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WIDE RANGE SUPERSONIC PROJECTOR FOR CALIBRATION WORK

Submitted by the Bell Telephone Laboratories for the Western Electric Company

Under Contract OEMsr-783

by Reginald L. Jones
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P R E F A C E

The work on the 6B Projector described in this report was initiated in Section 6.1 of the National Defense Research Committee.

This work proceeded in accordance with Contract OEMsr-783; to which the Office of Scientific Research and Development and the Western Electric Company are the parties.

A B S T R A C T

The 6B Projector described in this report was developed by the Bell Telephone Laboratories primarily for laboratory test work. It is a relatively low power device that produces moderate sound pressures. Its most useful frequency range is from 10 kilocycles to 80 kilocycles per second. It will respond to higher and lower frequencies however, and in situations where the rapid change in output below 10 kilocycles and the sharpness of the main beam above 80 kilocycles can be tolerated, it can be used from below 5 kilocycles to above 100 kilocycles per second.

This instrument may be used as a hydrophone as well as a projector, and data on its performance as such are included in this report.

WIDE RANGE SUPERSONIC PROJECTOR FOR CALIBRATION WORK

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WIDE RANGE SUPERSONIC PROJECTOR FOR CALIBRATION WORK

1.0 DESCRIPTION

The 6B crystal projector is an underwater sound projector designed primarily for short range testing work. It is a relatively low power projector that will produce moderate sound pressures throughout the frequency range from 5 kc to 100 kc. Its most useful range is from 10 kc to about 80 kc. Beyond this frequency the increasing sharpness of the main lobe restricts the size of the area where a uniform sound pressure field exists.

The 6B projector may also be used as a hydrophone. As a hydrophone, its useful range starts at about 5 kc and extends upward to about 100 kc.

2.0 CONSTRUCTION

The general appearance of the projector is shown in Fig. 1, a photograph of the complete projector, and its construction is shown in Fig. 2, a schematic assembly drawing. The sound pressures are radiated from the diaphragm, which is driven by an array of 45° Y-cut Rochelle salt crystals mounted between the diaphragm and the steel backing plate. Thin ceramic plates on both sides of the crystal array insulate it from the diaphragm and the steel backing plate. The assembly comprising these elements is bolted to the front of the hemispherical lower casting, to form the crystal head assembly. The crystal head assembly is bolted to the stem projecting from the upper casting which contains the transformer. The power leads are contained in the rubber covered cord that comes out through the packing gland on the top of the projector.

Watertight metal to glass seals are used to bring the connections out of the crystal chamber and are also used in the connections between the interior of the crystal head assembly and the stem protruding from the bottom of the upper casting. The mechanical joints between the crystal assembly and the lower casting, between the lower and the upper castings, and between the upper casting and the top are waterproofed with rubber gaskets.

The rear half of the crystal head assembly is enclosed in a casing of a low impedance, sound reflecting, cork and rubber material to reduce the amount of sound energy radiated toward the rear of the projector.

2.1 Mounting Facilities

Because of the variety of ways in which it may be desired to mount the projector, mounting facilities of a very general nature only are provided. Four holes, with 3/8-inch x 24 threads per inch, are provided in the four corners of the upper casting. These holes are spaced equi-distantly on a diameter of 3-15/16 inches.

3.0 DIMENSIONS AND WEIGHTS

Weight complete	30 pounds
Height overall	19-1/2 inches

Height from mounting surface to center of diaphragm	15-1/2 inches
Diameter of diaphragm	5 inches
Diameter of head overall	6-1/4 inches

The diaphragm face is approximately 5/8 inch ahead of the centerline of the transformer housing.

A 25-foot shielded flexible two-conductor rubber insulated and rubber jacketed cord is provided for connecting the projector to the source of power.

4.0 ELECTRICAL CHARACTERISTICS

4.1 Crystal Array

The crystal array of the 6B projector contains ninety-six 45° Y-cut Rochelle salt crystals connected in parallel. The dimensions of each crystal are .810" x .260" x .138" thick. The crystals vibrate along their .260 inch dimension.

After the two insulating plates are cemented tightly to the faces of the crystal array, the thickness of this assembly is reduced to approximately .360 inch.

The capacitance of the crystal array mounted between the steel backing plate and the diaphragm was determined by the three measurement method, with the housing grounded. The direct capacitance between the leads was 230 mmf. The capacitances appearing between the leads and the housing were 185 and 195 mmf. The total capacitance between leads was 325 mmf. These values are typical; there are, of course, some variations among individual projectors.

4.2 Transformer

A W31035 transformer is used to deliver the power from e low impedance source to the high impedsnce crystal array. The impedence ratio of this traneformer is nominally 1:300. Figure 3, the schematic circuit diegram of the projector, shows how it is connected.

The characterietics of this transformer are such that the voltage across the crystal array decreases with increasing frequency when the projector is connected to the recommended 135-ohm source of power. This characteristic counterects the inherent tendency of the crystal array to increase the energy output on the acousticel axis at frequencies below the resonant frequency of the crystels. Above this resonence, it accentuates the tendency of the output to fall with increaeing frequency.

4.3 Impedence

The input impedances of several 6B projectors were measured while they were immersed in water. The impedence curves shown in Figure 4 were plotted from theee deta. The resietence varies from ebout 25 ohms st 10 kc to about 50 ohme at 100 kc. The reactance epproximates e .1 mf cepacitance in series with a .83 millihenry inductence.

