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SHIP-SHORE RADIO DIVISION - SEARCH RADAR SECTION

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Submarine Intercept Antenna  
For Frequency Range 1000-3500 Mcs.

By Kenneth S. Kelleher

**FL-2776**

- Report R-2776 -

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Reviewer's name(s): H. DO, P. HANNA

**UNCLASSIFIED**

Declassification authority: NAVY DECLASS  
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ABSTRACT

A satisfactory electrical design has been developed for a submarine intercept antenna covering the range 900 to 3600 Mc by scaling down the Navy Type CAGW 66131 antenna. Horizontal radiation patterns on both polarizations and standing wave ratio curves are shown, and an intercept run against several radar sets is described. Two methods of pressurizing the end of the transmission line have been investigated; one of these holds some promise, but has not been developed into a satisfactory working model.

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## INTRODUCTION

The antenna described in this report was developed under problem S180.5R-S in accordance with reference 1 and 2. This problem requested that NRL develop a submarine intercept antenna that would match a 52 ohm (RG-16/U) cable and give omnidirectional coverage for both horizontal and vertical polarization in the frequency range 1000 to 3500 Mc. An adaptation of some existing antenna was thought to be the quickest solution to the problem. Therefore, tests were made to determine the electrical characteristics in this band of the CAGW-66131 (Modified AS-49/APR-2) described in reference 3 and the AS-125/APR described in references 4 and 5.

### 1. TESTS OF THE CAGW 66131 ANTENNA

1-1. The CAGW 66131 antenna, designed to operate between 300 and 1000 Mc, consists of a cone mounted above a partial ground plane of seven radial rods (Plate 1). The cone has been inclined 35 degrees from the normal to the ground plane in a plane perpendicular to the center rod. In actual use the ground plane is mounted at 45 degrees to the horizontal, with the center rod in a vertical plane.

1-2. Horizontal patterns of this antenna were taken at a number of frequencies from 900 to 3500 Mc on both vertical and horizontal polarizations. In an effort to realize free space conditions, the antenna was supported on a plywood pole about 8 feet above the test pedestal. A Model LAE or Hewlett-Packard Model B signal generator was used, depending on the frequency, while an APR-1 receiver and Esterline-Angus recording meter traced out the patterns shown in Plates 2 to 15. Throughout this report relative bearings are measured clockwise from the center rod, or, in the case of a solid sectoral ground plane, from its bisector. It will be noted that the coverage of the 66131 antenna becomes less uniform as the frequency increases. This is partly because the cone becomes long in terms of a wave length, and partly because the solid part of the ground plane begins to shield the cone.

1-3. Standing wave ratio measurements were carried out by means of a Hazeltine Model 1051A slotted line and a Hazeltine Model 1052A tuned amplifier. When corrected for attenuation of the feed cable, the standing wave ratio did not exceed 5 to 1 between 900 and 3600 Mc (Plate 16). This is entirely satisfactory for a receiving antenna.

### 2. TESTS OF THE MODIFIED AS-125/APR ANTENNA

2-1. In order to obtain more uniform coverage at the high end of the frequency band, it seemed desirable to reduce the dimensions of the CAGW-66131 antenna. Accordingly the cone from an AS-125/APR antenna (Plate 17) was mounted above a 120° ground

plane consisting of 7 rods  $7\frac{1}{2}$  inches in length (Plate 18). This was designated Model NRL-1. The high pass filter of the 125/APR was removed in an effort to extend the low end of the frequency band as far as possible. (BuShips representative had indicated a desire to provide for operation with reduced sensitivity at frequencies as low as 90 Mc.). When the inner conductor of the filter section was replaced with a rod of the same diameter, the characteristic impedance was 70 ohms. As the antenna was to be fed from 52 ohm cable, it seemed desirable to make this impedance 52 ohms so that no special transformer would be required. Standing wave ratio measurements (Plates 19 and 20) show that the match is better than 4 to 1 either way; thus the 70 ohm section was eliminated.

2-2. In comparing Model NRL-1 with the 66131, it is seen that while the impedance match is about the same, the horizontal radiation patterns of the former (Plates 21 to 34) are superior. On horizontal polarization the smaller cone showed no dips greater than 20 db below the maximum at most frequencies. On the other hand, each pattern for the 66131 had nulls in excess of 20 db, and at three frequencies the signal dropped more than 40 db. On vertical polarization the worst dip for the NRL-1 was 14 db, while the 66131 fell below 40 db in two cases. Vertical patterns were not taken, but it was thought that the small cone would give the better overhead coverage.

### 3. TESTS OF MODEL NRL-2

3-1. As Model NRL-1 showed promise of meeting the electrical requirements, attention was turned to the mechanical problem of pressure sealing the end of the transmission line. One possible method was to mold the cone into a block of polyethylene or Textolite 1421 and secure this to the end of the outer conductor by means of a clamping nut. Unfortunately the presence of the ground plane made this awkward. On the chance that the ground plane might be eliminated without sacrificing any electrical performance, antenna model NRL-2 was constructed with a removable ground plane (Plate 35). It also was provided with a removable block of polystyrene in which the cone could be imbedded to investigate the effect of dielectric on the impedance match. Instead of the modified filter section from the AS-125/APR used in NRL-1, this model had a length of standard  $7/8$  inch 52 ohm transmission line feeding into the cone. With the dielectric and ground plane in place, the match (Plate 36) was actually better than for NRL-1, as 3 to 1 was the highest standing wave ratio observed. However, the improvement resulted from the elimination of discontinuities in the transmission line rather than from the presence of the polystyrene. When the ground plane was removed the match fell off badly at the low end of the band, and the patterns (Plates 37 to 48) showed less uniform coverage at the higher frequencies. Thus the ground plane seemed to be essential. The idea of sealing with a block of dielectric was abandoned at this point.

as no good means was proposed for securing it with the ground plane present. At the time of writing this report, it appears that the difficulty might be avoided by lowering the ground plane by perhaps  $3/4$  inch with respect to the end of the outer conductor.

#### 4. TESTS OF MODEL NRL-3

4-1. An alternative method proposed for terminating the transmission line was to seal a heavy ring of glass between the inner and outer conductors. Experimental Model NRL-3 of the submarine antenna (Plate 49) was constructed to test the feasibility of this scheme from the r-f standpoint. It had a 120 degree solid brass ground plane with a radius of  $3\frac{1}{2}$  inches, the same transmission line as NRL-2, and a cylinder of Corning 706 glass  $1\frac{1}{2}$  inches in diameter by  $\frac{1}{2}$  inch thick to simulate the seal. The horizontal radiation patterns (Plates 50 to 59) were not significantly different from those of NRL-1, while the match (Plate 60) was better than 5 to 1 between 900 and 3600 Mc. It is interesting to note that when the glass seal was removed, the standing wave ratio was less than 2 to 1 over this band.

4-2. From these tests it was concluded that the glass seal had acceptable electrical properties. It remained to develop a method of sealing that would enable the antenna to withstand the hydrostatic pressures and shocks to which a submarine is subjected. The latter were stated by BuShips representatives to be 300 and 400 lbs/in<sup>2</sup> respectively. By consultation with the Corning Glass Works it was learned that glass to metal seals using Kovar or tungsten would not be serviceable in this case because the required thickness and diameter of the glass were too great. However, Corning Glass Works representatives proposed the use of insulator's formed of sintered Number 790 glass, which has a composition of nearly pure silica. The glass would be metallized on its curved surfaces, tinned, and soldered between inner and outer conductors of invar. The expansion of both the glass and invar would be almost negligible at any temperature likely to be encountered in practice. Several glass discs of this type were manufactured by the Corning Glass Works and delivered to the Air-Track Manufacturing Corporation of College Park, Md., which undertook the construction of three pre-production models based on the NRL-3.

4-3. When the first Air-Track antenna (Plate 61) was completed, it was taken to the Taylor Model Basin for pressure testing. Unfortunately one of the silver-soldered joints in the body of the antenna proved to be defective so that the seal itself could not be tested. This model was returned to Air-Track, where the seal was removed and the silver-soldering patched up. Difficulty was then encountered in sweating another insulator into place. Even in cases where the soldering process was apparently successful, the glass would begin to crack a day or two later. All the available glass discs were broken in these attempts so that pressure tests were never run. The contract with Air-Track was cancelled

at this point on the assumption that the Naval Research Laboratory would continue the development of a satisfactory mechanical design. However, as no further glass discs could be obtained from the Corning Glass Works, the work on this seal was dropped.

5. MOUNTING CONSIDERATIONS

5-1. For best results an intercept antenna should be mounted high and in the clear, but as the submarine silhouette must be kept to a minimum, few such locations are available. There should, however, be plenty of room to attach a small antenna to the shears. The effect of such an arrangement on the patterns of Model NRL-1 was investigated by mounting it 2 feet from a long sheet metal pipe 20 inches in diameter. As this antenna has a dip at a relative bearing of 240 degrees in its response to horizontally polarized radiation, it was oriented so that the pipe fell across this bearing.

5-2. In the resulting patterns (Plates 62 to 75), a line from the center of the pipe out through the antenna was taken as 0 degrees. It will be noted that the signal is very low in the neighborhood of 180 degrees, particularly on vertical polarization. Further, the patterns are very complex due to reflections from the pipe. It was concluded from these measurements that the antenna should be mounted as far as possible from all vertical surfaces, even if height must be sacrificed.

6. SENSITIVITY MEASUREMENTS

6-1. In addition to meeting certain requirements on pattern and impedance match, an intercept antenna should develop as great a signal voltage as possible for a given field strength. Sensitivity can be measured in absolute terms, but in this case it was easier and more important to compare the submarine antenna with the CAGW 66131, whose performance was already known. To check this, the two antennas were mounted side by side on the YP-354 and an intercept run was made on several radar sets at the Chesapeake Bay Annex. The YP followed a course of 020 true; at a range of 10,000 yards it began to execute small circles so that patterns could be taken. Each of the following radars was turned on in succession: the SF, SG, S<sub>2</sub><sup>1</sup>, Mark 12, SC-3, and SU. Signals were received on either the SPR-2 or APR-1, according to the frequency, and displayed on an APA-6 pulse analyzer. By adjusting the gain control continuously, the height of the pulse was kept at a reference mark on the APA-6 scope. The gain control dial was read every 15 seconds, which corresponded to something over 20 degrees of rotation of the YP. For each radar tested, one pattern was run using the Model NRL-3 and another with the CAGW 66131 antenna connected to the same receiver. The entire sequence was repeated at ranges of 20,000 and 40,000 yards.

6-2. After the tests had been completed, the receivers and pulse analyzer were calibrated against suitable signal generators so that the various patterns could be plotted. These are shown in Plates 76 to 90. No attempt was made to reduce the signal levels to micro-volts, so a direct comparison of sensitivity on various frequencies is not possible. However, at any one frequency the two intercept antennas may be compared, and the variation of signal with range is represented correctly.

6-3. Against the SF, SG, and  $S\frac{1}{2}$  the Model NRL-3 showed approximately equal sensitivity with the CAGW 66131 and considerably more uniform coverage. The SF and SG operate at approximately 3000 Mc., the  $S\frac{1}{2}$  at 2000 Mc. The SF was set up for vertical polarization, while the other two were horizontally polarized. The difference in coverage between the large and small intercept antennas is actually much greater than indicated in the patterns, where the points are spaced quite far apart. In the case of the CAGW 66131 the pulse on the APA-6 moved up and down every 2 or 3 degrees, while the signal from the NRL-3 was nearly as steady as shown in the curves.

6-4. The small cone was somewhat less sensitive than the large one against the Mark 4 Radar (700 Mc) and the SC-3 (200 Mc). The difference amounted to roughly  $5\frac{1}{2}$  and  $7\frac{1}{2}$  db respectively at the shorter ranges, 11 and 12 db at 40,000 yards. However, even at this range the Model NRL-3 picked up both radars without difficulty.

6-5. All attempts to pick up the X band SU radar were unsuccessful. This was not attributed to any fault of the antennas, but rather to the fact that the SPR-2 receiver is not designed for this frequency band. Either the third or fourth harmonic of the local oscillator would be used against 9000 Mc signals. Further tests should be run with an X Band receiver. However, it is reasonable to suppose that the patterns of Model NRL-3 at this frequency would be similar to those of the CAGW 66131 at S Band.

## 7. CONCLUSIONS

7-1. An antenna of the general type exemplified by Models NRL-1, 2, and 3 will meet the electrical requirements for a submarine intercept antenna in the frequency band 900 to 3600 Mc. At higher frequencies the attenuation of the dielectric cable will become important, and the radiation pattern will become complex when the cone is one or two wavelengths long. At lower frequencies the sensitivity falls off slowly, but the antenna is still usable at 200 Mc.

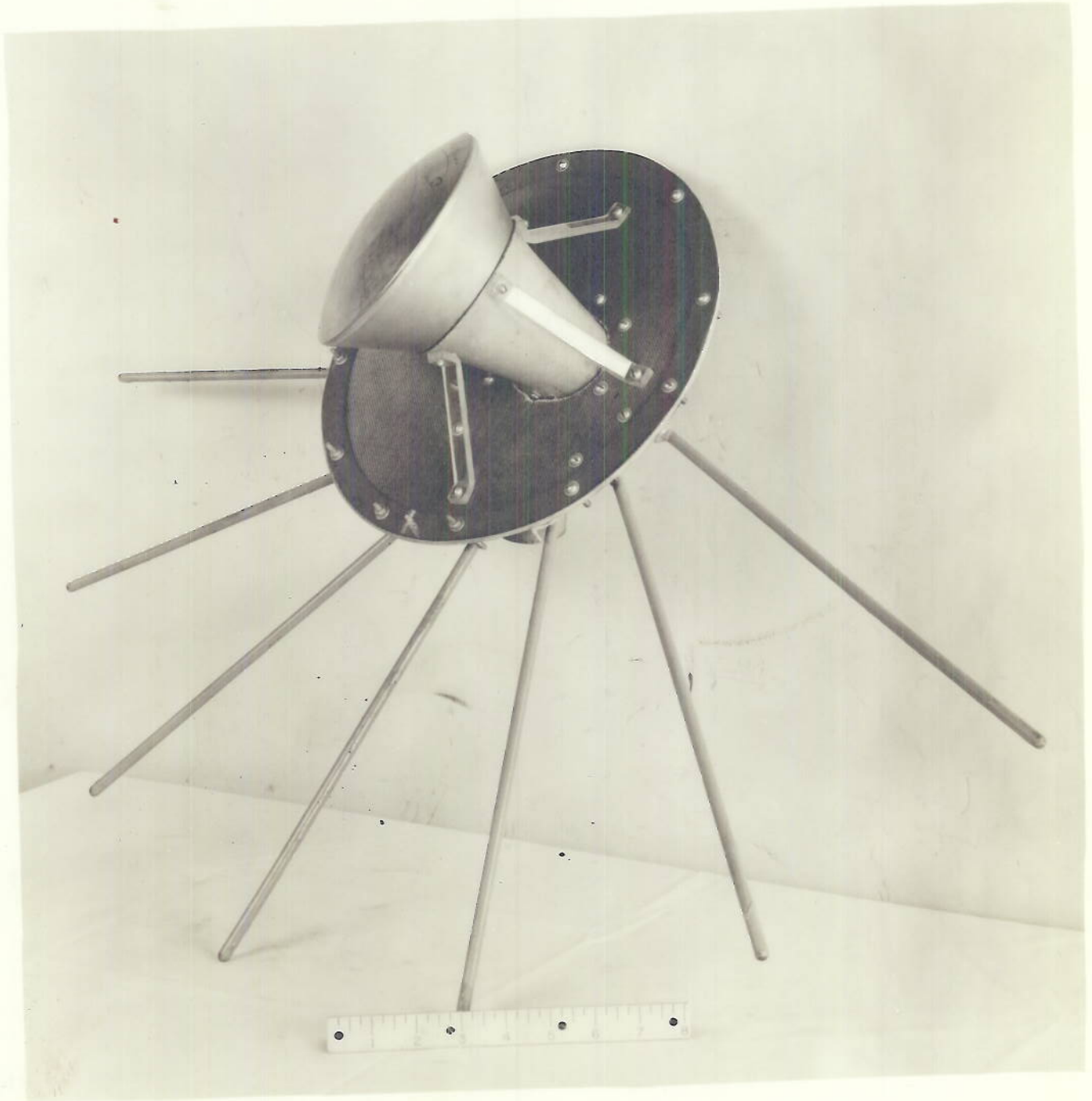
7-2. No vertical radiation patterns have been taken; these should be run on the final version of any antenna developed for this purpose, to insure that the overhead coverage is adequate.

7-3. The mechanical problem of sealing the end of the transmission line against hydrostatic and dynamic pressure has not been solved. At the present time, the system proposed for Model NRL-2 seems most promising. The cone could be molded into a block of Textolite 1421 and clamped without difficulty to the end of the outer conductor if the ground plane were moved down as much as  $3/4$  inch.

7-4. It is felt that the mechanical construction of the pre-production model is unnecessarily heavy.

REFERENCES

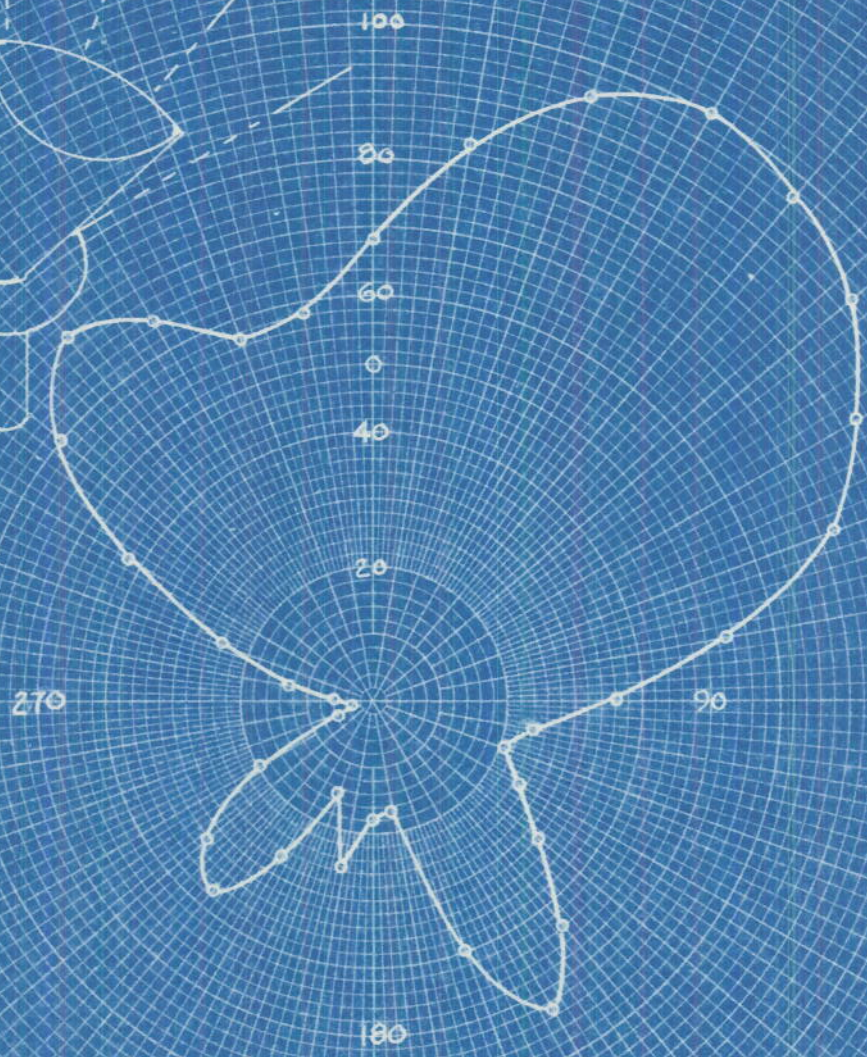
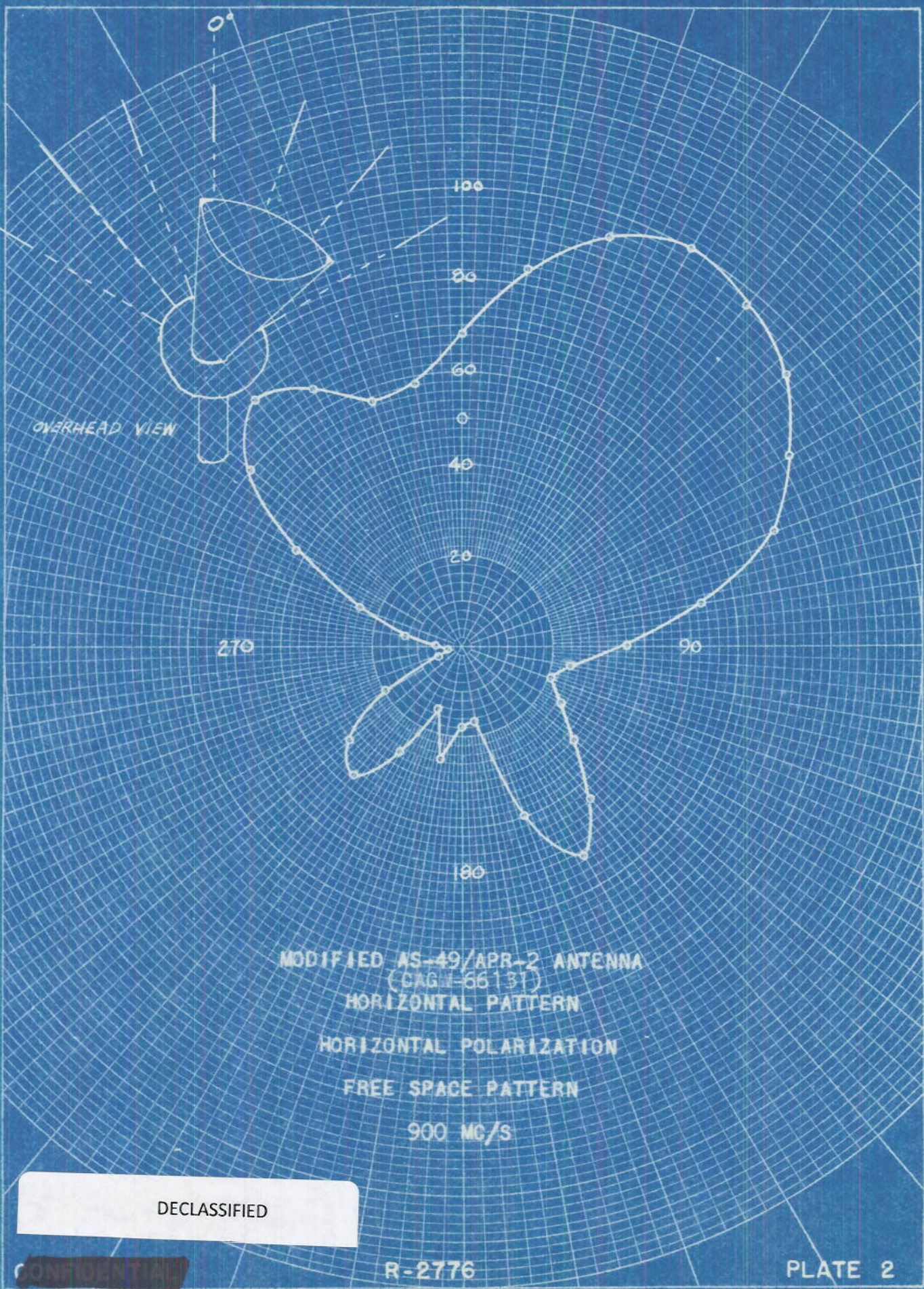
1. BuShips ltr. Sec. 929 Ser. 011268 of 16 November 1944 to NRL requesting design of search antenna for An<sup>3</sup><sub>2</sub>SPR-2 intercept receiver for use on submarines.
2. NRL ltr. S-S67-5/ss700 Ser. 4176 to BuShips Radio Problem Assignment Report - Problem S180.5R-S.
3. NRL Report R-2370 of 1 November 1944 "The Development of Search Antennas for the 75-300 Mc and 300-1000 Mc Bands".
4. NRL Tech. Manual 411-TM-113 of 13 July 1944 - The A-2602, A-2608 and A-2612 Cone Antennas.
5. NRL Tech. Manual 411-1B-45 of 10 October 1944 - Instruction Book for the A-2608 (AS-125/APR) and the A-2612 (AS-44/APR).



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CA/GW 66131 ANTENNA

PLATE 1

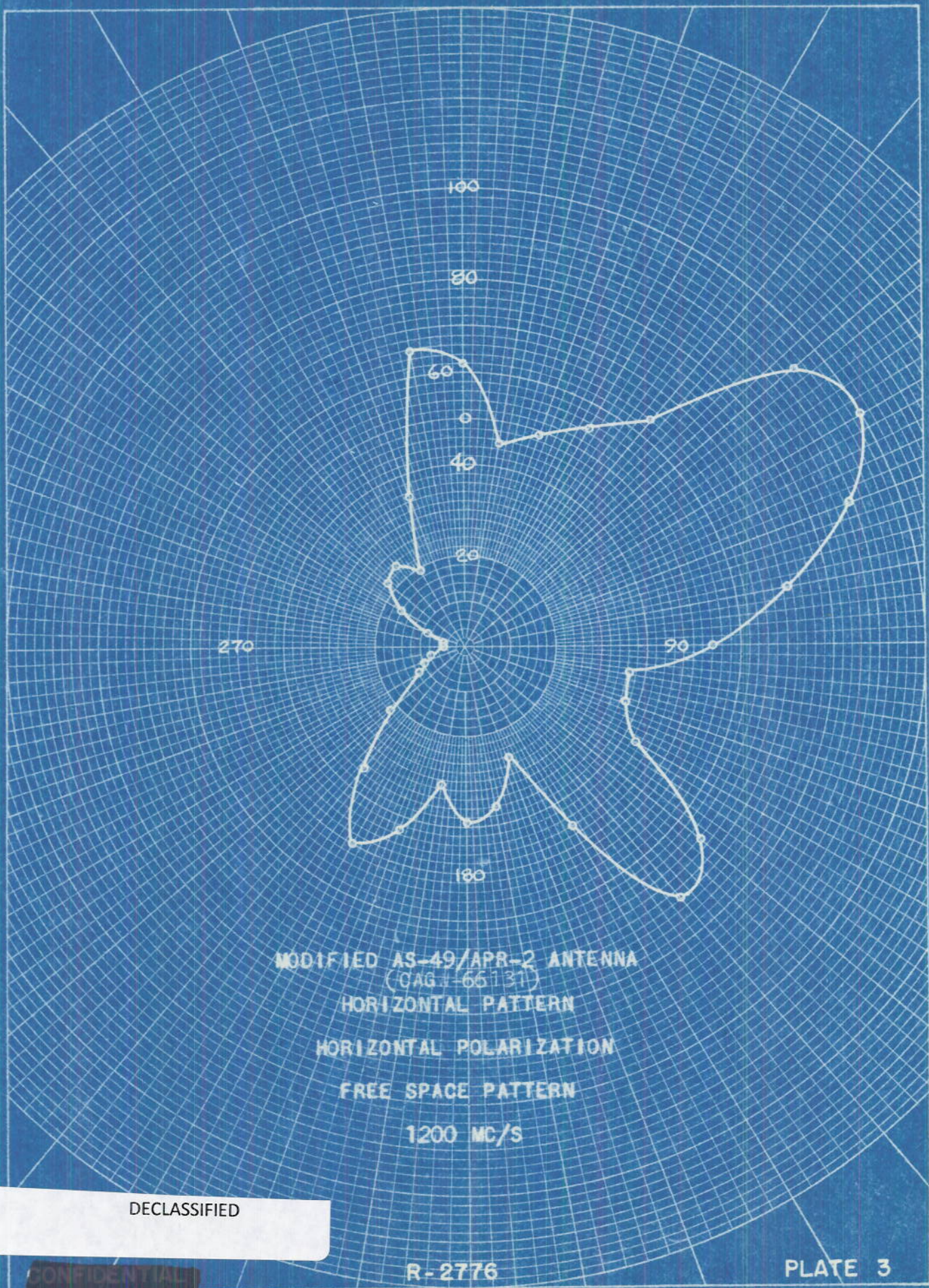


MODIFIED AS-49/APR-2 ANTENNA  
 (DAGN-66131)  
 HORIZONTAL PATTERN  
 HORIZONTAL POLARIZATION  
 FREE SPACE PATTERN  
 900 MC/S

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PLATE 2



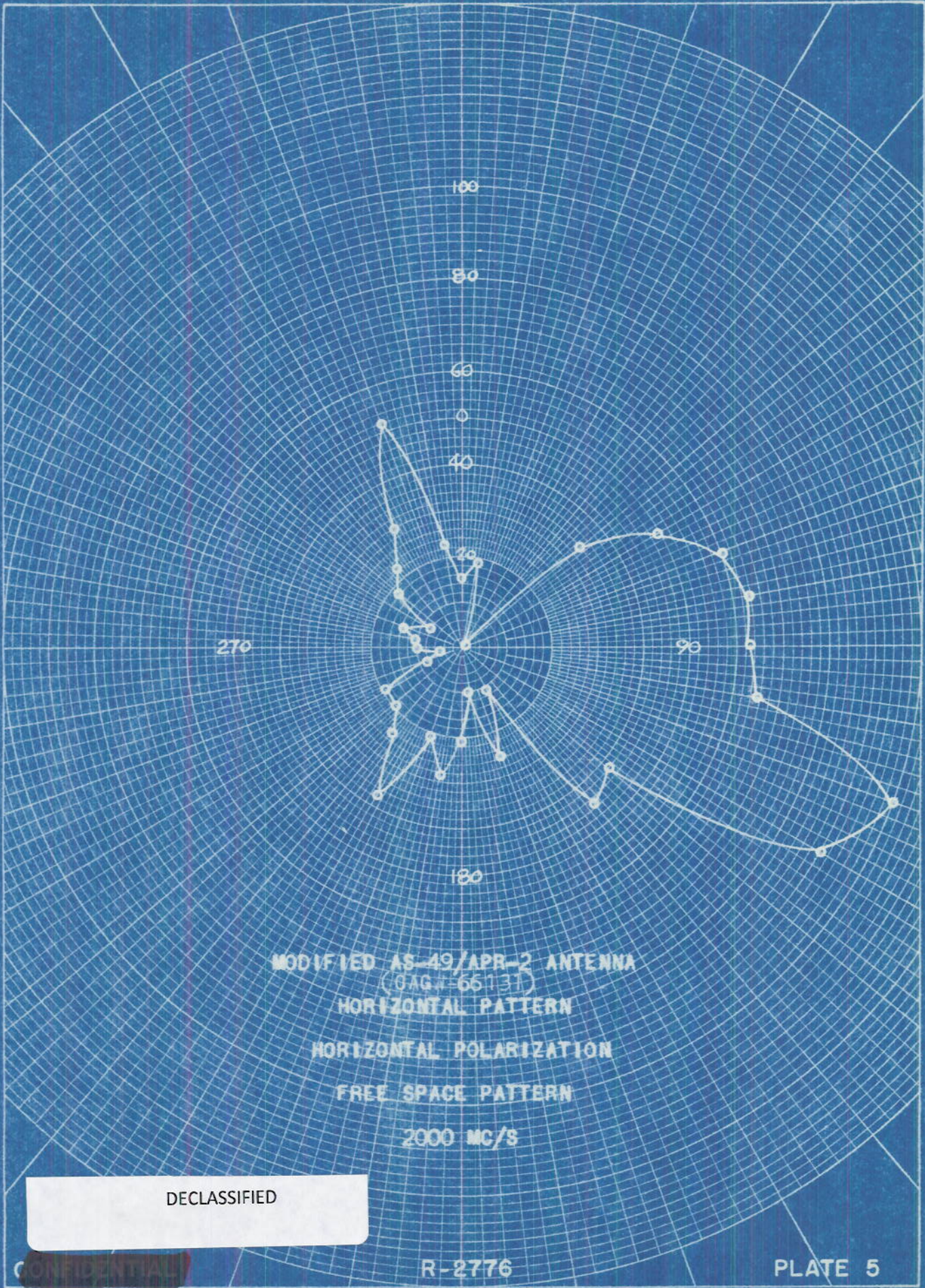
MODIFIED AS-49/APR-2 ANTENNA  
 (CAG V-66131)  
 HORIZONTAL PATTERN  
 HORIZONTAL POLARIZATION  
 FREE SPACE PATTERN  
 1200 MC/S

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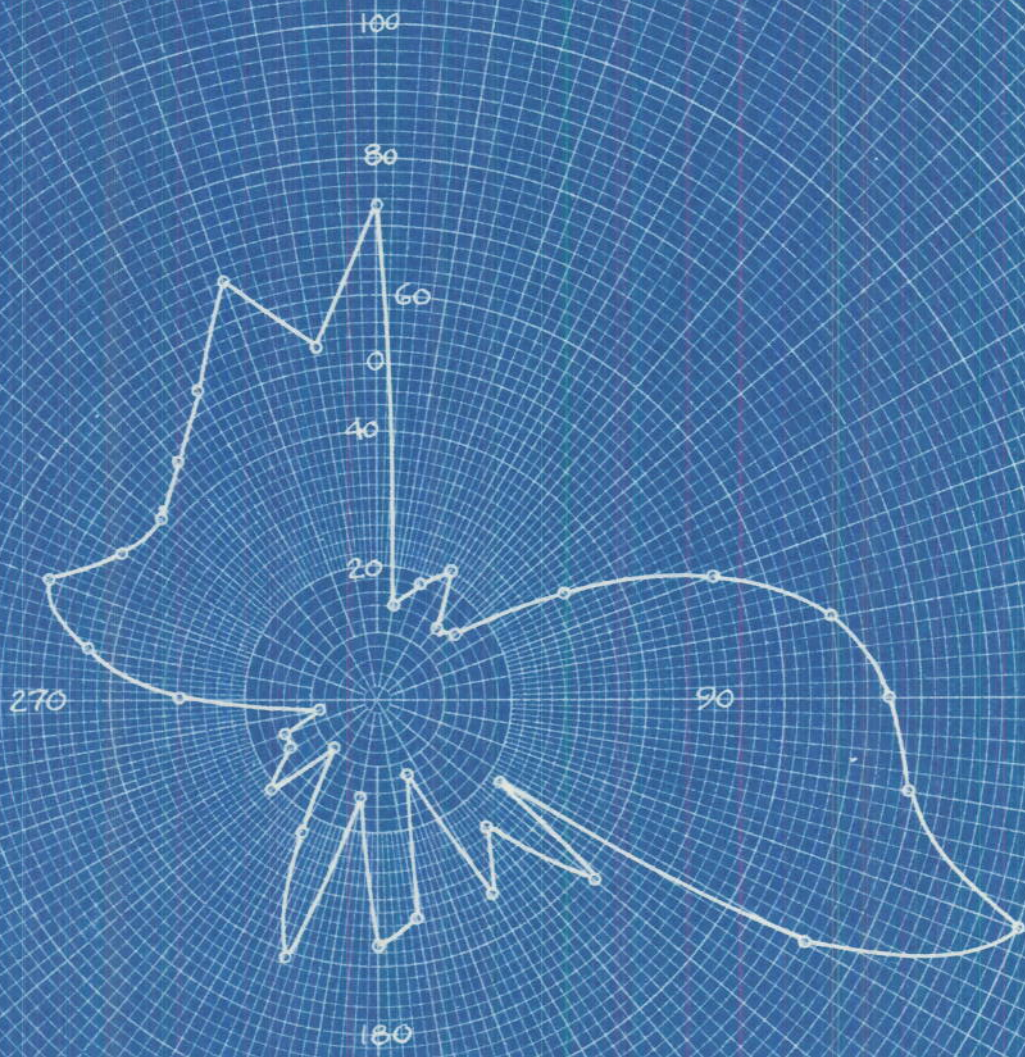
PLATE 3



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PLATE 5



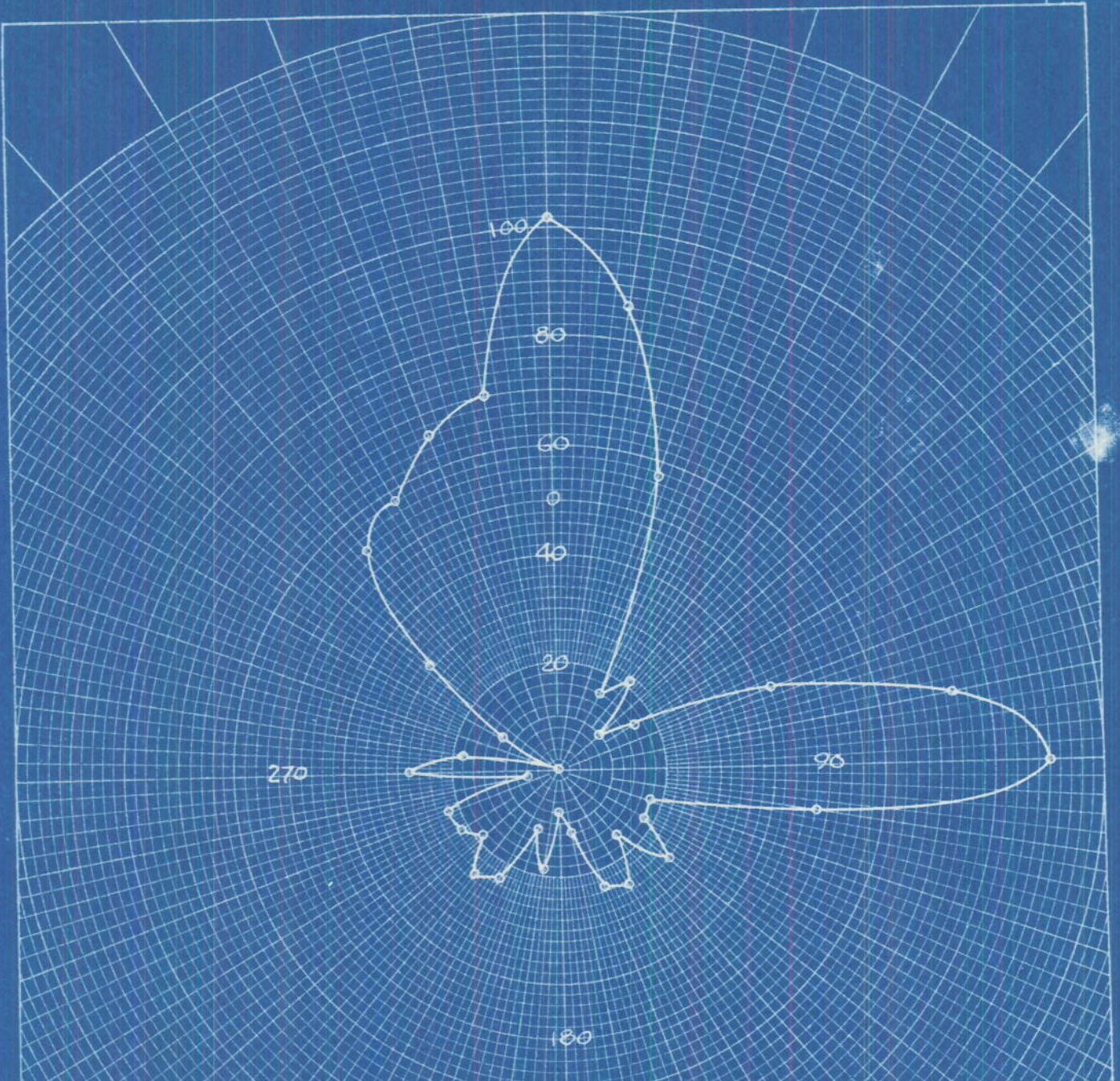
MODIFIED AS-49/APR-2 ANTENNA  
 (OAGW-66131)  
 HORIZONTAL PATTERN  
 HORIZONTAL POLARIZATION  
 FREE SPACE PATTERN  
 2500 MC/S

