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NEL REPORT 1232

449746

ACOUSTIC TRANSDUCER EVALUATION CENTER (TRANSDEC)

NONREVERBERATING POOL DEVELOPED AT NEL FOR CALIBRATION AND EVALUATION

C. E. Green

Research and Development Report

24 August 1964

U. S. NAVY ELECTRONICS LABORATORY, SAN DIEGO, CALIFORNIA 92152 • A BUREAU OF SHIPS LABORATORY

THE PROBLEM

Design, develop, and construct an acoustic transducer calibration facility in Point Loma to replace the facility on Sweetwater Lake.

RESULTS

1. An anechoic pool was designed and built to behave as an infinite body of water.

2. A computer and associated equipment were provided to permit complete analog evaluation of transducers of normal frequency range, size, and weight.

3. A bridge was constructed to house equipment and personnel and to isolate them acoustically from the water.

4. The design has been proved in performance. All calibration and evaluation tasks within the capability of the old Sweetwater Lake facility can now be accomplished at NEL on Point Loma.

5. A patent has been granted on the contour of the anechoic sonar calibration pool.

RECOMMENDATIONS

1. Consider the acoustic approach used in this design at other stations that require a transducer calibration capability.

2. Consider the merits of the analog computer to eliminate data reduction at proposed and existing stations.

ADMINISTRATIVE INFORMATION

Work was accomplished under SF 001 03 04, Task 8049 (NEL L3-1). This report covers work from May 1959 to December 1963 and was approved for publication 24 August 1964.

The author acknowledges the support of the many persons required to complete so large a project in so short a time; specifically, Mr. Russell Kimball, who provided field engineering support, Captain W. Burns and members of the Army Engineering Battalion, who assembled the bridge, Mr. Robert Bedore and Mr. Stephen Moran, who worked out the engineering details for the calibration house, and Mr. John Hickman, who provided constructive criticism of this report.

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ILLUSTRATIONS

ILLUSTRATIONS (Continued)

INTRODUCTION

Acoustic transducers of normal size were formerly calibrated by NEL engineers and technicians at Sweetwater Lake. Early in 1959 the Navy Electronics Laboratory was informed that the water level of the lake was to be lowered to reduce evaporation. The proposed new depth of approximately 18 feet was unsatisfactory for calibration purposes, and a new calibration site had to be found. A survey revealed no suitable natural lake, and construction of an artificial anechoic pool in Point Loma was proposed. It was recognized that relocation would afford advantages of proximity and security.

The limitations inherent in conventional anechoic pools made them unacceptable. A new anechoic concept[1] (see references at end of report) developed at NEL showed promise, and after verification through acoustic model studies, was accepted as the basis for the design of the final TRANSDucer Evaluation Center (TRANSDEC).[2]

POOL DESIGN

ACOUSTIC RAYS GUIDED INTO SOUND TRAP

Figure 1 shows the basic principle of operation[3,4] of the TRANSDEC pool. The bottom of the pool and the air-water interface serve as reflectors. Focus F_1 is underwater and focus F_2 is in the air above the pool. Acoustic rays from F_1 converge at F_2', which is the mirror image of F_2 and is located in the sound trap.

Figure 2 shows how the pool is shaped to trap acoustic rays traveling from the transducer in any direction. The pool wall surface (fig. 3) on the outside of the trap has a curvature which is a compromise between ellipses the focus pairs of which are F_1, F_3 and F_1, F_4. The function of this surface is made clear by the rays shown in figure 3. The sound trap is elongated on opposite ends of the pool to provide additional absorption in the preferred direction of transmission.

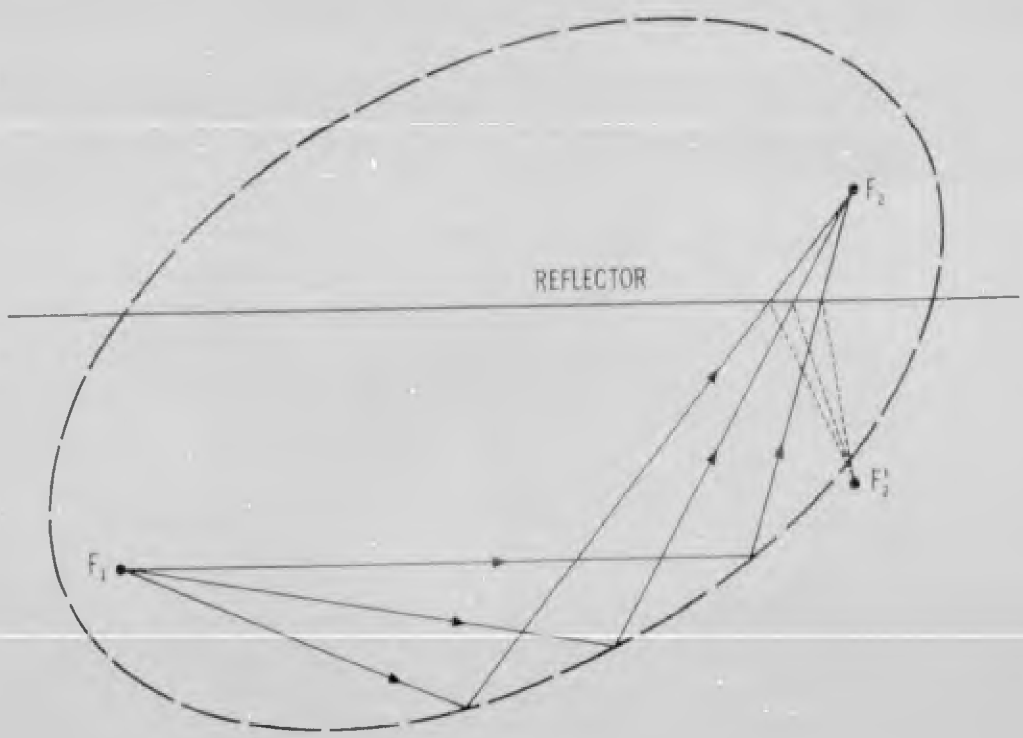

Figure 1. Ray theory applied to an ellipse.

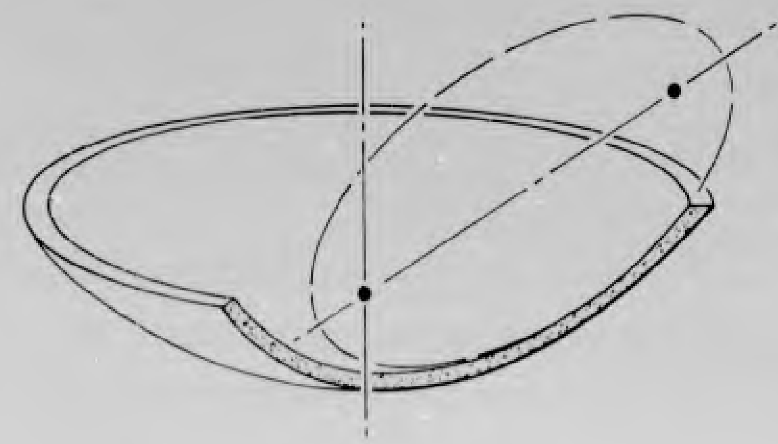

Figure 2. Ellipse rotated about the vertical configures the pool.