4.4 Power Supply and Allowable Power Level

The 6B Projector has been operated from power sources having internel output impedsnces of 64 ohms, 135 ohms and 600 ohms. The moet gradual increase in axial response with frequency was obtained using the 135-ohm source of power and this is recommended in "Operating Notes for the 6B Projector".

This projector has been operated without injury using a power level of 1 watt of maximum available power from a 135-ohm source.[1] However, it is recommended in the same notes that the power be limited to .1 watt maximum available power from a 135-ohm source.

4.5 Grounding

In general, the grounding scheme for any test setup is dictated by considerations of reducing the electrical crosstalk between the projector and the hydrophone to the lowest possible level. In order to provide the greatest flexibility in the projector, the shielding in the transformer is connected to the shield in the flexible cord and this circuit is insulated from the case of the projector. Both sides of the transformers and their associated circuits are ungrounded.

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[1] The maximum available power W of a source of power with internal impedance r_s and open circuit voltage e_s is defined as $W = \frac{e_s^2}{4r_s}$.

5.0 ACOUSTICAL CHARACTERISTICS

5.1 Calibrations

The acoustical characteristics of the 6B projector were determined by making free field tests, using 3A Standard Crystal Hydrophones to measure the sound pressures. In order to eliminate acoustical effects arising from the proximity of sound reflecting objects, measurements were made at various distances. This work was done at the Mountain Lakes and Orlando test stations of the Underwater Sound Reference Laboratories.

In the frequency response and directivity data given later the following system of angular designations are used throughout for uniformity. With the projector mounted vertically, the vertical centerline of the diaphragm is taken as the axis of rotations. 0° incidence signifies that the hydrophone is on the line extending out perpendicularly from the center of the diaphragm. Positive angles indicate that the projector has been rotated clockwise from this position and negative angles indicate that it has been rotated counter clockwise from this position.

5.2 Frequency Response

Figure 5 is a representative transmitting frequency response curve for the 6B projector connected to a 135-ohm source of power, as measured on the acoustical axis.

This calibration is expressed in terms of the sound pressures 1 meter from the diaphragm for an available power level of 1 watt.

There are some variations among individual projectors but their output follows the same general characteristics; a rapid rise up to 10 kc, a gradual rise from there to about 65-70 kc and a falling off above that.

5.3 Directive Characteristics

The distribution of the sound field about the 6B projector was determined by suspending it vertically in front of a hydrophone mounted in the horizontal plane passing through the center of the projector diaphragm, and rotating it about the vertical centerline of the diaphragm. The variation in the sound pressure with changing angles of incidence are shown graphically in Figs. 6, 7, 8, and 9 for 10, 20, 30, 40, 50, 60, 70 and 80 kc frequencies.

One of the principal points of interest in a test projector is the broadness of its main beam, because in many tests it is necessary to establish a uniform sound field over the device under test. Based on the averaged results of a number of directivity patterns taken on several 6B projectors the following table was established and is included in the operating notes for general reference purposes.

Frequency	Total Angle Over Which the Sound Pressure will not Very From the Maximum by More Than: 1 db	2 db
10	40°	60°
20	22°	34°
30	14°	20°
40	12°	17°
50	10°	14°
60	9°	12°
70	8°	11°
80	7°	10°

These figures are approximate and will vary somewhat between individual projectors. Occasional projectors also show a small angular displacement of the main lobe at some frequencies. When accuracy is required, it is recommended that the field be investigated using a hydrophone such as the 3A standard crystal hydrophone.

Measurements of the directivity in the vertical plane were also made on one projector. While the different relative positions of the transformer housing evidently caused differences in the distribution of the output, the results were substantially in agreement with the table above in so far as the characteristics of the main beam were concerned.

As mentioned earlier, the rear surface of the crystal head assembly was encased in a jacket of sound reflecting material in order to reduce to a minimum the radiation of energy in that direction which might cause undesired reflections.

Comparative tests indicated that the presence of this jacketing contributed materially to the relatively low intensity of the rear radiations, accounting for approximately 10 db at 10 kc and 15 to 20 db at higher frequencies.

6.0 RECEIVING CHARACTERISTICS

The receiving characteristics of the 6B projector were determined by comparisons with a 3A Standard Crystal Hydrophone in open water free field measurements. In these tests a high input impedance coupling amplifier was interposed between the 6B projector and the receiving system, so that essentially open circuit voltages were measured at the 6B projector leads. Fig. 10 shows the receiving frequency response of the projector whose transmitting response is shown in Fig. 5, through the range from 4 to 100 kc per second. Below this range the response was uneven, with large irregularities in some cases.

The spectrum noise level of the 6B projector, calculated on its measured effective resistance, is in the neighborhood of 180 db below 1 volt per cycle. The corresponding receiving threshold is at pressures in the neighborhood of 70 to 75 db below 1 dyne per sq. cm. What can be achieved in this direction in practice depends on the characteristics of the following circuit. It would appear that the calculated limit can be approached by the use of a suitable step-up transformer between the 6B projector and the following amplifier.

The same directive characteristics apply to the 6B projector used either as a projector or as a hydrophone.

