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UNDERWATER SOUND MEASUREMENTS AT HIGH HYDROSTATIC PRESSURES,(U)
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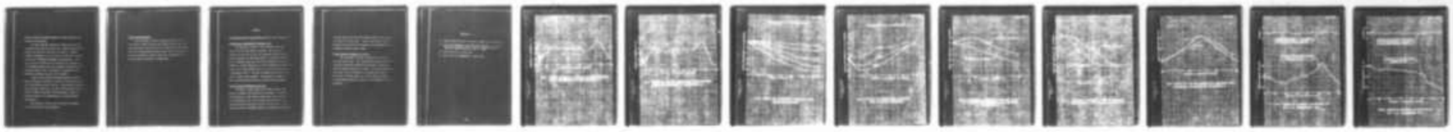

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ORLANDO, FLORIDA

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Abstract

Electroacoustic transducers used in underwater sound work may exhibit appreciable changes in transmitting and receiving responses when operated under high hydrostatic pressures. Changes in response as great as 6 db at 300 pounds per square inch have been measured.

Several curves which show the results of measurements on typical instruments are presented. Response hysteresis with direction of pressure change and shift of resonance frequency are two of the effects noted during tests at high pressures. The features of construction of two pressure-stable transducers which have been developed are given, and the transducer characteristics are shown in four Figures.

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USRL Report No. 15

UNDERWATER SOUND MEASUREMENTS AT HIGH HYDROSTATIC PRESSURES

Lloyd L. Paine and Charles L. Darner

Introduction

This report is a summary of the work done by the Research Group at the Underwater Sound Reference Laboratory in the field of underwater sound measurements at equivalent undersea depths to 600 feet in the intermediate frequency range (10 to 150 kilocycles). Its purpose is to indicate the effect of hydrostatic pressure upon the response of electroacoustic transducers.

The measuring equipment used has been described elsewhere (1) but will be reviewed briefly. Improvements in equipment and testing techniques have been made and two standard reversible transducers showing negligible change in response at high hydrostatic pressures have been constructed.

Data are presented showing the effect of high pressures upon the receiving response of typical instruments which can be subjected to the test conditions described. Changes in response as great as 6 db at 300 pounds per square inch have been measured at certain frequencies. The change in response may vary with the rate and direction of pressure change. There is some evidence that the resonance frequency can also vary with pressure.

The work reported must be considered of a preliminary nature only, but it indicates that appropriate acoustic tests should be made on all transducers designed for use at great undersea depths. Work is in progress to further improve the testing technique and to extend the test facilities to cover even greater limits of frequency, pressure, and temperature.

Testing Facilities

The tank in which underwater sound measurements can be made in the frequency range 10 to 150 kc and at any pressure to 300 psi is a horizontal steel cylinder eight feet in diameter and ten feet long, closed with concave ends that result in an overall length of about 14 feet. Two ports on top of the tank provide access to the interior for the rigging of test instruments. A motor-driven rotator operating through the cover of one top port permits 360° orientation of one instrument as well as constant-speed rotation for directivity pattern determinations. The other test instrument may be rotated through an arc of about 30° to permit proper acoustic orientation. The movement of this instrument is controlled by a mechanical linkage system that passes through pressure glands at the end of the tank. A movable carriage within the tank allows the distance between the two transducers to be varied from four to eight feet.

Cable leads to the test instruments pass through pressure glands in the port covers. When operating under pressure, the port covers are held down by hydraulically operated wedges, with rubber gaskets for sealing. Hydrostatic pressures are obtained by means of a high-pressure water pump. Safety valves protect the system from excessive pressures.

Acoustic measurements in the pressure tank differ from those in a free field because of the relatively small size of the tank and the presence of sound-reflecting walls. A pulsing technique must therefore be used in order that the direct signal from the projector is received and measured by the hydrophone before any reflected energy arrives at the hydrophone. Satisfactory operation in a steel tank by the pulsing method requires considerable dissipation of sound at the tank walls and ends, otherwise the reflected energy from the concave tank end can build up extremely high values of sound pressure at the hydrophone position. The electrical signal resulting from the reflected sound wave may be so strong that it will pass through the blocked receiver and increase the direct signal measurement. Dissipation of sound energy is necessary also to reduce the reverberant energy level in the tank from each transmitted pulse to a point where the energy remaining from one pulse does not affect the measurement of the direct signal from the succeeding pulse.

The best approximation to a sound-absorbing material that has been used with reasonable success is ordinary 8" x 8" x 16" concrete building blocks. The lower half and all of both ends of the tank have been lined with more than 200 of these blocks. Scattering and absorption of sound by the blocks is such that no concentration of reflected energy occurs at the hydrophone position and the direct signal measurement is not increased by an overriding reflected signal. The reverberant energy level for the bare tank is 20 to 30 db down after 40 milliseconds, but is more than 60 db down after 40 milliseconds when the tank contains 200 concrete building blocks.