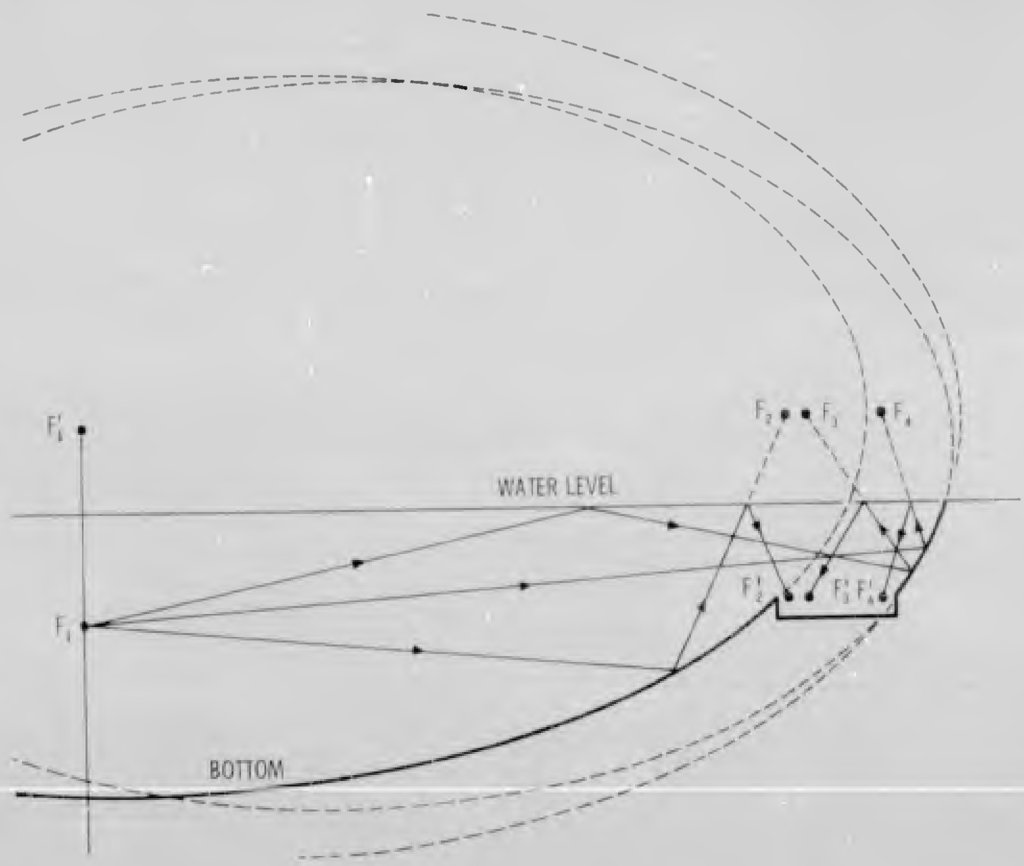

Figure 3. Acoustic rays are guided into sound trap.

MECHANICAL CONSIDERATIONS

Figures 4-9 show the general layout of TRANSDEC.

The modified bailey bridge makes a stable platform from which to evaluate transducers and associated equipment.

The calibration house in the central part of the bridge has three wells with independent mechanical systems. Each well has a pair of instrument carts that can be positioned independently so that the exact location is indicated on the console. Multiple wells permit concurrent evaluation of two or three transducers and also permit the insertion of one transducer without disturbing existing setups for others. Each well is 30 inches across and accepts transducers up to 5 feet long. Units as large as 6 by 10 feet can be lowered through a removable section of the floor and transferred into the central well and onto the carts in one operation. Loads up to 2 tons can be handled.

Operating depth is 20 feet. Transducers can be positioned 80 feet apart on the track-mounted instrument carts.

There is no evidence that a water filtration system is needed. A circulation pump with a chlorine injection system removes the thermocline and controls the algae. The acidity resulting from the chlorine gas requires the addition of caustic soda to maintain the pH value at 7.4 -- low enough to reduce the need for chlorine to control algae, but not so low as to aggravate corrosion of metals in or near the water.

The rate of evaporation depends on temperature and wind, and the latter appears to be the more significant factor. On calm days the rate of evaporation is less than 1/8 inch a day; on windy days it increases to 3/8 inch. A thin plastic sheet could be floated on the surface to reduce

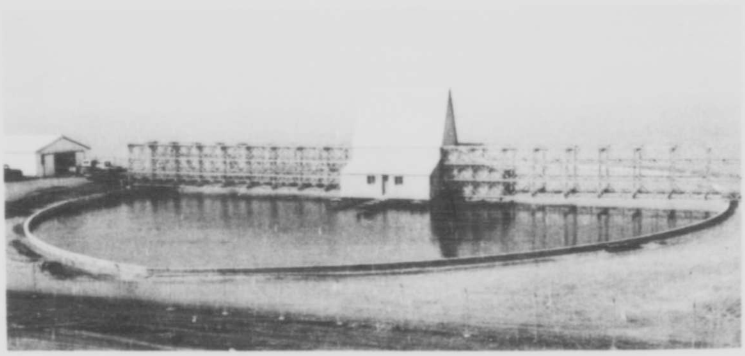

Figure 4. TRANSDEC facility.

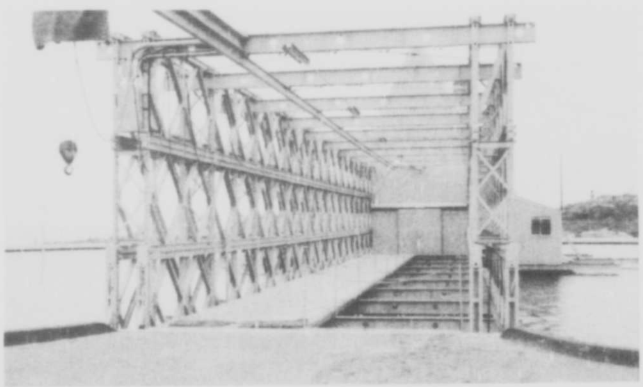

Figure 5. Walkway to calibration house.

evaporation. It would probably also help retain the chlorine. Residual chlorine is held at 1/2 part per million.

Leakage of water through the porous concrete is prevented by a 1/32-inch neoprene sheet lining. The trap is lined with asphalt impregnated with glass fiber.