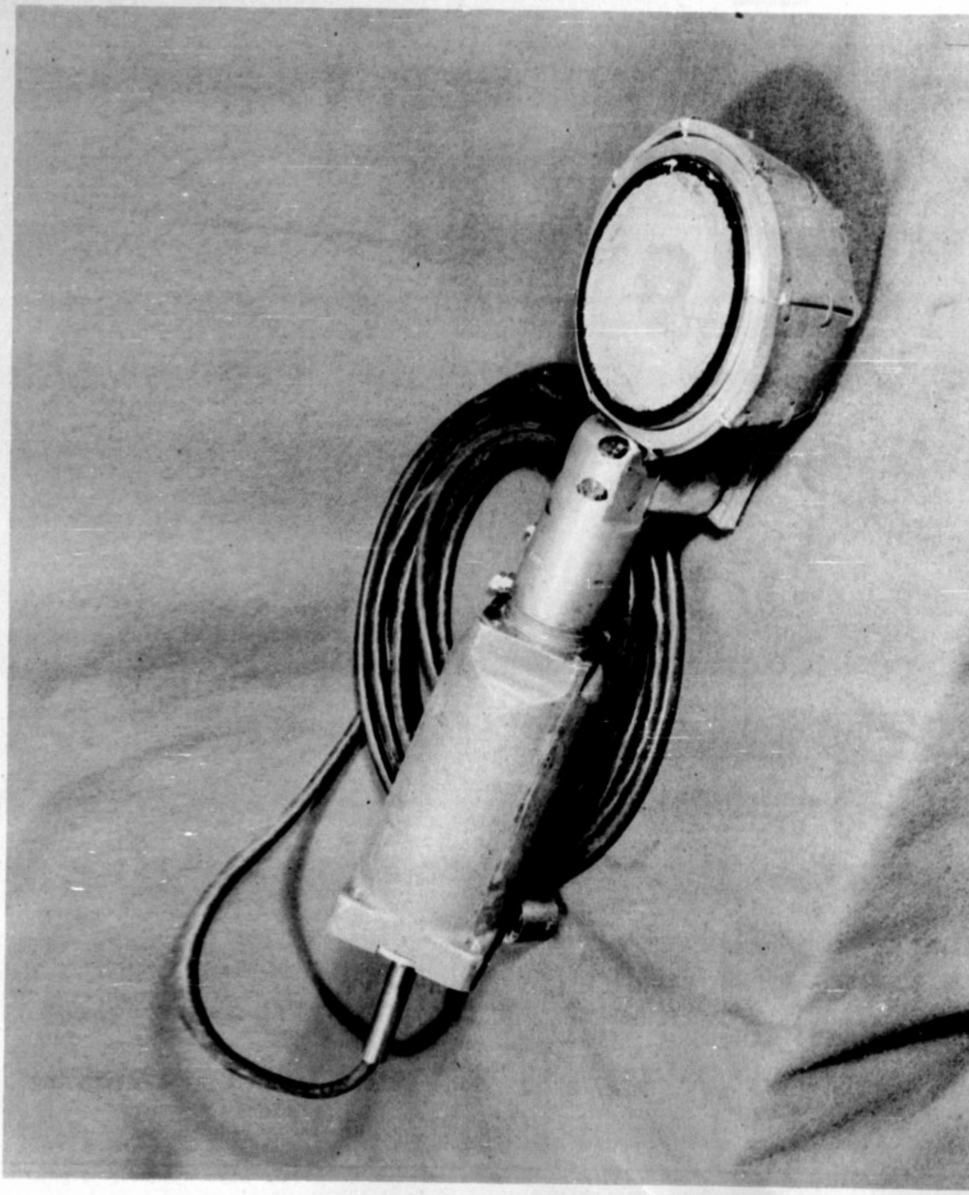

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Fig. 1 NDRC 6B Projector

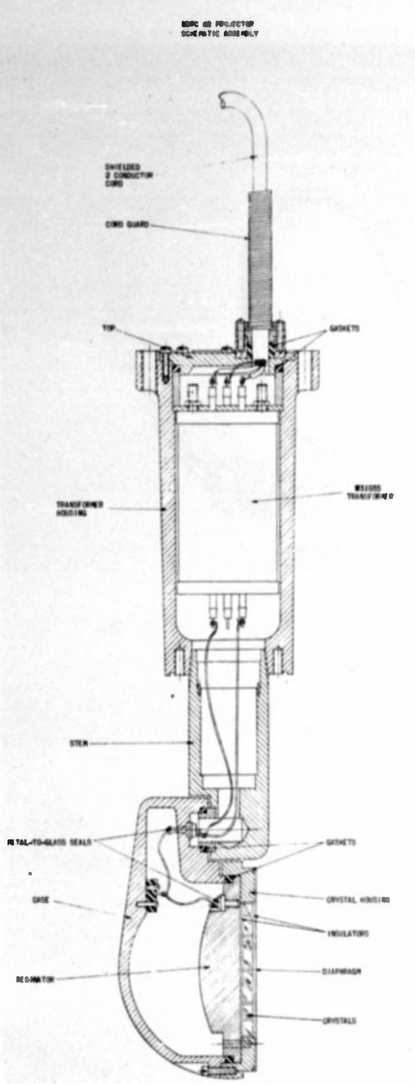

Fig. 2 Schematic Assembly Drawing

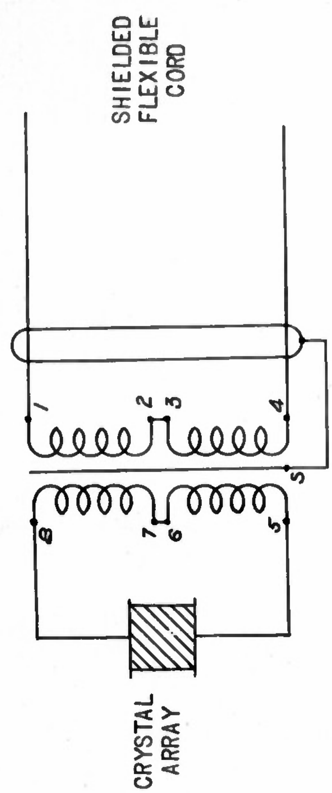

Fig. 3 Schematic Circuit Drawing

