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SPECIFICATION FOR ACTIVE TRANSDUCER. A PARALLEL APPROACH FOR FU--ETC(U)
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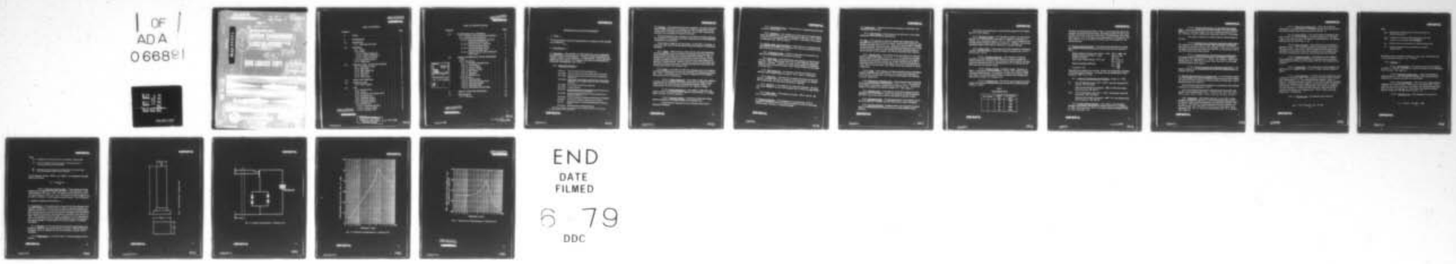

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SPECIFICATION FOR ACTIVE TRANSDUCER*

1. SCOPE. —

This specification covers the characteristics of a transducer unit for intended use on submarines.

2. REQUIREMENTS. —

2.1 Description. — The transducer unit shall consist of an outer pressureproof housing, an active transducer element, a vibration isolational mounting for the transducer element, an autotransformer, a switching matrix, and any associated cabling and seals required. All transducer units shall be mechanically and electrically interchangeable. (See Figure 1.)

2.1.1 Applicable Documents. —

MIL-C-915	Cable, Cord and Wire, Electrical (shipboard use)
MIL-E-16400	Electronic Equipment, Naval Ship and Shore General Specifications
MIL-E-21891	Electronics Type Designation, Identification Plates and Markings; requirement for
MIL-R-15624	Rubber Sheets, and Cut, Molded, and Extended Special Shape Sections, Synthetic, Medium Soft, Shipboard Gasket Use, except low temperature applications
MIL-W-16878	Wire, Electrical (Insulated, High Temperature)
MIL-D-16415	Installation Drawings
MIL-D-17419	Drawings, Engineering and Associated Documentation Preparation and Microfilming of (for Electronic Equipment)
MIL-E-17555	Electronic and Electrical Equipment and Associated Repair Parts, preparation for delivery of
MIL-R-22732	Reliability Requirement for Shipboard and Ground Electronic Equipment
Z24.24-1957	ASA Standards "Calibration of Electroacoustic Transducer"
MIL-S-901	Shockproof Equipment, Class HI (High-Impact) Shipboard Application, tests for
MIL-STD-167	Mechanical Vibrations of Shipboard Equipment

*Mr. Harvey L. Rathbun, of the Laboratory's Sonar Transducer Division, was the principal contributor of material for this specification.

2.2 Drawings. —All manufacturing drawings, procedures, and types of materials chosen by the contractor for the transducer units shall be approved by the contracting officer concerned prior to manufacture. One set of all manufacturing drawings will be forwarded to USN/USL for retention.

All quality assurance tests, procedures, and criteria for rejection chosen by the contractor for the transducer units shall be approved by the contracting officer concerned prior to manufacture.

Once the above approval has been granted, no deviations or changes, no matter how slight, shall be allowed without the specific approval of the contracting officer.