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PLATE 6



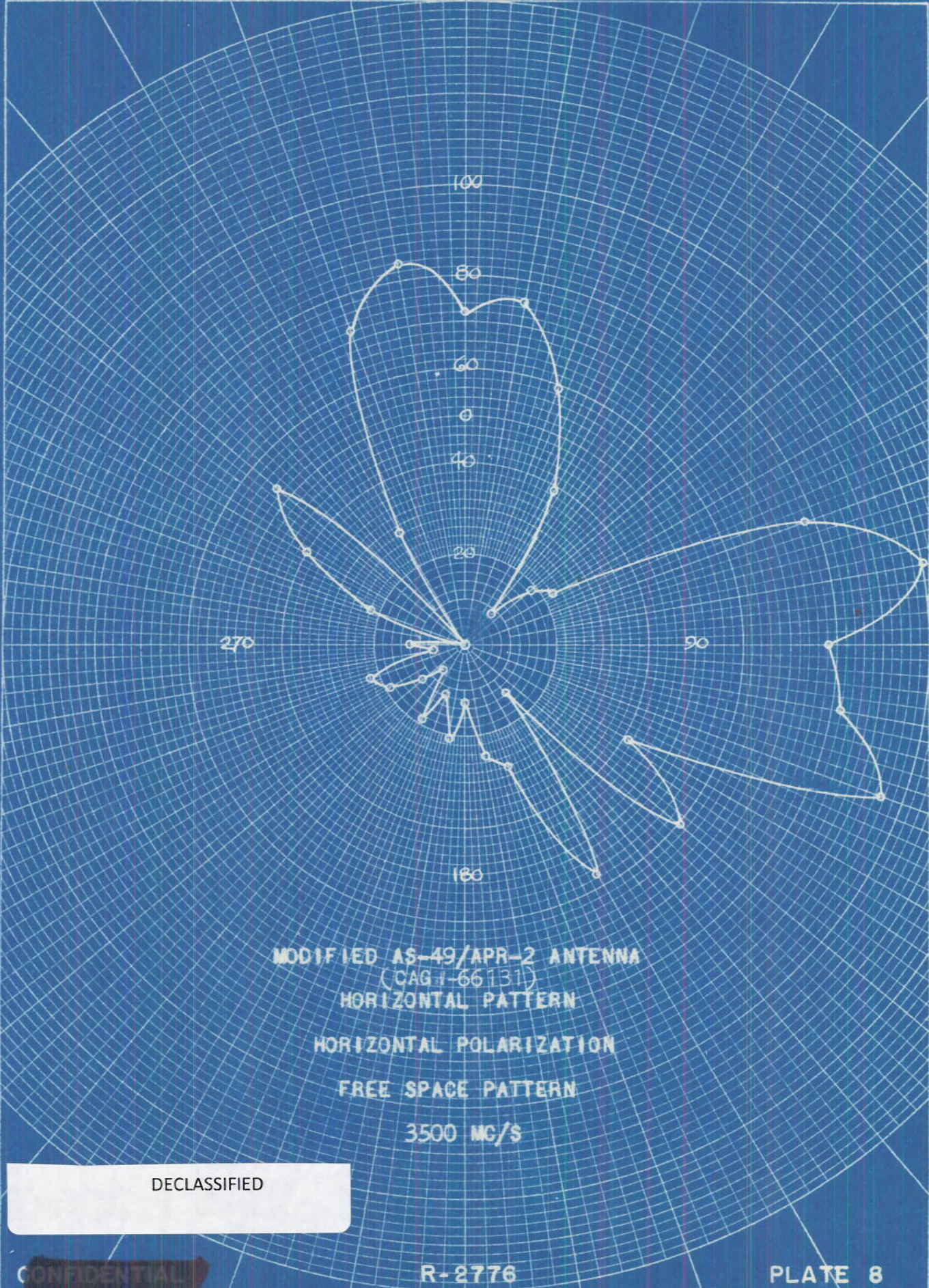
MODIFIED AS-49/APR-2 ANTENNA  
 (DAG-66131)  
 HORIZONTAL PATTERN  
 HORIZONTAL POLARIZATION  
 FREE SPACE PATTERN  
 3000 MC/S

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PLATE 7



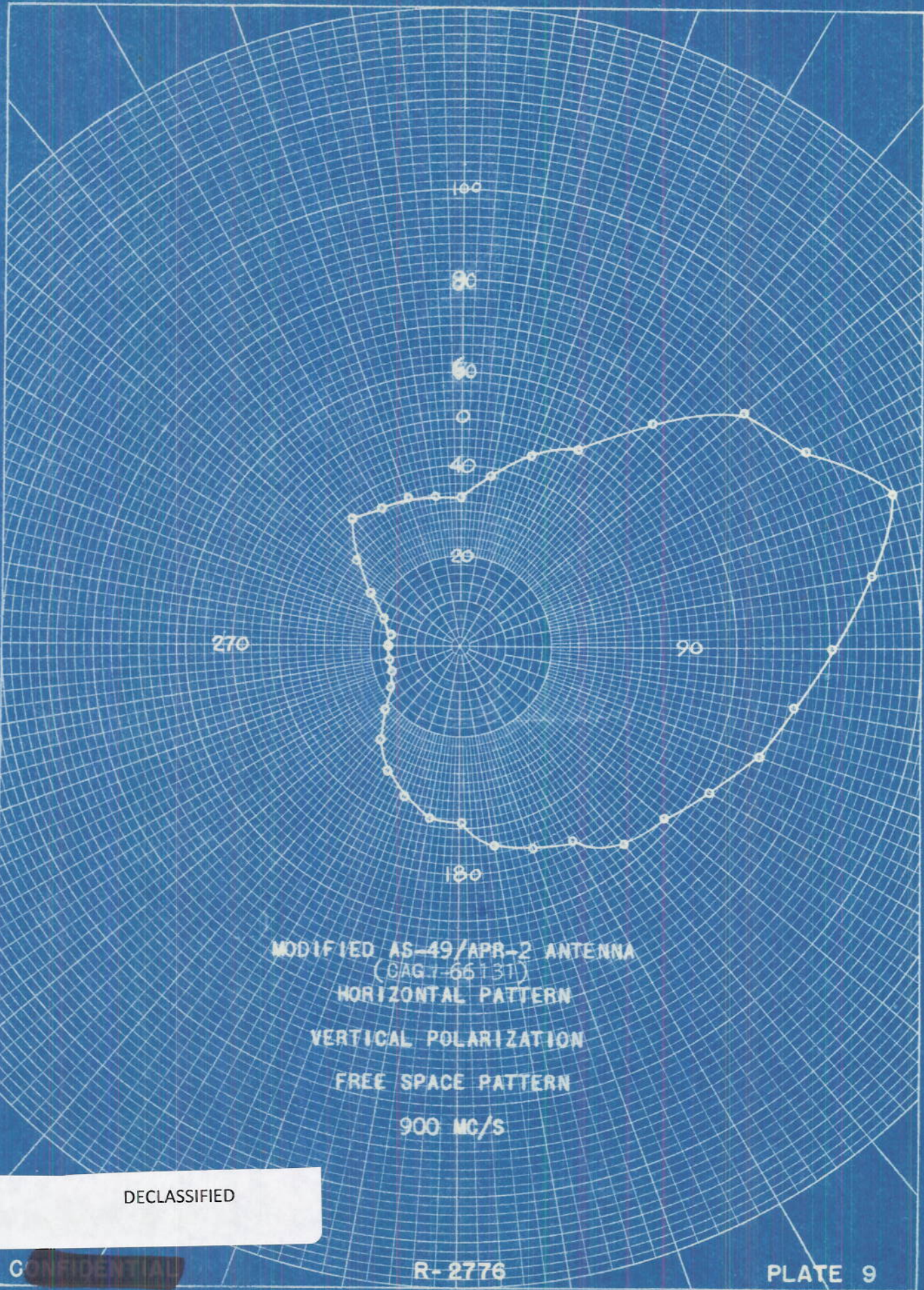
MODIFIED AS-49/APR-2 ANTENNA  
(CAG-66131)  
HORIZONTAL PATTERN  
HORIZONTAL POLARIZATION  
FREE SPACE PATTERN  
3500 MC/S

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PLATE 8

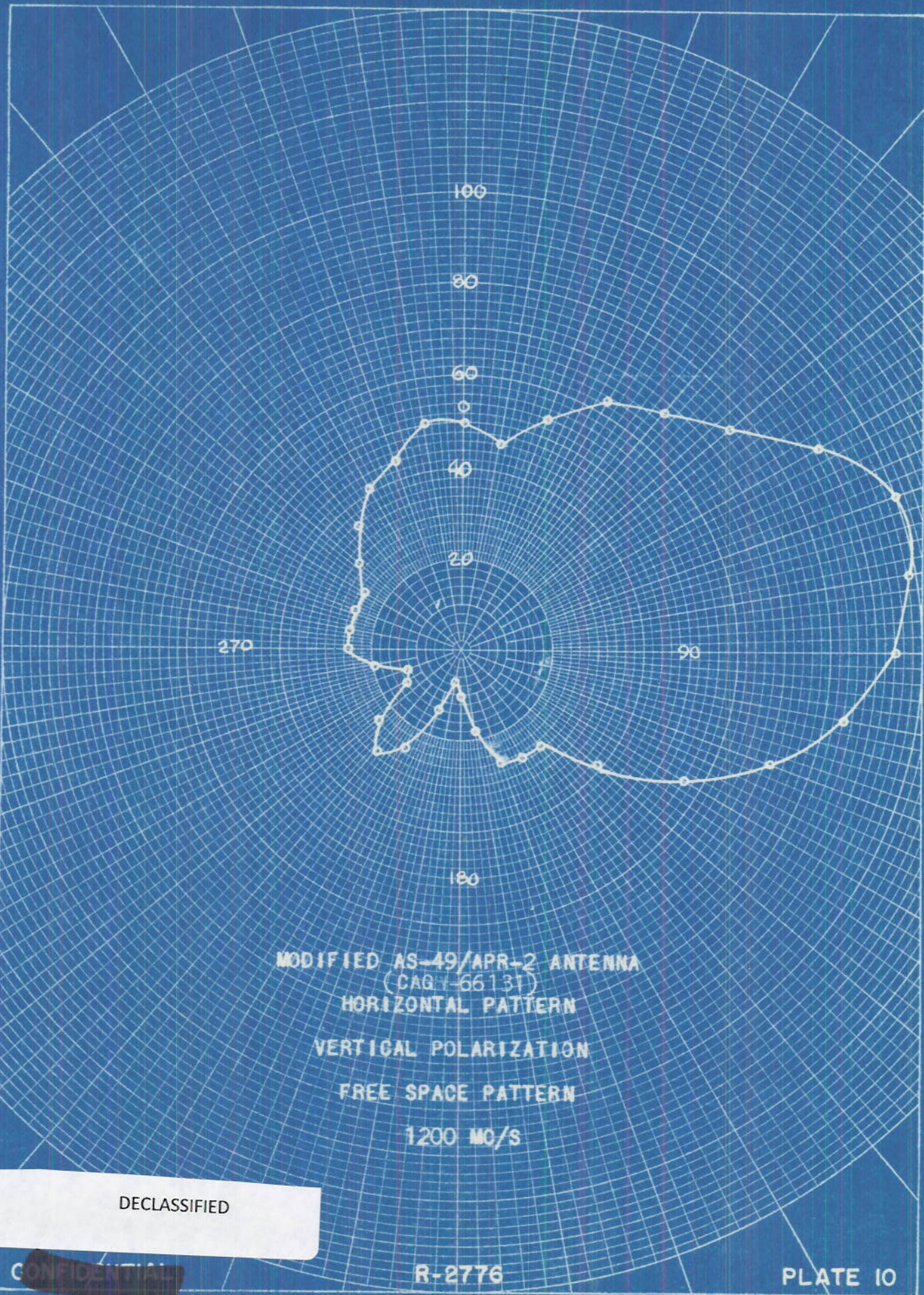


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PLATE 9

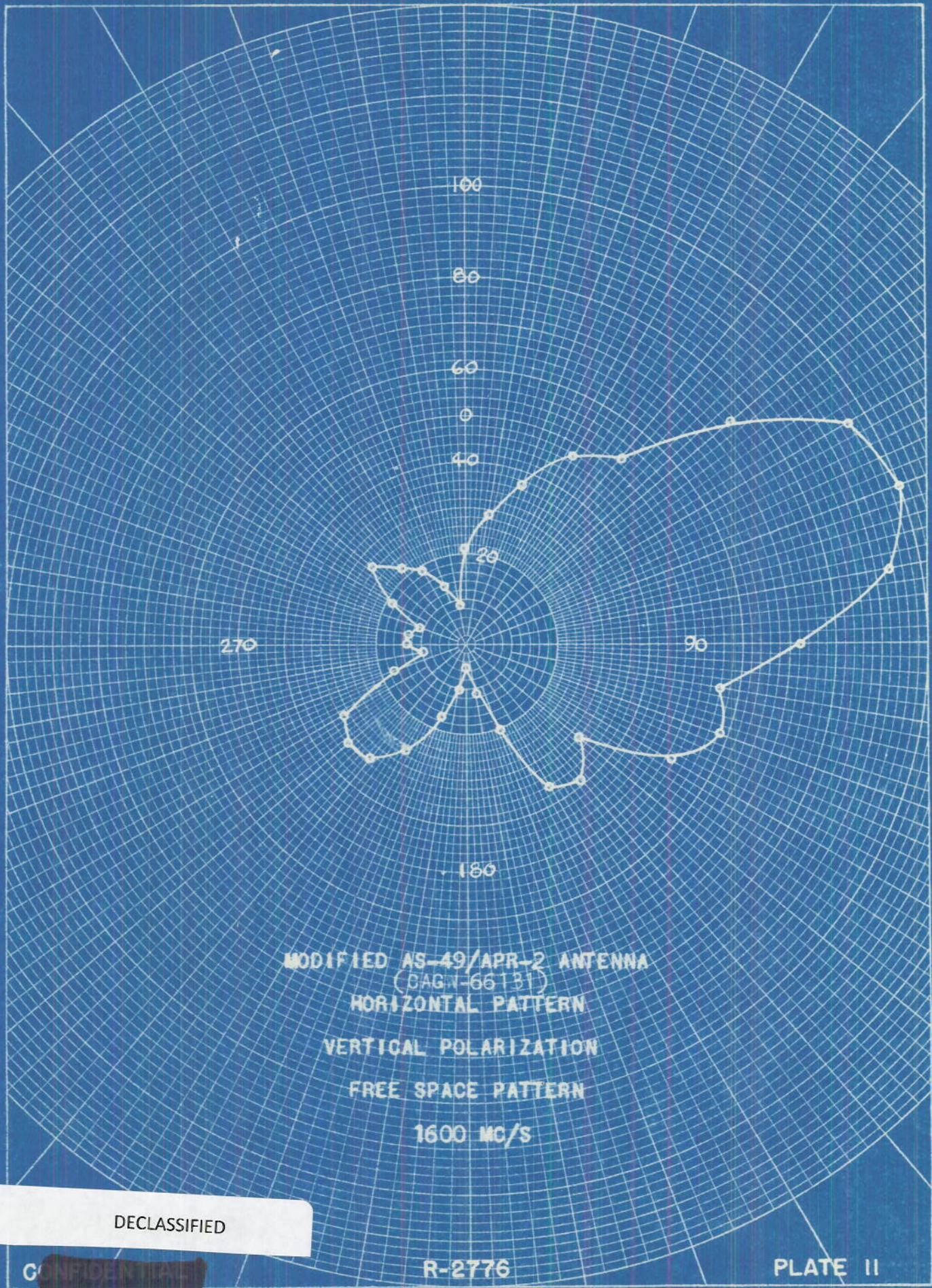


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PLATE 10



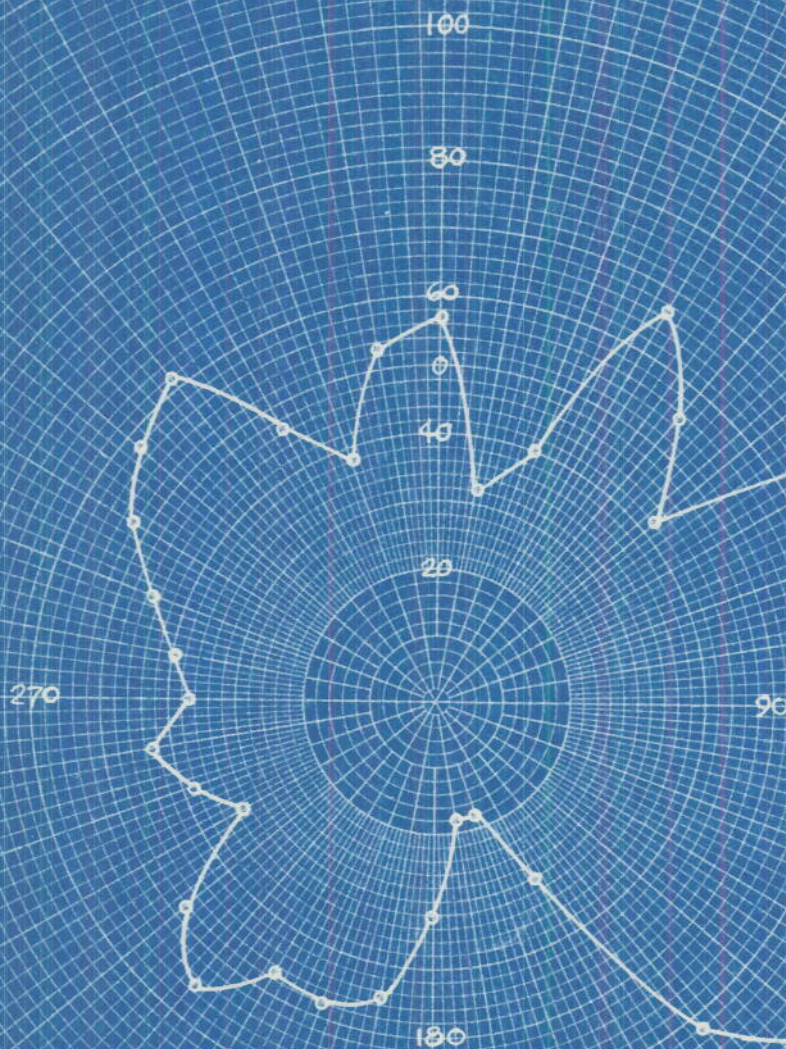
MODIFIED AS-49/APR-2 ANTENNA  
 (CAG-T-66131)  
 HORIZONTAL PATTERN  
 VERTICAL POLARIZATION  
 FREE SPACE PATTERN  
 1600 MC/S

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PLATE II

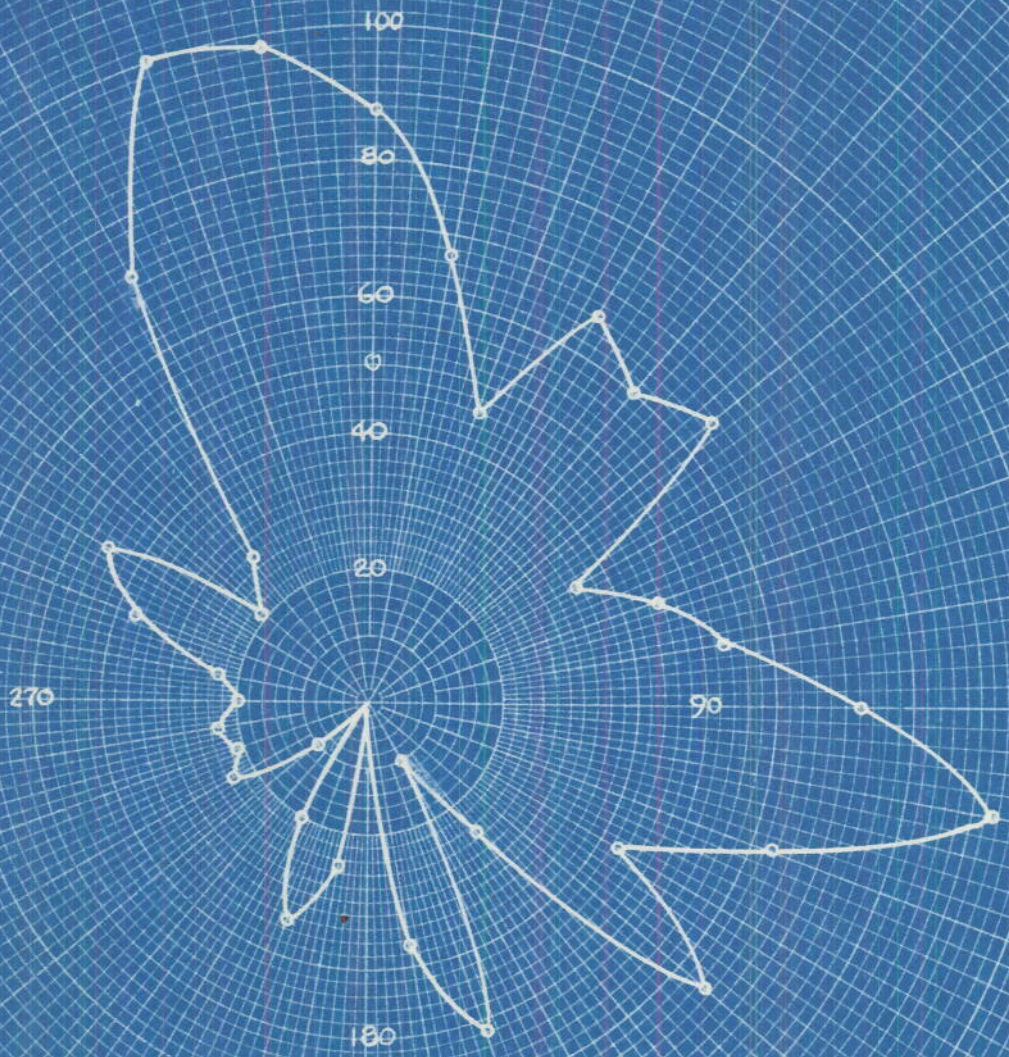


MODIFIED AS-49/APR-2 ANTENNA  
 (GAG-66131)  
 HORIZONTAL PATTERN  
 VERTICAL POLARIZATION  
 FREE SPACE PATTERN  
 2000 MC/S

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PLATE 12



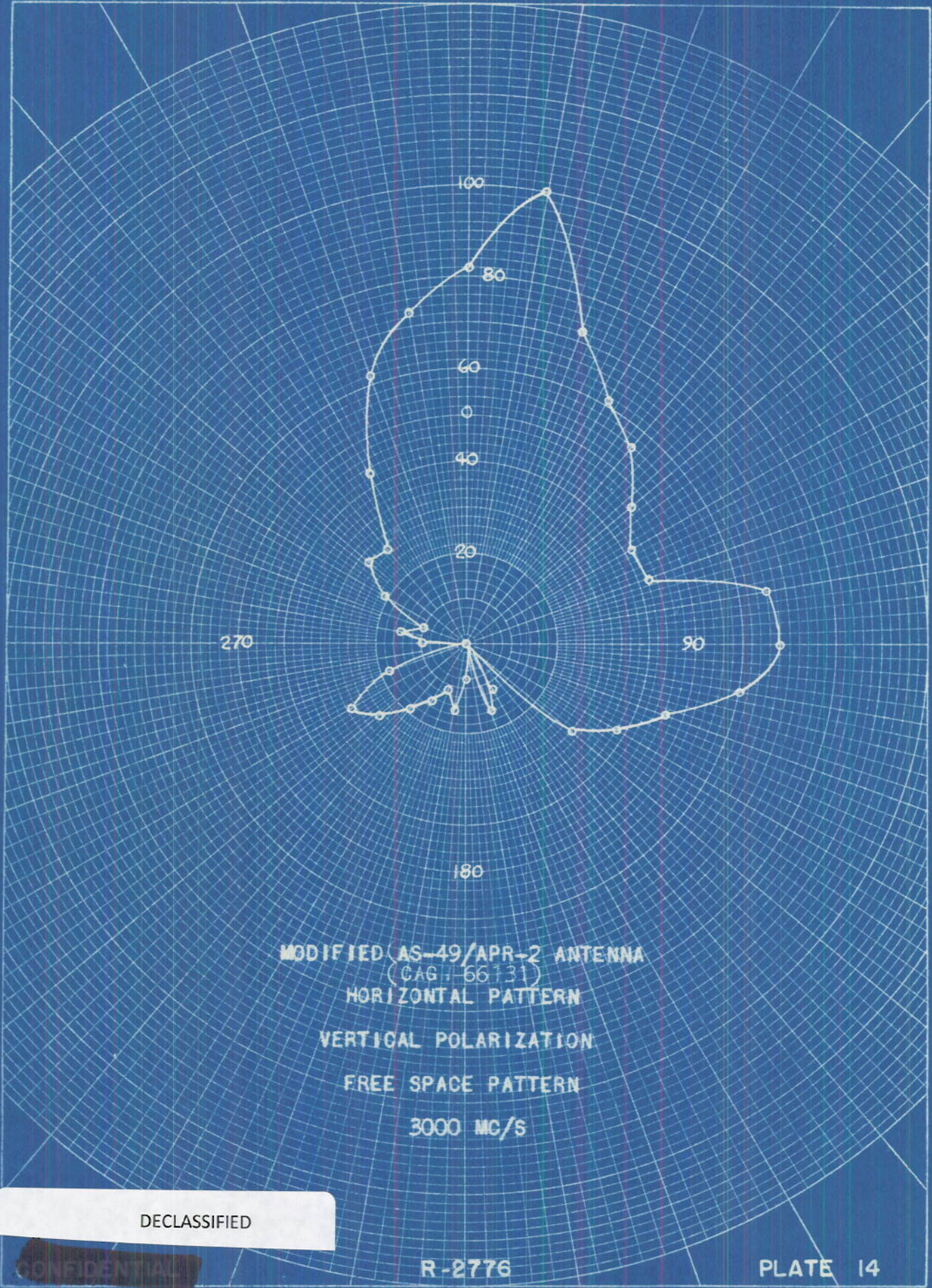
MODIFIED AS-49/APR-2 ANTENNA  
 (CAG 7-66131)  
 HORIZONTAL PATTERN  
 VERTICAL POLARIZATION  
 FREE SPACE PATTERN  
 2500 MC/S

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PLATE 13



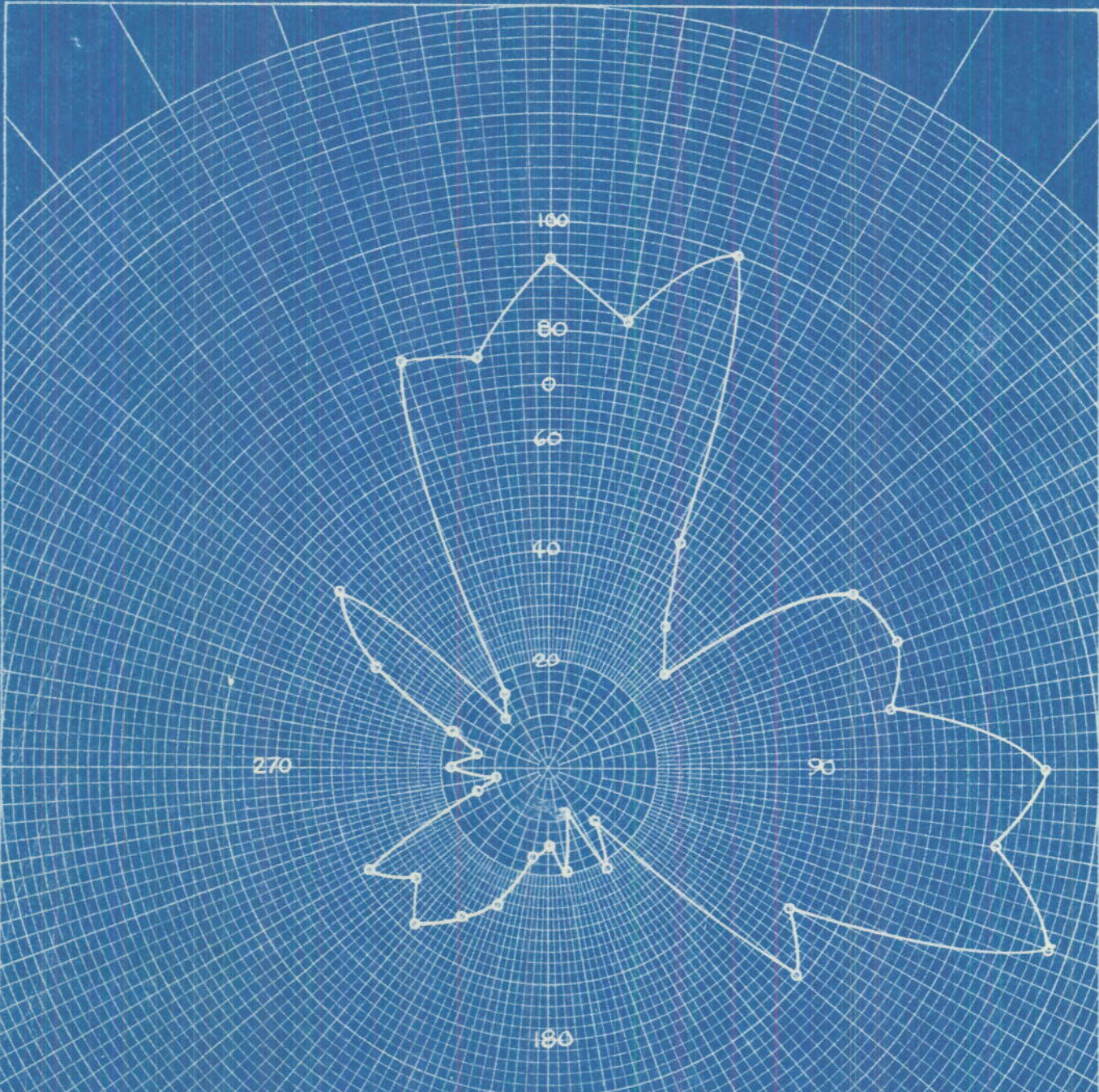
MODIFIED AS-49/APR-2 ANTENNA  
(CAG-66131)  
HORIZONTAL PATTERN  
VERTICAL POLARIZATION  
FREE SPACE PATTERN  
3000 MC/S

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PLATE 14



MODIFIED AS-49/APR-2 ANTENNA  
 (GAGW-66131)  
 HORIZONTAL PATTERN  
 VERTICAL POLARIZATION  
 FREE SPACE PATTERN  
 3500 MC/S

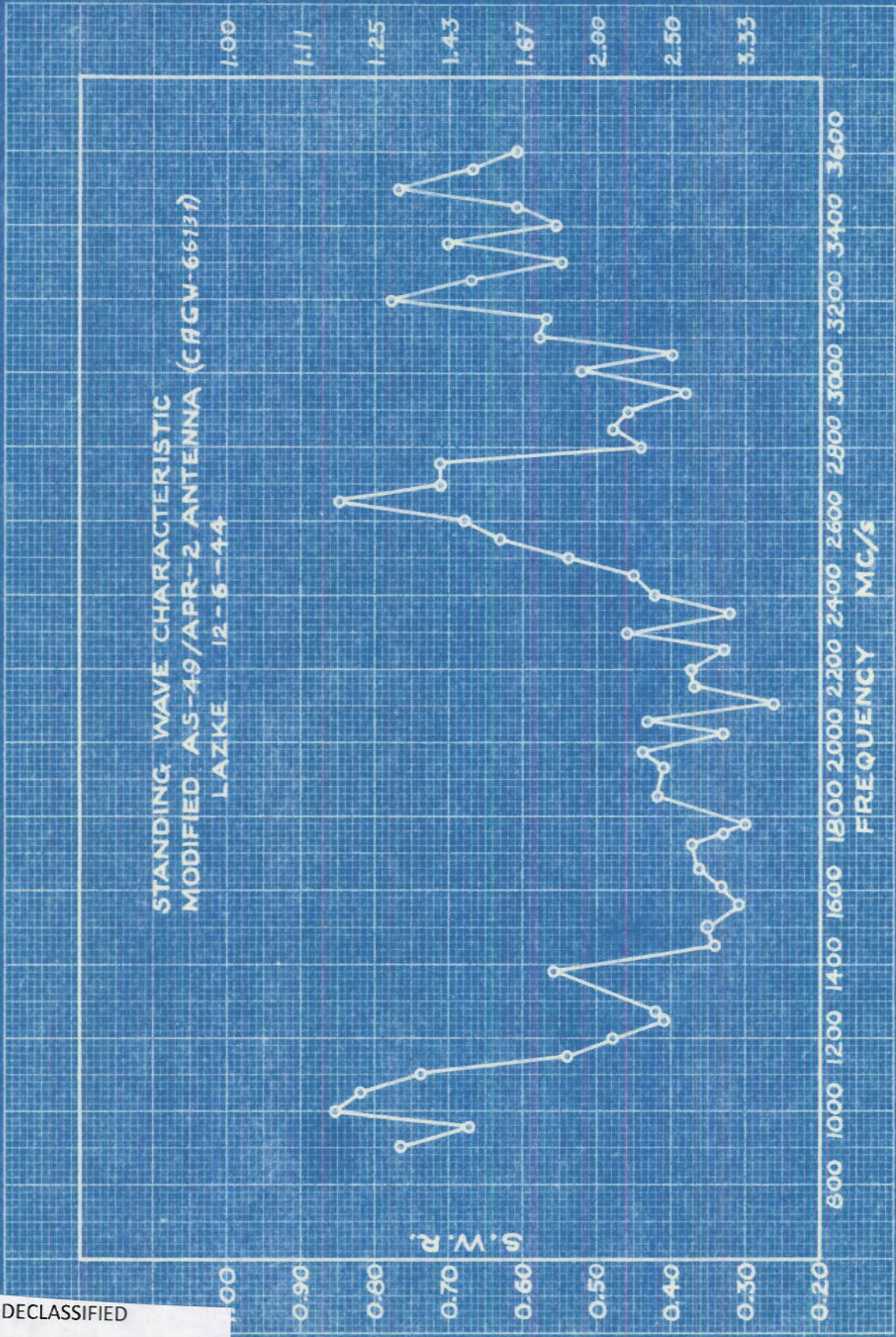
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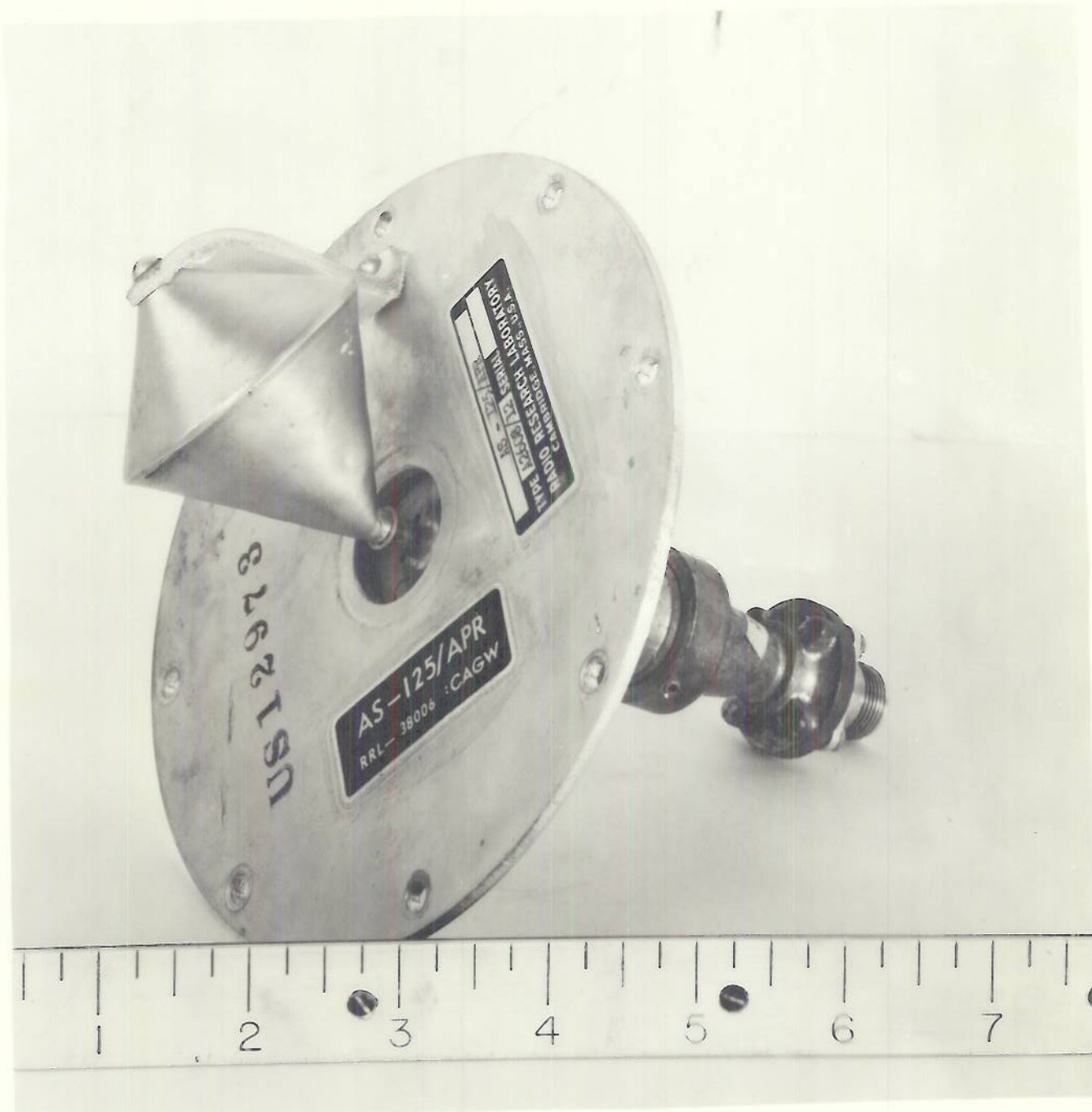
PLATE 15