The use of concrete blocks as a sound-absorbing material at the walls of the tank has permitted reciprocity calibrations of test instruments in the tank which are within ±1 db of calibrations made in open water by the Calibration Group of the USRL. The accuracy of the system is estimated to be about ±1 db.

A test distance of about six feet is normally used. This factor of course limits the size of transducers which may be calibrated in the tank. A transmitted pulse of 1.0 millisecond and a received pulse of 0.8 millisecond are used, with pulsing rates of 20 to 60 pulses per second. The satisfactory working range of the system is 10 to 150 kc, although experiments are in progress to extend the lower limit. Data are automatically and continuously recorded on special charts.

Results of Tests on Typical Instruments

Few types of instruments satisfactory for use in the high-pressure tank system are readily available, primarily because of the limited size and the high mechanical strength requirements.

One type of instrument which meets the requirements of size and strength shows a marked variation in response with pressure over portions of the frequency range. Figures 1 and 2 show the variation in receiving responses when Transducers A and B are subjected to 300 psi hydrostatic pressure. Transducers A and B are similar instruments with X-cut Rochelle salt crystals.

Figures 3 and 4 show the change in response for various frequencies resulting from hydrostatic pressures to 300 psi when Transducer A is used as a projector and Transducer B as a hydrophone. The variation shown includes both the change in transmitting response of Transducer A and the receiving response of Transducer B.

Figure 5 shows the change in response with pressure for Transducer C, a magnetostrictive-type unit. In this case the effect of pressure on the transmitting response is somewhat greater than the effect on the receiving response for equal amounts of pressure.

A hysteresis type of curve is obtained for Transducer A transmitting at 16 kc when the hydrostatic pressure is increased to 300 psi and then decreased to 0 psi at rates of about 40 psi per minute. Figure 6 shows the change of response with pressure under these conditions. Instruments showing this type of response variation with pressure should be calibrated at the rate of pressure increase or decrease under which they might be used.

Figure 6 indicates complete recovery of response upon return of pressure to its initial condition. In some cases it has been noted that recovery in response is not complete until a considerable period of time has elapsed. Instruments showing change in response with pressure should be investigated for delayed response-recovery time.

Another type of instrument which has been used for work under pressure shows only small response changes due to hydrostatic pressure. The construction of this type of instrument is such that repeated pressurizations cause a gradual change in characteristics, with ultimate breakdown of the mounting of the crystal motor. The instrument can be used for a time in reciprocity calibrations, but is unsuitable for use as a comparison standard.

It has been noted in tests on these projectors that the resonance frequency may be shifted under pressure. Figure 7 shows one such instance in which the resonance appears to be shifted about 2 kc by 300 psi. The effect shown in Fig. 7 lies almost entirely within the limits of error; nevertheless the trend seems definite and must be investigated further, especially on instruments which are tuned to resonate at a particular frequency and then operated under pressures considerably different from the pressures at which tuned.

Pressure-Stable Instruments

The reciprocity principle is the basis for the most reliable and accurate method for the calibration of sound instruments when certain "reciprocity" requirements are met. The principle has been discussed at length elsewhere (2).

The reciprocity method permits the absolute calibration of the instrument under test by means of two other instruments, one of which is reversible, and neither of which need be calibrated. The absolute calibration so obtained is therefore independent of the characteristics of the calibrating transducers.

Calibrations made at high pressures require that the test instruments meet the "reciprocity" requirements while under pressure. Instruments which show transmitting and receiving response changes resulting from hydrostatic pressure may be used, provided the changes are not accompanied by appreciable response hysteresis with time. Instruments that require an appreciable period of time for response recovery are usually unsuitable for reciprocity measurements.

It became desirable, therefore, to obtain two reversible transducers that would show little or no change in response with pressure and would have no response hysteresis. A standard Tourmaline Hydrophone (3, 4) was tested, but found to be unsatisfactory from a mechanical standpoint at high pressure. A new type housing was provided for the tourmaline disc assembly, and the resulting transducer has proven extremely satisfactory at all pressures tested to date. The methods of construction of the tourmaline hydrophones are given in the Appendix.

Figures 8 and 9 show the receiving response of the tourmaline transducers, designated as RL-T-1A No. 1 and RL-T-1B No. 1, over the frequency range 10 to 150 kc. The variation in response with a pressure of 300 psi is also shown in the Figures and lies within the limit of accuracy of the measurements; hence, for practical purposes, the instruments may be considered stable with pressure.

The directivity patterns of the tourmaline transducers at 100 kc are shown in Figs. 10 and 11.

