units would be similar, with perhaps a more favorable weight factor for the modified XCX.

91. This suggested revision of the XCX received the unanimous assent of the Sono Buoy operating group, at Portland, Maine, who demonstrated the ease of such a servicing principle by changing several JM-3 batteries and containers at an average of 10 minutes per change exclusive of running time between buoys.

ACKNOWLEDGEMENT

92. Acknowledgements are made to the staff of David Taylor Model

Basin for information and data on the boat design and hydrophone stabilization as reported in reference (3) and (5); to Mr. R. A. Fyfe, Small Boats Section, Bureau of Ships, for valuable suggestions on the design and layout of the boat; to the Chemistry Division, Naval Research Laboratory, for their suggested solution to the hydrogen problem, reported in reference (4) and to E. B. Roberts, U.S. Coast and Geodetic Survey for the basic design of the hull used in the subject equipment.

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2. U.S. Coast and Geodetic Survey by E. B. Roberts, June 1942: Buoy Characteristics and Design of a Buoy for Strong Currents.

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4. NRL Report P-2315, August 1944; The Evolution of Hydrogen from Dry Cells and Methods of Prevention of Explosions in Closed Battery Containers.

5. David Taylor Model Basin Research Report, Serial TMB-S66, September 1944: Tests of Depressors for Brush C-37 Hydrophone for NRL Mark III Boat Type Sono Radio Buoy.

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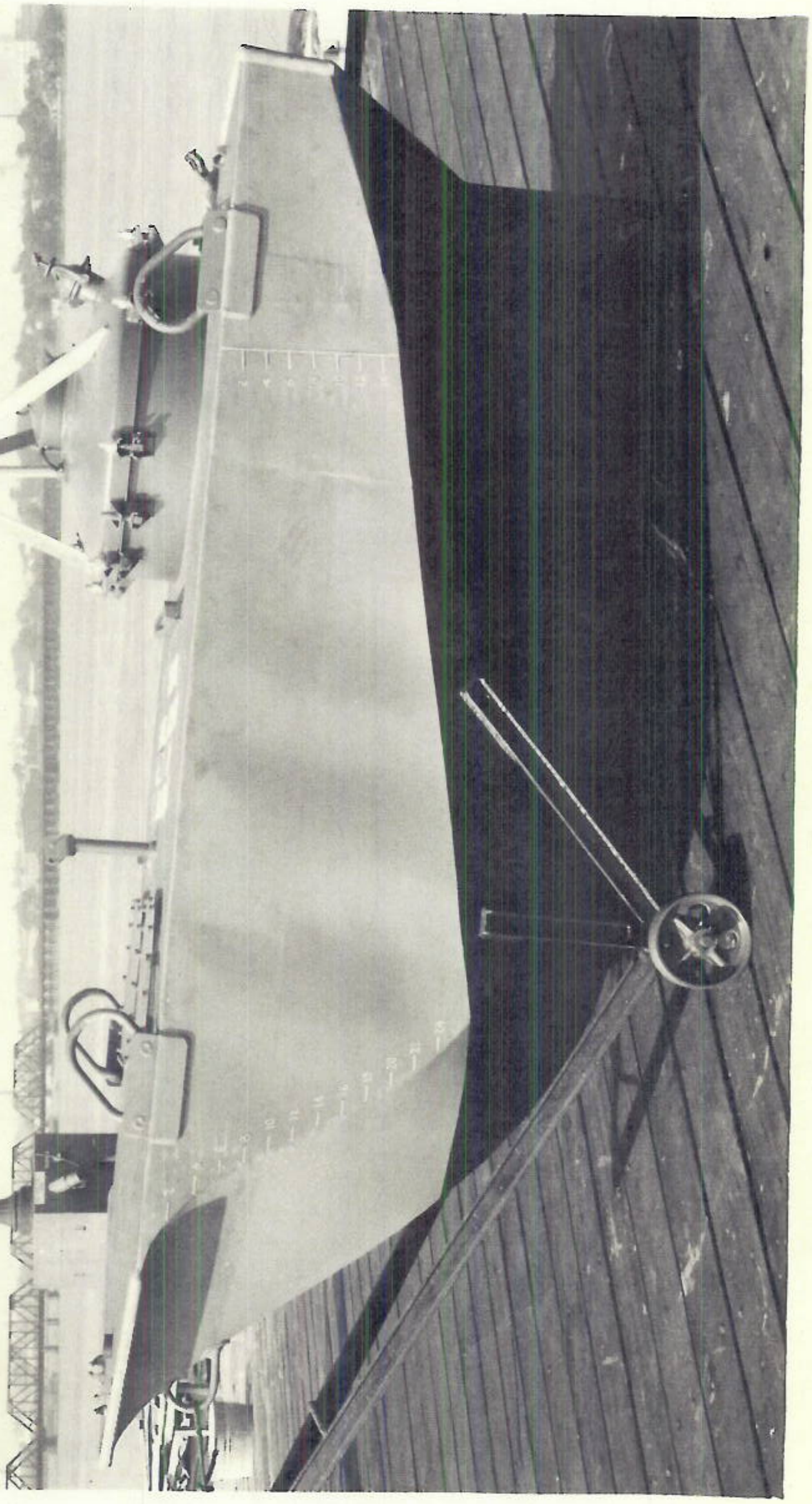
7. NRL memo (Code 470) C-S68/51(473-5) of 28 December 1943 to Director, NRL: Underwater Sound - Hydrophone for Sono Radio Buoy, Type AX56-3, Serial No. 2. Brush Development Co. - Calibration of.



XCX SONO RADIO BUOY - SIDE VIEW

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XCX SONO RADIO BUOY - TOP VIEW FROM PROW

XCX SONO RADIO BUOY - TOP VIEW FROM STERN

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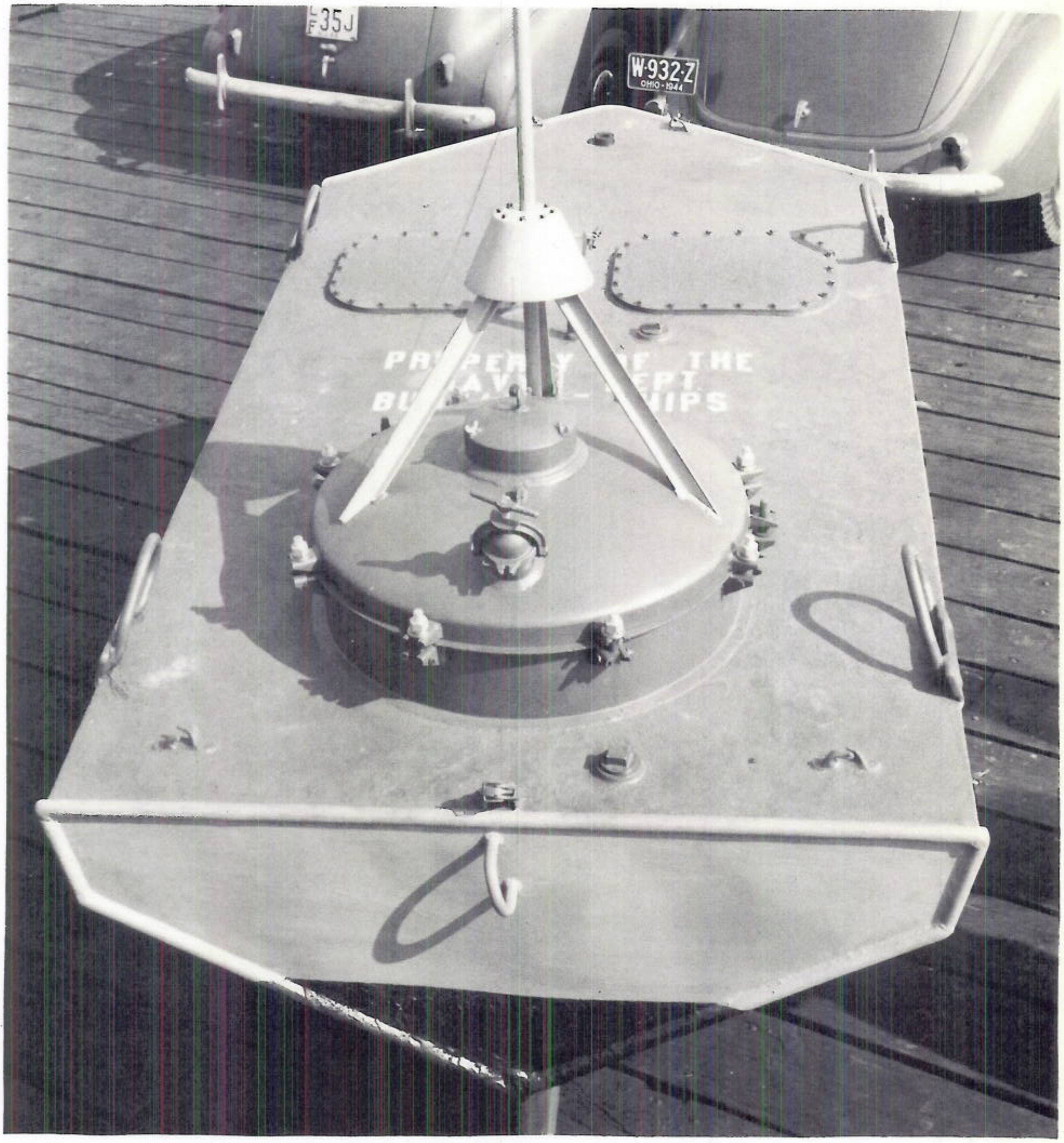
PLATE 3



