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NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report

on the

Performance of the Electrodynamic Sound Projector XQD-5

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Section I

INTRODUCTION

1. This report covers the performance of the electrodynamic sound projector constructed by the Naval Research Laboratory for the Bureau of Engineering under the following authorization: Bureau of Engineering letter C-L1-2/NP14(2-6-R4-13) of 10 February 1939. Its performance was determined in a test program carried out by the U.S.S. SEMMES in the New London area during the period 24 July - 4 August 1939. The projector is designated as XQD-5 in this report.

2. The basic design of a projector constructed by this Laboratory and designated as XQD-4, the performance of which was reported to the Bureau of Engineering in NRL Report No. S-1514, 6 February 1939, has been followed in the construction of XQD-5 with the following exceptions, made at the request of the Bureau of Engineering.

(a) The sound transparent section of the spherical housing of the projector is made of thin stainless steel rather than of rubber as in the earlier model.

(b) The mechanical constants of the vibrating element of the projector are modified to yield theoretically a higher mechanical selectivity or sharpness of resonance in the device.

Minor modifications in the basic design, not affecting the acoustical behavior of the device, have been made by this Laboratory to increase the ruggedness of the assembled projector.

Section II

PERFORMANCE AS A TRANSMITTER

3. The curves of Plates 1, 2, and 3 specify the effectiveness of the XQD-5 projector as a generator of sound.

(a) In Plate 1 the relative axial sound intensity at 160 feet, the distance from the main to the after sound room of the SEMMES, is plotted as a function of the input current of the projector, operated at resonance and with the field current maintained at 8 amperes d.c., the normal value. With this field current the electrical impedance of the XQD-5 is 16.5 + j 14.0 ohms, and the a.c. power in watts supplied to the projector may be determined by multiplying the square of the input current in amperes by 16.5 ohms. The relative sound intensity is expressed in decibels and the reference level is the axial intensity at 160 feet set up by the old standard of comparison of the SEMMES, a 17 inch QC-5 projector, operated at normal high power, with normal polarization, and on resonance at 23.6 kc/s. In absolute terms, this reference level is a sound intensity of 34 microwatts per square centimeter. (See NRL Report No. S-1514, 6 February 1939.)

It is to be noted that the axial sound intensity is directly proportional to the power supplied to the projector over the range investigated within the errors of measurement, which indicates that the efficiency of the device as a converter of electrical energy into sound energy is constant over this range. The highest power available for application to the XQD-5 in these tests was1650 watts, though it was designed to handle safely 2500 watts when operated intermittently as for echo ranging.

With 1650 watts applied to the XQD-5 at resonance, the axial sound intensity at 160 feet is 13.8 decibels above the reference level. This is an absolute intensity of 820 microwatts per square centimeter, and calculation gives an effective sound power output and acoustic efficiency of 540 watts and 33%, respectively, for the device operated at this power level.

This projector in service is to be used with standard QC-5 energizing and receiving equipment. The QC-5 driver with suitable impedance matching transformer sends 4.8 amperes into the XQD-5 at resonance. With this current input, the axial sound intensity at 160 feet is 7.5 decibels above the reference level. This is an absolute intensity of 190 microwatts per square centimeter and calculation gives an effective sound power output and acoustic efficiency of 126 watts and 33%, respectively, for the XQD-5 operated at this power level.

On Plate 1 in dashed line is the corresponding curve for the electrodynamic projector XQD-4 as given in NRL Report No. S-1514. This is included for comparison and shows that the XQD-5 is sensibly better than the XQD-4. For the same power input it gives an axial sound intensity approximately 1 decibel higher.

(b) In Plate 2 the axial sound intensity expressed in decibels below the maximum axial sound intensity at resonance is plotted against the frequency of the energizing current expressed in cycles per second off resonance. The resonant frequency of this projector as a transmitter is 24.03 kc/s. This is the resonance curve of the XQD-5 as a transmitter. For these measurements the field current was maintained at 8 amperes d.c. and the energizing alternating current was kept at 4 amperes. The width of the resonance curve at the -3 decibel point is 215 cycles per second, giving a value of 112 for the mechanical selectivity of the projector.

A mechanical selectivity of 125 was attained in the XQD-4 and as has been stated in the introduction of this report, the design of the XQD-5 was changed from that of the XQD-4 with the purpose of increasing the selectivity. Actually a decrease has resulted from the modification due to an unforeseen complication. It may be noted from the resonance curve of the XQD-5 that there is a distortion in the high frequency side of the curve. This is due to a parasitic, secondary resonance in the projector, and its frequency is so close to that of the main resonance that it effectively broadens the resonance curve. Its presence is not desirable. It should either be removed entirely or moved in frequency farther from the principal resonant frequency before the projector is sent out for service trials.

(c) The curve of Plate 3 shows the angular distribution of sound generated by the projector. The pattern is not symmetrical as it should be, the first and third ears or lobes on one side of the main sound beam being approximately 6 decibels higher than the corresponding ears of the other side. This is unsatisfactory and abnormal and shows that the projector is not properly adjusted. Plate 4 shows the angular distribution of sound generated by the XQD-4. A pattern as good as this should be obtained from the XQD-5 when it is adjusted.

Section III

PERFORMANCE AS A RECEIVER

4. The curves of Plates 5, 6, and 7 indicate the effectiveness of the XQD-5 projector as a receiver of sound.

(a) In Plate 5 the open circuit sensitivity expressed in decibels below the maximum open circuit sensitivity at resonance is plotted against the frequency of the incoming sound signal expressed in cycles per second off resonance. The resonant frequency of the projector as a receiver is 24.03 kc/s, which coincides with the resonant frequency of the projector as a transmitter. This is the resonance curve of the XQD-5 as a receiver. For these measurements the field current of the XQD-5 was maintained at 8 amperes d.c. and the test sound signal was kept at approximately constant intensity over the frequency range employed. The sound signal approached the projector along its axis. The width of the resonance curve at the -3 decibel point is 215 cycles per second, giving a value of 112 for the mechanical selectivity of the projector, just as in the case of the transmitting resonance curve. The distortion noted in the transmitting curve appears again here in the receiving resonance curve, with the same deleterious effects.