Future Testing Facilities

The new permanent structure laboratory which will soon be erected at Orlando, Florida, will contain facilities for testing at pressures to 1000 psi and over an extended range of temperatures in the intermediate-frequency range. Work is in progress to have test instruments available which will be suitable for use at the new extremes of pressure and temperature.

APPENDIX

CONSTRUCTION DETAILS OF TRANSDUCERS XL-T-1A No. 1 and XL-T-1B No. 1

Construction of Tourmaline Disc Assembly (3, 4)

The assembly is composed of four tourmaline discs 0.129 inches thick and 2.187 inches in diameter. These discs are stacked one on top of the other and separated by nickel electrodes of equal diameter and 0.005 inches thick. To assemble the discs, all the contacting faces were coated with Vulcalock, the stack was mounted on a steel backing plate of similar diameter and 0.312 inches thick, and the whole assembly baked in an oven for twelve hours at a temperature of 85° C. The unit was removed from the oven in the form of a hard, compact cylinder. This cylinder is mounted on a disc of 1/4-inch corprene backed by a disc of 3/4-inch plastic.

Pressure Case and Assembly, XL-T-1A No. 1

The case is a brass cylinder 6.375 inches long and 3.25 inches in diameter, with 0.25-inch wall thickness. The face of the transducer is a rho-c rubber window clamped across one end of the cylindrical case. The tourmaline disc assembly is in an oil-filled chamber sealed at one end by the rubber face. At the opposite end of the oil-filled chamber, the electrodes pass through conductor seals to the air-filled portion of the case where they are joined to the cable ends. Neither of the crystal leads is connected to the case or wire shielding, so the instrument may be considered as having balanced output.

Pressure Case and Assembly, XL-T-1B No. 1

This instrument is similar to XL-T-1A No. 1, but has a case 9-1/2 inches long. This provides space within the case for a matching transformer (100,000:135 ohms) which is inserted between the electrode leads and the cable. An LC network across the cable leads serves to eliminate the resonance peaks shown by XL-T-1A No. 1, but also lowers the overall receiving response. The transformer improves the transmitting characteristics of the transducer.