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			ES BA-250331

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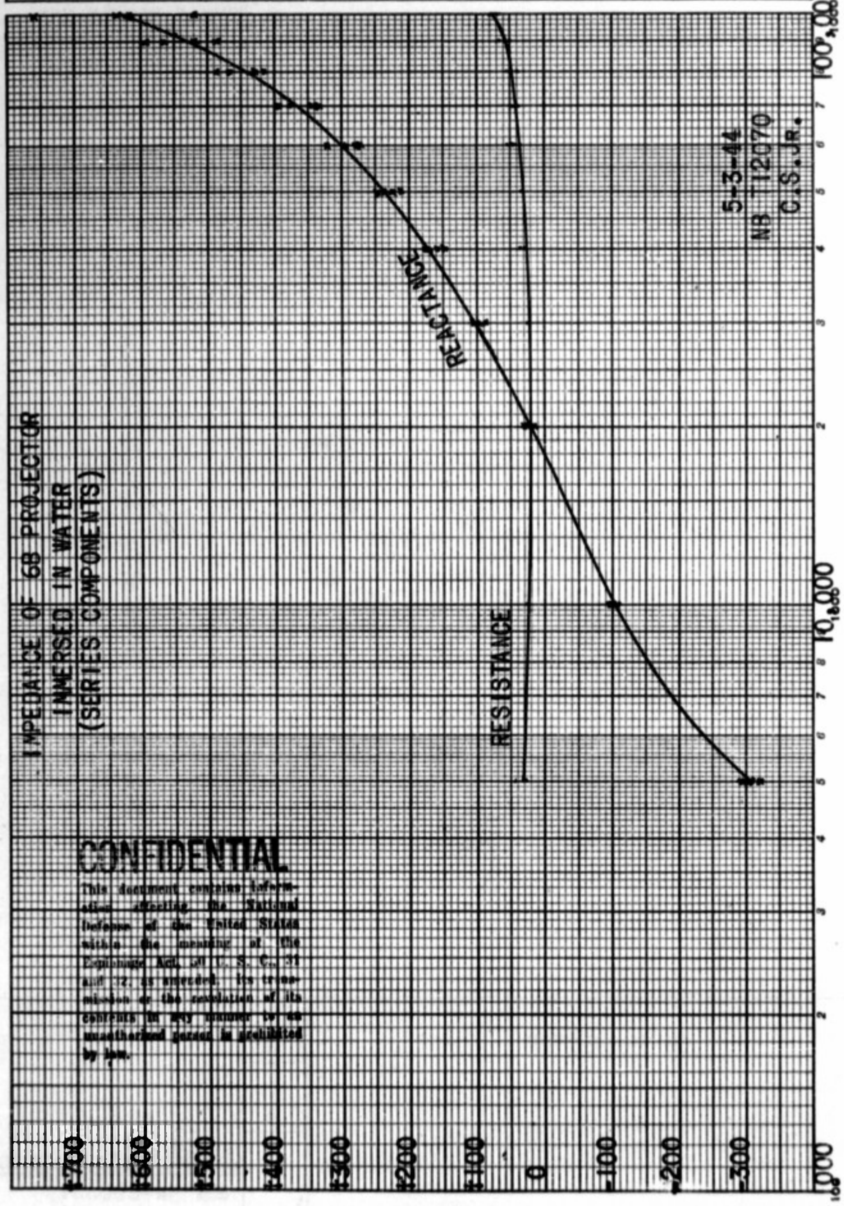

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Fig. 4 Impedance Characteristics