XCX SONO RADIO BUOY - DECK DETAILS

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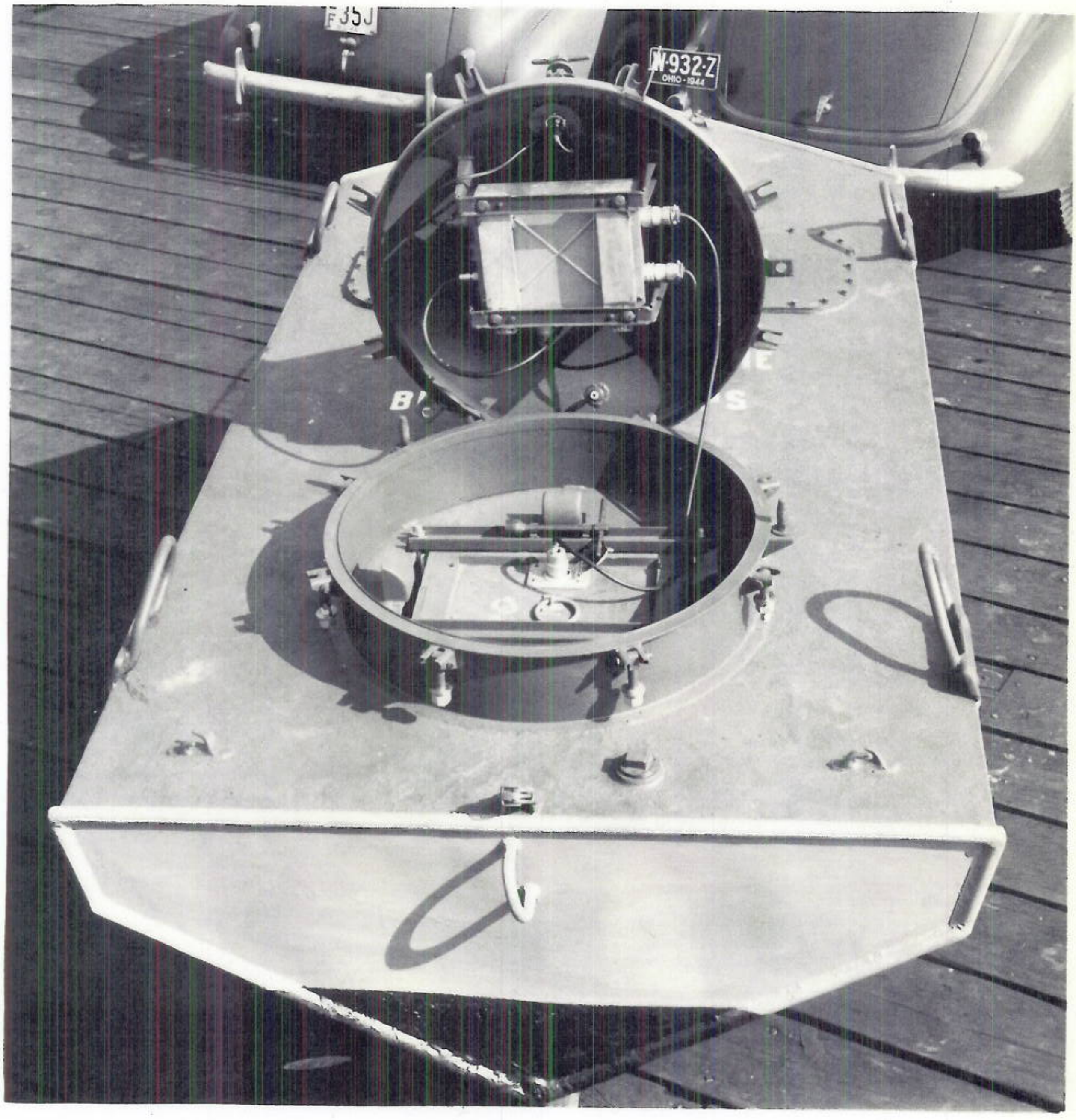
PLATE 4



XCX SONO RADIO BUOY - HATCH INTERIOR DETAILS

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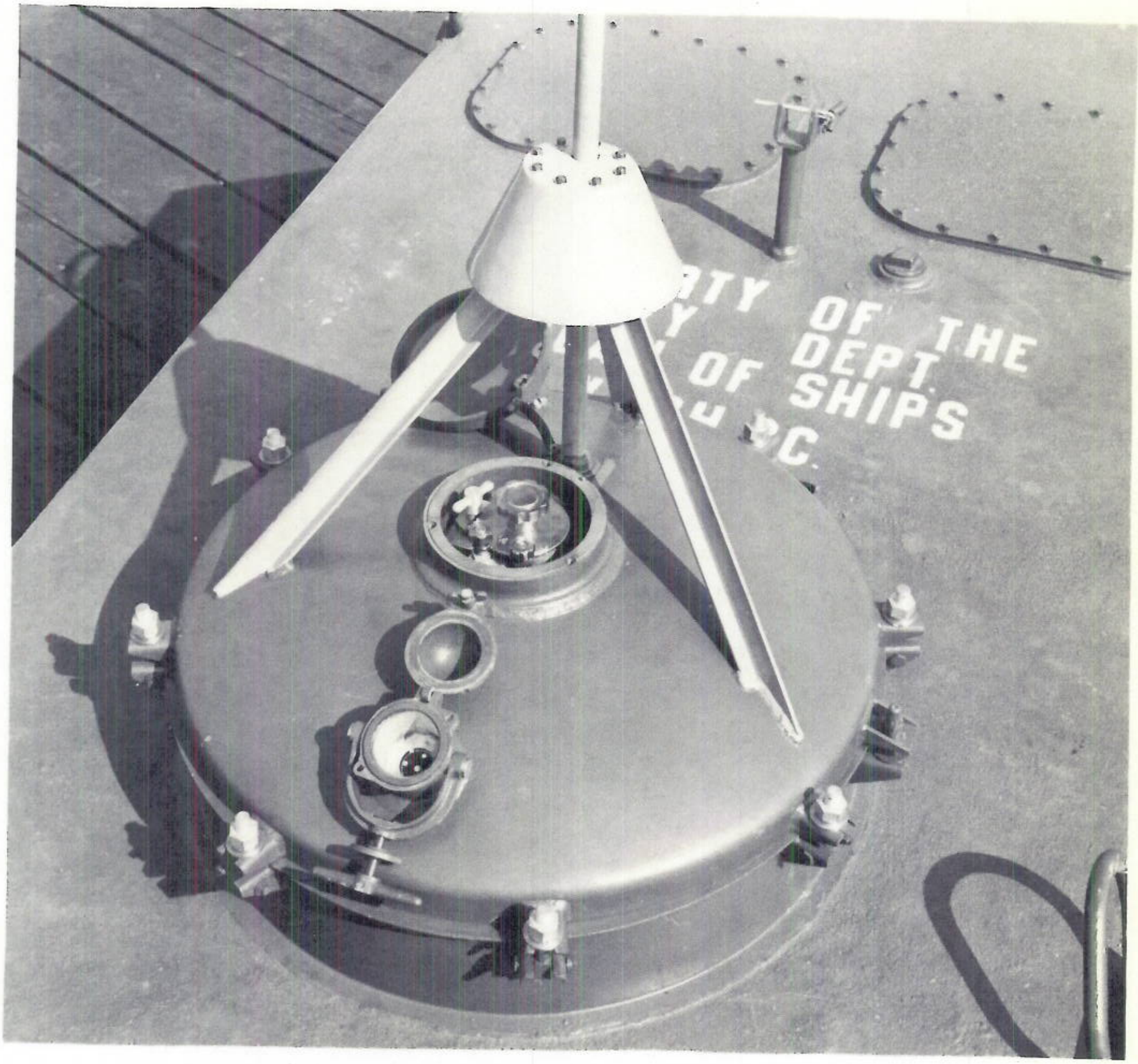
PLATE 5



XCX SONO RADIO BUOY - HATCH COVER DETAILS

PLATE 6

XCX SONO RADIO BUOY - HATCH COVER IN SERVICING POSITION

PLATE 7

TABLE II

BUOY A - Summary of Anchor Line Sizes

Anchoring Depth (Feet)	Type of Anchoring Line	Anchoring Line Length (Feet)		Maximum Current (Knots)	Anchor Line Sizes at Maximum Current (inches)		Recommended Anchoring Line Sizes (inches)			Maximum Current for Recommended Sizes (Knots)
		Cable	Chain		Cable (Diameter)	Chain (Bar Size)	Cable (Diameter)	Chain (Bar Diameter)		
								Actual	"Trade"	
1200	Plow Steel Cable	2400		4.0	0.229					
600	H.C. High Test Chain		1200	3.95		0.184		7/32	3/16	3.68
600	Proof Coil Chain		1200	2.75		0.325		11/32	5/16	2.65
600	Plow Steel Cable Plus H.C. High Test Chain	600	600	4.5	0.241	0.184	1/4	7/32	3/16	4.28
600	Plow Steel Cable Plus Proof Coil Chain	600	600	4.05	0.215	0.270	1/4	9/32	1/4	3.94
100	H.C. High Test Chain		200	>9.0				11/32	5/16	>9.0
100	Proof Coil Chain		200	7.55		0.432		13/32	3/8	7.30

TABLE III

BUOY B - Summary of Anchor Line Sizes

Anchoring Depth (Feet)	Type of Anchoring Line	Anchoring Line Length (Feet)		Maximum Current (Knots)	Anchor Line Sizes at Maximum Current (inches)		Recommended Anchoring Line Sizes (inches)			Maximum Current for Recommended Sizes (Knots)
		Cable	Chain		Cable (Diameter)	Chain (Bar Size)	Cable (Diameter)	Chain (Bar Diameter)		
								Actual	"Trade"	
1200	Plow Steel Cable	2400		4.0	0.226-0.368		1/4			4.25
600	H.C. High Test Chain		1200	4.62		0.212		7/32	3/16	4.55
600	Proof Coil Chain		1200	3.06		0.397		13/32	3/8	3.0
600	Plow Steel Cable Plus H.C. High Test Chain	600	600	5.33	0.271	0.205	1/4	7/32	3/16	5.12
600	Plow Steel Cable Plus Proof Coil Chain	600	600	4.48	0.281	0.352	5/16	11/32	5/16	4.35
100	H.C. High Test Chain		200	>9.0				15/32	7/16	>9.0
100	Proof Coil Chain		200	8.18		0.582		17/32	1/2	7.90