2.2.1 Metals. Metals coming in contact with sea water shall be selected for minimum galvanic action or corrosion in conformance with "Sea Water Corrosion of Galvanic Couples" data of Specification MIL-E-16400. If a type of stainless steel is used, necessary precautions shall be taken to prevent crevice corrosion at flanged joints and at screw thread holes (zinc oxide ointment overspread on all mating surfaces). Dissimilar metals in contact with each other shall not come in contact with sea water. Common pipe plugs shall not be used on the external metal surface of the transducer unit.

2.2.2 Rubber. —All rubber or rubber-like compounds used in the transducer unit shall be of a composition of minimum recrystallization temperature not greater than -12° C. Mold release used for molding all rubber parts of the transducer unit shall not be of the silicone type.

2.2.2.1 Rubber Compounds I. —Any rubber or rubber-like compound in contact with the electrodes of the active element shall not contain any substances which will contaminate these electrodes (for example, sulphur). The compound shall have an insulating resistivity of 10^{10} ohm/cm or higher.

2.2.2.2 Rubber Compounds II. —Any rubber or rubber-like compound in contact with sea water shall be resistant to the following: oil, sunlight, ozone, sea water, and water absorption.

2.2.2.3 Protective Coating. —A protective rubber-like coating shall be overspread on all external surfaces of the transducer unit.

Approval shall be obtained from the contracting officer prior to applying this treatment.

2.2.3 Encapsulating Plastic. —There shall be no encapsulating plastic used in contact with sea water.

2.2.4 Temperature. —The transducer unit shall meet all the specifications herein described over the environmental temperature range from -2° C to +32° C and shall not be damaged physically, electrically, or acoustically when exposed to temperatures from -28° C to +48° C.

2.3 Cabling, Leads, and Color Coding. — Leads shall be in conformance with specification MIL-S-16878. The black lead of the cable shall be used for the low side of the circuit of the transducer unit.

2.3.1 Grounding of Leads. — Neither a cable lead nor the shield of the cable shall be connected to the transducer unit housing.

2.3.2 Cable Type. —The cable used for each transducer unit shall comply with type TSS-4 of Specification MIL-C-915. It shall withstand a hosing test pressure of 1000 psig. In addition, the cable must be capable of withstanding 1000 psig external hydrostatic pressure without leakage through the outer sheath to the inner core.

2.3.3 High Voltage Test. — In accordance with MIL-C-915 (2.3.2) an additional high voltage test shall be made on TSS-4 cable at 1000 V(rms).

2.3.4 Cable Seals. —The cable and its molded (vulcanized with heat and pressure) watertight seals shall be designed to prevent transducer unit flooding due to cable breaks. The test pressure used shall be 1000 psig.

2.3.5 Cable Pull. — The transducer unit cable shall withstand a 25-pound pull without damage to the seal of the transducer unit or without the cable pulling out.

2.3.6 Cable Length. —The transducer unit cable (TSS-4) shall be 100 feet in length for each unit.

2.4 Shock and Vibration. —The transducer unit, with mountings, shall be designed to withstand all shock and vibration incidental to its use on Naval ships, without physical, electrical, or acoustical damage.

2.5 Nomenclature. — Nomenclature shall be requested in conformance with Specification MIL-E-21981.

2.5.1 Serial Numbers. — Each transducer unit shall have a serial number permanently affixed for positive identification.

2.6 Type. — The transducer unit shall be a double mass loaded element with electrostrictive ceramic as the active material. The driver shall consist of a consolidated ring stack driven in the k_{33} mode with an outer overlay of fiberglas for shock hardening. The driver shall be prestressed mechanically by use of a bias rod for all levels of stress up to and including maximum alternating stresses to prevent destructive tensile stresses in the ceramic during high power operation.

2.6.1 Ceramic Driver. — The ceramic driver shall consist of "n" electrostrictive ceramic rings (where $n = 2, 4, 6, \cdots,$) wired in parallel and assembled such that when excited electrically the strains are additive. The negative electrode shall be outermost on either end. Ceramic insulators shall be used to electrically isolate the driver from the masses. The value of free capacitance at 1 kHz shall not vary more than ±2% between drivers when measured at a given voltage level.