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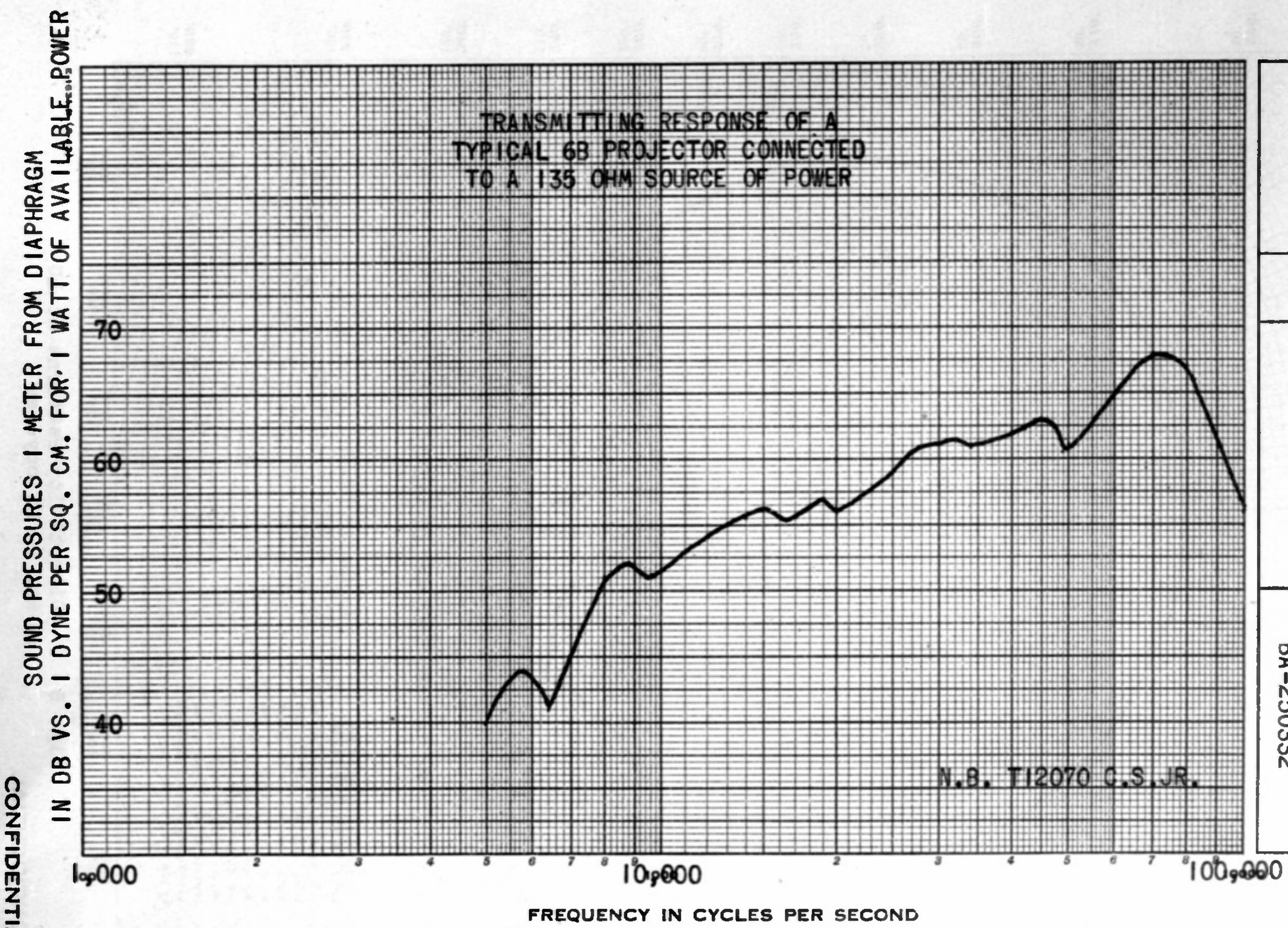

Fig. 5 Transmitting Response of 6B Projector

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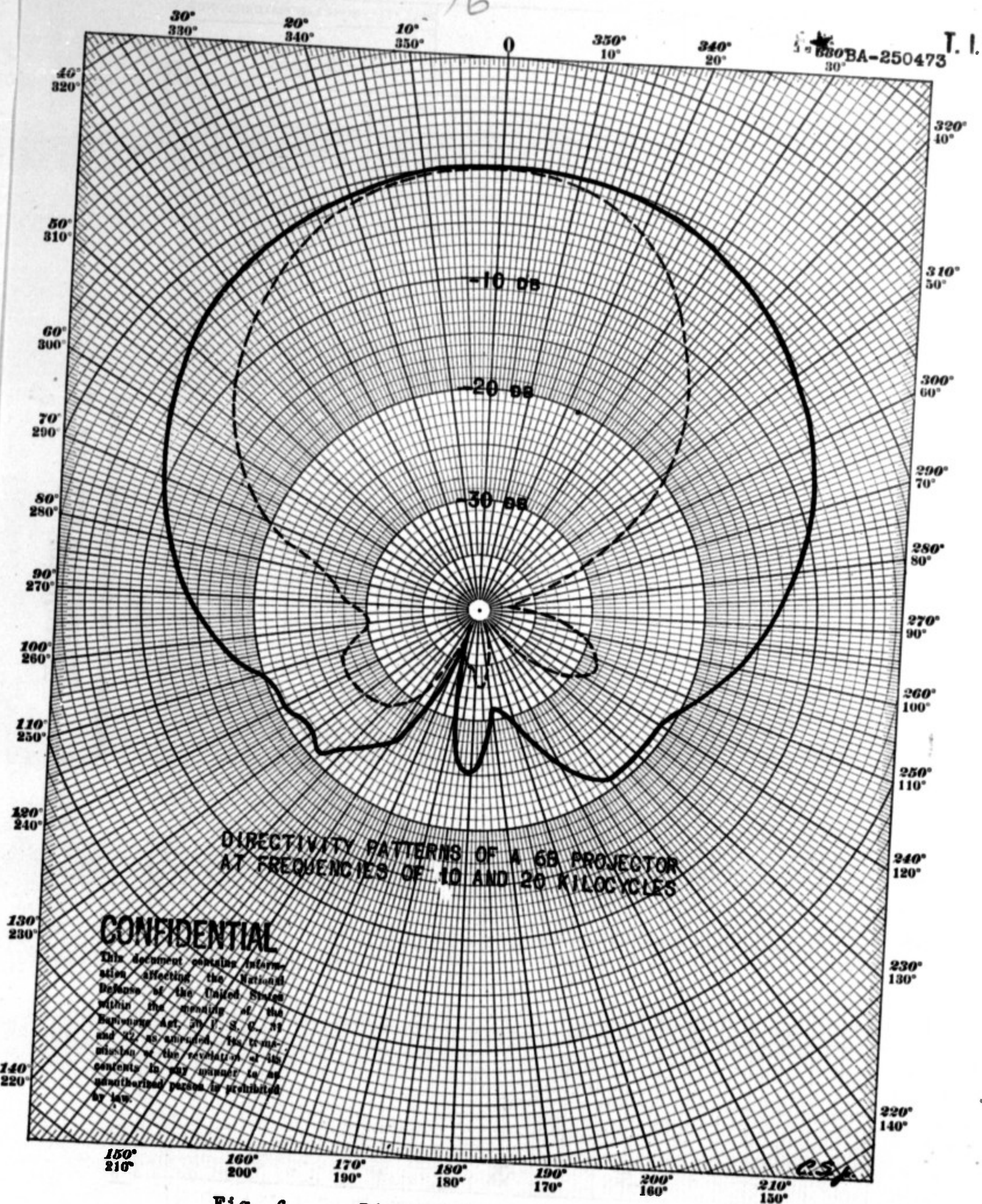