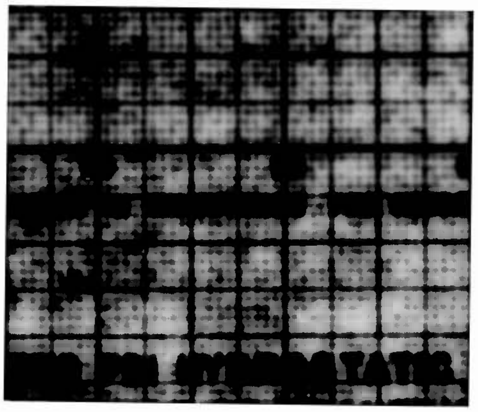
References

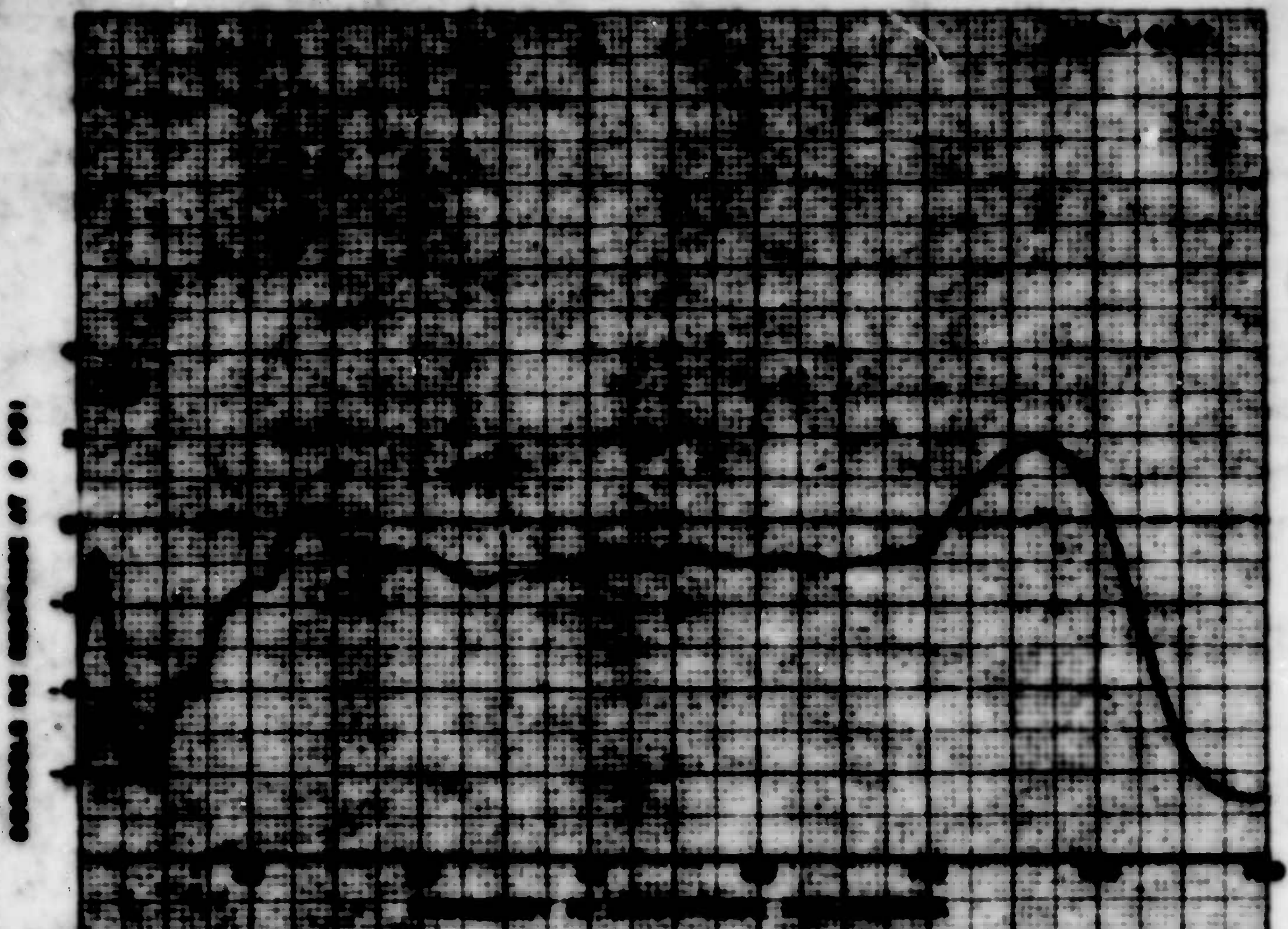
(1) Summary Technical Report of Division 6, NDRC Vol. 10 (1946) Chap. V

(2) Simplified Procedures for Reciprocity Calibration, A. A. Janszen. ONR Contract N5ORI-76, Project Order X. Acoustics Research Laboratory, Harvard University, Sept. 10, 1947.

(3) USRL Report No. 9, 19 Feb. 1948.

(4) NRL Report No. C-[illegible]/51(473) 17 April 1946.





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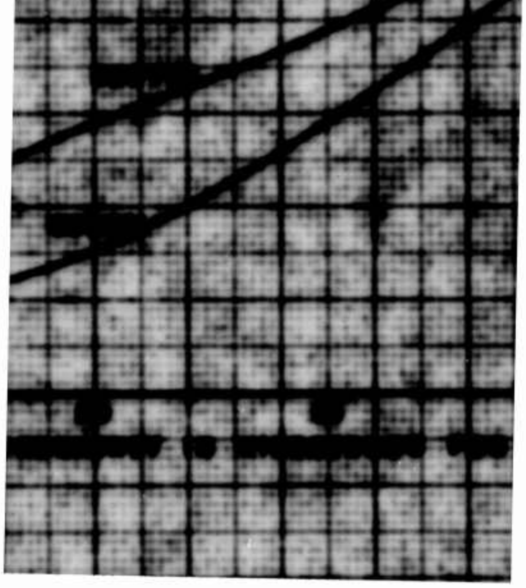