2.6.2 Tuning. — The transducer unit shall be parallel-tuned on transmission, whereas it shall be series-tuned on receive. The value of shunt inductance at 1 kHz shall not vary more than ±2% between autotransformers when measured at a given voltage level.

2.6.3 Dimensions of Transducer Units. — The outside rectangular dimensions of the radiating face support housing shall be 5.50" x 7.75". The diameter of the cylindrical pressureproo: housing shall be a nominal 4-1/2". The overall length of the transducer unit shall be a nominal 21". (See Figure 1.)

2.6.4 Transducer Unit. — The transducer unit shall be mechanically interchangeable with the AN/BQS-6. Further, the transducer unit shall be designed such that it can be taken apart without the destruction of any part or parts.

2.6.5 Submerged Weight. — The submerged weight of the transducer unit in sea water (density of 64 pounds per cubic foot) shall not exceed 56 pounds.

2.6.6 Electrical Insulation. — Exposed ceramic and wiring shall be coated with an insulating material as required to prevent voltage breakdown during operation.

The interior of the pressureproof housing shall be purged with dry nitrogen gas prior to final assembly.

2.6.7 Hydrostatic Pressure. —The individual transducer units shall operate and meet all the electroacoustic requirements at hydrostatic pressures up to 600 psig over a temperature range of -2° C to +32° C and be capable of withstanding repeated prolonged subjections to pressure of 1000 psig over the same temperature range without physical, electrical, or acoustical damage.

2.6.8 Impulse Shock. —The transducer unit shall be capable of withstanding repeated underwater explosive shocks when tested in accordance with 2.6.8.1, 2.6.8.2, and 2.6.8.3.

2.6.8.1 Transducer Mounting. —The transducer unit shall be mounted on a suitable floating platform simulating as closely as possible the actual intended ship installation. The transducer unit shall extend into the water and shall be mounted such that the floating platform will not interfere with the shock wave from any explosive charge.

2.6.8.2 Explosive Charge. —Explosive charges, 90 pounds of HBX-1, or equivalent, shall be detonated at 24-foot water depths at varying horizontal standoff distances. The transducer unit shall be at a nominal 8-foot water depth. The horizontal standoff distance is defined as the horizontal distance from the charge to the transducer unit.

2.6.8.3 Transducer Test. —The tests for each transducer unit shall consist of four separate underwater detonations at horizontal standoff distances as shown in Table 1.

Table 1

TRANSDUCER TESTS

Shot Number	Standoff (ft)	Peak Pressure (psi)
1	75	1000
2	50	1500
3	30	2000
4	20	3200

The shock wave peak pressures listed in Table 1 are the expected values at the transducer unit for the given shot number. The pressure pulse for the most severe shot (No. 4) will have a rise time in the order of 10 microseconds and an exponential decay to 1/e of the peak value in approximately 0.5 millisecond. The shock velocity will be in the order of 20 ft/sec and will be primarily in the vertical direction.

2.7 <u>Electromechanical Properties</u>. —The prepolarized electrostrictive ceramic shall conform to the following electromechanical properties when measured at 25° C.

Relative Dielectric Constant (low field at 1 kHz)	$(K_{33}^{T}) = 1000 + 100$
Dissipation Factor (low field at 1 kHz)	$(\tan \delta) < .005$
Density (10^3) kg/m^3	$(\rho) > 7.4$
Short Circuit Young's Modulus (10^{10}) n/m^2	$Y_{11}^{E} = 9.0 \pm .5$
	$Y_{33}^{E} = 7.2 \pm .5$
Material Coupling Coefficients	$k_{31} > .265$
	$k_{33} > .540$
Curie Point (°C)	> 300

There shall be an elapsed time of at least 30 days from poling before evaluation of electromechanical properties. All ceramic will be prestabilized by heat treatment at 200° C for 1 hour.