A value for the maximum open circuit sensitivity of the XQD-5 in absolute terms cannot be given as a calibrated standard was not available for these tests. A comparison between the maximum sensitivity of the SEMMES' new 19 inch QC-5 projector in conjunction with the new receiver amplifier (Type CBM 46061A No. 75581A) and the maximum sensitivity of the XQD-5 projector in conjunction with its impedance matching transformer and the same receiver amplifier showed the latter to be 7.5 decibels more sensitive than the former.

(b) In Plate 6 the curve shows the relative sensitivity of the XQD-5 to signals arriving from various bearings. Here as in Plate 3 the pattern shows an undesirable asymmetry. Certain of the ears or lobes are insufficiently depressed below the main lobe. Adjustments in the projector to correct the pattern of Plate 3 should automatically correct the receiving sensitivity pattern.

(c) Three pairs of curves are presented in Plate 7 to show the relative noise background against which a desired signal must be detected as a function of ship speed and projector bearing. The comparison is between the XQD-5 and the SEMMES' new 19 inch QC-5 projector. Correction has been made in plotting the curves for the difference in sensitivities of the two projectors, so that, as adjusted, the two devices present the desired signal to the listener with the same intensity. In making these measurements the same receiver amplifier was used with each projector and in each case was tuned to the resonant

frequency of the projector. The field or polarization in each case was normal. The XQD-5 was mounted on the port tube of the SEMMES and the 19 inch QC-5 on the starboard tube. When one projector was down for measurements the other was raised. Symmetry below ship is assumed and the noise on corresponding outboard bearings is compared. It is to be noted that the 19 inch QC-5 has a bad noise peak near 105° which appears at all speeds. Evidently something on the projector's housing stirs up abnormal turbulence at this bearing. Correction of this fault would be highly desirable and probably not difficult. In general, the XQD-5 is better than the 19 inch QC-5 at all speeds and bearings with the exception of small angle forward bearings at high speed. At 18 knots the superiority of the XQD-5 is very marked at all bearings. At 15 knots and below the noise background of both projectors is very low.

Section IV

ECHO RANGING PERFORMANCE

5. Extensive echo ranging tests with the XQD-5 were not attempted for lack of time. For the test actually carried through, the XQD-5 was used in conjunction with a suitable matching transformer and the QC-5 energizing and receiving equipment, just as it will be used in service trials. For comparison purposes simultaneous echo ranging tests were carried through using a standard 19 inch QC-5 projector of Submarine Signal Company manufacture with the same energizing and receiving equipment. The field current and the polarization in each case was normal. Each system was kept in tune. The S-20, on the surface, took a course and maintained constant speed. The SEMMES, having dropped astern, took a parallel course, and maintaining a constant speed of 15 knots, passed the S-20 abeam at 1000 yards. During the course of this run echo intensity measurements were made alternately with the two echo ranging equipments. The results are plotted in Plate 8. The XQD-5 gave consistent echoes from 6 to 7 decibels more intense than the 19 inch QC-5 equipment. At the 90° bearing echoes could not be heard with the QC-5 through the noise background. The reduction of echo intensity to be noted in both curves at bearings progressively removed from 90° on either side is due to the progressively longer ranges and the progressively changing target angle.