Fig. 6 Directivity Patterns at 10 and 20 Kilocycles

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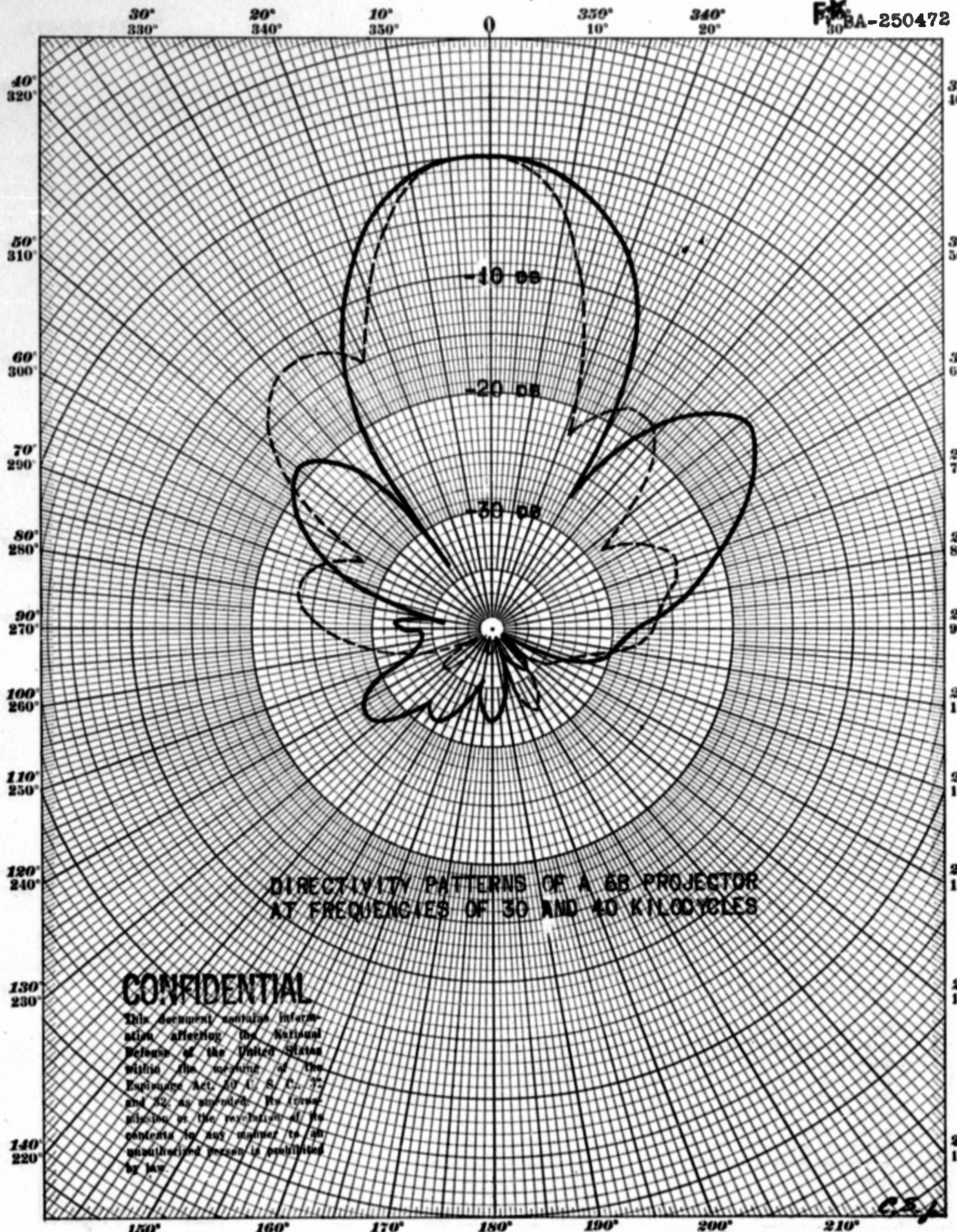