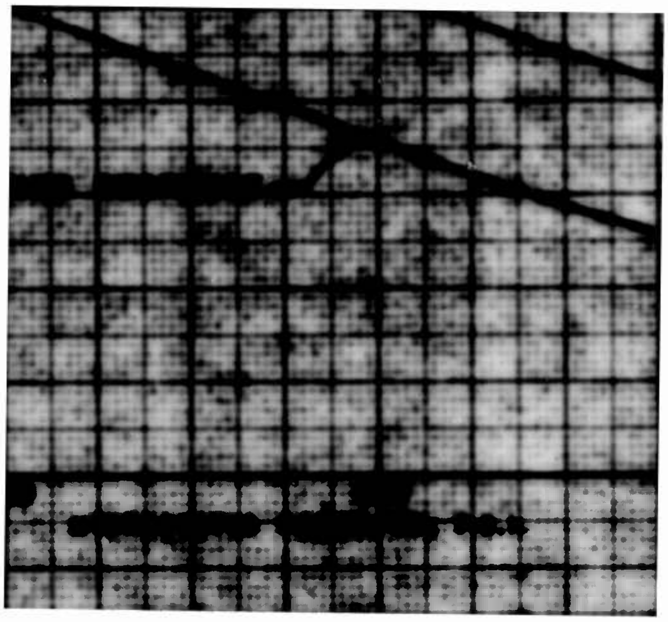

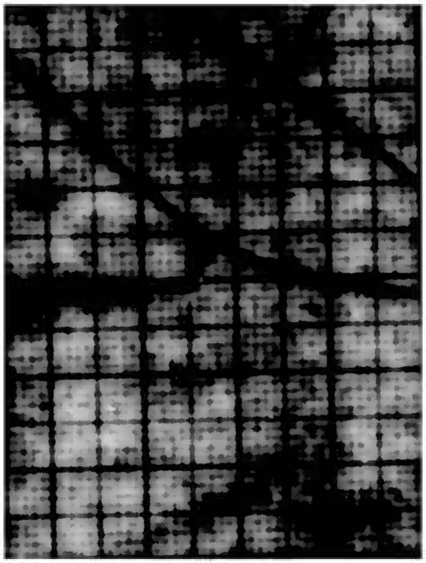

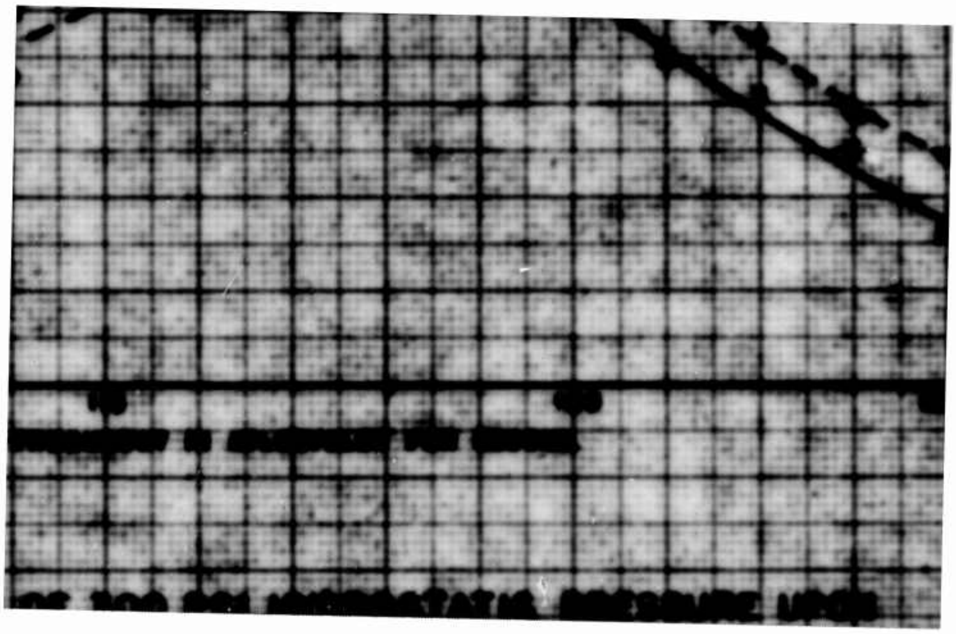