Section V

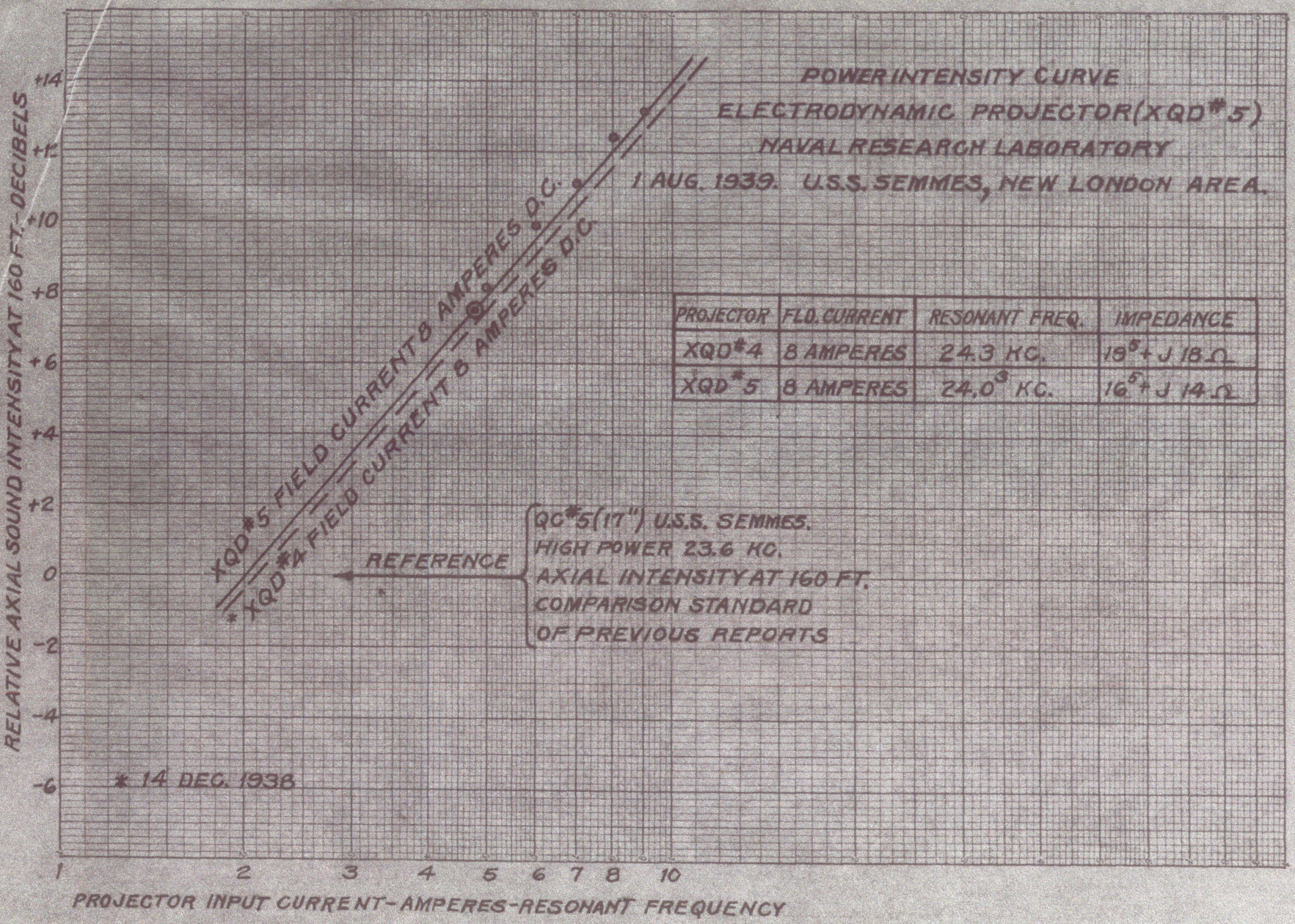
DISCUSSION AND CONCLUSIONS

6. The results presented in this report are the first indication the Laboratory itself has had concerning the performance of the XQD-5 projector. Due to the short time interval between the completion of the construction of the projector and the test period on the SEMMES and due to the lack of proper testing facilities at the Laboratory since the Sound Barge was decommissioned, no performance tests were made at the Laboratory prior to the tests on the SEMMES.

7. The results presented show that the XQD-5 is an efficient converter of electrical energy into sound energy, and conversely, an efficient converter of sound energy into electrical energy. Constructed

to equal or better the XQD-4 in these respects, it has succeeded. The substitution of thin stainless steel for rubber in the sound transparent section of the spherical housing of the projector, and minor changes in the design of the projector assembly have made the XQD-5 a more rugged device than was the XQD-4. The background noise level generated at various ship speeds and various projector bearings compares favorably with that generated by the XQD-4 at corresponding speeds and bearings and in an actual echo ranging test the XQD-5 was markedly superior to the best equipment on the SEMMES.

8. In two respects, however, this projector fails to perform as well as the XQD-4: (1) the angular distribution of the sound it generates about its axis is not as satisfactory, and (2) its mechanical selectivity is not as high. These defects in the XQD-5 are of such a nature that it is requested that the projector be retained at this Laboratory for adjustment before it is sent out for service trials. It is estimated that a period of two months may be required for the necessary adjustments in view of the limited testing facilities now available at the Laboratory.



PROJECTOR	FLD. CURRENT	RESONANT FREQ.	IMPEDANCE
XQD #4	8 AMPERES	24.3 KC.	$19^5 + J\,18\,\Omega$
XQD #5	8 AMPERES	24.0^3 KC.	$16^5 + J\,14\,\Omega$