STANDING WAVE CHARACTERISTIC  
 MODIFIED AS-49/APR-2 ANTENNA (CAGW-66131)  
 LAZKE 12-6-44



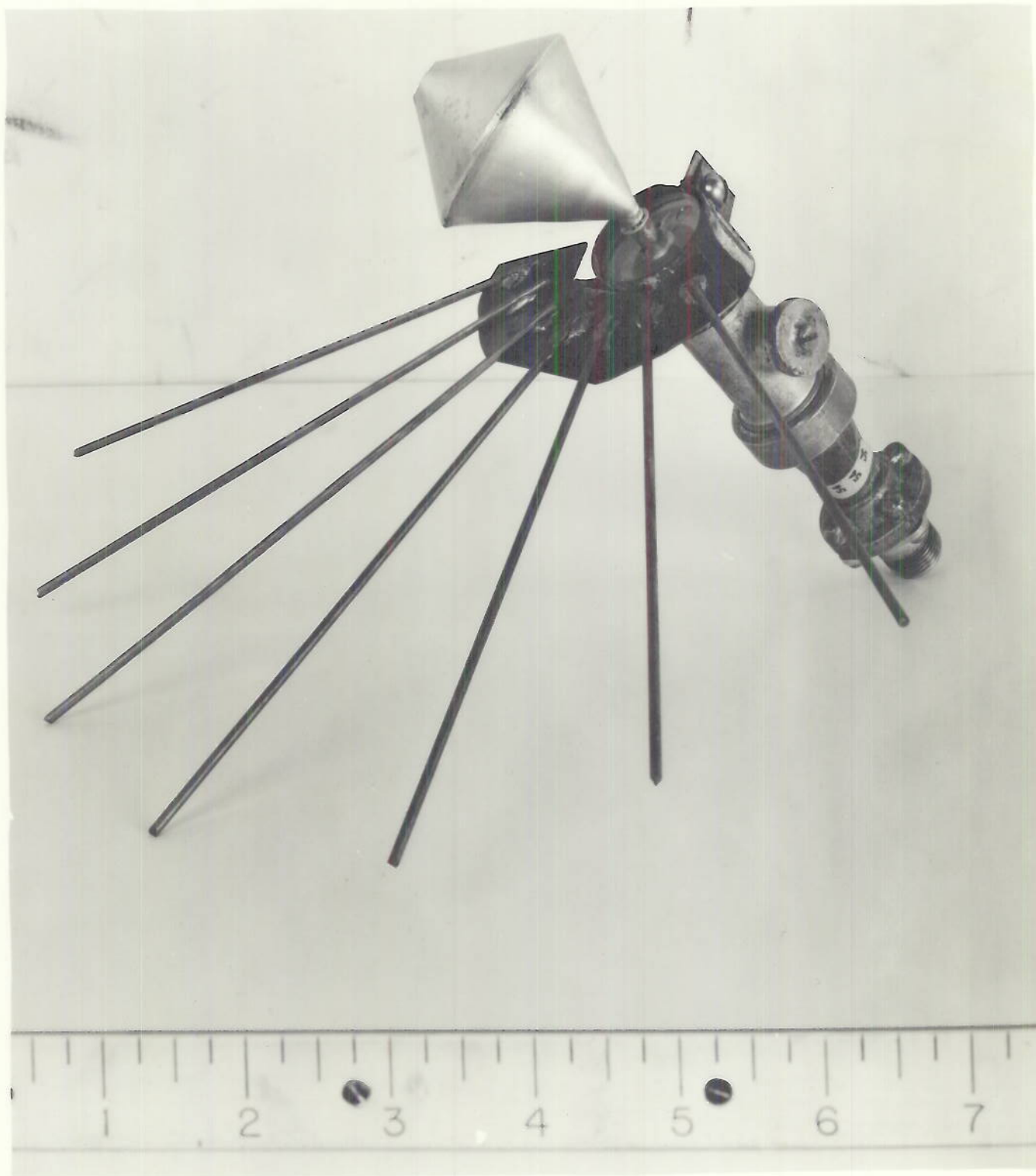
DECLASSIFIED



DECLASSIFIED

~~CONFIDENTIAL~~

AS-125/APR ANTENNA



DECLASSIFIED

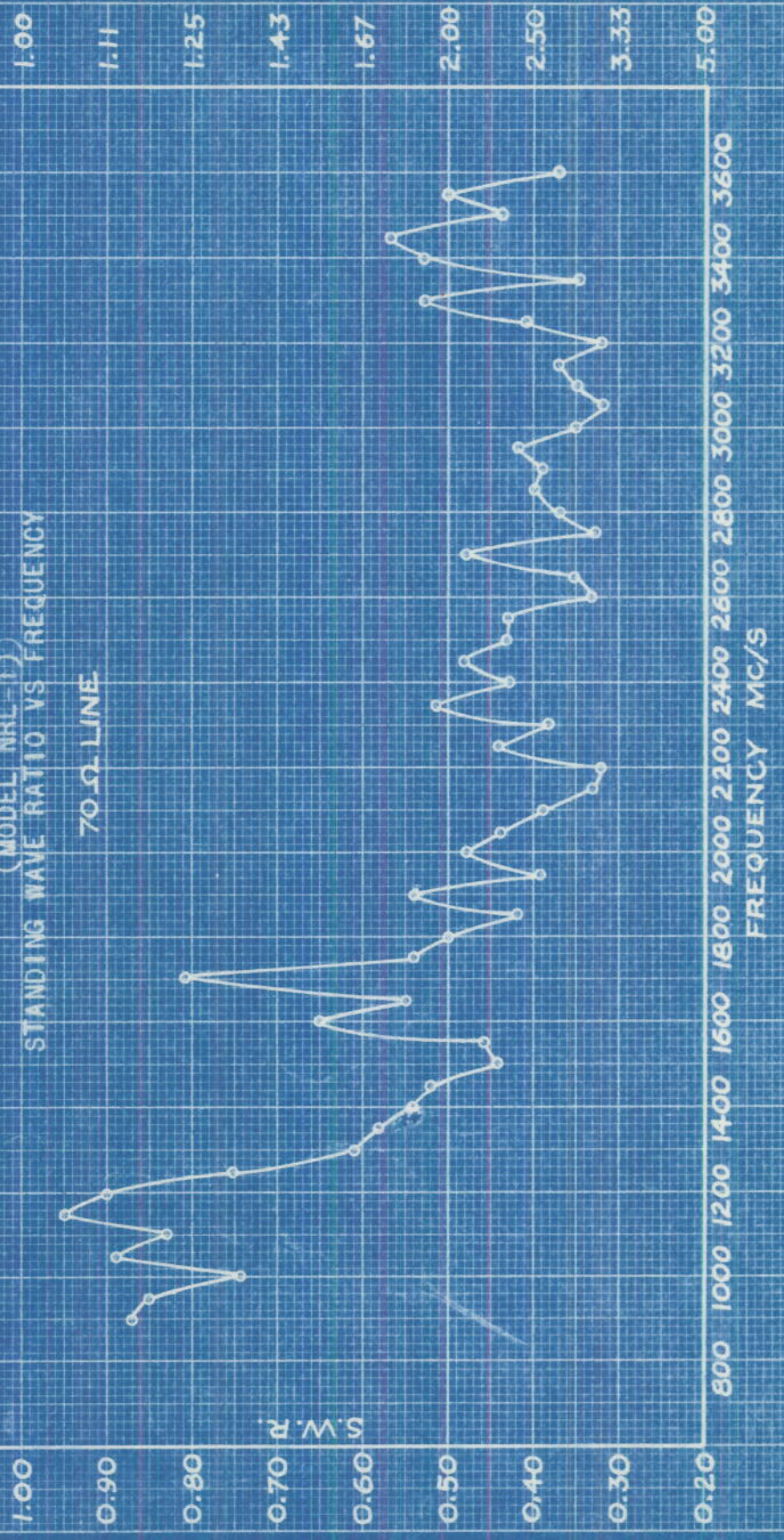
MODEL NRL-1 ANTENNA

PLATE 18

~~CONFIDENTIAL~~

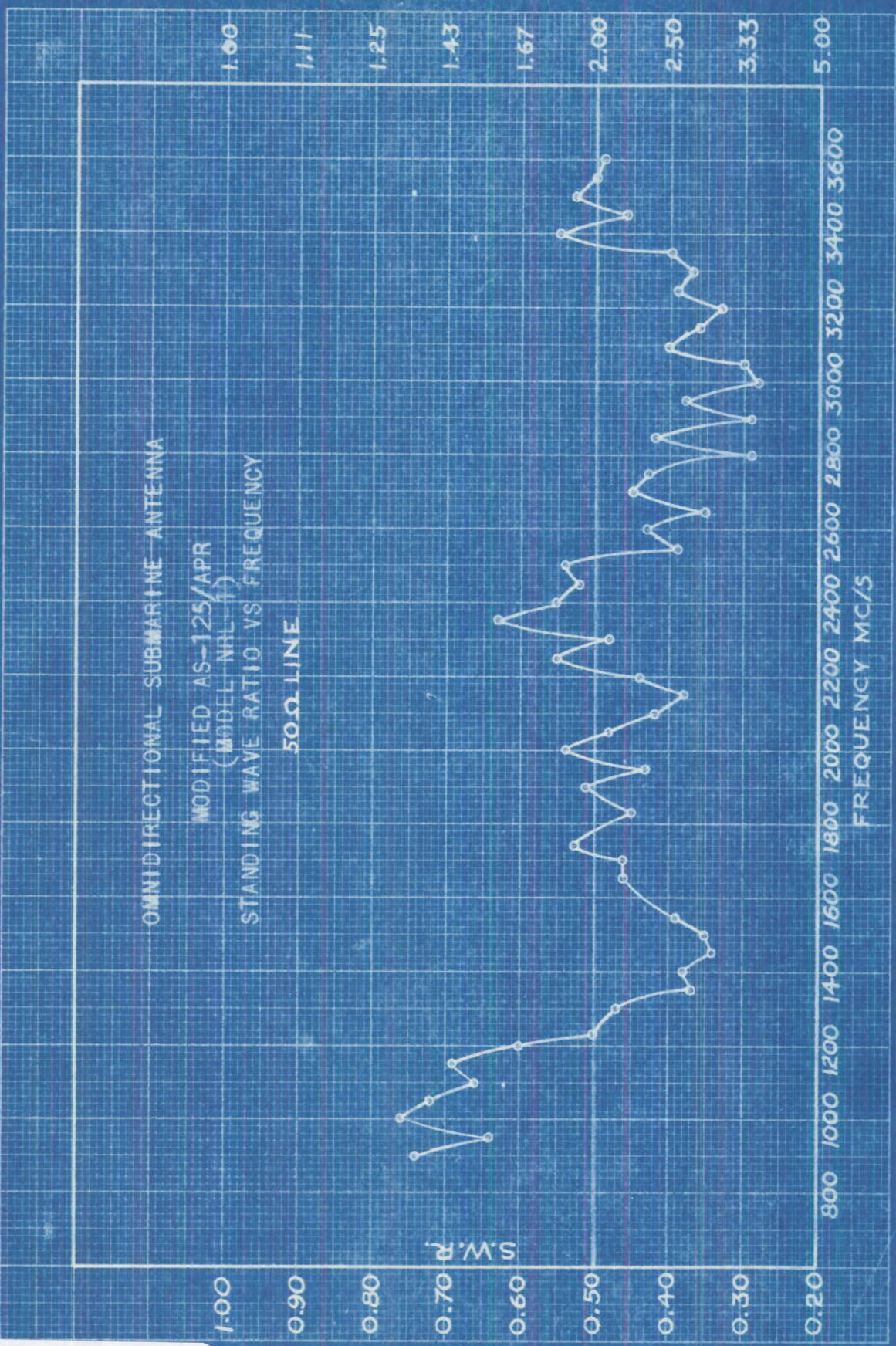


OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODIFIED AS-125/APR  
 (MODEL NRL-1)  
 STANDING WAVE RATIO VS FREQUENCY  
 70 Ω LINE



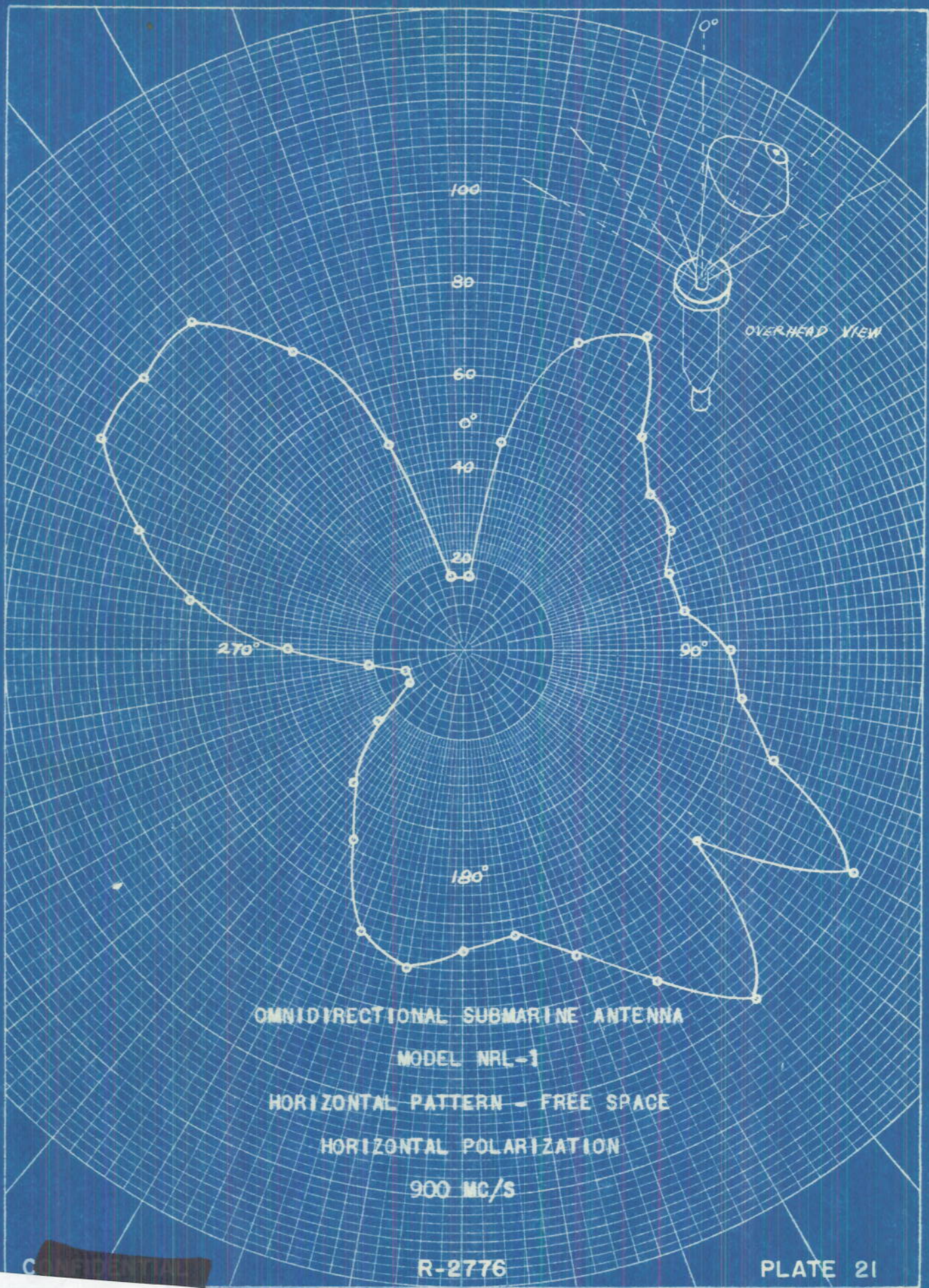
DECLASSIFIED

CONFIDENTIAL



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CONFIDENTIAL

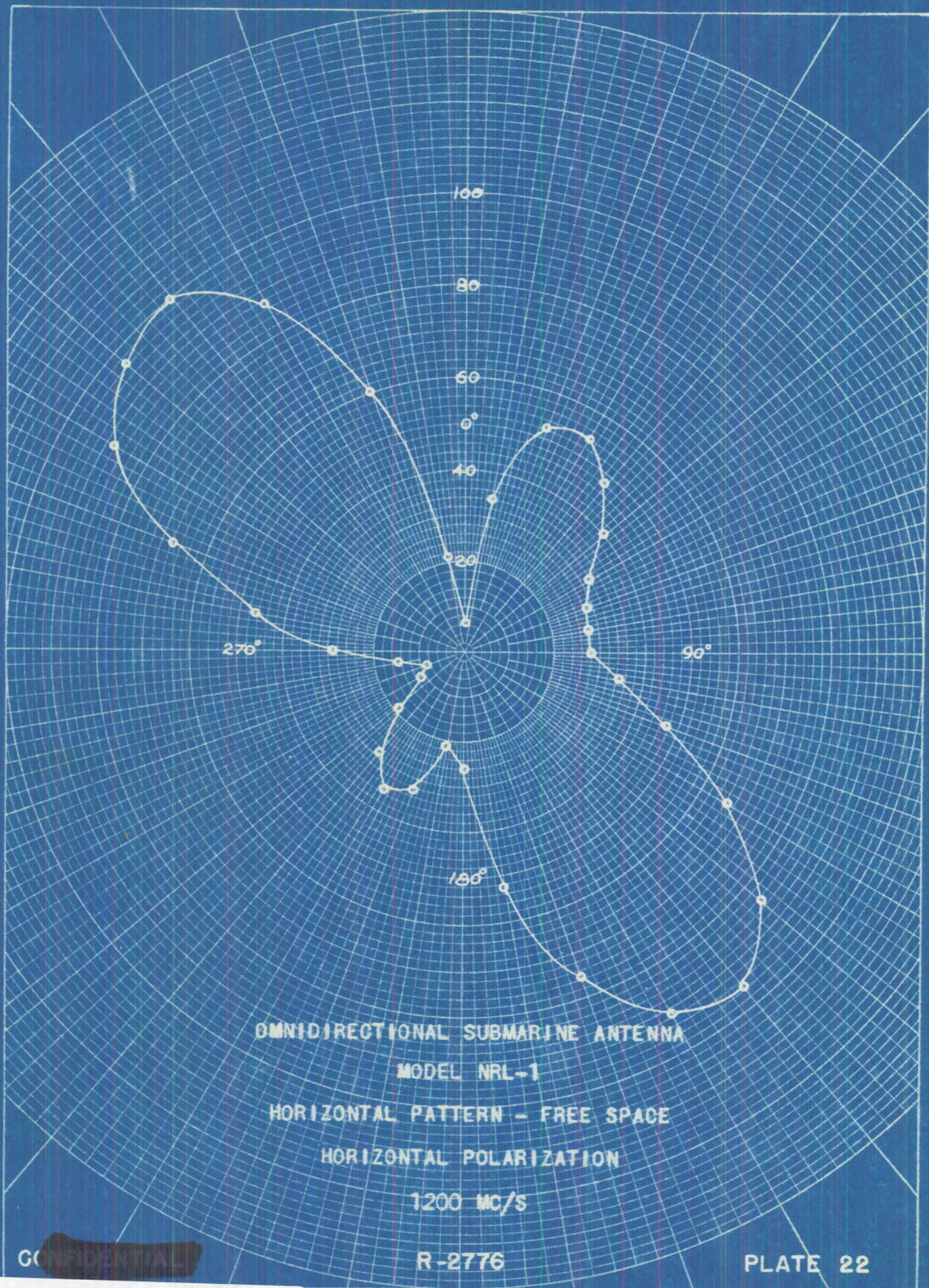


OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-1  
 HORIZONTAL PATTERN - FREE SPACE  
 HORIZONTAL POLARIZATION  
 900 MC/S

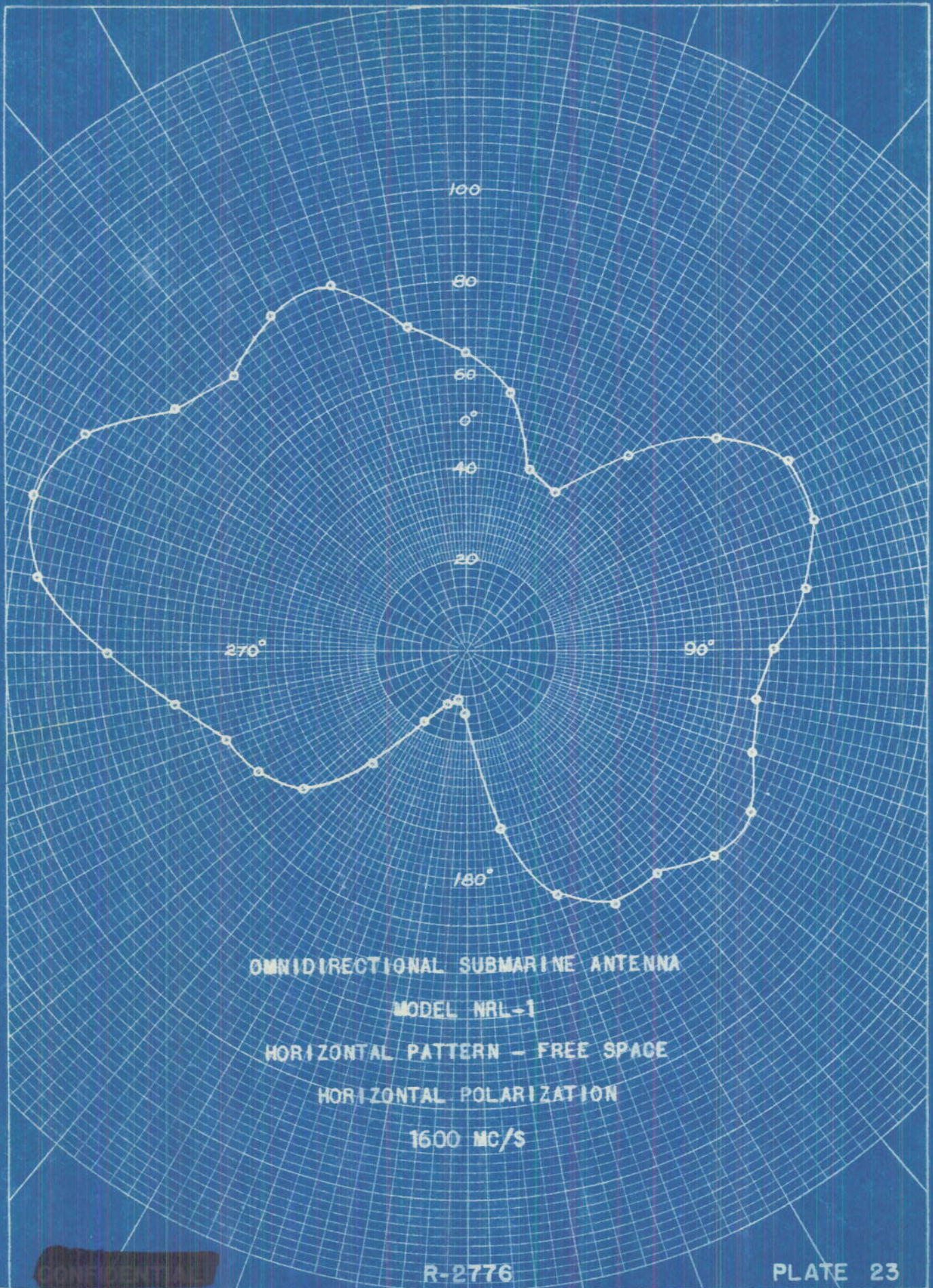
R-2776

PLATE 21

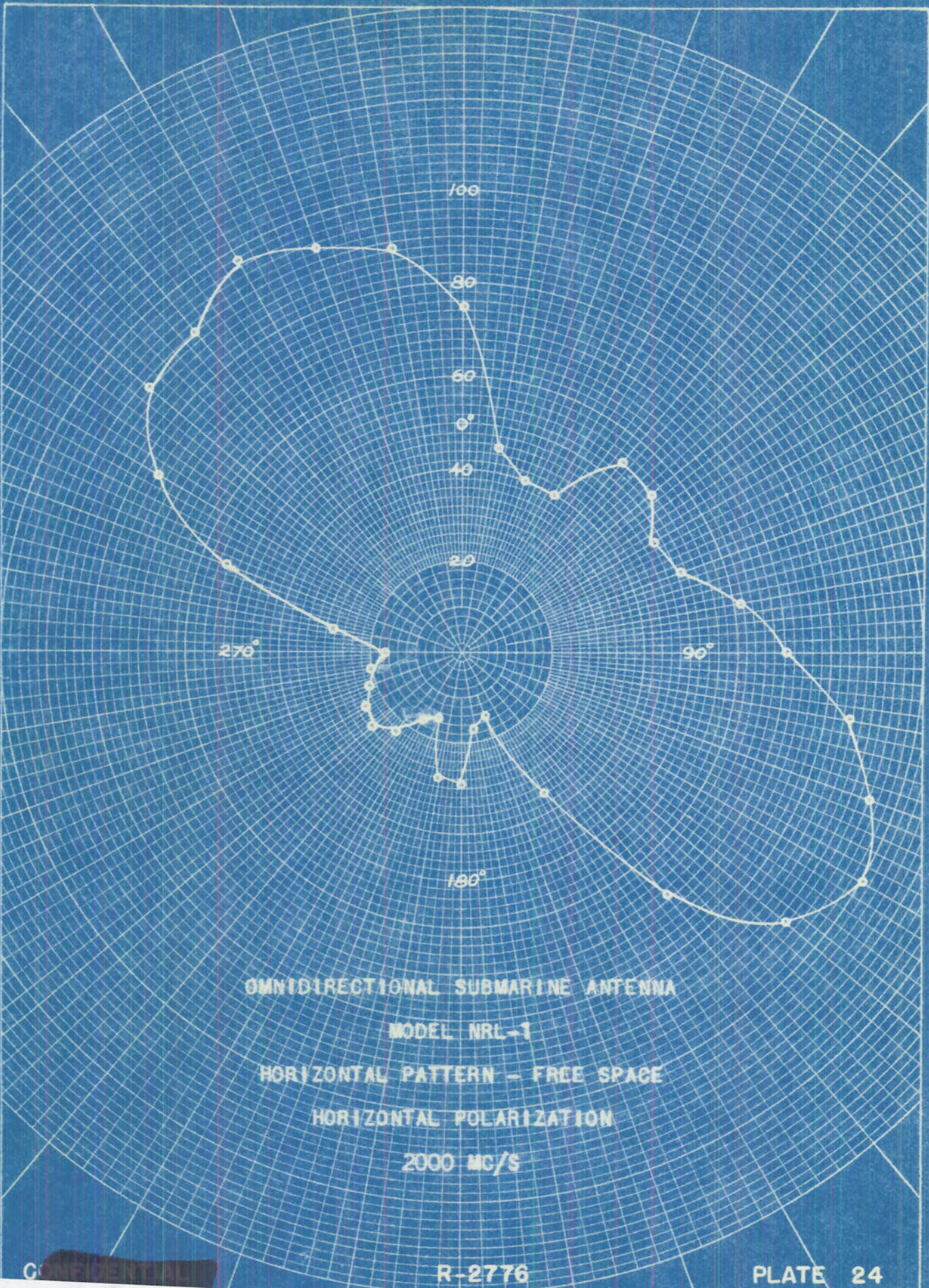
DECLASSIFIED



DECLASSIFIED



DECLASSIFIED



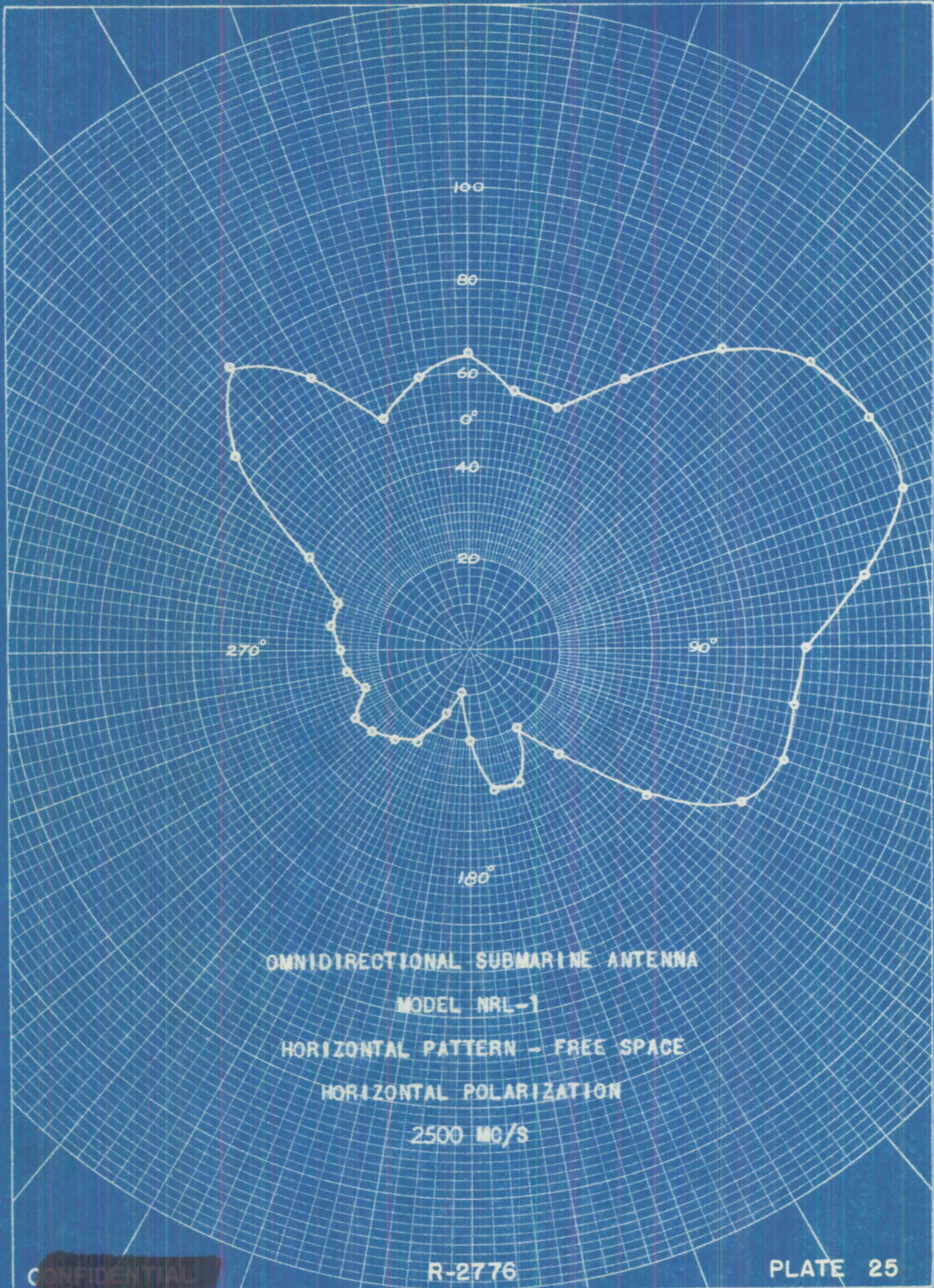
OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-1  
 HORIZONTAL PATTERN - FREE SPACE  
 HORIZONTAL POLARIZATION  
 2000 MC/S

C. [REDACTED]

R-2776

PLATE 24

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KEUFFEL & ESSER CO., N. Y. NO. 343B  
POLAR CO-ORDINATE  
MADE IN U. S. A.



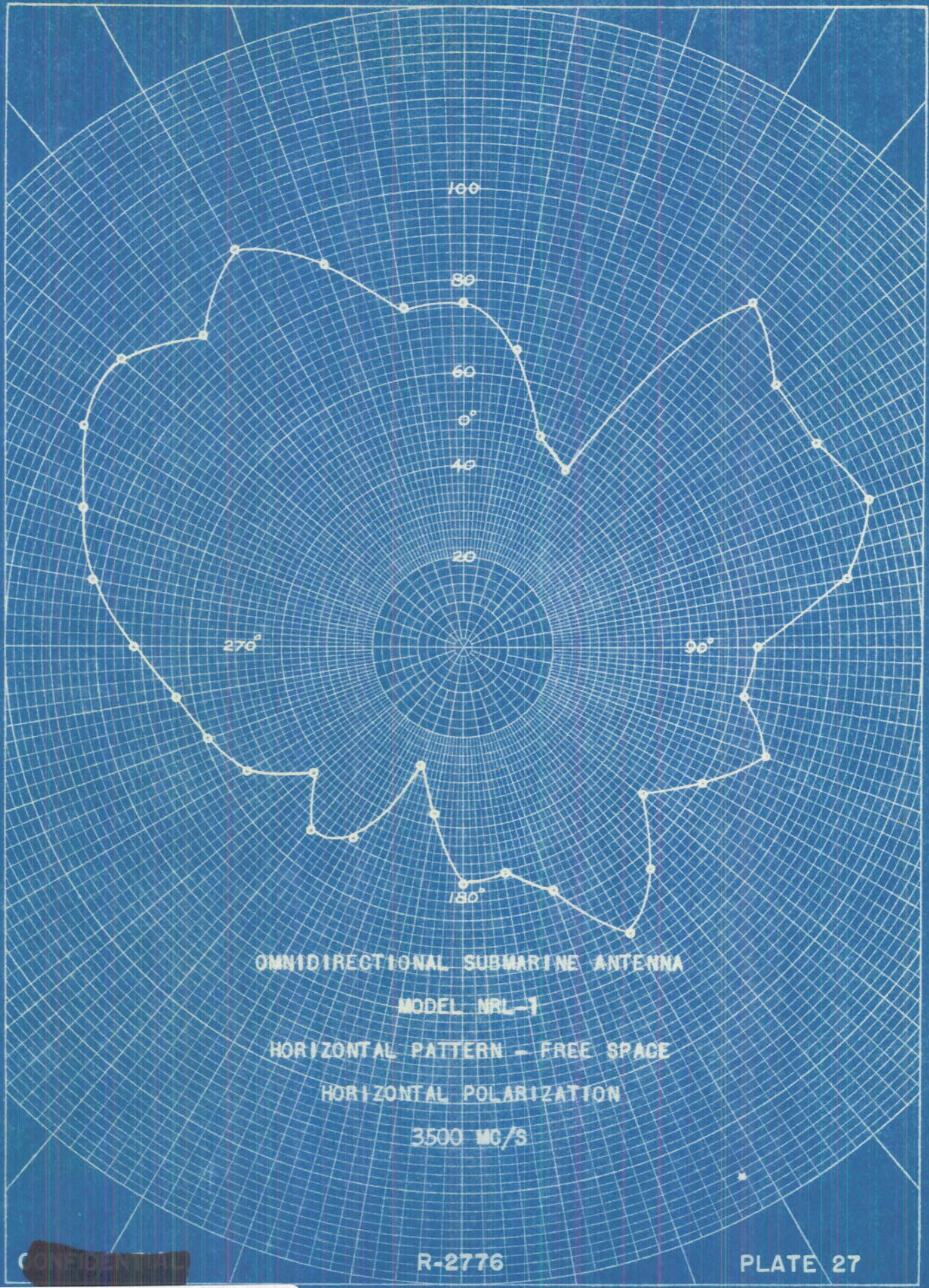
OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-1  
 HORIZONTAL PATTERN - FREE SPACE  
 HORIZONTAL POLARIZATION  
 3000 MC/S

DECLASSIFIED

C [REDACTED]

R-2776

PLATE 26



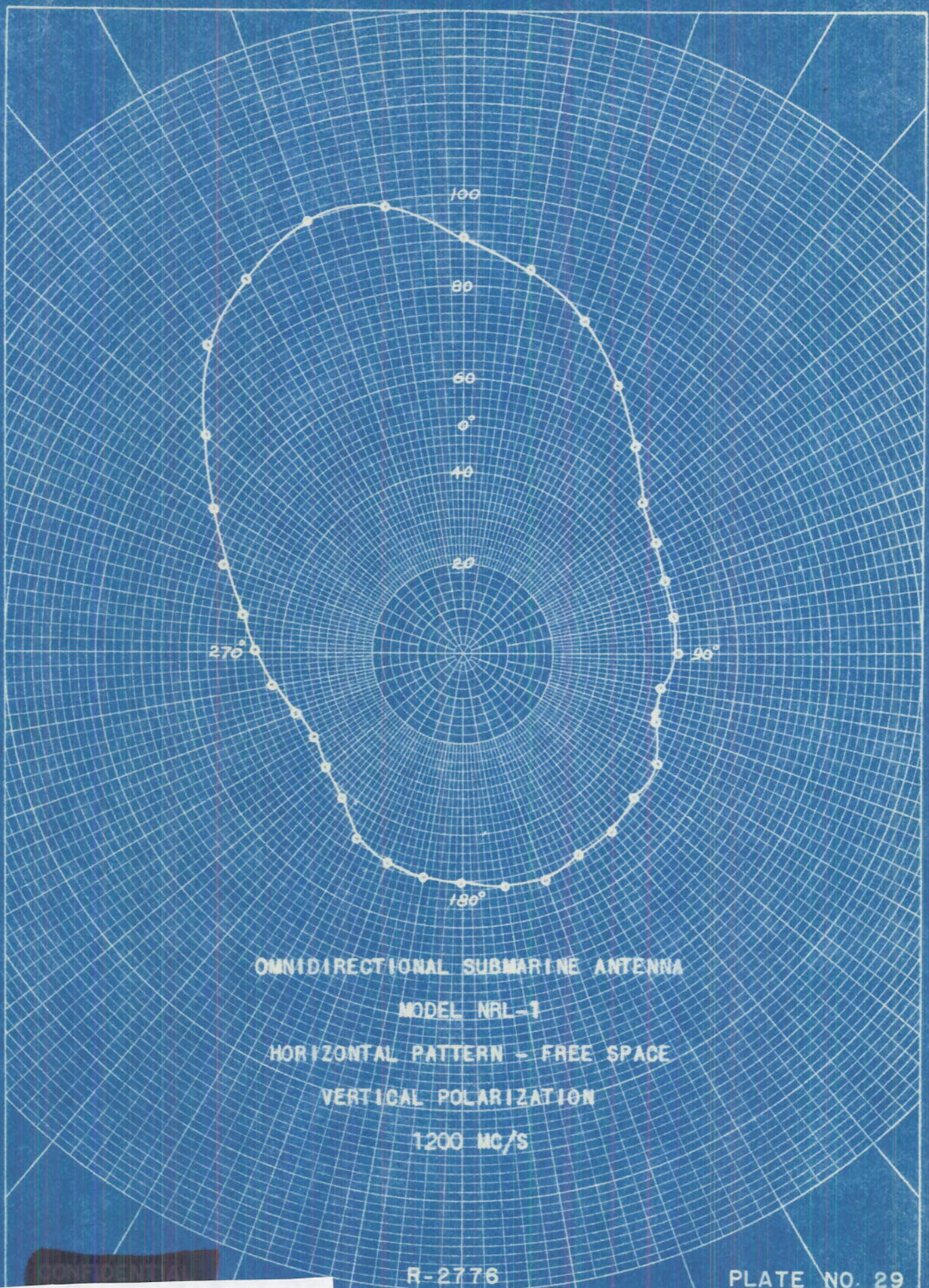
OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-1  
 HORIZONTAL PATTERN - FREE SPACE  
 HORIZONTAL POLARIZATION  
 3500 MC/S

R-2776

PLATE 27

DECLASSIFIED

KEUFFEL & ESSER CO., N. Y. NO. 343B  
 POLAR CO-ORDINATE  
 MADE IN U. S. A.

