DECLASSIFIED

REPORT NO. S-1582

DATE 20 December 1939

SUBJECT

Report on

Equipment and Procedure

for

Standardized Projector Performance Tests

FR-1582

DECLASSIFIED by NRL Contract
Declassification Team
Date: 12 MAY 2012
Reviewer's name(s): H. DO, P. HANNA

Declassification authority: NAVY DECLASS MANUAL, 11 DEC 2012, 05-038

by

E. Klein
F. E. Arnold

DISTRIBUTION STATEMENT A APPLIES
Further distribution authorized by
UNLIMITED only.

CLASSIFICATION CHANGED TO UNCLASSIFIED
BY AUTHORITY OF NRL Ltr. 2028-528:HWO; dt 8 May 1959 Ser 3462

E. Klein

NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.

DECLASSIFIED

20 December 1939

NRL Report No. S-1582
BuEng.Prob. U3-1C

NAVY DEPARTMENT

"UNCLASSIFIED"

[redacted]

Report

on

Equipment and Procedure

for

Standardized Projector Performance Tests

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

Number of Pages: Text - 9 Plates - 8

Authorization: BuEng let.C-S68(12-12-R4-4/15) of 16 January 1939.

Date of Test: 6 - 18 November 1939

Prepared by:

E. Klein, Sr.Physicist

P. N. Arnold, Assoc. Physicist

Reviewed by:

H. C. Hayes, Prin. Physicist

Approved by:

H. G. Bowen, Rear Admiral, U.S.N.
Director

"UNCLASSIFIED"

Distribution: BuEng (10)

LP

TABLE OF CONTENTS

Appendices

"UNCLASSIFIED"

[redacted]

SECTION I

INTRODUCTION

1. This report covers work carried on aboard the U.S.S. SEMMES by personnel of the Naval Research Laboratory from 6 to 18 November 1939. The objective of the work was to provide the SEMMES with calibrated sound intensity measuring equipment for measuring in absolute units the performance of underwater sound projectors submitted by manufacturers for test. This work was a continuation of that covered in a recent letter to the Bureau of Engineering (NRL letter C-S68/88 of 23 October 1939).

2. The acceptable acoustic performance of an underwater sound projector is set forth in Bureau of Engineering Specifications RE 13A 520D of 1 July 1939, paragraphs 7-14 to 7-17 inclusive. To determine whether or not a given projector meets these specifications, it is necessary that the SEMMES have, in addition to equipment already at hand and in use, a calibrated sound sensitive device. Up to the present the SEMMES has been limited in making performance tests to relative measurements, wherein the performance of a projector under test is compared with that of one already accepted and in use. To meet the need, a unit herein designated as the T-3 was installed in the new port calibrating well of the SEMMES and was calibrated in position by personnel of this Laboratory. The unit was used during the subject test period in measuring the performance of several projectors submitted for test by the RCA Manufacturing Company and by the Submarine Signal Company. The performance of the projectors as receivers was neglected in these tests for lack of time. The purposes of this report are to present the calibration of the T-3 and to illustrate its use in evaluating in absolute units the performance of a projector as a transmitter.

SECTION II

CALIBRATION OF THE T-3

3. In calibrating the T-3 as installed on the SEMMES, this Laboratory has relied upon its own primary standard, a 4-1/2 inch spherical unit with a sound sensitive element of quartz. This primary standard is herein designated as the Q-1 and its calibration over the frequency range 17 to 25 kilocycles per second inclusive is presented in Plate 1. This calibration, based on careful absolute sound intensity measurements in the Laboratory at 25 kilocycles per second and checked at 24.25 kilocycles per second in the calculable open water sound field of a simple piston source of a highly resonant type, the intensity of which was determined by motional impedance measurements, is reliable for acceptance tests of projectors operating in the frequency range 24 to 25 kilocycles per second. The calibration at other frequencies is based on questionable secondary standards of sound intensity and is accepted by this Laboratory for use only until a more reliable calibration can be made.

4. The calibration of the T-3 is presented in Plate 2. This unit is a 6 inch sphere with a sound sensitive element of tourmaline. Based on that of the Q-1, its calibration is reliable between 24 and 25 kilocycles per second and is open to question at other frequencies. The extended calibration is for use only until this Laboratory can make available more reliable figures.

[redacted]

5. The calibration of either unit, of course, gives the relation as a function of frequency between the open circuit rms voltage developed by the device in a sound field and the rms pressure of the sound wave which would exist at the point of measurement if the device were not there. By the device, in each case, is meant not simply the sound sensitive element, but the element in conjunction with its shielded cable as provided for use. The T-3, or the Q-1, as calibrated, reduces sound pressure measurement to a simple voltage measurement. The sound intensity and the rms sound pressure in sea water are related by the equation

$$I = P^2/1.55 \times 10^{12}$$

where the intensity I is in watts/cm^2 if the rms pressure P is expressed in bars.

6. It is desirable in a calibrated standard that the sensitivity to sound as a function of frequency over a considerable range be constant. Unfortunately, the T-3 is not as good in this respect as is the primary standard Q-1, and in the design of new units for calibration, an attempt will be made to improve upon the T-3 with respect to flatness of response.

7. The T-3 is superior to the Q-1, however, in absolute sensitivity. At 24.25 kilocycles per second its sensitivity is greater by 9.7 decibels. This sensitivity is high enough to eliminate the need for any pre-amplifier within the unit itself, and is sufficient to permit not only the measurement of the axial sound intensity developed by any average directive projector at any of the available positions for measurement in the main sound room of the SEMMES, but also the measurement of the complete radiation pattern of the projector, with only a simple logarithmic electronic voltmeter as auxiliary equipment. Such a voltmeter, made by the Ballantine Laboratories, Inc. (Model 300), is available on the market, and one of this type was used in making measurements in the subject tests. The voltmeter, which has a high input impedance, measures directly the rms open circuit voltage developed by the T-3.

8. The internal noise of the T-3 and any external noise developed around it as installed in the port calibrating well at ship speeds up to and including 5 knots was more than 50 decibels below the axial sound intensity developed by the poorest of all the projectors tested in the starboard main well. It is this low noise level which permits the measurement of the complete radiation pattern of the average projector with the T-3 and a voltmeter and without selective amplification.

SECTION III

APPLICATION OF THE T-3 TO PROJECTOR TRANSMITTING PERFORMANCE TESTS

9. The SEMMES is now provided in the main sound room with two main sound wells designated as port and starboard, and two calibrating wells, designated as port and starboard. In ordinary course the projector under

[redacted]

test is mounted in one of the main sound wells and a standard reference projector in the other. In the subject tests, the T-3 was mounted in the port calibrating well, and the starboard calibrating well was not used. Eventually a second calibrated unit will be provided for the starboard calibrating well to be used for standby and checking purposes. This disposition of wells allows intensity measurements at 11 feet 9 inches, 8 feet 10 inches, or, if one of the main wells is used for mounting a calibrated unit instead of a reference projector, at 4 feet 10 inches. These are distances between the centers of the supporting tubes of the respective wells and give corrected distances of 137, 102, and 54 inches, respectively, between the face of the projector under test and the sound sensitive face of the calibrated unit.