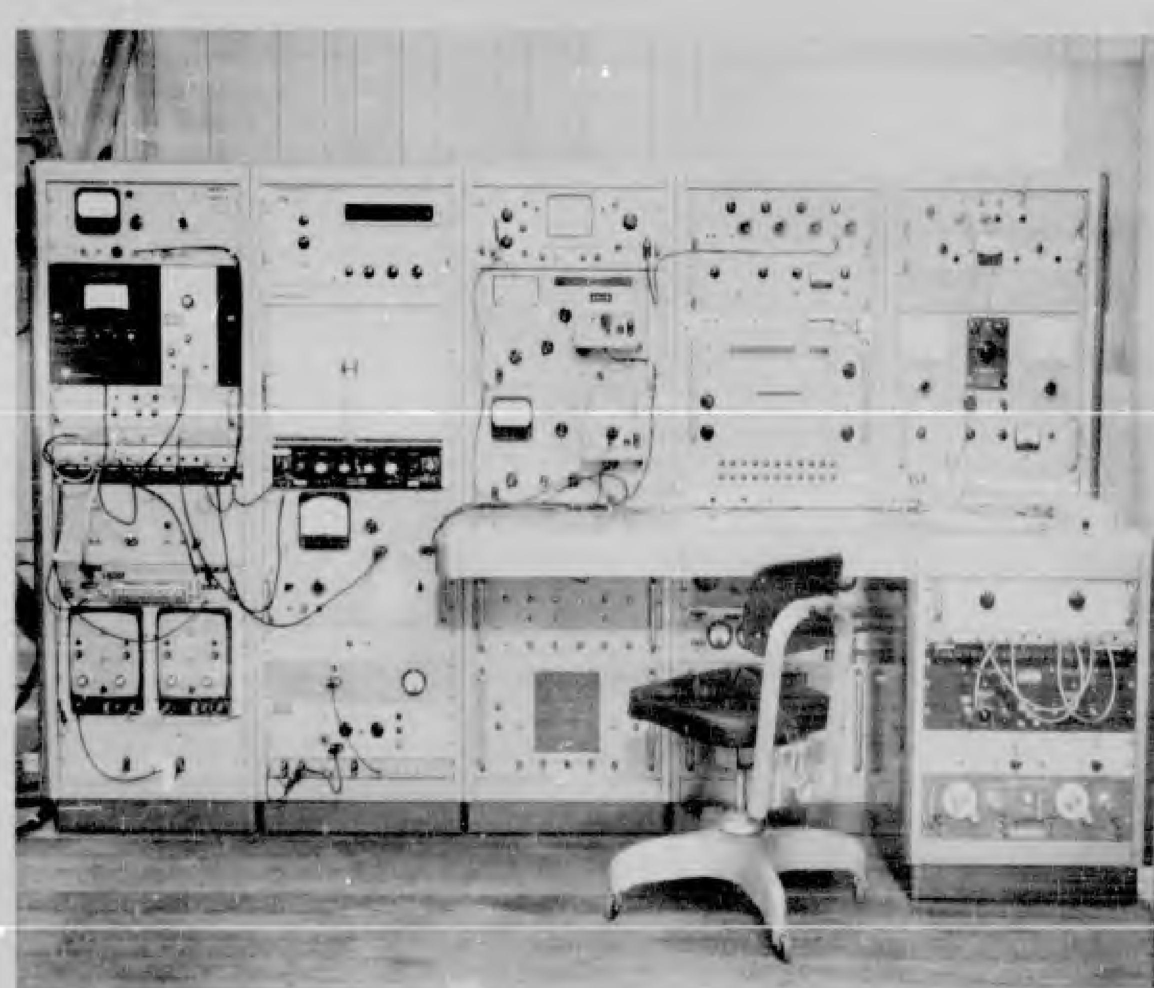

Figure 5. Console.

Figure 7. Flooring removed to enable positioning of large transducer.

Figure 8. Track-mounted instrument cart.

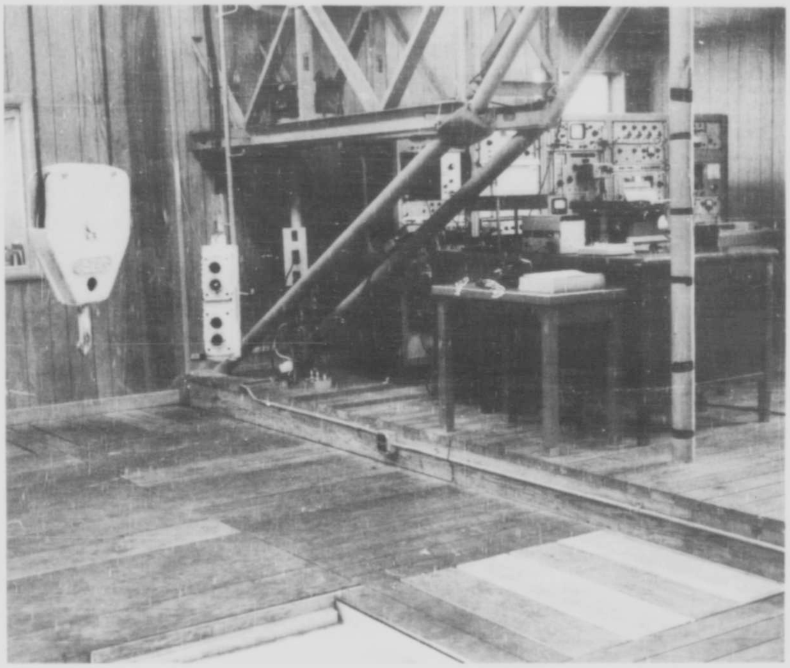

Figure 9. Interior of calibration house.

OPERATION

ELECTRONIC DRIVING AND RECEIVING SYSTEMS -- PULSED AND CONTINUOUS SIGNAL

TRANSDEC has independent driving and receiving systems, both operating over a range of 50 c/s to 1 Mc/s. The driving system provides for the transmission of pulsed or continuous signals. Pulsed signals of selected pulse length and repetition rate are received through a gate controlled to pass the whole signal (fig. 10) or any portion of it, down to individual cycles. A continuous signal is transmitted when it is not practicable to pulse the transducer.

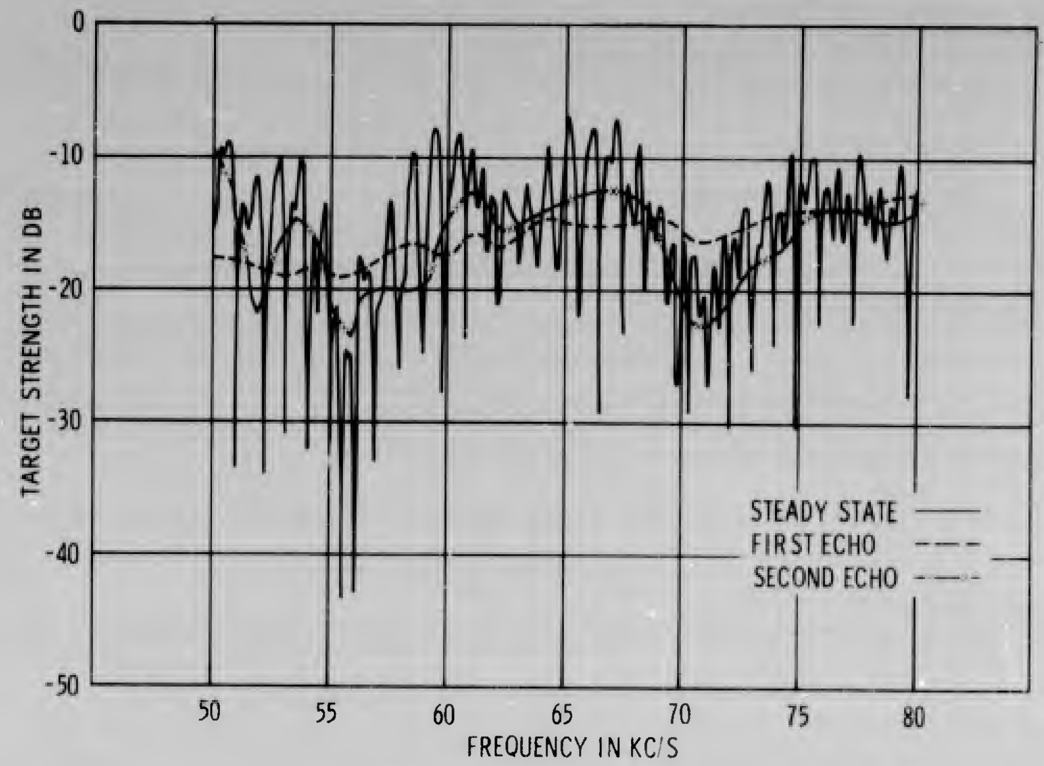

Figure 10. TRANSDEC demonstrates versatility by determining target strength of free-flooded sphere. Gate in control circuit is elongated to permit composite recording of reflections from both surfaces. Gate can be shortened to limit recording to a single reflection. Pulse length: 0.83 msec. Gate: 0.43 msec.