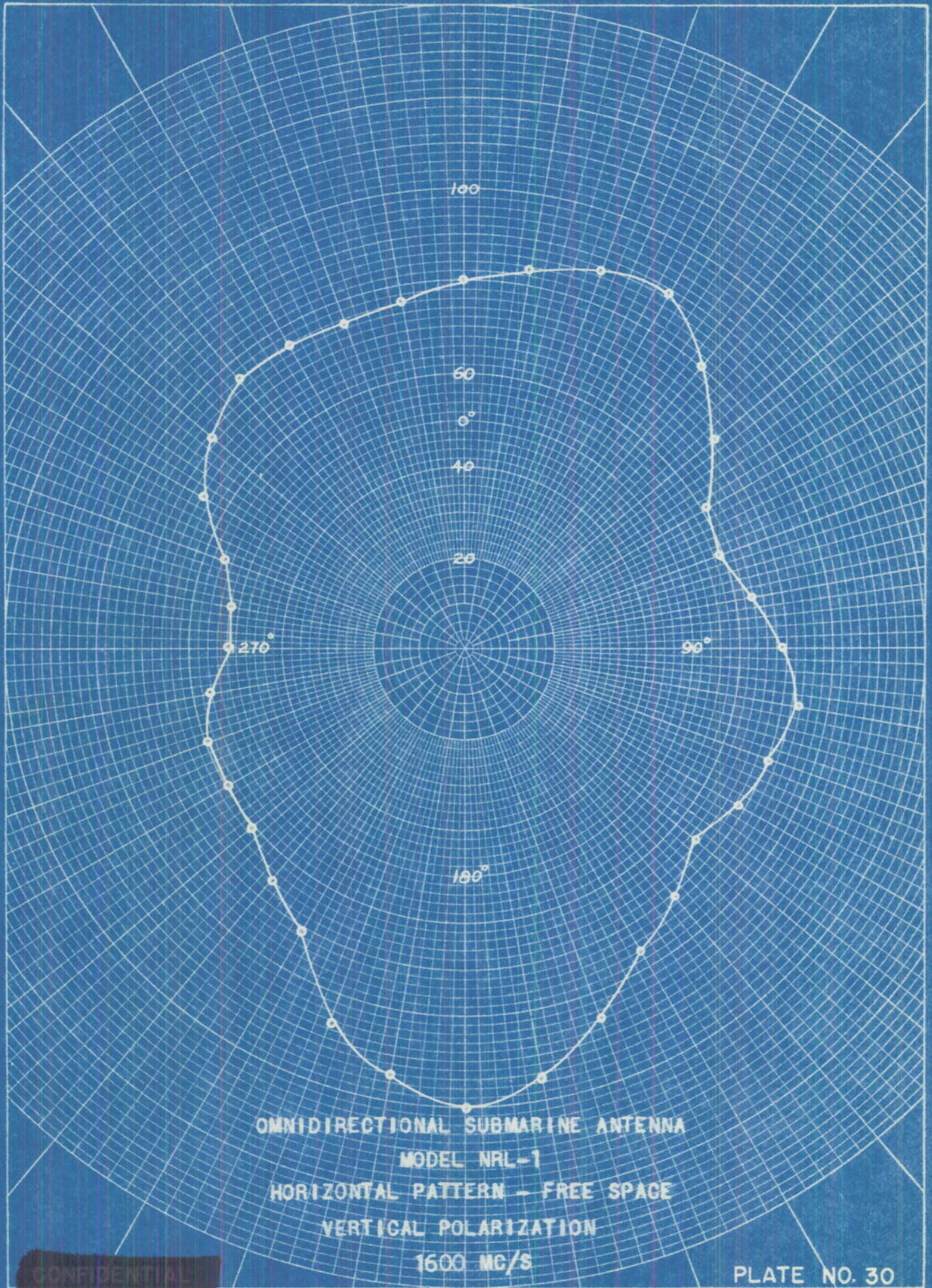


OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-1  
 HORIZONTAL PATTERN - FREE SPACE  
 VERTICAL POLARIZATION  
 1200 MC/S

R-2776

PLATE NO. 29

DECLASSIFIED

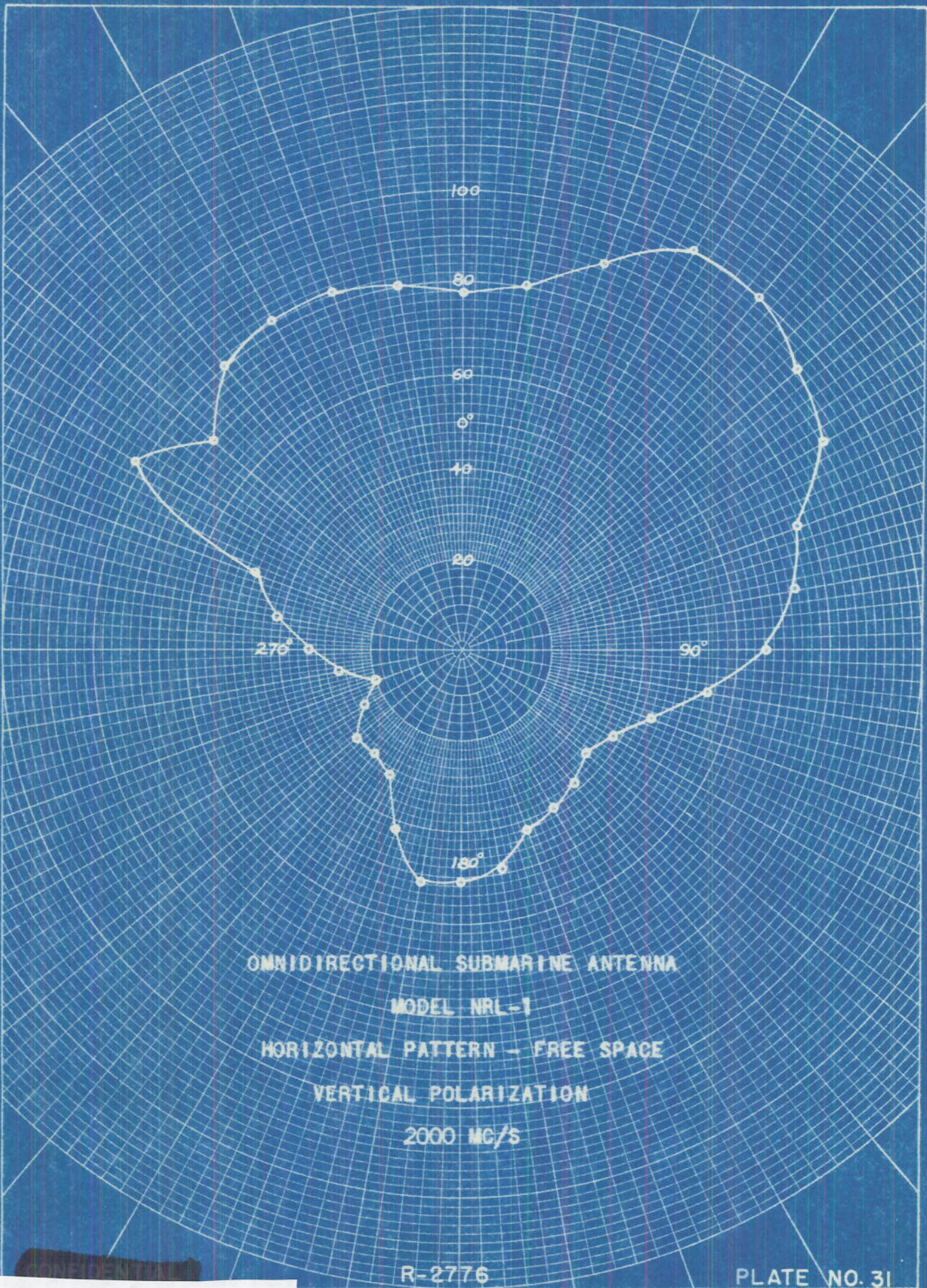


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DECLASSIFIED

KEUFFEL & ESSER CO., N. Y. NO. 343B  
 POLAR CO-ORDINATE  
 MADE IN U. S. A.

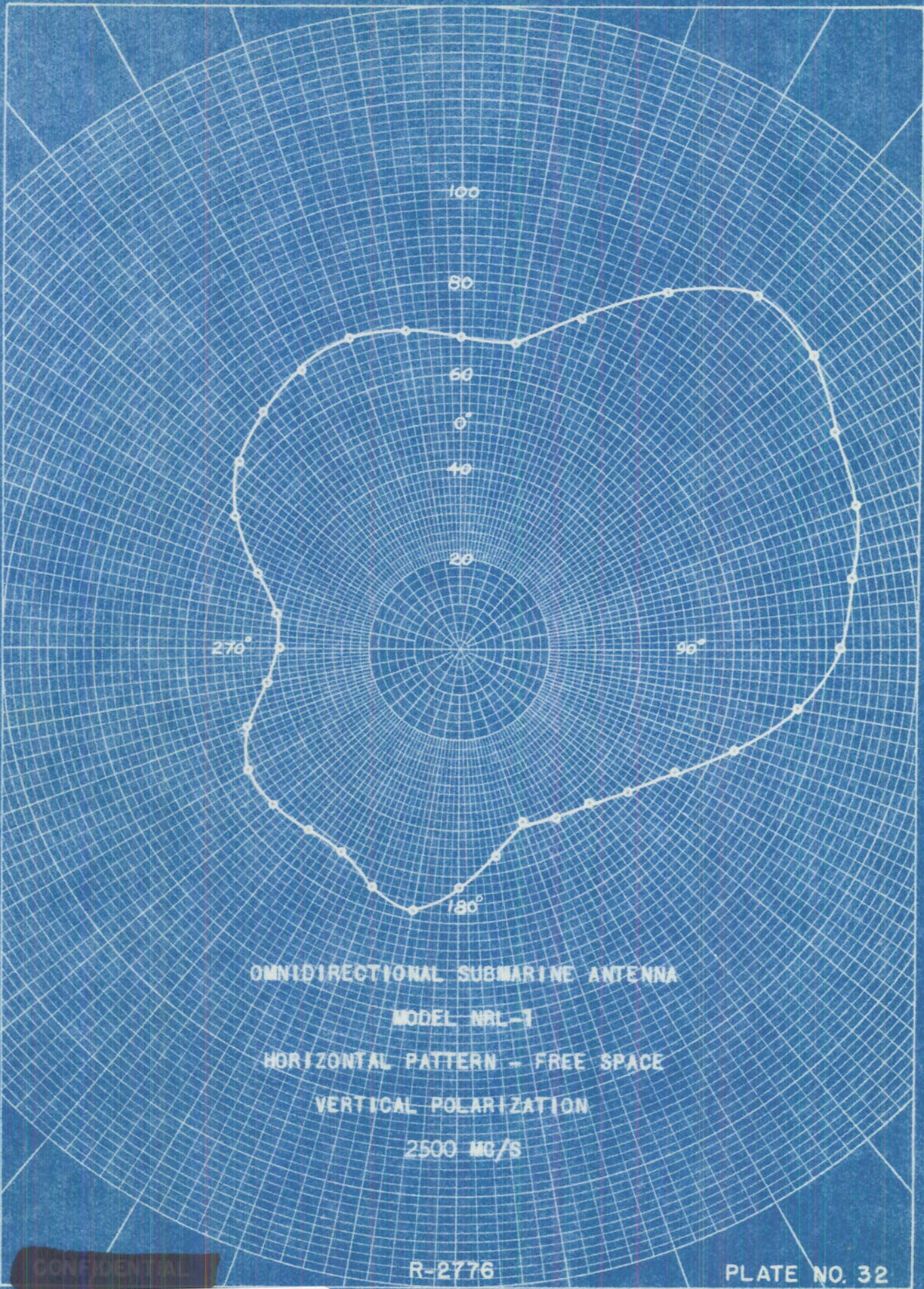


OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-1  
 HORIZONTAL PATTERN - FREE SPACE  
 VERTICAL POLARIZATION  
 2000 MC/S

R-2776

PLATE NO. 31

DECLASSIFIED



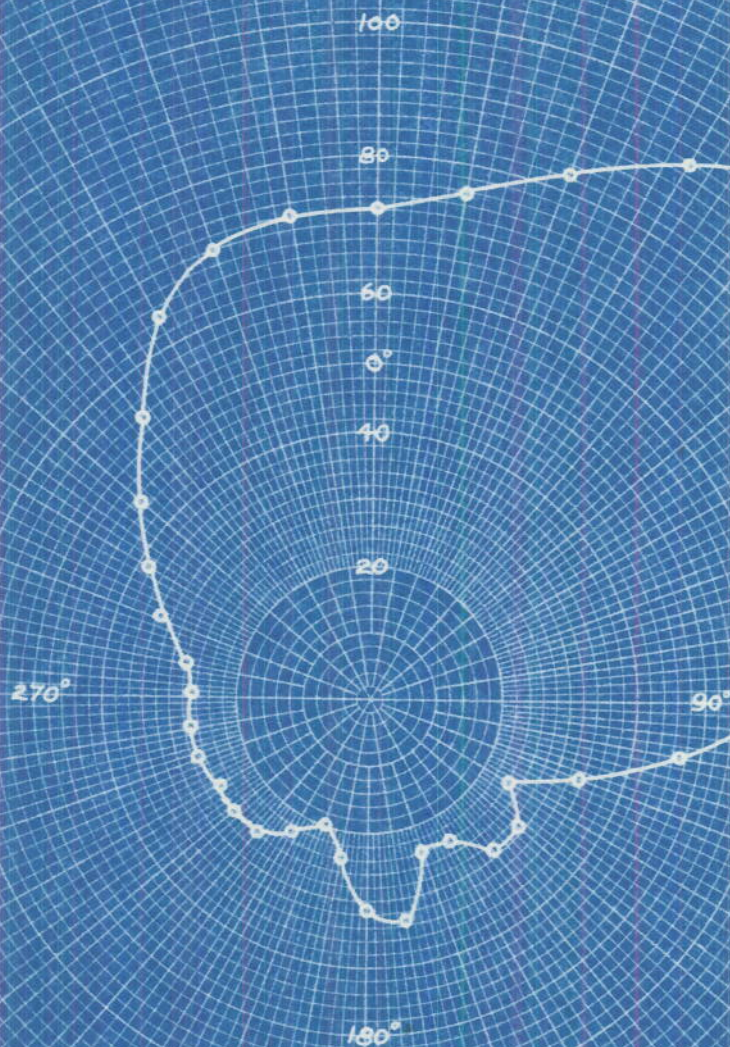
OMNIDIRECTIONAL SUBMARINE ANTENNA  
MODEL NRL-1  
HORIZONTAL PATTERN - FREE SPACE  
VERTICAL POLARIZATION  
2500 MC/S

R-2776

PLATE NO. 32

DECLASSIFIED

KEUFFEL & ESSER CO., N. Y. NO. 343B  
POLAR CO-ORDINATE  
MADE IN U. S. A.



OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-1  
 HORIZONTAL PATTERN - FREE SPACE  
 VERTICAL POLARIZATION  
 3000 MC/S

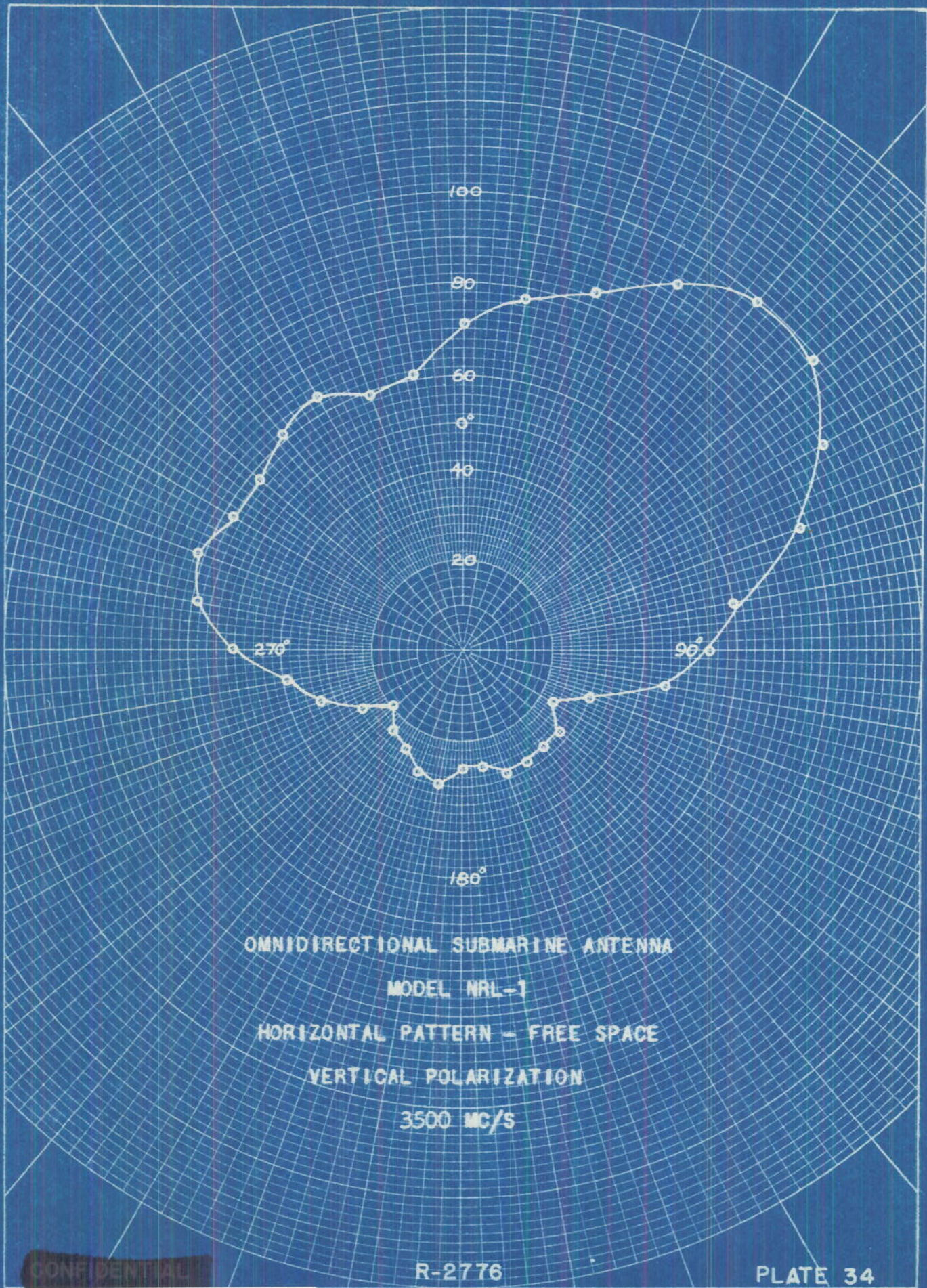
R-2776

PLATE 33

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KEUFFEL & ESSER CO., N. Y. NO. 343B  
 POLAR CO-ORDINATE  
 MADE IN U. S. A.



OMNIDIRECTIONAL SUBMARINE ANTENNA

MODEL NRL-1

HORIZONTAL PATTERN - FREE SPACE

VERTICAL POLARIZATION

3500 MC/S

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R-2776

PLATE 34

DECLASSIFIED

KEUFFEL & ESSER CO., N. Y. NO. 343B  
POLAR CO-ORDINATE  
MADE IN U. S. A.

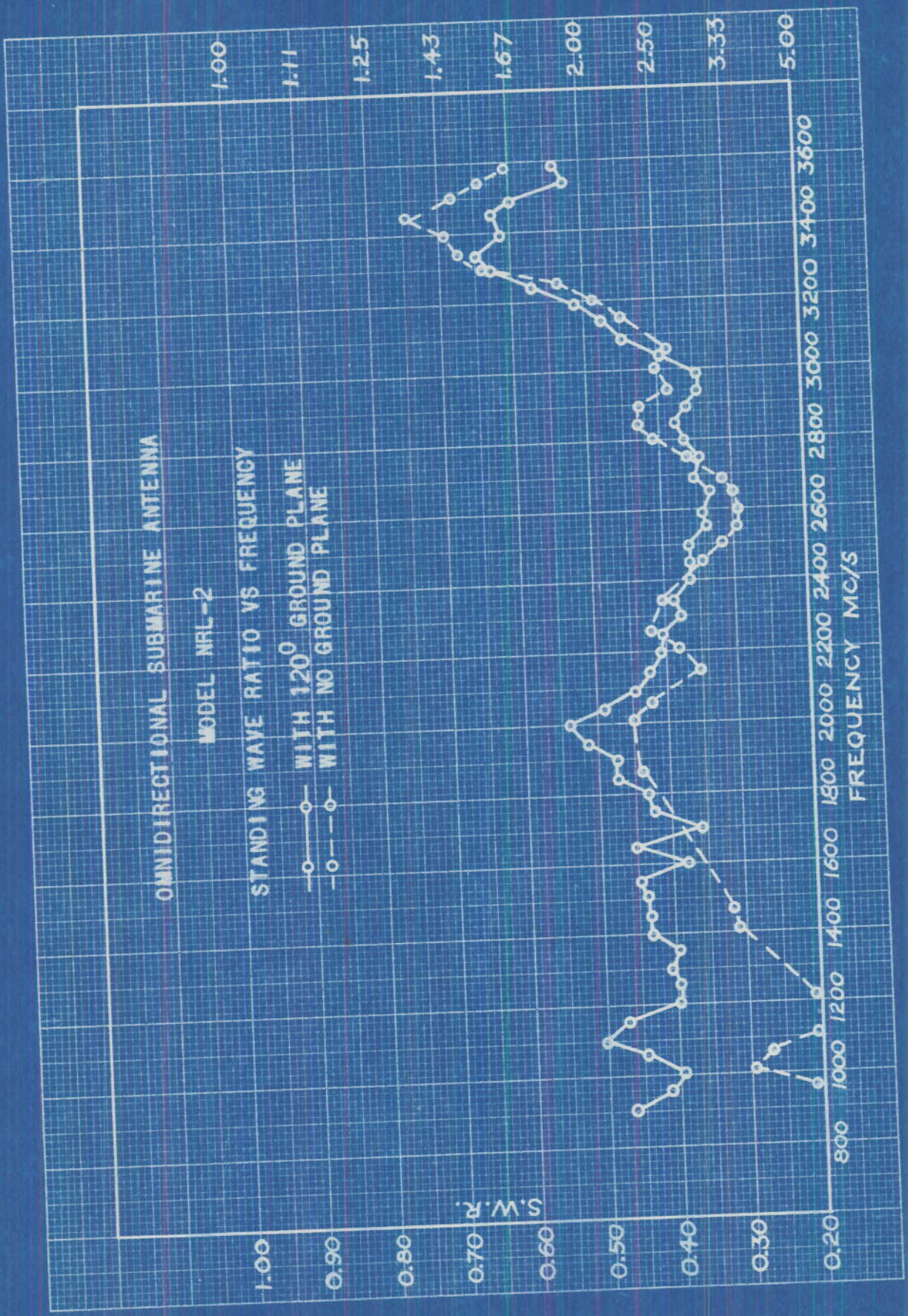


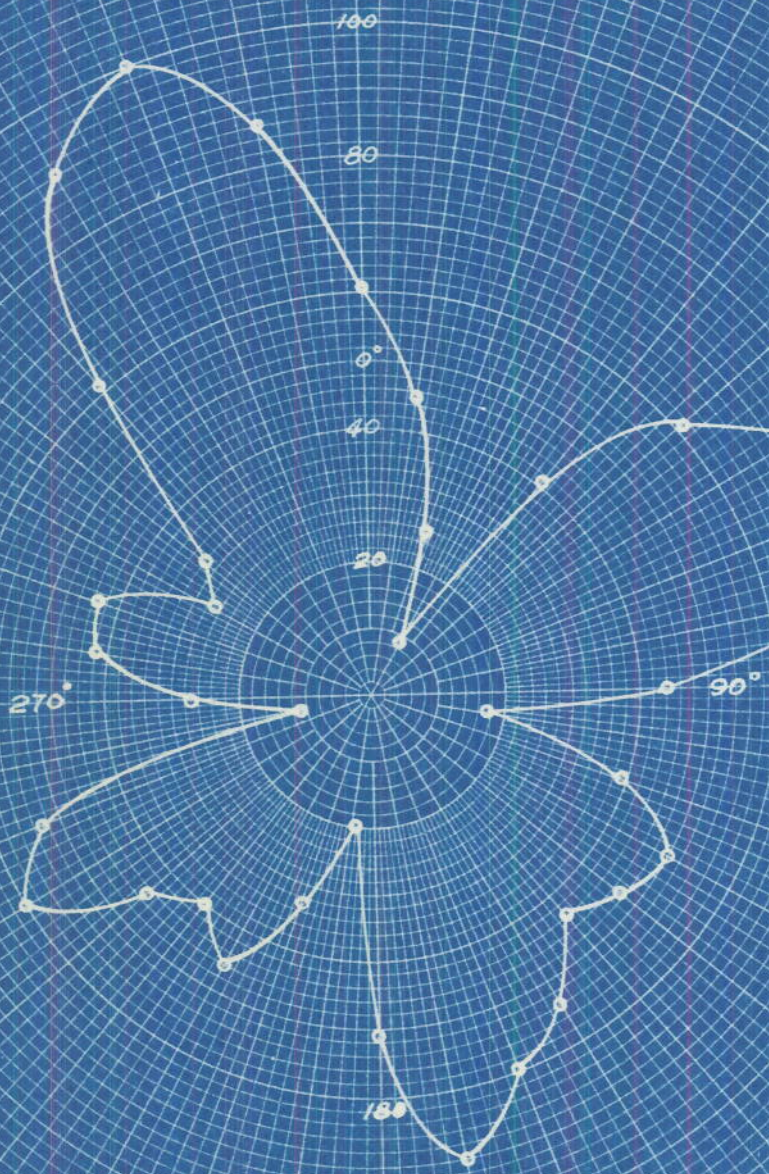
DECLASSIFIED

~~CONFIDENTIAL~~

MODEL NRL-2 ANTENNA

PLATE 35





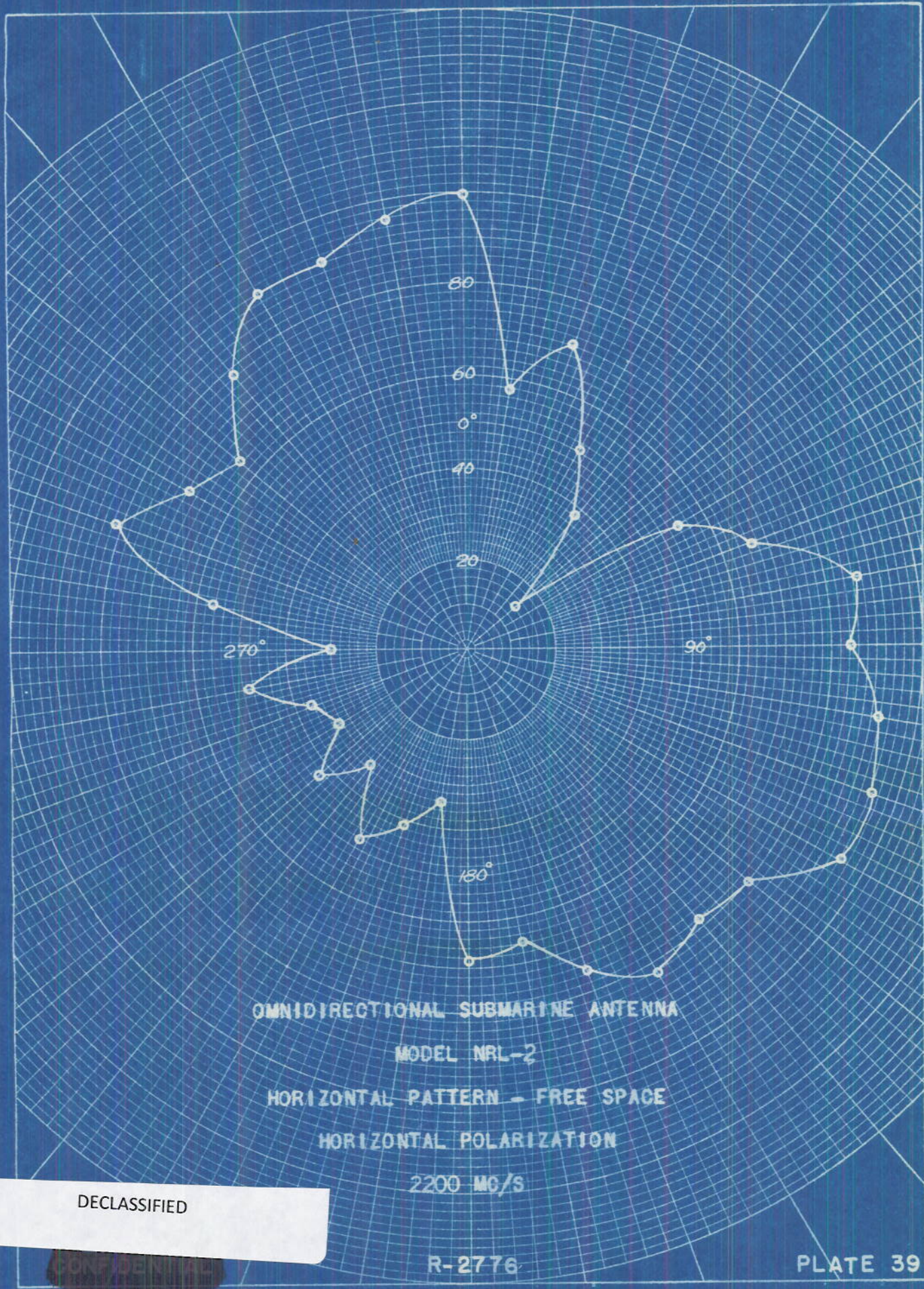
OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-2  
 HORIZONTAL PATTERN - FREE SPACE  
 HORIZONTAL POLARIZATION  
 1200 MC/S

R-2776

PLATE 38

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OMNIDIRECTIONAL SUBMARINE ANTENNA

MODEL NRL-2

HORIZONTAL PATTERN - FREE SPACE

HORIZONTAL POLARIZATION

2200 MC/S

R-2776

PLATE 39

DECLASSIFIED



OMNIDIRECTIONAL SUBMARINE ANTENNA

MODEL NRL-2

HORIZONTAL PATTERN - FREE SPACE

HORIZONTAL POLARIZATION

2500 MC/S

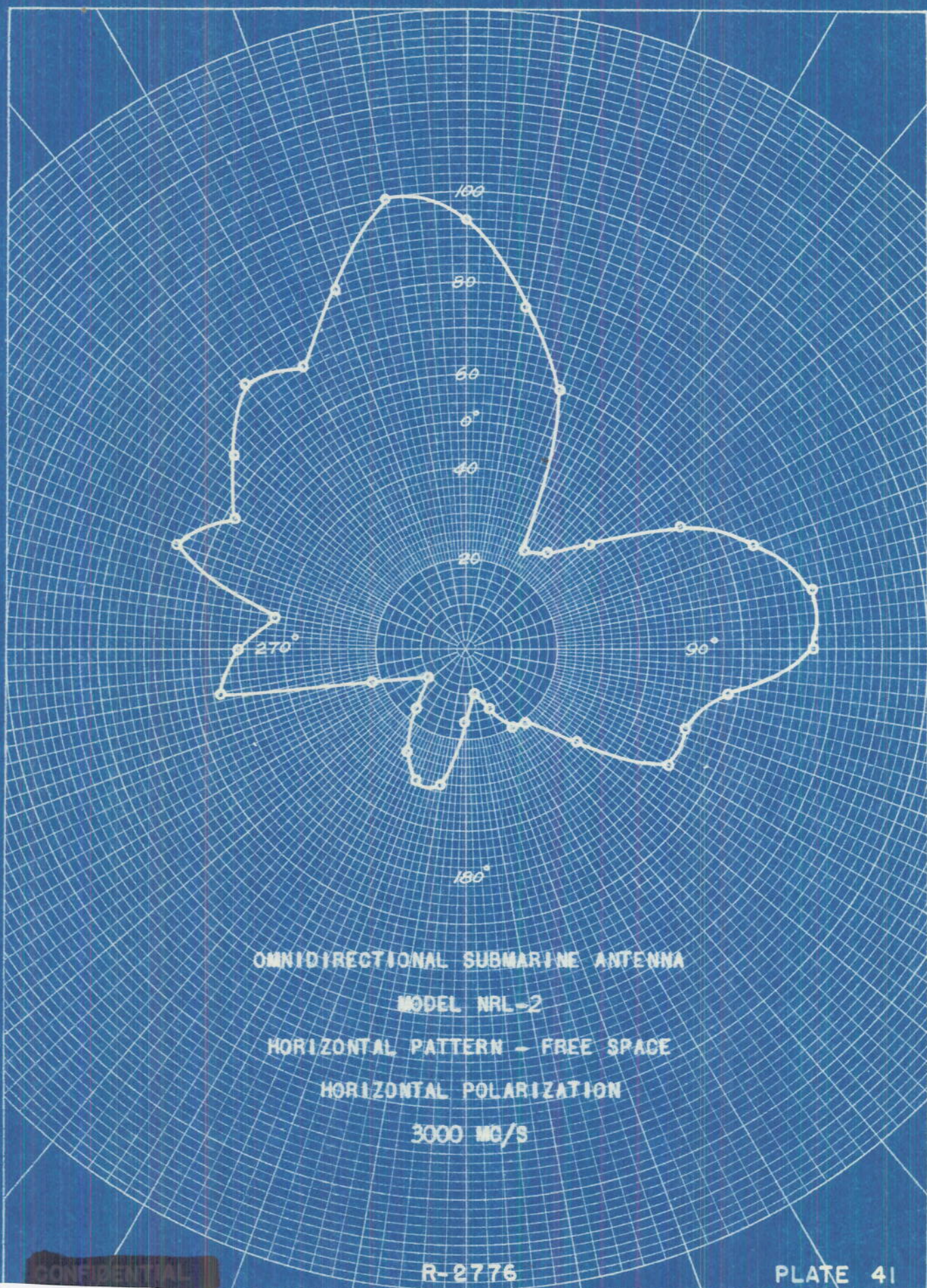
**CONFIDENTIAL**

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PLATE 40

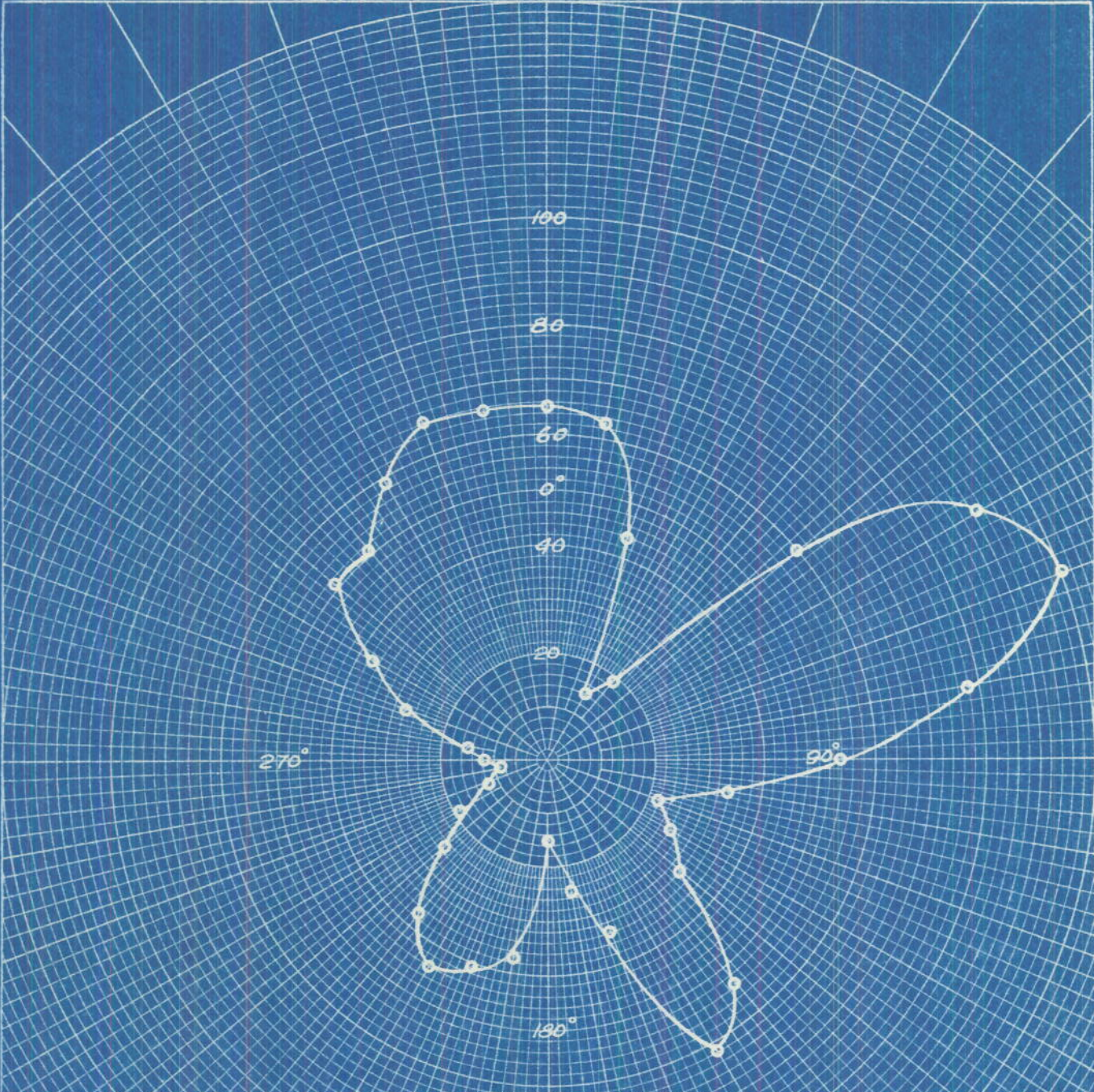
DECLASSIFIED

KEUFFEL & ESSER CO., N. Y. NO. 343B  
POLAR CO-ORDINATE  
MADE IN U. S. A.