PLATE 1

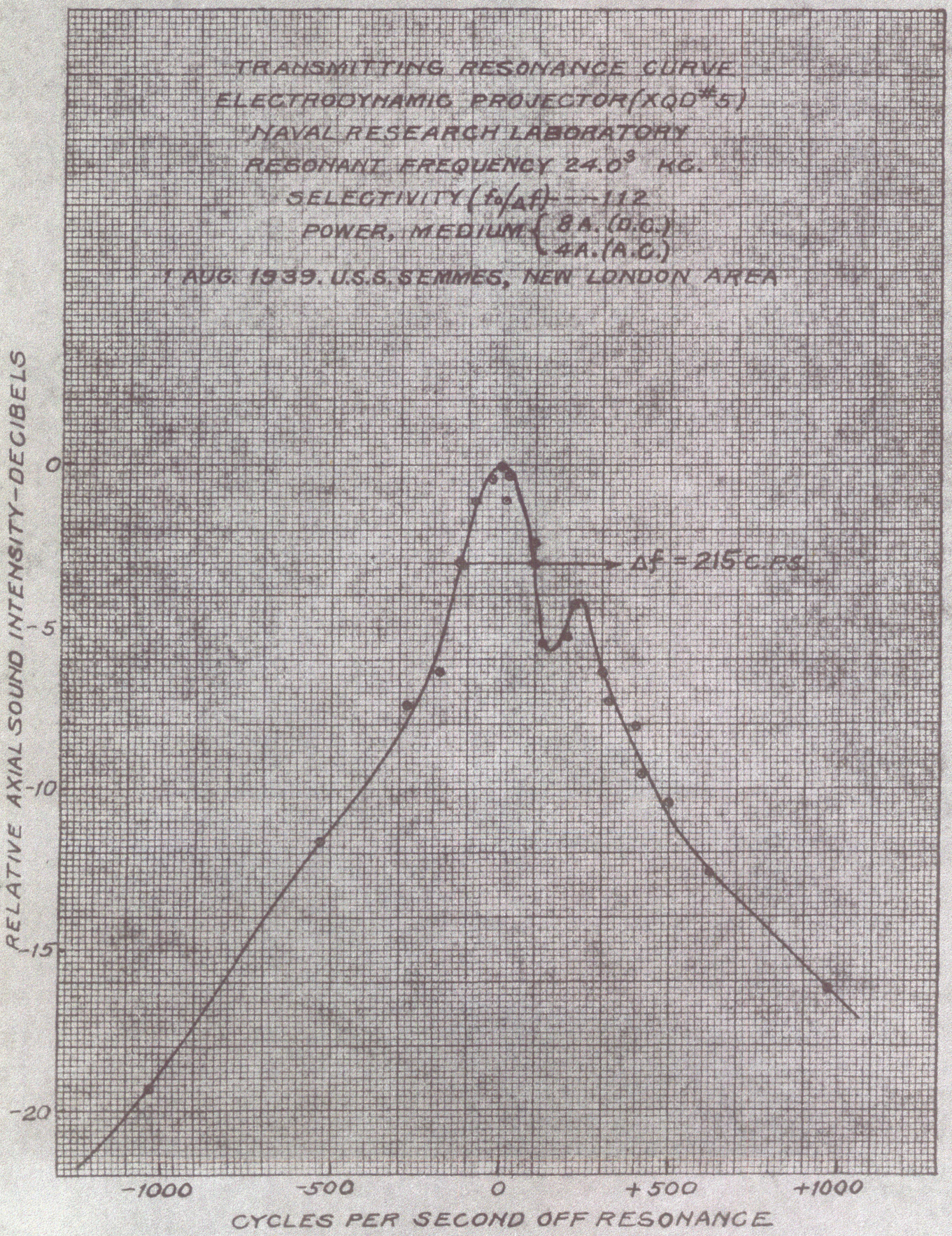
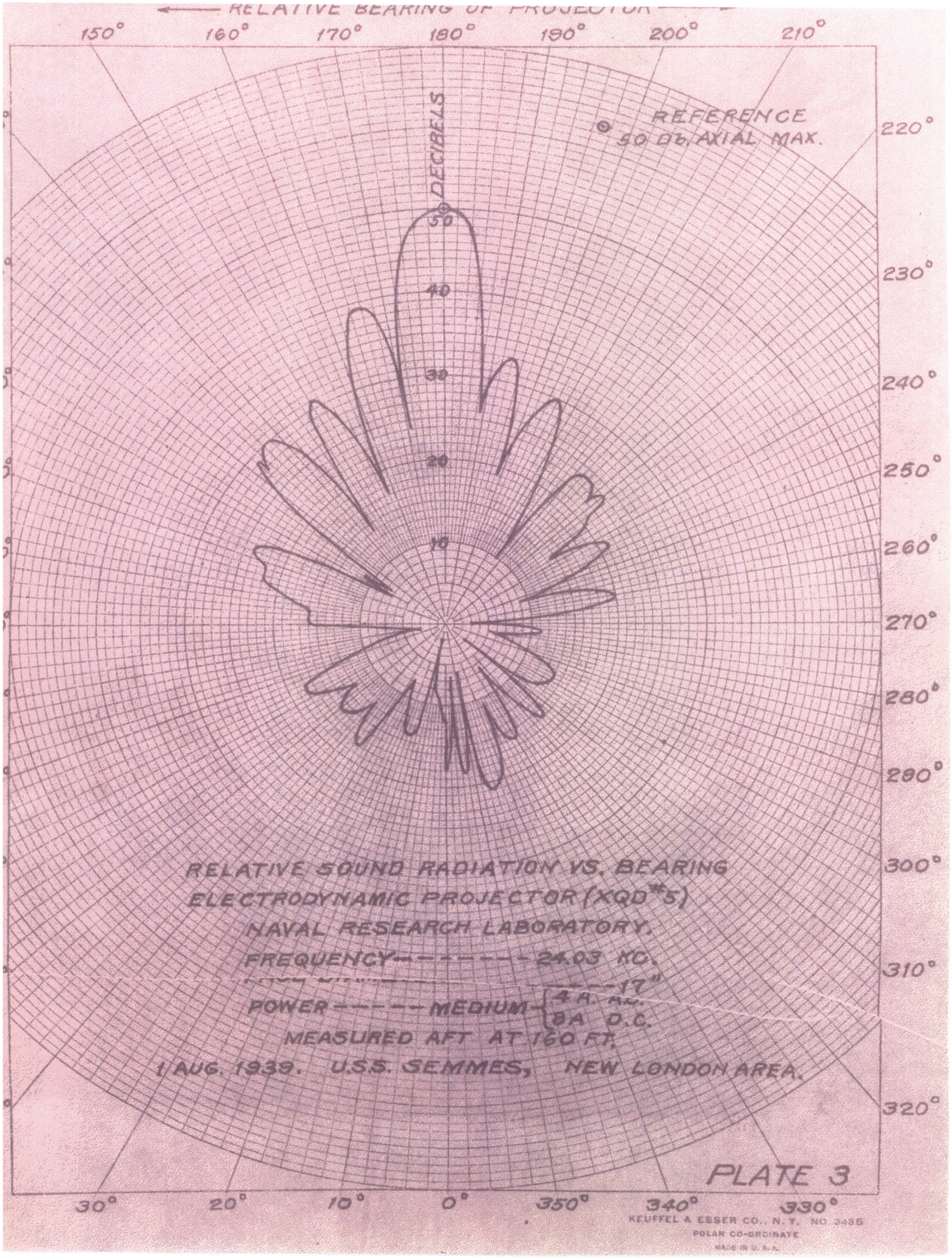
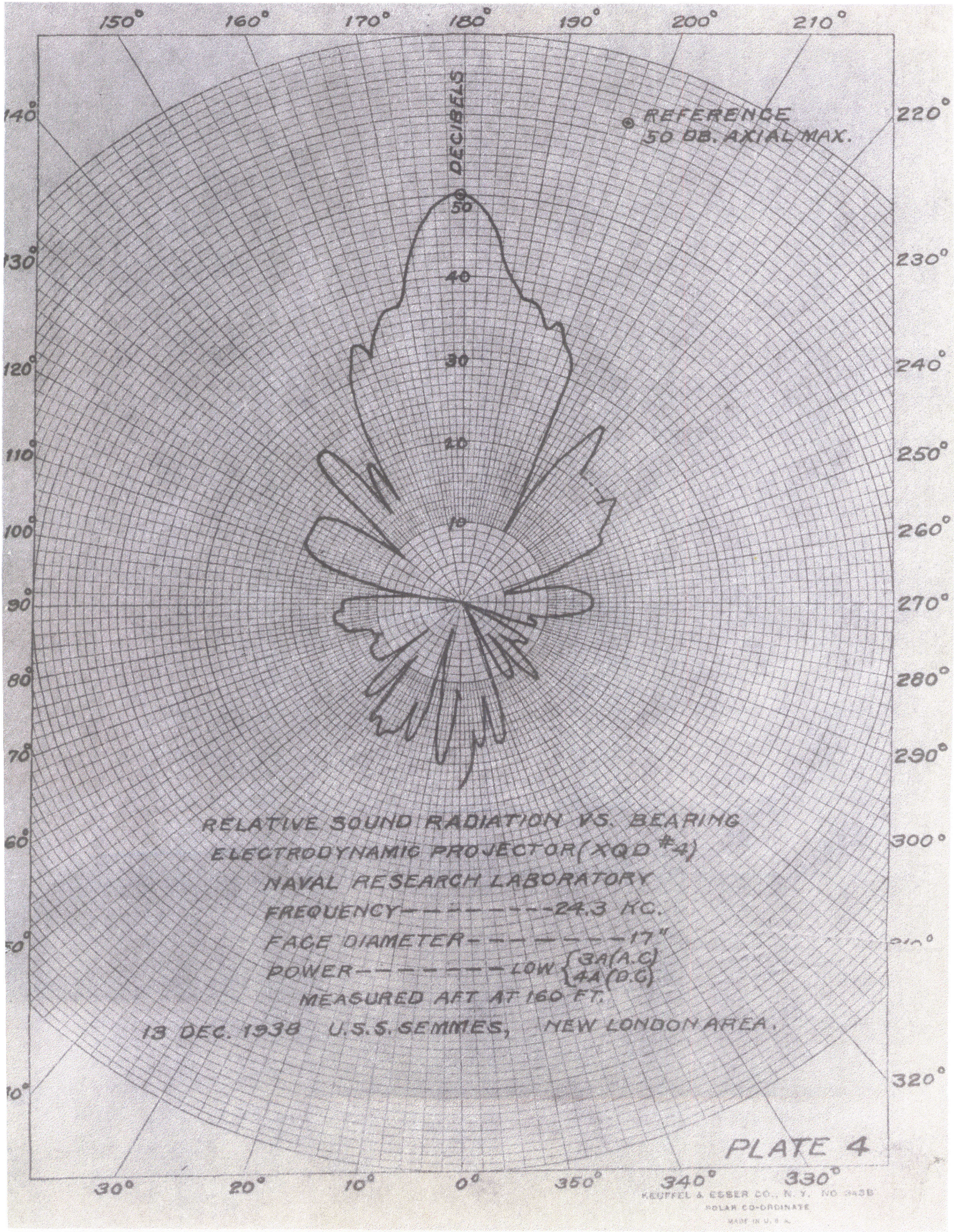