Fig. 7 Directivity Patterns at 30 and 40 Kilocycles

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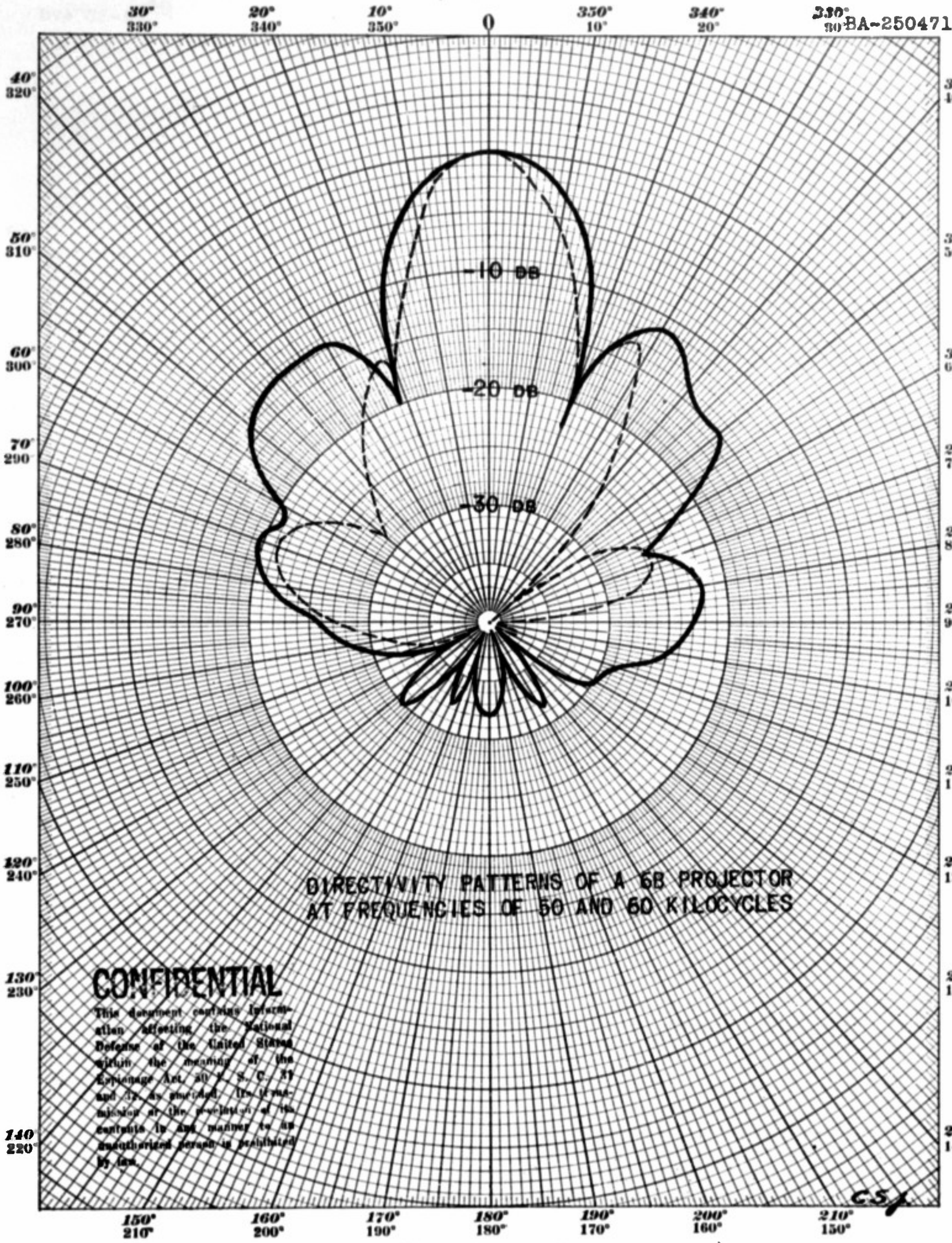

Fig. 8 Directivity Patterns at 50 and 60 Kilocycles

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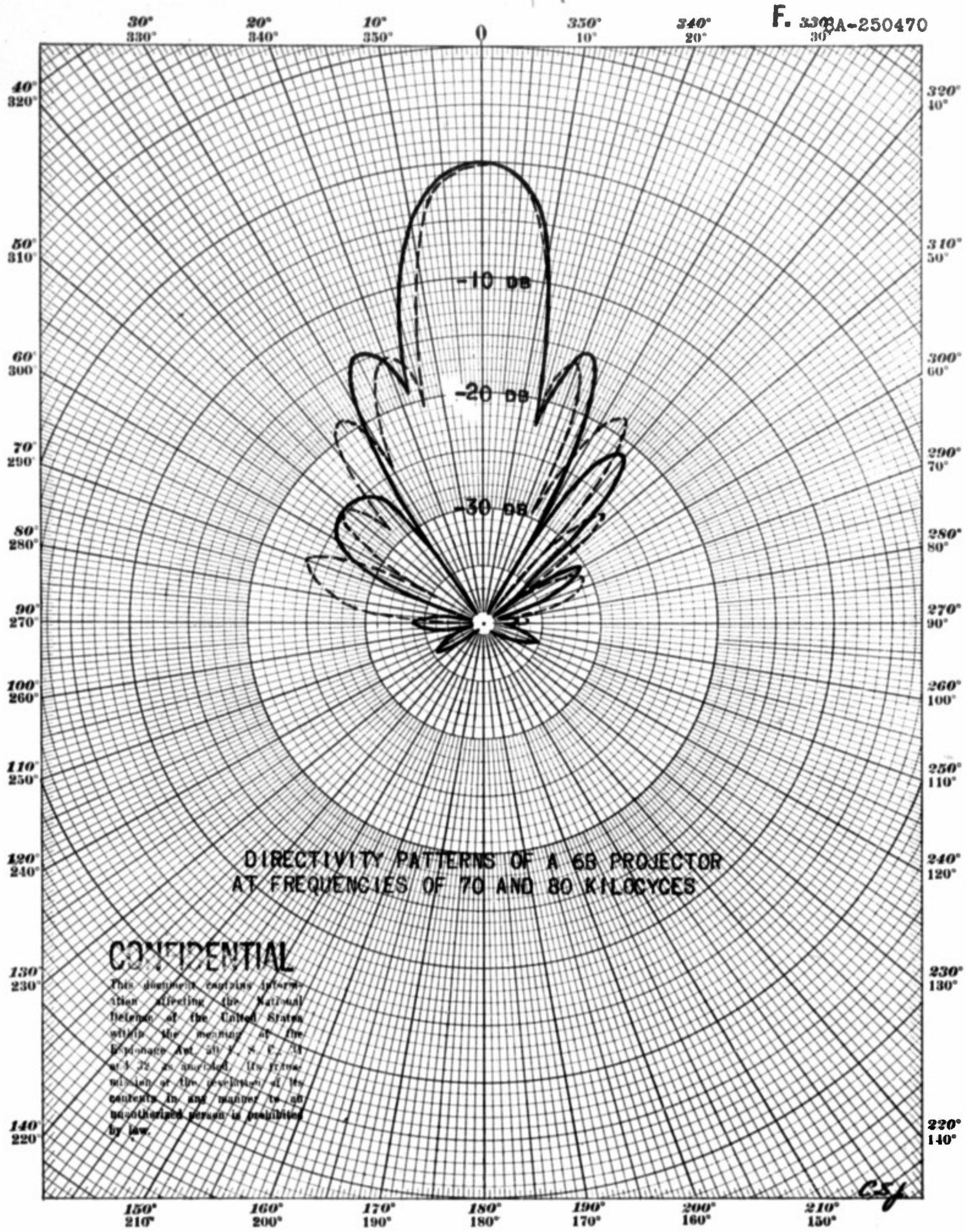