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DECLASSIFIED



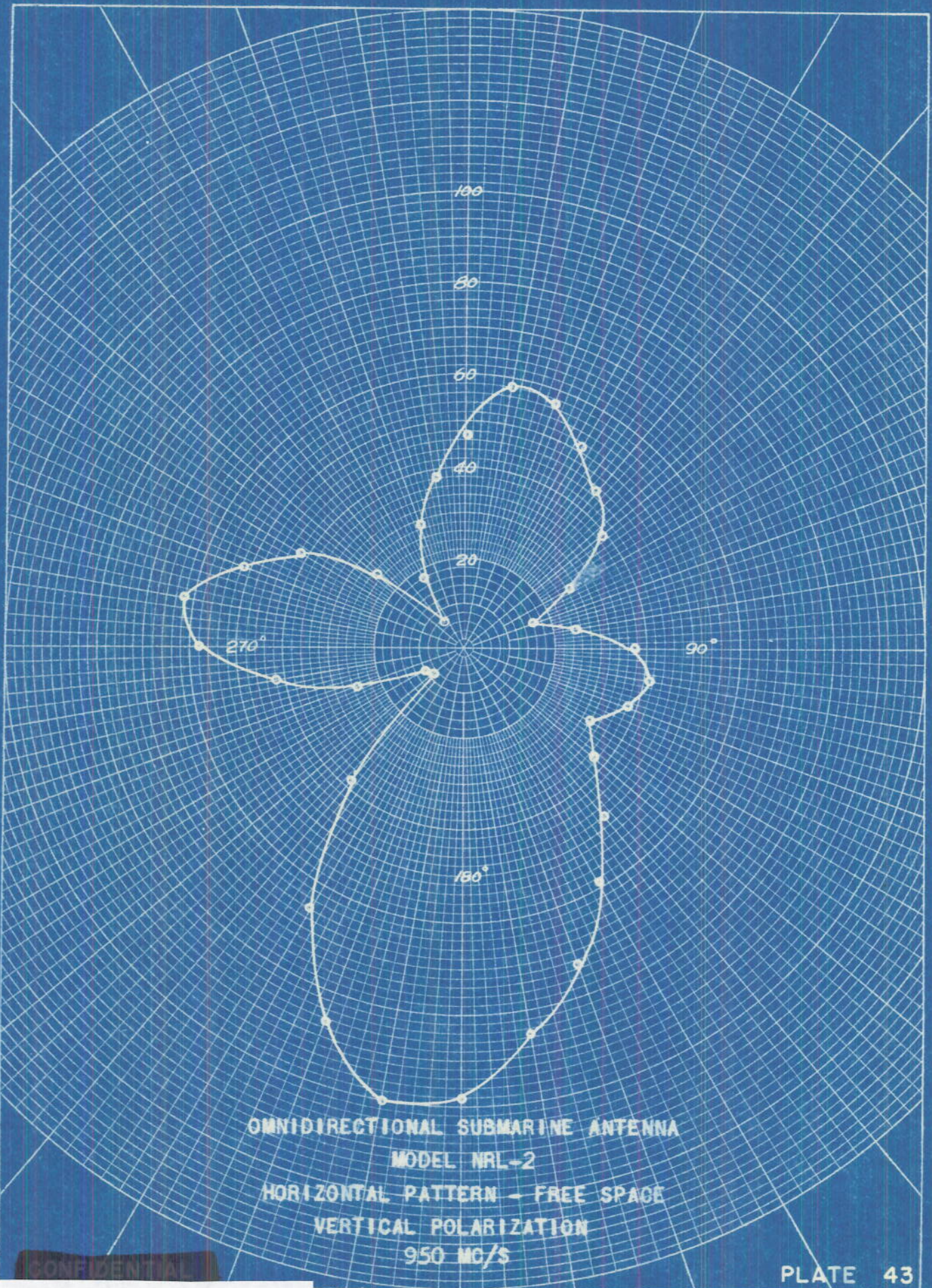
OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-2  
 HORIZONTAL PATTERN - FREE SPACE  
 HORIZONTAL POLARIZATION  
 3500 MC/S

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PLATE 42



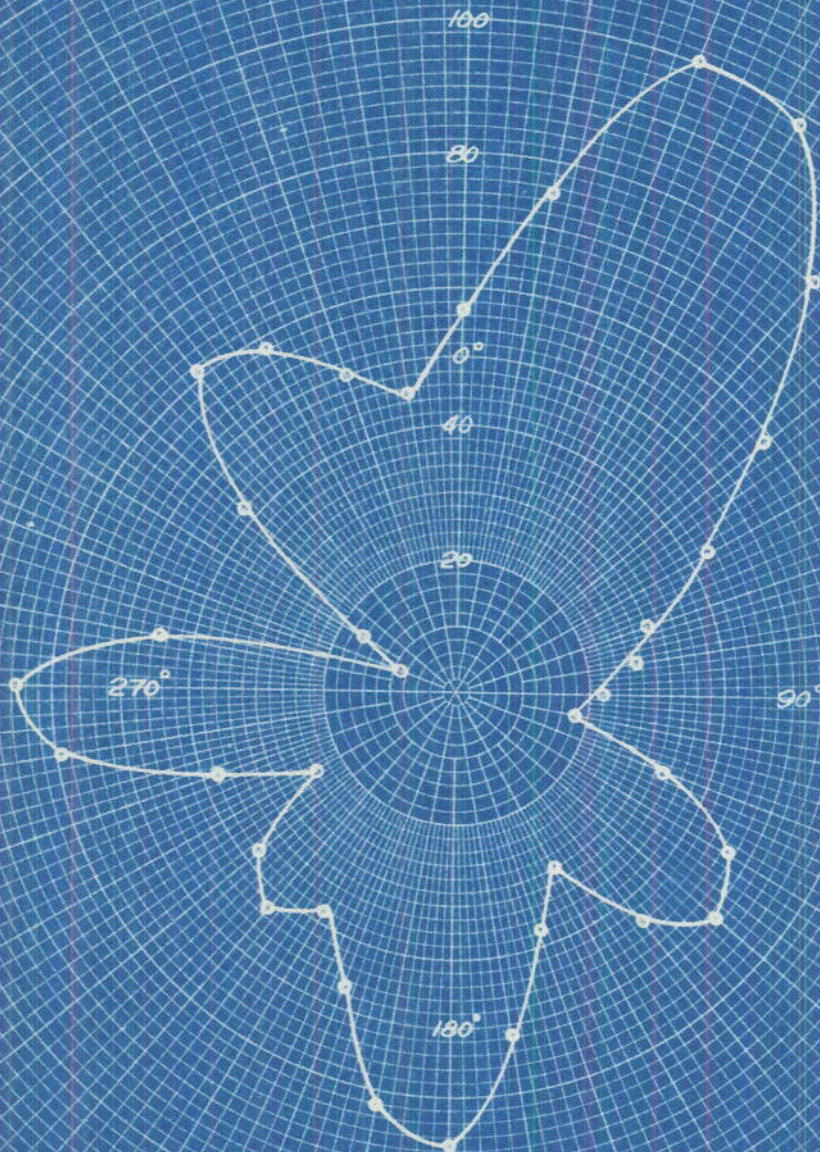
OMNIDIRECTIONAL SUBMARINE ANTENNA  
MODEL NRL-2  
HORIZONTAL PATTERN - FREE SPACE  
VERTICAL POLARIZATION  
950 MC/S

PLATE 43

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KEUFFEL & ESSER CO., N. Y. NO. 343B  
POLAR CO-ORDINATE  
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OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-2  
 HORIZONTAL PATTERN - FREE SPACE  
 VERTICAL POLARIZATION  
 1200 MC/S

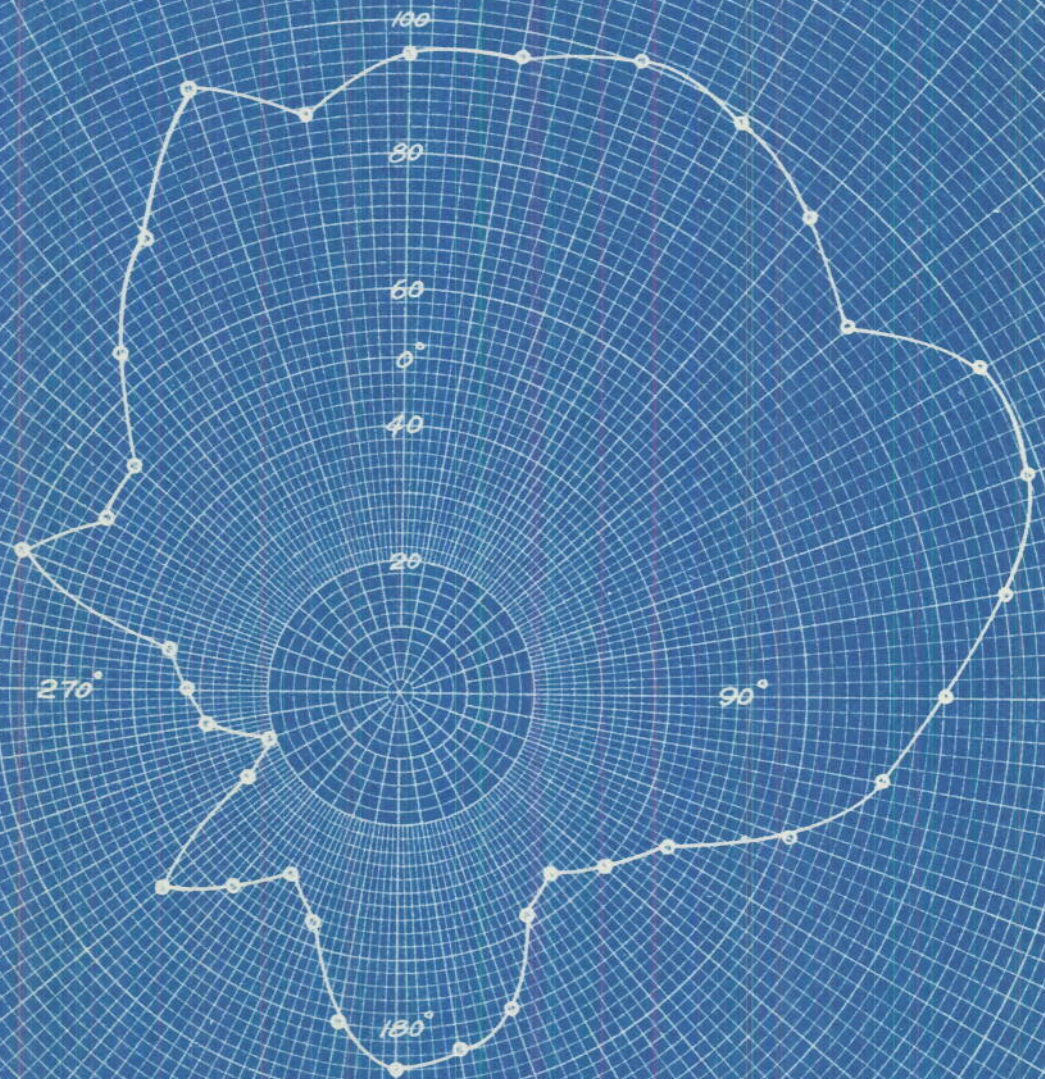
CONFIDENTIAL

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PLATE 44

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KEUFFEL & ESSER CO., N. Y. NO. 343B  
 POLAR CO-ORDINATE  
 MADE IN U. S. A.



OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-2  
 HORIZONTAL PATTERN - FREE SPACE  
 VERTICAL POLARIZATION  
 2200 MC/S

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PLATE 45



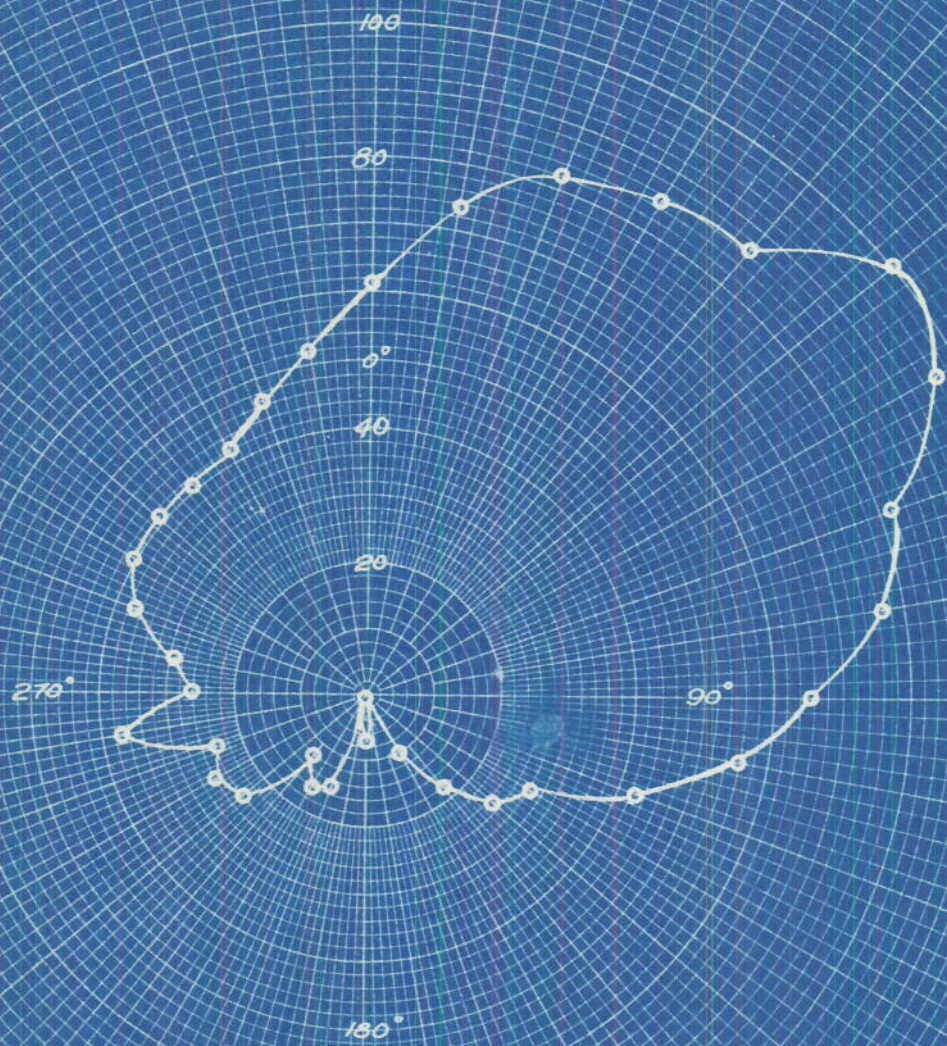
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PLATE 46

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KEUFFEL & ESSER CO., N. Y. NO. 343B  
 POLAR CO-ORDINATE  
 MADE IN U. S. A.

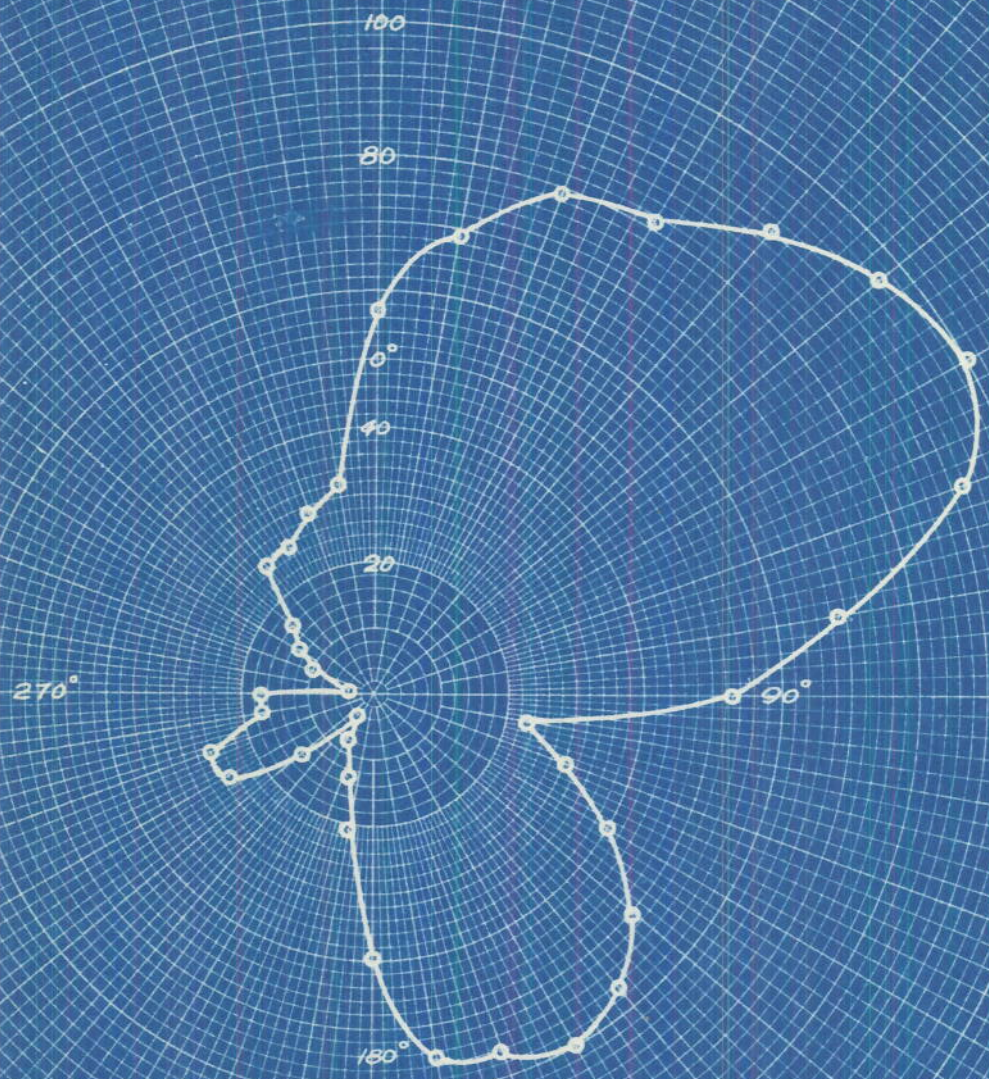


OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-2  
 HORIZONTAL PATTERN - FREE SPACE  
 VERTICAL POLARIZATION  
 3000 MC/S

R-2776

PLATE 47

DECLASSIFIED



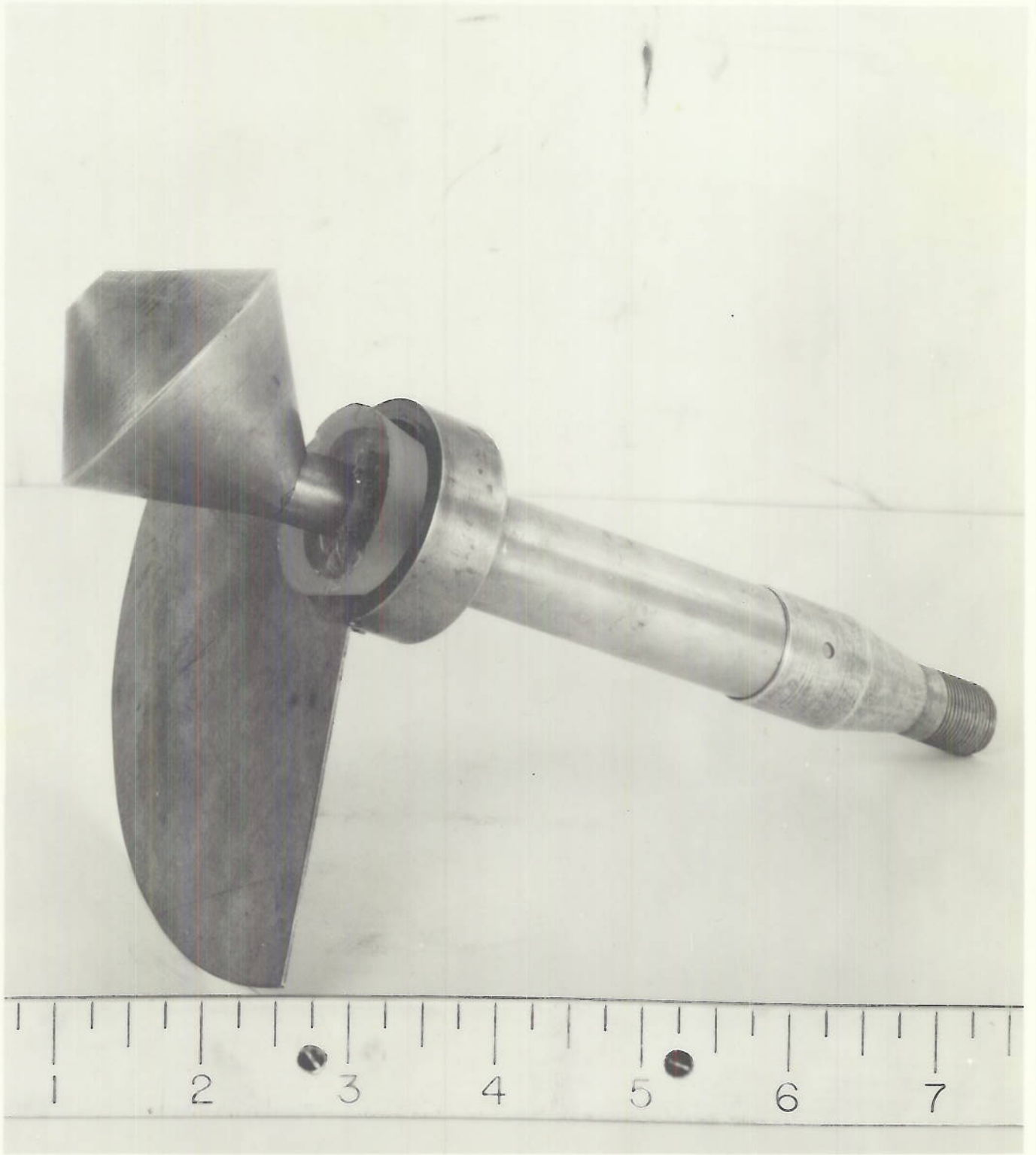
OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-2  
 HORIZONTAL PATTERN - FREE SPACE  
 VERTICAL POLARIZATION  
 3500 MC/S

CONFIDENTIAL

R-2776

PLATE 48

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MODEL NRL-3 ANTENNA

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PLATE 49



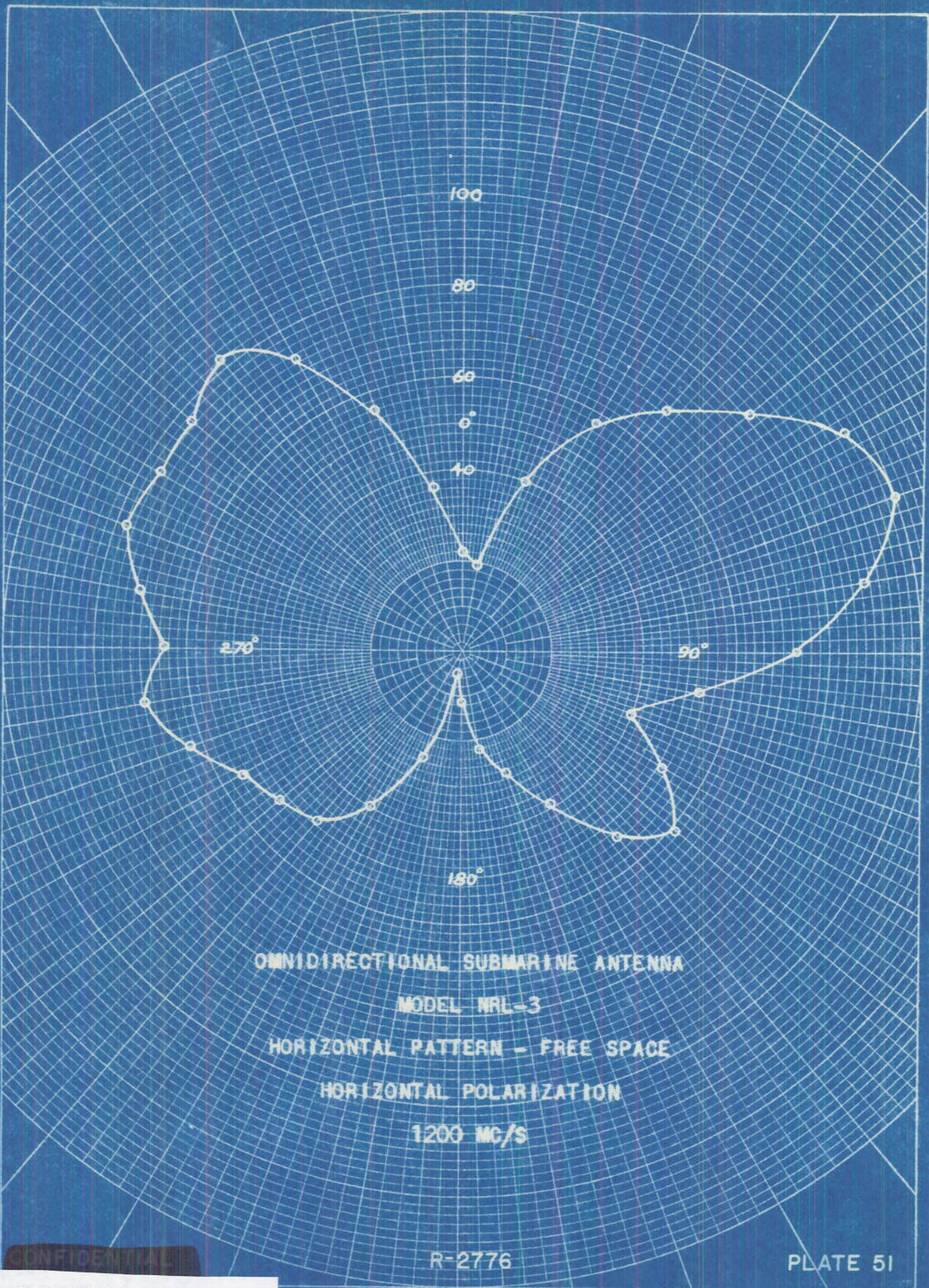
OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-3  
 HORIZONTAL PATTERN - FREE SPACE  
 HORIZONTAL POLARIZATION  
 1000 MC/S

R-2776

PLATE 50

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KEUFFEL & ESSER CO., N. Y. NO. 343B  
 POLAR CO-ORDINATE  
 MADE IN U. S. A.



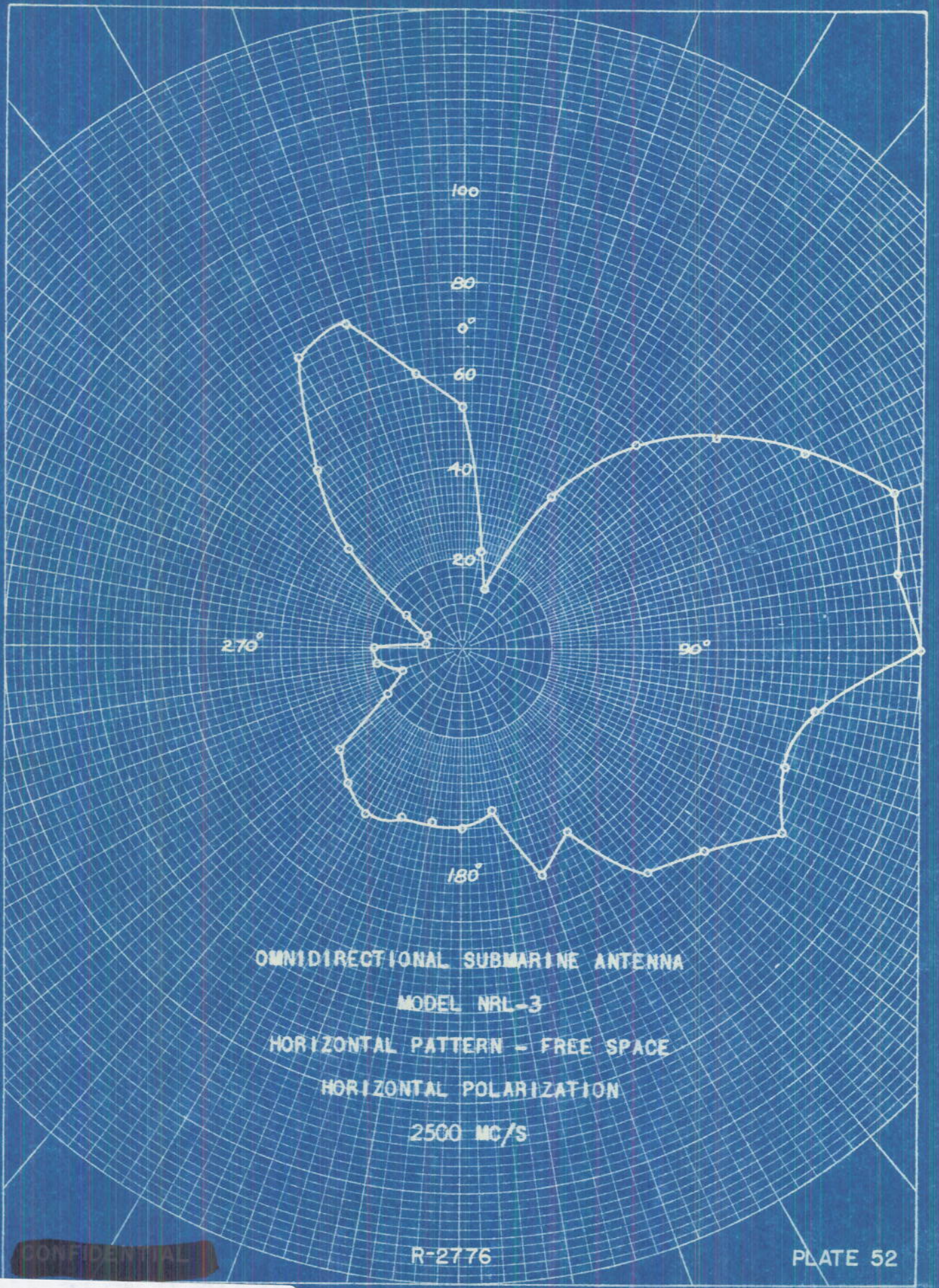
OMNIDIRECTIONAL SUBMARINE ANTENNA  
MODEL NRL-3  
HORIZONTAL PATTERN - FREE SPACE  
HORIZONTAL POLARIZATION  
1200 MC/S

R-2776

PLATE 51

CONFIDENTIAL

DECLASSIFIED

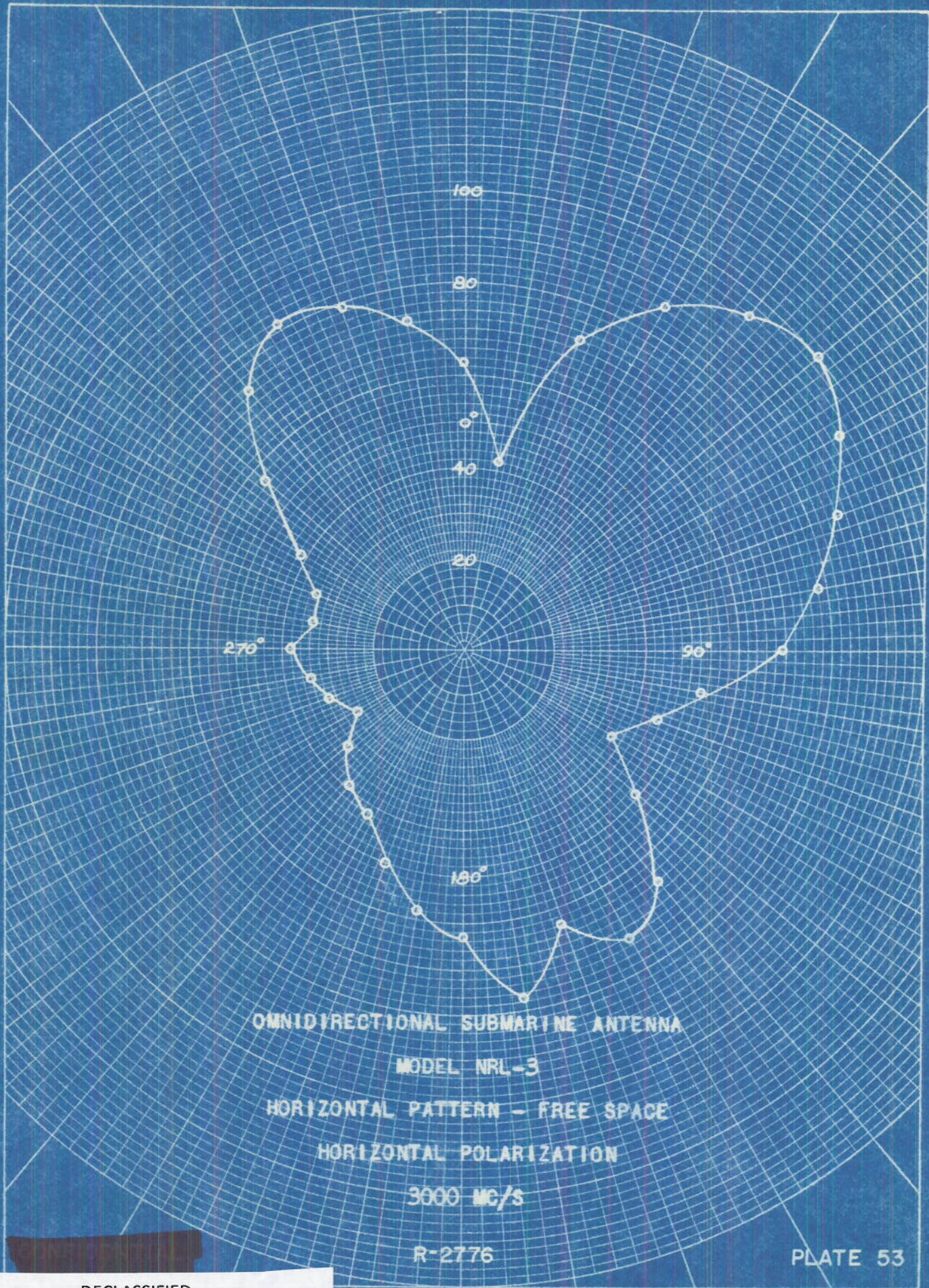


OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-3  
 HORIZONTAL PATTERN - FREE SPACE  
 HORIZONTAL POLARIZATION  
 2500 MC/S

R-2776

PLATE 52

DECLASSIFIED

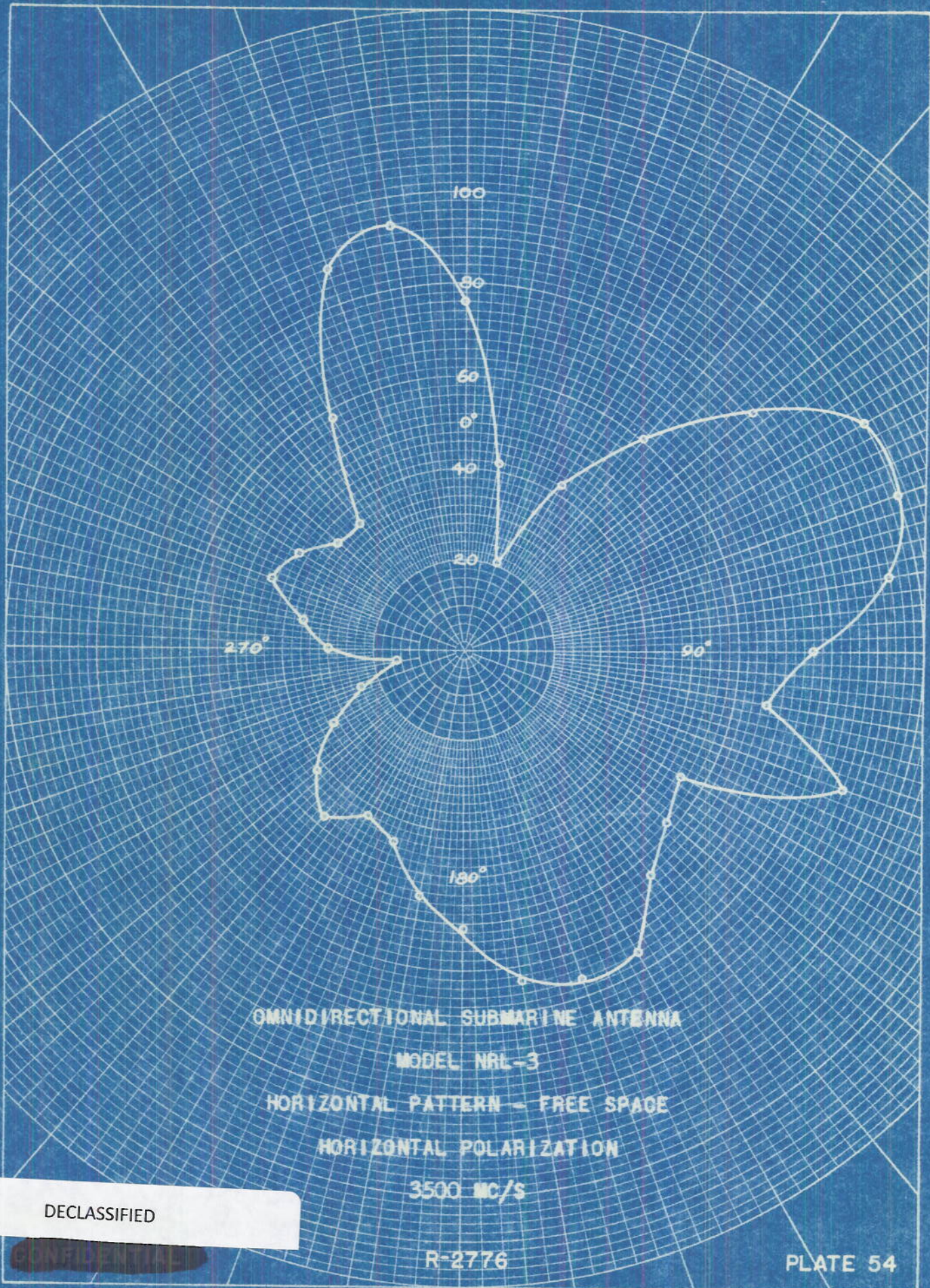


OMNIDIRECTIONAL SUBMARINE ANTENNA  
MODEL NRL-3  
HORIZONTAL PATTERN - FREE SPACE  
HORIZONTAL POLARIZATION  
3000 MC/S

R-2776

PLATE 53

DECLASSIFIED

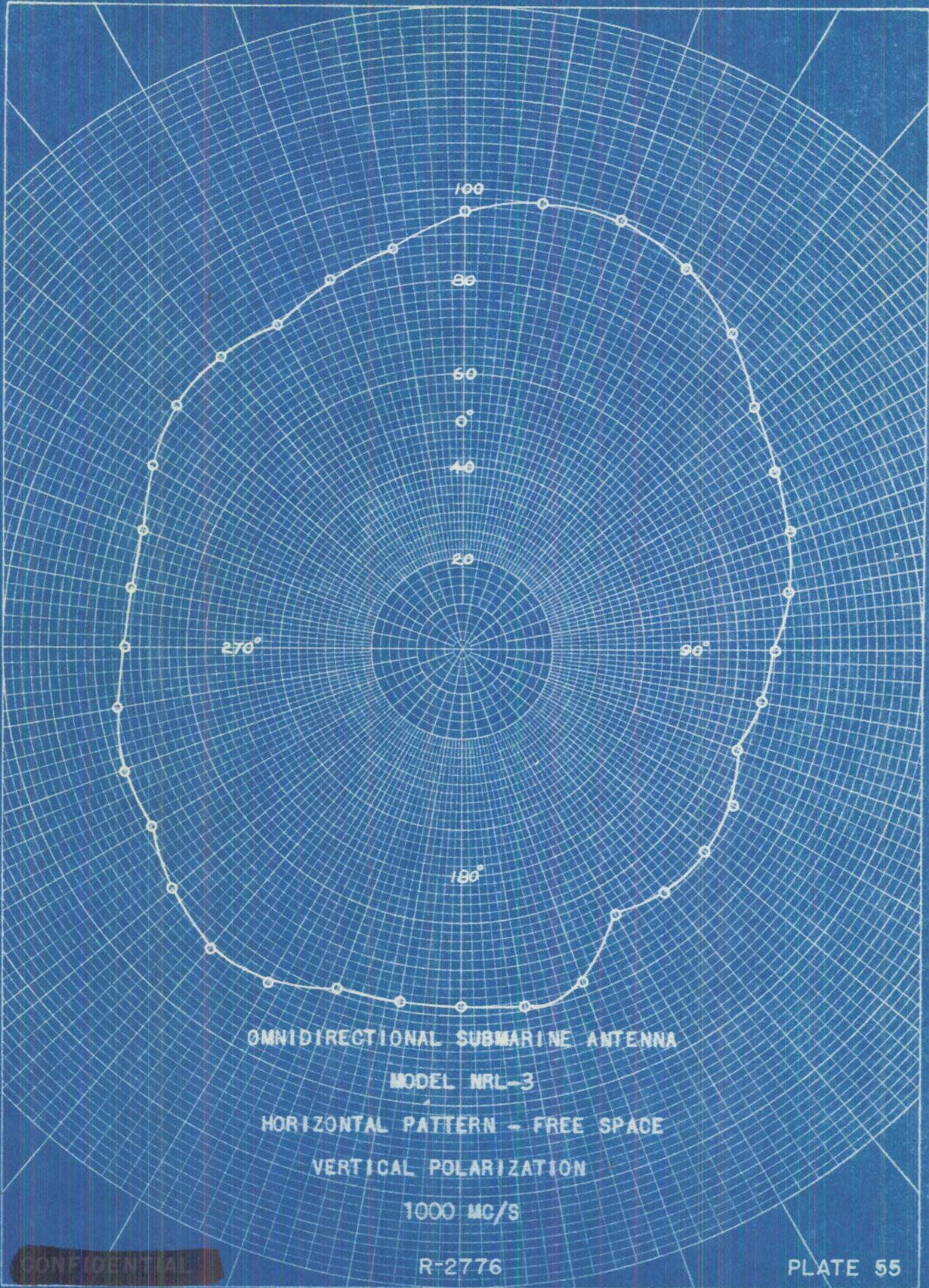


OMNIDIRECTIONAL SUBMARINE ANTENNA  
MODEL NRL-3  
HORIZONTAL PATTERN - FREE SPACE  
HORIZONTAL POLARIZATION  
3500 MC/S

DECLASSIFIED

R-2776

PLATE 54



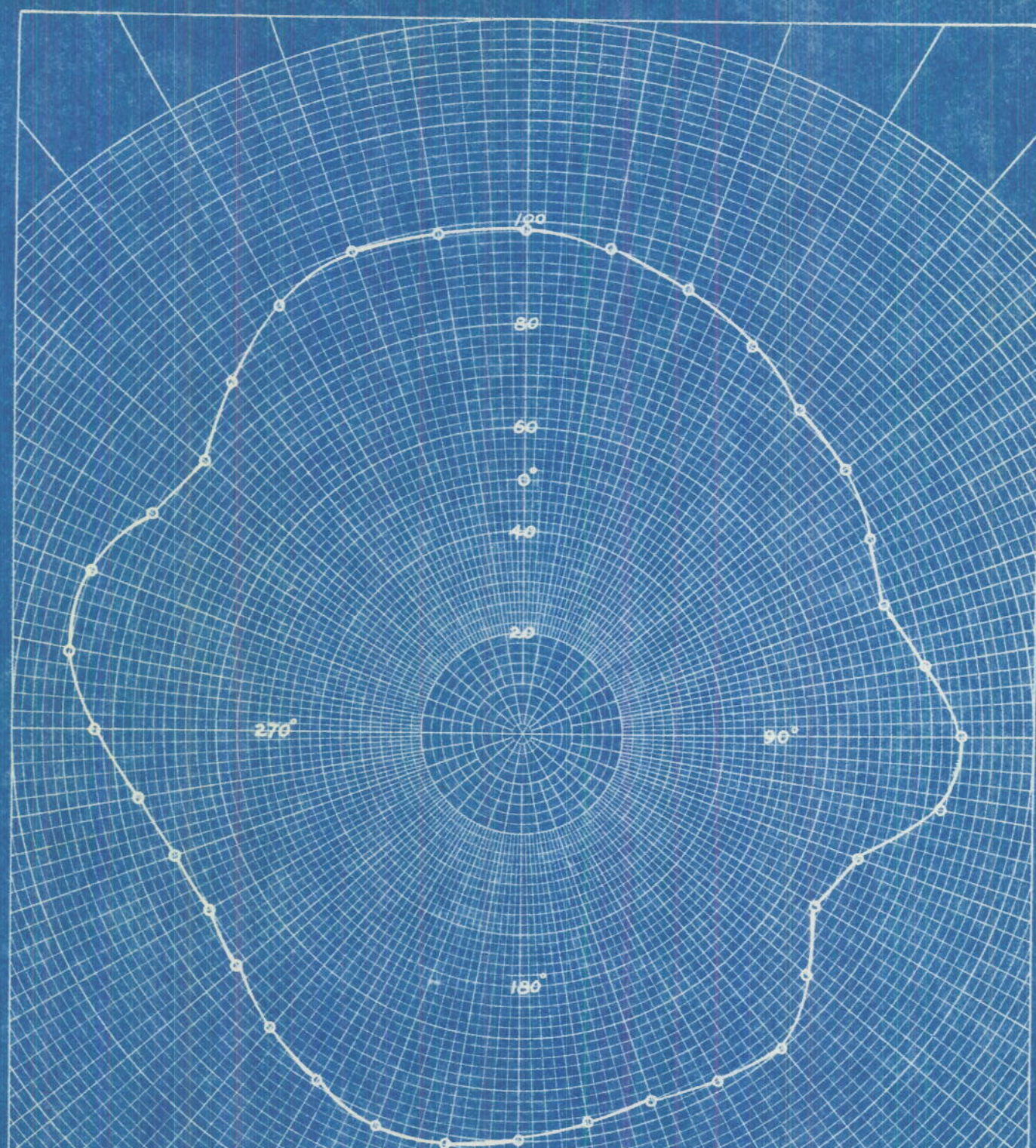
CONFIDENTIAL

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PLATE 55

DECLASSIFIED

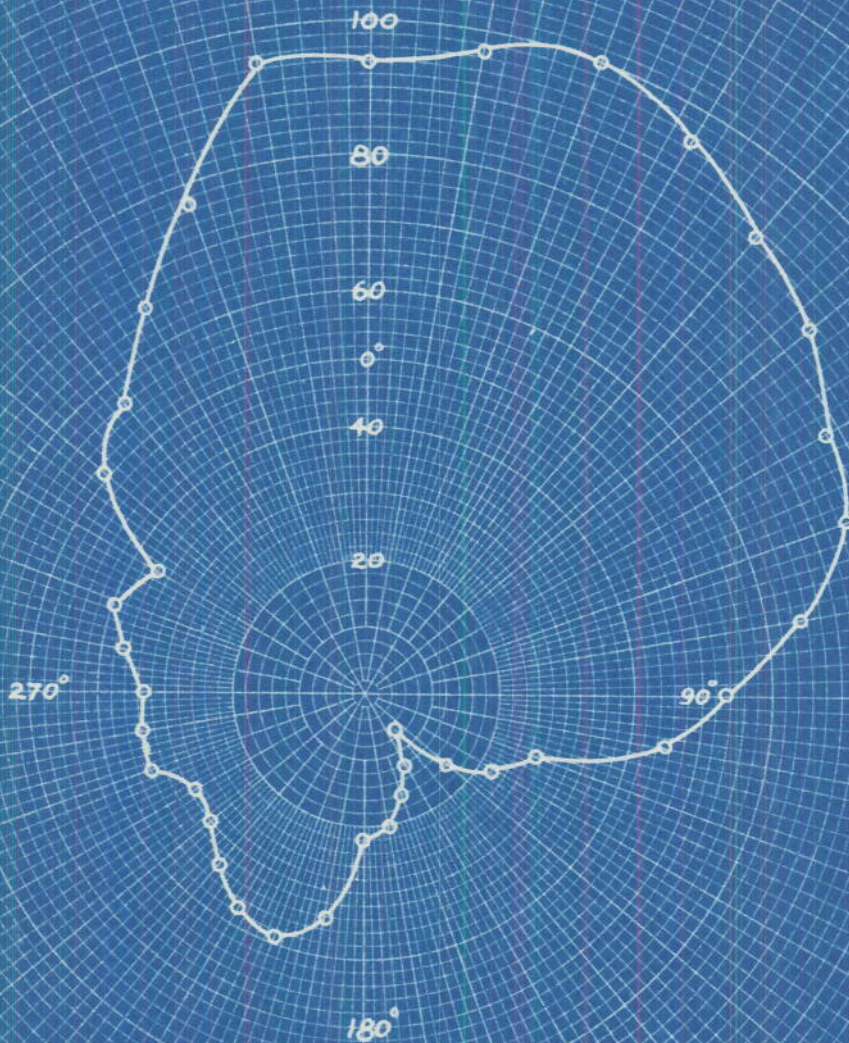
KEUFFEL & ESSER CO., N. Y. NO. 343B  
POLAR CO-ORDINATE  
MADE IN U.S.A.