2.7.1 <u>Variation of Electromechanical Properties</u>. —(meas. at 1 kHz)

K_{33}^{T} Over the temperature range 0° C to 30° C the total change shall be less than 5% (low field).

When the field strength is increased to 400K V/m the total change shall be less than 5% (25° C).

$\tan \delta$ Over the temperature range 0° C to 30° C the measured value shall be less than .010 (low field).

When the field strength is increased to 400K V/m the measured value shall be less than .010 (25° C).

2.7.2 <u>Ceramic Exposure Tolerance</u>. —The ceramic, when thoroughly cleanedof oil and grease, must be able to withstand exposure to an atmosphere of 100% relative humidity at 25° C for ten days without the dissipation factor at 1 kHz rising above .01.

2.7.2.1 Maximum Displacement in Air (for Experimental Model Tests). —The *maximum displacement test shall be made in air on the completed* transducer unit. The input voltage to the unit at mechanical resonance in air, fr_a^E , shall be such that the radiating face displacement shall be 1.2 mils peak.

(No change in efficiency or resonant frequency shall be caused by this test.)

2.7.2.2 Maximum Power in Water (for Experimental Model Tests).— The transducer unit shall be able to handle 5000 volt-amperes of electrical input power at mechanical resonance when submerged in water below the cavitation depth without permanent damage when pulsed on a continuous duty cycle of a one second pulse every fifteen seconds.

2.7.2.3 Voltage Breakdown Test (for Experimental Model Test). — The voltage breakdown test shall be performed on the transducer unit prior to installation of the autotransformer. A 60-Hz test voltage of 4000 V(rms) between leads and 2000 V(rms) between either lead and (1) the housing and (2) the masses shall be required.

2.7.2.4 Resonant Frequency (for Experimental Model Tests). —The resonant frequency in air as determined from the motional conductance shall be 3.70 kHz ±2-1/2%.

2.8 Specific Requirements for the Transducer Units. — For the following requirements the transducer unit shall be considered as consisting of the active element, any required tuning and impedance matching networks, switching matrix, and its associated cable. (See Figure 2.)

All the following requirements are based on the performance under freefield conditions at a water temperature of 10° C.

All of the following electroacoustic requirements shall be met after completion of all the following tests: 2.2.1, 2.2.2, 2.2.4, 2.3, 2.4, 2.6.1, 2.6.2, 2.6.3, 2.6.7, 2.6.8, 2.7.2.1, 2.7.2.2, 2.7.2.3, 2.7.2.4.

2.8.1 Transmitting. —The resonant frequency in water (fr_w^E) of each transducer unit shall be 3.25 kHz ± 1-1/2% (as determined from the peak of the constant voltage transmitting response) when measured at terminals 1 and 2 of Figure 2. The variation in resonant frequency of a given transducer unit shall be less than ±1% when driven at any level up to full power, at any temperature from -2° C to +32° C and at any pressure from 15 to 600 psig. (See Figure 3.)

2.8.1.1 Mechanical Storage Factor. —(Q^E_{mw}) The mechanical storage factor, at constant voltage, as determined from the 3-db down points in the constant voltage transmitting response shall be less than 5.

2.8.1.2 Sound Pressure. —The sound pressure at mechanical resonance in water, (fr^E_w), for the transducer unit shall be greater than +52.0 db// 1 μbar for one volt at one yard. The variation in sound pressure at fr^E_w between transducer units shall be less than ±1 db.

2.8.1.3 Acoustic Output. — Each transducer unit at mechanical resonance in water, (fr^E_w) shall have a minimum sound pressure source level of 108.5 db//1 μbar^2 at one yard for 3000 volt-amperes electrical input when submerged to a water depth at which the transducer unit is not limited by cavitation on a continuous duty cycle of one, one second pulse every 15 seconds.

2.8.1.4 Maximum Voltage. —The impedance of the transducer unit at mechanical resonance in water, (fr^E_w), shall be such that the maximum voltage required at full power will not exceed 750 volts when measured at the cable end.