TRANSMITTING RESONANCE CURVE
ELECTRODYNAMIC PROJECTOR (XQD #5)
NAVAL RESEARCH LABORATORY
RESONANT FREQUENCY 24.0³ KC.
SELECTIVITY ($f_0/\Delta f$) - - - 112
POWER, MEDIUM { 8 A. (D.C.) 4 A. (A.C.)
1 AUG. 1939. U.S.S. SEMMES, NEW LONDON AREA
RELATIVE AXIAL SOUND INTENSITY-DECIBELS
0
-5
-10
-15
-20
Δf = 215 C.P.S.
-1000
-500
0
+500
+1000
CYCLES PER SECOND OFF RESONANCE

PLATE 2


RELATIVE BEARING OF PROJECTOR
150° 160° 170° 180° 190° 200° 210°
220° 230° 240° 250° 260° 270° 280° 290° 300° 310° 320°
30° 20° 10° 0° 350° 340° 330°
DECIBELS
50 40 30 20 10
REFERENCE
50 DB. AXIAL MAX.
RELATIVE SOUND RADIATION VS. BEARING
ELECTRODYNAMIC PROJECTOR (XQD #5)
NAVAL RESEARCH LABORATORY.
FREQUENCY - - - - - - - - 24.03 KC.
POWER - - - - - MEDIUM
4 A. A.C.
8 A D.C.
MEASURED AFT AT 160 FT.
1 AUG. 1939. U.S.S. SEMMES, NEW LONDON AREA.
PLATE 3
KEUFFEL & ESSER CO., N.Y. NO 3435
POLAR CO-ORDINATE
MADE IN U.S.A.


150° 160° 170° 180° 190° 200° 210°
140° 130° 120° 110° 100° 90° 80° 70° 60° 50° 40°
220° 230° 240° 250° 260° 270° 280° 290° 300° 310° 320°
30° 20° 10° 0° 350° 340° 330°
DECIBELS
50
40
30
20
10
REFERENCE
50 DB. AXIAL MAX.
RELATIVE SOUND RADIATION VS. BEARING
ELECTRODYNAMIC PROJECTOR (XQD #4)
NAVAL RESEARCH LABORATORY
FREQUENCY - - - - - - - - 24.3 KC.
FACE DIAMETER - - - - - - - - 17"
POWER - - - - - - - - LOW {3A (A.C) 4A (D.C)}
MEASURED AFT AT 160 FT.
13 DEC. 1938 U.S.S. SEMMES, NEW LONDON AREA.
PLATE 4
KEUFFEL & ESSER CO., N.Y. NO. 343B
POLAR CO-ORDINATE
MADE IN U.S.A.