OMNIDIRECTIONAL SUBMARINE ANTENNA  
MODEL NRL-3  
HORIZONTAL PATTERN - FREE SPACE  
VERTICAL POLARIZATION  
1200 Mc/s  
R-2776

CONFIDENTIAL

DECLASSIFIED



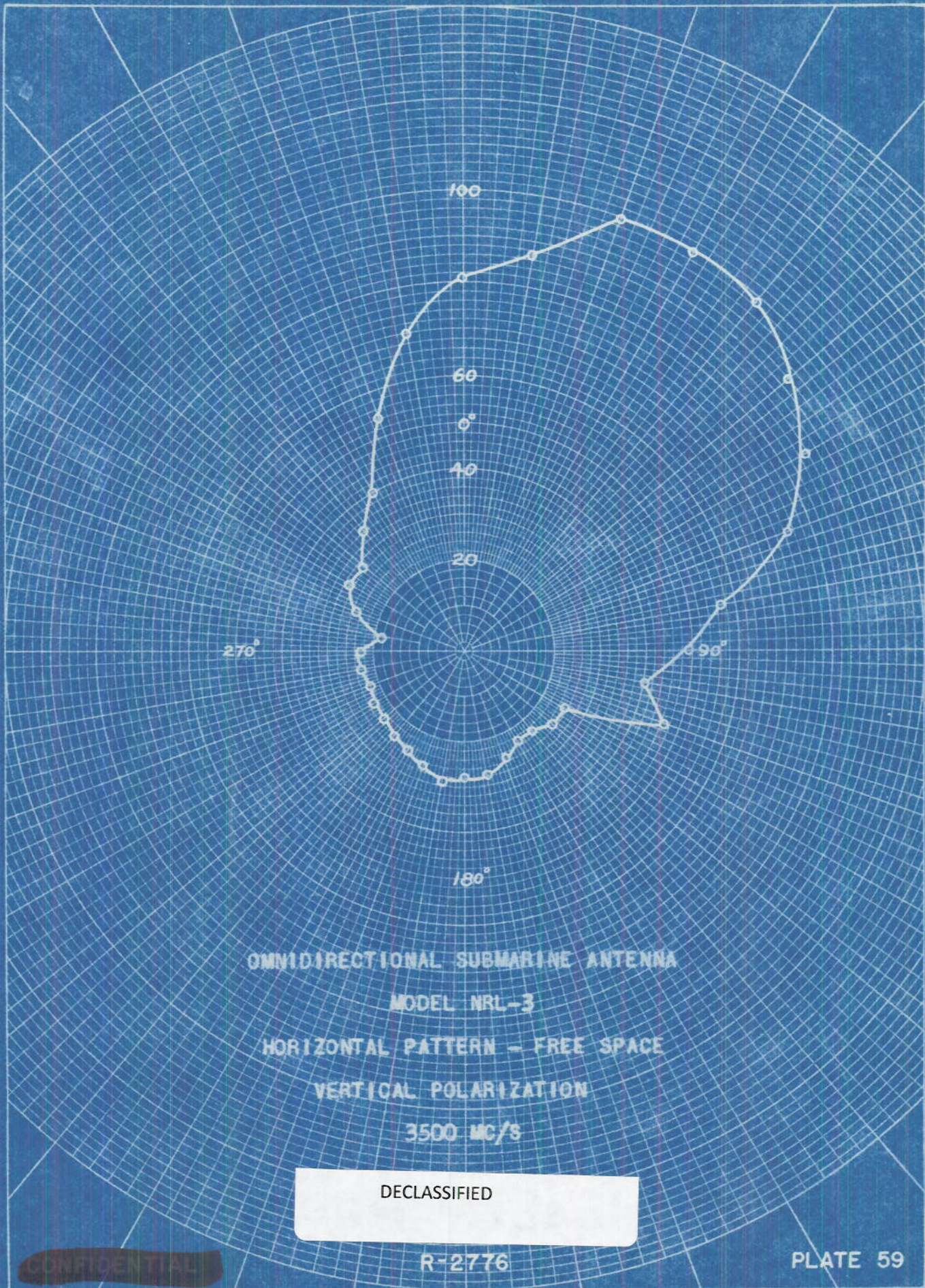
OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-3  
 HORIZONTAL PATTERN - FREE SPACE  
 VERTICAL POLARIZATION  
 3000 MC/S

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CONFIDENTIAL

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PLATE 58



OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-3  
 HORIZONTAL PATTERN - FREE SPACE  
 VERTICAL POLARIZATION  
 3500 MC/S

DECLASSIFIED

R-2776

PLATE 59

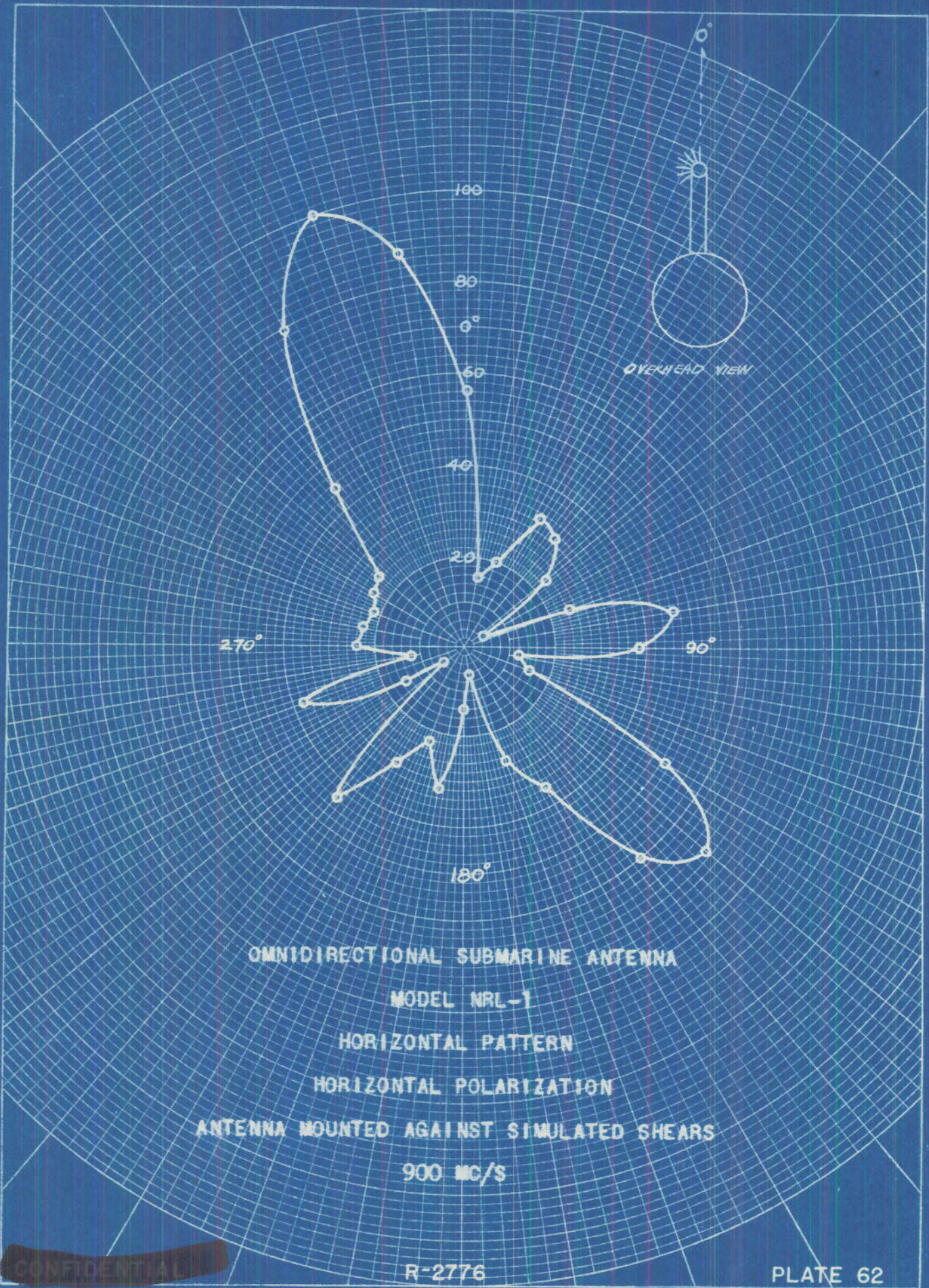


PRE-PRODUCTION SUBMARINE INTERCEPT ANTENNA

DECLASSIFIED

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PLATE 61

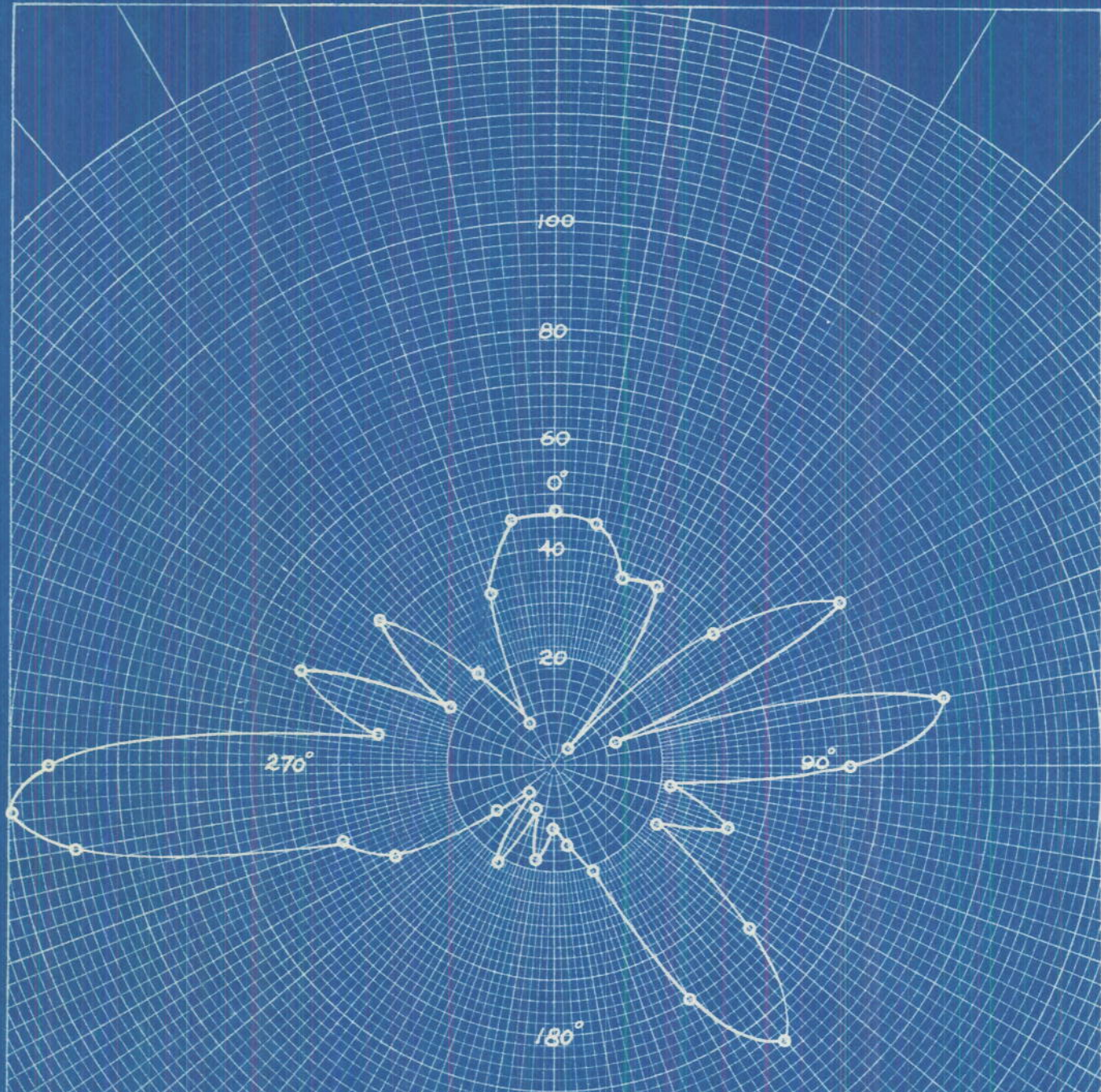


OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-1  
 HORIZONTAL PATTERN  
 HORIZONTAL POLARIZATION  
 ANTENNA MOUNTED AGAINST SIMULATED SHEARS  
 900 MC/S

**CONFIDENTIAL**

R-2776

PLATE 62



OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-7  
 HORIZONTAL PATTERN  
 HORIZONTAL POLARIZATION  
 ANTENNA MOUNTED AGAINST SIMULATED SHEARS  
 1200 MC/S

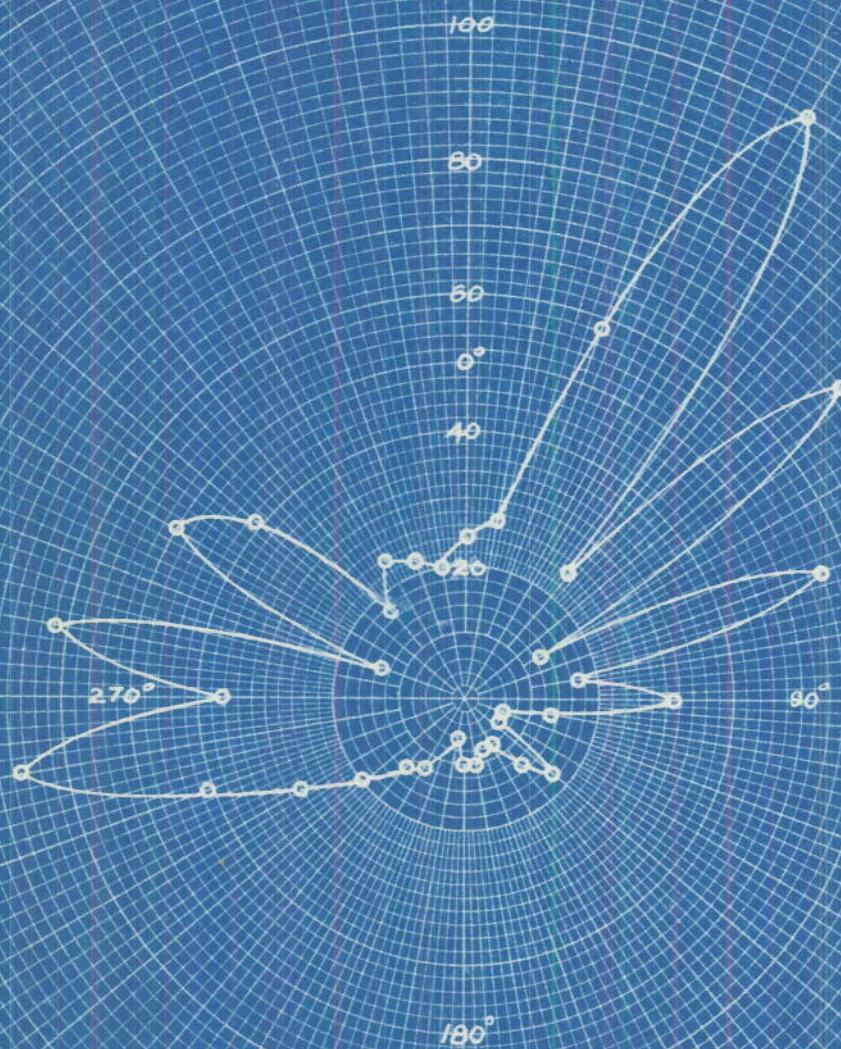
CONFIDENTIAL

R-2776

PLATE 63

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KEUFFEL & ESSER CO., N. Y. NO. 343B  
 POLAR CO-ORDINATE  
 MADE IN U. S. A.

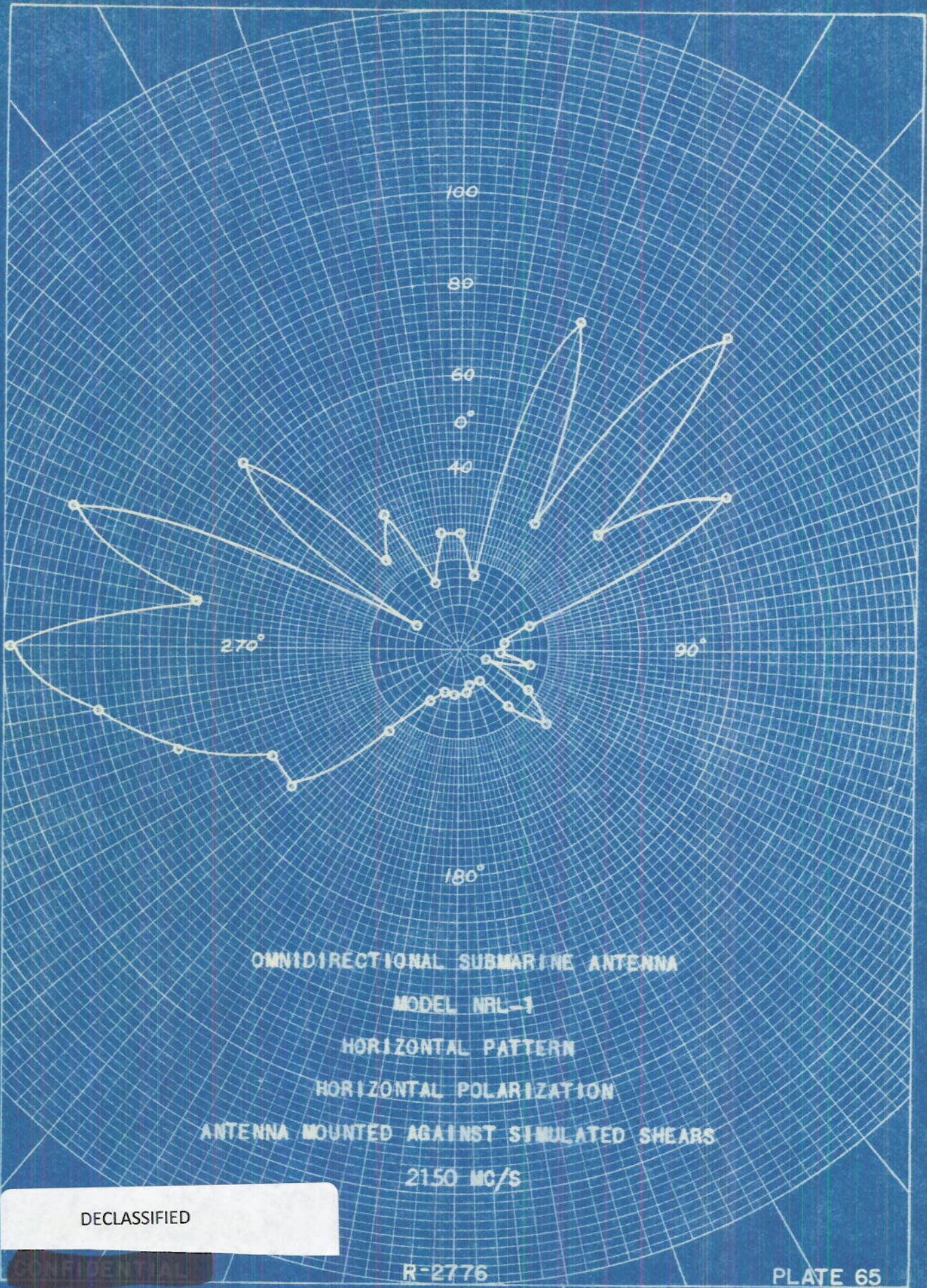


OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-1  
 HORIZONTAL PATTERN  
 HORIZONTAL POLARIZATION  
 ANTENNA MOUNTED AGAINST SIMULATED SHEARS  
 1600 MC/S

R-2776

PLATE 64

DECLASSIFIED



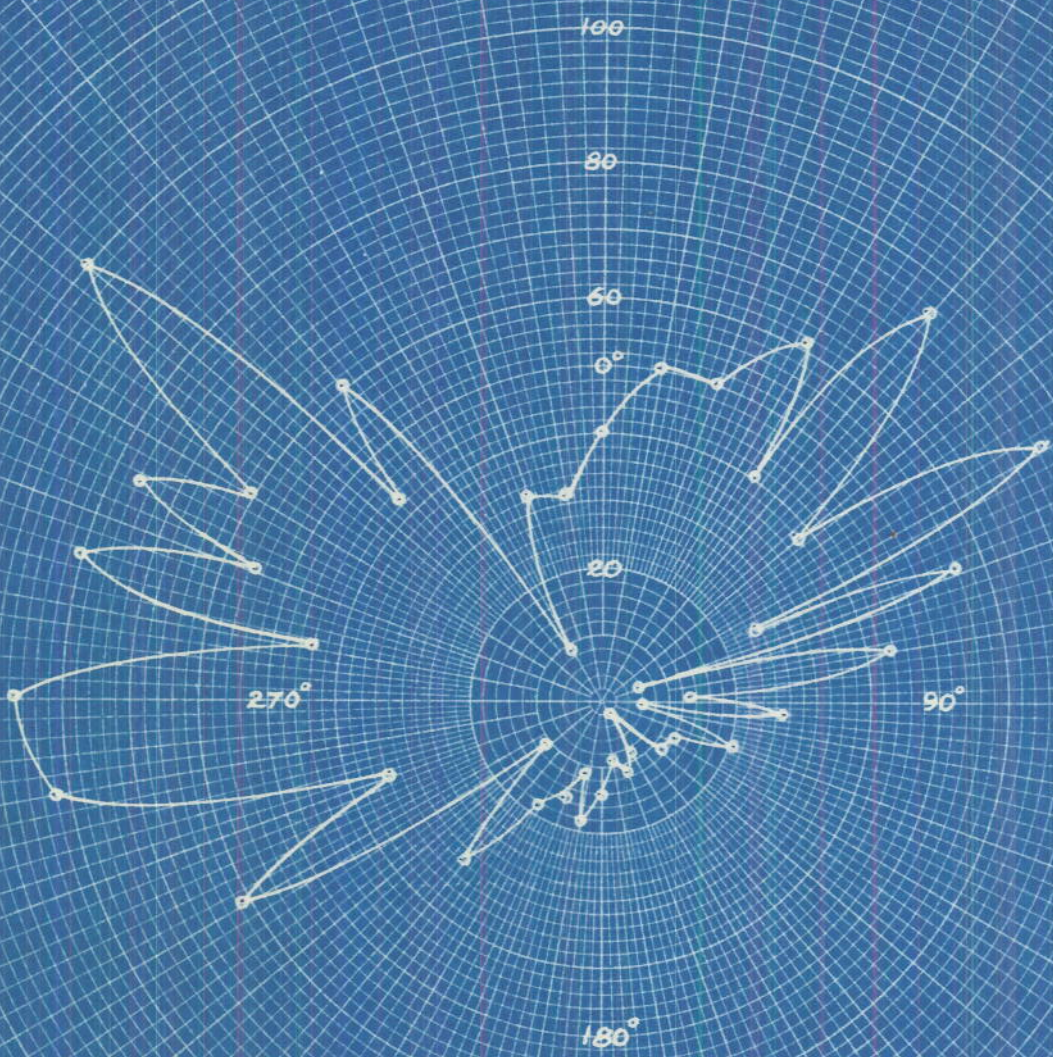
OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-1  
 HORIZONTAL PATTERN  
 HORIZONTAL POLARIZATION  
 ANTENNA MOUNTED AGAINST SIMULATED SHEARS  
 21.50 MC/S

DECLASSIFIED

~~CONFIDENTIAL~~

R-2776

PLATE 65



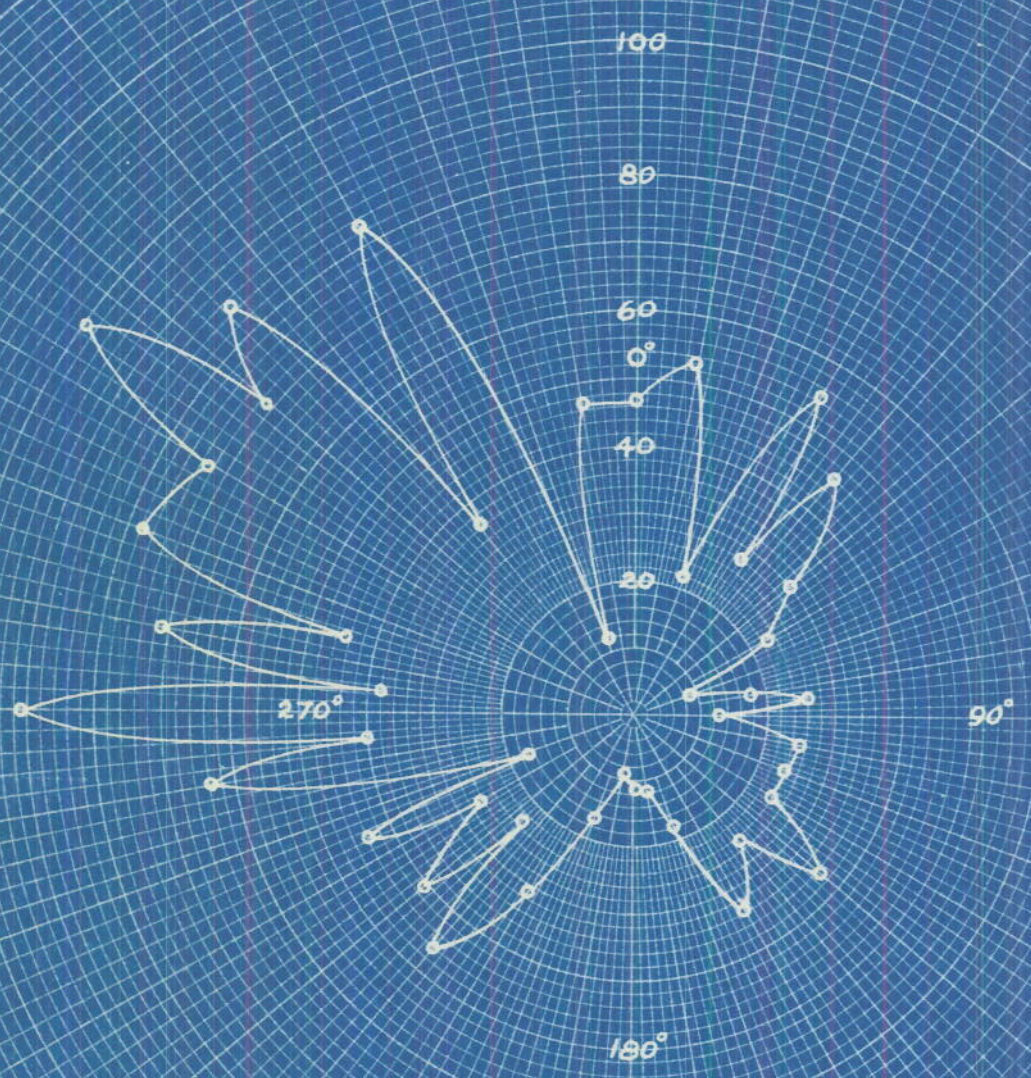
OMNIDIRECTIONAL SUBMARINE ANTENNA  
MODEL NRL-1  
HORIZONTAL PATTERN  
HORIZONTAL POLARIZATION  
ANTENNA MOUNTED AGAINST SIMULATED SHEARS  
2500 MC/S

DECLASSIFIED

CONFIDENTIAL

R-2776

PLATE 66



OMNIDIRECTIONAL SUBMARINE ANTENNA  
MODEL NRL-1  
HORIZONTAL PATTERN  
HORIZONTAL POLARIZATION  
ANTENNA MOUNTED AGAINST SIMULATED SHEARS  
3000 MC/S

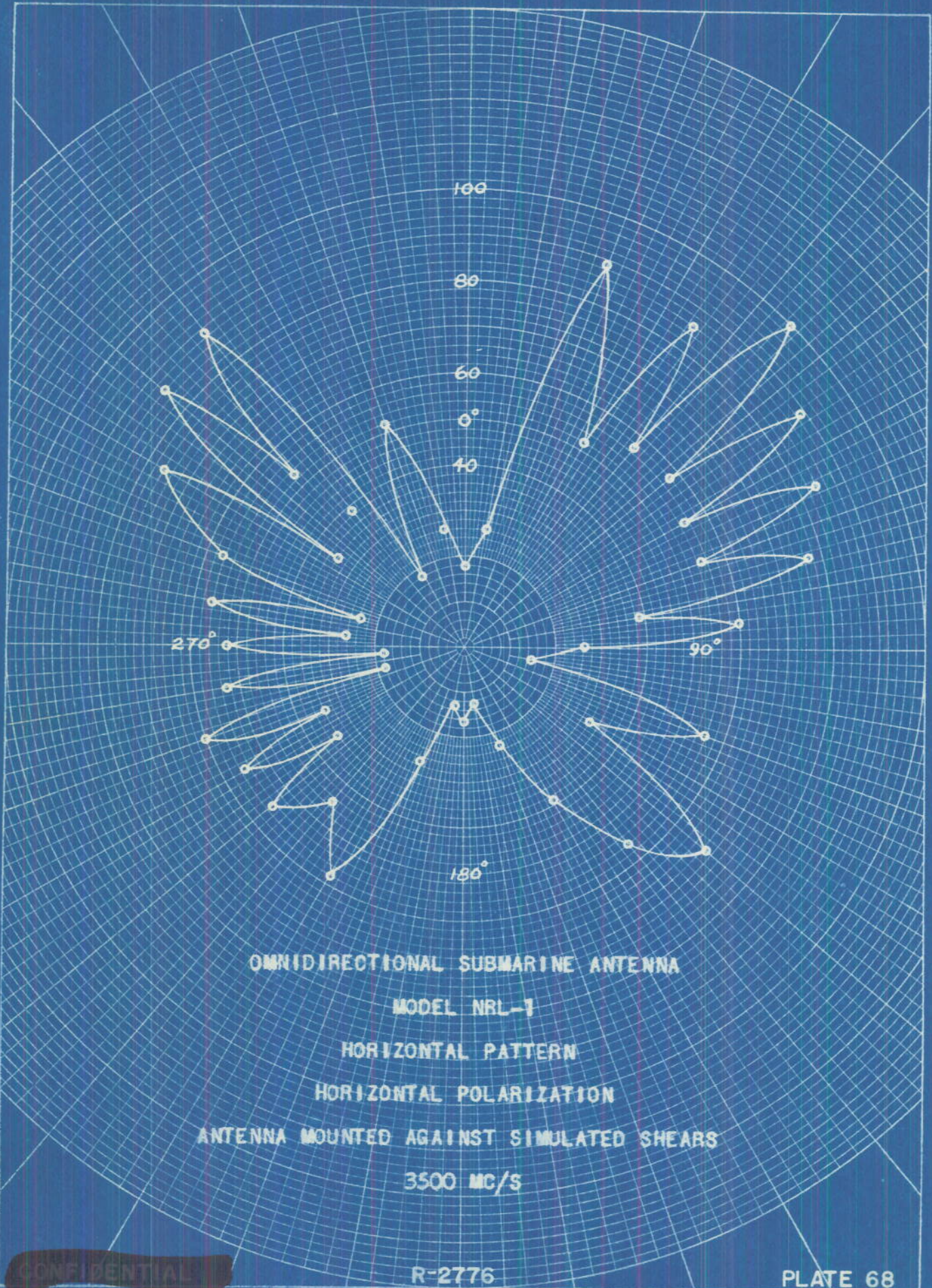
CONFIDENTIAL

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PLATE 67

DECLASSIFIED

KEUFFEL & ESSER CO., N. Y. NO. 343B  
POLAR CO-ORDINATE  
MADE IN U. S. A.



OMNIDIRECTIONAL SUBMARINE ANTENNA  
MODEL NRL-1  
HORIZONTAL PATTERN  
HORIZONTAL POLARIZATION  
ANTENNA MOUNTED AGAINST SIMULATED SHEARS  
3500 MC/S

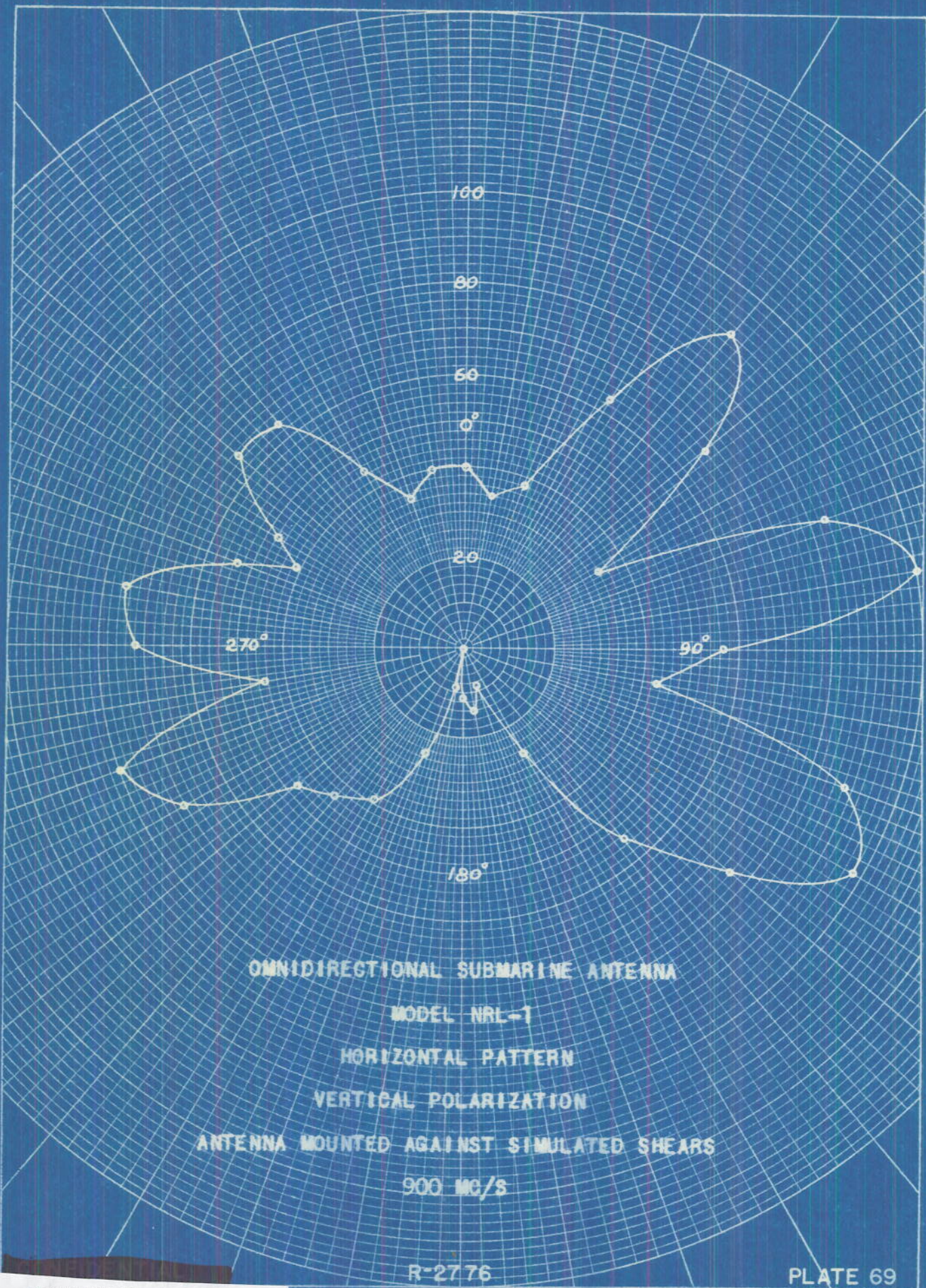
CONFIDENTIAL

R-2776

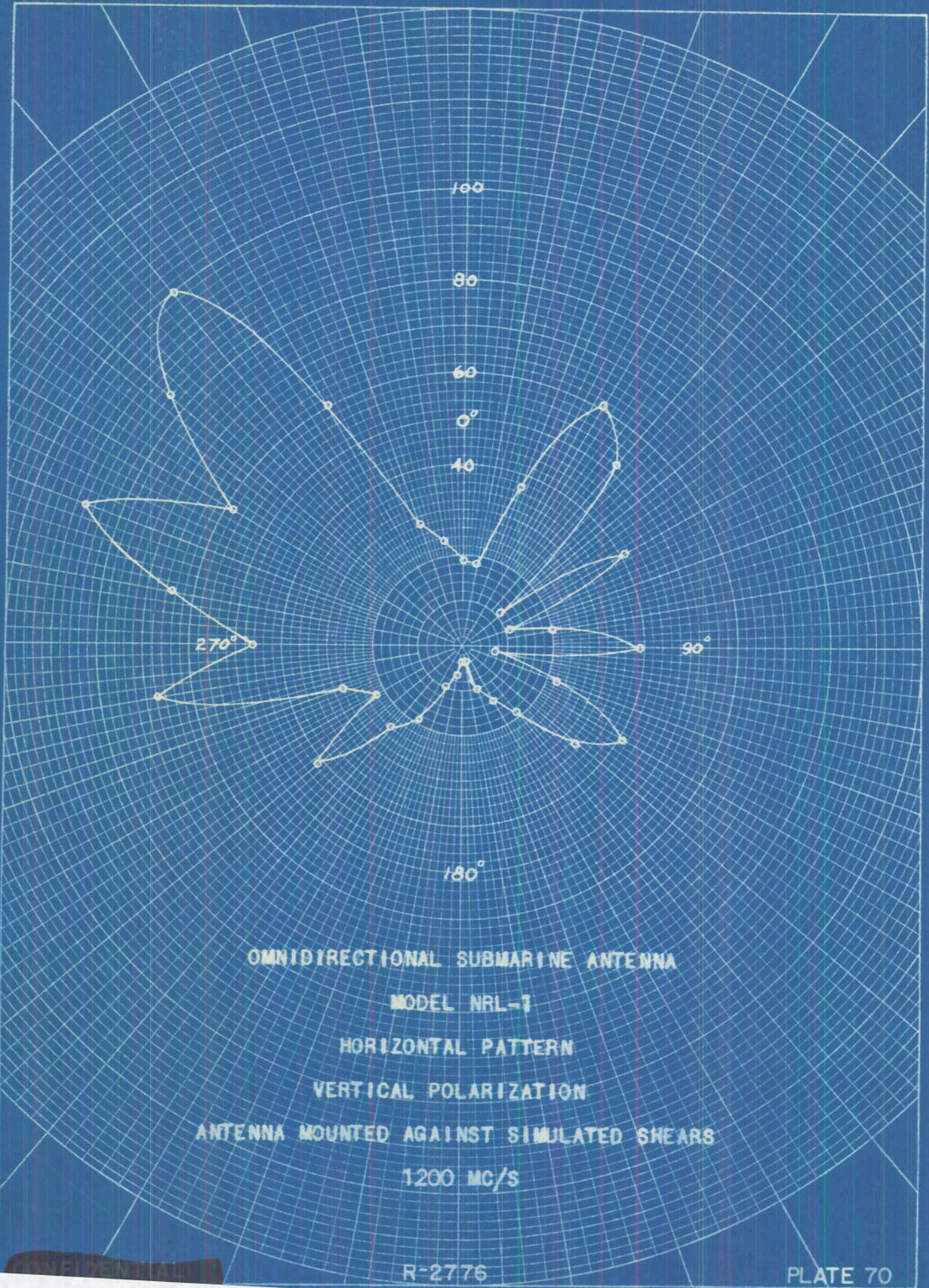
PLATE 68

DECLASSIFIED

KEUFFEL & ESSER CO., N. Y. NO. 343B  
POLAR CO-ORDINATE  
MADE IN U. S. A.