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ENCLOSURE (A)
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PLATE 8

TABLE IV

NRL MARK III BUOY "B"

Anchor Line Sizes and Combinations for Various Anchoring Depths and Currents

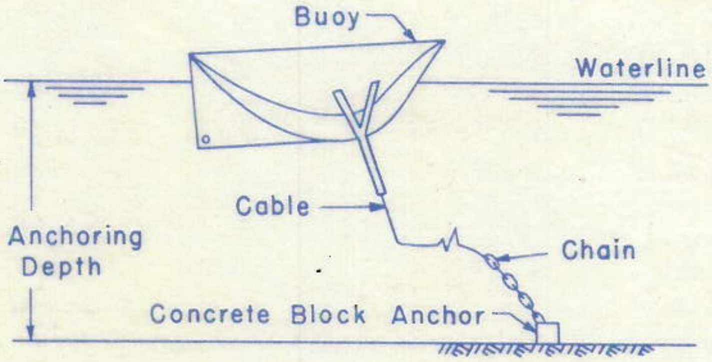
1. Anchor Line:

   3/8-inch Diameter Plow Steel Cable
   9/32 (1/4)-inch H.C. High Test Steel Chain

2. Anchor Line Length = 2 x Anchoring Depth

3. For Combination Chain and Cable Anchor Line:

   Chain Length = Cable Length



Anchor Depth (Feet)		100	200	300	400	600	900	1200
Maximum Current (knots)	Anchor Weight (pounds)	Recommended Anchor Line						
1.0	1500	Chain and Cable	Chain and Cable	Chain and Cable	Chain and Cable	Chain and Cable	Chain and Cable	Chain and Cable
2.0	1600	Chain and Cable	Chain and Cable	Chain and Cable	Chain and Cable	Chain and Cable	Chain and Cable	Chain and Cable
3.0	1700	Chain and Cable	Chain and Cable	Chain and Cable	Chain and Cable	Chain and Cable	Chain and Cable	Cable
4.0	1900	Chain and Cable	Chain and Cable	Chain and Cable	Chain and Cable	Chain and Cable	Cable	Maximum Current = 3.96 knots
5.0	2200	Chain and Cable	Chain and Cable	Chain and Cable	Chain and Cable	Cable	Maximum Current = 4.55 knots	
6.0	2500	Chain and Cable	Chain and Cable	Chain and Cable	Cable	Maximum Current = 5.2 knots		
7.0	3000	Chain and Cable	Chain and Cable	Chain and Cable	Maximum Current = 6.9 knots			
8.0	3700	Maximum Current = 7.9 knots	Maximum Current = 7.7 knots	Maximum Current = 7.25 knots				

ENCLOSURE (B)

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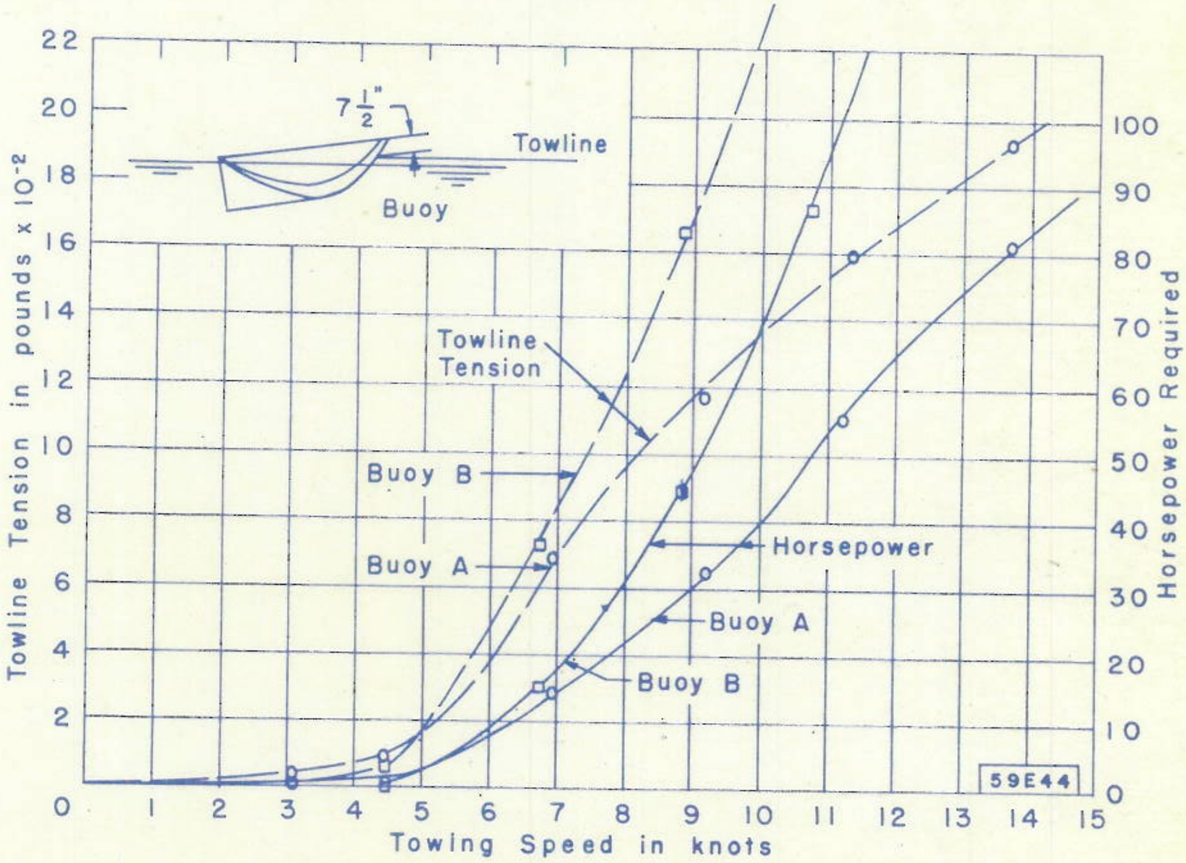
PLATE 9



NRL Mark III Buoy-Towline Tension and Horsepower
Required for Towing Astern of a Vessel

David Taylor Model Basin

12 February 1944
Enclosure (D)

420046

PLATE 10

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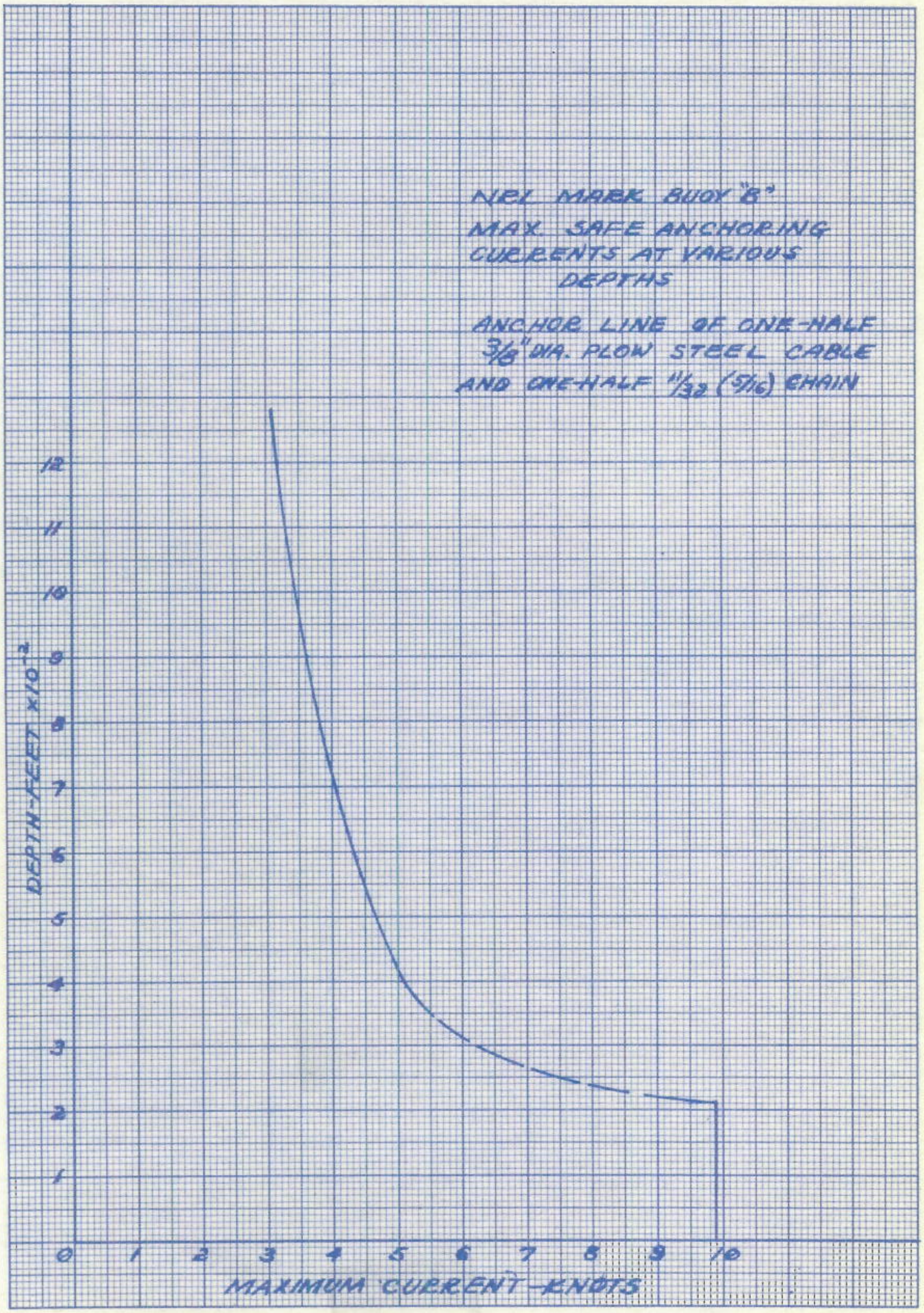