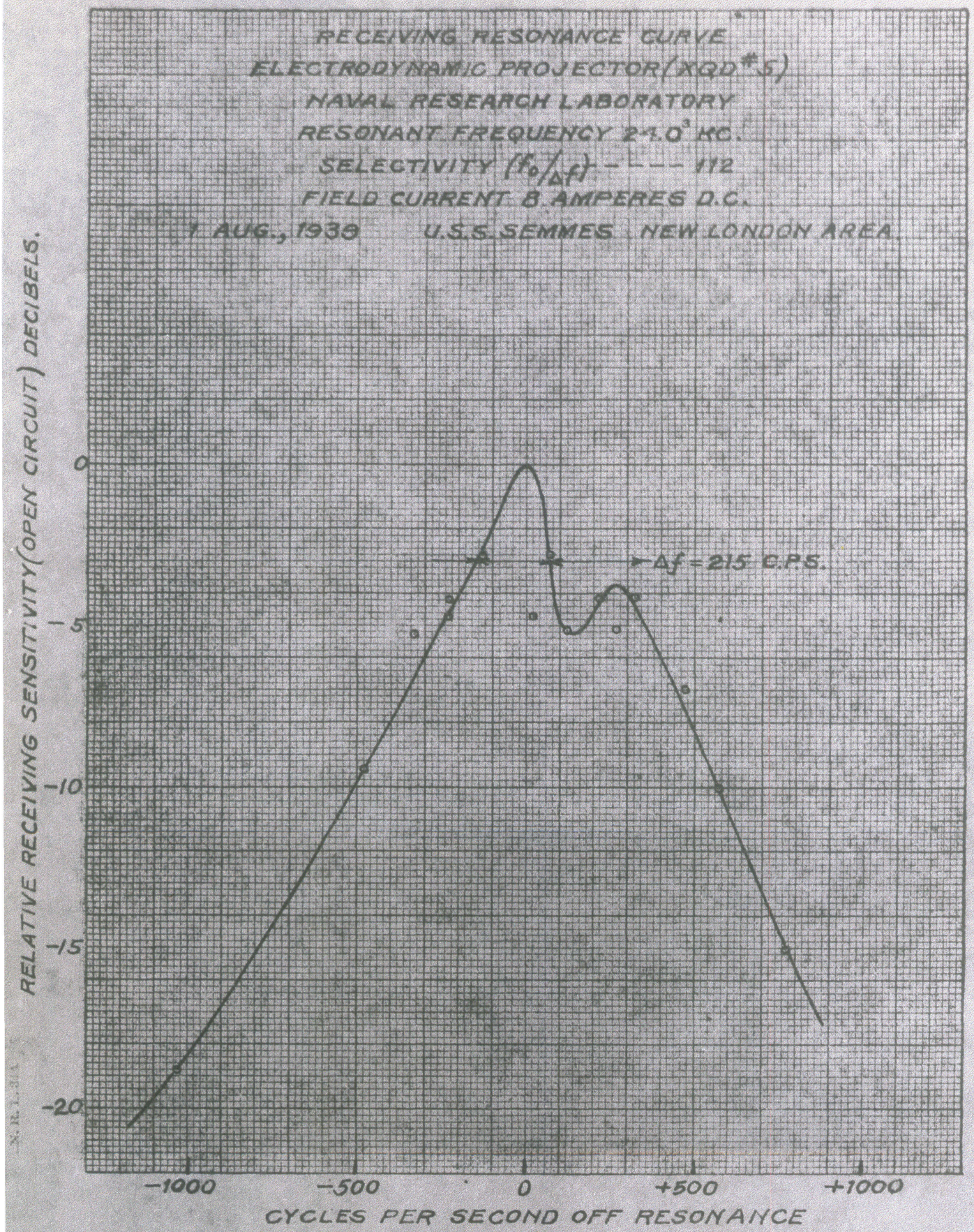
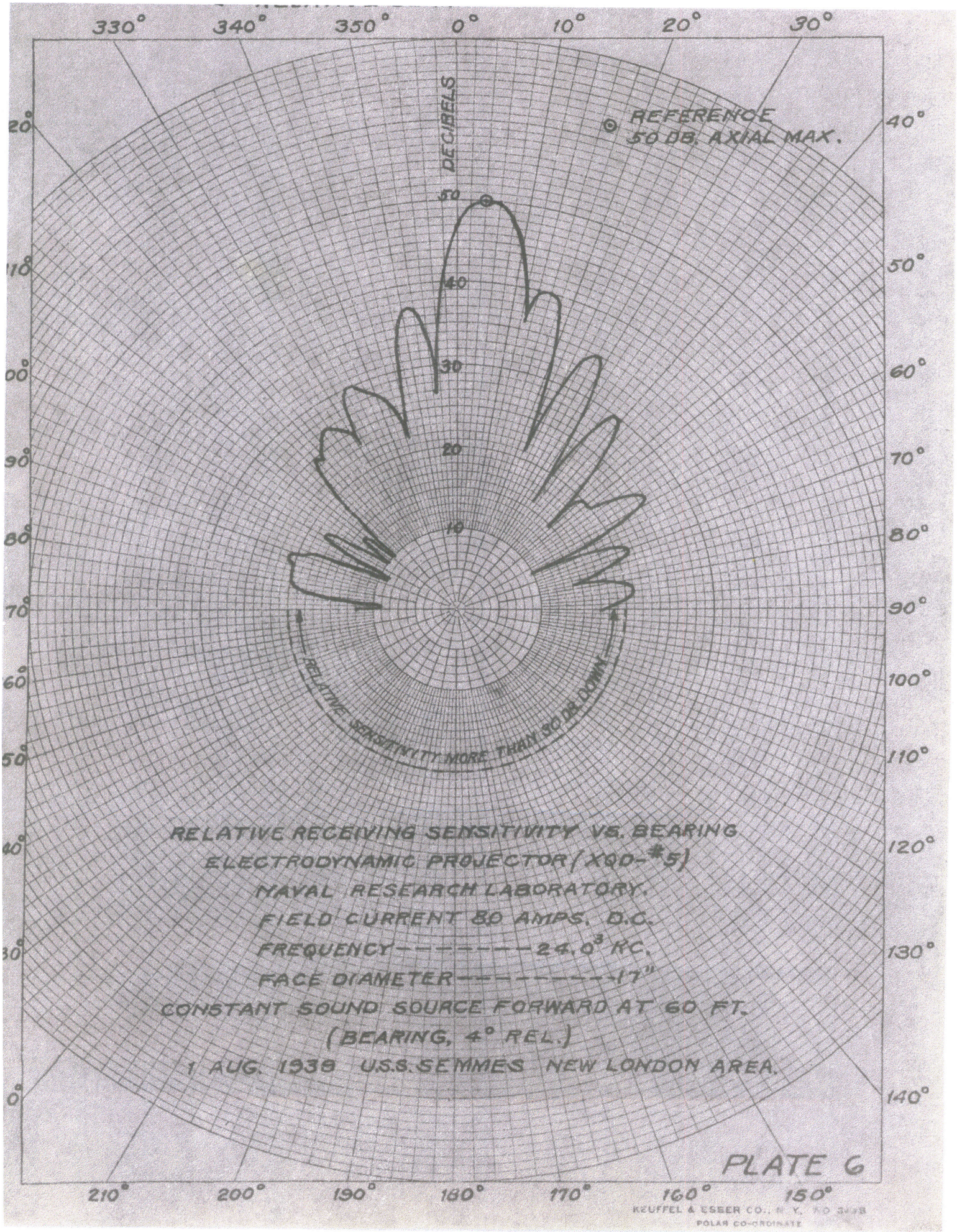