The signal is processed through a narrowband tracking filter to provide a large dynamic range and recorded by an analog recorder; or it is sampled by a pulse-sampling technique.

Drive power is provided for transducers which require more than the 125 watts available in the console by a power amplifier which delivers up to 10 kW over a range of 50 c/s to 30 kc/s, either pulsed or steady state.

WORKING PAPER ADEQUATE FOR IMMEDIATE TRANSDUCER EVALUATION

The calibration data sheet (fig. 11) lists the calibration tasks in order.

For calibrating a hydrophone, a standard projector of known characteristics is used. The analog computing system[5] corrects the electroacoustic behavior of the standard projector to give a known sound field. The receiving voltage response (*OCV*) (fig. 12) of the hydrophone under test is plotted against frequency.

For calibrating a projector, a standard hydrophone is used. The computer provides the constant-current (S/A) or constant-voltage (S/V) response of the projector automatically graphed against frequency.

The analog presentation is usable by the engineer and enables immediate evaluation of the transducer. A check is made on reciprocity, using the calibration work sheet (fig. 13), and test results are confirmed by a further check against impedance. The operator sets up levels on the left side. Response levels read directly from the graph paper are entered on the right side. The transmitting current response (S/A) and the resistive component of the complex impedance (R_e) establish J, the reciprocity parameter, and the value obtained is compared with the theoretical J. The difference between the transmitting current response and the transmitting voltage response (S/V) is the impedance (Z) of the transducer. At the three check frequencies calculated on the work sheet, the maximum error is a fraction of a dB. Total combined error should always be less than 1 dB. Combined error of the order of 0.3 dB is the rule. Electronically the variations in total system gain from oscillator to recorder are less than 0.5 dB per decade.

TRANSDUCER CALIBRATION DATA SHEET

NO. T 100

DATE: 5-11-64

H90237/414-7

E1-15

T

AIR 17 65 WATER 17

4.5 mmt supplied and 2.5 M added

cloudy

										ORIENTATION & CONNECTIONS
1	[illegible]	60kc			4 8	B90	GA2-9 10ma	6	avh jrr	
2		80								
3		40								
4	blu	40-80kc	Remote Mix	65	8	B90	GA2-9 10ma	6		OCV
	blu			65	8	Rec. Cal. -40DBV				
	grn		Local Mix	65	8	GA	B90 10ma			S/A
	grn			65	8	Rec. Cal. -40DBV				
	red			65	8	GA	B90 10 volts			S/V
	red			65	8	Rec. Cal. -40DBV				

Figure 11. Calibration data sheet.

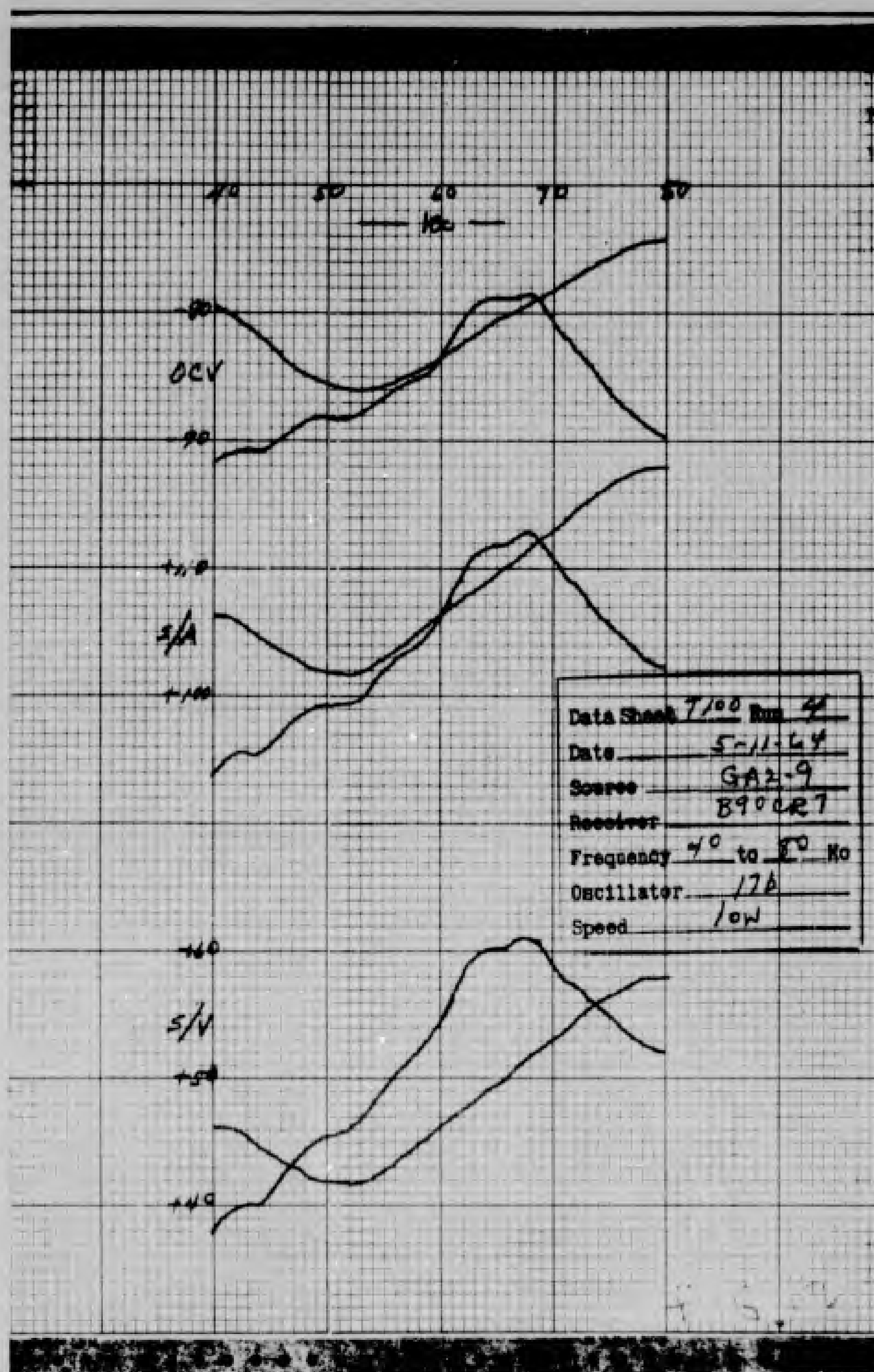

Figure 12. Response and calibration runs. Calibration run permits check later if error is suspected.

CALIBRATION WORK SHEET USING CURVE CORRECTOR

Reference Freq. 60KC Std GA2 9 Data Sheet T100 Date 11 May 1964

Std. Rec. Sens. -88.2

Rec. Cal. -40.0

48.2

8 Met. Separ. Cor. 18

66.2

10 amp Current Cor. 40

Rec. Cal. Point = 106.2 DB/Amp

Do not use #10 amp.

"J" at 1 meter -189.5

DB/Amp Rec. Cal pt. +106.2

R_e Rec. Cal. pt. -83.3 DBV

Use #10 Amp.