10. The radiation pattern of the QC-5 (19 inch) projector (SEMMES equipment) as measured by the T-3 at 102 inches is presented in Plate 3. The same pattern as measured by the T-3 at 137 inches is presented for comparison in Plate 4. Water conditions at the time of measurements at 137 inches were very poor. For the measurement of a radiation pattern a calibrated unit is not essential as intensity measurements at various bearings are relative to the axial intensity. However, in these and in previous tests, the pattern of a given projector taken simultaneously at different distances (160 feet, 60 feet, 137 inches, 102 inches) have shown no essential differences, and the ease and rapidity with which the pattern may be measured with the T-3 make it desirable that in the future all radiation patterns be taken with it or a similar device at either 102 or 137 inches as convenience dictates. The electronic voltmeter described above is calibrated not only in volts, but also in decibels, and the data for the usual polar plot can be taken nearly as fast as they can be recorded, if water conditions are reasonably good. The short water path between projector and the T-3 makes for a high signal to noise ratio, and patterns in these tests were successfully measured with water conditions such that the patterns could not be successfully measured with the D-2 at 160 feet. The usual initial adjustments, such as the training of the projector under test and the measuring unit on each other, the tuning of the projector and the regulation of the power applied to the projector are considerably expedited by the fact that the voltmeter across the T-3 is in direct view of the person making these adjustments. Telephone communication between the main sound room and the measuring point is not necessary. A comparison between the radiation pattern as measured with this equipment and an acceptable pattern as set forth in Bureau of Engineering Specifications RE 13A 520D of 1 July 1939, paragraphs 7-14(a) and (b), can be readily made and no comment need be made here.

11. In Plate 5 the resonance curve of the QC-5 (19 inch) projector is presented as measured by the T-3 at 102 inches and at 137 inches. The curve as measured by the Q-1 at 137 inches is also presented on the same plate. The three curves indicate the variation of the axial sound intensity developed by the projector at the respective distances as the frequency of the driving current is varied. Maximum intensity occurs at 24.25 kilocycles per second and this is the resonant frequency of the projector. The width of the curve 3 decibels down from the peak is not the same in the three cases, ranging from 340 to 360 cycles per second. This discrepancy indicates the order of precision of measure of this particular quantity.

The mechanical selectivity of the projector, f_o/Δ_f, or effective Q , lies between 67 and 71.

12. The curves of Plate 5 with the calibration curves of Plates 1 and 2 give three sets of data for the calculation of the axial sound intensity developed by the projector under the given conditions (normal high power, normal polarization, and at resonance) at the respective distances. If K_1 be the calibration constant of the calibrated unit at the appropriate frequency in microvolts per bar, and if E_o be the voltage in volts developed by the unit, the intensity in watts per square centimeter is given by the equation

$$I = 0.645\left(\frac{E_o}{K_1}\right)^2 \qquad (1)$$

In the case of the T-3, K_1 at 24.25 kilocycles per second is 1.93 microvolts per bar (see Plate 2). In the case of the Q-1, K_1 at 24.25 kilocycles per second is 0.630 microvolt per bar (see Plate 1). At 137 inches the T-3 developed 0.321 volt and at 102 inches it developed 0.428 volt. At 137 inches the Q-1 developed 0.105 volt. (For these figures, see Plate 5.) Hence the axial sound intensity at 137 inches developed by the projector was 0.0179 watts per square centimeter or 17.9 milliwatts per square centimeter as measured by either the Q-1 or the T-3. At 102 inches the axial sound intensity developed by the projector was 0.0318 watts per square centimeter or 31.8 milliwatts per square centimeter.

13. In Bureau of Engineering Specifications RE 13A 520D of 1 July 1939 the acceptable axial sound intensity for a projector is set forth in paragraph 7-14c. At the time these specifications were written, the calibrating wells on the SEMMES did not exist and intensity measurements at 54 inches were contemplated; that is, the calibrated unit was to be mounted in one of the main sound wells while the projector under test was to be mounted in the other. Measurements at 54 inches are of questionable validity as the calibrated unit is close enough to the projector to react on it, and furthermore, the sound intensity so close to the projector is not simply related to the intensity at long distances. Large errors in the estimate of the performance of a projector may occur if it is based on an intensity measurement at the very short distance. Now that the port and starboard calibrating wells are available for use, it is recommended that paragraph 7-14c of the specifications be revised so that the acceptable performance of a projector will be based on measurements of axial sound intensity at either 102 or 137 inches.

14. In the absence of actual intensity measurements at 54 inches in the subject tests calculated values must be used, based on intensity measurements at 102 or 137 inches. The relation between the intensity at 54 inches and that at 102 inches is given by the equation:

[redacted]

$$I_{54''} = 3.57\ K_2\ I_{102''} \qquad (2)$$

where the two intensities are expressed in the same units and where K_2 is a constant which may be read by interpolation from the family of curves presented in Plate 6(a). The relation between the intensity at 54 inches and that at 137 inches is given by the equation

$$I_{54''} = 6.44\ K_3\ I_{137''} \qquad (3)$$

In this case K_3 is a constant which may be read by interpolation from the family of curves presented in Plate 6(b). The value of the intensity at 54 inches as computed is to be compared with the required value as set forth in paragraph 7-14c of Bureau of Engineering Specifications RE 13A 520D of 1 July 1939. This conversion formula may be used without injustice to either the Navy or the manufacturer with projectors having acceptable and symmetric radiation patterns. The intensity at 54 inches as computed is the intensity developed by a simple piston source mounted in the same position as the projector under test which would also develop the measured intensity at 102 or 137 inches and at the same time have a radiation pattern with substantially the same main beam with respect to its width as measured at the -10 decibel points.

15. In the case of the QC-5 (19 inch) projector, the measured axial sound intensity was 17.9 milliwatts per square centimeter at 137 inches and 31.8 milliwatts per square centimeter at 102 inches. (See Section III, paragraph 12 above.) Examination of Plates 3 and 4 shows that the main beam of this projector, measured at the -10 decibel points, is 19 degrees wide. The resonant frequency is 24.25 kilocycles per second. By reference to Plate 6(a) and (b), it is found that K_2 for this beam width and frequency is 0.941 and that K_3 is 0.931. It follows by equations (2) and (3) that

$$I_{54''} = 3.57 \times 0.941 \times 31.8 = 107 \text{ milliwatts/cm}^2$$

or

$$I_{54''} = 6.44 \times 0.931 \times 17.9 = 107 \text{ milliwatts/cm}^2$$

This projector has an actual face diameter of 15.75 inches. The specifications require an axial sound intensity at 54 inches of

$$60 \times \frac{15.75}{15} \text{ or } 63 \text{ milliwatts/cm}^2$$

for a projector of this diameter. In this respect the performance of the QC-5 (19 inch) projector is satisfactory.