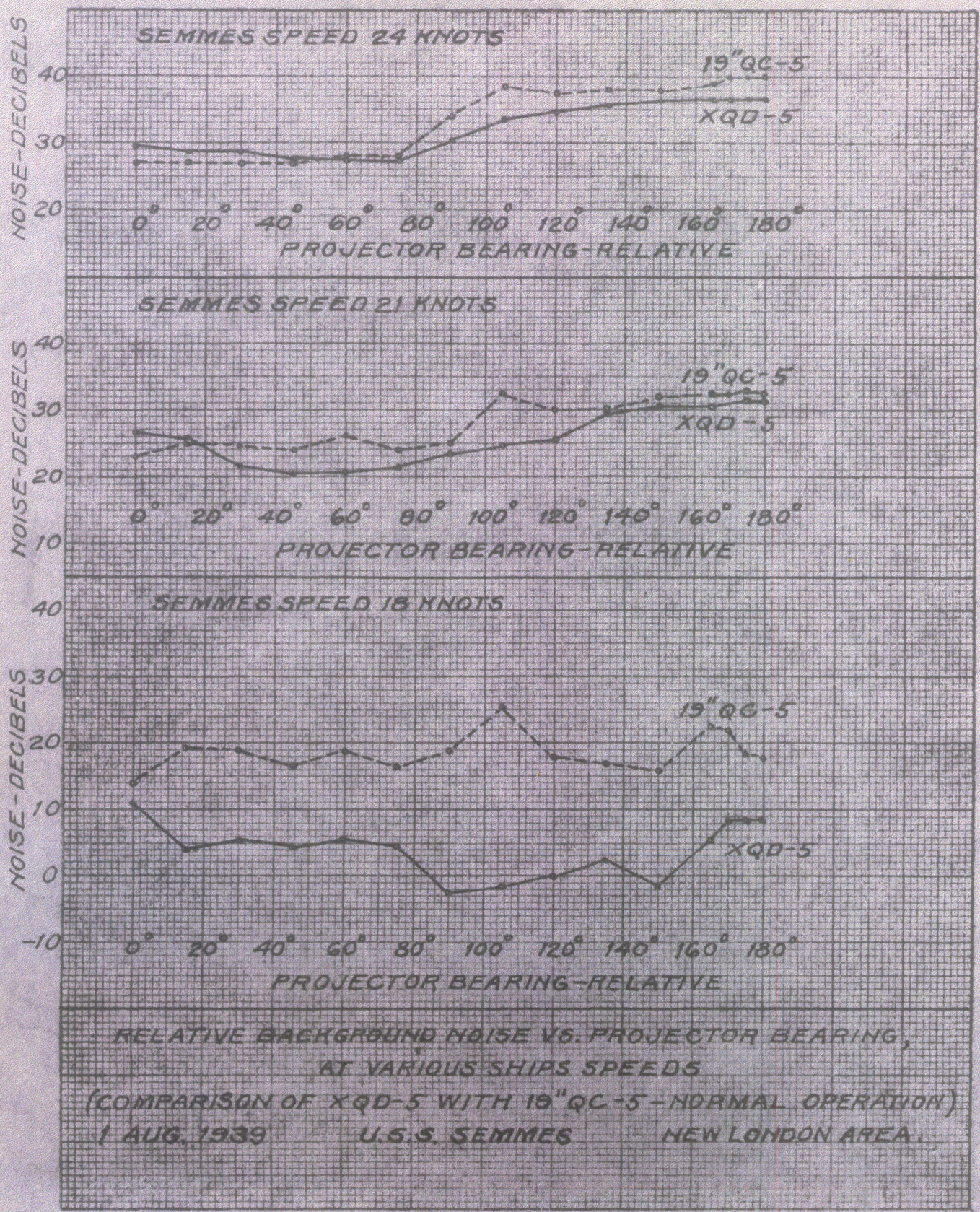