Std. Rec. Sens. -88.2

Rec. Cal. -40

+48.2

8 Met. Separ Cor. 18

+66.2

10 Volt Cor. 20

Rec. Cal. point 46.2 DB/Volt

Do not use #10 amp.

11ND-NEL-TRIAL 195 (200) 8-63

Check point freq. 80KC BRIDGE R C

"J" at 1 meter -192 11 00553

S/A 102.4 S/A 102.4 Z 360

R_e 89.7 S/V 57.8 = 51.0 db

J = 192.1 Z 50.6

Check point freq. 60KC BRIDGE R C

"J" at 1 meter 189.5 378 00687

S/A 106.2 S/A 106.2 Z 387

R_e 93.5 S/V 54.5 = 51.75 db

J = 189.7 Z 51.7

Check point freq. 40 kc BRIDGE R C

"J" at 1 meter 186.0 7.8 00610

S/A 94.0 S/A 94.0 Z = 652

R_e 91.8 S/V 38.0 = 56.3 db

J = 185.8 Z 56.0

Auxiliary check freq. ______

Std. Rec. Sens. ______

Std. DCV ______

______

______ Met. Separ Cor. ______

______

______ Cur. Cor. ______

Test unit Sens. ______ DB/Amp

Figure 13. Calibration work sheet.

DIRECTIVITY AND IMPEDANCE PLOTTING

Directivity patterns (figs. 14-16) are generally plotted in polar presentation. Magnitude of signal is a function of azimuth. For very-narrow-beam units rectangular graphing is sometimes used to spread the curve to permit more careful examination of beam width.

The directivity factor[6] of a transducer is determined by measuring the pattern factor in several sampling planes and averaging the readings. The pattern factor can be provided by either the internal computer, which computes it while the polar pattern is being plotted, or by an external computer which provides the digital readout of the pattern factor from a pre-plotted polar graph.

The impedance or admittance of transducers may be plotted on an X-Y graph with resistive and reactive or conductive and susceptive components shown independently as functions of frequency (fig. 17); or the two components of impedance can be graphed against each other to give an impedance circle. The complex impedance is also measured on a hybrid bridge, with resistive and reactive components (fig. 18) read from equivalent standard components within the bridge. This method is more accurate for conditions of high electric Q.

The impedance plot, polar patterns, and a photograph of the unit (fig. 19) are included in a complete evaluation. The evaluation is checked and released as a final report by the data reduction center.

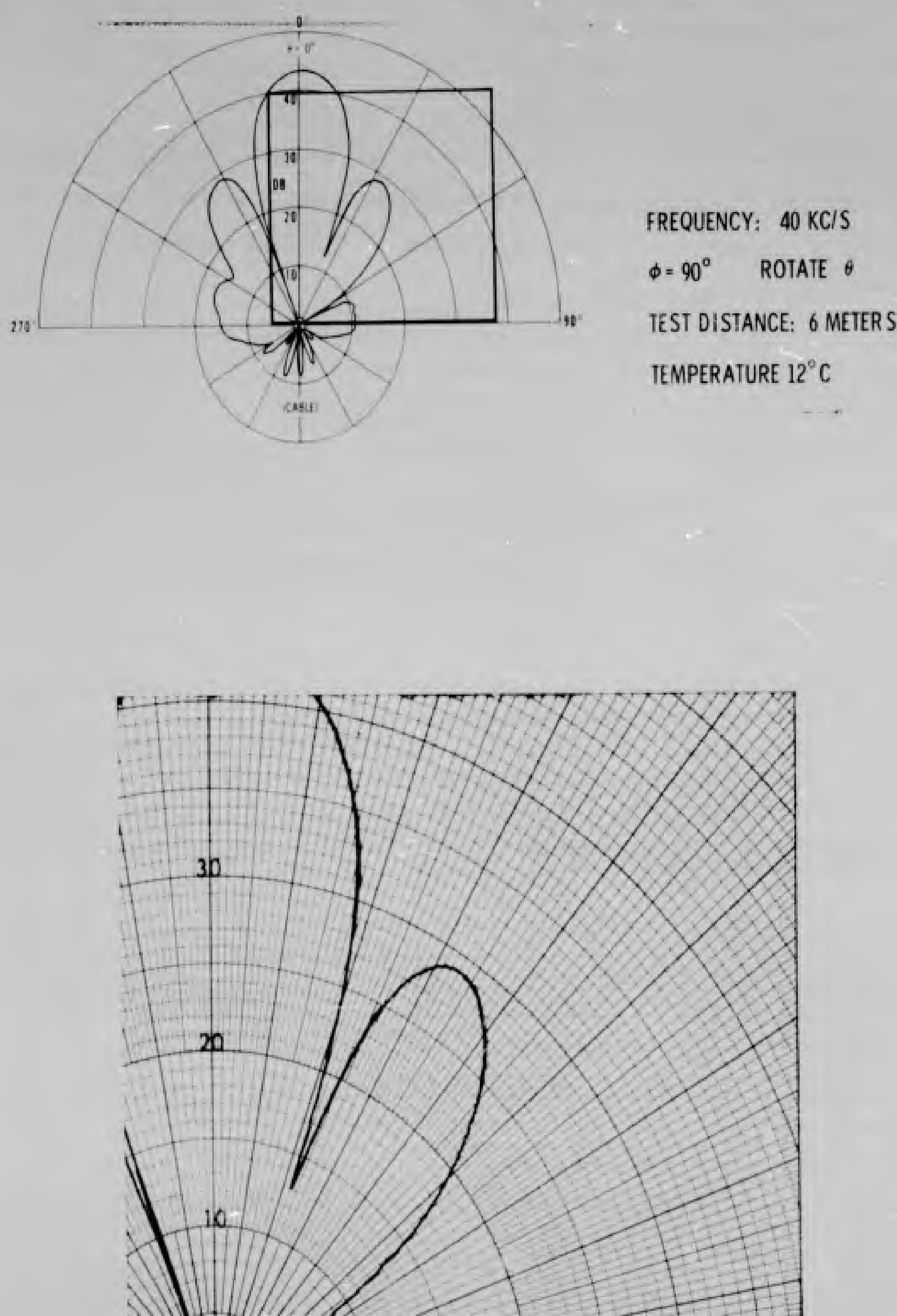

Figure 14. Directivity pattern at 40 kc/s. (SCALE: 1 dB per radial division)