DECLASSIFIED

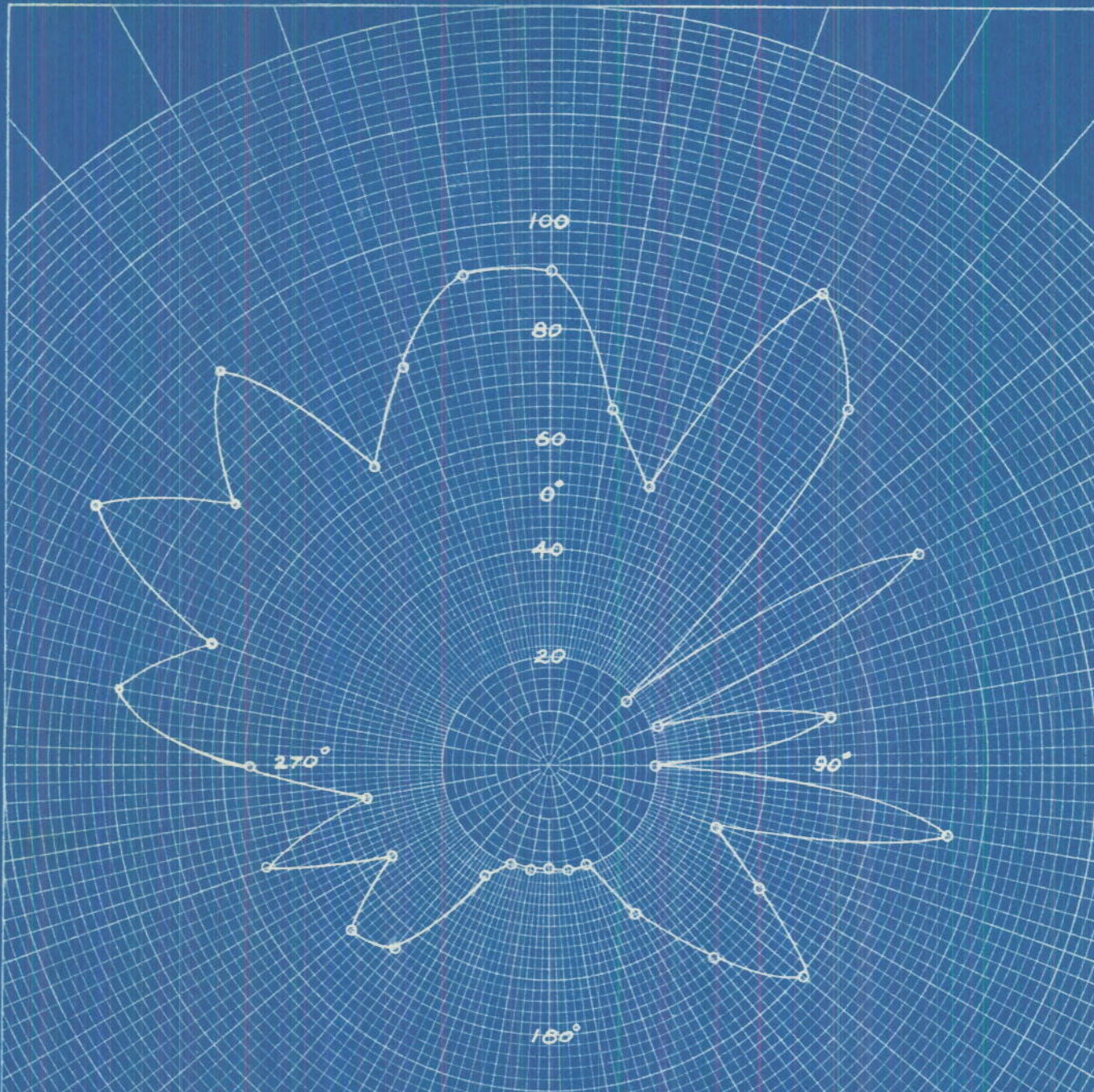


OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-1  
 HORIZONTAL PATTERN  
 VERTICAL POLARIZATION  
 ANTENNA MOUNTED AGAINST SIMULATED SHEARS  
 1200 MC/S

R-2776

PLATE 70

DECLASSIFIED



OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-1  
 HORIZONTAL PATTERN  
 VERTICAL POLARIZATION  
 ANTENNA MOUNTED AGAINST SIMULATED SHEARS  
 1600 MC/S

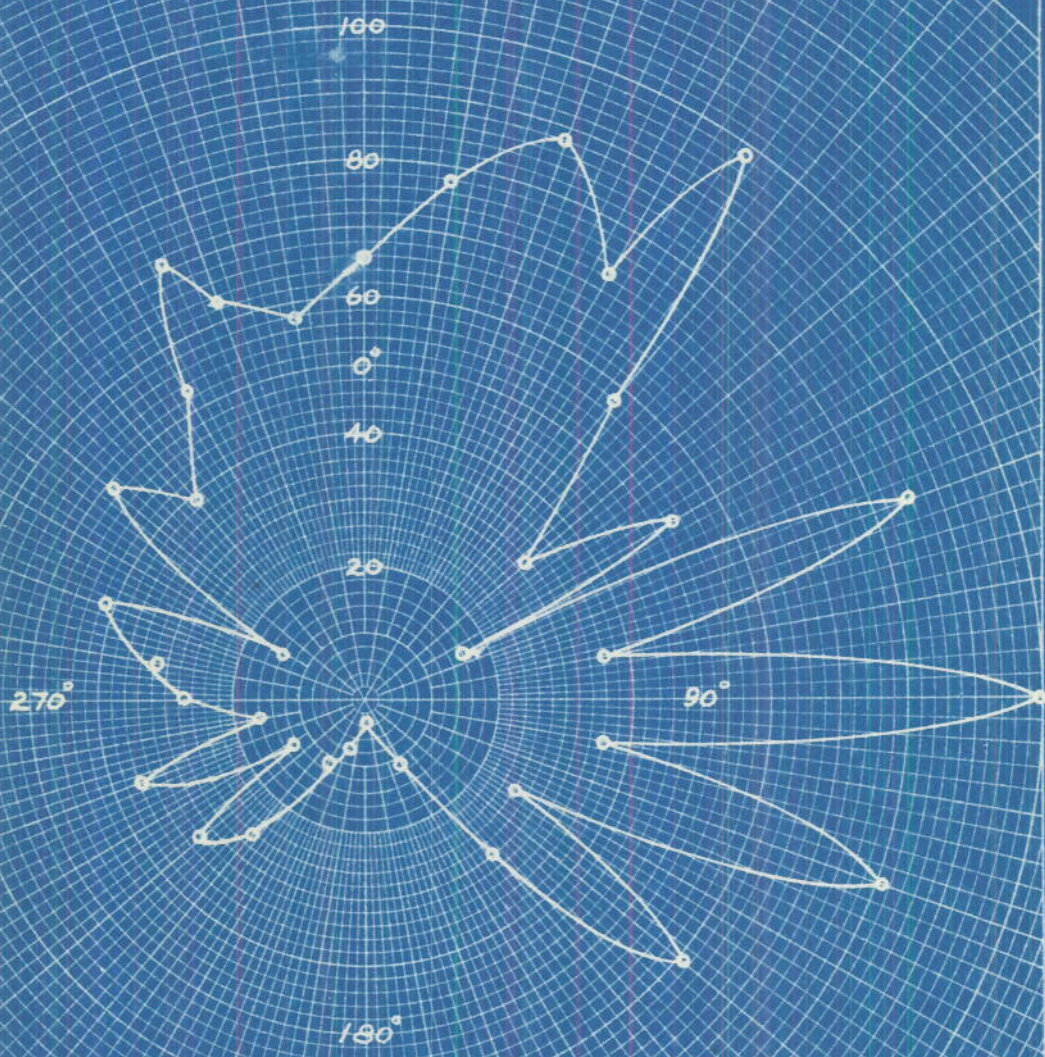
**CONFIDENTIAL**

R-2776

PLATE 71

DECLASSIFIED

KEUFFEL & ESSER CO., N. Y. NO. 345B  
 POLAR CO-ORDINATE  
 MADE IN U. S. A.



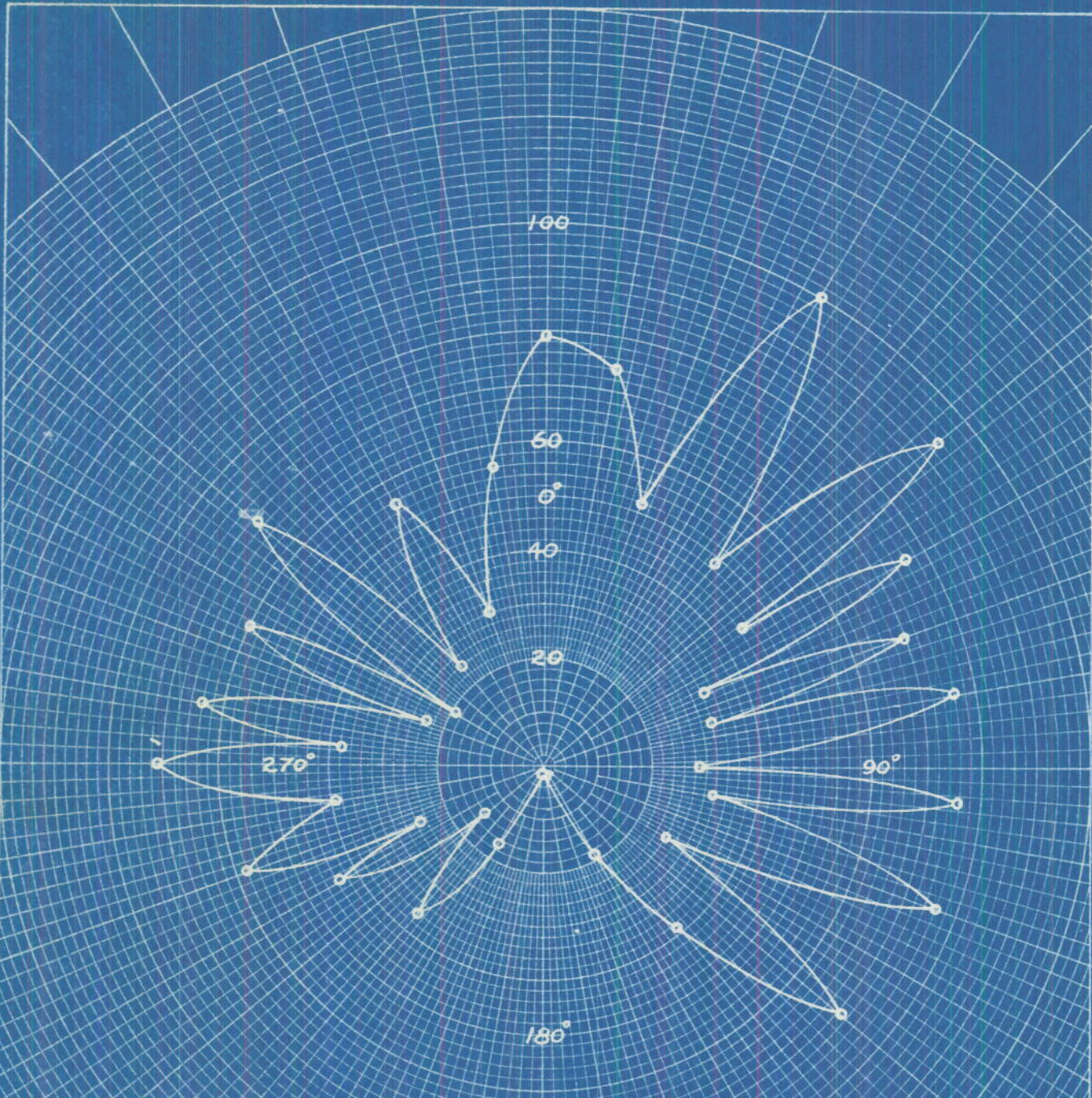
OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-1  
 HORIZONTAL PATTERN  
 VERTICAL POLARIZATION  
 ANTENNA MOUNTED AGAINST SIMULATED SHEARS  
 2150 MC/S

**CONFIDENTIAL**

R-2776

PLATE 72

DECLASSIFIED



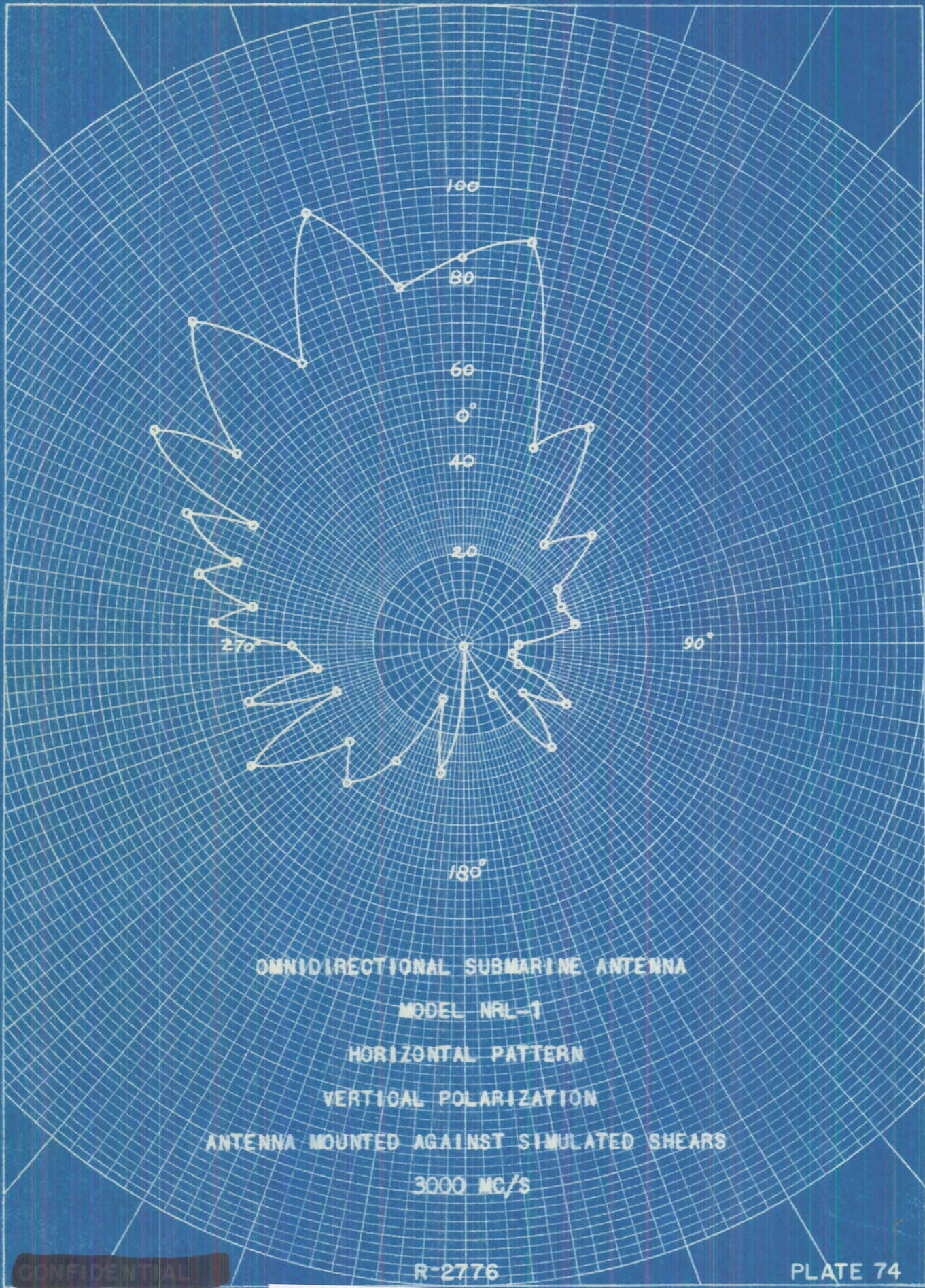
OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-1  
 HORIZONTAL PATTERN  
 VERTICAL POLARIZATION  
 ANTENNA MOUNTED AGAINST SIMULATED SHEARS  
 2500 MC/S

**CONFIDENTIAL**

R-2776

PLATE 73

DECLASSIFIED



OMNIDIRECTIONAL SUBMARINE ANTENNA

MODEL NRL-1

HORIZONTAL PATTERN

VERTICAL POLARIZATION

ANTENNA MOUNTED AGAINST SIMULATED SHEARS

3000 MC/S

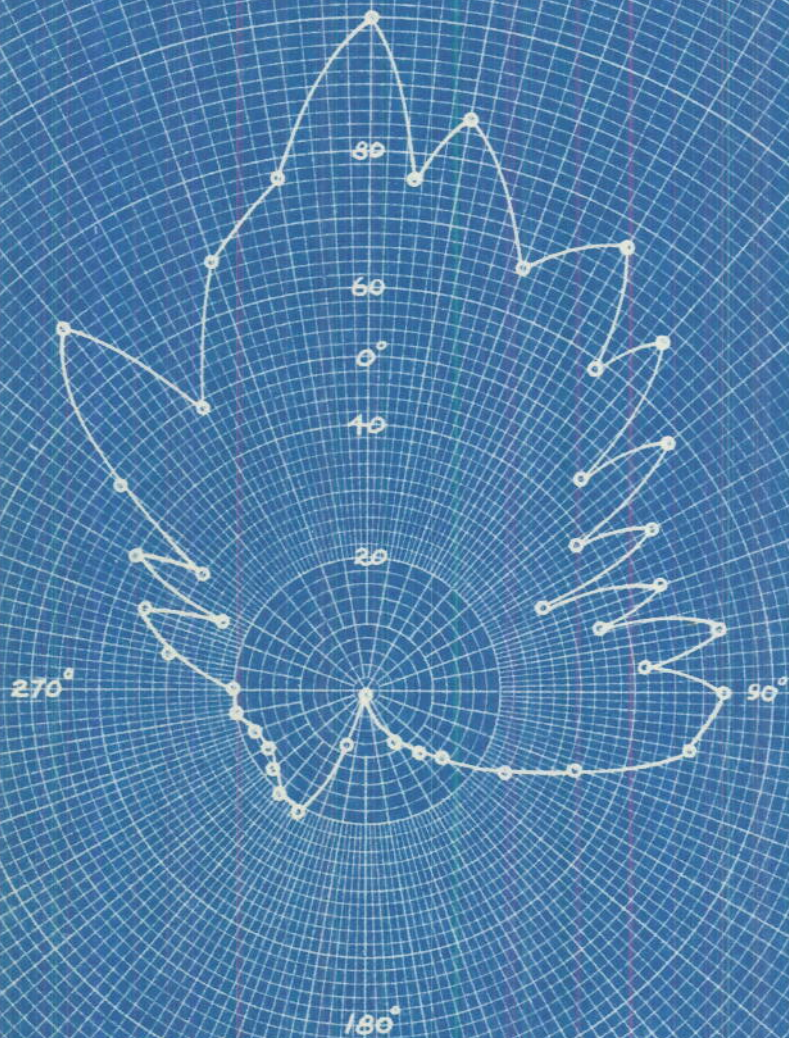
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PLATE 74

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POLAR CO-ORDINATE  
MADE IN U. S. A.



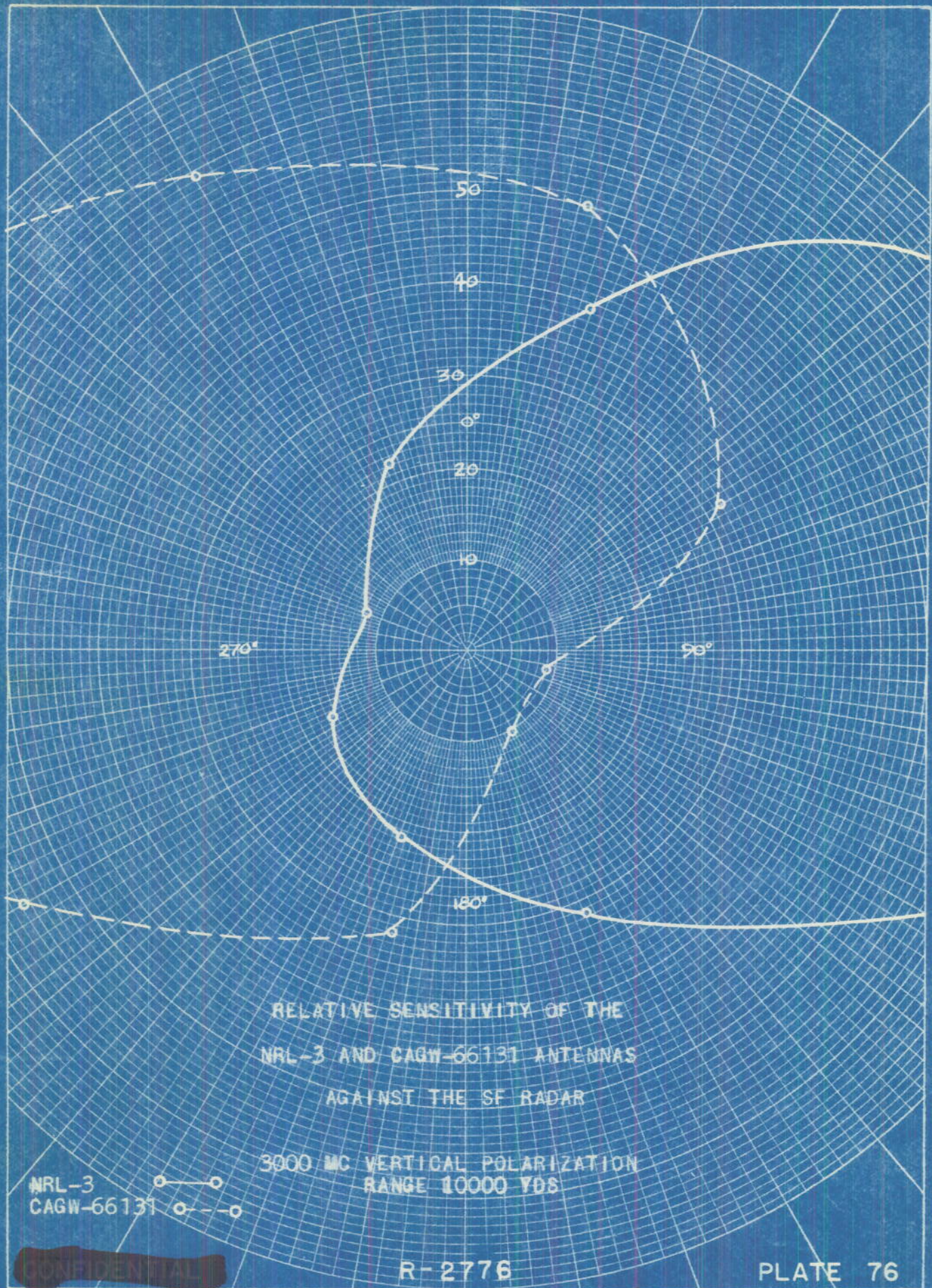
OMNIDIRECTIONAL SUBMARINE ANTENNA  
 MODEL NRL-1  
 HORIZONTAL PATTERN  
 VERTICAL POLARIZATION  
 ANTENNA MOUNTED AGAINST SIMULATED SHEARS  
 3500 MC/S

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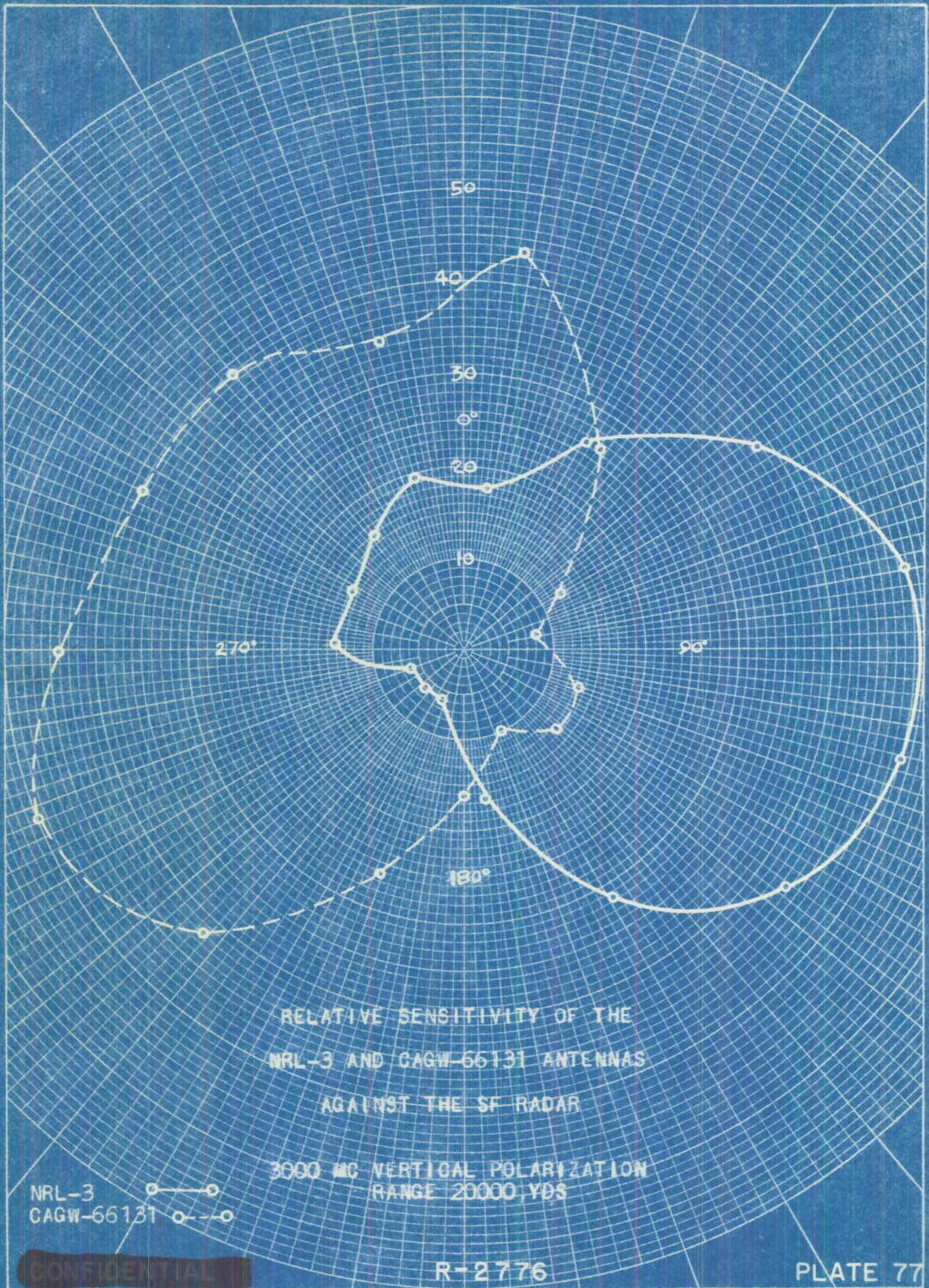
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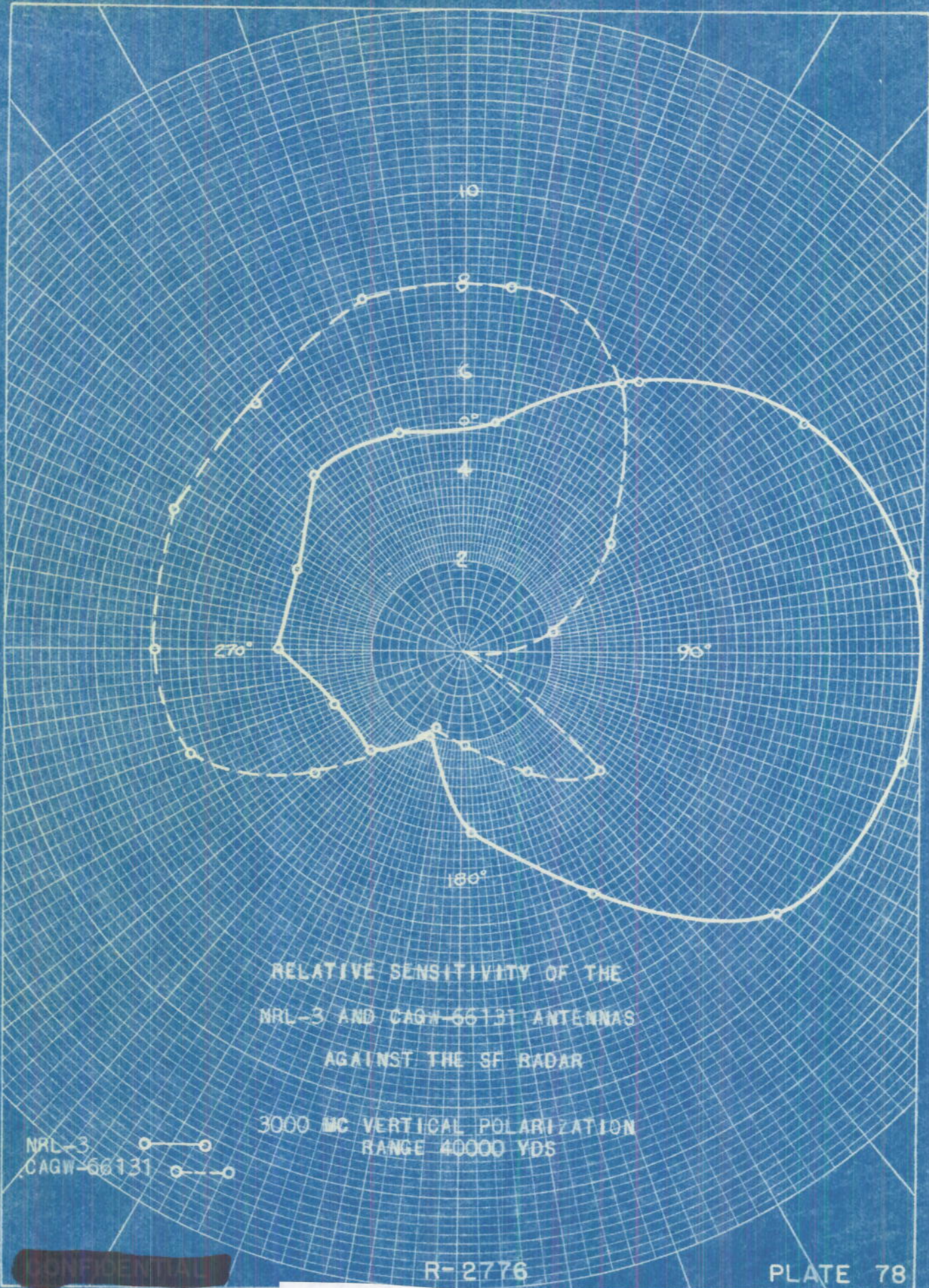
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RELATIVE SENSITIVITY OF THE  
 NRL-3 AND CAGW-66131 ANTENNAS  
 AGAINST THE SF RADAR

3000 MC VERTICAL POLARIZATION  
 RANGE 40000 YDS

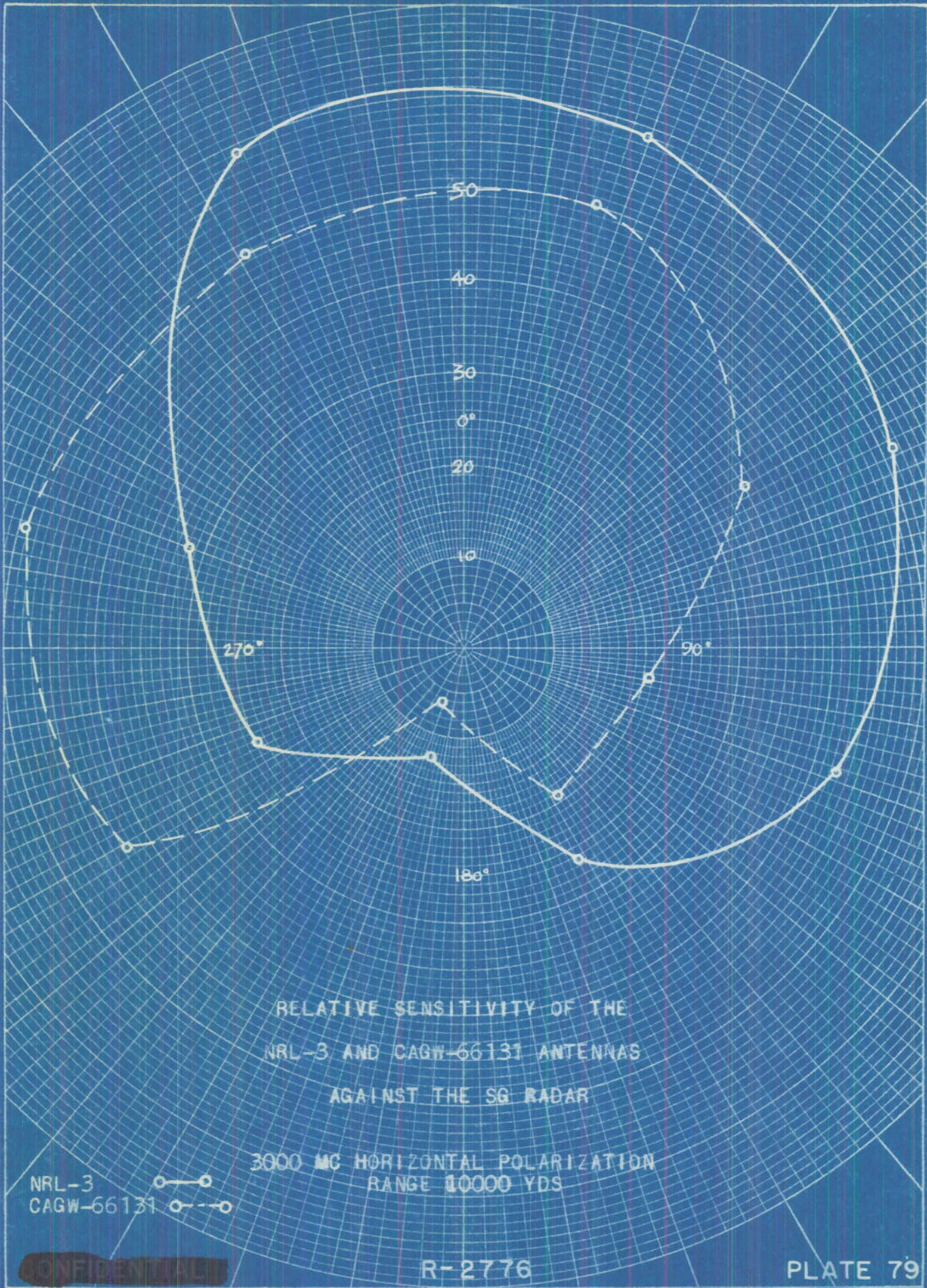
NRL-3 ———○———  
 CAGW-66131 - - -○- - -



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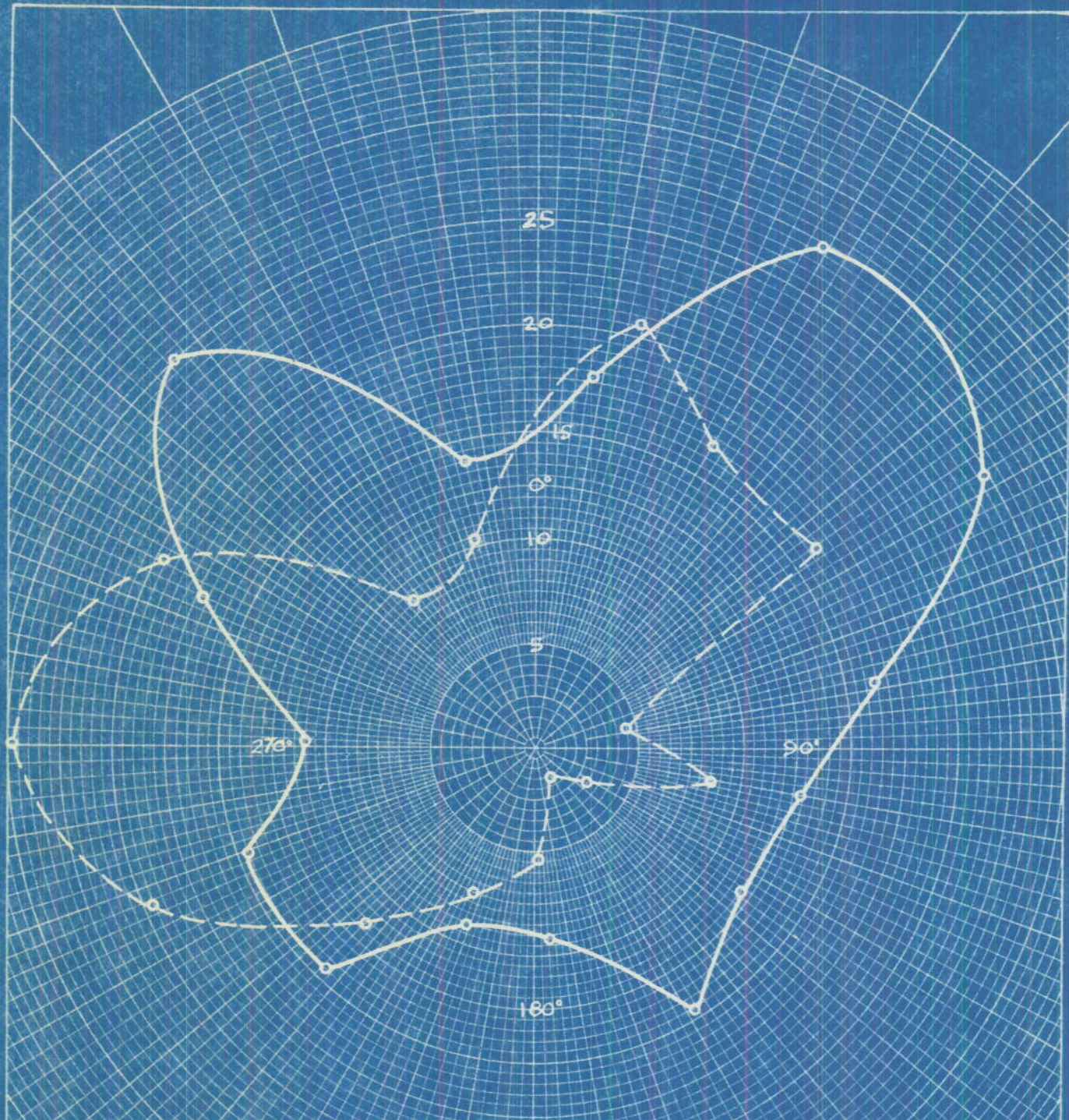
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RELATIVE SENSITIVITY OF THE  
 NRL-3 AND CAGW-66131 ANTENNAS  
 AGAINST THE SG RADAR