2.8.1.5 Beam Pattern. — The beam pattern of each transducer unit shall be that of a rectangular piston 4.5 by 6.7 inches mounted as shown in Figure 1.

2.8.1.6 Input Impedance. — The electrical input impedance in water at mechanical resonance, (fr^E_w) for the transducer shall be less than 175 ohms with a phase angle of +10° when measured between terminals 1 and 2 of Figure 2. The impedance between terminals 1 and 3 shall be nominally 250 ohms. Variation in impedance between transducer units shall be less than +10 percent with less than +2-1/2° variation in phase angles. The variation in impedance of a given transducer unit shall be less than 10 percent when driven at any level up to full power at any temperature from -2° C to +32° C and at any pressure from 15 to 600 psig.

2.8.1.7 Efficiency Loss. —The efficiency loss is given by

$$N_{eff} = 71.69 - 20 \log \frac{P}{(e_{in})} + N_{DI} + 10 \log G,$$

where

N_{eff} = efficiency loss of the transducer unit on the principal axis at a specified frequency (db)

$\frac{P}{(e_{in})}$ = transducer unit transmitting voltage response at one yard on the principal axis at a specified frequency $\left(\frac{\text{microbar}}{\text{volt}}\right)$

N_{DI} = directivity index on the principal axis at a specified frequency (db)

G = conductive component of the input admittance at a specified frequency (ohms).

The efficiency loss at mechanical resonance in water (fr_w^E) shall be less than 1.5 db. (For these calculations N_{DI} = 3.95 db.)

2.8.2 Receiving. —

2.8.2.1 Receiving Band. —The frequency band for receiving shall be 500 Hz to 7000 Hz. There shall be no spurious resonances or anti-resonances within this band. (See Figure 4.)

2.8.2.2 Mechanical Storage Factor. —(Q^I_{mw}) The bandwidth as determined from the 3-db down points in the open circuit voltage receiving response for the transducer unit shall be at least 600 Hz.

2.8.2.3 Receiving Response. —The open circuit voltage receiving response of the transducer unit at 1 kHz shall be more sensitive than -75 db referred to one volt for a pressure of one microbar. The variation between transducer units shall be less than ±1 db. The variation for hydrostatic pressures between 15 psig and 600 psig shall be less than 1 db.

2.8.2.4 Hydrophone Loss. —The hydrophone loss is given by

$$N_H = 10 \log R_T - 20 \log \frac{e_m}{P_h} - 115.85,$$

where

N_H = hydrophone loss on the principal axis at the frequency of operation (db)

R_T = resistive component of the input impedance of the transducer unit in water at the frequency of operation (ohms)

$\frac{e_m}{P_h}$ = transducer unit receiving open circuit voltage sensitivity on the principal axis at the frequency of operation (volts/microbar).

At any frequency between 500 Hz and 7000 Hz the hydrophone loss shall satisfy the following:

$$N_H < 10 \log \frac{F}{500} \text{ (db)}.$$

2.8.2.5 Capacitance and Loss Angle. —The capacitance of each transducer unit as measured at the cable end shall be .0182 microfarad ±2.5% when measured at 25°C and 1 kHz. The dissipation factor shall be less than .01 when measured at 25°C and 1 kHz. The applied sinusoidal voltage for this test shall be -30 db//1 volt RMS applied between terminals 1 and 2 of Figure 2.

3. QUALITY ASSURANCE PROVISIONS. —

3.1 Responsibility. —The supplier shall be responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own or any other inspection facilities and services acceptable to the Government. Inspection records of the examinations and tests shall be kept complete and available to the Government as specified in the contract or order. The Government reserves the right to perform any of the inspections set forth in the specification and any additional inspections when such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

3.1.1 Test Form. —A test form shall be provided with each transducer unit wherein the results of tests and inspections are recorded. Additional pertinent information which the manufacturer may deem advisable to present will be acceptable.