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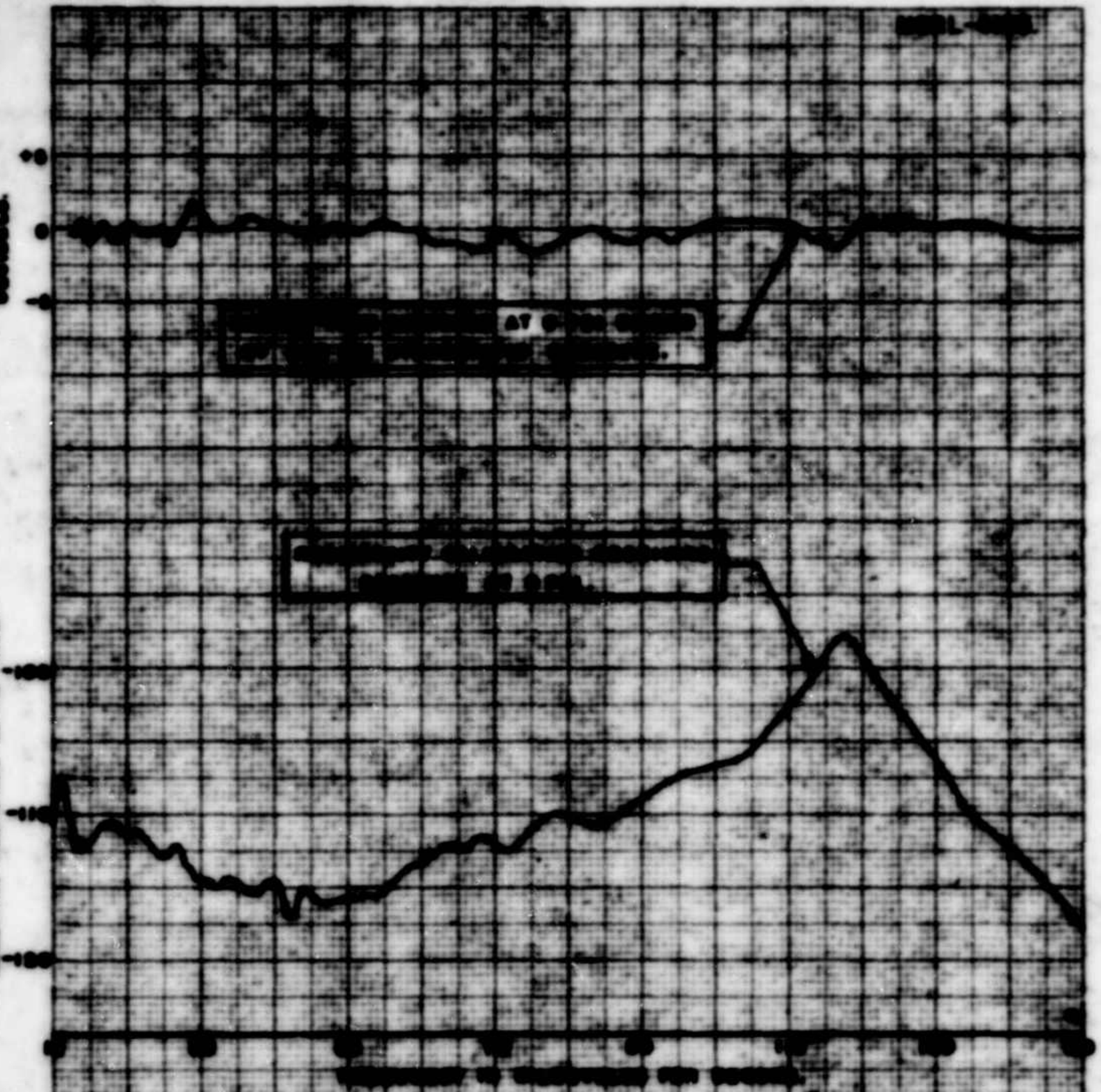