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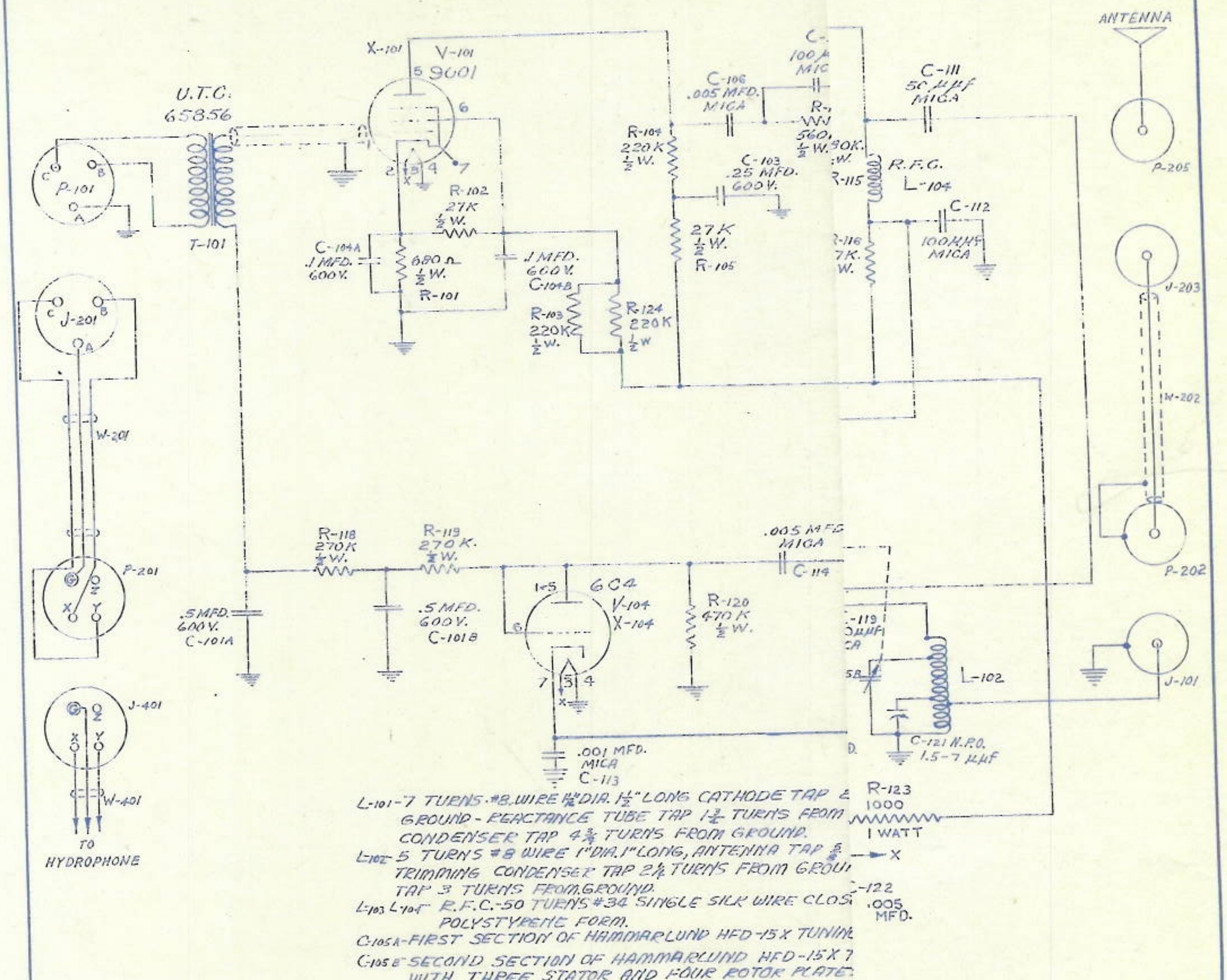
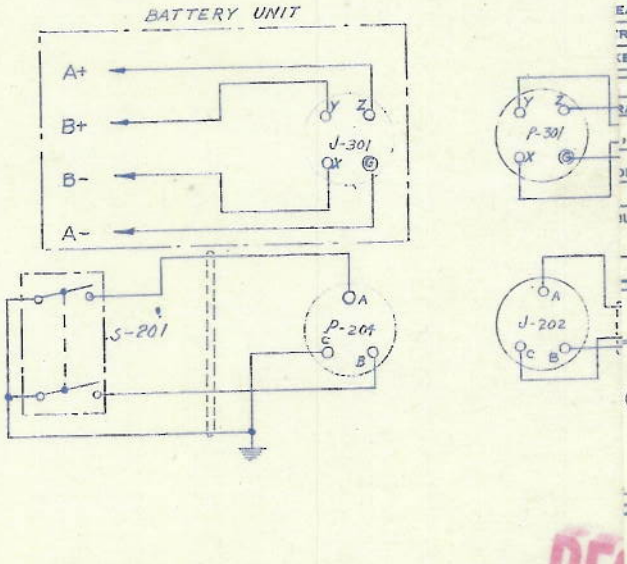
PLATE 12

N. R. L. 66



L-101-7 TURNS #8 WIRE ¼" DIA. 1½" LONG CATHODE TAP &
GROUND - REACTANCE TUBE TAP 1¾ TURNS FROM
CONDENSER TAP 4¾ TURNS FROM GROUND.
L-102-5 TURNS #8 WIRE 1" DIA. 1" LONG, ANTENNA TAP ⅝
TRIMMING CONDENSER TAP 2¼ TURNS FROM GROU
TAP 3 TURNS FROM GROUND.
L-103 L-104 R.F.C.-50 TURNS #34 SINGLE SILK WIRE CLOS
POLYSTYRENE FORM.
C-105A-FIRST SECTION OF HAMMARLUND HFD-15X TUNIN
C-105B-SECOND SECTION OF HAMMARLUND HFD-15X 7
WITH THREE STATOR AND FOUR ROTOR PLATE



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EATOR	RRB	IN CHARGE OF RADIO DRAFTING	CHIEF DRAFTSMAN
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. APPROVAL	
RADIO ENGINEER	SUPT. OF RADIO DIVISION
, Kulchowski	
DIRECTOR	
	COMDR. U. S. N.
UREAU OF SHIPS	REFERENCE

U. S. NAVAL RESEARCH LABORATORY
"BELLEVUE," ANACOSTIA, D. C.

ODEL XCX SONO-RADIO BUOY
SCHEMATIC DIAGRAM

LE
DATE OCT. 27, 1944

RA 54F 219A

DEC

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PLATE 13

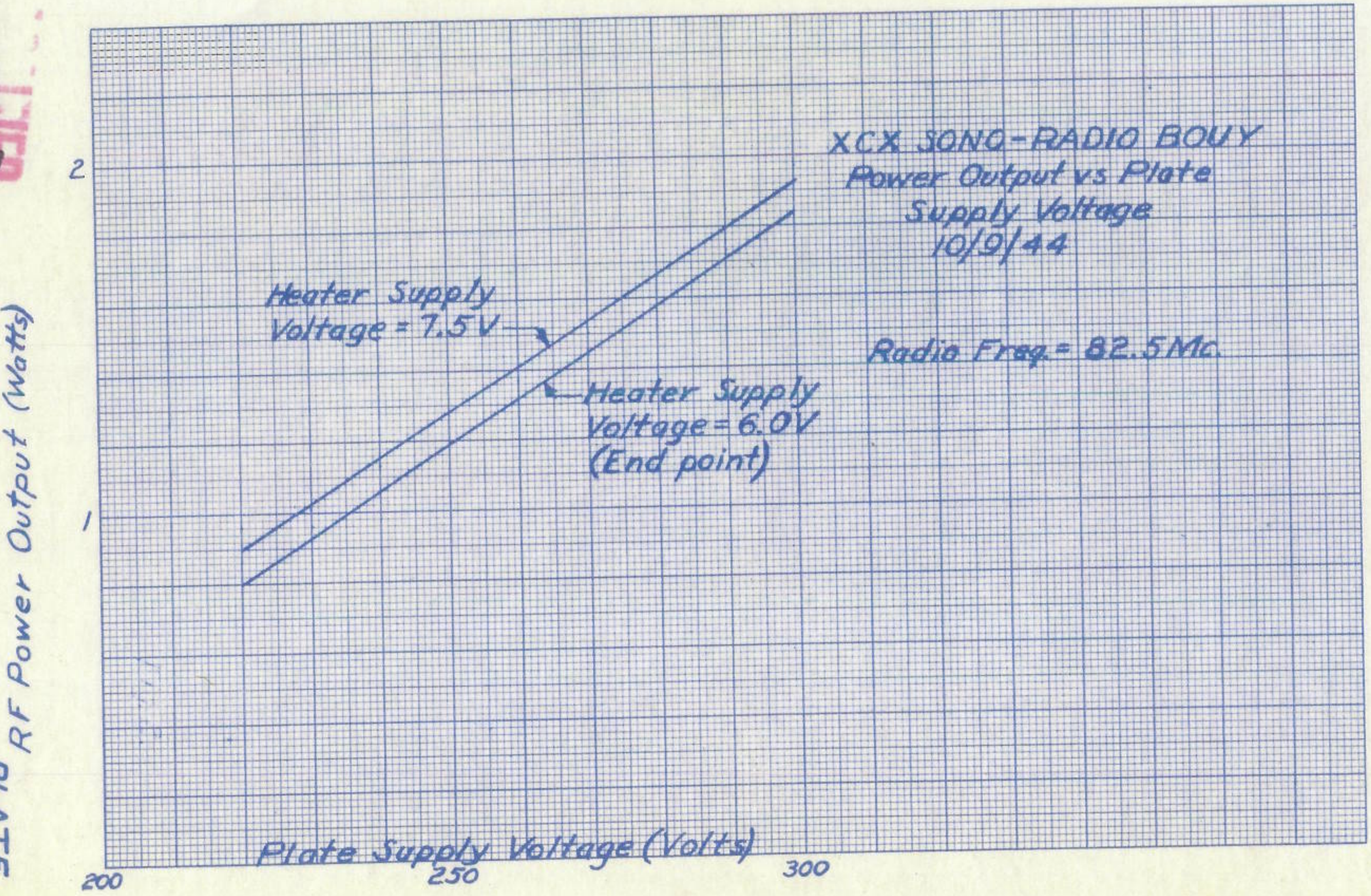

XCX SONO-RADIO BOUY
Power Output vs Plate
Supply Voltage
10/9/44
Radio Freq.= 82.5Mc.
Heater Supply
Voltage = 7.5V
Heater Supply
Voltage = 6.0V
(End point)
RF Power Output (Watts)
2
1
Plate Supply Voltage (Volts)
200
250
300