3.1.2 Progress Reports. —A monthly report on technical progress will be required.

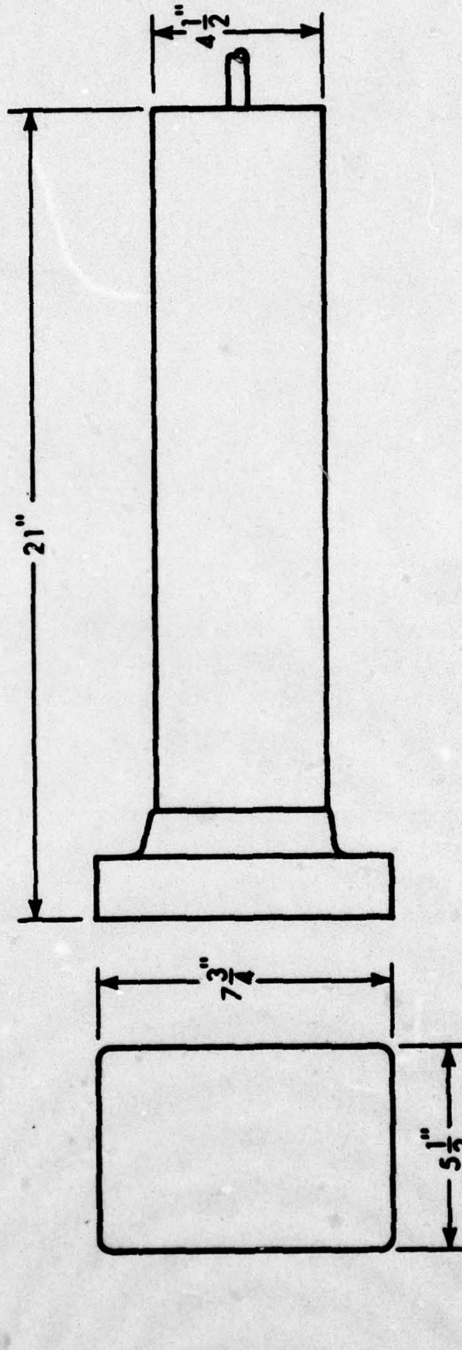

Fig. 1 - Outline Drawing — Transducer Unit