FIG. 8 RECEIVING RESPONSE CALIBRATION OF [illegible]-T-14 TRANSDUCER NO. 1.

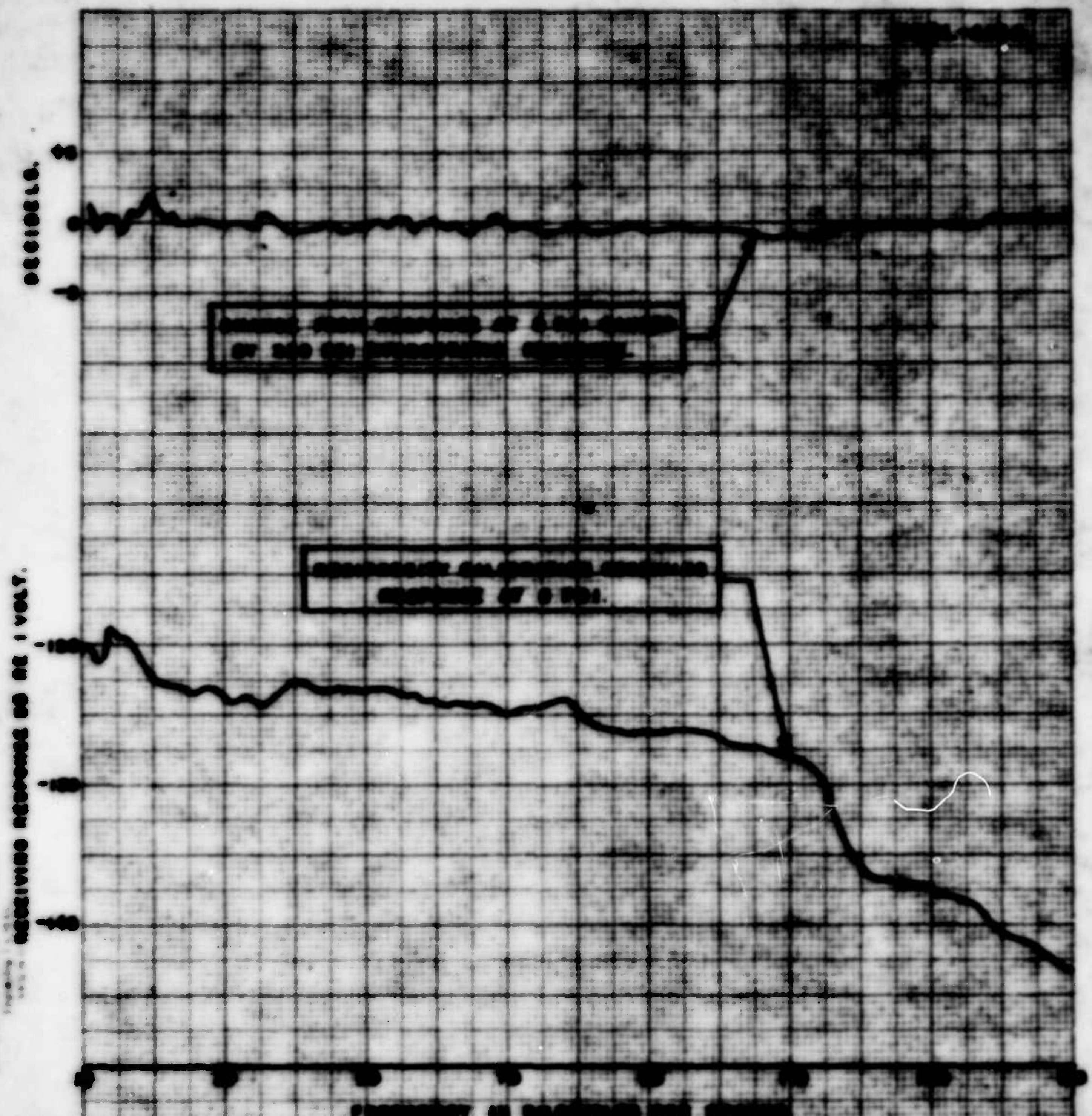

FIG. 5 RECEIVING RESPONSE CALIBRATION OF
RL-T-15 TRANSDUCER NO. 1

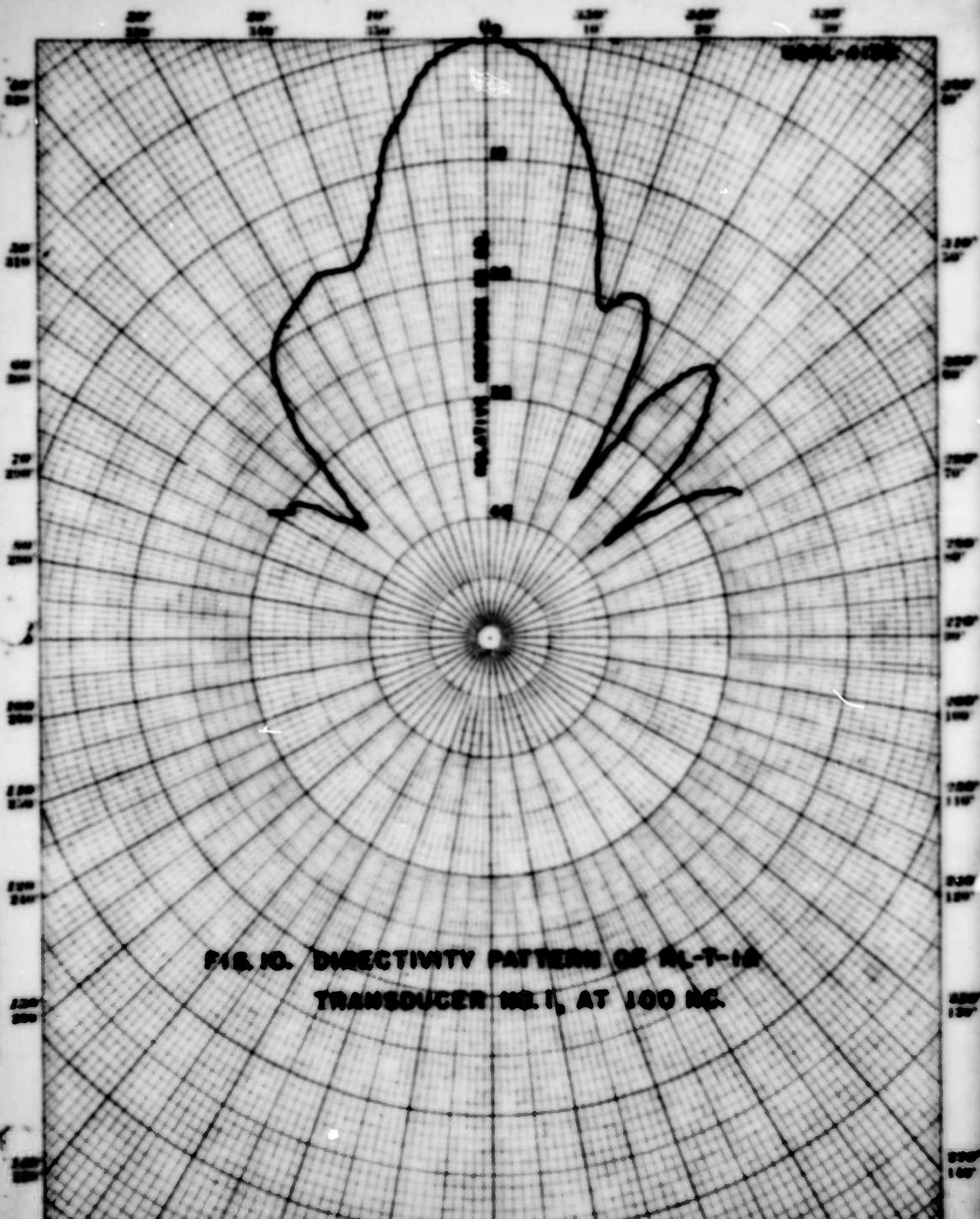