16. Additional curves are presented in Plates 7 and 8 to permit the rapid determination of the total sound output of the effective simple piston described above. If the axial sound intensity in watts per square centimeter measured at 102 inches is $I_{102''}$, the total sound output of the effective piston in watts is given by the relationship

$$(\text{Sound Power}) = 0.114 \times 10^6 \times K_4 \times \sin^2 \theta_{-10\ db} \times I_{102''} \qquad (4)$$

[redacted]

where K_4 is a constant which may be read by interpolation from the family of curves presented in Plate 7(a) and where $\sin^2 \theta$ may be read from the curve given in Plate 8. $\theta^\circ_{-10\ db}$ is one-half the width in degrees of the main beam as measured from the radiation pattern of the projector at the -10 decibel points. If the axial intensity in watts per square centimeter measured at 137 inches is $I_{137''}$ the total sound output of the effective piston in watts is given by the relationship:

$$(\text{Sound Power}) = 0.205 \times 10^6 \times K_5 \times \sin^2 \theta_{-10\ db} \times I_{137''} \qquad (5)$$

K_5 in this case is read by interpolation from the family of curves given in Plate 7(b). In the case of the QC-5 (19 inch) projector, as stated above, $2\theta^\circ_{-10\ db}$ is 19° and the resonant frequency is 24.25 kilocycles per second. $\theta^\circ_{-10\ db}$ is 9.5°. Consequently from Plate 7(a) and (b) $K_4 = 1.024$ and $K_5 = 1.013$, and from Plate 8, $\sin^2 \theta^\circ_{-10\ db} = 0.0272$. The measured intensity at 102 inches was 0.0318 watts per square centimeter and at 137 inches was 0.0179 watts per square centimeter. Hence by equation (4)

$$(\text{Sound Power}) = 0.114 \times 10^6 \times 1.024 \times 0.0272 \times 0.0318 = 101 \text{ watts}$$

and by equation (5)

$$(\text{Sound Power}) = 0.205 \times 10^6 \times 1.013 \times 0.0272 \times 0.0179 = 101 \text{ watts}$$

This value of total sound power in conjunction with the measured value of electrical power applied to the projector is useful in estimating the effective acoustic efficiency attained.

SECTION IV

DISCUSSION OF THE PROJECTOR TRANSMITTING PERFORMANCE MEASUREMENTS

17. In measuring the axial intensity developed by a projector under a ship, a question immediately arises as to the magnitude of errors introduced by undesired reflection of sound to the measuring unit from the hull of the ship. Measurements made at 54 inches from the projector face are certainly free from appreciable error in this respect, but are open to question on other grounds mentioned above. Measurements at 102 or 137 inches are undoubtedly influenced by the reflections but, that the error, with a directive projector as the object of study, is negligible is indicated by the following evidence.

(a) A non-resonant projector (NRL Quartz Analyzer) was mounted in the starboard main well of the SEMMES and used as a sound source. The axial intensity developed by this projector was measured with the Q-1 at 54 and at 102 inches at various frequencies between 16 and 36 kilocycles per second. At 54 inches the reflection cannot play a significant part and at 102 inches it can. The part it plays at 102 inches should depend upon the frequency as the reflected wave will vary in amplitude and in phase with respect to the direct wave as a function of frequency. However, plotting the intensity in the two cases against frequency and correcting for the difference in absolute level because of the difference in length of path, two curves were obtained which differed at any frequency in the range by no more than 1/2 decibel from the mean of the two curves. The experimental error of measurement was of this order. A similar experiment was carried through with the same sound source first mounted in the port main well and then in the starboard main well, measuring the axial intensity in these cases with the T-3 mounted in the port calibrating well. Here the difference at any frequency in the range from the mean of the two curves was even less than in the previous case. Evidently, the error introduced by hull reflections in the measurement of the transmitting performance of a directive projector by methods described in this report is not serious.

(b) Additional evidence is presented in the agreement between the measured and calculated value of the ratio of the axial intensity developed by the QC-5 (19 inch) projector at 102 inches to that developed at 137 inches. The measured intensity ratio is $(428/321)^2$ or 1.778. The calculated ratio is 1.783.

SECTION V

<u>DISCUSSION OF REFERENCE PROJECTORS - U.S.S. SEMMES</u>

18. The QC-5 (19 inch) projector, the transmitting performance characteristics of which have been presented in the body of this report as an illustration of the use of the T-3 in making performance measurements, resonates at 24.25 kilocycles per second, and has been used by the ship in recent months as the reference in making relative performance measurements of test projectors, operating at or near this frequency. Prior to the acquisition of this projector, the SEMMES used as a reference a QC-5 (17-inch) projector resonating at 23.6 kilocycles per second. The SEMMES has reported the axial sound intensity developed at 160 feet by the new reference projector to be 7.5 decibels above that developed at the same distance by the old. Since 1937 this Laboratory has reported to the Bureau of Engineering the performance characteristics of certain projectors in absolute terms as well as in relative terms. (NRL Reports No. S-1554 of 17 August 1939, No. S-1514 of 6 February 1939, and No. S-1404 of 5 October 1937.) The primary standard of the Laboratory upon which these reports were based was the Q-1 of this report and the reference projector was the old SEMMES reference, the QC-5 (17 inch) projector. The calibration of the Q-1 as presented in this report is a revision of that used in the older reports and is more reliable. By the old calibration as recorded in older reports, the SEMMES reference QC-5 (17 inch) projector radiated 33 watts (normal high power, normal polarization, and at resonance) and developed a calculated axial sound intensity at 160 feet of 34 microwatts per square centimeter. This projector had a beam width measured at the -10 decibel points of 21.4° and developed a measured axial intensity at 54 inches of 39 milliwatts per square centimeter. Applying the new and

better calibration of the Q-1 to the original data for this projector, it is found that it developed a measured axial intensity at 54 inches of 21 milliwatts per square centimeter, radiated 24 watts, and developed a calculated axial sound intensity at 160 feet of 17 microwatts per square centimeter. The calculated axial sound intensity developed at 160 feet by the new reference QC-5(19 inch) projector (normal high power, normal polarization, and at resonance) is 92.2 microwatts per square centimeter. The ratio of the calculated intensities of the two reference projectors at 160 feet is therefore, 92.2/17 or 5.42 or 7.3 decibels. This compares satisfactorily with the value measured and reported by the SEMMES.