PLATE 14

[redacted]

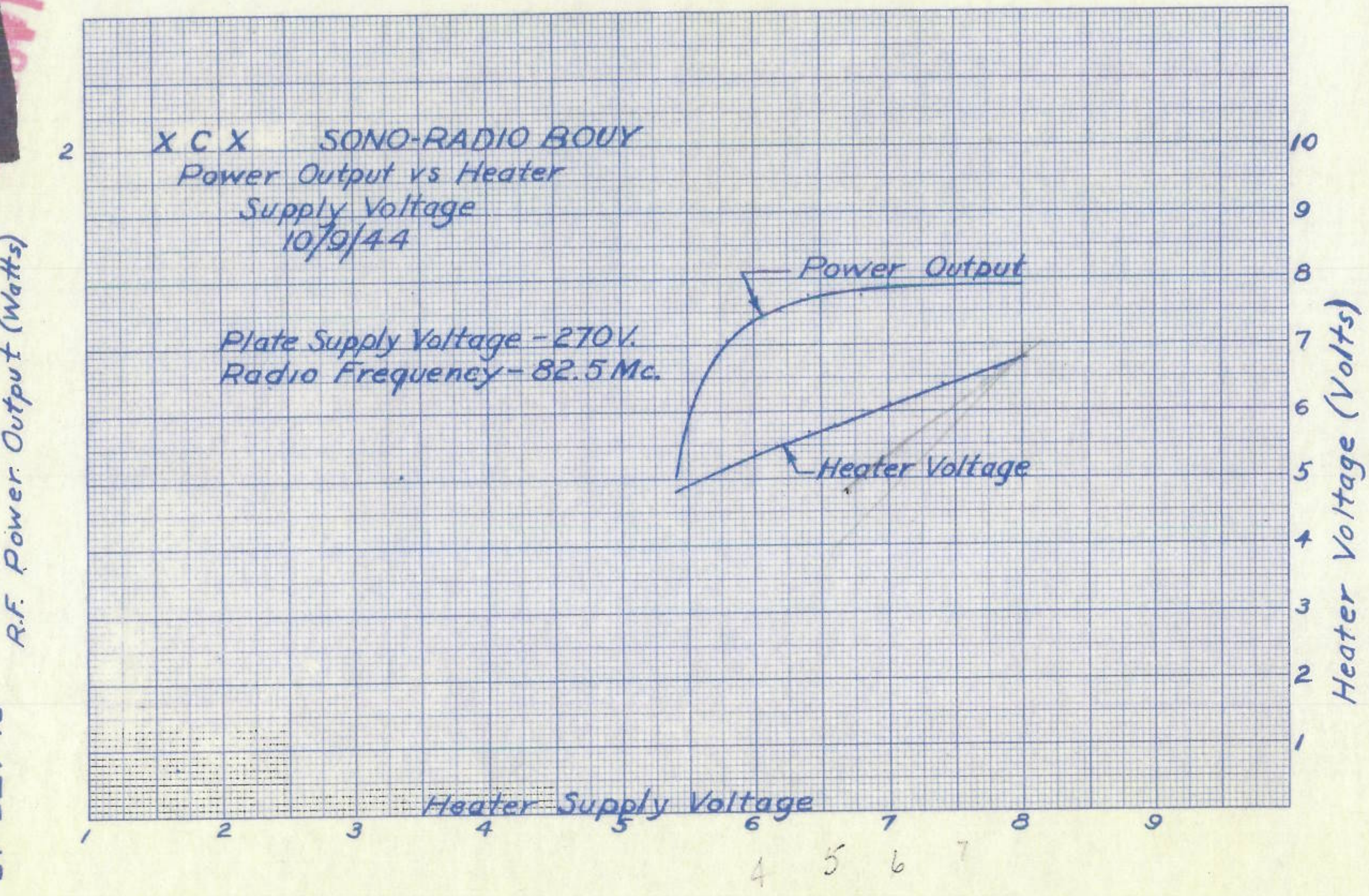
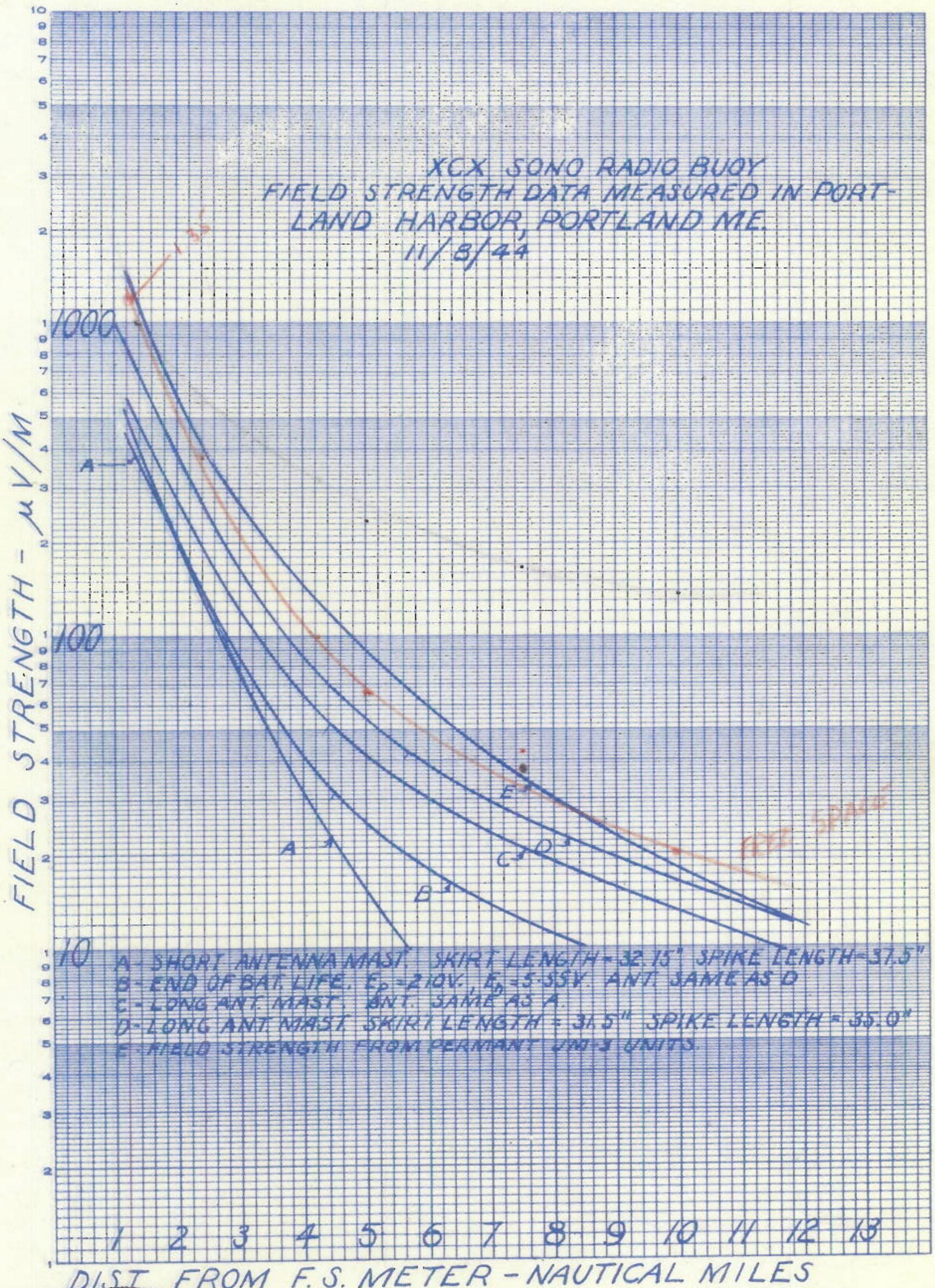


PLATE 15



XCX SONO RADIO BUOY
FIELD STRENGTH DATA MEASURED IN PORT-
LAND HARBOR, PORTLAND ME.
11/8/44

A - SHORT ANTENNA MAST, SKIRT LENGTH = 32.15" SPIKE LENGTH = 37.5"
B - END OF BAT. LIFE. E_p = 210V., E_h = 5.55V. ANT. SAME AS D
C - LONG ANT. MAST. ANT. SAME AS A.
D - LONG ANT. MAST. SKIRT LENGTH = 31.5" SPIKE LENGTH = 35.0"
E - FIELD STRENGTH FROM PERMANT JM-3 UNITS.