FIG. 10. DIRECTIVITY PATTERN OF NL-T-18 TRANSDUCER NO. 1, AT 100 KC.

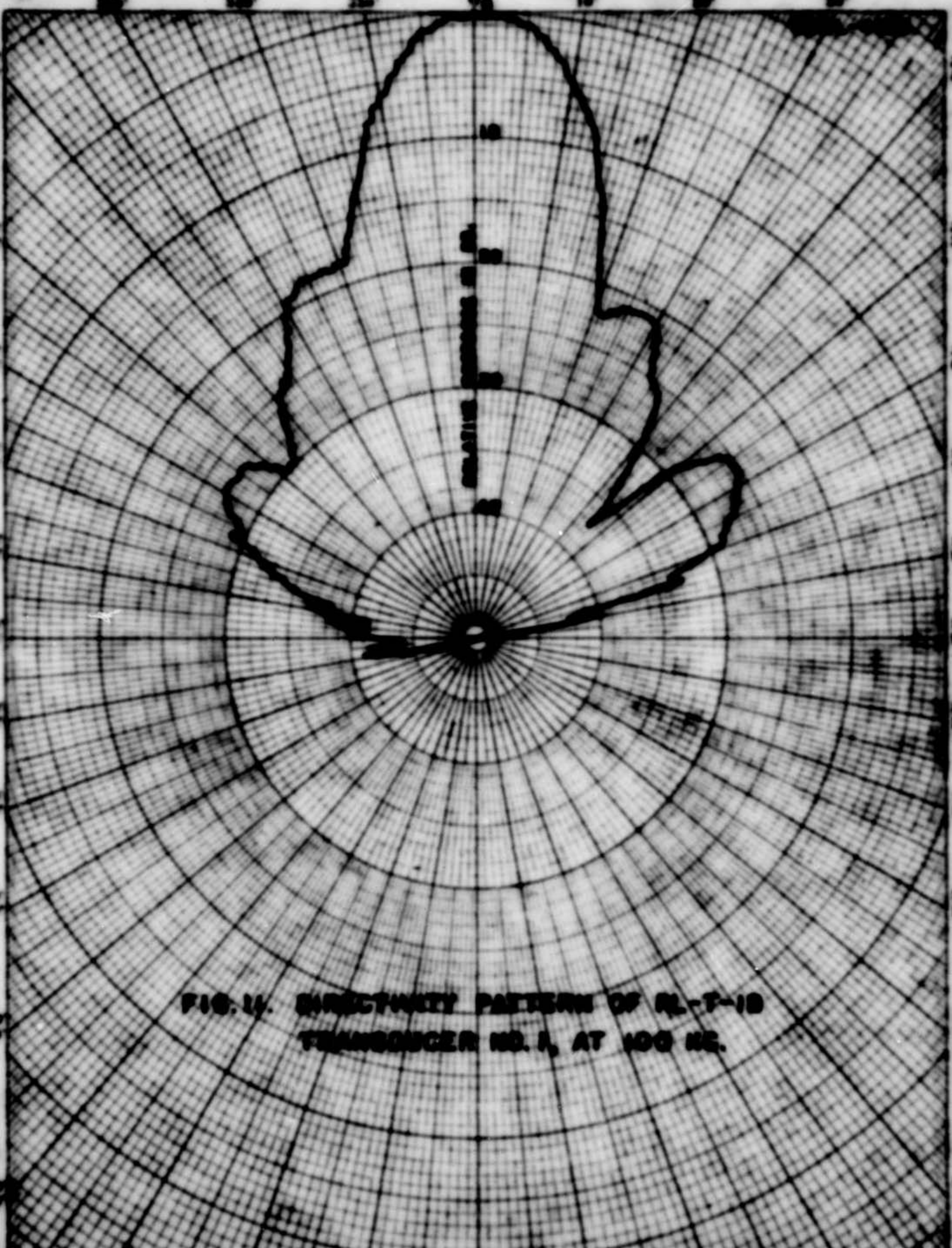

FIG. 14. DIRECTIVITY PATTERN OF RL-T-10 TRANSDUCER NO. 1, AT 100 KC.

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