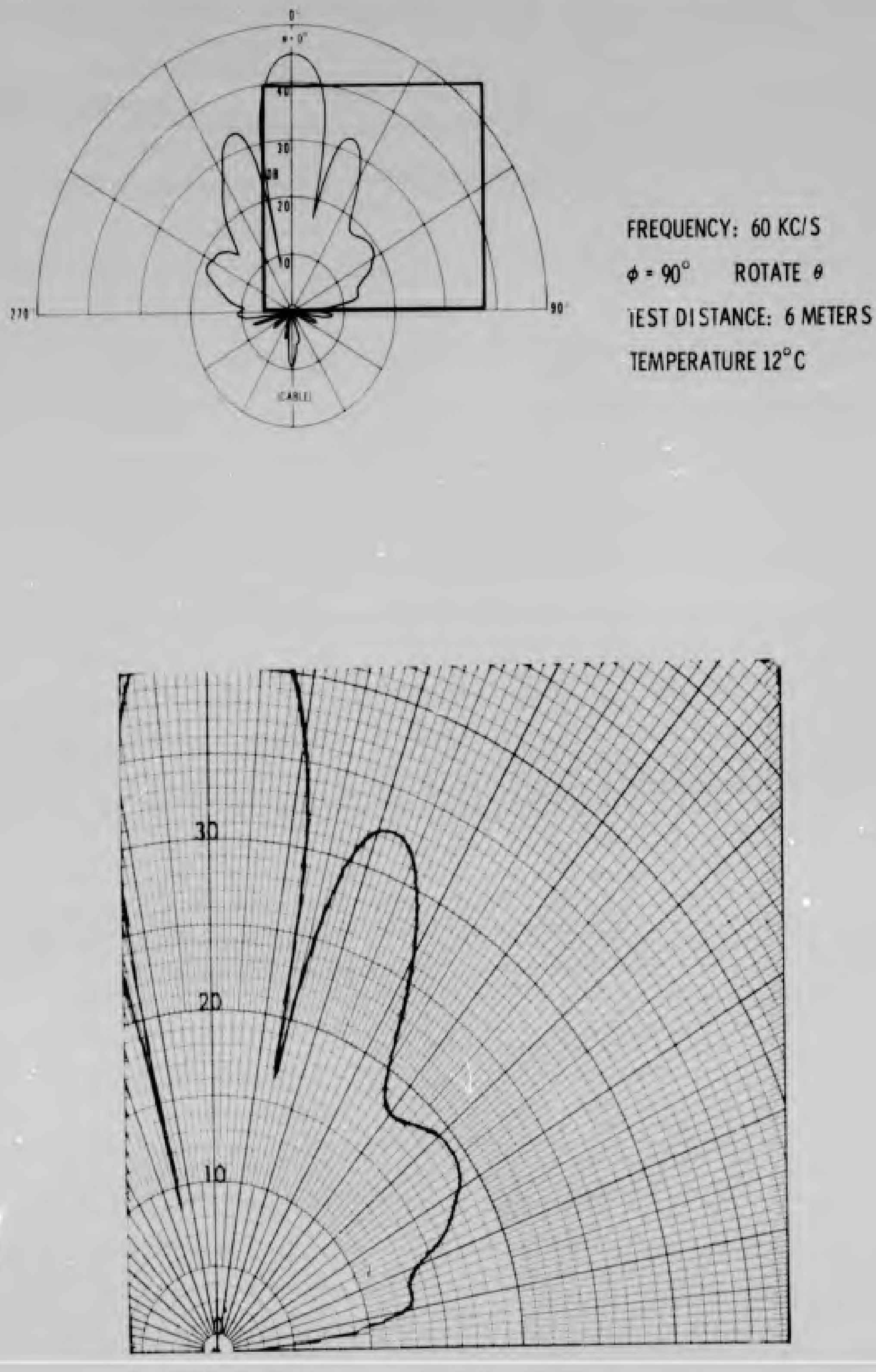

Figure 15. Directivity pattern at 60 kc/s. (SCALE: 1 dB per radial division)

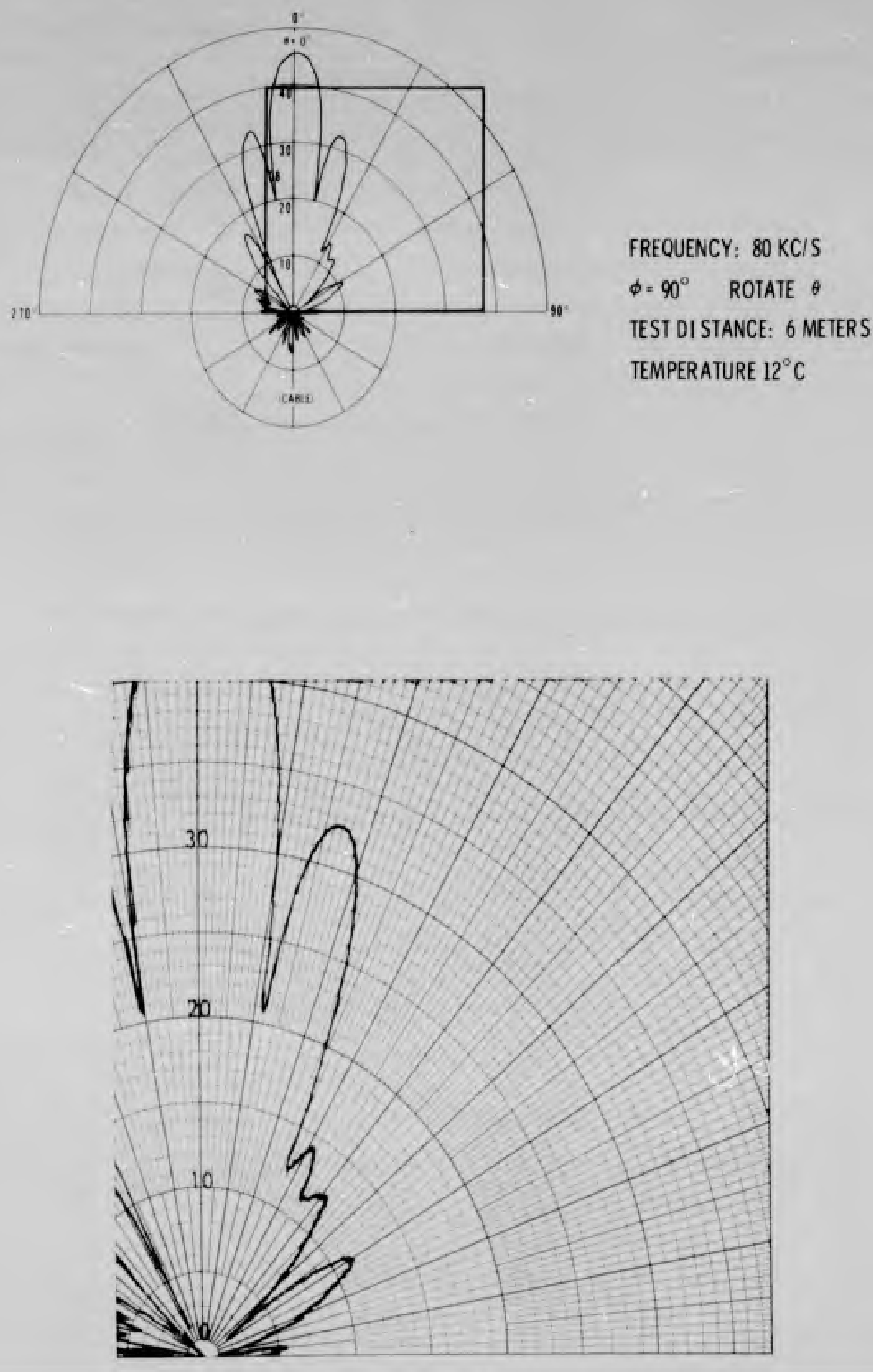

Figure 16. Directivity pattern at 80 kc/s. (SCALE: 1 dB per radial division)