PLATE 16

[redacted]

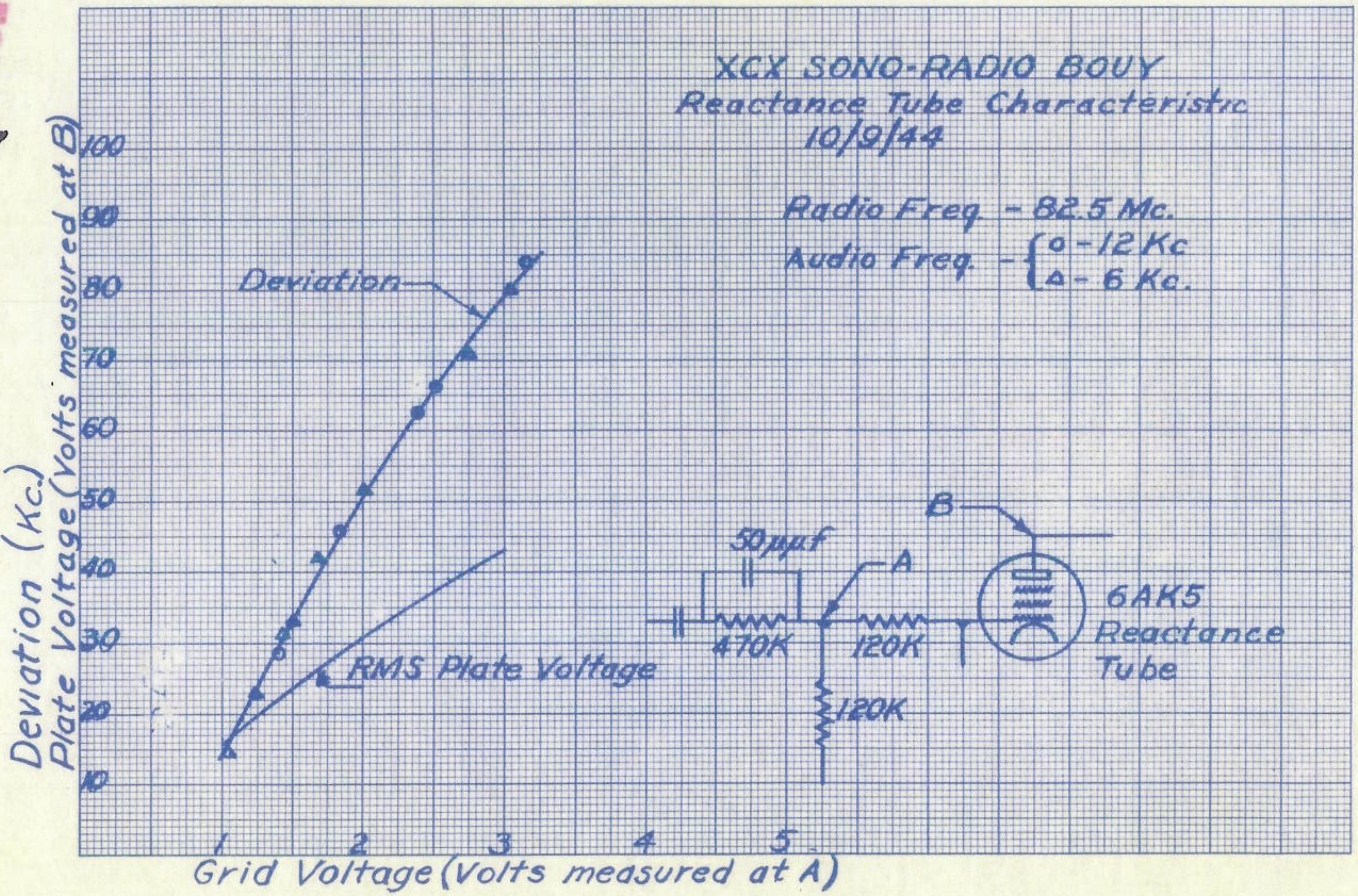


PLATE 17

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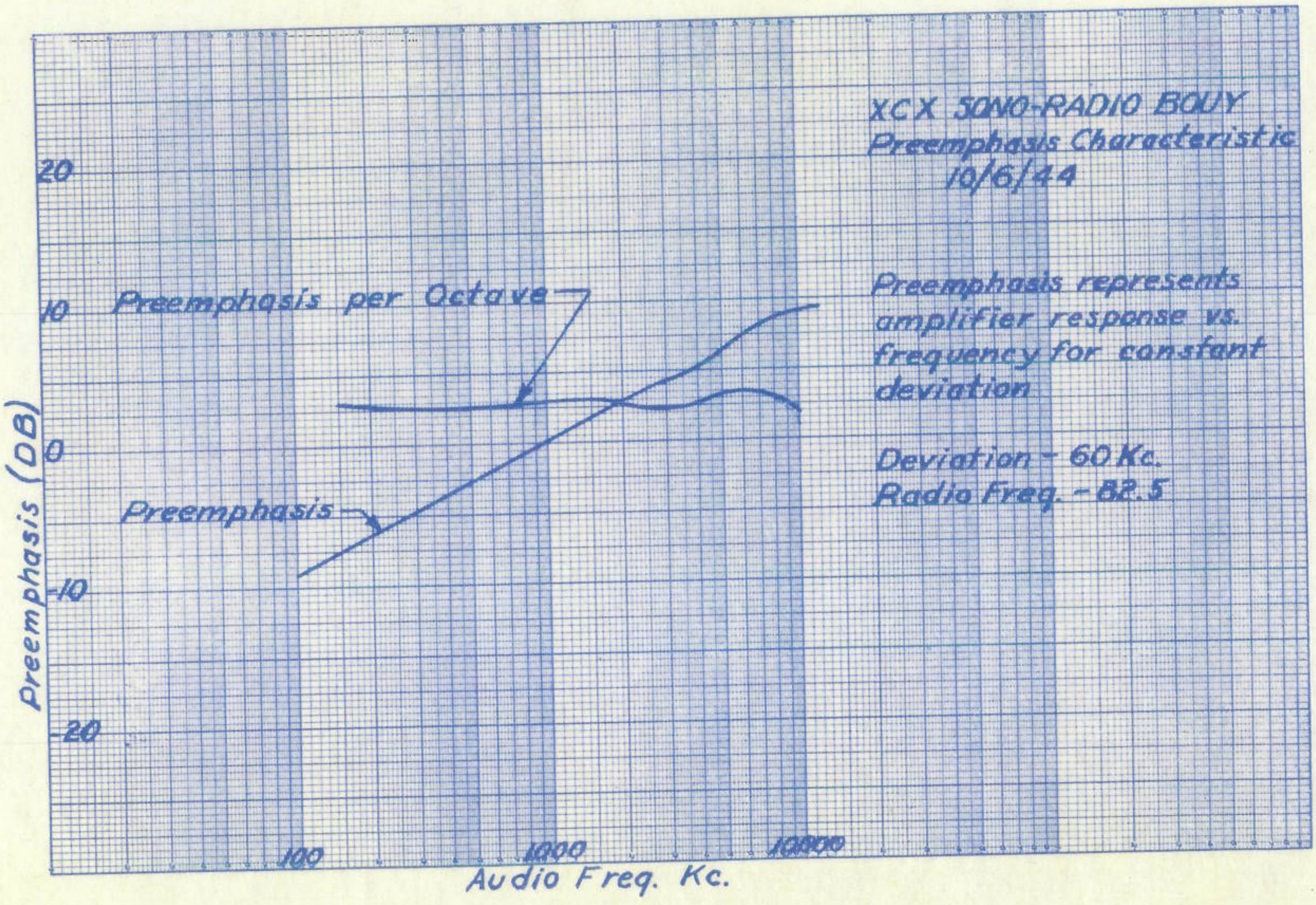

XCX SONO-RADIO BOUY
Preemphasis Characteristic
10/6/44

Preemphasis represents amplifier response vs. frequency for constant deviation

Deviation - 60 Kc.
Radio Freq. - 82.5

[redacted]