SECTION VI

CONCLUSIONS AND RECOMMENDATIONS

19. A calibrated sound sensitive unit designated as the T-3 was installed in the port calibrating well of the U.S.S. SEMMES for the test period 6 to 18 November 1939. This unit was employed in testing the transmitting performance of various projectors submitted for test by the RCA Manufacturing Company and by the Submarine Signal Company. This report presents the calibration of this unit and illustrates the use of the calibration in evaluating in absolute terms the transmitting characteristics of a specimen projector. It is recommended that this calibration be used in a similar manner to evaluate in absolute terms the transmitting performance of all the projectors tested in the subject period for comparison with the acceptable performance as set forth in Bureau of Engineering Specifications RE 13A 520D of 1 July 1939, paragraphs 7-14 a, b, and c.

20. The T-3 installed on a temporary basis for the subject test period, operated satisfactorily and considerably expedited the work involved in making performance tests of underwater sound projectors. If this unit or one similar to it is to be added to the regular equipment of the SEMMES, it should be provided with a different type of shielded cable to increase its mechanical and electrical stability and to insure the watertight integrity of the complete unit. Additional work should be carried on by this Laboratory to extend the frequency range of reliable calibration of sound intensity measuring devices and a frequency response characteristic flatter than that of the T-3 should be an objective in the design of any new unit to perform the same function.

21. Because of lack of time, the T-3 was not used during the subject test period to measure the receiving performance characteristics of any of the test projectors for comparison with the acceptable performance as set forth in the specifications. It is adapted, however, for making these measurements also, and it is recommended that this Laboratory be given opportunity aboard the SEMMES for comparing and checking various procedures to establish a preferred standardized receiving performance test.

22. In the body of this report are given in absolute terms the transmitting performance characteristics of the QC-5 (19 inch) projector used in recent months by the SEMMES as the reference projector in making relative performance tests of projectors operating at or near 24 kilocycles

per second. Also given are the transmitting performance characteristics of the QC-5 (17 inch) projector used by the SEMMES for the same purpose prior to the acquisition of the new reference projector. The characteristics of the older reference are a revision of those previously reported by this Laboratory and are believed to be more reliable. These characteristics are presented to relate the relative measurements of the old test procedure to the absolute measurements of the new.

23. Now that the calibrating wells are available for use on the SEMMES, it is recommended that Bureau of Engineering Specifications RE 13A 520D of 1 July 1939, paragraph 7-14 (C) be revised to base the acceptable axial sound intensity developed by a projector with a satisfactory radiation pattern and with a given driving power applied on measurements at 137 inches or 102 inches, rather than on measurements at 54 inches.

"UNCLASSIFIED"

"UNCLASSIFIED"
[redacted]

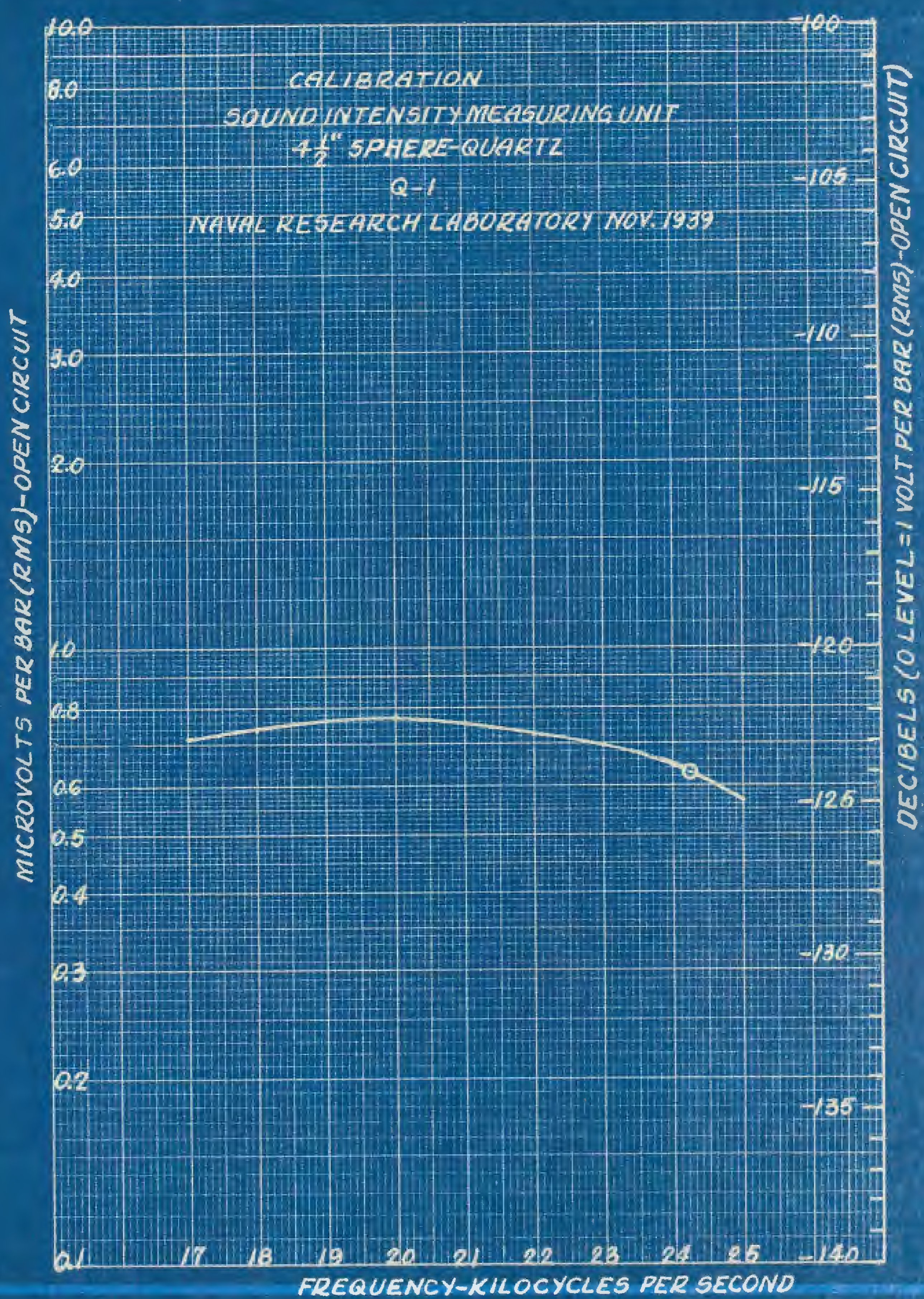

CALIBRATION
SOUND INTENSITY MEASURING UNIT
4½" SPHERE-QUARTZ
Q-1
NAVAL RESEARCH LABORATORY NOV. 1939
MICROVOLTS PER BAR (RMS)-OPEN CIRCUIT
DECIBELS (0 LEVEL=1 VOLT PER BAR (RMS)-OPEN CIRCUIT)
FREQUENCY-KILOCYCLES PER SECOND
10.0
8.0
6.0
5.0
4.0
3.0
2.0
1.0
0.8
0.6
0.5
0.4
0.3
0.2
0.1
-100
-105
-110
-115
-120
-125
-130
-135
-140
17
18
19
20
21
22
23
24
25