RECEIVING RESONANCE CURVE
ELECTRODYNAMIC PROJECTOR (XQD #5)
NAVAL RESEARCH LABORATORY
RESONANT FREQUENCY 2·1.0³ KC.
SELECTIVITY (f₀/Δf) - - - - 112
FIELD CURRENT 8 AMPERES D.C.
7 AUG., 1939 U.S.S. SEMMES NEW LONDON AREA.
Δf = 215 C.P.S.
RELATIVE RECEIVING SENSITIVITY (OPEN CIRCUIT) DECIBELS.
0
-5
-10
-15
-20
-1000
-500
0
+500
+1000
CYCLES PER SECOND OFF RESONANCE

PLATE 5


330° 340° 350° 0° 10° 20° 30°
DECIBELS
50
40
30
20
10
REFERENCE
50 DB. AXIAL MAX.
RELATIVE SENSITIVITY MORE THAN 30 DB DOWN
RELATIVE RECEIVING SENSITIVITY VS. BEARING
ELECTRODYNAMIC PROJECTOR (XQD-#5)
NAVAL RESEARCH LABORATORY.
FIELD CURRENT 80 AMPS. D.C.
FREQUENCY - - - - - - - - 24.0³ KC.
FACE DIAMETER - - - - - - - - - 17"
CONSTANT SOUND SOURCE FORWARD AT 60 FT.
(BEARING, 4° REL.)
1 AUG. 1938 U.S.S. SEMMES NEW LONDON AREA.
PLATE 6
210° 200° 190° 180° 170° 160° 150°
KEUFFEL & ESSER CO., N. Y.
POLAR CO-ORDINATE



RELATIVE BACKGROUND NOISE VS. PROJECTOR BEARING, AT VARIOUS SHIPS SPEEDS
(COMPARISON OF XQD-5 WITH 19" QC-5 - NORMAL OPERATION)
1 AUG. 1939 U.S.S. SEMMES NEW LONDON AREA

PLATE 7

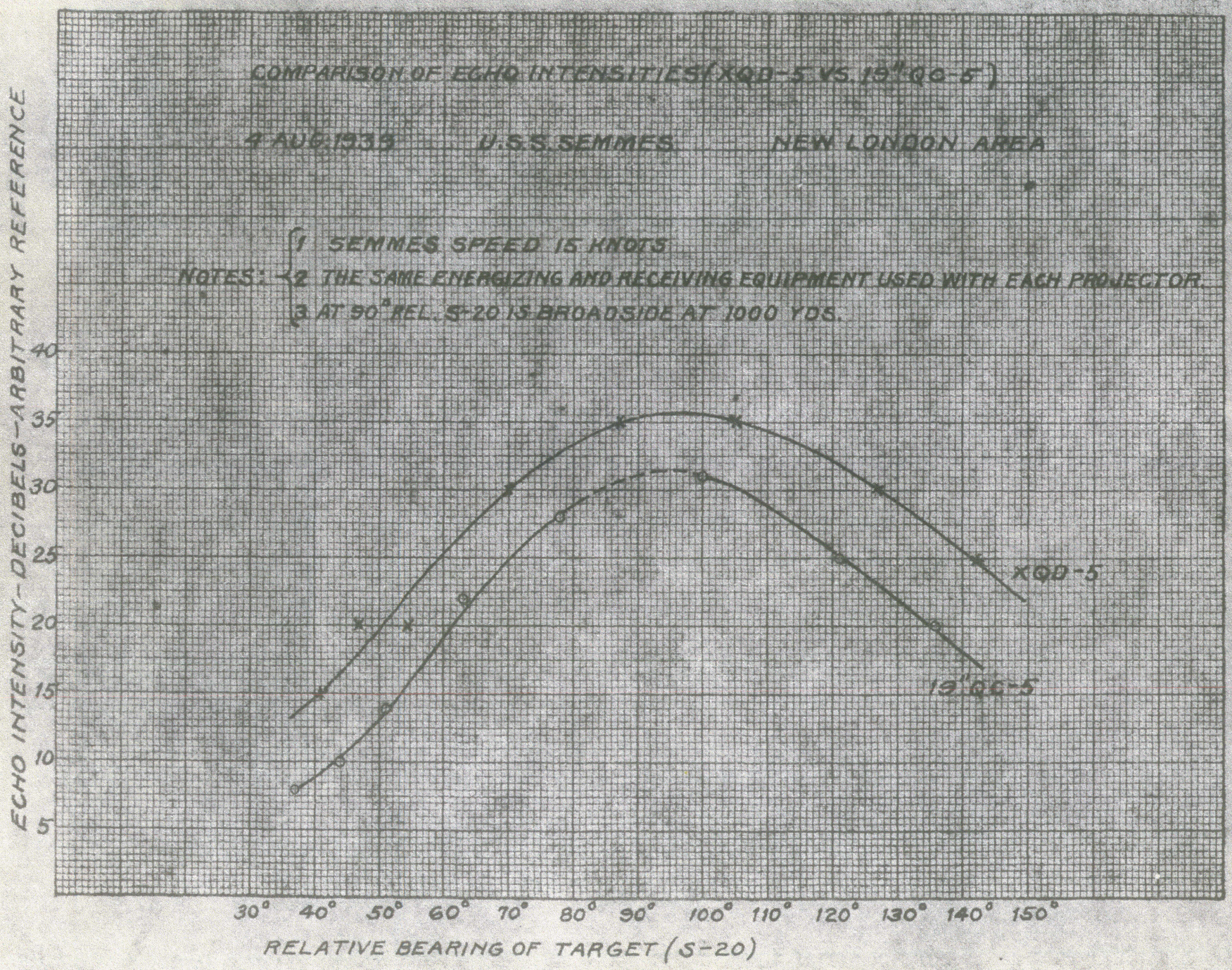

COMPARISON OF ECHO INTENSITIES (XQD-5 VS. 19" QC-5)
4 AUG. 1935
U.S.S. SEMMES.
NEW LONDON AREA
NOTES:
1 SEMMES SPEED 15 KNOTS
2 THE SAME ENERGIZING AND RECEIVING EQUIPMENT USED WITH EACH PROJECTOR.
3 AT 90° REL. S-20 IS BROADSIDE AT 1000 YDS.
ECHO INTENSITY - DECIBELS - ARBITRARY REFERENCE
40
35
30
25
20
15
10
5
XQD-5
19" QC-5
30° 40° 50° 60° 70° 80° 90° 100° 110° 120° 130° 140° 150°
RELATIVE BEARING OF TARGET (S-20)

PLATE 8