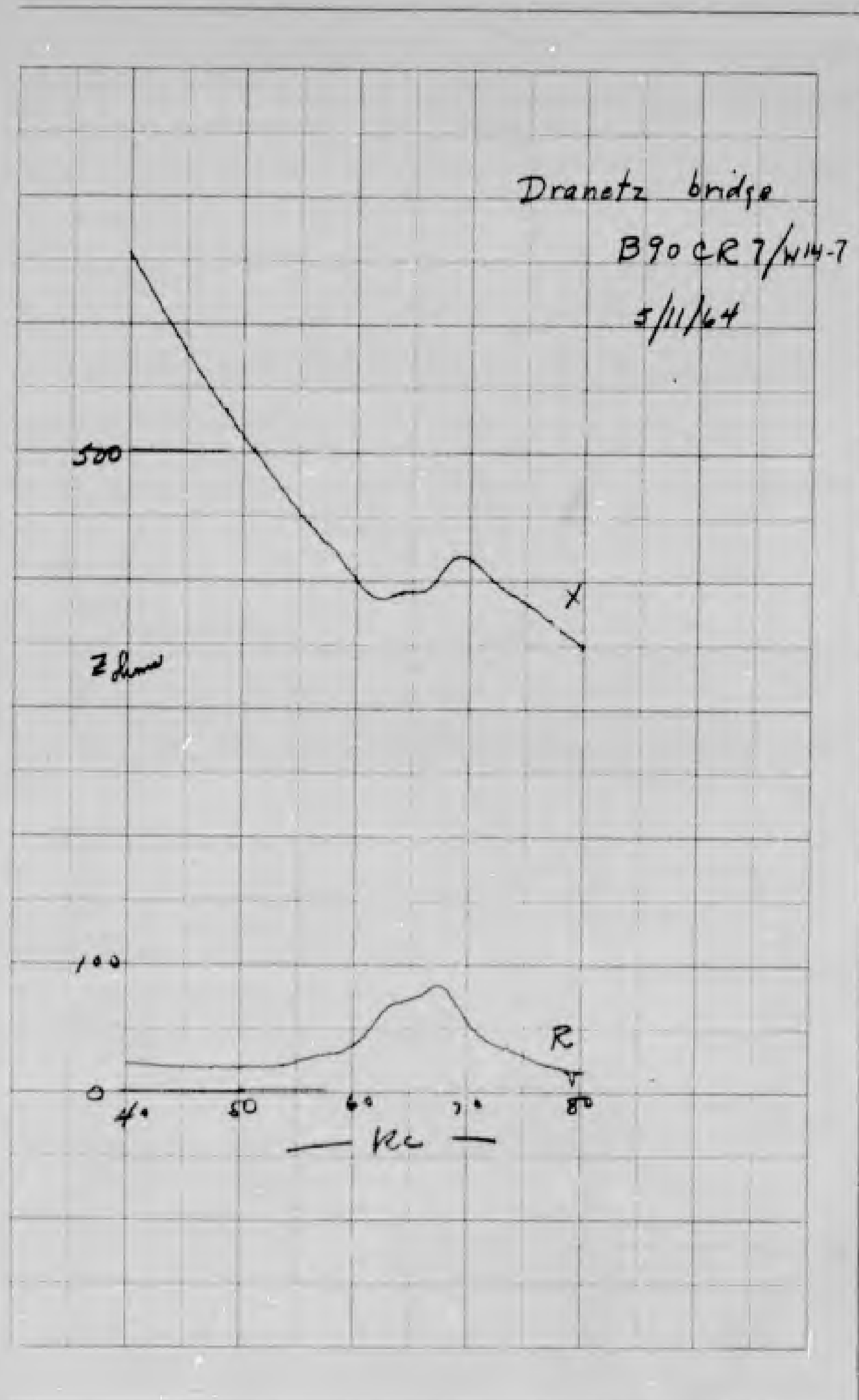

Figure 11. Response impedance.

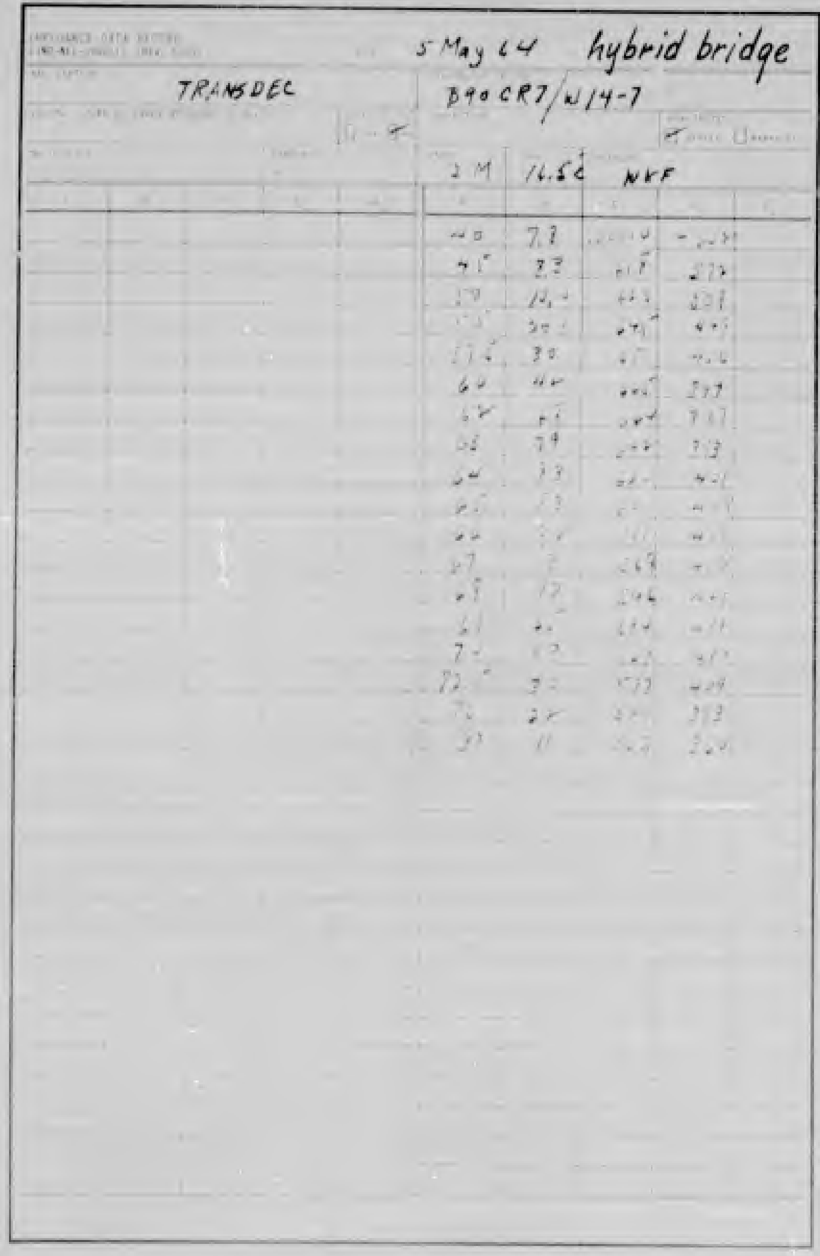

Figure 15. Bridge impedance.