PLATE I

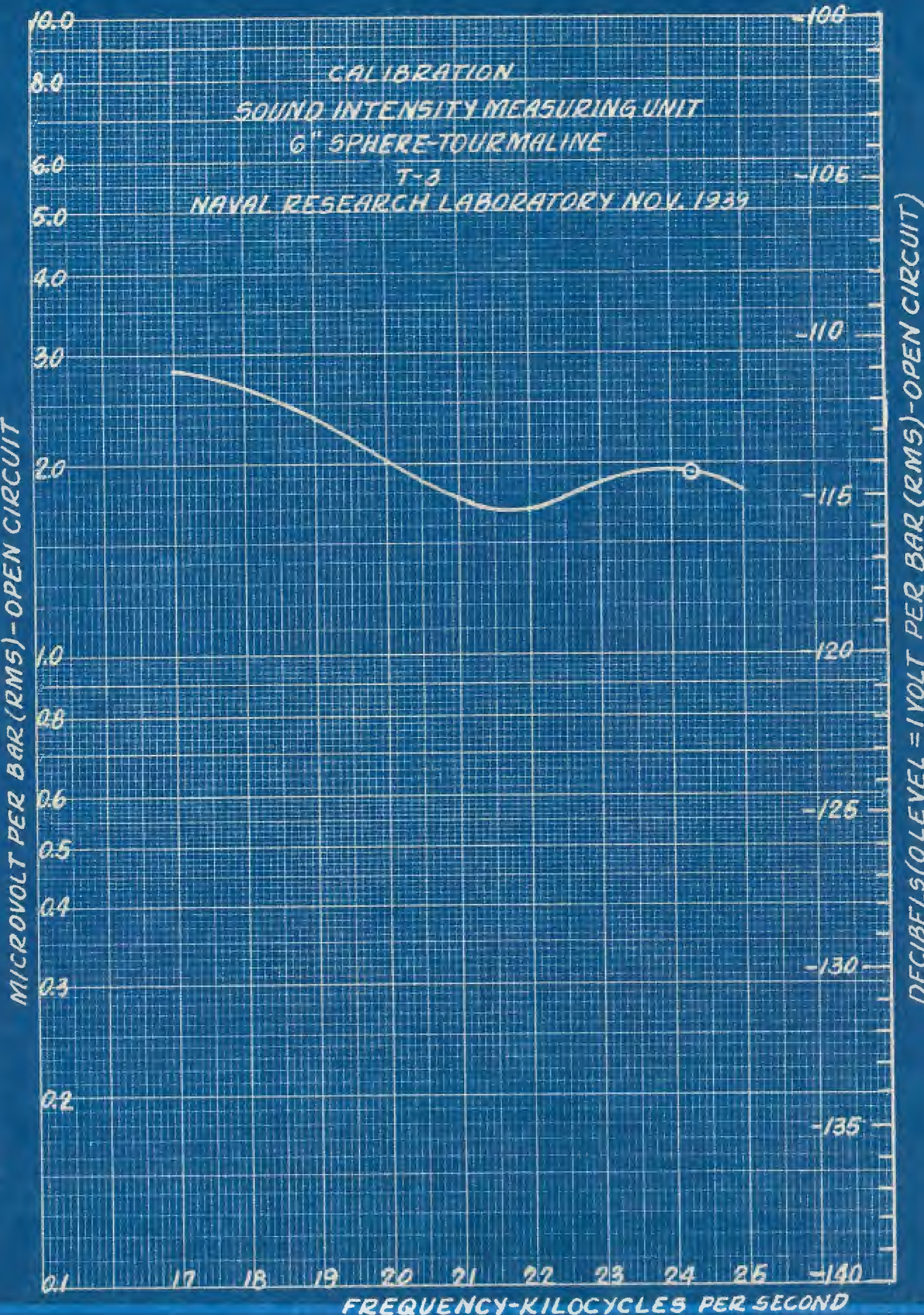
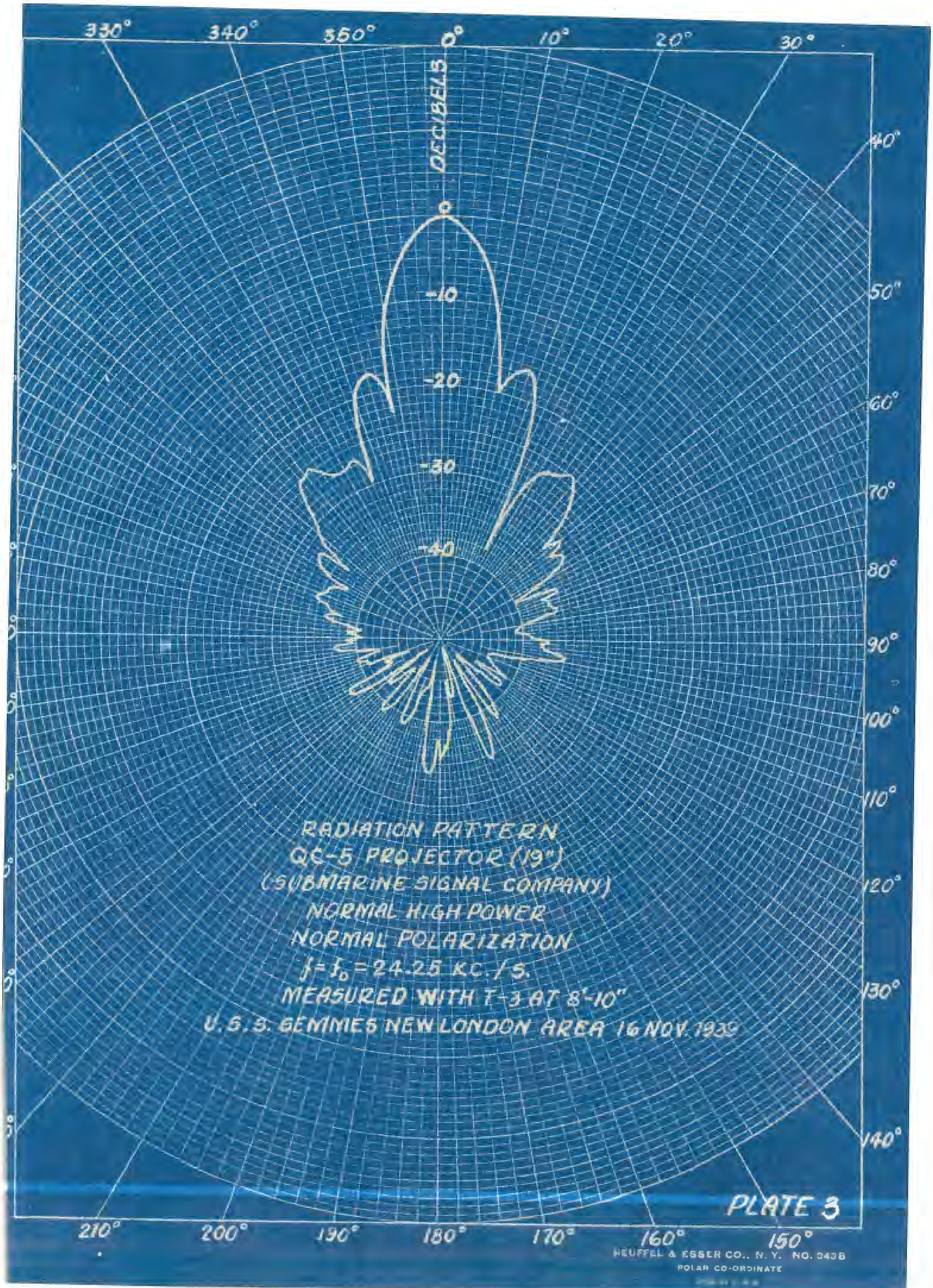
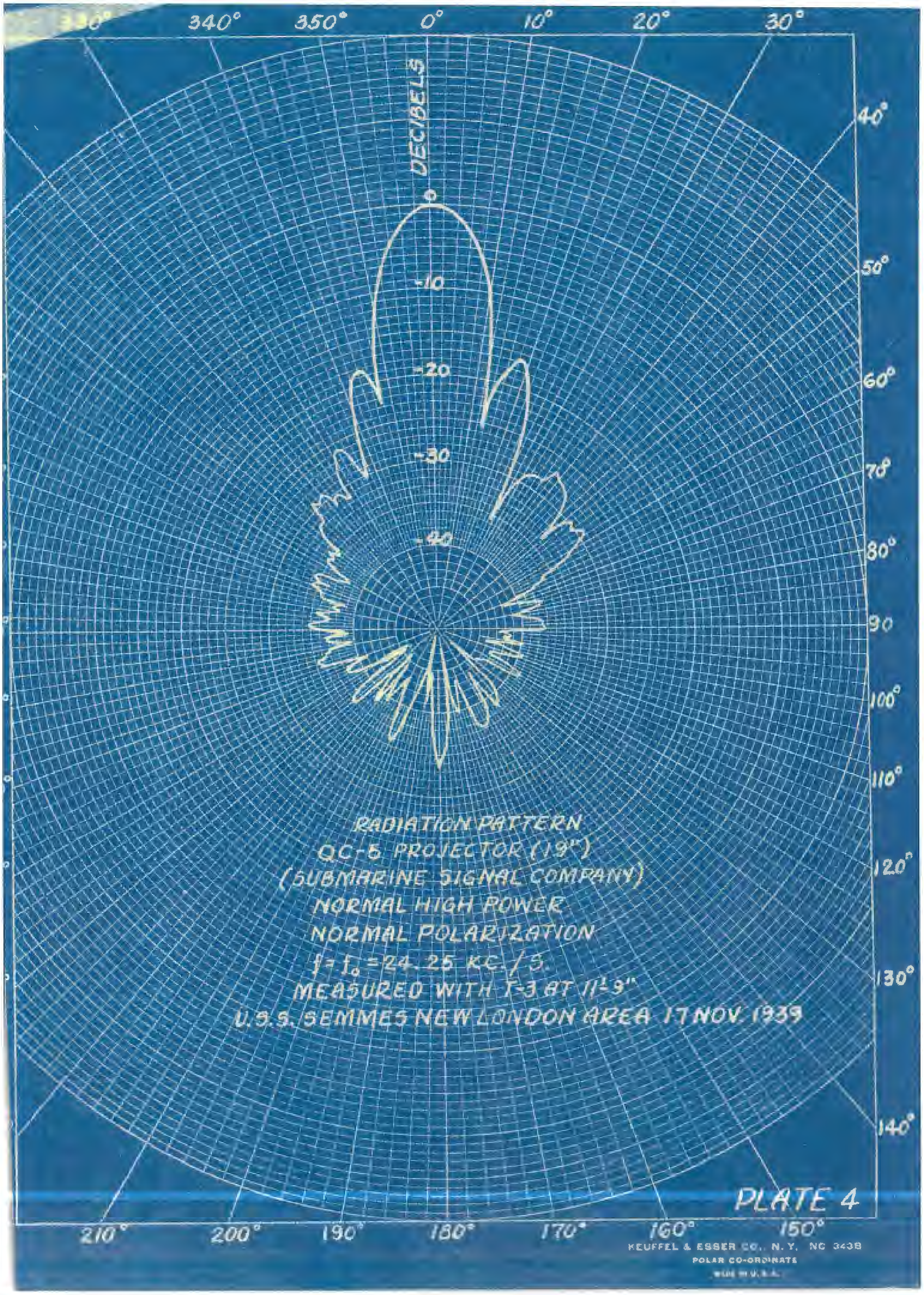