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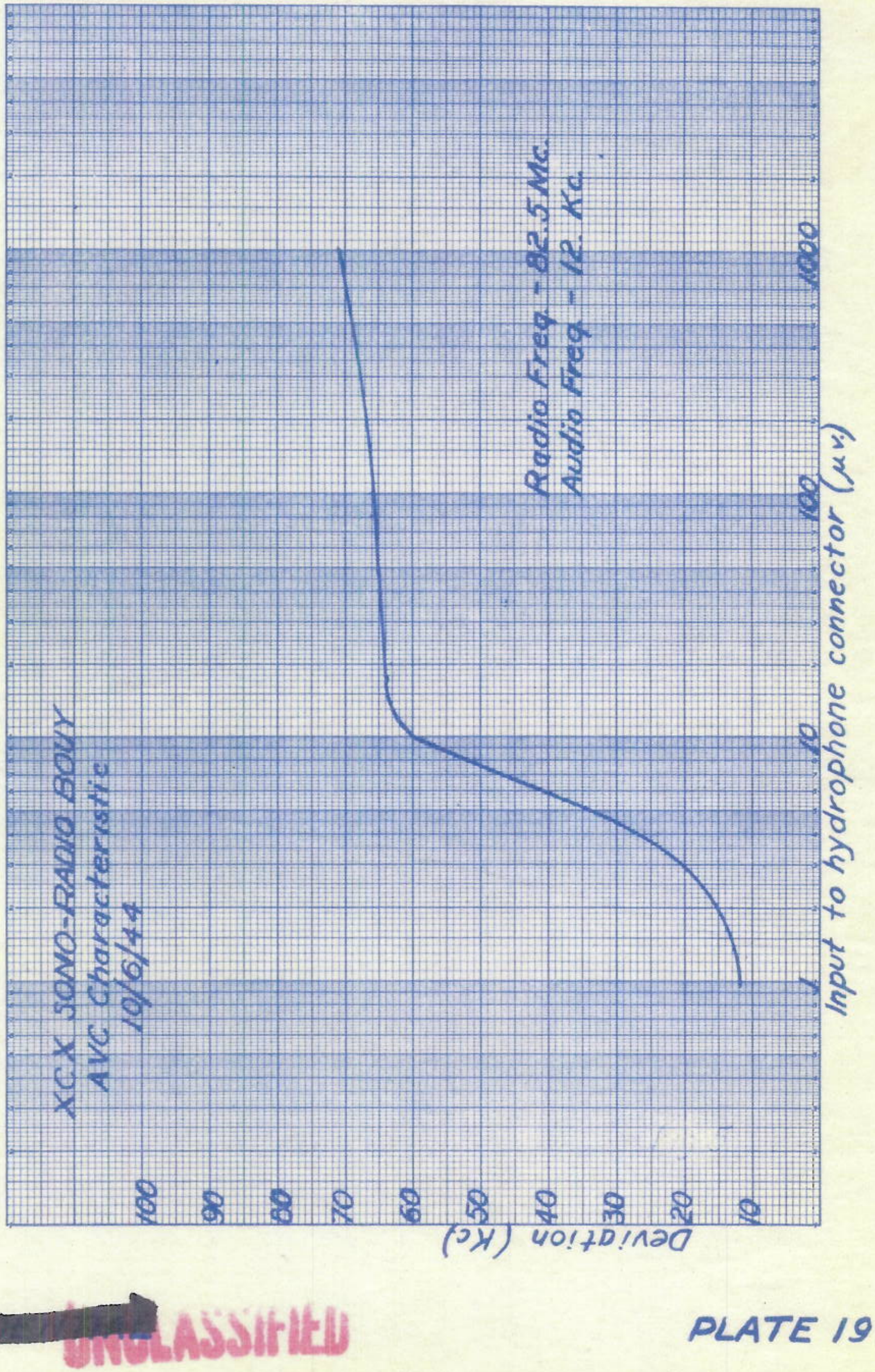
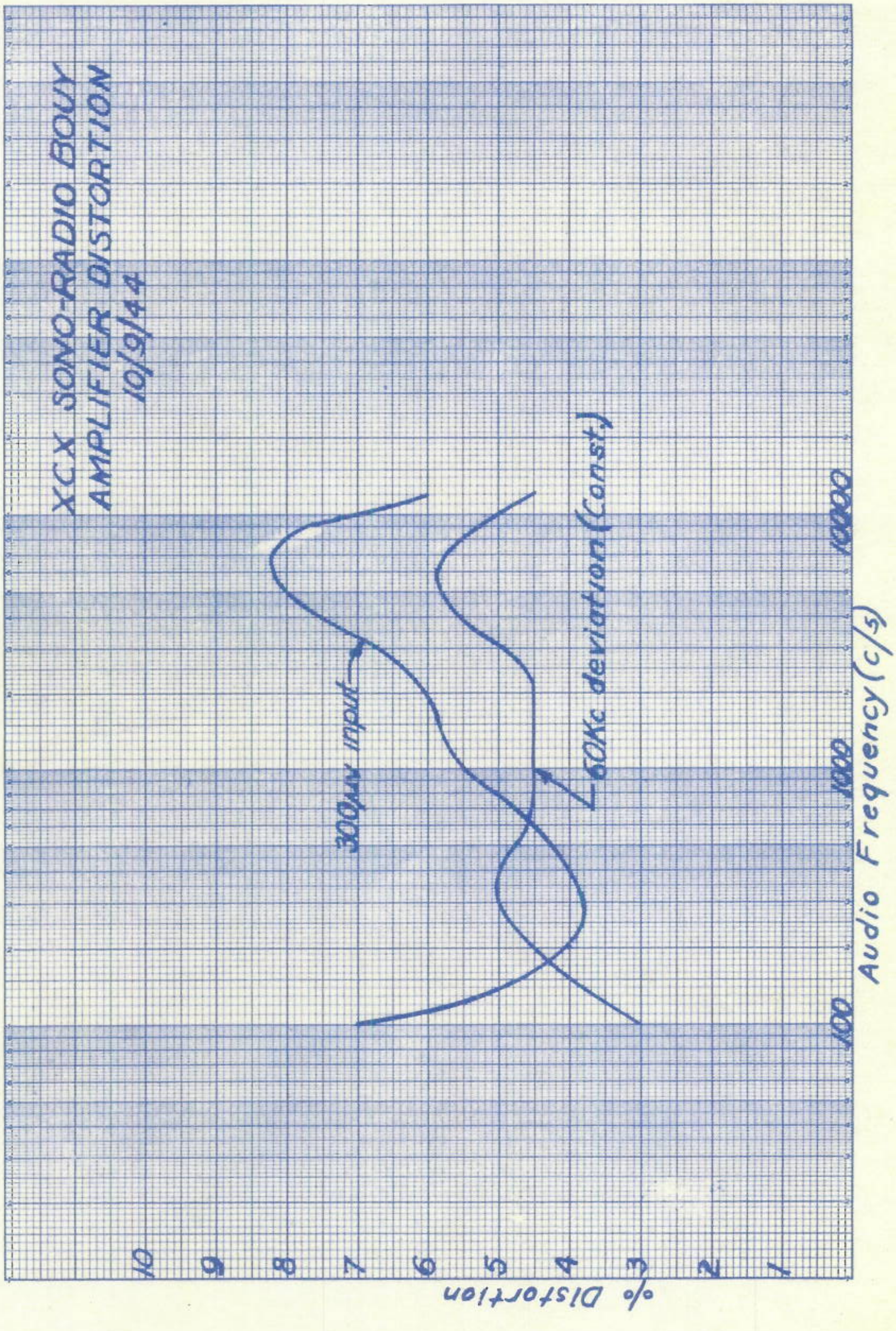
PLATE 18