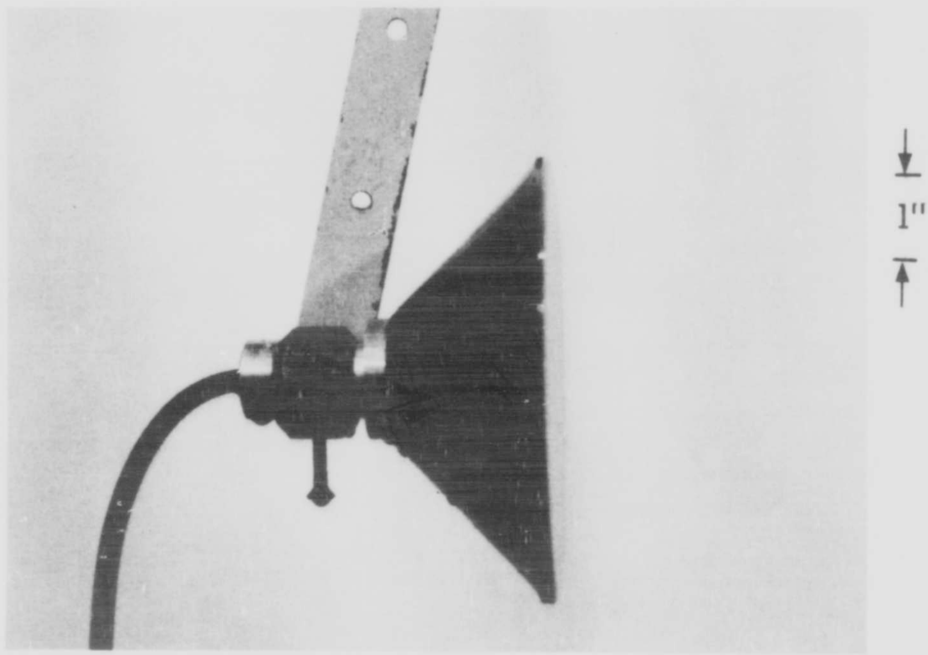

Figure 19. Photograph of transducer becomes part of final test report. B90CR6/W14-6 shown.

REMOTE CALIBRATOR PROVIDES EQUAL ACCURACY

Many times it is impractical if not impossible to calibrate a transducer with a long cable attached. For these cases a remote calibrator (fig. 20) is used. Measurements are made on the transducer with a short cable attached to the remote box. This calibrator provides with equal accuracy the same information normally provided by the console.

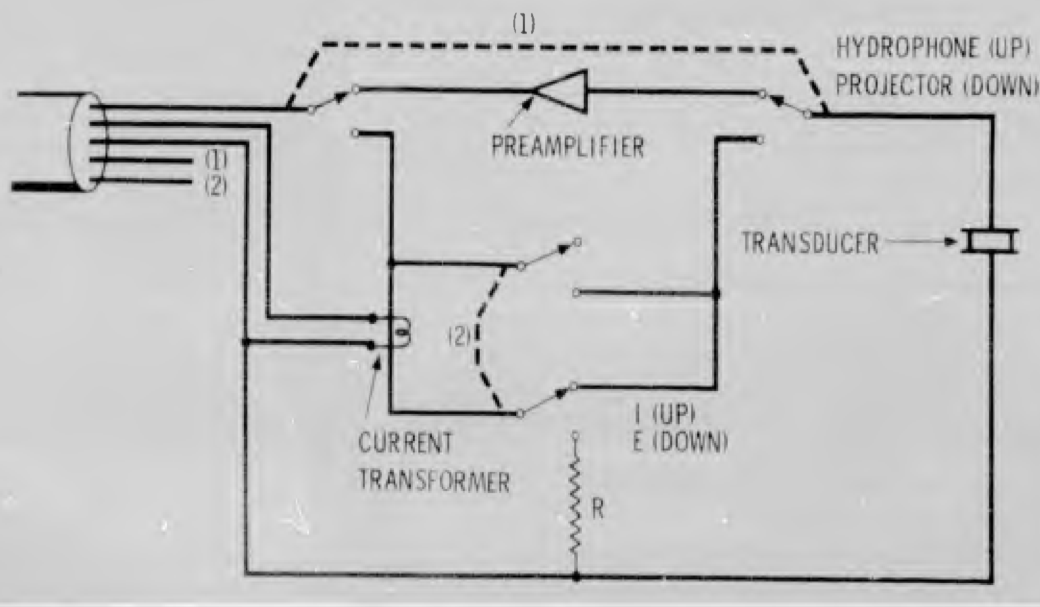

Figure 20. Remote calibrator permits transducer evaluation with very short cable.

WATER NOISE NO BAR TO DETERMINING TRANSDUCER NOISE THRESHOLD

When the noise threshold of a transducer is measured, it is essential that ambient water noise be less than electronic noise. This condition prevails in the TRANSDEC pool. Ambient noise is below the measurement threshold of even sensitive hydrophones with quiet preamplifiers, or of PQM equipment operating wide band.

Ambient water noise exceeds electronic noise only when the wind is of sufficient velocity to cause water to slap against the sides of the pool. Since the calibration house is on the bridge above the water, there is no other source of wave noise.

TRANSDEC SPECIFICATIONS

Frequency range, complete electroacoustical evaluation:
100 c/s to 1 Mc/s

Frequency range, 10 kW power amplifier:
50 c/s to 30 kc/s

Well size, maximum:
6 by 10 feet

Handling capacity:
2 tons

Transducer cabling:
25 feet

Transducer cabling, remote calibrator:
2 feet

Standard transducer mounting:

$4\frac{1}{2}$ inch center-line and $10\frac{1}{2}$ inch center-line bolt circle

Mounting systems:

3

Transducer separation on tracks, maximum:

80 feet

Operating depth:

20 feet

Primary power:

440/220/120-volt, 60-cycle; 120-volt, 3-phase, 400-cycle

Water depth:

38 feet in bowl, 16 feet in trap

Bowl diameter:

160 feet

Pool length:

300 feet

Pool width:

200 feet

Bridge length alignment:

Due north and south

Magnetic North:

15 degrees east of due north

Acoustic water noise in pool:

Below measurable value

Pool water:

Fresh with pH value of 7.4

CONCLUSIONS

TRANSDEC can evaluate all transducers that could have been calibrated at Sweetwater Lake. The completed full-scale facility behaves acoustically better than a 30:1 scale model used for acoustic studies indicated it would; performance of the scale model was perhaps hampered by transducer scaling difficulties. Transducer evaluation in the sonar range of 100 c/s to 1.1 Mc/s has been achieved with complete success. There is no reason to believe that 100 c/s is the low-frequency limit. The actual limit will be determined as requirements occur and transducers become available.

TRANSDEC is not a cure-all for every calibration need and is not a substitute for the NEL calibration station on Lake Pend Oreille, which remains the Navy's principal deep-water calibration facility for large, high-power, low-frequency transducers.

REFERENCES

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4. Green, C. E., "TRANSDEC," p. 603-606 (UNCLASSIFIED) in Office of Naval Research ACR-87, v. 2, 21st Navy Symposium on Underwater Acoustics, CONFIDENTIAL, December 1963

5. Navy Electronics Laboratory Technical Memorandum 469, Electroacoustical Transducer Calibration Combined With Semiautomatic Data Reduction, by J. R. Roshon, 18 April 1961*

6. Navy Electronics Laboratory Report 1196, Directivity Factor Computer For Electroacoustic Transducers, by C. E. Green and J. R. Roshon, 13 September 1963

*NEL Technical Memoranda are informal documents intended primarily for use within the Laboratory.

Navy Electronics Lab., San Diego, Calif.
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ACOUSTIC TRANSDUCER EVALUATION CENTER (TRANSDEC) (U), by C. E. Green. 29 p., 24 Aug 64.

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1. TRANSDEC
2. Transducers - Test facilities
3. NEL - Test facilities

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SF 001 03 04, Task 8049
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