CALIBRATION
SOUND INTENSITY MEASURING UNIT
6" SPHERE-TOURMALINE
T-3
NAVAL RESEARCH LABORATORY NOV. 1939
MICROVOLT PER BAR (RMS)-OPEN CIRCUIT
DECIBELS (0 LEVEL = 1 VOLT PER BAR (RMS)-OPEN CIRCUIT)
10.0
8.0
6.0
5.0
4.0
3.0
2.0
1.0
0.8
0.6
0.5
0.4
0.3
0.2
0.1
-100
-105
-110
-115
-120
-125
-130
-135
-140
17
18
19
20
21
22
23
24
25
FREQUENCY-KILOCYCLES PER SECOND

PLATE 2



330°
340°
350°
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
DECIBELS
0
-10
-20
-30
-40
RADIATION PATTERN
QC-5 PROJECTOR (19")
(SUBMARINE SIGNAL COMPANY)
NORMAL HIGH POWER
NORMAL POLARIZATION
$f = f_0 = 24.25$ KC./S.
MEASURED WITH T-3 AT 8'-10"
U.S.S. SEMMES NEW LONDON AREA 16 NOV. 1939
PLATE 3
KEUFFEL & ESSER CO., N.Y. NO. 343B
POLAR CO-ORDINATE



340°
350°
0°
10°
20°
30°
40°
50°
60°
70°
80°
90
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
DECIBELS
0
-10
-20
-30
-40
RADIATION PATTERN
QC-5 PROJECTOR (19")
(SUBMARINE SIGNAL COMPANY)
NORMAL HIGH POWER
NORMAL POLARIZATION
f = f₀ = 24.25 KC./S.
MEASURED WITH T-3 AT 11'-9"
U.S.S. SEMMES NEW LONDON AREA 17 NOV. 1939
KEUFFEL & ESSER CO., N.Y. NO 343B
POLAR CO-ORDINATE