3000 MC HORIZONTAL POLARIZATION  
 RANGE 20000 YDS

NRL-3 ———○  
 CAGW-66131 - - -○

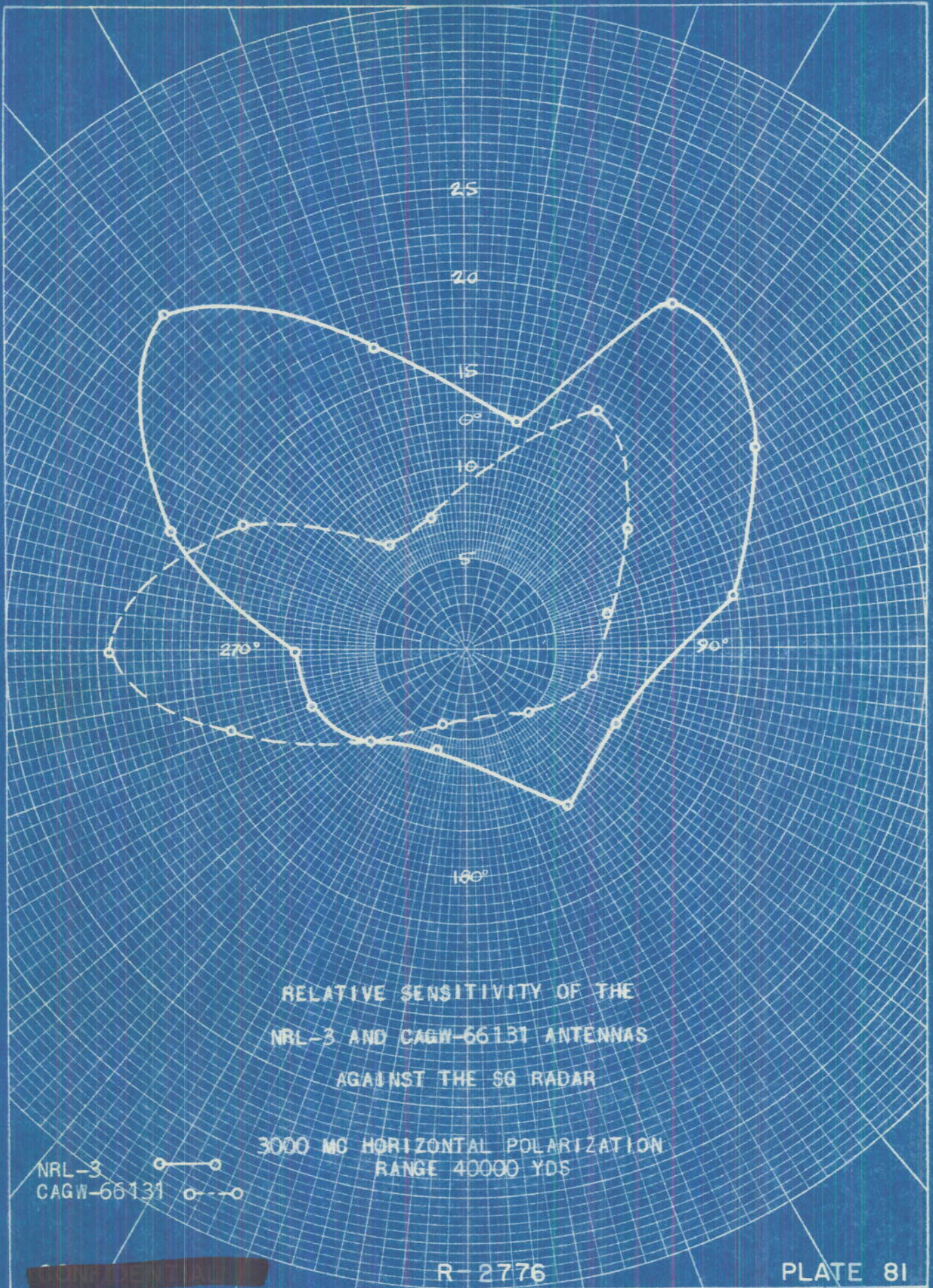
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PLATE 80

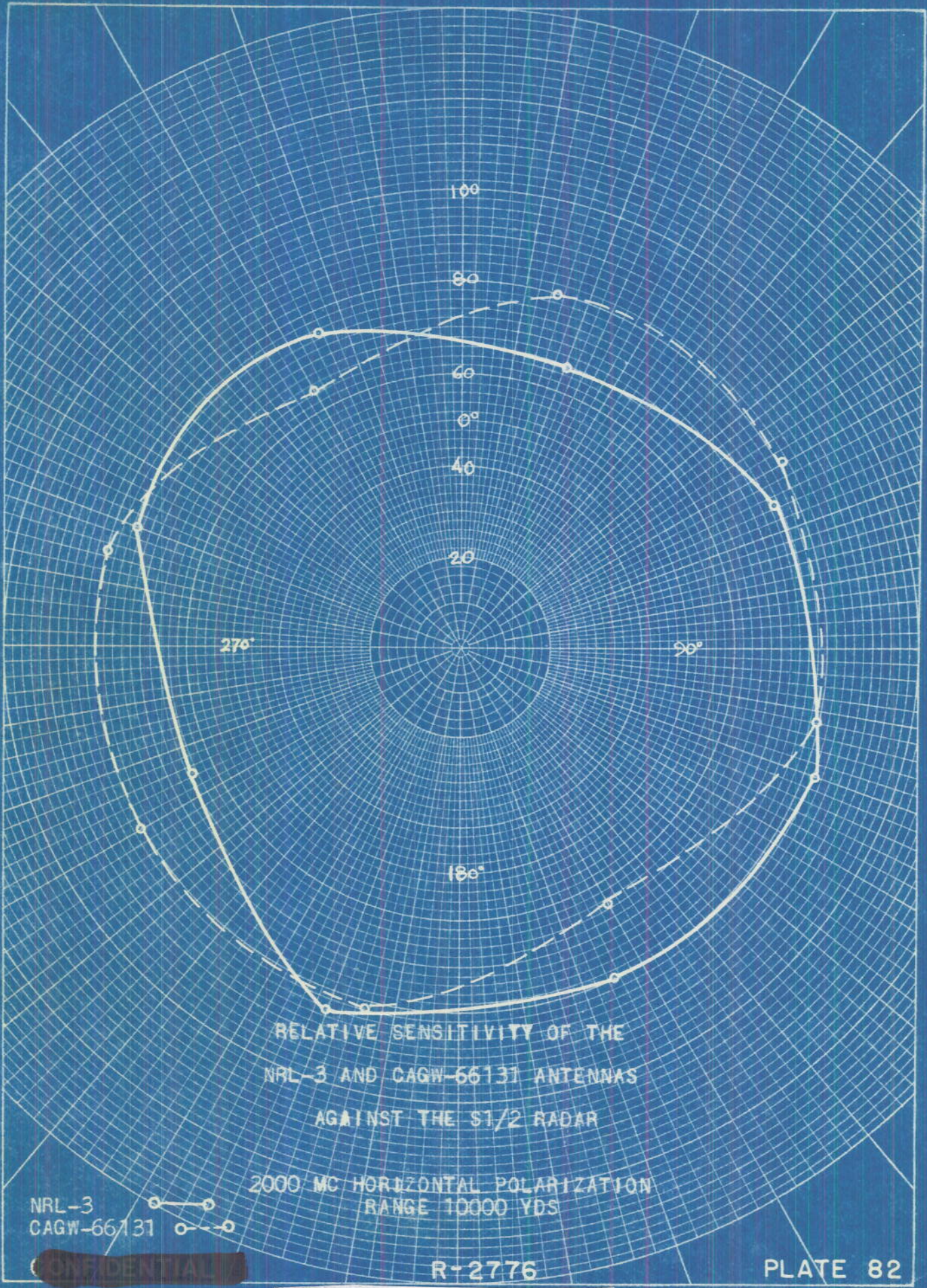
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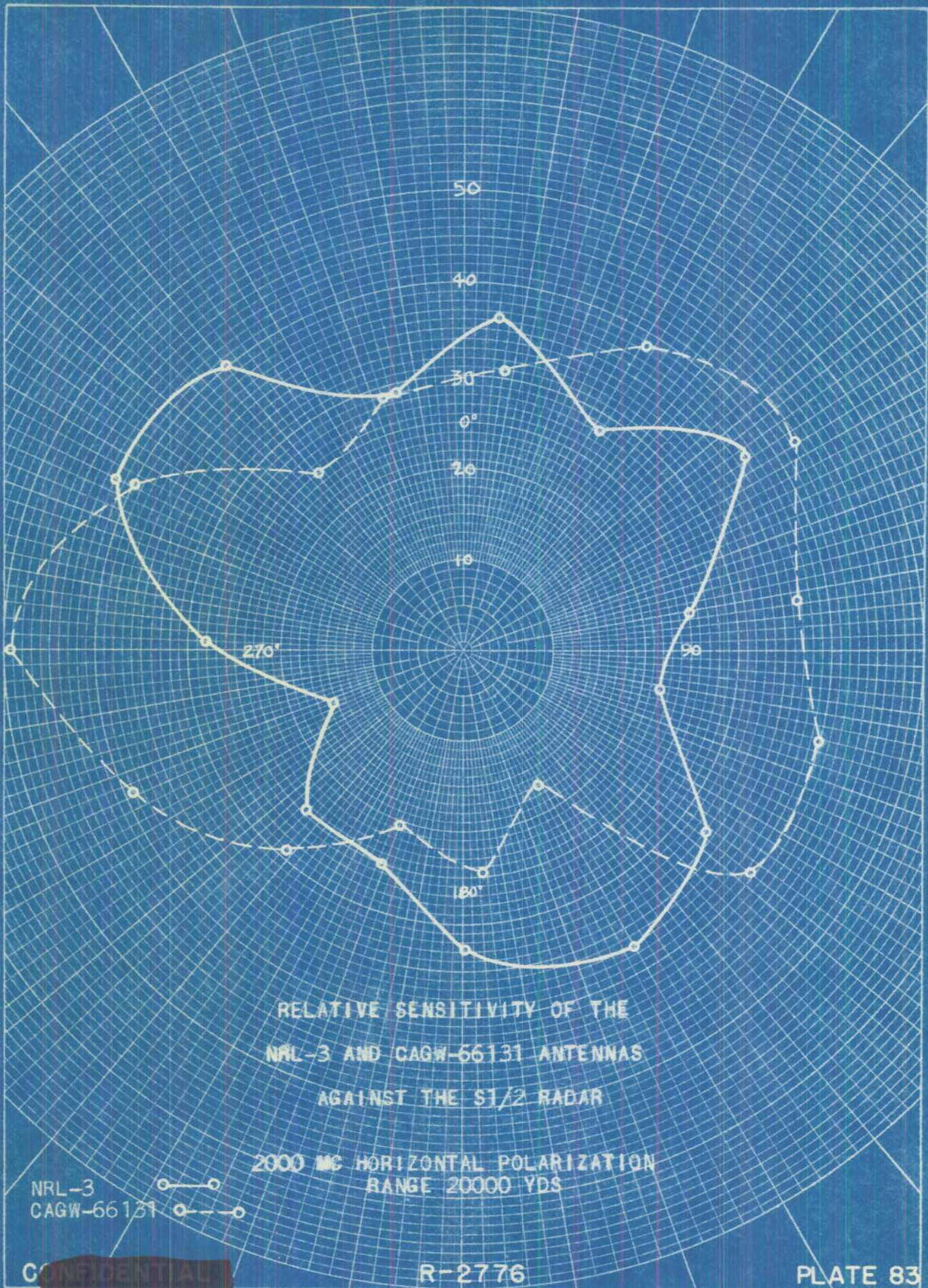
HUFFEL & ESSER CO., N. Y. NO. 343B  
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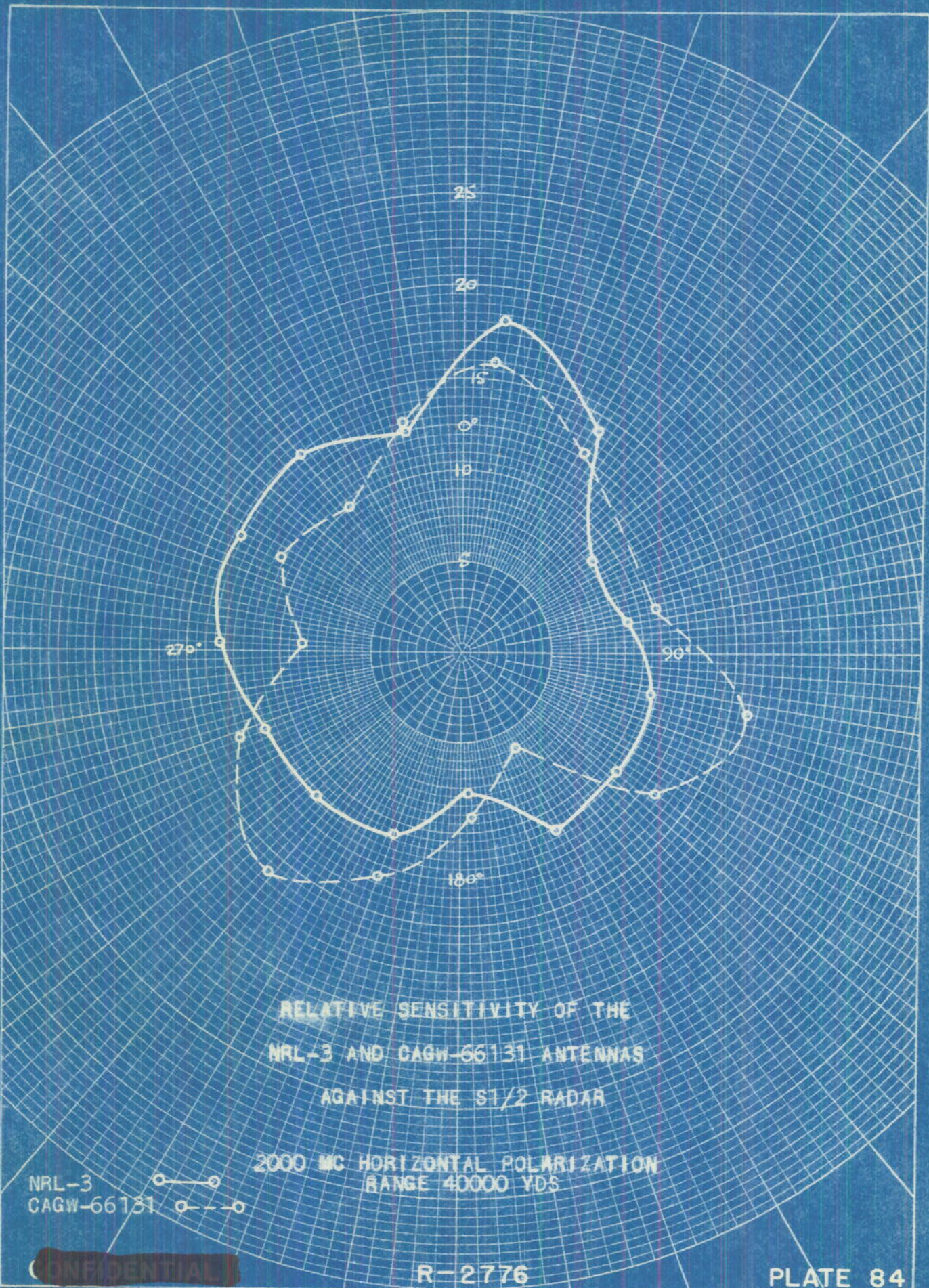
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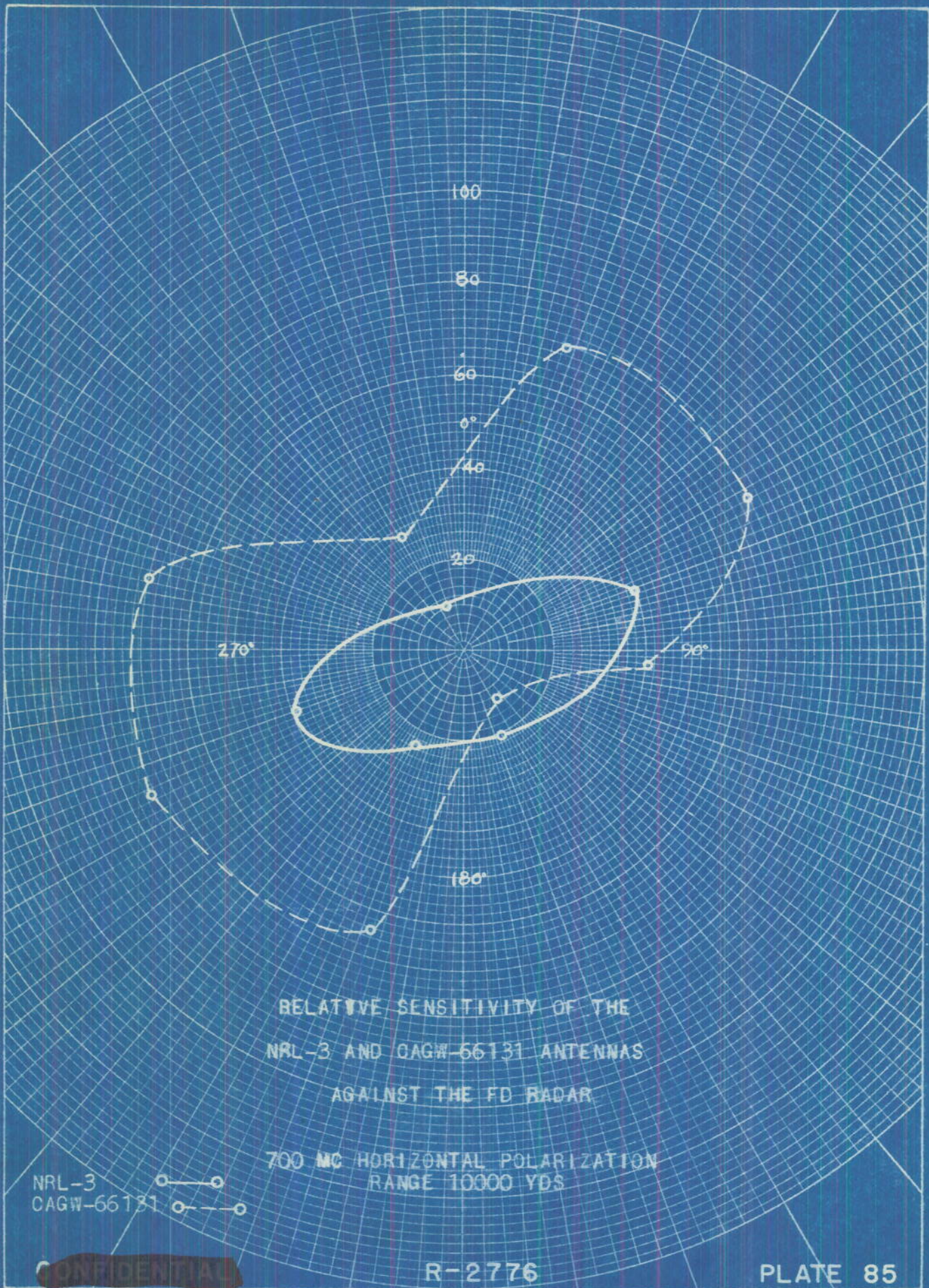
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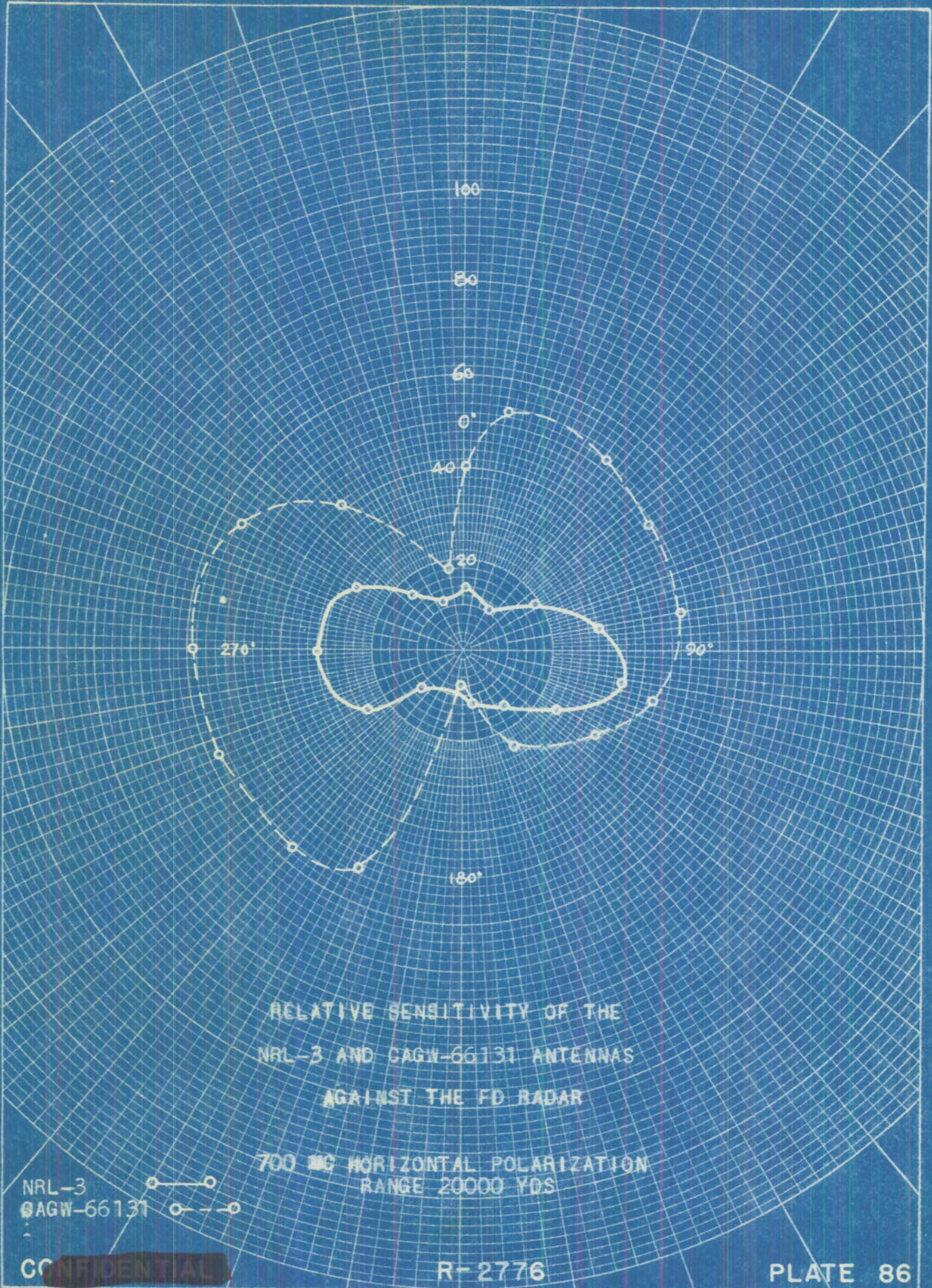
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RELATIVE SENSITIVITY OF THE  
 NRL-3 AND GAGW-66131 ANTENNAS  
 AGAINST THE FD RADAR

700 MC HORIZONTAL POLARIZATION  
 RANGE 20000 YDS

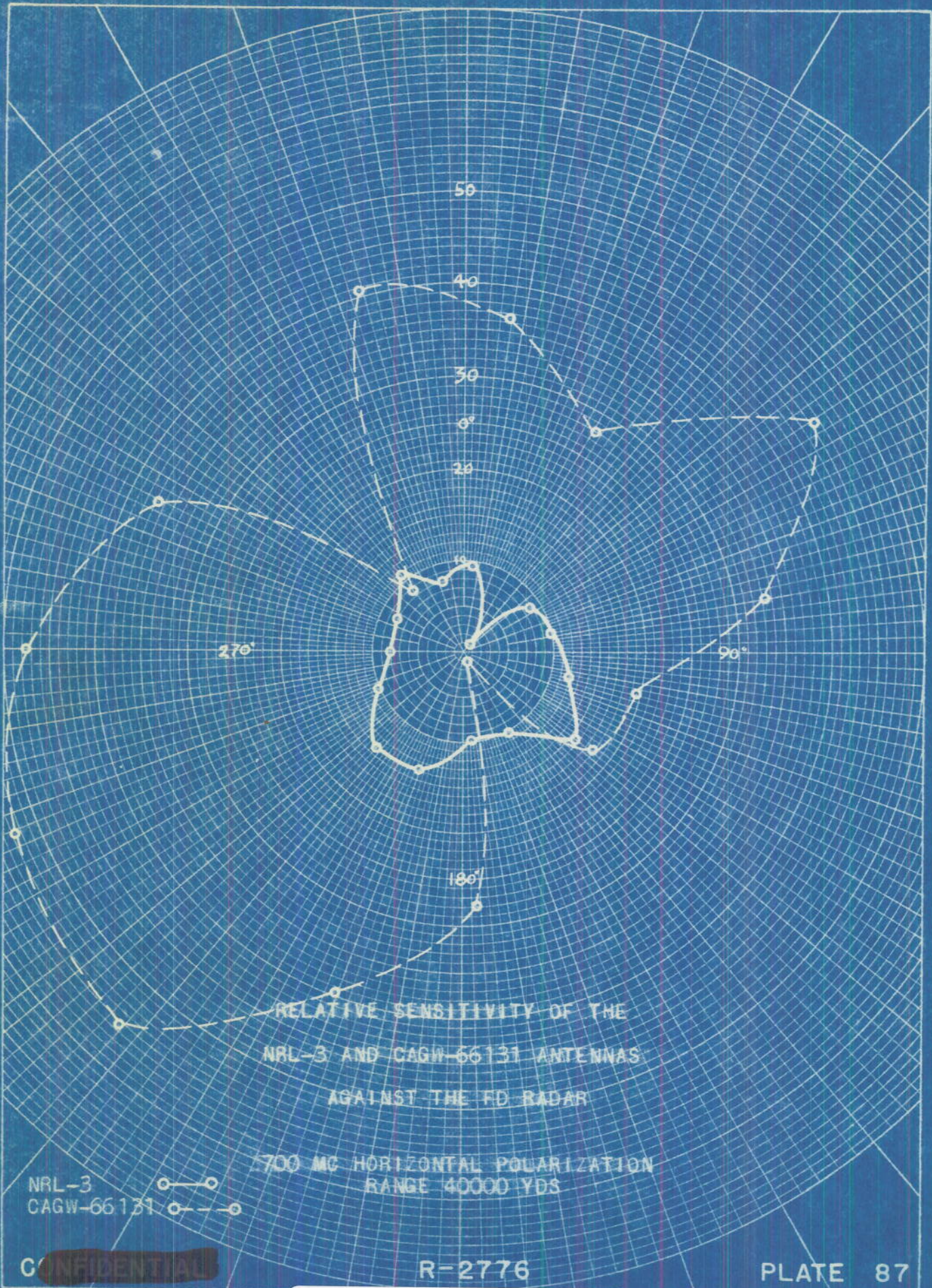
NRL-3 —○—○—  
 GAGW-66131 -○--○-

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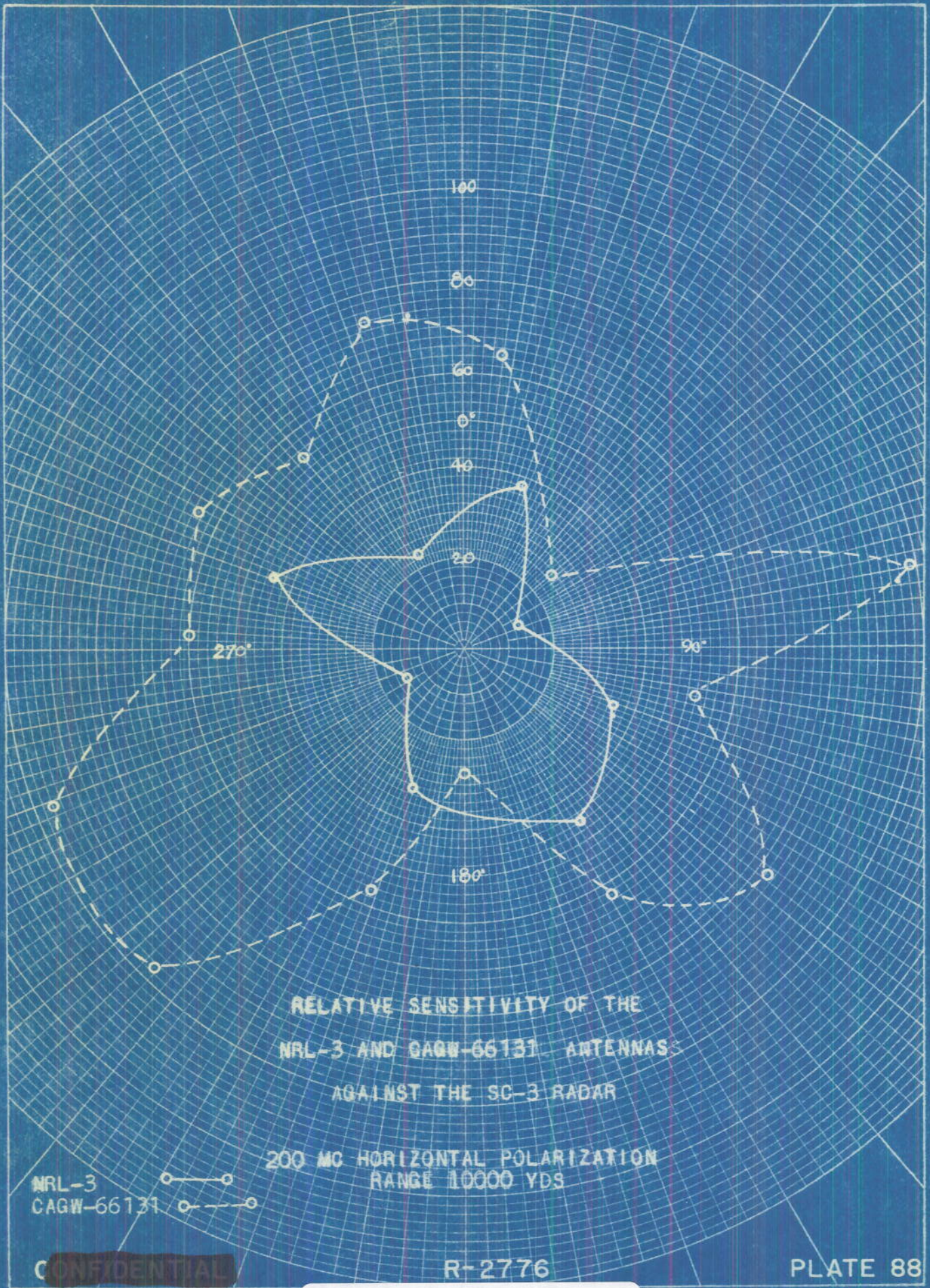
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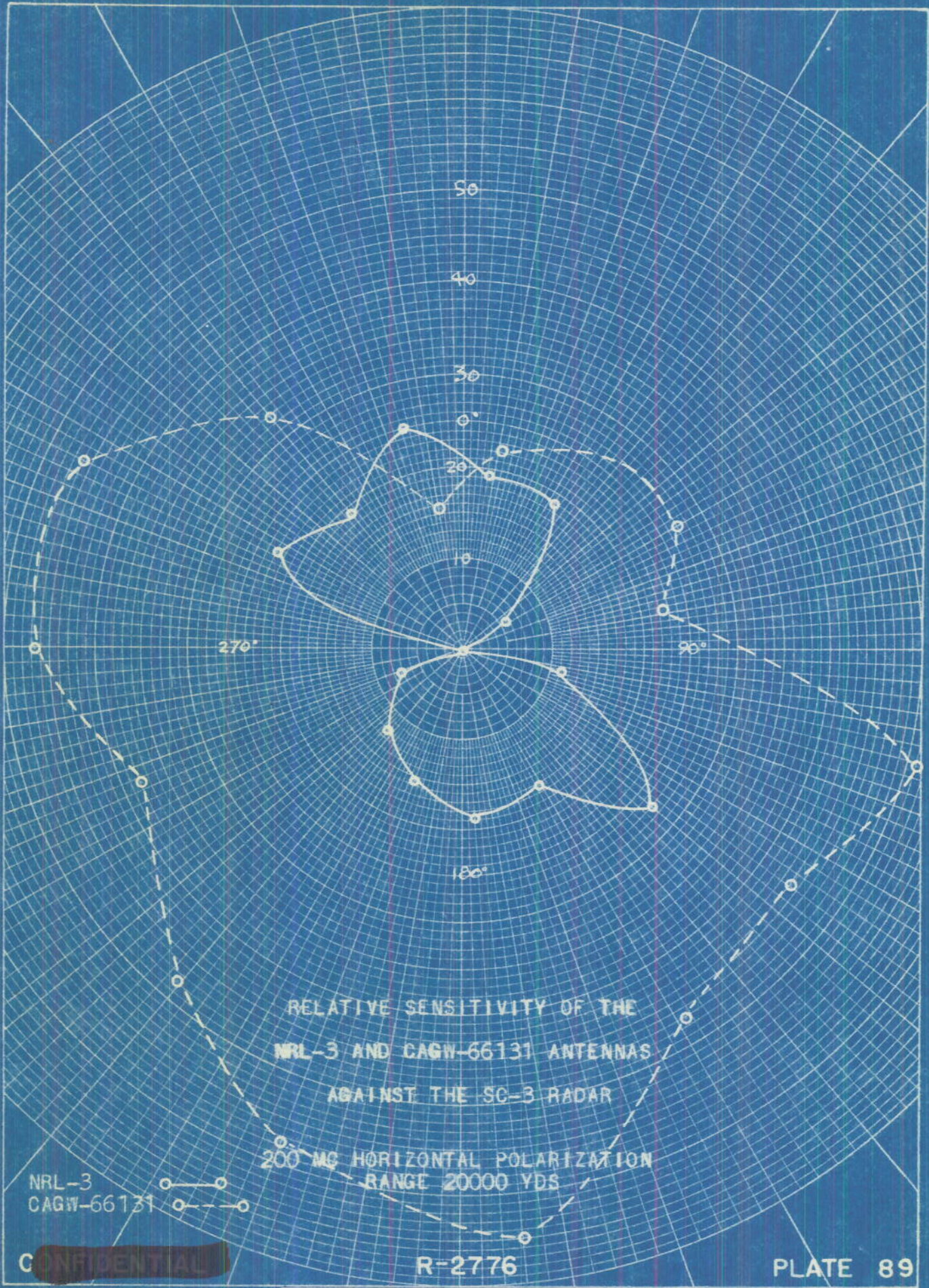
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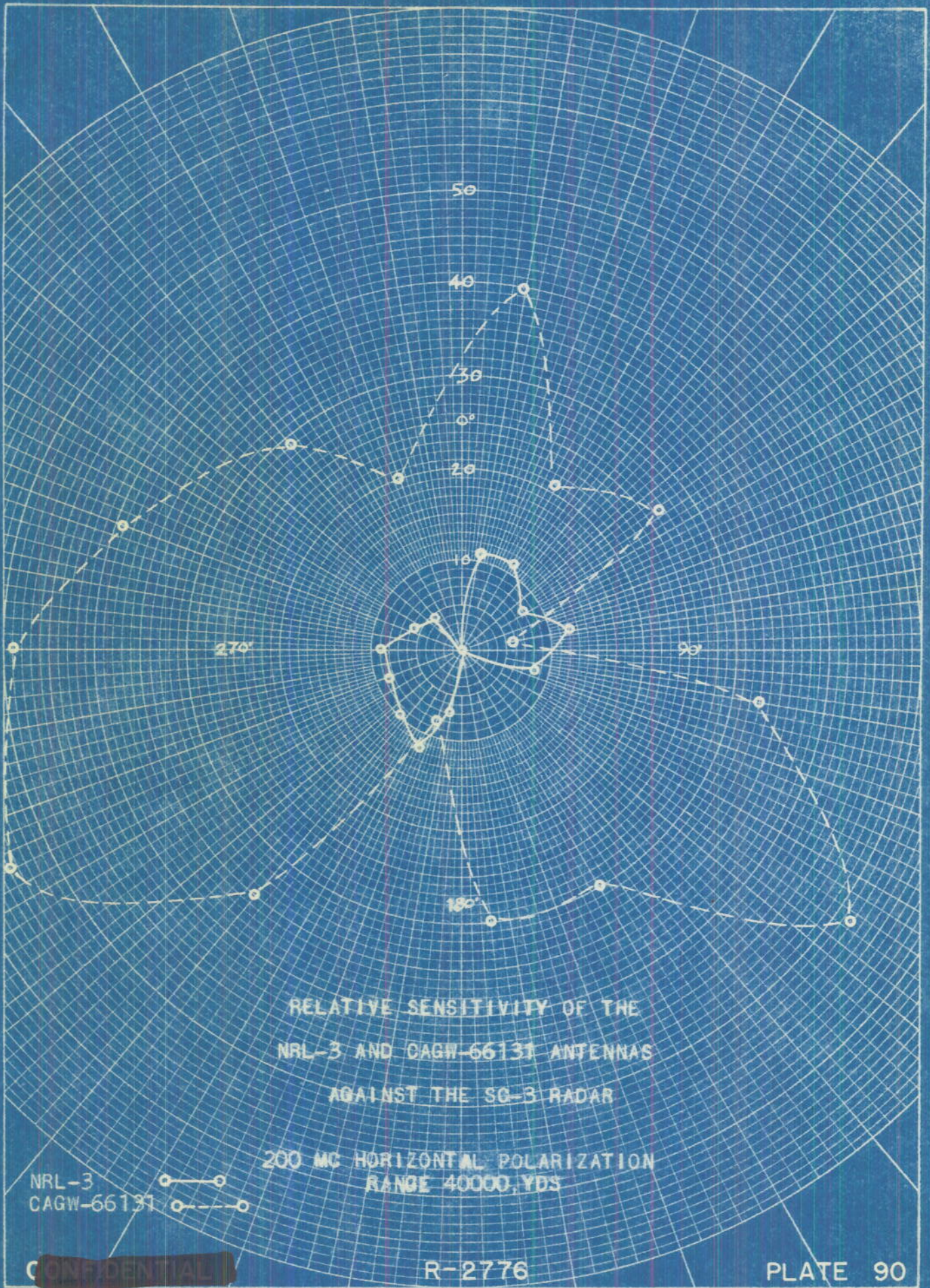
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