Fig. 9 Directivity Patterns at 70 and 80 Kilocycles

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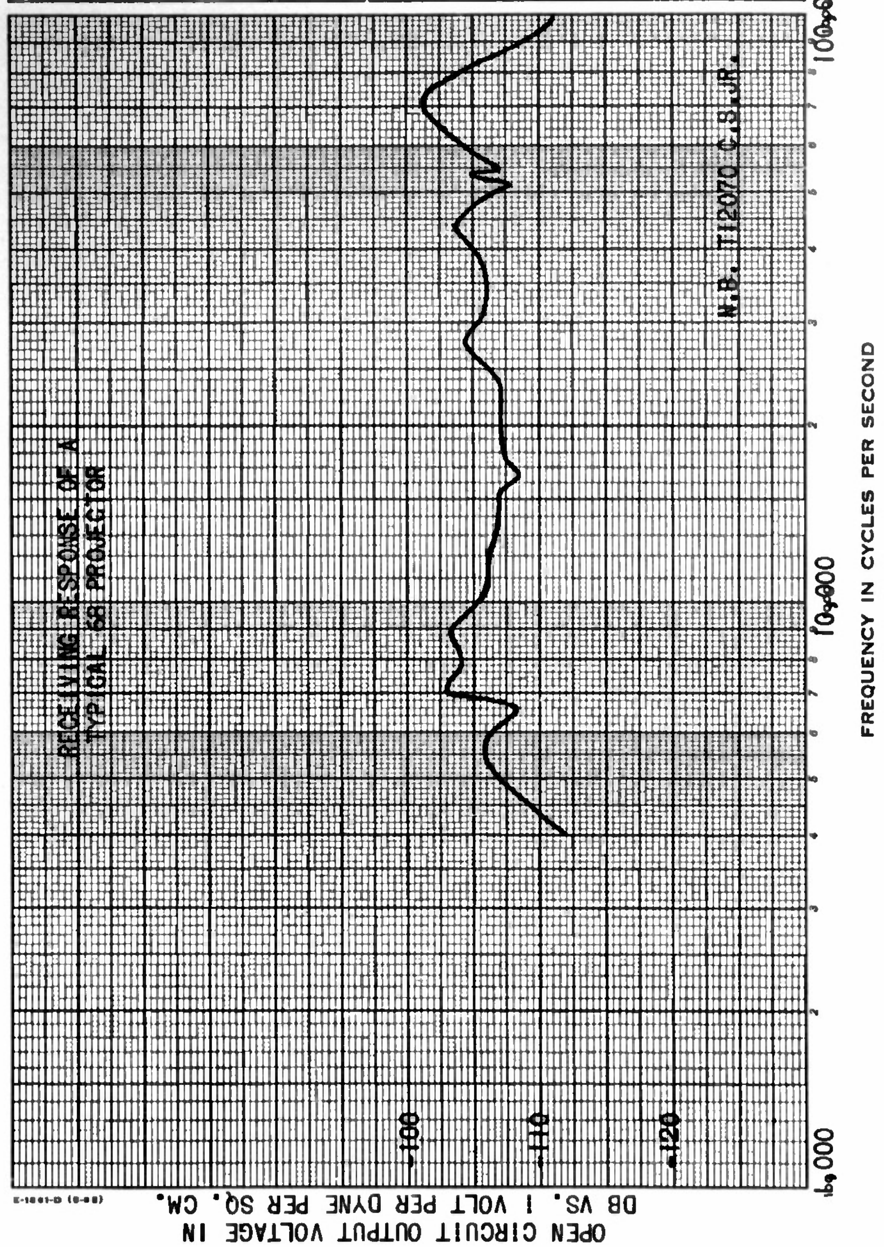

Fig. 10 Receiving Response of 6B Projector

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