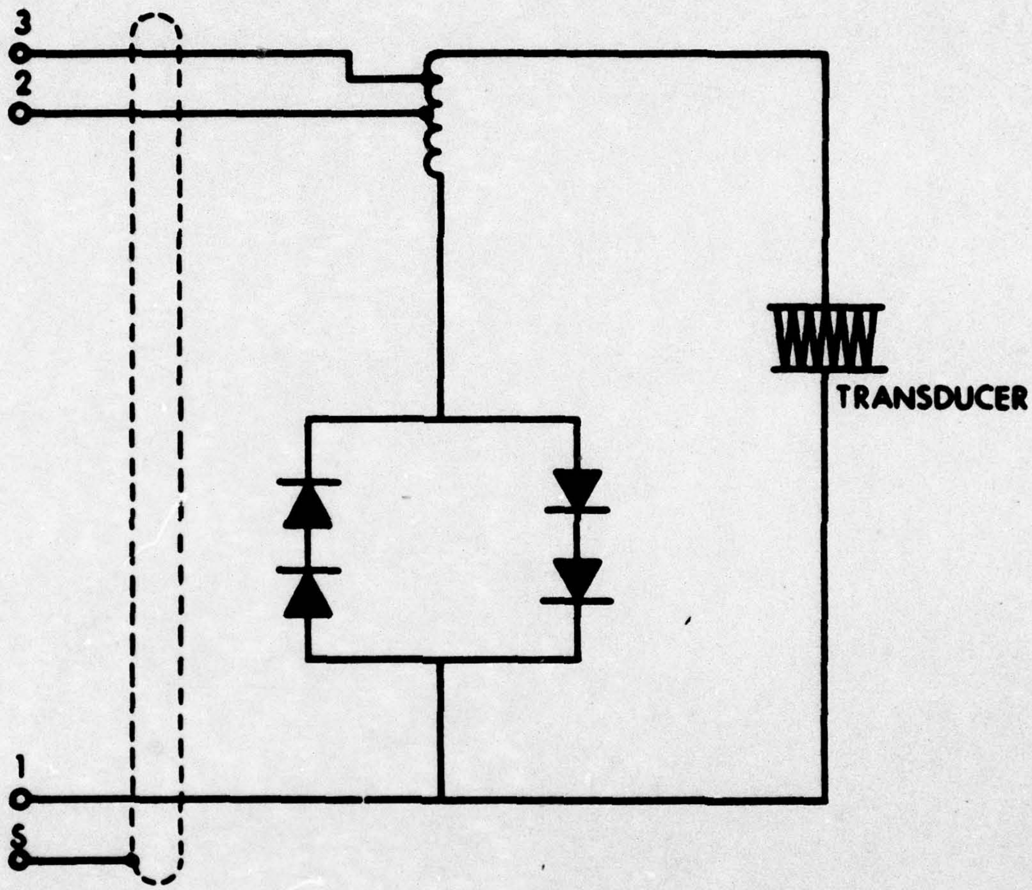

Fig. 2 - Schematic Representation — Transducer Unit

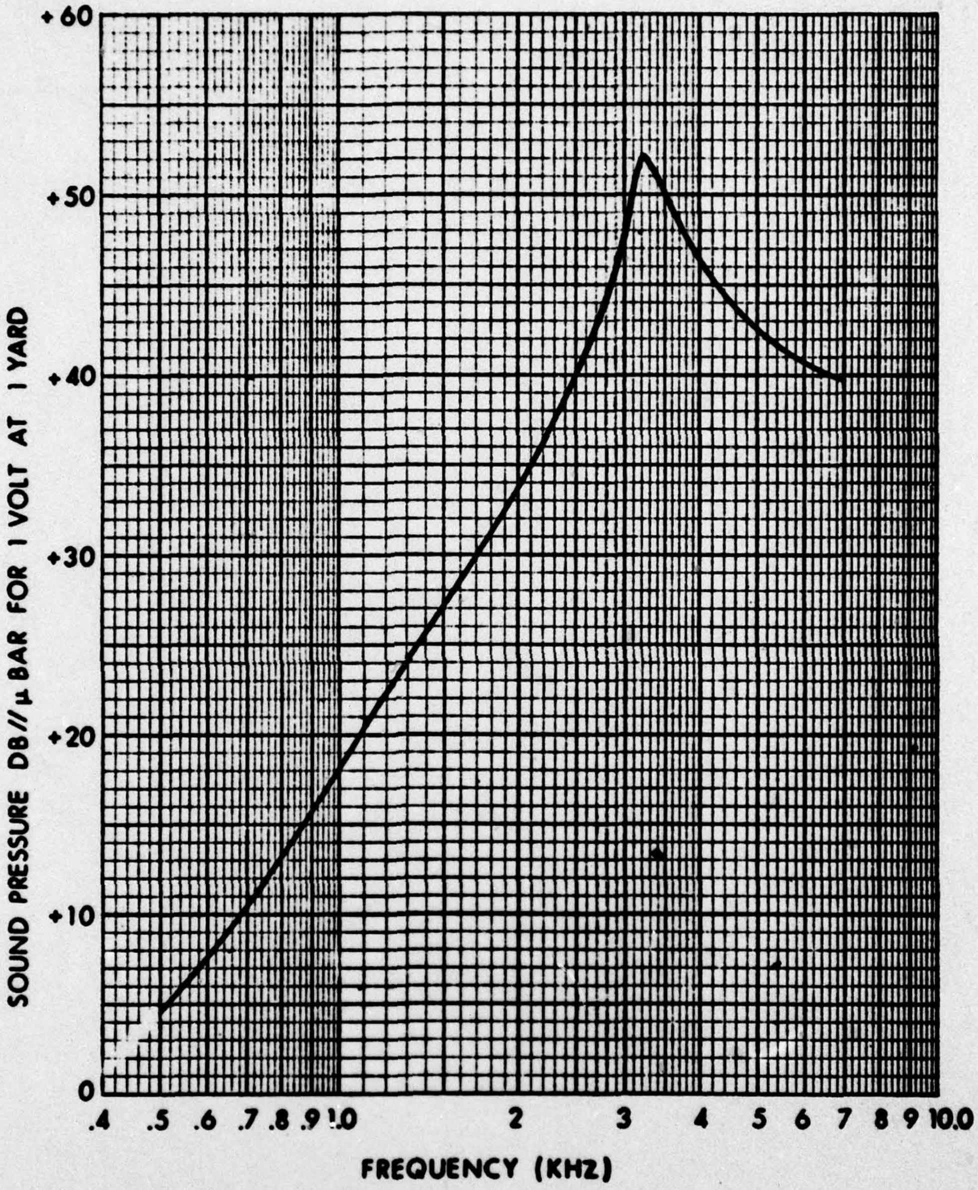

Fig. 3 - Transmitting Voltage Response — Transducer Unit