PLATE 4

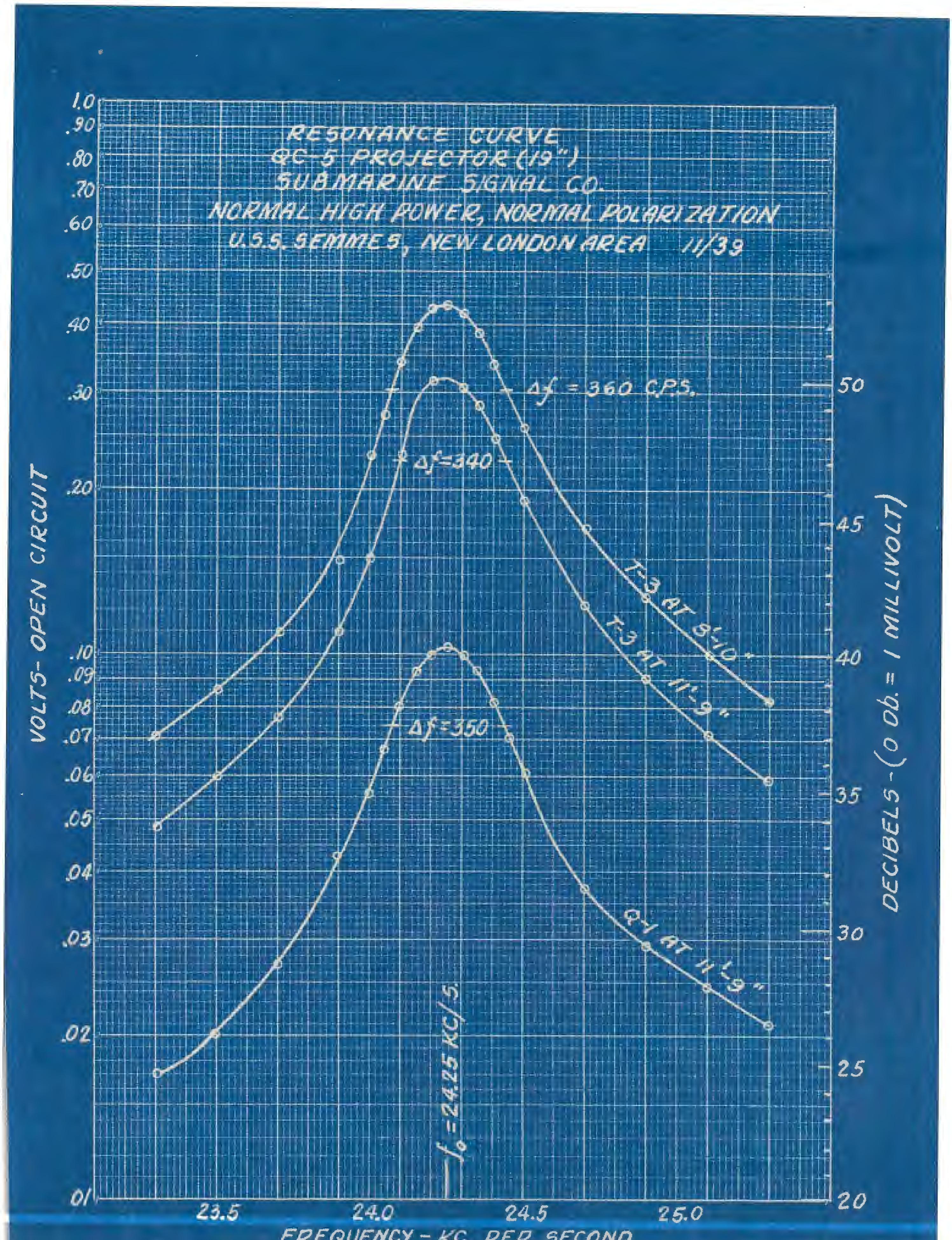
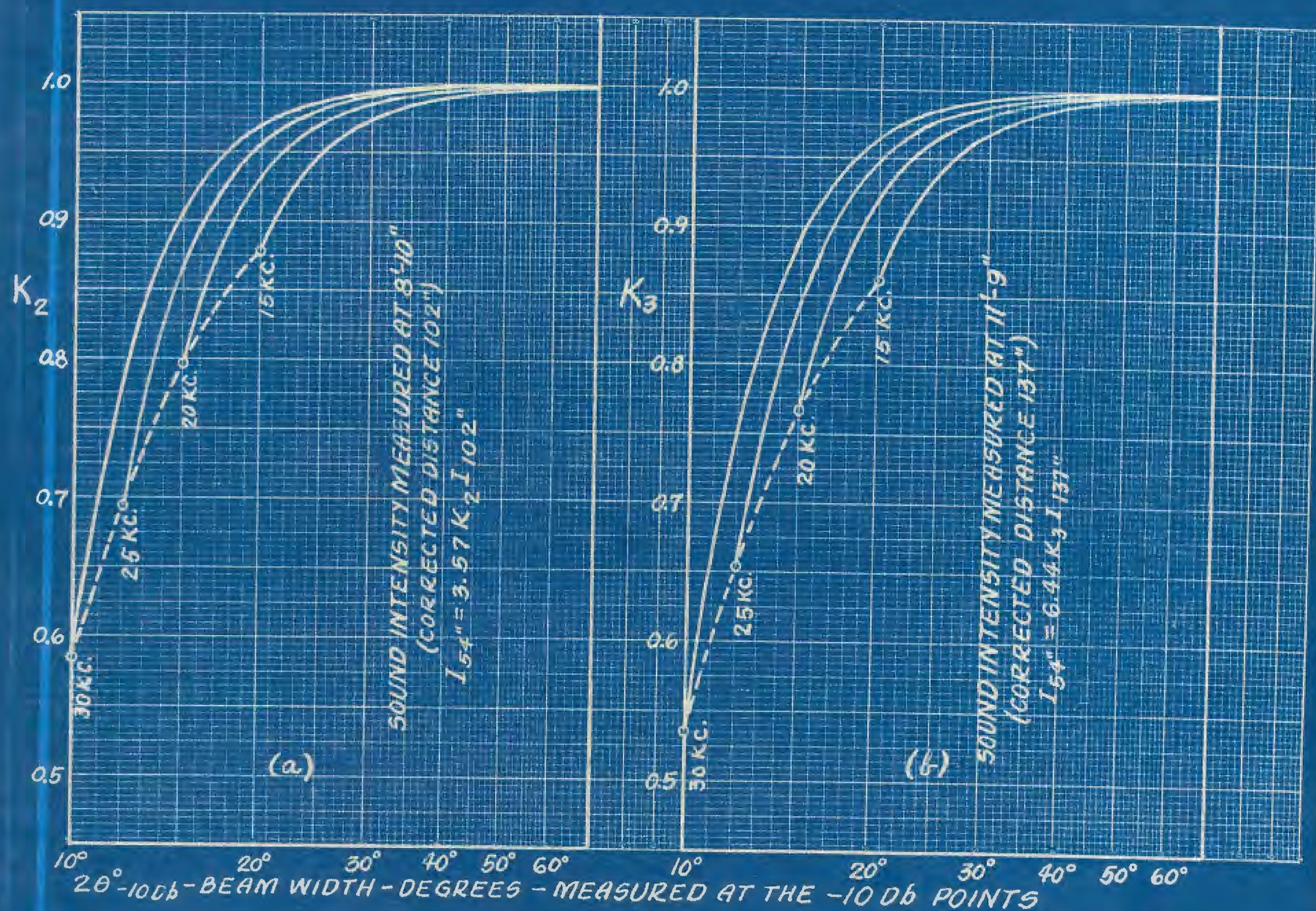