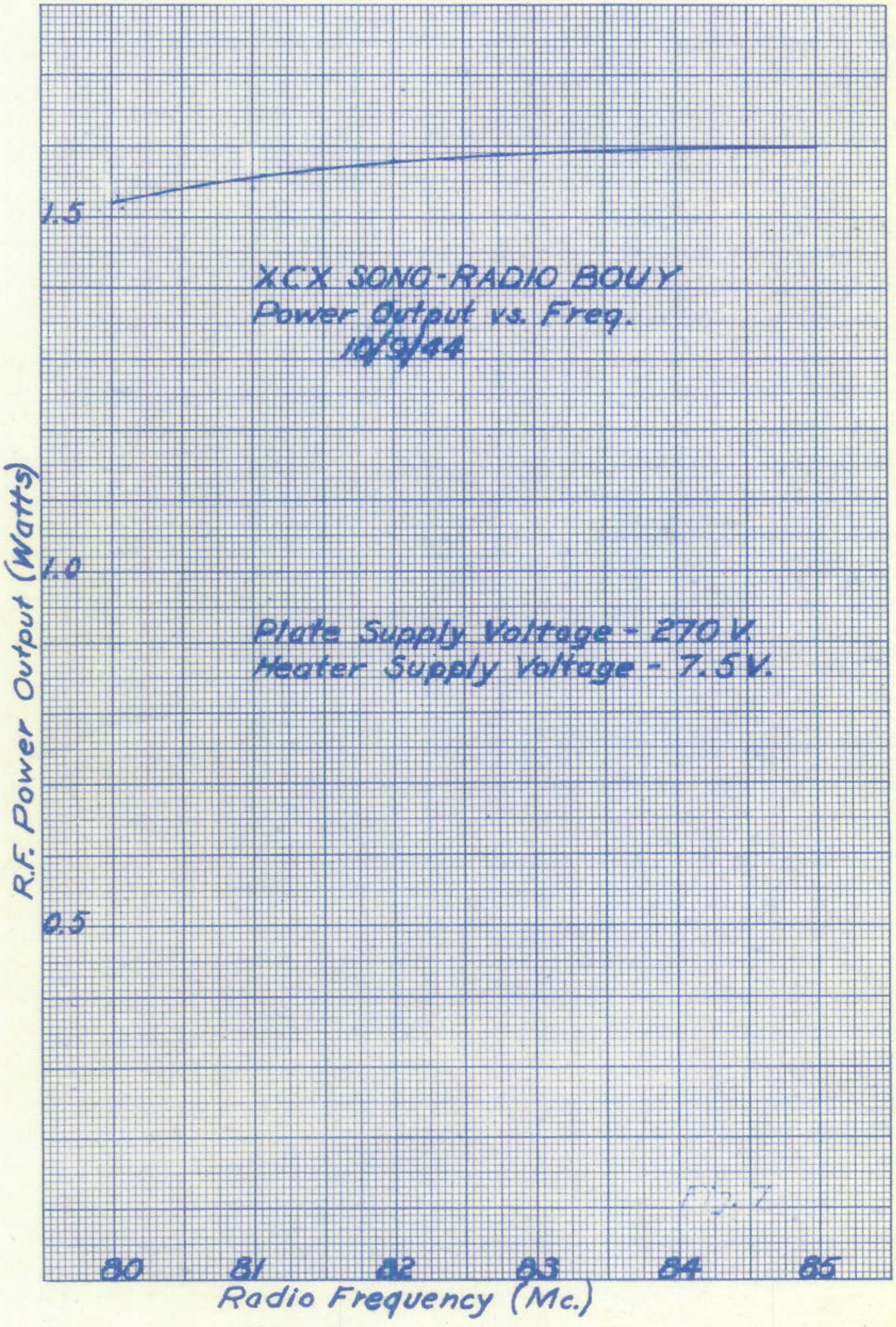
[redacted] UNCLASSIFIED

PLATE 19



[redacted] UNCLASSIFIED

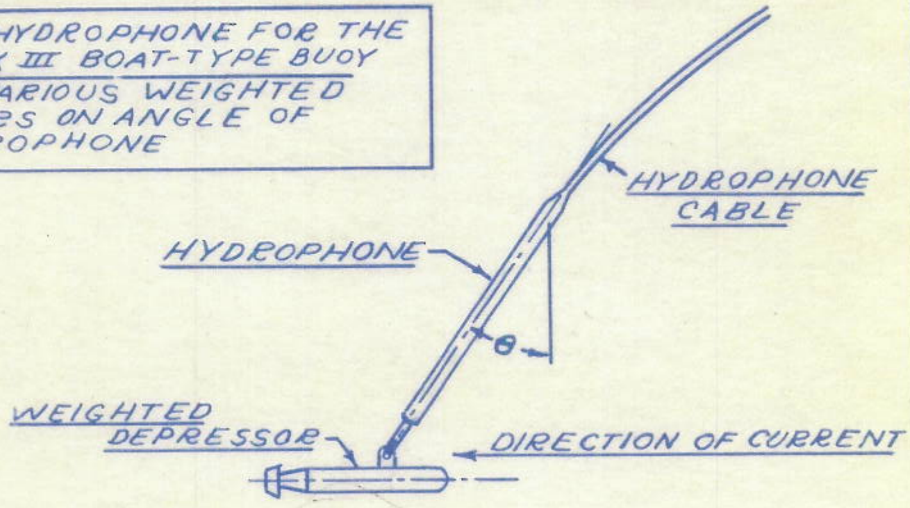
PLATE 20

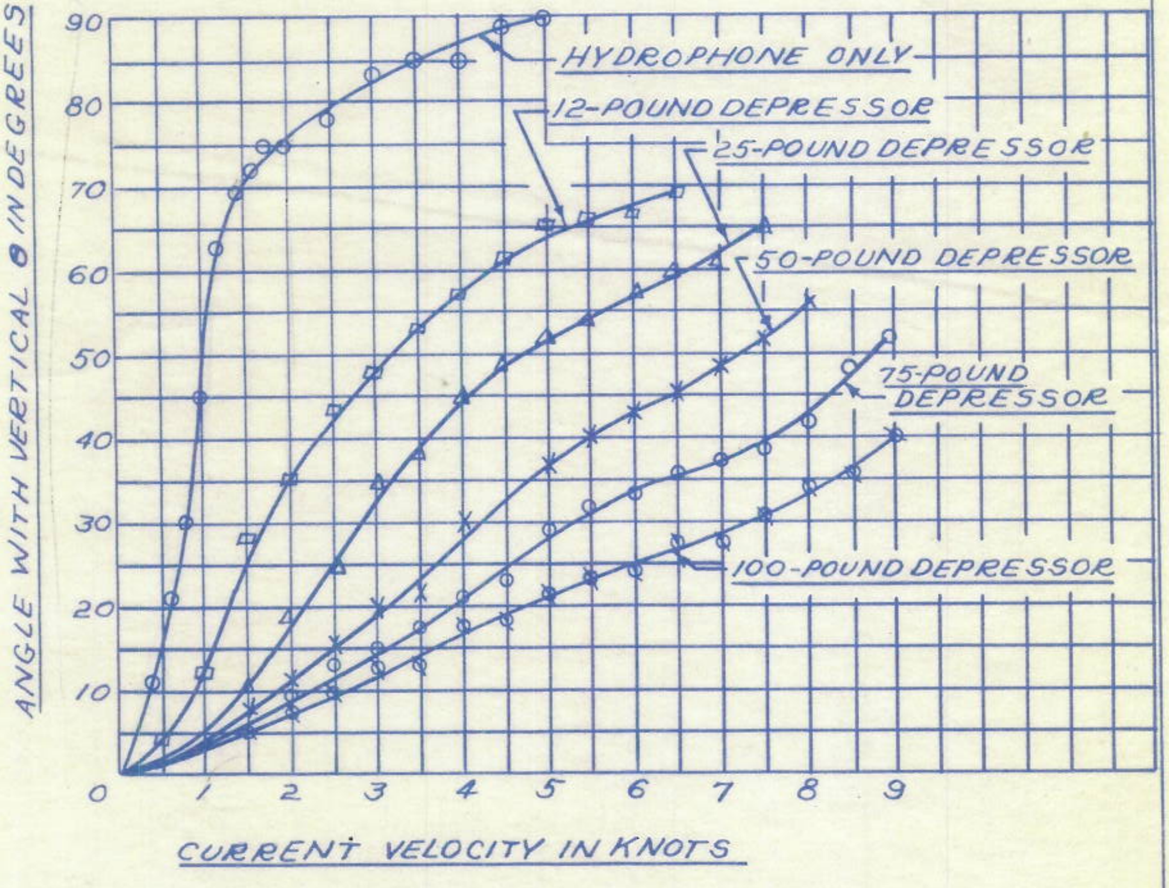


[redacted] UNCLASSIFIED

PLATE 21

BRUSH C-37 HYDROPHONE FOR THE
NRL MARK III BOAT-TYPE BUOY
EFFECT OF VARIOUS WEIGHTED
DEPRESSORS ON ANGLE OF
HYDROPHONE





DAVID W. TAYLOR MODEL BASIN 22 AUGUST 1944 ENCLOSURE-B

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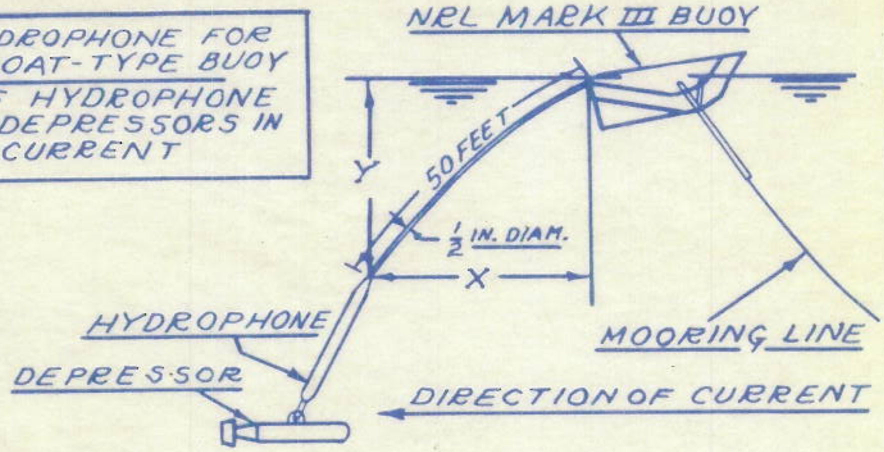
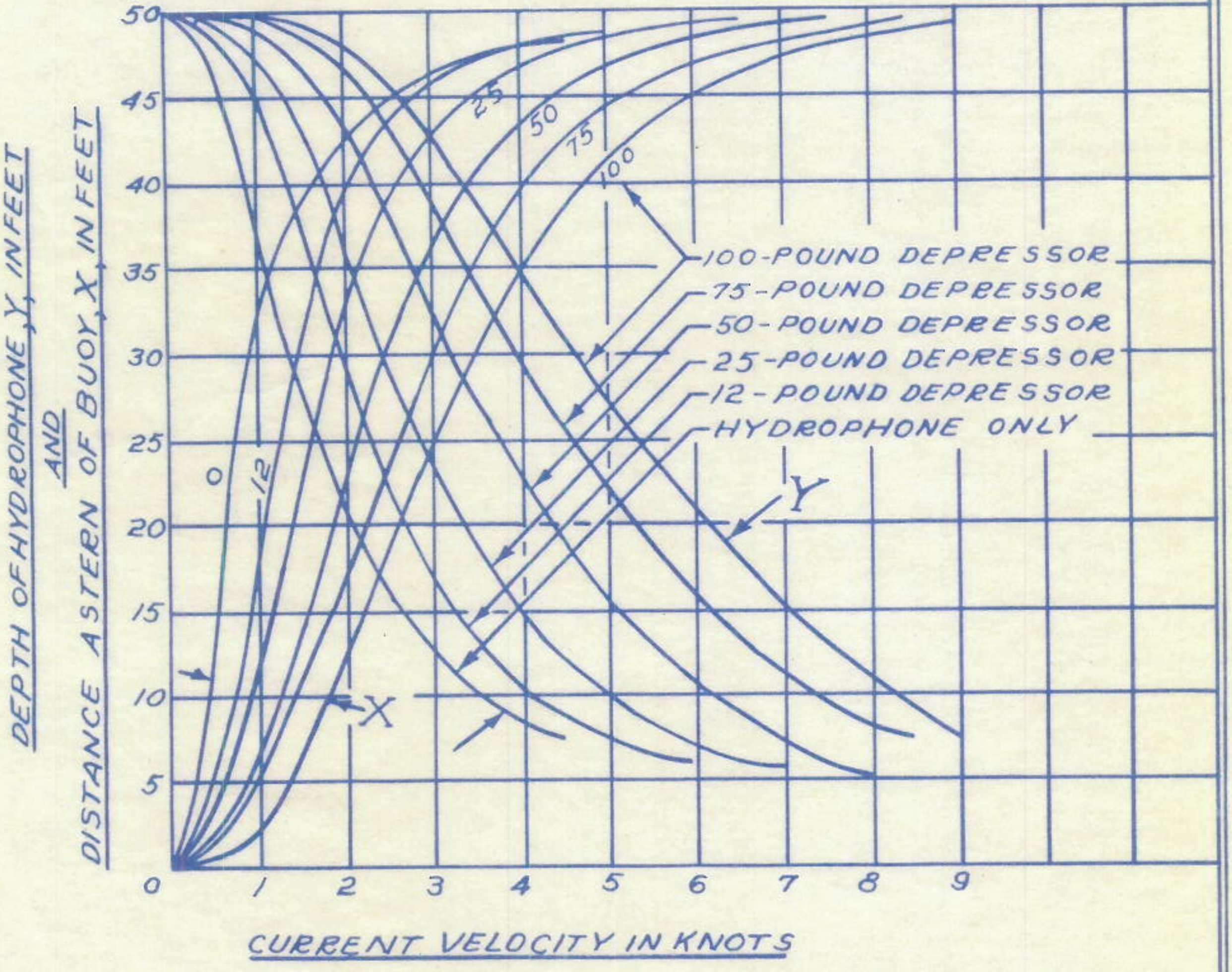
[redacted]

PLATE 22

BRUSH C-37 HYDROPHONE FOR
NRL MARK III BOAT-TYPE BUOY

ORIENTATION OF HYDROPHONE
WITH VARIOUS DEPRESSORS IN
A UNIFORM CURRENT





DAVID W. TAYLOR MODEL BASIN 22 AUGUST 1944 ENCLOSURE-C

[redacted] UNCLASSIFIED

PLATE 23

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