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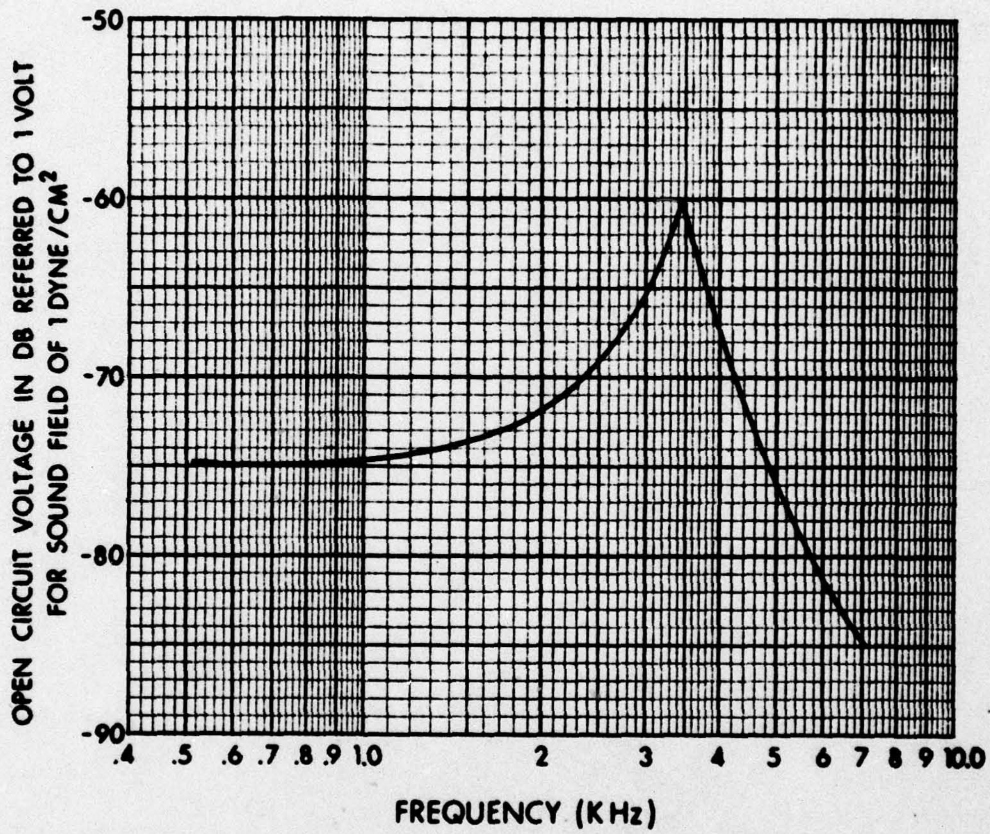

Fig. 4 - Open-Circuit Voltage Response — Transducer Unit

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