RESONANCE CURVE
QC-5 PROJECTOR (19")
SUBMARINE SIGNAL CO.
NORMAL HIGH POWER, NORMAL POLARIZATION
U.S.S. SEMMES, NEW LONDON AREA 11/39
Δf = 360 C.P.S.
Δf=340
Δf=350
T-3 AT 8'-10"
T-3 AT 11'-9"
Q-1 AT 11'-9"
f₀=24.25 KC/S
VOLTS- OPEN CIRCUIT
DECIBELS-(0 Db. = 1 MILLIVOLT)
FREQUENCY - KC. PER SECOND
1.0
.90
.80
.70
.60
.50
.40
.30
.20
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
50
45
40
35
30
25
20
23.5
24.0
24.5
25.0

PLATE 5



1.0
0.9
0.8
0.7
0.6
0.5
K2
K3
30 KC.
25 KC.
20 KC.
15 KC.
SOUND INTENSITY MEASURED AT 8'-10"
(CORRECTED DISTANCE 102")
I54" = 3.57 K2 I 102"
SOUND INTENSITY MEASURED AT 11'-9"
(CORRECTED DISTANCE 137")
I54" = 6.44 K3 I 137"
(a)
(b)
10° 20° 30° 40° 50° 60°
2θ°-10db - BEAM WIDTH - DEGREES - MEASURED AT THE -10 Db POINTS

PLATE 6

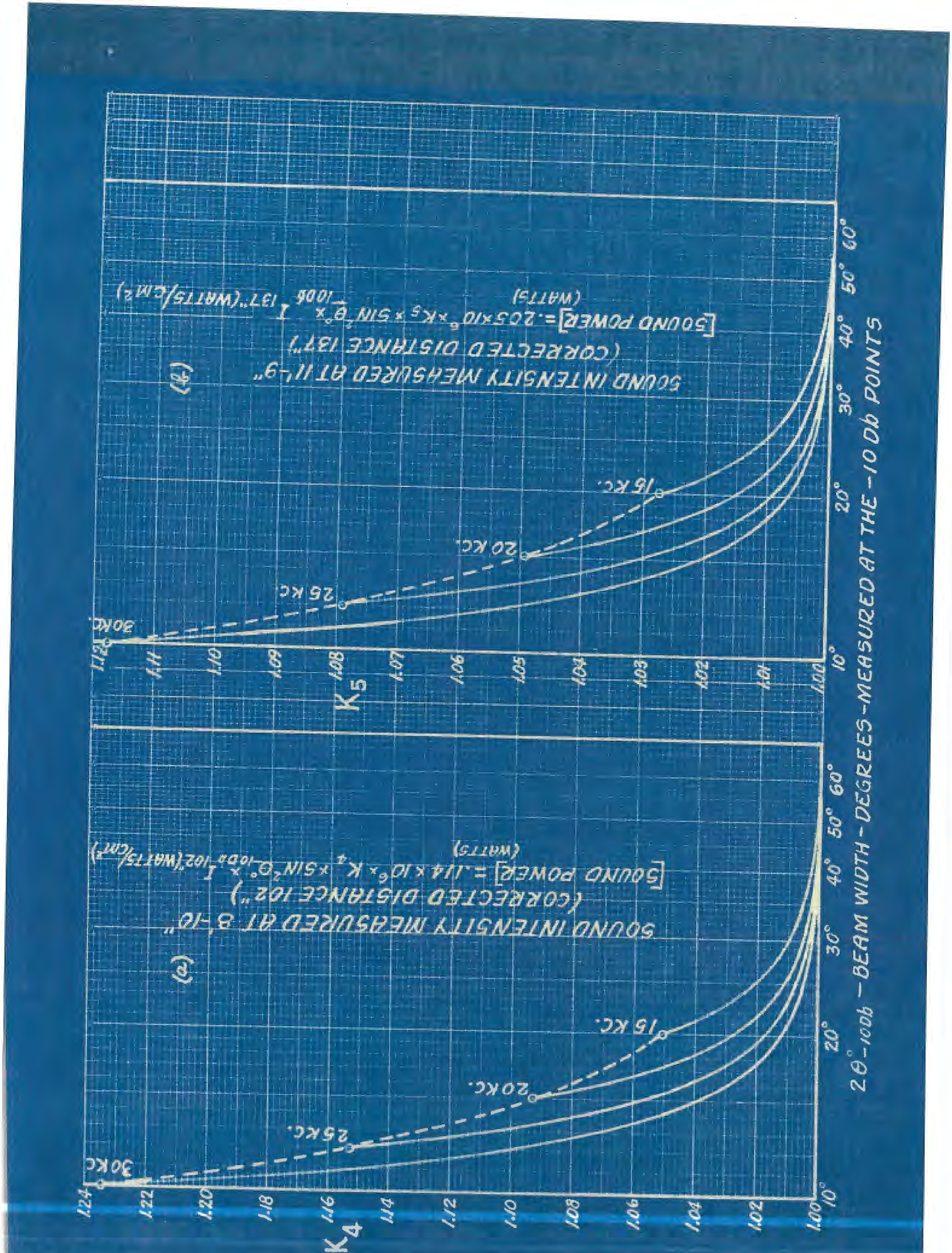

(a)
SOUND INTENSITY MEASURED AT 8'-10"
(CORRECTED DISTANCE 102")
[SOUND POWER] = .114 × 10^6 × K4 × SIN²θ° × I -10Db 102"(WATTS/CM²)
(WATTS)
(b)
SOUND INTENSITY MEASURED AT 11'-9"
(CORRECTED DISTANCE 137")
[SOUND POWER] = .205 × 10^6 × K5 × SIN²θ° × I -10Db 137"(WATTS/CM²)
(WATTS)
K4
K5
30 KC.
25 KC.
20 KC.
15 KC.
1.24
1.22
1.20
1.18
1.16
1.14
1.12
1.10
1.08
1.06
1.04
1.02
1.00
1.12
1.11
1.10
1.09
1.08
1.07
1.06
1.05
1.04
1.03
1.02
1.01
1.00
10° 20° 30° 40° 50° 60°
2θ° -10Db — BEAM WIDTH - DEGREES - MEASURED AT THE -10 Db POINTS

PLATE 7